A STUDY OF THE EFFECTS OF STORAGE METHODS ON THE QUALITY OF MAIZE AND HOUSEHOLD FOOD SECURITY IN RUNGWE DISTRICT, TANZANIA

By

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Declaration

I, Rose Mboya, declare that:

(i) The research reported in this thesis, except where otherwise indicated, is my original research.

(ii) This thesis has not been submitted for any degree or examination at any other university.

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Abstract

A sample of 260 farm households that were randomly selected in Katumba ward, Rungwe district, Tanzania were studied for the effects of storage methods on the quality of maize grain and household food security using qualitative and quantitative methods. Maize storage problems, amounts of maize that farm households harvested and amounts of maize that farm households lost to pests per year, food security status and farm households' perceptions concerning their food security status were investigated using face - to - face semi - structured and structured interviews. Common storage methods that farm households used to store maize and the dietary importance of maize were investigated through interviews, seasonal calendars and the matrix for scoring and ranking. The quality of maize was investigated through conducting mycological analysis and through investigating levels of insect infestation using the incubation method on maize samples collected from a sub-sample of 130 farm households at harvest and after five months of storage period.

It was found that farm households in Katumba ward preferred maize meal rather than other types of food that provide bulk such as rice and green bananas/plantains. Maize contributed 66.8 % - 69.5 % of the total energy and 83 - 90 % of the total protein required per day, and farm households stored maize using roof and sack storage methods. It was also found that 34.5 % of 2323 tonnes of maize that were harvested per annum in Katumba ward were lost to pests during storage. *Fusarium*, *Diplodia*, *Aspergillus* and *Penicillium*s species were identified as the main fungal pathogens that attacked stored maize. *Sitophilus zeamais*, *Sitotroga cerealella* and rodents were also identified as the main maize storage pests. About 25 % of the maize samples that were collected at harvest and 93 % of the maize samples that were collected from the same farm households after five months of storage were infested by either *Sitophilus zeamais* or *Sitotroga cerealella* or both. Maize samples from the two storage systems had an average number of 80 insect pests per 120 maize kernels (or 51 g of maize), amounting to 1569 insects per kg. The high levels of insect infestation reduced the amount of maize that could have been available to the farm households and subjected stored maize to fungal infections and subsequent contaminations, thus, rendering the farm households vulnerable to food insecurity. Furthermore, it was also found that most of the infestation of maize by insect pests and moulds in Katumba ward occurred during storage, and that farm households were not well informed concerning maize storage and the negative effects that fungal activities in maize can have on the health of the consumers. An average of 87717 µg/kg fumonisins, 596 µg/kg aflatoxins, 745 µg/kg ochratoxins and 1803 µg/kg T-2 toxins were detected in the maize samples. Currently, there are no set standards for T-2 toxins, whereas the internationally accepted standards for aflatoxins, fumonisins and ochratoxins in cereals are 20 µg/kg, 4 mg/kg and 50 µg/kg, respectively. It was concluded that the levels of mycotoxins detected in maize from Katumba ward were far above the internationally accepted standards and that the farm households were at risk of ill health through consuming maize meals made from contaminated maize grain. The presence of high concentrations of mycotoxins, together with the high levels of insect infestation in the maize led to the conclusion that reduction of the nutrient content of the maize grain in Katumba ward was inevitable. Thus, the pests that infested maize stored using the roof and sack storage methods in this ward compromised not only the availability of food, but also the utilization of the nutrients in the maize and its safety, leading to the farm households' food insecurity.

It was further concluded that the quality of maize stored using roof and sack storage methods in Katumba ward was low and that the roof and sack storage methods were inadequate for protecting stored maize from pests. It was recommended that an efficient method for rapid drying of maize prior to storage be found, that the roof and sack storage methods be improved so that they can effectively protect stored maize from moisture content problems. It was also recommended that the farm households' awareness concerning maize storage and food security be raised, and that the extension staff in Katumba ward should urge the Tanzanian government to implement an agricultural policy which promotes efficient maize storage and maize quality in order to improve the current status quo. Above all, since maize is the predominant staple, it was recommended that the maize breeding program in Tanzania should emphasize development of maize varieties that are resistant to ear rots, storage insects and to contamination by mycotoxins as part of a larger program to improve food security in this part of the country. Breeding programs that aim at enhancing the nutritional value of maize were also recommended.

Dedication

To my family

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TABLE OF CONTENTS

Page

List of Tables

Table **Page**

List of Figures

Figure **Page**

CHAPTER ONE

INTRODUCTION

1.1 The importance of maize in sub-Saharan Africa

Maize (*Zea mays* L) is the third most important food crop in the world (Escobedo, 2010; Organization for Economic Co-operation and Development (OECD) and the Food and Agriculture Organization of the United Nations (FAO), 2010) and it is a staple food crop in Africa (Bryceson, 2009; M'mboyi *et al*., 2010). It is estimated that at least 40 million tonnes of maize are produced in sub-Saharan Africa annually {FAO Statistics (FAOSTAT), 2010 a}, which accounts for 35 % of the total amount of maize produced in the world (Mukanga, 2009). Table 1.1 shows estimated amounts of maize that were produced in 1998 - 2007 in sub-Saharan Africa.

Table 1.1: The estimated amounts of maize produced in Africa in 1998-2007 (Tonnes)

Year	Amount of Maize Produced (1000 tonnes)
1998	40,113
1999	42,398
2000	44,284
2001	41,384
2002	44,786
2003	45,586
2004	47,562
2005	49,864
2006	49,617
2007	47,737

Source: FAOSTAT (2010 a)

Statistics from 12 selected countries in sub-Saharan Africa (Table 1.2) confirm the claim that maize is not only produced but also consumed widely in this region, which further sheds light on the extent to which maize is an important food crop in this continent. It is estimated that maize accounts for 40 % of the total dietary intake of consumers in southern and eastern Africa (Mugo *et al*., 2002). It is a good source of carbohydrates, it consists of protein and small quantities of fat, vitamins, dietary fibres and minerals such as iron and phosphorus (Klopfenstein, 2000; Iken *et* *al.*, 2002), and it can be stored for extended periods. Thus, maize is a key crop in ensuring availability of food and ensuring food security among the poor communities in sub-Saharan Africa.

Table 1.2: Estimated average maize production and consumption in 12 selected countries in sub-Saharan Africa (1998 - 2007)

Country	Maize production per annum (1000 tonnes)	Per capita consumption (kg per annum)	Total consumption per annum (1000 tonnes)
Angola	535	37.40	578.90
Cameroon	929	39.20	659.30
Ghana	1,142	40.70	842.70
Kenya	2,654	83.80	2810.2
Malawi	1,832	128.90	1506.3
Mozambique	1,164	57.30	1114.70
Nigeria	5,474	21.40	2924.80
South Africa	9,010	108.70	5056.00
Tanzania	3,161	112.50	2385.60
Uganda	1,153	27.50	726.30
Zambia	993	119.80	1326.90
Zimbabwe	1,321	114.50	1425.30

Source: FAOSTAT (2010 a, b; Katinila *et al*, 1998)

The wide variation in the per capital consumption of maize in Table 2 shows that the extent of the importance of maize as a source of food differs from country to country in sub-Saharan Africa.

1.2 The importance of maize in Tanzania

In Tanzania maize is the dominant staple food crop (Government of the United Republic of Tanzania, 2000; Amani, 2004). It is estimated that over 80 % of the population of Tanzania depends on maize for food (Bisanda and Mwangi, 1996). Although FAOSTAT's (2010 a) report indicates a lower figure for the annual per capita consumption of maize in Tanzania, Katinila *et al*. (1998) estimated that maize contributes up to 60 % of the total energy in the diets of the consumers in Tanzania, and that the annual per capita consumption of maize in Tanzania is 112.5 kilograms and that this amounts to three million tonnes of maize consumed annually.

Nevertheless, the maize potential in relation to ensuring availability of food in Tanzania is not being fully realized because 34 % (Kimenju and De Groote, 2010) of the maize produced is lost due to inadequate post-harvest management (Government of the United Republic of Tanzania-Ministry of Agriculture, 2006; Makundi *et al*., 2006), of which poor storage methods and maize seeds susceptibility to storage pests attack play major roles. Inadequate storage technologies jeopardize not only the amount of maize that the consumers can access, but also the quality of stored maize. High quality maize is that which is rich in nutrients and free from pathogens and physical and chemical contaminants (Weinberg *et al*, 2008, Golob, 2004).

1.3 Maize storage problems and maize quality

The greatest setback during maize storage is that it is susceptible to attack by pests, of which insect pests (Makate, 2010), moulds (Weinberg *et al*., 2008) and rodents {International Research Institute (IRRI) and International Maize and Wheat Improvement Centre (CIMMYT), 2009} top the list. The attack of stored maize by storage pests is associated with loss of millions of tonnes of stored maize through insects infestations (Dhliwayo and Pixley, 2003) and through attack by rodents and moulds (Compton and Sherington, 1999). It is estimated that 30 - 40 % of cereal grains, 45 % of roots and tubers and 40 - 80 % of vegetables and legumes produced in Tanzania are lost to pests and diseases (Government of the United Republic of Tanzania-Ministry of Agriculture, 2006). As a result of the crop losses, consumers access inadequate amounts of food, which in turn has led to malnutrition, anaemia, energy and vitamin deficiencies being common in Tanzania (Government of the United Republic of Tanzania-Ministry of Agriculture, 2006). However, whether the figures indicated by the Government of the United Republic of Tanzania (2006) concerning the amounts of food crops lost to pests are based on scientific estimations is not known.

The outcomes of the attack also include loss of maize quality (IRRI and CIMMYT, 2009), which includes reduction in the nutrient content of the maize (Jood *et al*., 1992). Stored maize can also become unsafe for consumption as a result of contamination by waste products and mycotoxins where moulds are concerned {Sallam, 1999; Weinberg *et al*., 2008; Somali Agriculture Technical Group (SATG), 2009}. On-farm storage technologies play a major role in determining the quality of stored maize and determine quantities of maize that can be available to the consumers

(Thamaga, 2001; Thamaga-Chitja *et al.,* 2004; Golob, 2004). In turn this improves not only the purchasing power of the farm households by making it possible for them to market the maize and raise income for purchasing non-farm products and food commodities that they do not produce, but it also contributes to poverty alleviation and food security of the consumers.

Moisture content of the grains, humidity, temperature, foreign materials in maize and poor handling of the maize prior to storage are factors that influence the development of micro-organisims in stored maize, which eventually cause maize losses and contaminations (Weinberg*et al*., 2008; Murdolelono and Hosang, 2009). Contamination of food products by mycotoxins have been reported worldwide (Wild and Gong, 2010), and over 300 types of mycotoxins have been identified, out of which 20 types have been found to occur naturally in foods and feeds {Institute of Food Science and Technology (IFST), 2009}. *Fusarium,Aspergillus* and *Penicillium* species have been identified as the most important types of fungi that infest stored maize and produce mycotoxins which are harmful to both human beings and animals (Sweeney *et al.,* 2000; Bennet and Klich, 2003; Ngoko *et al.,* 2008; Wild and Gong 2010). Mycotoxins that are produced by the indicated fungal species include fumonisins and T-2 toxins which are mainly produced by *Fusarium* species (Atkins and Norman, 1998, Akande *et al.,* 2006), aflatoxins which are produced by *Aspergillus* species (D'Mello and Macdonald, 1997; Cousin *et al.,* 2005; Perduri and Gobba, 2009) and ochratoxins which are mainly produced by *Penicillium* and some *Aspergillus* species such as *Aspergillus niger* (Cousin *et al.,* 2005, Magalhãesa and Bernado, 2010).

While contaminations of cereal products have been reported in several countries in the world (Wild and Gong, 2010), alarming concentrations of mycotoxins in maize have been reported in developingcountries (IFST, 2009). In Africa, outbreaks of diseases and deaths associated with the ingestion of foods and feeds that are made from maize that is contaminated with mycotoxins have been reported (Wild and Gong, 2010). Consumption of maize which is contaminated by the mycotoxins may lead to diseases such as cancer and kidney problems (Hayes, 2000; Munkvold *et al.,* 2009). Other diseases that mycotoxins cause include suppression of the immune system, interference with neurone function and protein synthesis, and retarded growth (Hayes, 2000; Munkvold *et al.,* 2009). Death may also occur as a result of chronic exposure to high levels of mycotoxins (Hayes, 2000; Munkvold *et al.,*2009). In 2004 death of more than 100 people in

Eastern Kenya was associated with consumption of maize meals that had high levels of aflatoxins. Outbreaks of illnesses coused by consumptions of high levels of mycotoxins were also reported in 2005 and 2006 in Kenya (Muthoni *et al.*, 2009). Much of the contamination of commodities by mycotoxins has been associated with inadequate storage technologies and climatic conditions such as high humidity, dampness and temperatures {World Health Organization (WHO), 2006; Williams, 2004; Gourama and Bullerman, 1995; Tachin, 2008}. This shows that storage technologies play a major role in determining the quality of maize. Thus, ensuring maximum efficiency of the storage technologies is crucial to the safety of stored maize and health of the consumers.

1.4 The Nutrient deficiency of maize

Maize is deficient in the essential amino acids lysine and tryptophan, thus, the protein which is found in maize is of low quality (Friedman, 1996; Escobedo, 2010). This, together with its deficiency in minerals and vitamins, means that maize may subject the consumers to poor nutrition especially in places where it is the staple food crop. This robs the consumers of nutrition security and subjects them to food insecurity. The nutrient deficiency of maize is being addressed through breeding and molecular technologies that aim at not only improving maize yield, but also improving and enhancing its nutrient content (Ortiz-Monasterio *et al.*, 2007). However, in Tanzania breeding technologies are focused on improving maize seeds for high yield. The susceptibility of maize seed to attack by pests, together with the use of inefficient storage technologies especially among small scale farmers in Africa are still hindering achievent and maintainance ofthe highest quality of maize (Adda *et al.*,2002).

1.5 Food security in Sub Saharan Africa

1.5.1 Food security defined

The definition of food security has been evolving over time (Maxwell, 2001; Babu and Sanyal 2009) due to the progressive shifts in the concern regarding issues that are central to food security. While initially food security was concerned with issues of global and national food supply, with time, issues of household and individual access to food and consumption, nutrition and health have become important components (Maxwell, 2001). In the current study, FAO's (2010) recent and a more inclusive definition of food security applies. It states that "Food security exists when all people, at all times, have physical, social, and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life". Household food security is the application of this concept to the family level, with individuals within households as the focus of the concern.

In view of the FAO's (2010) definition, unlimited availability of nutritious preferred food, access to the food and the degree to which the food is safe for consumption are components of food security. There are four main factors that determine food security, namely: food availability, food access, food utilization (Babu and Sanyal, 2009) and stability {World Food Programme (WFP), 2009}. While 'availability' is concerned with food supply, 'access' is the ability of an individual or household to get food, 'utilization' is the capacity that an individual has regarding selecting, and taking in the nutrients in food and 'stability' has to deal with unlimited availability and access to food, and unlimited utilization of the food (WFP, 2009). Several factors are used as indicators of food security, namely: the amount of food that people consume, the quality of the food in terms of its nutrient content, food diversification (Smith *et al.,* 2006) and wealth in terms of the amount of income levels. The quantity of assets that people own is also an indicator of food security (Maxwell and Smith, 1992). Through these food security indicators, it is possible to estimate the degree to which people have access to food and to predict whether people are able to purchase food when their food supplies run out.

1.5.2 The state of food insecurity in sub-Saharan Africa

Food insecurity is the opposite of food security, and it manifests itself through hunger or vulnerability to hunger, which WFP, 2009 defines as 'a condition in which people lack the required nutrients, both macro (energy and protein) and micro (vitamins and minerals) for fully productive, active and healthy lives'. Hunger can be short term/acute or longer term/chronic, and has a range of mild to severe effects. It can result from insufficient nutrient intake or from people's bodies failing to take in the required nutrients (WFP, 2009). Severe nutrient deficiencies can lead to sickness and death {Administrative Committee Coordinator-Subcommittee on Nutrition (ACC/SCN), 2010}.

It is estimated that millions of people in the world are hungry, and that 848 million of the hungry people are in developing countries of Asia and Africa (WFP, 2009). In 2008 it was reported that most of the undernourished children were in developing countries, especially South Asia and sub-Saharan Africa, where prevalence of underweight children was 42 % and 28 %, respectively {United Nations Children's Fund (UNICEF), 2008}. Therefore, ensuring unlimited access to adequate amounts of nutritious food is critical to health in sub-Saharan Africa.

1.6 Justification for the study

As indicated in section 1.3, inefficient storage technologies have been associated with major crop losses. However, in Tanzania, no practical verification that provides evidence to efforts being made to improve storage technologies especially at household level was found. Also, the quality of maize and its dietary importance in Katumba ward, and the capacity of storage methods that farm households in this ward use to protect stored maize against pests have also never been studied before.

Furthermore, as with other parts of Rungwe district Katumba ward is characterized by heavy rainfall (Mckone, 2002), and like the rest of the high zone of Rungwe district, it receives up to 2,700 mm of rainfall per annum (Administrator, 2010). Temperatures range between 10 - 25 ^{0}C (Annon, 2008) almost throughout the year. The climatic conditions in Rungwe district encourage dampness and ultimately growth of moulds, which can lead to contamination of stored maize by mycotoxins and exposure of maize consumers to the mycotoxins. No study has been conducted before in Katumba ward to investigate the capacity of farmers to protect stored maize from moulds and mycotoxin contaminations. Furthermore, studies conducted on home - stored maize obtained from 120 households from Ruvuma, Iringa and Kilimanjaro regions of Tanzania in 2005 revealed the presence of unacceptable levels of aflatoxins (Kimanya *et al.*, 2008). However, the mycotoxins were not associated with any storage method. Thus, this study attempted to fill the gaps indicated in this section.

1.7 Research design

A case study of Katumba ward, Rungwe district, Tanzania was conducted in order to investigate the storage methods that subsistence farmersuse and the impact that these storage methods have on the quality of maize and food security of the farm households. The reason for the choice of a case study approach was because of its feasibility and the possibility of an indepth analysis of the research questions through group interaction (Bryman, 2004). Katumba ward was chosen because of the researcher's long term involvement in agricultural activities in the ward. The question of the effectiveness of the storage methods used in the area and their impact on the quality of stored grains and food security in the area has always bothered the researcher. In order to enrich the research findings, both qualitative and quantitative methods were used. The application of both qualitative and quantitative methods for a study have been found to be effective in deepening understanding of research findings (Moore, 2006). While quantitative research focuses on numeric figures, qualitative reseach, on the other hand, focuses on studying perceptions and views of the population being studied (Galvan, 2006; Mouton, 1990). It also helps to explain the quantitative results such as providing answers to why and how things happen in specific contexts. A combination of the qualitative and quantitative methods was expected to be more helpful in understanding how storage methods affect maize quality in Katumba ward than using the methods independently from one another.

1.8 Theoretical framework

In this study the *ecohealth approach to human health* was used. The *ecohealth* approach seeks to better understand how different components of the ecosystem namely: biophysical, socio-economic, and cultural systems relate, and how these interactions influence health and well being in specific contexts (Lebel, 2003). There are three pillars that the ecohealth approach focuses on, aimed at helping in understanding interactions between society and science in general and ultimately contributing to the improvement of health. These include interdisciplinarity, gender sensitivity and stakeholder participation for understanding ways in which socio-economic systems link with other ecological systems to influence health (De Plaen and Kilelu, 2004; Lebel, 2003).

While interdisciplinarity is concerned with linking social and ecological systems, gender sensitivity has to deal with understanding roles that men and women play in specific contexts, and how these roles affect health. Stakeholder participation is concerned with involving stakeholders from the initial stage of the research for future action (De Plaen and Kilelu, 2004; Bopp and Bopp, 2004). In general the ecohealth approach involves identifying key persons in specific contexts and studying the roles that they play in order to involve them in taking action for change. Due to the fact that this study is concerned with maize storage at household level, farm households were considered as the most important components of the stakeholders, thus, roles that individuals in the farm households play with respect to maize storage were of interest for this study. The ecohealth approach was considered appropriate for the purpose for this study, which ultimately aimed at improving maize storage methods and health of the community that was studied. Furthermore, the ecohealth approach was used because it is applicable and it has been applied before in other places in Africa such as Malawi and Egypt with good results (Kerr and Chirwa, 2004; Kishk *et al.*, 2004).

1.9 Main Objective

The major objective of the study was to investigate the effects of storage methods on the quality of maize and the implications on household food security in Katumba ward, Rungwe district Tanzania. This study provides insights into storage mechanisms among poor communities and helps to understand how climatic conditions interact with storage mechanisms to influence household food insecurity in such communities.

1.10. Specific objectives

The specific objectives were as follows:

(i) To identify maize storage methods and investigate the associated storage problems focusing on pest infestation of stored maize and subsequent losses and their implications on the farm households' food security.

(ii)To investigate farm households' understanding of maize storage problems and the implications on the quality of stored maize and household food security.

(iii) To establish the dietary importance of maize and its contribution to household food security in Katumba ward, Rungwe district, Tanzania.

(iv) To examine the quality of stored maize in terms of the presence of pathogenic species of fungi and levels of associated mycotoxins in maize and determine the implications on household food security from an ecohealth perspective.

(v) To evaluate the food security status of farm households and assess the farm households' understanding of food security from an ecohealth perspective.

The following hypotheses were tested in this study:

(i) Due to the climatic conditions in Rungwe district, maize storage methods may be inadequate for keeping stored maize safe from pests and subsequent contaminations, thus, the quality of stored maize may be poor, and the farm households may be at risk of ill health, thus vulnerable and food insecure.

(ii) Traditionally, green bananas/plantains are the preferred food crop in Rungwe district. However, maize production is gaining significance in this district, thus, maize consumption may also be rising, whereas farm households may not be well equipped in achieving and maintaining high quality of stored maize.

1.11 Research questions

The following research questions were addressed in this study:

- ✓ What are the maize storage methods that farm households in Katumba ward use for long term storage of maize and how much maize do the farm households harvest, store and or lose to pests during storage per annum?
- ✓ What are the main maize storage pests in Katumba ward and how do the farm households control them?
- ✓ What are the characteristics of the maize storage technologies that farm households use and how do the farm households perceive the storage technologies?
- ✓ What impact do the storage methods, the farm households' perceptions of the maize storage methods and maize storage pests have on the quality of maize and household food security?
- ✓ Do farm households in Katumba ward have access to information concerning maize storage?

- ✓ Are farm households in Katumba ward aware of diseases that are associated with consumption of foods that are contaminated with mycotoxins?
- ✓ How does the farm households' awareness or lack of awareness concerning diseases that are associated with consumption of foods that are contaminated with mycotoxins influence their food security?
- ✓ What is the food security status of the farm households in Katumba ward and how do farm households understand food security and perceive their food security status?
- ✓ What are the reasons for the farm households' perceptions concerning their food security status and how do the farm household's perceptions and understanding of food security impact on their food security status?
- ✓ What importance does maize have in the diets of the farm households and how does this influence the farm households' food security?
- ✓ What are the heads of farm households' levels of formal education and what implications does the level of formal education have on maize storage and consumption?
- ✓ What is an average size of a farm household in Katumba ward and who are the key persons in the farm households as far as maize storage is concerned?

1.12 Organization of the thesis

The 'papers' format was utilized for writing up this thesis, thus, while the general introduction and the literature review apply to all of the chapters of the thesis, the chapters that deal with finding answers to the specific objectives of the study are further introduced at the beginning of each chapter. Furthermore, sections for the materials and methods, the presentation and discussion of findings, the conclusions and recommendations, the reference and appendices for the parts of the study that have been dealt with in each chapter have been provided for each chapter independently. However, in some cases the same materials and methods were used for finding answers to more than one of the specific objectives indicated above, thus, overlapping of the materials, methods and findings occurred in some chapters. In general, the Food Policy Journal (Elsevier), 2010 format was used, and the chapters are arranged as follows:

(i) Chapter One: Introduction

(ii) Chapter Two: Literature review

(iii) Chapter Three: The dietary importance of maize in Katumba ward, Rungwe district, Tanzania and its contribution to household food security[1].

(iv) Chapter Four: Maize storage problems and the quality of maize in Katumba ward, Rungwe district, Tanzania: implications on household food security

(v) Chapter Five: The importance and characteristics of roof and sack storage methods and their implications on household food security in Katumba ward, Rungwe district, Tanzania

(vi) Chapter Six: The effects of fungal infection and mycotoxin contaminations on the quality of maize stored using roof and sack storage methods in Katumba ward, Rungwe district, Tanzania[2].

(vii) Chapter Seven: Farm households' food security status and the farm households' understanding of food security in Katumba ward, Rungwe district, Tanzania.

(viii) Chapter Eight: Overview of the research findings

References

Adda, C., Borgemeister, C, Biliwa, A., Meikle, W.G., Markham, R.H., Poehling, H.M., 2002. Integrated Pest Management in Post-harvest maize: a case study from the Republic of Togo (West Africa). *Agriculture, Ecosystems and Environment*. 93. 1 - 3, 305 - 321.

Administrator, 2010. *Overview of the Council- Rungwe*. <http://www.mbeya.go.tz/index.php?option=com_content&view=article&id=173&Itemid=190> (Accessed 2010 October, 10).

ACC/SCN, 2010. Sixth Report on the World Nutrition Situation. UN Standing Committee on Nutrition, Geneva.

Akande, K.E., Abubakar, M.M., Adegbola, T.A., Bogoro, S.E., 2006. Nutritional and Health Implications of mycotoxins in Animal Feeds: A Review. *Pakistan Journal of Nutrition*. 5, 398-403.

Amani, H.K.R., 2004. *Agricultural Development and Food Security in Sub-Saharan Africa: Tanzania Country Report*. Economic and Research Foundation (ESRF), Dar-es-Salaam.

[1] Chapter Three (The dietary importance of maize in Katumba ward, Rungwe district, Tanzania and its contribtion to household food security) was published in the African Journal of Agricultural research. 6. 11, 2617-2626.

[2] Findings from this chapter were published as follows: Rose Mboya, R., Tongoona, P., Yobo, K.S., Derera, J., Mudhara, M., Langyintuo, A., The quality of maize stored using roof and sack storage methods in Katumba Ward, Rungwe District, Tanzania:Implications on household food security. Journal of Stored Products and Postharvest Research. 2, 9, 189 - 199.

Atkins, D., Norman, J., 1998. Mycotoxins and Food Safety. *Nutrition and Food Science*. 5, 260 - 266.

Babu, S.C., Sanyal, P., 2009. *Food Security, Poverty and Nutrition Policy Analysis: Statistical Methods and Applications*. ELSEVIER: Burlington.

Bennet, J.W., Klich, M., 2003, Mycotoxins. *Clinical Microbiology Reviews*. 16, 3, 497 - 516.

Bisanda, S., Mwangi, W., 1996 'Introduction', Adoption *of Recommended Maize Technologies in Mbeya Region of the Southern Highlands of Tanzania*. Fifth Eastern and Southern Africa Regional Maize Conference, 3rd-7th June 1996. The International Maize and Wheat Improvement Centre, Dar-Es-Salaam, pp. 2 - 6.

Bopp, M., Bopp J., 2004. Welcome to the Swamp: Addressing Community Capacity in Ecohealth Research and Intervention. *Ecohealth*.1. 2, 24 - 34.

Bryceson, D.F. (2009). Sub-Saharan Africa's Vanishing Peasantries and the Specter of a Global Food Crisis. *Monthly Review*. 61, 3, 48 - 62

Bryman, A., 2004. *Social research methods*, second ed. Oxford University press, New York.

Cochran, W.G., 1977. *Sampling Techniques*, third ed. John Willey and Sons, New York.

Compton, J.A.F., Sherington, J., 1999. Postharvest Weight Loss Estimates for Cereal Supply Calculations in East and Southern Africa. *Journal of Stored Products Research*. 16, 75 - 80.

Cousin, M.A., Riley, R.T., Pestka, J.J., 2005. Foodborne mycotoxins: Chemistry, Biology, Ecology and Toxicology, in Fratamico, P.M., Bhunia, A.K., Smith, J.L. *Foodborne Pathogens: Microbiology and Molecular Biology*. Caister Academic Press, Wymondham. 163 - 226.

De Plaen, R., Kilelu, C., 2004. From Multiple Voices to Common Language: Ecosystem Approaches to Human Health as an Emerging Paradigm. *Ecohealth*.1 2, 8 - 15.

Dhliwayo, T., Pixley, K., 2003.Divergent Selection for Resistance to Maize Weevil in Six Maize Populations.*Crop Science*. 43, 2043 - 2049.

D'Mello, J. P., F., Macdonald, A. M. C., 1997.Mycotoxins.*Animal Feed Science Technology* 69, 155 - 66.

Escobedo, G.E., 2010. *Comparative analysis of the Quality Protein Maize (QPM) and Normal Maize Cultivars (Zea Mays L).* <http://www.scribd.com/doc/34756747/Comparative-Analysis-of-the-Crude-Protein-Lysine-and-Tryptophan-of-Quality-Protein-Maize-QPM-and-Normal-Maize-Cultivars> (Accessed 2010 November 25).

FAO, 1994. Grain Storage techniques- Evolution and trends in Developing Countries. FAO Agricultural Bulletin No. 109. FAO, Rome.

FAO, 2010. *The State of Food Insecurity in the World. Addressing Food Insecurity in Protracted Crises*. FAO, Rome.

FAOSTAT, 2010 a. *Production: Maize*. <http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor> (Accessed 2010, October 03).

FAOSTAT, 2010 b. *Production: Food Balance Sheets*. <http://faostat.fao.org/site/368/DesktopDefault.aspx?PageID=368#ancor> (Accessed 2010 October 04).

Friedman, M., 1996. Nutritional Value of Protein from Different Sources. A Review. *Journal of Agricultural Food Chemistry*. 44, 1, 6 - 29.

Galvan, J. L., 2006. *Writing Literature Reviews: A Guide for Students of the Social and Behavioural Sciences*, third ed. Pyrczak, Glendale.

Golob, 2004. Maize: Tanzania (East and Central Africa). In Golob, P., Hodges, R., Farrell, G., *Crop Post-Harvest: Science and Technology Vol 2*. Blackwell Publishing Company, Oxford, pp. 26 - 41.

Gourama H., Bullerman, L. B., 1995. *Aspergillus flavus* and *Aspergillus parasiticus*: Aflatoxigenic Fungi of Concern in Foods and Feeds: A review. *Journal of Food Protection*. 58, 12, 1395 - 1404.

Government of the United Republic of Tanzania-Office of Prime Minister and vice president. 1995. Mbeya Regional Development Perspective Strategies: A Program to raise Household Income. Unpublished document, April 1995.

Government of the United Republic of Tanzania, 2000. *Agriculture in Tanzania since 1996. Follower or leader of growth?* The world bank, Washington.

Government of the United Republic of Tanzania, 2005. *About Tanzania*, <http://www.tanzania.go.tz. (Accessed 2006 October 22).

Government of the United Republic of Tanzania-Ministry of Agriculture, 2006. *Agriculture*. <http://www.tanzania.go.tz/agriculture/htm> Accessed 2010 May 19).

Hayes, A.W., 2000. *Principles and Methods of Toxicology*, fourth ed. Taylor and Francis, Philadelphia and London.

IFST, 2009. *Mycotoxins. Information Statement*. <http://www.ifst.org/about_ifst/hotspot/index/29514/Updated_Mycotoxins_Information_Statement> (Accessed 2010 (March 02).

Iken, J.E, Amusa, N.A., Obatulu, V.O., 2002. Nutrient Composition and Weight Evaluation of some Newly Developed Maize varieties in Nigeria. *Journal of Food Technology in Africa*. 7, 1, 27 - 29.

IRRI/ CIMMYT, 2009. Maize Seed Management-Post-harvest Treatment and Storage. <http://www.knowledgebank.irri.org/ckb/index.php/post-harvest/maize-seed management> (Accessed 2010 January 03).

Jood, S., Kapoor, A.C., Singh, R., 1992. Biological evaluation of Protein Quality of Maize as Affected by Insect Infestation. *Journal of Agricultural and Food Chemistry*. 40. 12, 2439 - 2442.

Katinila, N., Verkuijl, H., Mwangi, W., Anandajayasekeram, P., Moshi, A., 1998. *Adoption of maize Technologies in Southern Tanzania*. CIMMYT, Mexico.

Kerr, R. B. and Chirwa, M., 2004. Participatory Research Approaches and Social Dynamics that Influence Agricultural Practices to Improve Child Nutrition in Malawi. *Ecohealth*.1, 2, 109 - 117.

Kimanya, M.E., De Meulenaer, B., Tiisekwa, B., Ndomondo-Sigoda, M., Devlieghere, F., Van Camp, J., and Kolsteren, P., 2008. Co- occurrence of fumonisins with aflatoxins in home-stored maize for human consumption in rural villages of Tanzania. *Food Additives and Contaminnts*. 11, 12, 1353 - 1364.

Kimenju, S.C., H., D., 2010. *Economic Analysis of Alternative Maize Storage Technologies in Kenya*. 2010 African Association of Agricultural Conference (AAAE), Third Conference/AEASA 48th Conference. September 19 - 23, Cape Town, South Africa.

Kishk, F. M., Gaber, H. M., Abd-Allah, S. M., 2004. Towards Enhancing Community Health in EL- Fayoum, Egypt, Using Ecosystem Approaches. *Ecohealth*. 1, 2, 84 - 96.

Klopfenstein, C.E., 2000. Nutritional Quality of Cereal Based Foods. *Handbook of Cereal Science and Technology,* second ed. Marcel Dekker, New York, 705 - 723.

Lebel, J., 2003. *Health. An Ecosystem Approach*. International Development and Research Centre (IDRC), Ottawa.

Magalhãesa, S., Bernado, F., 2010. Mycobiota and Ochratoxin A in Laboratory Mice Feed: Preliminary Study. *Research Communications Journal*. 34, 381 - 386.

Makate, N., 2010. The Susceptibility of Different Maize Varieties to Post Harvest Infestation by *Sitophiluszeamais* (MOTSCH) (Coleoptera:Cuclionidae). *Scientific Research and Essay*. 5, 1, 030 - 034.

Makundi, R.H., 2006. Challenges in Pest Management in Agriculture: Africa and Global Perspectives. In Makundi, R.H., (Ed). *Management of Selected Crop Pests in Tanzania*. Tanzania Publishing House, Dar-es-Salaam, p. 476.

Maxwell, S, Smith, M, 1992. *Household Food Security: A Conceptual Review*. Institute of Development Studies, Sussex.

Maxwell, S., 2001. The Evolutionary Thinking about Food Security. In Devereux S, Maxwell, S. (Ed). *Food Security in Sub-Saharan Africa*. ITDG Publishing, London, pp. 13 - 27.

Mckone, D., 2002. *A Brief Survey of the Traditional Forest Reserves of Rungwe District, Mbeya Region, Tanzania*. <http://wwmckone.org/tfrrung.html> (Accessed 2007 July 07).

M'mboyi, F., Mugo, S., Mwimali, M., Ambani, L., 2010. *Maize Production and Improvement in sub-Saharan Africa*. The African Biotechnology Stakeholders Forum (ABSF), Nairobi.

Moore, N., 2006. *How to do Research. A practical guide to designing and Managing Research Projects*, third ed. Facet, London.

Mouton, J., 1990. *Knowledge and method in the human Science*. Human Sciences, Pretoria. Research Council.

Mugo, S. Songa, J., De Groote, H., Hoisington, D., 2002. *Insect Resistant Maize for Africa (IRMA) Project: An Overview.* <http://www.syngentafoundation.com/pdf/p4_08_mugoS_etal_2002_IRMA_overview_Syngenta_Symposium.pdf> (Accessed 2007 July 14.

Mukanga, M., 2009. *Genetic Improvement of Zambian Maize (Zea mays L.)* Populations for Resistance to Ear Rots and a Survey of Associated Mycotoxins.PHD Thesis, University of KwaZulu-Natal, Republic of South Africa, pp 1 - 3.

Munkvold, G., Hurburgh, C., Meyer, J., 2009. *Aflatoxins in Corn*. <http://www.extension.iastate.edu/publications/pm1800.pdf> (Accessed 2010 April10).

Murdolelono, B., Hosang, E., 2009. Effects of Storage Technologies on Quality of Maize Seeds of Lamuru and Local Varieties in East Nusa Teggara. *Indonesian Journal of Agriculture*. 2, 2, 93 - 102.

Muthoni, J.W., Njenga, L.N., Gathumbi, J.K., Chemining'wa. 2009. The Occurrence of Aflatoxins in Maize and Distribution of Mycotoxin-Producing Fungi in Eastern Kenya. *Plant Pathology Journal* 8: 113 - 119.

NBS, Mbeya Regional Commissioner's Office. 2003. *The United Republic of Tanzania, Mbeya Region: Socio- Economic Profile*. NBS, Dar-es-Salaam.

Ngoko, Z., Daoudou, Imele, H, Kanga, p.t., Mendi, S., Mwangi, M., Bandyopadhyay, R., Marasas, W.F.O.,2008. Fungi and mycotoxins associated with food commodities in Cameroon. *Journal of Applied Biosciences*. 6: 164 - 168.

OECD/FAO, 2010. *Agricultural Outlook 2010-2019 Highlights*. <http://www.agri-outlook.org/dataoecd/13/13/45438527.pdf> (Accessed 2010, November 18).

Ortiz-Monasterio, J.L., Palacios-Rojas, N., Meing, E, Pixley, K., Trethwan, R., Pena, R.J., 2007.Enhancing the Mineral and Vitamin Content of Wheat and Maize through Plant Breeding. *Journal of Cereal Science*. 46, 3, 293 - 307.

Perduri, R., Gobba, S., 2009. Unexpected Aflatoxin Exposure in a Woman in Northern Italy: A Case Study. *Cases Journal*. 2, 7732.

Sallam, M.N., 1999. *Chapter II Insect Damage on Post –harvest*. <http://www.fao.org/inpho/content/compend/text/ch02.htm> (Accessed 2010 January 22).

SATG, 2009.*Post-harvest and Grain Storage Losses: Training Module*. <http://www.satg.org/wp-content/uploads/2010/02/Training-Module-Losses.pdf> (Accessed 2010 October 25).

Simbuso, E. F., Nyanga, A. W., 2000. *Tea Extension System in Rungwe District, TTU Working Document No 3*, Tea Research Institute of Tanzania, Dar- es-Salaam.

Smith, L. C., Alderman, H., Aduayom, D., 2006. *Food Insecurity in sub - Saharan Africa*. International Food Policy Research Institute, Washington DC.

Sweeney, M.J., White, S., Dobson, A.D.W., 2000. Mycotoxins in Agriculture and Food Safety**.** *Irish Journal of Agriculture and Food Research*. 39, 2, 235 - 244.

Tachin, E. S., 2008. *Aflatoxins in Maize, Human Life and Economy System are in Trouble*. *Script of the Audio Document No 6*. IITA- Ibadan, Ibadan.

Thamaga, J. M., 2001. *The Impact of Crop Storage Methods on Household Food Security in rural KwaZulu- Natal.* Masters Thesis University of Natal, Pietermaritzburg, March 2001, pp 9 - 12.

Thamaga- Chitja, J. M., Hendriks, J., Ortmann, G.F., Green, M., 2004. Impact of Maize Storage on rural household food security in Northern KwaZulu - Natal. *Journal of Family Ecology and Consumer Sciences*. 32, 8 - 15.

UNICEF, 2008. The state of the world's Children 2008, Child Survival. UNICEF, New York.

Weinberg, Y.Y., Chen, Y., Finkelman, S., Ashbell, G., Navarro, S., 2008. The Effect of Moisture Level on High-moisture maize (*Zea mays* L.) under hermetic storage conditions- in vitro studies. *Journal of Stored Products Research* 44:136-144.

WFP, 2009. World Hunger Series: Hunger and Markets, third ed. Earthscan, London.

WHO, 2006. *Nutrition and Food Security*.<http://euro.who.int/nutrition/security/sectop> (Accessed 2006 October 17).

Wild, C.P., Gong, Y.Y., 2010. Mycotoxins and Human Disease; A Largely Ignored Global Health Issue. *Carcinogenesis*. 1, 31, 71 - 82.

Williams, J.H., 2004. Human aflatoxicosis in developing countries: a review of toxicology, exposure, potential health consequences and interventions. *The African Journal of Clinical Nutrition*. 80, 1106 - 1122.

CHAPTER TWO
LITERATURE REVIEW

2.1. Introduction

Maize is the main staple food crop in Tanzania (Amani, 2004; Organization for Economic Co-operation and Development and the Food and Agricultural organization (OECD/FAO), 2010). An estimate of over 80 % of the population of Tanzania depends on maize for food (Bisanda and Mwangi, 1996). Thus, maize makes an important contribution to nutrition in Tanzania. However, as with the rest of the countries in Sub-Saharan Africa (Lamboni and Hell, 2009), maize losses due to infestations by pests is well acknowledged in Tanzania (Makundi, 2006; Government of the United Republic of Tanzania, 2006). While much of the grain losses in Africa have been attributed to inadequate post-harvest technologies, it has also been acknowledged that the infestations affect the quantities and quality of grain (Obetta and Daniel, 2007). High quality maize is that which is rich in nutrients, is free from pathogens, and is free from physical and chemical contaminants (Weinberg *et al*., 2008, Golob, 2004). Thus,the presence of physical and chemical contaminants, loss of vigour and reduction in the nutrient component of the grain are components of loss of maize. Maize which is free from infestations offers consumers possibilities for having maximum access to the nutrients that are found in the maize grain.

2.2. The nutritional importance of maize

Since the study at hand focuses mainly on maize which is used for consumption purposes, the literature review in this section provides estimates of nutrients found in dent and flint types of maize only because these two types of maize are the most widely grown for consumption purposes (Johnson, 2000). While the nutritional composition of maize varies with maize type (Johnson, 2000; FAO, 1984), variation in the nutritional composition of maize can also occur as a result of variation in environmental factors such as the nutrient content of the soil in which maize grew (Nuss and Tanumihardjo, 2010). However, on average 100 g of maize would consist of the amounts of nutrients shown in Table 2.1, which are further discussed in section 2.2.1 - 2.2.6.

Table 2.1: The estimated amounts of nutrients in 100 g of white maize

Nutrients	Amount
Carbohydrates	73.40 g
Protein	8.06 g
Thiamine	39 mg
Riboflavin	0.2 mg
Niacin	3.63 mg
Pantothenic acid	0.42 mg
Vitamin B-6	0.62 mg
Folate	19.00 µg
Carotene	0.15 mg
Phosphorus	210.00 mg
Potassium	287.00 mg
Calcium	7.00 mg
Magnesium	127.00 mg
Sodium	35.00 mg
Iron	2.71 mg
Copper	0.30 mg
Manganese	0.40 mg
Zinc	2.20 mg
Selenium	15.50 µg
Dietary fibers	7.30 g
Ash	1.40 g
Ether extract	3.94 g

Source: Klopfenstein, 2000; Nuss and Tanumihardjo, 2010; Ariahu *et al*., 2009

2.2.1 Carbohydrates

About 72 % of the carbohydrates in maize are in the form of starch situated in the kernel's endosperm and simple sugars, most of which are situated in the germ (Nuss and Tanumihardjo, 2010). The starch granules in the endosperm are held together with a matrix of protein (Johnson, 2000). The bonds between the starch granules and the protein matrix in the endosperm are said to be so strong that water alone cannot break them (Hoseney, 2000). This implies that mere washing or soaking of maize does not alter the quantity of protein in maize. Carbohydrates are good sources of energy, and they contribute to the texture and taste of food. It is recommended that 55 % of a person's daily required energy should come from carbohydrates, which must be obtained from different types of food (Nantel, 1999; Nuss and Tanumiharrdjo, 2010). Thus, since maize is rich in carbohydrates, it is an important part of the food crops from which the required daily carbohydrates can be obtained. Reduction in the amount of carbohydrate in stored maize grain can occur as a result of infestations by insect pests and rodents where inadequate maize storage technologies apply. This claim is based on the understanding that pests such as insects and rodents that attack stored maize grain make holes on the grain and feed on it causing reduction of considerable amount of the grain by mass (Kgware *et al.*, 2008; Lamboni and Hell, 2009). Since 72 % of a maize kernel is made up of carbohydrates, significant loss of grain by mass implies that significant amount of carbohydrates have also been lost. Thus, while maize has the capacity to provide significant amounts of carbohydrates to consumers, inefficient storage technologies contribute to reducing the amount of carbohydrates that can be obtained from it.

There is a general understanding that pests and moulds (Reed *et al.*, 2007) that attack stored maize reduce its nutritional value. However, there is no empirical evidence that establishes the quantities of carbohydrates that can be lost to specific pests in maize stored on farm using specific storage methods.

2.2.2 Protein

The protein found in maize comprises the following essential amino acids which must be obtained daily from a diet for health: histidine, isoleucine, leucine, lysine, methionine, threonine, tryptophan, valine and arginine. Two amino acids, namely: lysine and tryptophan are found in very small quantities in maize (Law, 2010; Friedman, 1996), thus, as opposed to animal protein, maize protein is considered to be of poor quality. Maize also comprises non - essential amino acids that the body can manufacture, namely: alanine, aspartic acid, cystein and cystine, glutamic acid, glycine, proline, serine and tyrosine (Hoseney, 2000). Prolonged consumption of foods that are deficient in protein can lead to *kwashiorkor* and *marasmus*, the latter being a result of energy deficiency (Smolin and Grosvenor, 2010). While maize makes it possible for consumers to access several essential amino acids mentioned above, the low quality of its protein necessitates that maize be consumed in the company of foods that are rich in quality protein. Also, with modern breeding technologies the quality of protein in maize can be improved (Bajaj, 1994, Nuss and Tanumihardjo, 2010) through improving quantities of lysine and tryptophan. This should be a priority where maize is the main staple food crop especially in poor communities where diversification of diet is limited. Currently, Quality Protein Maize (QPM) initially developed by CIMMYT to enhance maize protein (Vasal, 2002) has been acknowledged in several countries with respect to its immense potential for improving the consumers' nutrition (Nuss and Tammihardjo, 2011). The use of QPM can make a huge contribution to fighting against malnutrition among the poor in developing countries where maize is a staple food.

However, as with carbohydrates, inefficient storage technologies subject maize to reduction in its protein quantity due to pests. It has been noted that rodents prefer the protein and vitamin rich foods (Cao *et al*., 2002). Thus, when rodents and some insect pests feed on the parts of maize kernels that consist of protein such as the embryo, reduction in the protein component of the maize grain is inevitable. Nevertheless, literature that indicates amounts of protein that can be lost in maize stored on farm using specific storage methods to specific pests was not found, which suggests that this issue has not been given adequate attention.

2.2.3 Fat

Much of the fat in a maize kernel is found in the germ, which consists of the grain's sprouting root and shoots (Klopfenstein, 2000). It is estimated that 4.7 % of the total mass of a maize kernel consists of fat (Klopfenstein, 2000), amounting to 9 kcal per gram of maize (Smolin and Grosvenor, 2010). This means fats may be regarded as good sources of energy. In maize, fats exist in the form of oils, made up mainly of unsaturated fatty acids which are healthier than the saturated fatty acids that make up the fats in meats (Nuss and Tanumihardjo, 2010). In general, since only a small amount of fat is found in maize, together with the fact that the fat is of good quality, make maize to be an important food crop in alleviating diseases that are associated with consumption of saturated fats.

Reduction in fat content of food grains due to infestations has been acknowledged (Kung'u *et al*., 2003). Thus exhaustion of much of the fats in maize by pests is most likely to occur where storage facilities in which maize is stored allow pest proliferation, especially by rodents since much of the fat in maize kernels is found in the embryo, which is most likely to be consumed by rodents that infest maize. Empirical data concerning quantities of fats that can be lost to rodents was not found. This infers that this matter has not been given sufficient consideration. The role that inefficient storage technologies play in the reduction of the fat content of maize grain during storage at household level has also not been given adequate attention. In order to maximize accessibility of good quality fat found in maize, storage technologies must efficiently protect stored maize from invasions by pests.

2.2.4 Vitamins

Small quantities of vitamins are required daily in the body to assist and normalize procedures required for growth, reproduction and maintenance (Smolin and Grosvenor, 2010). While vitamin A assists with vision, thiamine (Webb, 1995), and carotenes function in the same way as vitamin A. Riboflavin, niacin and pantothenic acid promote function of enzymes that are responsible for the metabolism of carbohydrates, protein and fat (Smolin and Grosvenor, 2010). Deficiency of vitamin A can lead to night blindness; while deficiency of thiamin and niacin can lead to beriberi and pellagra, respectively (Webb, 1995), deficiency of pantothenic acid is rare, thus, the resulting outcomes in the body have not been established (Linus Paulin Institute, 2008).

Also known as pyridoxine, vitamin B-6 assists the body in similar ways as thiamine, riboflavin and niacin, but is specifically important for metabolism of protein and amino acids (National Institutes of Health, 2010). Without vitamin B-6 the non-essential amino acids cannot be synthesized (Smolin and Grosvenor, 2010). Vitamin B-6 also assists with synthesis of haemoglobin and supports the growth of the immune system. Deficiency of vitamin B-6 can cause suppression of the immune system and a form of anaemia similar to iron deficiency (National Institute of Health, 2010). Likewise, folate, also known as folic acid or vitamin B-9, is necessary for growth and reproduction of cells. It assists with DNA and RNA synthesis and promotes rapid division of cells, thus, helps to reduce birth defects and anaemia, and to prevent cancer (Ellis-Christen, 2010).

Deficiency of folate can cause poor growth, problems in nerve development and function and anaemia (Smolin and Grosvenor, 2010). The World Health Organisation (WHO, 2011) estimates that 250 - 500 thousands of children become blind every year, and 125 - 250 thousands of the children who become blind due to Vitamin A deficiency die within 12 months of losing their sight. Vitamin A deficiency has also been associated with night blindness and maternal mortality in pregnant and lactating women as well as susceptibility to infectious diseases by infants (WHO, 2011). While vitamins exist in small quantities in maize (Nuss and Tanumihardjo, 2010), further reduction of the vitamin's content in stored maize grain due to invasion by pests and moulds is most likely to happen. Trials by Jood and Kapoor (1994) showed losses of up to 75% of vitamins' in stored cereals when exposed to insect pests. However, since the insect pests were introduced into the stored maize in the laboratory they do not provide a picture of the reality concerning quantities of protein in maize that farm households can lose to invasions during storage.

2.2.5 Minerals

Minerals are needed in the body as components of the body structures that make up the whole body, and are important for regulating processes in the body (Smolin and Grosvenor, 2010). Jood *et al*. (1992) reported reduction in the mineral content in maize exposed to high levels of insect infestation. However, it seems that like other nutrients, the association between storage technologies, storage pests and the reduction in mineral content of maize grain at household level has not been adequately studied. The importance of minerals in humans is further shown in section 2.2.5.1 2.2.5.2.

1.2.5.1 The importance of calcium, phosphorus, magnesium, potassium and sodium in humans.

Calcium, phosphorus, magnesium, potassium and sodium are among a group of minerals that are required daily in the body in amounts of 100mg or more, which are also referred to as major minerals (Smolin and Grosvenor, 2010). Calcium and phosphorus are specifically necessary for formation and strength of bones and teeth (Obikoya, 2010 a, b). Calcium also assists nerves and muscles to function properly. It regulates the release of hormones and regulates blood pressure (Webb, 1995). Its deficiency can impact negatively on bone mass (Smolin and Grosvenor, 2010).While phosphorus provides firmness to bones it also assists membranes to function effectively (Webb, 1995). Other benefits of phosphorus include promoting proper digestion of riboflavin and niacin, assisting with nerve impulse transmission, helping kidneys to function, speeding up healing, helping to prevent and treat osteoporosis and rickets, and preventing stunted growth in children (Obikoya, 2010a). Problems that result from phosphorus deficiency include reduction of body mass, fatigue, loss of appetite, bone pain, anaemia and rickets in children (Linus Pauling Institute, 2003). Apart from the metabolism of calcium, magnesium also assists with the function of several enzymes that are essential for the metabolism of energy. It helps with protein, RNA and DNA synthesis and also in the maintenance of the nervous tissues and cell membranes (WHO and FAO, 2004). Deficiency of magnesium causes several problems including difficult contraction of muscles, urinary spasm, anxiety, swallowing and breathing difficulties, hyperactivity, panic attacks, numbness and tingling sensations and high blood pressure (Schachter, 1996). Sodium is necessary for helping nerves to transmit impulses and for maintaining the acid-base balance in the body; potassium is necessary for contraction of muscles and the heart, and like sodium it promotes nerve impulse transmission and maintains the acid-base balance in the body (Webb, 1995). Lastly like magnesium, sodium assists nerves to transmit impulses while it also maintains water balance in the cells (Anderson *et al*., 2010).

2.2.5.2 The importance of iron, copper, zinc, manganese and selenium in humans

Iron, copper, zinc, manganese and selenium are among minerals that are required in the body in amounts of 100mg or less per day known as 'trace elements'(Smolin and Grosvenor, 2010). Iron is important for transportation of oxygen from the lungs to the cells, for synthesis of steroid hormones and bile acids, for detoxification in the liver (WHO and FAO, 2004) and it is an important component of several enzyme systems (Smolin and Grosvenor, 2010). Deficiency of iron can cause anaemia (WHO and FAO, 2004).Copper in the body assists with enzymes functioning and maintenance of a healthy heart, blood and connective tissues. It also promotes normal function of the immune system and it is a necessary component of several antioxidant enzymes (Gissen, 1994). Other functions of copper include assisting with neurotransmission and development of the brain in fetuses (Science Daily, 2007). Deficiency of copper is associated with abnormalities of the skeleton, impaired growth, degeneration of the heart and nervous system, suppressed immune function and altered hair structure and colour (Smolin and Grosvenor, 2010).

In general zinc is necessary for growth and repair (Smolin and Grosvenor, 2010). It assists enzymes, vitamins and immune system function, DNA and RNA synthesis, absorption of folate, health of cell membranes and carbohydrate metabolism. Other functions of zinc include the storage and release of insulin, regulation of hormones and healing of wounds (Hambidge, 2000). Deficiency of zinc causes impaired growth, immune, nervous and reproductive systems (Hambidge, 2000). While manganese is essential for bone development and enzyme function, its deficiency in humans has not been studied, thus, it is not known (Linus Pauling Institute, 2001; Smolin and Grosvenor, 2010).

Selenium is a component of enzymes that fight against free radicals in the body, and it is also associated with enhanced immunity, prevention of heart disorders, enhanced function of the thyroid gland, prevention of tissue degeneration due to aging and reduction in rates of cancer (The Caribbean Food and Nutrition Institute, 2005). Deficiency of selenium causes a type of heart muscle disease known as Keshan and a type of bone and joint disease known as Kaschin-Beck (FAO, 2002). As indicated in Table 1.1, iron, copper, zinc, manganese and selenium can be obtained from maize. Thus, maize has capacity to contribute to minerals that are essential for the function of body systems indicated in this section.

2.2.6 Dietary fibers

A maize kernel also consists of 13.4 % of dietary fiber, the indigestible complex carbohydrates situated in the bran (Klopfenstein, 2000). Normally the bran and the aleurone layer break away and are removed during milling of maize (Hoseney, 2000). As a result the nutrients that are comprised in the aleurone and the bran are lost, thus, the end product would have lesser of the nutrients than the original grains. Apart from helping the bowels to function properly (The European Food Information Council (EUFIC, 2010), some of the dietary fibers such as the prebiotics have capacity to stimulate growth of bifidobacteria in the colon, which have capacity to prevent pathogenic species from infecting the colon (Nantel, 1999). Obviously, pests that feed on stored maize impact negatively on the content of dietary fibers in maize grain. However, similar to the rest of the nutrients in maize, it seems that the reduction in dietary fibers due to pests during storage has not been given enough attention.

Where processing of maize involves grinding and sifting, FAO (1968) estimates that 100 g of maize flour would have 368 cal of energy and the following quantities of nutrients: 9.4 g protein, 3.3 g fat, 74.1 g carbohydrates, 1.0 g dietary fiber and 18 mg calcium. It will also have 178 mg phosphorus, 3.3 mg iron, 0.26 mg thiamine, 0.08 mg riboflavin and 1.0 mg niacin. However, this will depend on maize cultivars and soil nutrient status at the time of production.

In general, the cited literature elaborates the immense importance of maize with respect to the diversity of nutrients that can be obtained from it, which makes it an important crop in ensuring not only availability of food but also in contributing to nutrition. Pests (CIMMYT and Dubin, 2010; Mulungu *et al*., 2010) and moulds (Reed *et al*., 2007) reduce not only the amounts of maize that can be available to consumers, but they also reduce the nutrient composition of maize grain. Thus, the degree to which storage technologies are efficient in protecting maize from infestations and infections plays a major role in determining the quality of accessible maize especially with respect to its nutrient content and safety for consumption as further reviewed in section 1.3.

2.3 Maize storage problems and their effects on the nutrient content and safety of maize

2.3.1 A perfect storage method

Coulter and Schneider (2004) characterized an ideal storage method as one which fulfills the following factors**:** the ability to provide maximum possible protection from moisture and pests; and the capacity to provide the farmer with ease of performing all of the activities that are involved with management of the stored grain and the storage facility, such as inspection, disinfection, loading and unloading, cleaning and reconditioning. It should also be suitable for use in the climatic conditions of the place where it is being used. Thus, storage methods that lack these characteristics create favourable conditions for growth of pests, which ultimately affect the quantity and quality of stored maize (Jood *et al*., 1992).

Storage methods influence the quantities of food available to farm households for both consumption and marketing purposes (Thamaga, 2001; Thamaga-Chitja *et al.*, 2004), thus, they play an important role in determining food security of the consumers (Kimenju and De Groote, 2010). Efficient crop storage methods maintain the availability and quality of crops (Nations Development Fund for Women (UNIFEM), 1995), while poor storage technologies lead to crop deterioration due to pest attack. Apart from contaminating maize with physical and chemical wastes (Lewis *et al*., 2008), maize storage pests create unpleasant odours (Hansel *et al*., 2004), they reduce the marketability of the infested maize due to its reduced quality (De Groote, 2004; Hill, 2008) and render the foods made from the infested and infected maize unpalatable (Mejia, 2003).

2.3.2 Insect pests of stored maize and their effect on maize quality and quantity

In sub-Saharan Africa, the larger grain borer, *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae), was identified as the most damaging storage pest that causes great losses of maize (Lamboni and Hell, 2009). It was estimated that in Africa, *P. truncates* causes up to 40 % of maize loss within six moths of storage (Lamboni and Hell, 2009), whereas an estimate of 34 % of maize loss due to *P. truncatus* after 3 - 6 months of storage were reported in East Africa (Hodges, 1998). *Sitophilus zeamais* (Motschulsky) (Coleoptera: Curculionidae), was named as the next most important insect pest of stored maize in Africa, followed by *Tribolium* spp (Coleoptera: Tenebrionidae), *Cathartus quadricollis* (Gue´rin) (Coleoptera: Silvanidae), *Rhyzopertha dominica* (Fabricius) (Coleoptera: Bostrichidae), *Oryzaephilus* spp (ColeopteraCucujidae), *Gnatocerus* spp (Coleoptera Tenebrionidae) *Palorus* spp (Coleoptera Tenebrionidae), *Cryptolestes ferrugineus* (Stephens) (Coleoptera: Laemophloeidae) (Lamboni and Hell, 2009).

However, recently moths, particularly *Sitotroga cerealella* (Adda *et al.*, 2002) and *Plodia interpunctella* (Mohandass *et al*., 2007) have been identified as important insect pests next to *Sitophilus zeamais* in the order of importance. While up to 12 % of maize loss due to maize weevils alone has been reported in the tropics (Pingali and Pandey, 2001), *Sitophilus zeamais* has been reported to be responsible for 10 - 20 % of maize losses after three months of storage (Boxall, 2002, as cites by Tefera *et al*., 2011). Thus, due to inefficient storage technologies millions of tonnes of maize are lost to insect pests in the world each year. In Tanzania losses of up to 34 % of maize due to insect pests have been reported (CIMMYT and Dubin, 2010). However, the authors have neither indicated what methodologies they used to estimate these losses nor stated whether they took into consideration the consumption patterns of the people studied, thus, the accuracy of the estimations is not guaranteed.

Insect pests impact negatively on maize in the following ways: insects' activities in stored maize damage maize kernels by making holes in them, which make the maize kernels susceptible to infestation by moulds (Sallam, 1999). Insects further spread moulds in storage facilities through moving from one place to another (Lamboni and Hell. 2009). In fact, moulds in maize have been found to intensify with the intensification of insect pests (Wright, 2011). Insect pests may also affect the quality of maize by contaminating the stored maize with wastes, which may further lead to interference with the odour, colour and taste of the maize. In addition, insect pests would reduce the nutritional value of stored maize (Lamboni and Hell, 2009), possibly through feeding on the nutrient rich germ and the outer layer of the maize kernels, which in turn leads to significant reduction in the kernels' nutrient content. Humidity and temperature in the storage facilities, moisture content of maize grain prior to storage, materials from which storage facilities are made, damage of maize grain prior to storage and length of time during which maize is stored are the main factors that influence development of pests in stored maize. Issues raised in this paragraph are further reviewed in the sections that follow.

2.3.3 Effects of temperature, humidity and moisture content of maize on insect pest infestation of maize in storage.

Relative humidity determines how much more water vapour in the air can hold at a specific temperature. While there are different opinions concerning specific temperatures and relative humidity at which maize can be stored safely, the general understanding is that exchange of moisture occurs between stored maize and the storage environment until an equilibrium is reached (Metananda, 2001; Abba and Lovato, 1999). Thus, exposure of dry maize to moist air will lead to intake of more moisture from the air by the crops. The opposite can also take place until the air in the storage facilities is saturated. Abba and Lovato (1999) have shown that unless packed in waterproof material, dry maize stored at 25 ^{0}C and 65-70 % relative humidity may gradually absorb moisture from the storage facilities, which will result into loss of the maize kernels' viability within three to four months of storage. Metabolic activities of insects may also lead to increase in moisture content of the stored crops through respiration and condensation (Williams, 2004).

Furthermore, through respiration moist grain releases more heat and moisture in the storage facilities (Obetta and Daniel, 2007). The resulting heat raises temperatures in the storage facilities, leading to increase in humidity in the storage facilities due to condensation thus, promoting growth of moulds and micro-organisms (Williams, 2004). In turn this leads to further increases in moisture content of the grain and increase in humidity and temperature in the storage facilities, thus, creating possibilities for more infestations and germination of the stored maize. In order to prevent maize from absorbing moisture from storage facilities, Metananda (2001) and Abba and Lavato (1999) recommend that maize should be stored at 20 ^{0}C and 40 % - 50 % relative humidity and 11.5 % moisture content. Practically, this may not be easy for poor farm households in Africa to achieve because they do not use modern facilities to measure moisture content of maize kernels or relative humidity and temperature in storage facilities.

Most species of insect pests are killed when exposed to temperatures above 45 ^{0}C (Sallam, 1999) for more than ten hours (Fields, 1992; Gwinner *et al.*, 1996). Insect pests will also die if exposed to temperatures below 5 ^{0}C (Gwinner *et al.*, 1996) for 72 hours (Sallam, 1999). Growth and development of most of insect pests occur at 10 - 40 ^{0}C (Yigezu *et al.*, 2010), and at 50 - 60 ^{0}C insect pests die within a few minutes (Fields, 1992). Thus, temperatures below 10^{0}C are generally suitable for maize storage. However, 10 ^{0}C for maize storage is not practical for poor farmers in Africa due to lack of facilities for maintaining low temperatures in storage facilities, thus, they store grain at ambient temperatures, often higher than 10 ^{0}C. Consequently, pests would easily develop in stored maize.

2.3.4 Fungal species that damage maize grain and their effect on maize quality

Under favourable conditions, metabolic activities of several species of fungi produce toxic secondary products known as mycotoxins. In the presence of moisture, temperatures at 20 ^{0}C - 40 ^{0}C have been reported to be favourable conditions for growth of moulds (FAO, 1985). Therefore, moulds would infect stored maize where conditions in the storage facilities are as indicated above. At 5 ^{0}C - 8 ^{0}C growth is very slow (Agrios, 2005), below 5 ^{0}C fungi become inactive. Thus, storage temperatures below 5 ^{0}C can keep food products safe from fungal infestation. However, farm households in Africa store maize at ambient temperatures, thus, maintaining storage temperatures below 5 ^{0}C is not practical for them.

Much of the mycotoxins contamination of commodities has been associated with inadequate storage technologies, maize kernels being damaged, and climatic conditions such as high humidity, dampness and low temperatures (Williams, 2004; Gourama and Bullerman, 1995).

Thus, it is recommended that in order to prevent infection by storage fungi, stored maize should be free from injury, insect pests, moulds and dirt prior to storage, and 12 % moisture content of maize or less should be maintained (Kaaya and Khamunyangire, 2010). For preventing growth of moulds in maize, Reed *et al.* (2007) recommended rapid drying prior to storage for maize which is not dry enough at harvest; whereas Semple *et al*. (1989) recommended up to 48 hours after harvest as the time limit within which maize which is not dry enough at harvest should be dried depending on drying conditions. Apart from contaminating maize, moulds also reduce its energy content and its viability, which in turn reduces its marketability (Reed *et al.,* 2007).

Maize which is infested by fungi is susceptible to infestation by insect pests as well due to the attraction of the pests to the odour caused by the deterioration of the fungi infested maize (Ako *et al*. 2003). Thus, maize storage methods that allow growth of moulds also put stored maize at risk of being infested by insect pests. *Aspergillus, Penicillium* and *Fusarium* species have been associated with production of mycotoxins that affect both human beings and animals (Sweeney *et al.,* 2000; Akande *et al.,* 2006). These fungal pathogens may start infesting crops before they are ready for harvest (Sweeney *et al.,* 2000), during drying, or during storage (Stack *et al.,* 2003). Furthermore, *Fusarium* (Chelkowski *et al.,* 2007), *Penicillium* and *Aspergillus* (Stack *et al.,* 2003) species cause ear and kernel rots of maize. A more detailed account of the three ear rots mentioned above is provided in the sections that follow.

2.3.4.1 Penicillium ear rot and associated mycotoxins

Penicillium ear rot is caused by *Penicillium* species and a maize cob that is infested with *Penicillium* ear rot would be characterized by blue green powdery growth on the surface, between kernels and in the germ (Stack *et al.,* 2003). On culture, flat cotton-like filamentous structures grow rapidly to form colonies which are initially white in colour and later turn blue green. When observed under the microscope, colonies show septate hyaline hyphae with long conidiophores that branch in a broom-like manner spores that look like glass beads (De Hoog *et al.,* 2000). Conidia are single-celled and may measure up to 5 µm in diameter (Clinical Microbiology Proficiency Testing (CMPT), 2007). Mycotoxins caused by *Penicillium* species include ochratoxins which often contaminate decaying vegetation, cereals, peanuts and cotton seeds (Almeida *et al.,* 2010) and patulin which can be found in apples and apple products (FAO, 2004).

Ochratoxin A, a type of ochratoxins mostly found in food (Lawley, 2007), is produced at 15 - 37 ^{0}C (FAO, 2004) in the presence of moisture. Exposure to unacceptable levels of ochratoxins causes kidney problems in animals and human beings (Hayes, 2001, Diekman and Green, 1992). Ochratoxins may also cause retarded growth to chickens that are raised for slaughter, decreased egg production to laying hens (Diekman and Green, 1992) and may cause cancer of the liver in human beings (Munkvold *et al.,* 2009; Wood *et al.,* 2003). Although there are no international set standards for acceptable levels of ochratoxins, 50 µg per kilogram of maize (µg/kg) is the highest acceptable level for a number of countries (FAO, 2001). Thus, levels above 50 µg/kg ochratoxins in maize may be harmful to the consumers.

2.3.4.2 Fusarium ear rot and associated mycotoxins

Fusarium ear rot is caused by *Fusarium* species (Chelkowski *et al*., 2007; Parsons and Munkvold, 2010). Maize kernels that are infested with *Fusarium* ear rot would be characterized by growth of white cotton-like mycelium which remains white or turns pale pink, pale purple or reddish pink upon maturity (University of Adelaide, 2011; Seifert, 1996). On culture, *Fusarium* ear rot form hyaline, slightly curved macro conidia which are 2 - 5 µm in diameter, 3-7 septate with an apical cell (Seifert, 1996). Micro conidia are single celled and may be 2 - 3 µm in diameter and 5 - 12 µm long. Mycotoxins that are produced by *Fusarium* species include fumonisins, zearalenone, diacetoxycirpenol, T-2 and HT-2 toxins, deoxynivalenol, moniliformin, beauvericin and fusaproliferin (Logrieco *et al.,* 2002). While fumonisins are said to be mainly produced by *F. moniliforme* and *F. proliferatum*, T-2 toxins are produced by *F. tricinctum*, *F. equiseti* and *F. sporotrichioides* (Öhlinger *et al*., 2004) in the presence of moisture and warm temperatures.

There are no known temperatures that favour the production of T-2 toxins (FAO, 2004); whereas fumonisins are produced at 25 - 30 ^{0}C (Marin *et al.,* 1995). Fumonisins may cause cancer of the oesophagus, kidney, pancreas, gastrointestinal tract and blood cells problems, and they may interfere with brain, liver, and lungs function (Vercelli and Parker, 2002). The effects of fumonisins on animals and chickens as highlighted by Tardieu *et al*., (2007) are the same as those of ochratoxins. Consumption of high levels of T-2 toxins are said to cause aleukia, a disease of the alimentary canal, and digestive disorders (Bennet and Klich, 2003) and immunosuppression

(Tai and Pestka, 1990). In chickens T-2 toxins can cause lesions, low egg production, reduced weight and other diseases similar to those caused by ochratoxins (Soković *et al*., 2008; Tardieu *et al.,* 2007). Currently, there are no set acceptable standards for T-2 toxins in maize. The FDA's standards for fumonisins in milled maize is four parts per million (4ppm), equivalent to 4mg/kg (Wu, 2004). Thus, commodities that have more than four mg/kg of fumonisins may cause health problems.

2.3.4.3 Aspergillus ear rot and associated mycotoxins

Aspergillus ear rot is caused by different species of *Aspergillus*, predominantly *A. flavus* and *A. parasiticus*, and like *Penicillium* species *Aspergillus* species may be found in the soil and in decaying organic matter (Stack *et al*., 2003). Maize which is affected by *Aspergillus* ear rot is characterized by a production of powdery masses of either black, pale yellow, yellow or yellow green spores that turn dark green to brown with maturity {International maize and Wheat Improvement Center(CIMMYT), 1999}. When cultured, the ear-rot forms septate hyaline hyphae and globose fruiting bodies which are flask shaped or round at the end. The phialides may be attached directly to the vesicle or via a sprouting cell, while conidia form chains on the phialides. They are globose, smooth or slightly rough, and measure 2 - 8 µm in diameter and 2 µm in length (Eltem *et al.,* 2003). Aflatoxins in maize are mainly produced by *A. Flavus* (Munkvold *et al*., 2009). However, *A. parasiticus, A. nomius, A. ochraceoroceus, A. pseudotamari* (Bennet and Klich, 2003) and *A. Bombycis* (Peterson *et al*., 2001) also produce aflatoxins in stored cereals such as maize.

Moisture and 15 ^{0}C - 43 ^{0}C temperatures are factors that favour the production of aflatoxins (FAO and the International Agency for Atomic Energy (IAEA), 2001). Aflatoxins may cause cancer of the liver in human beings, decreased eggs production in chickens (Exarchos and Gentry, 1982; Oliveira *et al*., 2002), decreased milk production and interference with reproductive efficiency in animals (Cornell University, 2009). Suppression of the immune system in both human beings and animals can also occur (Bennet and Klich, 2003).

Acceptable levels of aflatoxins for human beings are 20 parts per billion (20 ppb) or 20 µg/kg for all types of foods except milk (Munkvold *et al.,* 2009; Wu, 2004). In this case maize meal that has more than 20 ppb of aflatoxins would cause health problems to the consumers. Aflatoxin contamination resulting from moulds infestations of food crops has been identified as a major problem in many countries (Siwela *et al.,* 2005), including Sub- Saharan Africa (Ranajit, 2007). Other toxigenic types of fungi include *Phomopsis leptostromiformis* which produce phomopsins, (Culvenor *et al*, 1983), *Acremonium lolii* which produce lolitrem alkaloids, *Acremonium coenophialum* which produce ergopeptin alkaloids, *Pithomyces chartarum* which produce sporidesmins and *Clavices purpurea* which produce ergot alkaloids (D’Mello, 2000). In April 2004, 125 people in Kenya alone died due to aflatoxin contamination (Lewis *et al.*, 2005). In Tanzania, studies that were conducted on home stored maize obtained from 120 households from Ruvuma, Iringa and Kilimanjaro regions in 2005 revealed the presence of unacceptable levels of aflatoxins (Kimanya *et al.*, 2008). However, there is no indication that studies have been done in Tanzania in general and in Rungwe district in particular to relate specific storage technologies with mycotoxins contamination of commodities.

2.3.5 Rodents that attack stored maize

Three types of rodents: black rats, brown rats and house mice scientifically known as *Rattus rattus*, *Rattus norvegicus* and *Mussmuscullus* species, respectively, are significant contributing factors to crop loss worldwide (De Groote, 1996; Kgware *et al*., 2008). Rodents multiply fast and may consume considerable produce per day depending on their species. It is estimated that 15 % of maize produced in Africa is lost to rodents alone each year (Stenseth *et al*., 2003). Likewise, in Tanzania outbursts of pre-harvest and post-harvest rodents infestations of maize are common, causing an estimated loss of 15 % of maize per annum (Makundi *et al.*, 2005; Mulungu *et al*., 2010). Rodents make holes in storage containers, and through this they create moisture problems in the stored products (The Somali Agricultural Technical Group (SATG), 2009); while they also contaminate food grains with their excretions and hair (Cao *et al*., 2002).

Rodents can transmit about 60 types of diseases to humans, and are carriers of diseases that affect both humans and domestic livestock (Parshad, 1999). Black rats are associated with transmission of bubonic plague, whereas brown rats are associated with spreading the weil’s disease, cryptosporidiosis, viral hemorrhagic fever (VHF), Q fever and hantavirus pulmonary syndrome (Public Health of Canada, 2008; Mills and Childs, 2001). House mice are notorious for transmitting lyme disease, an infection caused by the bacterium *Borrelia burgdorferi* of which house mice are hosts (Noble Pest Management, 1994; Public Health of Canada, 2008). House mice also transmit the lymphocytic chloriomeningitis arenaviruse (Mills and Childs, 2001), which cause aseptic meningitis (Roebroek, 1994.). In the light of the above literature review, storage pests do not only reduce the amount of food that can be available to the consumers, but they also cause health problems through contaminations and reduce the nutritional content of the infested foods. As indicated in Section 2.2.2, rodents prefer foods that are rich in vitamins and protein, thus, when infestation of stored maize by rodents occurs, the rodents are likely to consume the most nutritious parts of the maize grain thus, causing reduction in the vitamin and protein content of the grain. Thus, storage methods that allow the infestation of stored maize by rodents to take place impact negatively on the quantity and quality of the maize grain.

2.4 Common storage methods used by small scale farmers in Africa

In Africa, the poor status of small scale farmers leads them to select storage methods which are cheap to construct regardless of their inadequacy, consequently, most of the grain losses occur during storage (Obetta and Daniel, 2007). This necessitates improvement of the storage technologies. Factors that usually affect the farmers' choice of the storage methods include the cost of building and running the storage method, availability of the materials and expertise for building the storage facility, climatic conditions of the area and the types of pest problems in the area (FAO, 1985). Other factors include the amounts of crops that are to be stored and the expected quality of the stored crops (FAO, 1985). In section 2.4.1 - 2.4.10 storage technologies that small scale farmers commonly use in Africa are reviewed.

2.4.1 Sack storage

Storage sacks are made of different materials such as sisal natural fibres such as jute and synthetic fibers, and they can store up to 100 kg of grain each (Lindblad and Druben, 1976). To prevent the storage sacks from absorbing moisture from the floor, the sacks need to be stacked on platforms raised off the floor as demonstrated in Figure 2.1, with space between them to allow air to flow under the sacks and between them. This cools the stored crops from the heat that results from respiration of the

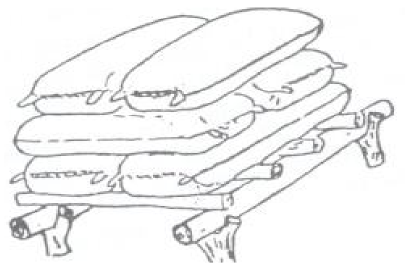


Figure 2.1: Sack storage
Source: De Groote, 2004

grain. Regular inspection of crops stored in sacks is necessary for keeping the grains safe from attacks by pests (De Groote, 2004). The weakness of sack storage is that sacks do not last long (FAO, 1994). New storage sacks are likely to be needed after every harvest, which makes this storage method expensive. Sack storage methods require that the storage sacks be treated with pesticides prior to storage to reduce chances of infestation (FAO, 1994).

The advantage of sack storage is that it provides the farmer with ease of access to the stored crops because the farmer can choose to store the grain filled sacks at any convenient place in the home. However, sacks can be easily damaged by rodents, which would expose the stored maize to rodents' infestations. Lastly, although sack storage method is commended for having the capacity to keep stored grain cool, the extent to which sack storage method is efficient for protecting maize from moisture content problems, especially in humid places, has not been given adequate attention. It was hypothesized that because storage sacks allow aeration to take place, they can easily allow moisture to enter, which can lead to moisture content problems and development of fungi in the stored grain especially in humid places such as Katumba ward.

2.4.2 Storage cribs

Storage cribs can offer stored crops up to six months of storage, they can last more than a year and the amount of crops that they can store would depend on the size of the crib (UNIFEM, 1995). The advantage of storage cribs is that maize stored in them continues to dry through ventilation due to the manner in which the cribs are built. However, the rate at which maize dries in a crib depends upon the force at which air currents pass through the maize cobs, and this is influenced by the width of a crib (FAO, 1987). Thus, maize would dry faster in a cribs 60 cm wide crib than it would in a crib which is wider than 60 cm (FAO, 1987). Placing the longer side of the crib in line with the orientation of the prevailing wind has also been found to be helpful in allowing as much air current as possible to be blown into the maize cobs in the crib (FAO, 1987). Thus, purposeful designing and positioning of cribs may be helpful in maize drying. However, it has also been noted that it takes eight to ten days to bring maize in a crib to the right moisture content during the dry season, and 80 days during the wet season (FAO, 1980). Generally, maize with 30 % moisture content at harvest can take about six weeks to be appropriately dried in a crib (Shepherd, 2010). The length of time that it takes for maize in storage cribs to dry is a lot longer than the time recommended by Semple *et al*., 1989 and Reed *et al.*, 2007) for drying maize which is not dry enough for storage at harvest mentioned in Section 2.3.4. As a result development of moulds and insect pests on maize stored in cribs in humid areas is likely to occur. Thus, cribs may not be suitable for use in areas characterized by prolonged seasons of rainfall, coolness and high humidity because they would create conditions that are favourable for the growth of pests.

Storage cribs can be metallic or non-metallic (Figure 2.2). Walls and floors of non-metallic cribs are made using wood and mud, while roofs are thatched. Rodents can easily make holes through them, while moisture can also penetrate into the cribs and cause moisture content problems in the stored grain. As opposed to non-metallic cribs, metallic ones are made using materials which rodents cannot make holes through such as iron or aluminum sheets, and they can be rodent proofed by fitting into them structures that prevent rodents from getting into the cribs (Figure2.2).

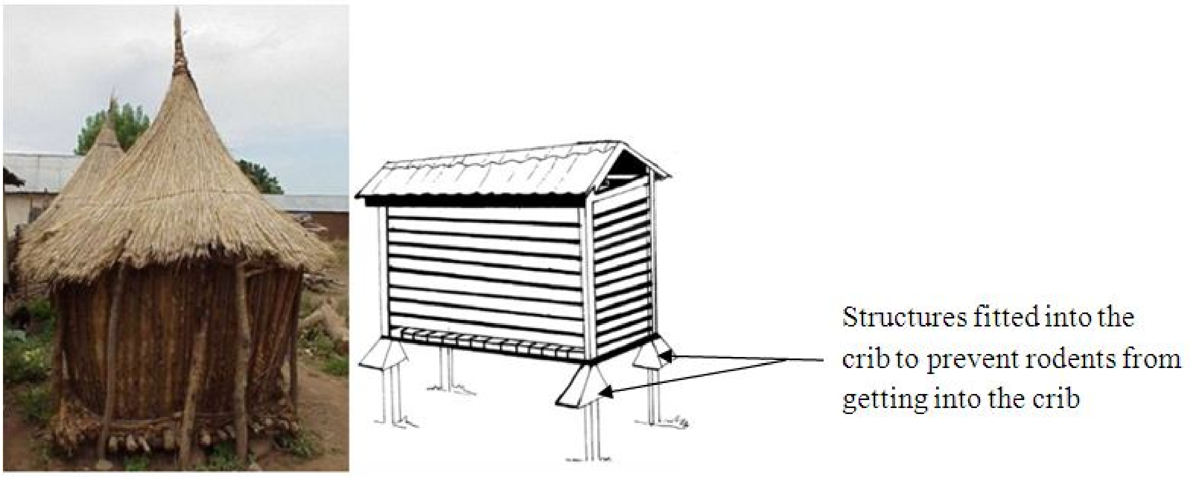


Figure 2.2: Storage cribs
Source: International Institute of Tropical Agriculture (IITA), 2009

2.4.3 Storage baskets

As shown in Figure 2.3, storage baskets are made of reeds, elephant grass, bamboo, supple sticks or sorghum stalks, and they can be plastered in order to make them somewhat airtight (FAO, 1994). Furthermore, storage baskets can last relatively longer if they are not exposed to moisture, thus, it is recommended that storage baskets should be raised above the ground in order to prevent them from absorbing moisture (Shepherd, 2010). Storage baskets are cheap to make using local materials, and they can hold up to 100 kg of grain (Lindblad and Druben, 1976), which is relatively small. In addition, storage baskets may be roofed or not roofed (Shepherd, 2010). A storage basket which is not roofed makes it very easy for stored grain to be infested by rodents. Thus, roofing of the storage baskets is recommended for more efficiency. However, like non-metallic cribs, in general, the materials from which storage baskets are made, make it easy for rodents to make holes through them, whereas absorption of moist air by the storage baskets is also possible. This can lead to development of insect pests and moulds in the storage facilities. Therefore, storage baskets may subject stored maize to rodents, insect pests, and possible contaminations especially in humid environments. Consequently, the quality of stored maize in relation to its nutritive value would be impacted upon negatively.

Figure 2.3: A storage basket

Source: UNIFEM, 1995

2.4.4 Air tight storage methods

Lindblad and Druben (1976) classified the use of different types of silos and other storage methods such the use of plastic bags that restrict entrance of air into stored maize grain under 'air tight storage methods'. With air tight storage methods grains are stored in metallic, plastic, concrete or earthenware containers that prevent air from getting into the crops (FAO, 2010). Maize is poured into the containers through an opening on the top part of each container, followed by sealing the opening (Lindblad and Druben, 1976). This eventually stops the respiration of the stored crops and organisms in them if any, leading to death of the organisms

(De Groote, 1996). With the exception of air tight plastic bags, maize from the air tight storage containers is accessed through a small opening which can be closed tightly after every use (Lindblad and Druben, 1976). For effective storage, containers must not have cracks or holes, and they must be filled to the top to keep air out of the containers. Air tight storage methods are further reviewed in section 2.4.5 - 2.4.8.

2.4.5 Concrete silos

Concrete silos (Figure 2.4) are made using concrete bricks and they can store up to five tonnes of grain depending on the size of the silo. Concrete silos are said to have the capacity to offer storage grain up to one year of protection. Concrete silos include cement-stave silos which have the capacity to store up to 10 tonnes of grain and Thai-Ferro cement silos which can store four to six tonnes of grain. Although they are durable, concrete silos are expensive because the materials required and the cost of constructing them is high. Thus, poor small scale African farmers may not be able to cope with the cost of making concrete silos regardless of the benefits.

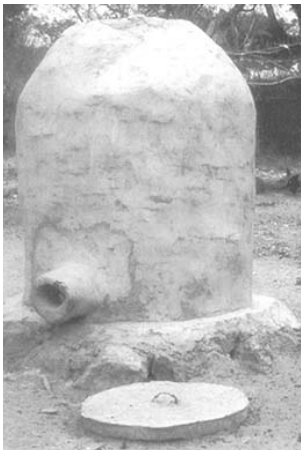


Figure 2.4 Concrete silo
Source: Shepherd, 2010

Furthermore, concrete silos are criticized for allowing build-up of heat leading to condensation and moisture problems, and ultimately to infestations by insect pests and moulds infections (Villers *et al.*, 2006). Unlike concrete silos, wooden silos were found to maintain coolness in the storage facilities (Alabadan, 2005) thus, they offer an alternative way of storing maize. However, since wood can easily be chewed by rodents especially, grain stored in wooden silos may be subjected to attack by rodents especially where the silos are made of thin wood.

2.4.6 Mud block silos

Mud block silos (Figure 2.5 a and 2.5 b) are made using compacted soil (Lindblad and Druben, 1976). Compact soil is naturally a poor conductor of heat and has high thermal inertia (Darlington, 2007) because heat does not flow through it easily. Thus, when exposed to heat a brick silo would build up heat on the surface while the inner parts of the bricks remain cool. This helps to keep crops stored in the brick silo cool, leading to longer storage (UNIFEM, 1995). Other advantages of mud brick silos include that the bricks can be made locally and that the farmers can choose to make a silo of the desired size and that they are cheap to build (UNIFEM, 1995). Also, a slanted floor and a grain chute (Figure 2.5 a and 2.5 b) makes it easy for the farmers to reach the grain when necessary without opening the top of the silo (Lindblad and Druben, 1976). However, due to the nature of the material used to make the mud brick silos, moisture can easily get into the storage facilities and cause moisture problems and damage to the storage facilities. The ease with which mud block silos break renders them expensive since new ones will have to be built after every breakage (Coulter and Schneider, 2004). Also rodents can easily make holes through the mud bricks, which, apart from damaging the storage facilities under discussion in this section, leads to infestation of the stored grain and subsequent problems such as loss of grain to the rodents and moisture content problems. Proper handling and protection can ensure 6-8 years of use of mud brick silos; whereas burnt mud brick silos can be used for 20 years or more (Coulter and Schneider, 2004). Thus, it is recommended that mud bricks be burnt to increase their durability.

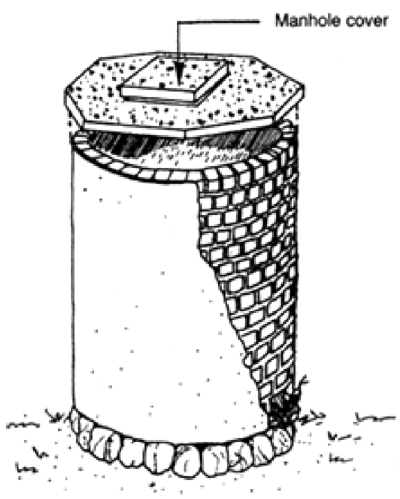


Figure 2.5 a: Brick silo

Source: Shepherd, 2010

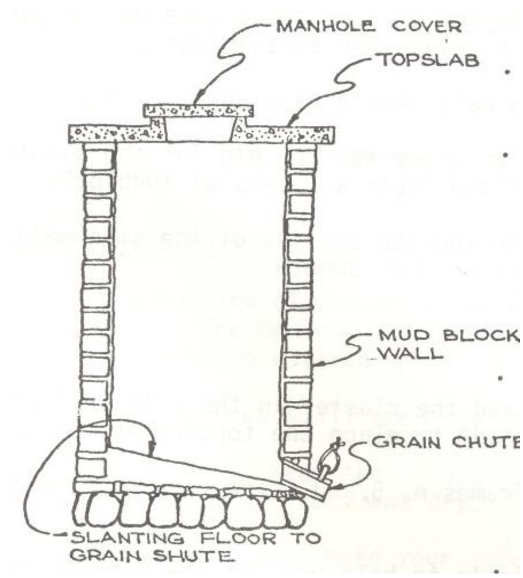


Figure 2.5 b: A cross section through a mud block silo
Source: Lindblad and Druben, 1976)

2.4.7 Metal silos

Metal silos (Figure 2.6) can hold up to 4000tonnes of grain depending on the sizes of the silos (Ikisan, 2000). Due to the fact that they are metallic, rodents cannot make holes through them.

Furthermore, metal silos can be made airtight by lining the inner walls with air proof plastic materials, and they can easily be fumigated. Thus, metallic silos have the capacity to protect stored grain from rodents and insect pests. However, metals are good conductors of heat (Stoker, 2010), thus, heat flows through them easily. Therefore, unlike brick silos, build-up of heat inside the metallic silos can occur when they are exposed to heat (Villiers *et al.,* 2006). Condensation can also occur when temperatures drop, which leads to moisture content problems and creates favourable conditions for infestations (Villiers *et al.,* 2006). Other disadvantages of metal silos include that they are expensive to construct (Lindblad and Druben, 1976). Thus, poor farmers in Africa may not be able to afford them. They may also be subject to corrosion in moist environments (Villers *et al.,* 2006). The latter shortens the metallic silos' lifespan and makes them unsuitable for use in humid places.

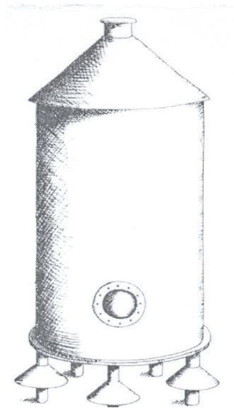


Figure 2.6: Metal silo
Source: UNIFEM 1995

2.4.8 Air tight plastic bags

Air tight plastic bags can store up to 60kg of grain for six to nine months (UNIFEM, 1995). They can prevent moisture and air from getting into the stored grain, which leads to death of insect pests or micro-organisms that may have been hiding in the stored grain. They also make it possible for small scale farmers to access only the required amount of crop when necessary (Lindblad and Druben, 1976). The latter is important because it minimizes exposure of the stored crops to external factors such as moisture. Thus, air tight plastic bags may be more beneficial to small scale farmers than storage sacks. Suggestions for improvement of air tight plastic bags include placing cotton liners inside them and closing them tightly (UNIFEM, 1995). However, air tight plastic bags are easily torn, and rodents can eat through them. Maize stored in airtight plastic bags can be kept safe from rodents by storing the plastic bags in solid containers.

2.4.9 Underground storage pits

Underground storage pits can offer protection to stored crops for up to two years if the walls of the pits are lined with bricks or concrete to hinder moisture from getting in (Ikisan, 2000). The amount of maize that an underground storage pit can store depends on the size of the storage pit. It has been noted that while this method can protect stored crops from rodents and insects, moisture and air from other parts of the soil may move into the storage pit, and crops stored in such pits may be attacked by mites (UNIFEM, 1995). Grain stored in an underground storage pit cannot be accessed easily because the entrance to the pit is covered with soil to prevent air and moisture from getting into it (Ikisan, 2000). Therefore, underground storage pits cannot be used for storage of grain intended for daily consumption.

2.4.10 Roof storage

In most cases farm households hang maize cobs on beams below the roof of the kitchen so that smoke and heat from the fireplace can dry and protect stored maize from insect pests (UNIFEM, 1995). However, due to the limited size of the area below the roof, farm households can store relatively small amounts of maize using this type of roof storage method. Furthermore, this type of storage is mostly used for storing seeds for planting.

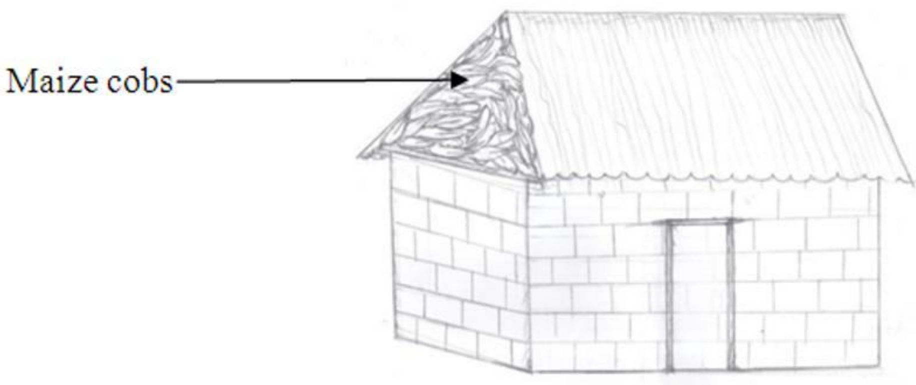


Figure 2.7: Roof storage method

For prolonged storage, maize cobs are piled on planks spaced in the roof space of a building (Figure 2.7). Using roof storage, farmers may store maize for up to one year. Roof storage provides the farmer with a facility that can last for as long as the roof lasts, and the farmer can also store as much harvest as possible depending on the size of the roof. Heat and smoke from the fire are used to keep the stored crops dry and to protect them from infestations by insects. Nevertheless, maize which has high moisture content at storage may take a long time to dry in the roof storage facilities since it is piled up. This may lead to development of fungi and possible mycotoxin contamination of the stored grain. The roof storage method may easily expose stored crops to attack by rodents and moisture from the surrounding areas.

2.4.11 Earthenware pots and gourds

Earthenware pots and gourds are used to store small quantities of crops (Lemma, 2006). The small size of these earthenware pots and gourds makes them inefficient for storage of bigger quantities of crops, thus, they are more useful for storing seeds for planting. In some places in East and Central Africa farm households plaster these storage facilities to make them more durable (Golob, 2004).

2.4.12 Suspension of crops on a tree or above the fireplace

Hanging unthreshed crops such as maize cobs on a bunch in a tree is used for storage of small quantities of maize (Lemma, 2006). This method allows drying of maize to continue through exposure to the sun (UNIFEM, 1995). However, this storage method has been criticized for exposing the crop to rain, wind, rodents, birds and insects, which may lead to infestations and moisture problems.

In view of the literature reviewed above, the quality of stored maize is highly dependent upon the efficiency of the storage method used. Inefficient storage methods allow favourable conditions for growth of pests in stored maize, which apart from reducing the quantity of grain through feeding on it, also reduce its nutrient content and contaminate it. This necessitates the re-assessment of these storage methods especially in humid environments such as in Katumba ward. Inefficient storage methods impact negatively on the quality of stored maize, thus limit its marketability and rendering the households vulnerable, while the reduction in maize quantity reduces the amounts of maize that can be accessed, thus impacting negatively on the food security status of farm households. Attention needs to be paid to the extent of infestation, infection and contamination that stored maize is exposed to and its effect on the consumers' health and food security in general. Other ways of enabling the storage methods to perform more efficiently should also be sought where necessary.

2.5 Ways of assessing crop storage methods:

There are two main ways of assessing efficiency of crop storage methods. They include: assessing losses of stored crops and using the matrix to score and rank storage technologies depending on farmer's perceptions (FAO, 1994).

2.5.1 Assessing storage losses using quality of crops

Crop loss by quality can be measured through testing quality changes during storage. This can be done through several ways which fall into three main methods, namely: observing crop losses by weight using samples of the crops at intervals over a specific period of time (Golob *et al.*, 2002), determining levels of contaminations caused by metabolic activities of pests in stored grain and determining the extent of damage through counting damaged grains. Other methods include counting the number of insect pests in samples of grain at intervals over a specific period of time (Derera *et al.*, 2001), or inoculating dilutions made from infested grain on media to determine the extent of infestation by micro-organisms such as bacteria or moulds (Mid-West Seed Services, 2006).

2.5.2 Assessing storage losses through determining levels of contaminations

Uric acid is an excretory product produced in larger amounts by animals and in smaller quantities by other living organisms. The presence of large amounts of uric acid in stored crops suggest infestation of the crops by animals such as rodents(Majunder, 1982), or insect pests (Jood and Kapoor, 2003). This method involves isolation of urine from the stored crops through chemical combinations with other chemical compounds, or through ultraviolet absorption or adding arsenophosphotungtic acid and sodium cyanide to a solution obtained from the sample crops (Majunder, 1982). A solution containing uric acid will develop a blue colour when these chemicals are added to it. The intensity of the blue colour determines the concentration of the uric acid in the tested crops (Majunder, 1982).

2.5.3 Assessing storage loss using the mass of the crops

Grain loss can also be determined by measuring the weight of crops at the time of storage and comparing it with their weight after storing them for a specific time (*Golob et al*., 2002) . This method has also been criticized because the grain weight may include unseen bodies of micro organisms, moulds or absorbed/reduced moisture, leading to inaccuracy in calculating crop loss. This method may also provide inaccurate results especially when applied on farm because reduced grain weight may be due to the fact that grain is being consumed by the farm household rather than due to infestations.

Other methods include measuring the amount of carbondioxide resulting from respiration of micro-organisms in the stored crops, and inspecting kernels for degradation caused by infestations (Majunder, 1982). These methods can provide a general picture with respect to whether stored crops are infested or not without being specific regarding the cause of crop loss and quantification.

2.5.4 The matrix for scoring and ranking

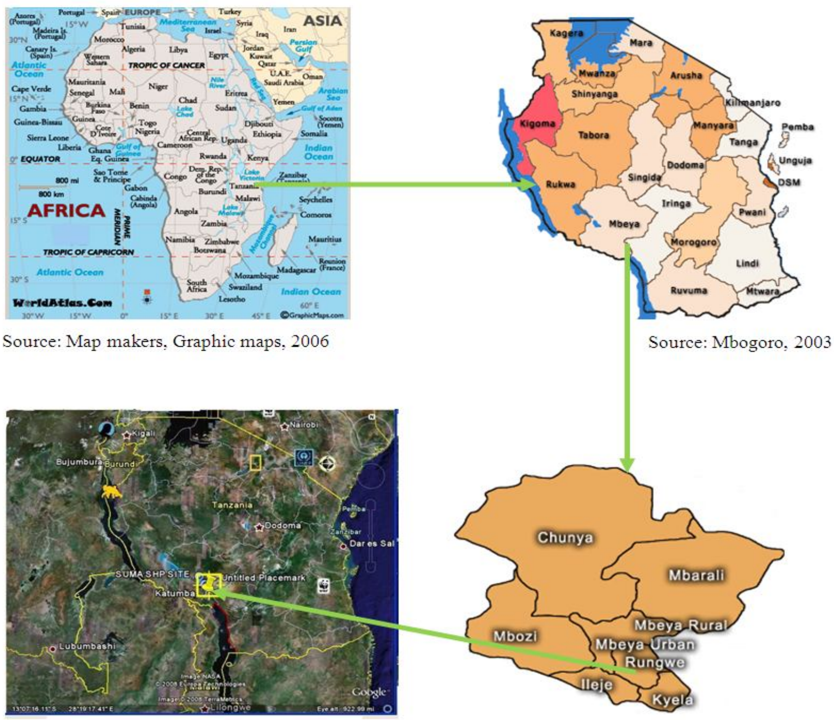
Semple *et al.* (1992) suggests the involvement of farmers' experiences and perceptions using the matrix method for scoring and ranking crop storage technologies as a means of obtaining a more accurate picture of each storage technology's performance. The matrix for scoring and ranking involves tabulating the technologies being studied against the full range of the criteria that is used to explain the importance or efficiency of the technology on the horizontal and vertical axis, respectively. Each of the technologies can then be scored or ranked based on the respondents' perceptions of the technology with respect to its performance against each criterion such as durability and quantity of crops that the storage technology can accommodate. This method gives the respondents a chance to air their views in relation to the experiences they have encountered when using the technologies.

2.6 Introducing the Research area

2.6.1 Location

Tanzania, the country in which Katumba ward is situated is located in East Africa between longitude 29^0 and 41^0 East, Latitude 1^0 and 12^0 South (Government of the United Republic of Tanzania, 2005). Tanzania borders with Kenya and Uganda in the North, Rwanda, Burundi, and the Democratic Republic of Congo in the West, Zambia, Malawi and Mozambique in the South, and the Indian Ocean in the East (Figure 2.8). Rungwe district covers an area of 2,211 square kilometres, ranging from 770 to 2265 metres above sea level, with an estimated population of

307,270 (National Bureau of Statistics (NBS) and Mbeya Regional Commissioners Office, 2003; Simbuso and Nyanga, 2000; Mbogoro, 2003). Twenty five percent of Rungwe district is covered with forests, mountains and residential areas, while approximately 75 % of it is land suitable for farming of various food crops (NBS and Mbeya Regional Commissioner's Office 2003; Simbuso and Nyanga, 2000). Furthermore, Rungwe district is characterized by rainfall throughout the year ranging from an average of 900 mm in the lowland zone to 2,700 mm in the highland zone and cool temperatures ranging from 18 - 25 ^{0}C (Administrator, 2010 a). As with all other highland areas, in Rungwe district temperature may drop to a minimum of 10 ^{0}C during the cold season (Anon, 2008). Fog and mist are also common. The residents in Rungwe district speak Nyakyusa and Swahili, and the latter is the official language in Tanzania. Katumba ward is located in Rungwe district, Mbeya region, Tanzania, between 9^{0} 13´ 60 South and 30^{0} 37´ 0 East (Anon, 2008) and it lies 1349 meters above sea level, with an estimated population of 10,965 and 2649 households. As with the rest of Rungwe district, Katumba ward is also characterized by rainfall throughout the year and cool temperatures ranging from an estimate of 10^{0}C during the night to an estimate of 25 ^{0}C during the day (Anon, 2008).



Source: Map makers, Graphic maps, 2006

Source: Mbogoro, 2003

Source: Europa technologies, 2008

Source: Mbogoro, 2003

Figure 2.8: Location of Katumba ward in Rungwe district, Mbeya region, Tanzania

2.6.2 Food crops produced in Rungwe district

The major food crops produced in Rungwe district include maize, bananas, potatoes, beans and rice (Administrator, 2010 a). While bananas and potatoes are grown in the highland agro-ecological zones, rice is grown in the low agro-ecological zone. A report by the Tanzanian government district official showed that in Rungwe district green bananas are the most widely grown food crop (Administrator, 2010 b), and in 2004 - 2008 the annual maize production was lower than the annual production of green bananas/plantains and potatoes (Table 2.2), which suggests that maize production in Rungwe district is lower than the production of the indicated food crops. However, the Government report from which the estimates in Table 2.2 were obtained does not provide clarity concerning the food crop which is most consumed in the district, which implies that the report was based on crop production rather than consumption. Thus, the report is rather inadequate. Data concerning amounts of food crops that farmers in Rungwe district marketed and amounts that they used for consumption was not found.

Most of the farming activities, processing and storage of harvested crops in Rungwe district are done by women(FAO, 1994), thus, the same is likely to be the case in Katumba ward.

Table 2.2: Estimated annual food crop production (Tonnes) in 2007 and 2008 in Rungwe district

Food crop	2004	2005	2006	2007	2008
Maize	55,400	58,700	55,218	68,492	70,237
Green Bananas/Plantains	230,000	250,00	364,513	298,819	331,170
Potatoes	75,000	72,200	81,215	82,500	95,223
Rice	1,900	2,015	2,399	1,243	1,273

Source: Administrator, 2010 a; DALDO’s reports (2009), as quoted by Mwankenja, 2010

Rungwe district’s soil fertility and its climatic condition allow production of a variety of food crops including maize (McKone, 2002). This, together with the fact that residents of this district are already involved in farming puts this district in a good position to make a meaningful contribution to food security in Tanzania. Finding ways of improving storage technologies in this district may contribute to improving the food security status of farm households and consumers at large in this district.

References

Abba, J.E., Lovato, A., 1999. Effect of Packing Material and Moisture Content on the viability of seed paddy. *Tropical Agriculturist*. 141, 37 - 54.

Adda, C., Borgemeister, C., Biliwa, A., Meikle, W.G., Markhan, R.H., Poehling, H.M., 2002. Integrated Pest Management in post-harvest maize: A case study from the Republic of Togo (West Africa).*Agriculture, Ecosystems and Environment*. 93, 305 - 321.

Administrator, 2010 a. *Overview of the Council - Rungwe.* <http://www.mbeya.go.tz/index.php?option=com_content&view=article&id=173&Itemid=190> (Accessed 2010 October, 10).

Administrator, 2010 b. *Agriculture - Rungwe*. <http://www.mbeya.go.tz/index.php?option=com_content&view=article&id=174&Itemid=192> (Accessed 2010 November 25).

Anon, 2008. *Weather in Katumba* <*http://freemeteo.com/default.asp?pid=180lta=1&sid=639320&gid=151851&alls=2*>(Accessed 2008 August 01).

Agrios, G.N., 2005. *Plant Pathology*, fifth ed. Elsevier Academic Press, Burlington.

Ajala, S., 2009. Screening and Breeding for Resistance to Maize Stem Borers and Eldana in West and Central Africa. *African Crop Science Conference Proceedings*. 9, 559 - 564.

Akande, K.E., Abubakar, M.M., Adegbola, T.A., Bogoro, S.E., 2006. Nutritional and Health Implications of mycotoxins in Animal Feeds: A Review. *Pakistan Journal of Nutrition*. 5, 398 - 403.

Ako, M., Schulthess, F., Gumedzoe, M.Y.D., Cardwell, K.F., 2003. The Effect of *Fusarium verticillioides* on Oviposition behaviour and Bionomics of Lepidopteran and Coleopteran Pests attacking the Stem and Cobs of Maize in West Africa. *Entomologia Experimentalis et Applicata*. 106, 201 - 210.

Alabadan, B.A., 2005. Temperature changes in Bulk stored Maize. AU J.T. 9, 3, 187 - 192.

Almeida, I., Martins, H.M., Bernado, F., 2010. Mycobiota and Ochratoxin A in Laboratory Mice Feed Preliminary Study. *Veterinary Research Communications*. 34, 381 - 386.

Amani, H.K.R., 2004. Agricultural *Development and Food Security in sub-Saharan Africa: Tanzania Country Report.*<http://www.fao.org/tc/tca/work05/Tanzania.pdf> (Accessed 2010 November 15).

Anderson, J., Young, L., Long, E., Prior, S., 2010.Sodium in the Diet. <http://www.ext.colostate.edu/pubs/foodnut/09354.htm> (Accessed 2010 November 16).

Ariahu, C.C., Ingbian Imanuel K. and Ojo, M., 2009. Effects of germination and fermentation on the quality characteristics of maize/mushroom based formulation. *African Journal of Food, Agriculture, Nutrition and Development*. Short communication.

Bajaj, Y.P.S., 1994. *Biotechnology in Maize Improvement*, in Bajaj, Y.P.S., *Maize*. Springler, Verlag, pp. 3 - 23.

Bennet, J.W., Klich, M., 2003, Mycotoxins. *Clinical Microbiology Reviews*. 16, 3, 497 - 516.

Bewley, D.J., Black, M., Halmer, P., 2006. *The Encyclopedia of Seeds: Science Technology and Uses*. CAB International, Wallington.

Bisanda, S., Mwangi, W., 1996 ‘Introduction’, Adoption *of Recommended Maize Technologies in Mbeya Region of the Southern Highlands of Tanzania*. Fifth Eastern and Southern Africa Regional Maize Conference, 3^{rd}-7^{th} June 1996. The International Maize and Wheat Improvement Centre, Dar-Es-Salaam, pp. 2 - 6.

Cao, Dongfeng, Pimentel, D., Hart, K., 2002. *Encyclopedia of Pest Management*. Marcel Dekker, New York.

Chelkowski, J., Ritieni, A., Wiśniewska, H., Mule, G., Logrieco, A., 2007. Occurrence of Toxic Hexadepsipeptides in Prehavest Maize Ear Rot Infected by *Fusarium Poae* in Poland. *Journal of Phytopathology*. 155, 8 - 12.

CIMMYT, 1999. *Aspergillus ear rot (extended information)*. <http://maizedoctor.cimmyt.org/index.php?id=235&option=com_content&task=view&id=227> (Accessed 2010 April 26).

CIMMYT, Dubin, J., 2010. *Insects - Maize*. <http://cropgenebank.sgrp.cgiar.org/index.php?option=com_content&view=articles&id=496&Itemid=678&lang=English> (Accessed 2010 January 2).

CMPT, 2007. *Mycology Plus 0701-3 Penicillium Species*. <http://www.cmpt.ca/pdf_mycology_2007>(Accessed 2011 January 11).

Cornell University, 2009. *Plants Poisonous to Livestock*. <http://www.ansci.cornell.edu/plants/toxicagents/aflatoxin.html> (Accessed 2010 March 12).

Coulter, J., Schneider, K. 2004.*Feasibility Study of Post Harvest Project in Mozambique and Tanzania*. Consultancy Report to the Swiss Agency for Development and Cooperation (SDC) <http://www.postcosecha.net/en/home/Knowledge_Network/ongoing_POSTCOSECHA_Programs/Eastern_andsouthern_Africa> (Accessed 2010 September02).

Culvenor, C.C.J., Edgar, J.A., Mackay, M.F., Gorst-Allman, C.P., Marasaa, W.F.O/, Steyn, P.S., Vleggaar, R., Wessels, P., 1989. Structure Elucidation and Absolute Configuration of Phomopsin a, a Hexapeptide Mycotoxin produced by *Phomopsis leptostromiformis*. *Tetrahedron*.45, 8, 2251 - 2372.

Darlington, J.P.E.C.D., 2007. Arena Nests Built by Termites in the Masai Mare, Kenya. *Journal of East African Natural History*. 96, 1, 73 - 81.

Derera, J., Denash, G., Pixley, K.V, 2001. Resistance of maize to the maize weevil:1. Antibiosis. *African crop Science Journal*.9, 2,431 - 440.

D'Mello, J.P.F.Macdonald, A.M.C., 1997. Mycotoxins. *Animal Feed Science Technology* 69, 155 - 166.

D'Mello, J.F.P., 2000. *Microbiology of Animal Feeds*. <ftp://ftp.fao.org/docrep/fao//007/y5159e00.pdf> (Accessed 2010 October 15).

De Groote, I., (1996). *Protection of stored grains and pulses*. CTA, Wageningen.

De Groote, I., 2004. *Protection of Stored Grains and Pulses*, fourth ed. Agromisa Foundation: Wageningen.

De Hoog, G.S., Guarro, J., Gene, J., Figueras, M.J., 2000. *Atlas of Clinical Fungi*, second ed. Centraal Bureau voor Schmmelcultures, Ultrecht.

Diekman, M.A., Green, M.L., 1992. Mycotoxins and Reproduction in Domestic Livestock .*Journal Animal Science*. 70, 1615 - 1627.

Ellis-Christen, T., 2010.*What is Folate?* <http://www.wisegreek.com/what-is-folate.htm> (Accessed 2011January 04).

Eltem, R., Askan, t., Sarigül, N., Taskin, E., Efendiler, H., 2003. Colonial and Morphological characteristics of some *Aspergillus* Fr. :Fr. Species Isolated from Vineyards in Manisa and Izmir Provinces (Turkey). *Turkish Journal of Botany*. 28, 287 - 298.

EUFIC, 2010. *How the Body Uses Carbohydrates*.<http://www.suite101.com/content/how-the-body-uses-carbohydrates-a305031>(Accessed 2011 March 03).

Europa Technologies 2008. *Katumba, Tanzania* <http://www.googlemaps.com> (Accessed 2008 May 28).

Exarchos, C.C., Gentry, R.F., 1982. Effects of Aflatoxin B_1 on egg production. *Avian Diseases*.26, 1, 191 - 195.

FAO, 1968. *Food Composition Table for use in Africa*. <http://www.fao.org/docrep/03/x6877E/x6877E05.htm> (Accessed 2008 October 31).

FAO, 1980. *On Farm Maize Drying and Storage in Humid Tropics, first ed*. The African Rural Storage Centre Project, Rome.

FAO, 1984. *Food Balance Sheets, 1960 62 Average*. Rome, FAO.

FAO, 1985. *Prevention of post- harvest food losses: a training manual*. FAO, Rome.

FAO, 1987. *On - farm Maize Drying and Storage in the Tropics*. The African Rural Storage Centre Project, Rome.

FAO, 1994. Grain *Storage techniques- Evolution and Trends in Developing Countries*.FAO, Rome.

FAO, 2001. *Manual on the Application of the HACCP system in Mycotoxin Prevention and Control*. FAO/IAEA, Rome.

FAO, 2002. *Vitamin and Mineral Requirement*. FAO, Rome.

FAO, 2004. *Mycotoxin Regulations in 2004 and 2003 and current Developments*. FAO, Rome.

FAO, 2010. *A guide to Maize Marketing for Extension Officers*. FAO, Rome.

Friedman, M., 1996. Nutritional Value of Protein from Different Sources. A Review. *Journal of Agricultural Food Chemistry*. 44, 1, 6 - 29.

Fields, P., 1992. The Control of Stored- Product Insects and Mites with Extreme Temperatures. *Journal of Stored Products Research*. 28, 2, 89 - 118.

Gissen, A.S., Copper. 1994. *The Maligned Mineral*. <http://www.oralchelation.com/technical/copper1.htm> (Accessed 2011 January 10).

Golob, P., Farrell, G., Orchard, J.E., 2002. *Crop Pest Harvest: Principles and Practices*. Blackwell Science, Oxford.

Golob, 2004. Maize: Tanzania (East and Central Africa), in Golob, P., Hodges, R., Farrell, G., Crop Post-Harvest: Science and Technology. Durables Case Studies, in: Golob, P., Hodges, T., Farrell, G. (Eds). *The Handling and Storage of Durable Commodities*. Blackwell Publishing Company, Oxford, pp. 26 - 41.

Gourama H., Bullerman, L. B., 1995. *Aspergillus flavus* and *Aspergillus parasiticus*: Aflatoxigenic Fungi of Concern in Foods and Feeds: A review. *Journal of Food Protection*. 58, 12, 1395 - 1404.

Government of the United Republic of Tanzania, 2006. *Agriculture*. <http://www.tanzania.go.tz/agriculture/htm> Accessed 2010 May 19).

Gwinner, J., Harnisch, R., Mück, O., 1996. *Manual of the Prevention of Post Harvest Grain Losses*. Post Harvest Project GTZ, Eschborn.

Hambidge, M., 2000. Zinc and Health: Current Status and Future Directions. *The Journal of Nutrition*. 1344 - 1349.

Hansel, L.S., Skovgård, H., Hell, K., 2004. Life Table Study of *Sitotroga cerealella* (Lepidoptera: Gelichiidae), a strain from West Africa. *Journal of Economic Entomology*. 97, 4:1484 - 1490.

Hayes, A.W., 2001. *Principles and Methods of Toxicology*, fourth ed. Taylor and Francis, Philadelphia and London.

Hill, D.S., 2008. *Pests of Crops in Warmer Climates and Their Control*. Springer, Lincs.

Hodges, R., 1998. *Larger Grain Borer*. *Technical Leaflet No. 1*. CTA, Wageningen.

Hoseney, C. R. 2000. *Principles of Cereal Science and Technology*, second ed. American Association of Cereal Chemists, Minnesota.

Ikisan, 2000.*Post Harvest*. <http://agroinfo.ikisan.com/crop%20specific/Eng/links/ap_harvest> (Accessed 2011, January 06).

IITA, 2009. *Cereal and Legume Systems. Maize. Post Harvest*. <http://old.iita.org/medialib/displayimage.php?albumin+9&pos=47> (Accesed 2011 January 10).

Johnson, L.A., 2000. Corn :The major Cereal of the Americas, in Kulp, K. 2000. *Handbook of Cereal Science and Technology*, second ed. Marcel Dekker, New York, 705 - 723.

Jood, S., Kapoor, A.C., Singh, R., 1992.Mineral Content of Cereal Grains as Affected by Storage and Insect Infestation. *Plant Food Human Nutrition*. 46, 237 - 243.

Jood, S., Kapoor, A.C., 1993.Protein and Uric Acid Contents of Cereal Grains as Affected by Insect Infestation. *Food Chemistry*. 2, 46, 143 - 146.

Jood, S., Kapoor, A.C., 1994.Vitamin Content of Cereal Grains as Affected by Storage and Insect Infestation. *Plant Foods for Human Nutrition* (Formaly Qualitas Plantarum). 46, 3, 237 - 243.

Kaaya, A.N, Khamunyangire, W., 2010. Drying maize using Biomass-Heated Natural Convection Dryer Improves Grain Quality During Storage. *Journal of Applied Sciences*. 10, 11, 967 - 974.

Kgware, M., Maniram, J., Maharaj, P.P., 2008. *Public Vectors and Pests*. <http://www.kznhealth.gov.za/environ/vector/brownrat.htm>. (Accessed 2008 December 04).

Kimanya, M.E., De Meulenaer, B., Tiisekwa, B., Ndomondo-Sigoda, M., Devlieghere, F., Van Camp, J., and Kolsteren, P., 2008. Co- occurrence of fumonisins with aflatoxins in home-stored maize for human consumption in rural villages of Tanzania. *Food Additives and Contaminnts*. 11, 12, 1353 - 1364.

Kimenju, S.C., H., D., 2010. *Economic Analysis of Alternative Maize Storage Technologies in Kenya*. 2010 African Association of Agricultural Conference (AAAE), Third Conference/AEASA 48TH Conference. September 19-23, Cape Town, South Africa.

Klopfenstein, C.E., 2000. Nutritional Quality of Cereal Based Foods. *Handbook of Cereal Science and Technology*, second ed. Marcel Dekker, New York, 705 - 723.

Kung'u J.K., Muroki, N., Omwega, A., 2003. Effect of Storage on the quality and safety of grains in Tharaka District, Kenya. African Journal of Food, Agriculture, Nutrition and Development. 3, 2.

Lamboni, Y., Hell, K., 2009. Propagation of Mycotoxigenic fungi in Maize Stores by Post-harvest Insects. *International Journal of Tropical Insect Science*. 29, 1, 31 - 39.

Law, C., 2010. *Quality Protein Maize: A Solution Against Malnutrition*. <http://www.suite101.com/content/quality-protein-maize-qpm-a313985> (Accessed 2011 January 04.

Lawley, R., 2007. *Ochratoxins*.<http://www.foodsafetywatch.com/public/492.cfm> (Accessed 2010 October 07).

Lemma, T., 2006. Storage Systems and Pest Management in Small- Scale Agriculture in Ethiopia, in: Bekele, E., Azerefegne, F., Abate, T. (Eds). Facilitating the Implimentation and Adoption of Integrated Pest Management in Ethiopia, Planning Workshop 13 - 15 October, 2003.*Drylanda Coordination Group Proceedings*. Oslo, Norway, pp. 68 - 73.

Lewis, L., Onsongo, M., Njapau, H., Schurz-Rogers, H., Luber, G., Kieszak, S., Nyamongo, J., Backer, L., Dahiye, A.M., Misore, A., DeCoke, K., Robin, C., Kenya Aflatoxicosis Investigation Group, 2005. Aflatoxin Contamination of Commercial Maize Products during an Outbreak of Acute Aflatoxicosis in Eastern and Central Kenya. *Environmental Health Perspectives*.113 (12), 1763 - 1767.

Lewis, D., Hahn, J., Pelliteri, P., 2008. *Insect Pests of Store Foods*. <http://www.extenxion.umn.edu/distribution/nutrition/DJ1000.html> (Accessed 2010 January 22).

Lindblad, C., Druben, L., 1976. *Small Farm Grain Storage Vol III. Storage Methods*. South Africa, Volunteers in Technical Assistance.

Linus Pauling Institute, 2003. *Phosphorus*. <http://Ipi.oregonstate.edu/infocenter/minerals/phosphorus> (Accessed 2011 January 08).

Linus Pauling Institute, 2001. *Manganese as Essential and Possibly Toxic Mineral*. <http://www.chelatontherapyonline.com/articles/p35.htm> (Accessed 2011 January 10).

Linus Pauling Institute, 2008. *Panthothenic Acid*. <http://lpi.oregonstate.edu/infocenter/vitamins/pa> (Accessed 2011 January 09).

Logrieco, A., Mule, G., Moreti, A., Bottalico, A., 2002. Toxigenic *Fusarium* Species and Mycotoxins Associated with Maize Ear Rot in Europe. *European Journal of Plant Pathology*. 108, 597 - 609.

Mabbett, T., 2004.Contamination Control in Seeds. *African Farming and Food Processing*. 42, 28.

Makundi, R.H., Bekele, A., Leirs, H., Massawe, A.W., Rwamugira, w., Mulungu, L.S., 2005. Farmers Perceptions, of Rodents as Crop Pests: Knowledge, Attitudes and Practices in Rodent Pest Management in Tanzania and Ethiopia. *Belgium Journal of Zoology*. 135 (Supplement): 153 - 157.

Makundi, R.H., 2006. Challenges in Pest Management in Agriculture: Africa and Global Perspectives, in Makundi, R.H., (Ed). *Management of Selected Crop Pests in Tanzania*. Tanzania Publishing House, Dar-es-Salaam, p. 476.

Majunder, S. K., 1982. Approaches to the Assessment of Food Losses. *Food and Nutrition Bulletin*. 4, 25 - 32.

Marin, S., Sancis, V., Vinas, I., Canela, R., Magan, N., 1995. Effect of water activity and temperature on growth and fumonisin B_1 and B_2 production by *Fusarium proliferatum* and *Fusarium moniliforme* on maize grain. *Letters in Applied Microbiology*. 21, 5, 298 - 301.

Map makers, Graphic maps, 2006. *Africa*. <http://www.worldatlas.com/webimage/country/af.htm> (Accessed 2008/ August/01).

Mbogoro, K. D., 2003. *2002 Population and Housing Census: General report*. Government of the United Republic of Tanzania, Central Census Office, National Bureau of Statistics, President's office, Planning and Privatization, Dar-esSalaam.

Mejia, D., 2003. *Maize Post- Harvest Operation chapter 4*. <http://www.fao.org/inpho/content/compend/text/ch23_03.htm#TopOfPage> (Accessed 2010 February 2010).

Metananda, K.A., Weerasena, S.L., Liyanage, Y., 2001. Effect of Storage Environment, Packaging material and Seed Moisture Content on Storability of Maize (*Zea mays* L.) seeds. *Annals of Srilanka Department of Agriculture*. 3, 131 - 142.

Mid - West Seed Services, 2006. *Seed Health. Testing*. <http://www.bpi.da.gov.ph/Services/seedtesting.html> (Accessed 2007 August 15).

Mills, J.N., Childs, J.E., 2001. Rodent borne Hemorrhagic fever, in Williams, E.S. *Infectious diseases of wild mammals*, third ed., Blackwell, Iowa, pp. 254-267.

Mohandass, F.H., Arthu, K.Y., Thione, J.E., 2007. Biology and Management of Plodia Interpunctella (Lipidoptera: Pyralidae) in stored products. *Journal of Stored Products Research*. 43, 302 - 311.

Mulungu, L.S., Ngowo, V.D., Makundi, R.H., Massawe, A.W., Leirs, H., 2010. Wining the Fight against Rodent Pests: Recent Developments in Tanzania. *Journal of Biology and Science*. 10, 333 - 340.

Munkvold, G., Hurburgh, C., Meyer, J., 2009. *Aflatoxins in Corn*. <http://www.extension.iastate.edu/publications/pm1800.pdf> (Accessed 2010 April10).

Mwankenja, J. 2010. *Rungwe district Council*. <http://www.mbeya.go.tz/index.php?option=com_docman&task=doc_download&gid=8&Itemid=179. (Accessed 2010 March 10).

Nantel, G., 1999. Carbohydrates in Human Nutrition. *Food, Nutrition and Agriculture*. 24, 6 - 10.

National institute of health, 2010.*Vitamin B-6*. <http://ods.od.nih.gov/factsheets/vitaminb6>. (Accessed 2011 January 07).

Noble Pest Management, 1994.*House Mice*.<http://www.noblepest.com/rodents.html> (Accessed 2008 December 14).

Nuss, E.T., Tanumihardjo, S.A, 2010. Maize: A Paramount Staple in the Content of Global Nutrition. *Comprehensive Reviews in Food Science and Food Safety*. 9, 4, 417 -4 36.

Nuss, E.T., Tanumihardjo, S.A., 2011. Quality Protein Maize for Africa: Closing the Protein Inadequacy Gap in Vulnerable Populations. *Advances in Nutrition*. 2, 217 - 224.

Obetta, S., Daniel, C., 2007. Preliminary Investigation into some Quality Control Indices for Selected Stored Grain in Makurdi, Nigeria. *Nigerian Food Journal*. 25, 1, 117 - 129.

Obikoya, G., 2010 a. *The benefits of phosphorus*.<http://www.vitamins-nutrition.org/vitamins/phosphorus.html> (Accessed 2011 January 02).

Obikoya, G., 2010 b. *Calcium Information*. <http://www.vitamins-nutrition.org/vitamins/calcium.html> (Accessed 2011 January 02).

OECD, FAO, 2010. *Agricultural Outlook 2010-2019 Highlights*. <http://www.agri-outlook.org/dataoecd/13/13/45438527.pdf> (Accessed 2010, November 18).

Öhlinger, R., Adler, A., Kräutler, O. and Lew, H., 2004. Occurrence of toxigenic fungi and related mycotoxins in cereals, feeds and foods in Austria, in: Logrieco, A., and Visconti, A (Eds). *An overview on Toxigenic Fungi and Mycotoxins in Europe*, Kluwer publishers, Dordrecht, pp.1 - 10.

Oliveira, C.A.F., Rosmoninho, F.F., Butkeraitis, P., Correa, B., Reis, T.A., Guerra, J.L., Albuquerque, R., Moro, M.E.G., 2002. Effects of Low Levels of Dietary Aflatoxin B_1 on laying Japanese Quail. *Poultry Science*. 81, 976 - 980.

Parshad, V.R., 1999. Rodent Control in India. *Integrated Pest Management Review*. 4, 2, 97 - 126.

Parsons, M.W., Munkvold, G.P., 2010. Association of Planting Date, Drought Stress and Insects with *Fusarium* Ear Rot and Fumonisn B_1 Contamination in California Maize. *Food Additives and Contaminants*: Part A. 27, 5, 591 - 607.

Peterson, S.W., Ito, Y., Horn, B.W, Goto, T., *Aspergillus bombycis*, a new aflatoxigenic species and genetic variation in its sibling species. *A. nomius*. *Mycologia*. 93, 4, 689 - 703.

Pingali, P.L., Pandey, S., 2001. *Meeting the Maize needs: Technology Opportunities and Priorities for the Public sector*. CIMMYT, Mexico.

Public health of Canada, 2008. *Lyme Disease*. <http://www.publichealth.gc.ca> (Accessed 2008 December 10).

Ranajit, B., 2007. *New Hope for Improved Food Safety in Sub- Saharan Africa*. <http://www.cgiar.org/monthlystory/July_August2007.html#photos> (Accessed 2007 July 06).

Reed, C., Doyungan, S., Loerger, B., Getchell, A., 2007. Response of Storage Molds to Different Initial Moisture Contents of Maize (Corn) Stored at 25 ^{0}C, and effect on respiration rate and nutrient Composition. *Journal of Stored Products Research*, 43, 443 - 458.

Roebroek, R.M.J.A., Postma, B.H., Dijkstra, U.J., 1994. Clinical Neurology and Neurosurgery. 96, 2, 178 - 180.

Sallam, M.N., 1999. *Chapter II Inset Damage on Post - harvest*. <http://www.fao.org/inpho/content/compend/text/ch02.htm> (Accessed 2010 January 22).

SATG, 2009. Post-Harvest and Grain Storage Losses: Training Module. SATG: Somalia

Schachter, M.B., 1996. *The Importance of Magnesium to Human Nutrition*. <http://www.mbschachter.com/importance_of_magnesium_to_human.htm> (Accessed 2011 January 11).

Science Daily, 2007. Copper: *An Important Nutrient for Fetal Brain Development*. <http://www.sciencedaily.com/releases/2007/10/071006084704.htm> (Accessed 2008 January 02).

Seifert, K., 1996. *Fusarium Interactive Key*. <http://res.org.ca/bod/fusarium/home/html> (Accessed 2011 January 04).

Semple, R.L., Frio, A.S., Hicks, P.A., Lozare, J.V., 1989, *Mycotoxin Prevention and Control*. www.fao.org/docrep/x5036e/x5036E0v.htm (Accessed 2007 June 18).

Semple, R.I., Hichs, P.A., Lozare, J.V., Castermans, A., 1992.*Towards Integrated Community and Pest Management in Grain Storage*. <http://www.fao.org/inpho/content/documents/vlibrary/x00484/x0048E00.htm> (Accessed 2009 December 18).

Shepherd, 2010. *A Guide to Maize Marketing for Extension Officers, revised edition*. FAO, Rome.

Siwela, A.H., Siwela, M., Matindi, G., Dube, S., Nzirayamasanga, N., 2005. Decontamination of aflatoxin- contaminated maize by dehuling. *Journal of the Science of Food and Agriculture*. 89, 2535-2538.

Smolin, L.A., Grosvenor, M.B., 2010. *Nutrition: Science and Application, second ed*. John Wiley and Sons, New Jersey.

Sokolović, G., Garaj-Vrhovac, V., Šimpraga, B., 2008. T-2 Toxin: Incidence and Toxicity in Poultry. *Archives of Industrial Hygiene and Toxicology*. 59, 1, 43 - 52.

Stack, J.P., Giesler, L.J., Harveson, B.M., Watkins, J.E., Chaky, J.L., 2003. *Ear Rots and Grain Molds in Corn*. <http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=2535&content=extensionhist > (Accessed 2011 January 05).

Stenseth, N., Leirs, H., Skonhoft, A., Davis, S.A., Pech, R.P., Andreassen, H.P., Singleton, G.R., Lima, M., Machangu, R.M., Makundi, R.H., Zhang, Z., Brown, P., Shi, D., Wan, X., 2003. Mice and Rats: The Dynamics and Bio-Economics of Agricultural Rodent Pests. *Frontiers in Ecology and Environment*.1, 7, 000 - 000.

Stoker, H.S., 2010. *General Organic and Biological Chemistry*, 5^{th} ed. Cengage Learning, Belmont.

Sweeney, M.J., White, S., Dobson, A.D.W., 2000. Mycotoxins in agriculture and food safety**.** *Irish Journal of Agriculture and Food Research*. 39, 2, 235 - 244.

Tai, J.H., Pestka, J.J., 1990. T-2 Toxin Imparement of Murine Response to Salmonella Tryphimurium: a Histopathologic Assessment. *Mycopathologia*. 109, 3, 149 - 155.

Tardieu, D., Bailly, J.D., Skiba, F., Metayer, J.P., Grosjean, F., Guerre, P., 2007. Immunology, Health and Disease. *Poultry Science Association*. 86. 1887 - 1893

Thamaga, J. M., 2001. *The Impact of Crop Storage Methods on Household Food Security in rural KwaZulu - Natal.* Masters Thesis University of Natal, Pietermaritzburg, March 2001, 9 - 12.

Thamaga-Chitja, J.M., Hendriks, S.L., Ortmann, G.F., Green, M., 2004.Impact of Maize Storage on rural household food security in Northern KwaZulu- Natal. *Journal of Family Ecology and Consumer Sciences*. 32, 8 - 15.

The Caribbean Food and Nutrition Institute, 2005. Selenium, Nutrition and Health. *Nyam News*. 1, 2.

Underson, J., Young, L., Long, E., Prior, S., 2010. *Sodium in the Diet*. <http://www.ext.colostate.edu/pubs/foodnut/09354.html> (Accessed 2010 November 01).

UNIFEM. 1995. *Storage*: *Food Cycle Technology Source Books*. Intermediate Technology and UNIFEM, London.

University of Adelaide, 2011.*Mycology online: Fusarium oxysporum*. <www.mycology.adelaide.edu.au/Fungal_Descriptions/Hypomycetes_(Hyaline)/Fusarium/oxysporum.html?template=2> (2011 January Accessed 11).

Vasal, S.K., 2002. Quality Protein Maize: Overcoming the Hurdles. *Journal of Crop Production*. 6, 35, 193 - 227.

Villers, P., Bruin, T., Navarro, S., 2006.*Feed Technology Update. Volume 1, Issue 3*. Links Publishing, Honolulu.

Vincelli, P., Parker, G., 2002. *Fumonisins, Vomitoxin and Other Mycotoxins in Corn Produced by Fusarium Fungi*. University of Kentucky CES publication ID-121 <http://www.ca.uky.edu/agc/pubs/id/id121/id121.pdf> (Accessed 2010 July 25).

Webb, G.P., 1995. *Nutrition. A Health Promotion Approach*. Edward Arnold, London.

Weinberg, Y.Y., Chen, Y., Finkelman, S., Ashbell, G., Navarro, S., 2008. The Effect of Moisture Level on High-moisture maize (*Zea mays* L.) under hermetic storage conditions- in vitro Studies. *Journal of Stored Products Research*. 44, 136 - 144.

WHO, 2011.*Micronutrient deficiencies*. <http://who.int/nutrition/topics/vad/en> (Accessed 2011 August 23).

WHO and FAO, 2004. *Vitamin and Mineral Requirements in Human Nutrition*, second ed. FAO, Rome.

Williams, J.H., 2004. Human aflatoxicosis in developing countries: a review of toxicology, exposure, potential health consequences and interventions. *The African Journal of Clinical Nutrition*. 80, 1106 - 1122.

Wood, G.E., Trucksess, M.W., Henry, S.H, 2003. Major Fungal Toxins of Regulatory Concern. In Miliotis, M.D., Bier, J.W, *International Handbook of Foodborne Pathogens*. Marcel Dekker, New York.423 - 226.

Wright, V., 2011.*Assessment of Insect Infestation in Stored Maize and their Relationship to Aspergillus flavus Contamination.* <http://www.mycotoxins.net.br/boletin41.pdf> (Accessed 2011 January 07).

Wu, F., 2004. Mycotoxins Risk Assessment for the purpose of Setting International Regulatory Standards. *Environmental Science and Technology*. 38, 15, 4049-4055.

Yigezu, Y.A., Alexander, C.E., Preckel, P.V., Maier, D.E., Mason, L.J., Woloshuk, C., Lawrence, J., Moog, D.J., 2010. Economics of Integrated Insect Management of Stored Corn. *Journal of Economic Etomology*. 103, 5: 1896 - 1908.

CHAPTER THREE[3]

THE DIETARY IMPORTANCE OF MAIZE IN RUNGWE DISTRICT, TANZANIA AND ITS CONTRIBUTION TO HOUSEHOLD FOOD SECURITY

Abstract

The dietary importance of maize in Katumba ward was investigated through studying its importance as a source of food and nutrients using secondary data and face - to - face structured and semi-structured interviews. The interviews were administered to 260 randomly selected farm households using a structured questionnaire. The aim of the study was to provide empirical data that would show how maize contributes to household food security in Katumba ward. It was found that farm households in Katumba ward preferred maize meals. They started consuming maize while it was still green in the fields. They could obtain 66 - 69 % of the total energy and 83 - 90 % of the total protein required per day through maize meals consumption. It was also found that the portions of land that the farm households allocated to growing maize were bigger than the portions of land that they allocated to growing other food crops. Therefore, it was concluded that maize was a very important food crop in Katumba ward, and that it influenced the type of nutrition that farm households accessed. It was further concluded that the importance of maize in the ward necessitates that the farm households be able to produce and maintain a high quality of the maize with respect to its nutritive value and the degree to which it is safe for consumption. This involves using efficient farming and storage technologies. Therefore, it was recommended that storage management in Katumba ward be given adequate attention in order to maximize the quality of stored maize for the enhancement of healthy diets and food security of the consumers.

Key words: Maize nutrition, Food security, Katumba ward,

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3.1 Introduction

Reports show that maize is an important staple food crop in Africa (Adeyemo, 1984; Bryceson, 2009; Olakojo *et al*., 2005), and that it is the major food crop in Tanzania (Katinila *et al.*,1998; Amani 2004). Factors such as the ease of production, processing and storing, and the capacity for maize to produce high yields per unit of land (Brandes, 1992) make maize a key crop in ensuring availability of food.While over 80 % of the population of Tanzania depends on maize for food (Bisanda and Mwangi, 1996), maize production in Tanzania varies with time (Table 3.1).

Table 3.1: Variations in quantities of maize produced per annum in Tanzania

1990-1991	2000	2001	2002	2006-2007	2009-2010
2,635,000	2,551,000	2,698,000	2,700,000	2,638,000	2,107,000

Source: FAO Bulletin of Statistics, 2004; UNESCO National Commission of the United Republic of Tanzania, 2010).

It is also estimated that the annual per capita consumption of maize in Tanzania is 112.5 kilograms, which contributes 60 % of the total energy in the diets of Tanzanians, and amounts to 3,000,000 tonnes of maize consumed annually (Katinila *et al.,* 1998). Thus, the amount of maize produced in Tanzania per annum is less than the amount of maize required in this country per annum, which implies that Tanzania is a deficit country in relation to maize needs. In Tanzania, maize is also used for brewing beer, as animal feed and as a cash crop (Green, 1999; Katinila *et al*., 1998).

FAO's (1968) estimates for the quantities of nutrients that can be found in 100 g of ground sifted maize in Africa (Table 3.2) were used for determining the amounts of nutrients that farm households in Katumba ward could access through maize consumption.

Table 3.2: Estimated amounts of nutrients in 100 g of sifted ground white maize in Africa

Nutrients	Amount
Energy	368 cal
Protein	9.40 g
Fat	3.30 g
Carbohydrates	74.10 g
Fiber	1.00 g
Ash	1.00 g
Calcium	180.00 mg
Phosphorus	178.00 mg
Iron	3.30 mg
Thiamine	0.26 mg
Riboflavin	0.08 mg
Niacin	1.00 mg

Source: FAO, 1968

In Rungwe district, maize is highly valued (National Bureau of Statistics (NBS), Mbeya Regional Commissioner's Office, 2003), it grows well and it is well adapted to the climate of Rungwe district. The general concept in Tanzania is that green bananas/ plantains are the most preferred food crop in Rungwe district (Administrator, 2010), thus, maize production in this district has not been sufficiently documented. However, currently, maize production in the district seems to be gaining significance, such that its production reports are available. In 2007, 68,492 tonnes of maize were produced in Rungwe district, and the amount increased to 70,237 tonnes in 2008. Although maize production is gaining significance in Rungwe district, its dietary importance and ways in which it contributes to household food security in this district has not been studied.

In addition, maize is known to be deficient in two essential amino acids, that is, lysine and tryptophan, thus, the protein which is found in maize is of low quality (Friedman, 1996; Escobedo, 2010). This, together with its deficiency in minerals and vitamins, suggests that maize may subject the consumers to poor nutrition especially in places where it is the staple food crop. However, today, breeding technologies for improving maize yield and nutrient content are available (Ortiz-Monasterio, 2007; Pachón*et al.*, 2009). However, there is concern that in Tanzania breeding technologies are focused only on improving maize seeds for high yield (Katinila *et al.,* 1998). Thus, the farm households in Katumba ward may be exposed to poor nutrition and food insecurity through maize consumption. This study was conducted in order to investigate and establish the dietary importance of maize and its contribution to household food security in Katumba ward. The establishment of the dietary importance of maize in Katumba ward is significant as it provides empirical data that highlights ways in which maize contributes to household food security in the ward. It is hoped that the empirical data obtained through this study can also be used for advocating for agricultural policy that can promote production and safety of maize in Rungwe district and other places that have similar climatic conditions as Katumba ward.

3.1.1 Main objective

To establish the dietary importance of maize and its contribution to household food security in Katumba ward, Rungwe district, Tanzania.

3.1.2 Specific objectives

1. To study the importance of maize as a source of food and its contribution to household food security, and investigate the influence of the level of formal education, gender and ages of the farm household heads on the importance of maize as a source of food in Katumba ward, Rungwe district, Tanzania.

2. To explore the nutritional importance of maize with emphasis on its importance as a source of energy and protein and the implications on household food security in Katumba ward, Rungwe district, Tanzania.

3. 2 Materials and Methods

3.2.1 Sampling of farm households

Katumba ward consisted of 2649 households (Mbogoro, 2003). Since 10 farm households were excluded from the actual research, 2639 farm households were involved in the sampling procedure. In order to minimize sampling errors that can result from handling large amounts of data (Israel, 1992), coupled with limited time and resources, a sample of 260 small scale farm households was selected using systematic random sampling. This sampling approach is easy and it gives everyone in the population being studied an equal chance of being selected thereby avoiding selection bias (Pierre, 1996). It also provides a sample which is more evenly distributed over the population being studied unlike sampling methods such as simple random sampling, stratified sampling and cluster sampling.

The sample size was calculated using a sample size calculator, a computer programme commonly used for easy and fast calculation of sample size (Dattalo, 2008). The calculation was done at 95 % confidence level, 6 % precision and 100 % response rate. With 6 % precision level the calculation produced a more affordable sample size than lower precision levels such as 5 % or 3 %. Moreover, at 95 % confidence level and 6 % precisison, the calculation produced a larger sample size than it did when using higher levels of precision such as 10 %. The procedure for the calculation entails feeding into the programme the population size to determine the required sample size (Appendix 3.1). Households that should participate in this study were randomly selected on the basis that they resided in Katumba ward and stored maize. As explained by Trochim (2001), in choosing the target households to participate in the study, the total number of households in Katumba ward was divided by the required number of sample households to get the interval at which a sample household should be selected. In this case 2639 divided by 260 equals about 10 after rounding off. Therefore, a sample household was selected by walking through the population and selecting every tenth household from the starting point which was randomly selected. Where the farm households were unavailable at home when selected and visited, the interviews had to be re-scheduled in order to accommodate them.

3.2.2 Data collection

Semi- structured and structured face-to-face interviews were administered to the 260 sample households to make possible the inclusion of participants who could not read nor write (Trochim, 2001). The questionnaire that was used to guide the interviews is presented in Appendix 3.2.The interviews were conducted in Swahili, the official language in Tanzania, at the participants own homes or venues of their choice in order to make easier the participation of women. In Rungwe district most of the farming activities including processing and crop storage are done by women {Food and Agriculture Organisation of the United Nations (FAO), 1994} just as it is in the whole of Tanzania (Government of the United Republic of Tanzania, 2006). Thus, participation of women in this study was considered crucial.

Seasonal calenders were used for identifying the time in a year when each sample household experienced maize shortage, and for studying farm household's coping strategies in the indicated times of maize shortage. Among other participatory techniques, seasonal calenders drawn from the participants knowledge of the issue being studied enable involvement of the participants in planning and managing matters pertaining to the concerned study (Preece, 2006; King, 1994). Data that wascollected in order to answer the specific objectives for the study included information regarding the amount of land that farm households allocated to growing maize, the amount of land that the farm households allocated to growing other types of foods, the time in a year when the farm households started consuming maize and the time in a year when the farm households ran out of maize. Information regarding the coping strategies that the farm households used when maize supplies ran out was also collected. The amounts of maize consumed by farm households and the amounts of maize they used for purposes other than consumption were recorded and used for answering specific objective two. The level of formal education, gender and age of farm household heads were also recorded for investigating their influence on maize consumption.

Data set concerning the type of maize that the farm households grew and the type of maize meal that the farm households often used was also collected. The number of days per week during which each farm household consumed the maize meal, the number of maize meals that each household consumed daily, the total number of meals that farm households consumed per day and quantities of maize flour that they used per meal were recorded. Data set concerning the reasons pertaining to the frequencies at which the farm households consumed maize meals was collected, farm households' perceptions concerning the importance of maize and reasons for the perceptions, were also recorded.

3. 2.3 Statistical analyses

Data was analyzed using theStatistical Programme for Social Sciences (SPSS) version 15 by Pallant (2005), which required coding and capturing of the participants' responses. Frequencies were calculated in order to find the number of scores per response. Pearson product-moment correlation was used to explore relationships between variables. In line with Pallant's (2005) recommendation, preliminary analyses were executed prior to exploring relationships in order to make sure that assumptions of normality, linearity and homoscedasticity are not violated. The preliminary analyses were done through scatter plots to check for outliers, and no outliers were found, hence the use of Pearson product-moment correlation. Parts of the outputs from data analysis are shown in Appendices 3.3 - 3.6.

The amount of nutrients that the farm households in Katumba ward could obtain from maize consumption per meal was calculated through converting the average amount of maize flour that farm households in Katumba ward utilized per meal into grams, followed by dividing the result by 100 g, then multiplying the obtained figure by FAO's (1968) estimated figures for the quantity of each nutrient in 100g of maize flour as follows:

Amount of nutrients that the farm households can obtain per day from maize meals

$$= \frac{\text{quantity of maize flour consumed per day}}{100\text{ g}} \times \text{Quantity of nutrients in 100 g sifted maize flour}$$

Furthermore, the amount of nutrients required daily per individual differs with age, gender and activity (Food Nutrition Board, Institute of Medicine of the National Academies, 2005). However, the quantities of nutrient intake recommended by the Food Nutrition Board, Institute of Medicine of the National Academies (2005) are also used as general estimates for the specified age groups of people who engaged in moderate activity. Thus, in this study, the estimated quantities of nutrients a farm household in Katumba ward could access from maize were calculated based mainly on the ages of the individuals in the farm households. The total amount of energy that an average farm household in Katumba ward required per day was calculated using the following equation:

Percentage of the daily required energy that the farm household obtains from maize=

$$\frac{\text{Estimated amount of energy that can be obtained from maize per day}}{\text{Total energy that the household requires}}$$

Likewise, the percentage of protein that a farm household in Katumba ward can access from maize was calculated based on the amount of maize flour that a farm household consumes per meal, and the Food and Nutrition Board, Institute of Medicine of the National Academies' (2005) estimates for the amount of required protein per individual. Thus, the estimated percentage of protein that a farm household in Katumba ward could get from maize per day was calculated using the following equation:

Percentage of the daily required protein that the farm household obtains from maize =

$$\frac{\text{Estimated amount of protein that can be obtained from maize per day}}{\text{Total amount of protein that the household requires per day}} \times 100$$

Total estimated amount of maize that the farm households in Katumba ward produced per year was calculated by multiplying the average amount of maize that such a household produced per annum by the total number of farm households in the ward.

3.3 Results

3.3.1 Type of maize grown and type of maize meal that the farm households used most

The farm households in Katumba ward grew both hybrid and local white maize, often in scattered plots. All of the 260 farm households that participated in this study indicated that they started consuming maize prior to harvest when it was still green in the fields. During this time maize ears were roasted or boiled, then whole kernels of maize were eaten. It was not possible to estimate the proportions of maize that the farm households consumed prior to harvest because the farm households did not keep records of the quantities of maize cobs used and the frequency at which they roasted or boiled them. It was also found that after the maize is harvested, all of the farm households that participated in this study preferred the type of maize meal called *ugali*. *Ugali* is a type of maize meal made from sifted ground maize, and is always eaten concurrently with meat, fish, legumes, vegetables, sour milk known as *maziwa ya mgando* in Swahili or with meat and vegetables, fish and vegetables or legumes and vegetables.

3.3.2 The importance of maize as a source of food in Katumba ward

3.3.2.1 Sizes of land that the farm households allocated for food crops in Katumba ward

Hectares of land that the farm households allocated to growing other sources of carbohydrates such as green bananas/plantains and cassava ranged from 0 to 0.8; while maize was allocated up to two hectares. As indicated in Table 3.3, the size of land allocated for maize had the highest mean of 0.70 hectares, which suggests that more importance was attached to maize than to the other food crops.

Table 3.3: Size of land (hectares) allocated for different food crops in Katumba ward

Food crop	Size of land (Mean)	Size of land (Maximum)	Standard error of mean
Magimbi (*Colocasia esculenta*)	0.12	0.81	0.010
Potatoes	0.02	0.40	0.040
Sweet potatoes	0.09	0.30	0.003
Bananas and plantains	0.22	0.81	0.011
Cassava	0.02	0.81	0.005
Legumes	0.18	1.01	0.008
Vegetables	0.10	0.61	0.039
Maize	0.70	2.43	0.027

3.3.2.2 Time in a year when farm households faced maize shortages and strategies that they used in order to cope with the shortages

Farm households in Katumba ward harvest maize between February and March depending on the period when maize was planted. Maize supplies for farm households that participated in this study started running out as early as May of the same year, but 69.9 % of farm households started experiencing maize shortages between August and October of the same year. For about 64.0 % of the farm households' maize supplies completely ran out between October and December of the same year and 13.8 % of farm households maize supply lasted till January of the next year. Also 9.6 % of farm households' maize supply lasted till February to April of the next year, and only 1.9 % of farm households got maize harvests that lasted till far beyond the new harvest season. When maize supplies completely ran out, farm households would either buy more maize or use other types of food or beg for maize from close relatives. 'Buy more maize' had 80.8 % of the total scores, which was the highest.

3.3.2.3 The frequencies at which farm households' consumed maize in Katumba ward

Findings also revealed that farm households that took part in this study consumed maize in a minimum and maximum of one day and seven days per week, respectively. The number of maize meals that farm households consumed per day ranged from one to three (Fig. 3.1), and the total number of meals that the farm households consumed per day ranged from two to three (Figure 3.3). The mean and standard deviation for the number of days in a week during which farm households consumed maize were 6.16 and 1.45, respectively. While the mean and standard deviation for the total number of meals that the farm households consumed per day were 2.82 and 0.39, respectively. The percentages of farm households that consumed maize meals once - six days per week are as shown in Figure 3.2.

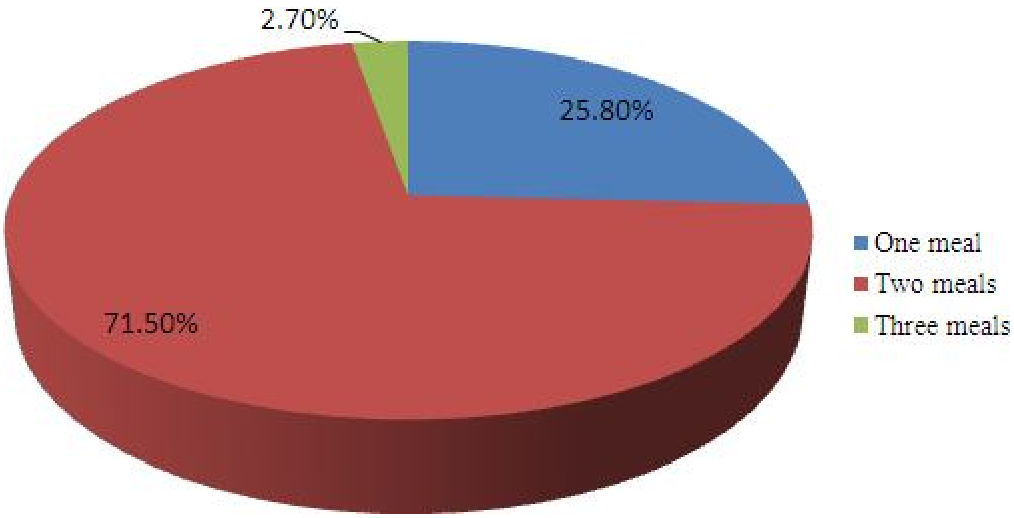

Figure 3.1: Number of maize meals that the farm households consumed daily

More information about the frequencies at which the farm households consumed maize meals in a week and the total number of meals that the farm households consumed per day is shown in Figures2.2, 2.3 and 2.4.

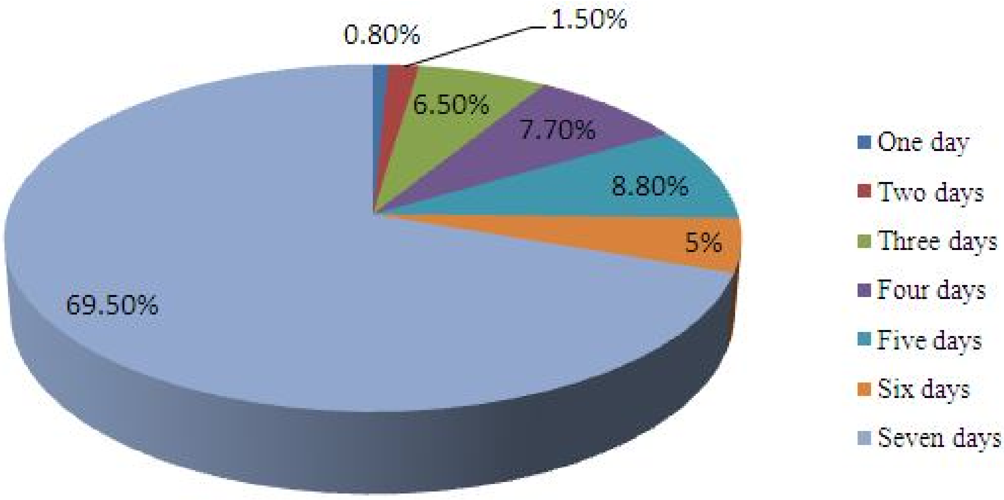

Figure 3.2: Number of days per week during which the farm households consumed maize meals

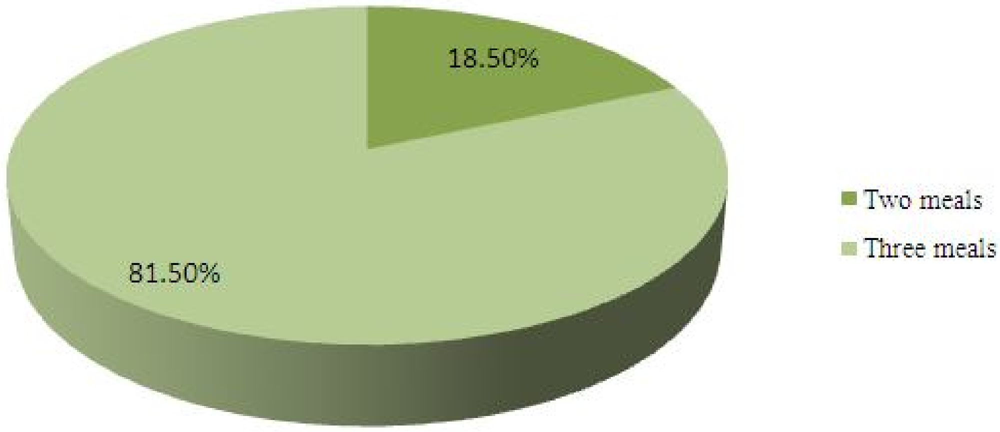

Figure 3.3: Total number of meals that the farm households consumed per day

The importance of maize in Katumba ward was also realized through considering the fact that maize produced by farm households in this ward was consumed not only by the farm households that produce it. An estimate of 70 % of the farm households that participated in this study indicated that they marketed some of the maize that they produced. An estimate of 87 tonnes of maize that the farm households harvested per annum was marketed.

3.3.3 The nutritional importance of maize in Katumba ward

The amounts of maize flour that farm households that took part in this study consumed per meal ranged from 0.5 to 3 kg, with a mean of 1.1308 kg. Farm household size ranged from two to 16, with 5.61 mean and 2.08 standard deviation. The mean for the number of female and male adults in the farm households was 1.16 and 0.90, respectively, and standard deviation was 0.49 and 0.39, respectively. Moreover, the number of male children aged above 18 years of age in the farm households ranged from 0 to 6 and the number of male children aged below 18 years of age ranged from 0 to 11, with 0.42 and 1.42 mean, respectively, and standard deviation of 0.76 and 1.38, respectively.

The number of female children aged above 18 years ranged from 0 to 5, and the number of children aged below 18 years also ranged from 0 to 5. The mean for the above was 0.37 and 1.41, respectively, standard deviation was 0.72 and 1.06, respectively. The above figures show that an average farm household in Katumba ward would consist of one male adult, one female adult, one male child aged above 18 years, one male child aged below 18 years, one female child aged below 18 years and no female child aged above 18 years. The mean number of people per farm household would be about five or six. Since the farm households in Katumba ward utilized an average of 1.13 kg of maize flour per meal, the farm households could obtain average amounts of calories of energy and other nutrients indicated in Table 3.3 daily through maize meal consumption alone. Lesser quantities of nutrients could be obtained from maize by households that utilized 0.5 kg of maize flour per meal; whereas farm households that utilized 3 kg of maize flour per meal could obtain relatively higher quantities of nutrients from maize per day (Table 3.3). However, whether these estimates apply to the farm households in Katumba ward or not depended on the degree of the quality of maize which the farm household could produce and properly store.

Table 3.3: The estimated amounts of energy and nutrients from maize that farm households that participated in the study could consume per day

Nutrients	Amount of nutrients from 1 - 1.13 kg of maize		Amount of nutrients from 0.5 kg of maize		Amount of nutrients from 3 kg of maize	
	per meal	per day	per meal	per day	per meal	per day
Energy	4161.34 cal	8322.69 cal	1840 cal	3680 cal	11040.00 cal	22080.00 cal
Protein	106.26 g	212.59 g	47.00 g	94 g	282.00 g	564.00 g
Fat	37.32 g	74.63 g	16.50 g	33 g	99.00 g	198.00 g
Carbohydrates	837.92 g	1675.85 g	370.50 g	741 g	2223.00 g	4446.00 g
Fiber	11.31 g	22.62 g	5.00 g	10 g	30.00 g	60.00 g
Ash	11.31 g	22.62 g	5.00 g	10 g	30.00 g	60.00 g
Calcium	203.54 mg	407.09 mg	900.00 mg	1800 mg	5400.00 mg	10800.00 mg
Phosphorus	11.31 mg	22.62 mg	890.00 mg	1780 mg	5340.00 mg	10680.00 mg
Iron	37.35 mg	74.63 mg	16.50 mg	33 mg	99.00 mg	198.00 mg
Thiamine	2.94 g	5.88 mg	1.30 mg	2.6 mg	7.80 mg	15.60 mg
Riboflavin	0.91 mg	1.81 mg	0.40 mg	0.8 mg	2.40 mg	4.80 mg
Niacin	11.31 mg	22.62 mg	5.00 mg	10 mg	30.00 mg	60.00 mg

3.3.3.1 The importance of maize as a source of energy in Katumba ward

In line with the findings in section 3.3.3, an average farm household in Katumba ward would consist of one boy aged above 18 years, one boy aged below 18 years, one girl aged below 18 years a female parent aged above 27 years and a male parent aged above 27 years. The recommended daily intakes of energy for an average farm household which is composed of two boys, one girl and two parents are as indicated in Tables 3.4 and 3.5 (Food Nutrition Board-Institute of Medicine of the National Academies, 2005), which are also applicable to an average farm household in Katumba ward.

Table 3.4: The estimated caloric requirement per day for an average farm household in Katumba ward where the female child and one of the male children in the household are aged 11 - 14 years

Household member	Age (years)	Energy (cal)
Boy	11-14	2500
Boy	19- 24	2900
Girl	11- 14	2200
Mother	27- 50	2200
Father	27- 50	2900
Total energy required		12700

Table 3.5: The estimated caloric requirement per day for an average farm household in Katumba ward where the female child and one of the male children in the household are aged 15 - 18 years

Household member	Age (Years)	Energy (cal)
Boy	15-18	3000
Boy	19- 24	2900
Girl	15- 18	2200
Mother	27- 50	2200
Father	27- 50	2900
Total energy required		13200

The Estimated 8322.69 cal that a farm household can obtain from maize per day in Katumba ward (Table 3.3) equals 69 % of the total energy that an average farm household in Table 3.5 required per day, and it also equals 66.8 % of the total energy that the farm household in Table 3.6 required per day. Thus, it was estimated that an average farm household in Katumba ward can obtain 66.8 - 69.5% of the daily required energy from consumption of maize in their diets.

3.3.3.2 The importance of maize as a source of protein in Katumba ward

Based on the average amounts of nutrients recommended by Food Nutrition Board, Institute of Medicine of the National Academies (2005) for specific age groups, the estimated amounts of the required protein that an average farm household in Katumba ward should be able to consume daily are as shown in table 3.6 and 3.7.

Table 3.6: The estimated protein requirement per day for an average farm household in Katumba ward where the female child and one of the male children are aged 11 - 13 years

Household member	Age (Years)	Protein (g)
Boy	11-13	34
Boy	19- 24	56
Girl	11- 13	34
Mother	27- 50	56
Father	27- 50	56
Total protein required		236

Thus, after rounding off, the estimated 212.59 g of protein that a farm household in Katumba ward can obtain from maize (Table 3.3) equals 90 % of the total quantity of protein that the average farm household in Table 3.6 requires and it equals 83 % of the total quantity of protein that the average farm household in Table 3.7required.

Table 3.7: The estimated protein requirement per day for an average farm household in Katumba ward where the female child and one of the male children in the household are aged 15 - 18 years

Household number	Age (Years)	Protein (g)
Boy	15-18	52
Boy	19- 24	56
Girl	15- 18	46
Mother	27- 50	46
Father	27- 50	56
Total protein required		256

Therefore, it was estimated that an average farm household in Katumba ward could obtain from maize 83 - 90 % of the total protein that the household required per day.

3.3.3.3 The importance of maize with respect to the nutrients that the farm households obtained through the other types of food that were consumed concurrently with maize meals

As shown in Figure 3.4, all of the farm households in Katumba ward often consumed maize meals concurrently with other types of food, especially beans, fresh leafy green vegetables, dry fish and meat. A significant percentage of the farm households ate maize meals with eggs regularly.

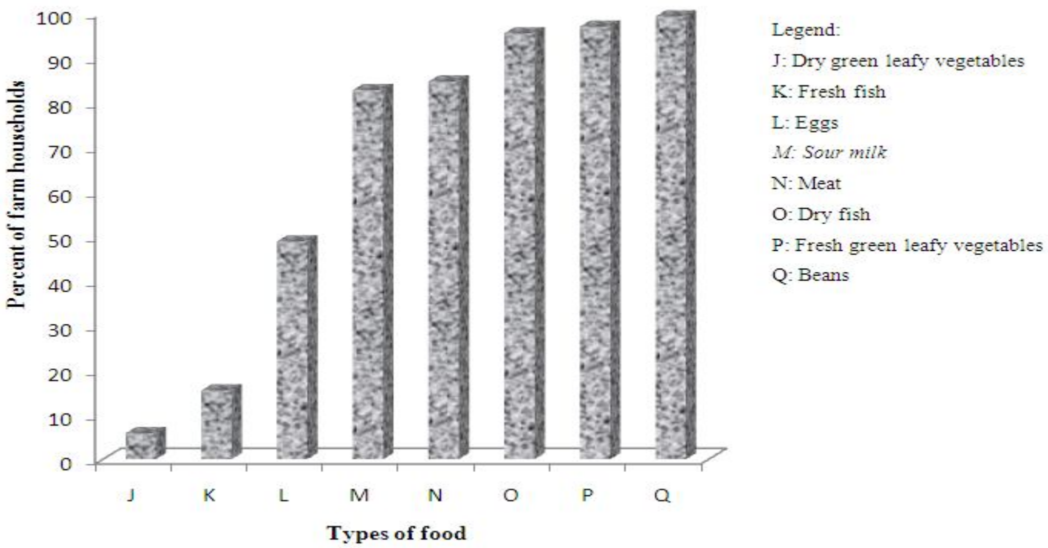

Figure 3.4: Types of food that the farm households in Katumba ward ate concurrently with maize meals

3.3.3.4 The importance of maize based on the farm households' perspectives

It was found that the importance of maize meal to farm households in Katumba ward was based on several perceptions (Figure 3.5), and the perception that maize meals are more filling than the other types of food had more than 60 % of the total scores, and was the highest.

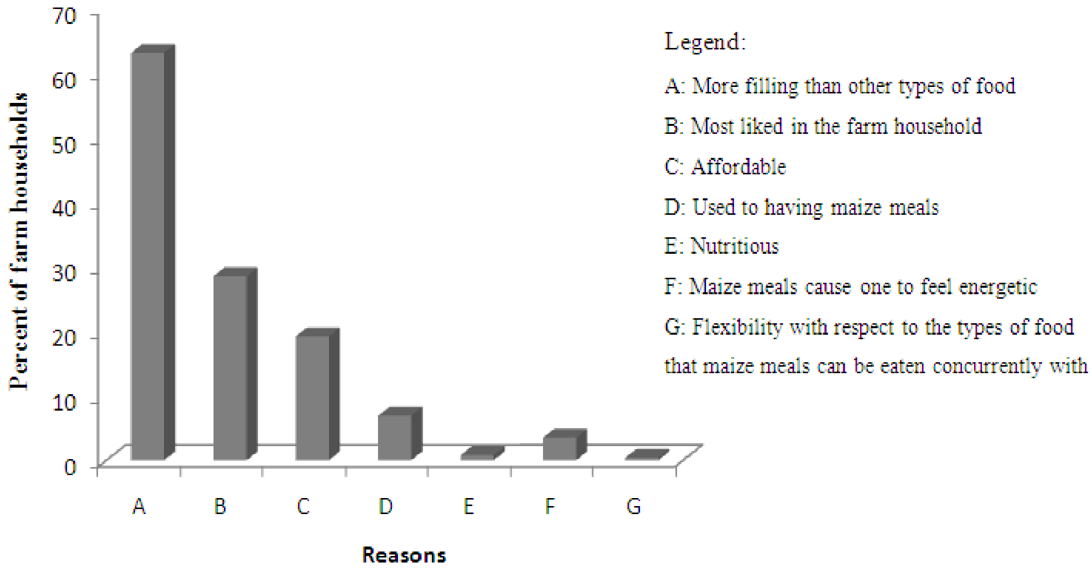

Figure 3.5: Reasons for which the farm households in Katumba ward preferred maize meals

3.3.4 Heads of farm households' level of formal education

About 10 % of the farm household heads had no formal education at all, 68.5 % had 1 - 7 years of primary education and 18.8 % had secondary education and only 2.3 % had college education. The mean for the heads of farm households' years of formal education was 6.57 and standard deviation was 3.08. The low level of formal education of the heads of farm households could possibly lead to vulnerability of the farm households as a result of the farm households being insufficiently informed concerning issues around food security. The Pearson product-moment correlation between heads of farm households' level of formal education and the frequency at which the farm households consumed maize meals revealed no significant relationship between these two variables. Thus years of formal education of heads of farm households did not influence the frequencies at which maize meals were consumed in the farm households.

3.3.5 Age of heads of farm households

Age of heads of farm households ranged from 27 to 78 years. The median for the age of farm households was 45 years, whereby 6.9 % of the farm households were aged 45 years. Standard deviation was 12.34. The results obtained through performing the Pearson product-moment correlation between the age of heads of farm households and the frequency at which the farm households consumed maize meals showed that there was no significant relationship between the two variables. Thus age of farm household heads did not influence the frequencies at which farm households consumed maize.

3.4 Discussion

3.4.1 The importance of maize as the main source of food in Katumba ward

The farm households in Katumba ward regard maize as more important than other food crops. This statement is partly based on the outcome of the comparison of the size of land that each farm household that participated in this study allocated for growing maize than that allocated for other crops. The number of hectares of land that each farm household allocated for other crops ranged from 0 - 1; while maize was allocated up to about two hectares of land, which implies that maize was the most preferred food crop in Katumba ward. Although the farm households in Katumba ward allocated larger portions of land to growing maize than to other food crops, in general, the average size of land on which maize was grown was less than a hectare. Naturally this would have a negative effect on the length of time during which maize is available to the consumers, given that the yield is generally low in the smallholder sector.

The importance of maize as a source of food in Katumba ward was portrayed by the frequency at which the farm households consumed maize meals. The total number of meals that the farm households consumed per day was on average three meals, while the average number of maize meals consumed per day was approximately two, and the average number of days per week during which the farm households consumed maize meals was six. These numeric figures imply that farm households consumed maize meals at least once per day in an average of six days per week, and that two out of an average of three meals consumed per day were made from maize. This study agrees with the Tanzanian government’s reports concerning the importance of maize as the main source of food in the country (Amani, 2004).

However, elsewhere, Tanzanian government’s record shows higher production of green bananas/plantains than maize per annum in Rungwe district (Administrator, 2010). Thus, it is possible that bananas/plantains are more used for non-consumption purposes such as marketing than for consumption purposes in Rungwe district. The Tanzanian government may not be fully aware of the extent to which maize has gained importance as a source of food in Rungwe district especially in the light of the fact that currently farm households allocate more land to growing it than other sources of carbohydrates such as green bananas/plantains. The former could lead to the government's failure to fully address issues of the farm households' vulnerability in Rungwe district.

Furthermore, an average of five to six people revealed in the findings for a farm household in Katumba ward is slightly higher than the average of four people per household indicated by Tanzanian government reports (Mbogoro, 2003), which implies that there are more maize consumers in Katumba ward than what the Tanzanian government reports suggest. The absence of female children aged above 18 years in Katumba ward can be explained in that in Tanzania, girls can get married by law at the age of 15 years (United Nations Girls' Education Initiative (UNGEI), 2006), thus, 20 - 40 % of the teen aged girls cease to be regarded as children in the households after getting married.

3.4.2 The nutritional importance of maize in Katumba ward

Roughly 66.8 % - 69.5 % of the total energy required per household in Katumba ward can be obtained from maize alone, which implies that maize contributes significantly to the food security of the farm households in this ward. It seems that farm households could obtain from maize slightly higher amounts of energy than the 60 % dietary energy reported in records by Green (1999) and Katinila *et al.,* (1998) regarding the amount of energy that consumers obtained from maize in Tanzania. An average farm household in Katumba ward may also obtain about 83 % to 90 % of the daily required protein from maize meal alone, which is higher than the estimated 50 % (Katinila *et al.,* 1998) daily required protein recorded as obtained from maize in Tanzania.

In fact a lot more protein and other nutrients such as fats minerals and vitamins can be obtained from maize consumption when whole grains of maize are consumed without being subjected to the milling process. During milling some of the nutrients are lost when bran is removed (Hoseney, 2000; Klopfenstein, 2000). Consequently, this reduces the nutritional value of the end product (Hoseney, 2000; Klopfenstein, 2000), but since in Katumba ward the farm households started consuming maize while it was still green in the fields, it was possible for the farm households to obtain a lot more protein and other nutrients from maize than when they utilized milled maize. However, the protein found in maize is of poor quality due to its deficiency in two essential amino acids, namely, lysine and tryptophan (Escobedo, 2010). Its mineral and vitamin content is also deficient (Welch, 2002), thus, the consumption of meals made from whole grains of maize does not guarantee adequate nutrition. Nevertheless, technologies for breeding for better nutrition makes it possible to improve the nutrient content of maize (Welch, 2002). Thus, consumption of whole grains of enriched maize would boost the farm households' food security. This renders maize very important where the farm households' food security is concerned. The fact that the farm households in Katumba ward obtained a higher percentage of the daily required protein from maize which had low quality protein raises questions concerning the nutritional status of the people in the ward. The farm household could improve their nutrition through using Quality Protein Maize (QPM), which was developed by CIMMYT in order to advance the protein quality in maize (Vasal, 2002). The consumption of QPM has been proven to enhance the nutrition and health of consumers (Nuss and Tanumihardjo, 2011).

3.4.3 The importance of maize with respect to the nutrients that the farm households may access indirectly through maize consumption

In Katumba ward, maize also promotes access to nutrients that are available in other types of foods that are eaten concurrently with maize. This statement is based on the findings in Figure 2.4, which reveal that all of the farm households in Katumba ward often consumed maize meals concurrently with other types of food, especially beans, fresh leafy green vegetables, dry fish and meat. Meat, fish, eggs, beans and milk are good sources of protein (FAO, 1992; 1999; Ofuya and Akhide, 2005). However, the foods that are eaten together with maize meals are normally consumed in small quantities; whereas maize provides the bulk in the meals. The fact that the farm households could obtain up to 90 % of the daily required protein from maize alone implies that the farm households utilized more of the low quality protein than the high quality protein from the other foods such as meat. Although the consumption of maize meals concurrently with the other types of foods indicated above created possibilities for the farm households to access protein and other nutrients found in the foods, their diets could have been even better if maize was enriched with the deficient nutrients.

Green leafy vegetables are also good sources of essential amino acids, vitamins, minerals and roughage (Singh *et al.,* 2001; Flyman and Afolayan, 2006; Olaiya and Adebisi, 2010). The farm households could access the above nutrients through eating maize meals concurrently with the other types of foods mentioned above. Vitamins (Webb, 1995) and minerals (Smolin and Grosvenor, 2010) are required in small quantities in the body per day, thus, green leafy vegetables could promote the farm households' nutrition security regardless of the fact that they are taken in smaller quantities than maize meals.

More nutrients such as fats and vitamins are obtained from ingredients that are added to foods when foods eaten with maize meals are cooked. In general, nutrients that are obtained from foods eaten together with maize meal add value to the diets and complement the nutrient deficiencies in maize, which improves the food security of the consumers. In this way maize has the capacity to make an indirect positive influence on nutrition and food security of the farm households. The current worldwide efforts to improve the level of vitamin A in maize (Ortiz-Monestario *et al., 2007*) can be beneficial to farm households in Katumba ward and thus, needs to be promoted in this ward among other places.

3.4.4 The importance of maize based on the farm households' perceptions

The perception that 'maize meals are more filling than the other types of food' had the highest scores implies that the farm households possibly prefer maize meals. Feeling full is a sensation opposed to the painful feeling caused by lack of food, which the Agriculture and Natural Resources Team of the United Kingdom Department for International Development (DFID) and Wiggins (2004) defines as hunger. While food security is concerned with eliminating hunger, the elimination of hunger goes beyond getting rid of the uncomfortable sensation indicated above to include ensuring that the consumers obtain adequate nutrition from the food being consumed for a healthy life (WFP, 2009).

Since maize meals are preferred in Katumba ward, maize influences the type of nutrition that the farm households access, thus, it is not enough for maize to be merely more filling than the other types of food. It is imperative that farm households be able to obtain maximum amounts of nutrients from maize. Thus, it is imperative that the maize be of high quality, and that farming and storage technologies that enhance its yield, nutritional value and resistance to infestations and infections be available to the farm households.

3.4.5 The implication of gender, formal education and age of heads of farm households on maize consumption

Relationships between years of formal education, age and gender of heads of households, and the frequency at which maize meals were consumed in Katumba ward were investigated using Pearson product-moment correlation and no significant relationships were found. This implies that the farm households' preference of maize meals above other types of food was not influenced by the level of formal education, age or gender of farm household heads.

3.5 Conclusions and recommendations

Maize is the most important food crop in Katumba ward. Farm households in this ward prefer maize meals regardless of age, gender or formal education of farm household heads. Thus, maize is immensely important for the availability of food to the farm households. It contributes directly to the enhancement of household food security through the nutrients that are available to households from maize meal consumption and indirectly through helping consumers to access necessary nutrients through foods that are eaten together with maize meals. Other reasons for the importance of maize in Katumba ward include: farm households perceiving maize meal as more filling than other types of food, the ease of its availability and its flexibility with respect to the other foods with which it is eaten concurrently.

On a daily basis farm households could access from maize about 63 - 65 % of the total required energy and 83 - 90 % of the total required protein and it also provides smaller quantities of other nutrients such as calcium and phosphorus. Thus, maize has great potential for enhancing food security of the farm households. The ease of maize availability and its capacity to be filling also contributes to household food security in this ward through hunger reduction. However, the fact that maize protein is of low quality, yet the farm households' prefer maize meals above the other types of food exposes the farm households to poor nutrition, which impacts negatively on their food security. The farm households could access better nutrition through the use of Quality Protein Maize. Thus, breeding technologies that make it possible to improve the quantities of nutrients that are deficient in maize are necessary in this ward. Furthermore, the majority of farm households in Katumba ward run out of maize before the next harvest season. This impacts negatively on the farm households' availability of preferred food, which would naturally create anxiety among households' members thus, render them vulnerable and food insecure.

In order to ensure availability of maize for longer periods of time, it is critically important that appropriate farming and storage technologies be made available to the farm households so that maximum amounts of maize per unit of land can be obtained. It is also recommended that appropriate agricultural policy should be implemented by the government of Tanzania in order to ensure availability of technologies that make it possible for the farm households to achieve high quality maize production and storage.

References

Adeyemo, R., 1984. Maize- Consumption Expenditure of Rural and Urban Workers: Implications for Nigeria. *The Journal of Modern African Studies*. 22, 1, 163-166.

Administrator, 2010. *Rungwe district Council*. <http://www.mbeya.go.tz/document/profile_rungwe.pdf> (Accessed 2010 November 25).

Amani, H.K.R., 2004. *Agricultural Development and Food Security in Sub-Saharan Africa: Tanzania Country Report*. <http://www.fao.org/tc/tca/work05/Tanzania.pdf> (Accessed 2010 November 15).

Bisanda, S., Mwangi, W., 1996 'Introduction', Adoption *of Recommended Maize Technologies in Mbeya Region of the Southern Highlands of Tanzania*. Fifth Eastern and Southern Africa Regional Maize Conference, 3rd-7th June 1996. The International Maize and Wheat Improvement Centre, Dar-Es-Salaam, pp. 2 - 6.

Brandes, S., 1992. Maize as a Culinary Mystery. *Ethnology*. 31, 4, 331 - 336.

Bryceson, D.F., 2009. Sub-Saharan Africa's Vanishing Peasantries and the Specter of a Global Food Crisis. *Monthly Reviews*. 61, 3, 48 - 62.

Dattalo, P., 2008. *Determining sample size: Balancing Power, Precision and Practicality*. Oxford University, Oxford.

DFID/Wiggins, 2004. *Agriculture, Hunger and Food Security*. <http://www.observatory.org/documents/Agriculture_Hunge_and_Food_Security.pdf> (Accessed 2010 December 16).

Escobedo, G.E., 2010. *Comparative analysis of the Quality Protein Maize (QPM) and Normal Maize Cultivars (Zea mays L).*<http://www.scribd.com/doc/34756747/Comparative-Analysis-of-the-Crude-Protein-Lysine-and-Tryptophan-of-Quality-Protein-Maize-QPM-and-Normal-Maize-Cultivars> (Accessed 2010 November 25).

FAO, 1968. *Food Composition Table for use in Africa*. <http://www.fao.org/DOCREP/003/X6877E/X6877E00.HTM> Accessed (Accessed 2010 October 19.

FAO, 1984. *Food Balance Sheets. 1960 62 Average*. Rome, FAO.

FAO, 1992. FAO *Food and Nutrition Papers*. FAO, Rome.

FAO, 1994. *Grain Storage techniques - Evolution and trends in Developing Countries*. FAO. Rome.

FAO, 1999. *Fish is Food for the Brain as well as good Protein*. <http://www.fao.org/focus/e/fisheries/nutr.htm> (Accessed 2010 Otcober 19).

FAO Bulletin of Statistics Vol.4 No. 2-2003. 2004. *FAO Production Year Book*. FAO, Rome.

FAO, 2008. *What is food security?*<http://www.fao.org/spfs> (Accessed 2008 September 10).

Flyman, M.V., Afolayan, A.J., 2006. The Suitability of Wild Vegetables for Alleviating Human Dietary deficiencies. *Journal of Botany*. 72, 4, 492 - 497.

Food Nutrition Board, Institute of Medicine of the National Academy, 2005.*Dietary Reference Intakes for Energy, Carbohydrates, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids (Macronutrients)*.National Academy of Sciences Press, Washington.

Friedman, M., 1996.Nutritional Value of Protein from Different Sources. A Review. *Journal of Agricultural Food Chemistry*. 44, 1, 6 - 29.

Government of the United Republic of Tanzania, 2006. *Agriculture*. <http://www.tanzania.go.tz/agriculture/htm> Accessed 2010 May 19).

Green, M., 1999. Trading on Inequality: Gender and the Drinks Trade in Southern Tanzania. *Africa: Journal of the International African Institute*. 69, 3, 404 - 425.

Hoseney, C. R. 2000. *Principles of Cereal Science and Technology*, second ed. American Association of Cereal Chemists, Minnesota.

Israel, G. D., 1992. *Sampling the Evidence of Extension Program Impact.* <http://edis.ifas.ufl.edu/PD005> (Accessed 2008 July 19).

Johnson, L.A., 2000. Corn: The major Cereal of the Americas. In Kulp, K., 2000.*Handbook of Cereal Science and Technology*, second ed. Marcel Dekker, New York, 705-723.

Katinila, N., Verkuijl, H., Mwangi, W., Anandajayasekeram, P., Moshi, A. 1998. *Adoption of maize Technologies in Southern Tanzania*. CIMMYT, Mexico.

King, A. B., 1994. *Tools for Participatory Research on Crop and Tree Diversity*. <www.ipgri.cgiar.org/themes/human/Articles/particip-research2.doc> (Accessed 2008 July 22).

Klopfenstein, C. E. 2000. Nutritional Quality of Cereal Based Foods. In Kulp, K. (Ed), *Handbook of Cereal Science and Technology*, second ed. New York, Marcel Dekker, pp.705 - 7230.

Mbogoro, K. D., 2003. *2002 Population and Housing Census: General report*. Government of the United Republic of Tanzania, Central Census Office, National Bureau of Statistics, President's office, Planning and Privatization, Dar-es-Salaam.

Nuss, E.T., Tanumihardjo, S.A., 2011. Quality Protein Maize for Africa: Closing the Protein Inadequacy Gap in Vulnerable Populations. *Advances in Nutrition*. 2, 217 - 244.

NBS, Mbeya Regional Commissioner's Office, 2003. *The United Republic of Tanzania, Mbeya Region: Socio- Economic Profile*. NBS, Dar-es-Salaam.

Ofuya, Z.M., Akhide, V., 2005. The Role of Pulses in Human Nutrition: A Review. *Journal of Applied Sciences and Environmental Management*. 9, 3, 99-104.

Olaiya, C., Adebisi, J., 2010. Phytoevaluation of the nutritional values of ten green leafy vegetables in South-Western Nigeria. *The Internet Journal of Nutrition and Wellness*, 9, 2.

Olakojo, S.A.., Kogbe, J.O., Iken JE, Daramola, A.M., 2005. Yield and Disease Evaluation of Some Improved Maize (*Zea mays* L) varieties in South Western Nigeria. *Tropical and Subtropical Agroecosystems*. 5: 51 - 55.

Ortiz-Monasterio, J.L., Palacios-Rojas, N., Meing, E, Pixley, K., Trethwan, R., Pena, R.J., 2007.Enhancing the Mineral and Vitamin Content of Wheat and Maize through Plant Breeding. *Journal of Cereal Science*. 46, 3, 293 - 307.

Pachon, H., Ortiz, D.A., Araujo, C., Blair, M.W., Restrepo, J., 2009. Iron, Zinc, and Protein Bioavailability proxy Measures of Meals Prepared with Nutritionally Enhanced Beans and Maize. *Journal of Food Science*. 74, 5, 147 - 154.

Pallant, J., 2005. *SPSS Survival Manual. A Step by Step Guide to Data Analysis using SPSS for Windows (Version 12)*, second ed. Open University Press, Philadelphia.

Pierre, G.Y., 1996. *Sampling for Analytical Purposes*. John Willey & Sons, New York.

Preece, A. J., 2006. Participatory Rural Appraisal. *International Journal of Action Research*. 2, 2, 198 - 1921.

Smolin, L.A., Grosvenor, M.B., 2010. *Nutrition: Science and Application*, second ed. John Wiley and Sons, New Jersey.

Singh, G., Kawartra, A., Sehgal, S., 2001.Nutrition Composition of Selected Green Leafy Vegetables, Serbs and Carrots. *Plant Foods for Human Nutrition*. 56, 359 - 364.

Trochim, W. M. K., 2001. *The Research Methods Knowledge Base*. Atomic Dog, Cincinnanti.

UNESCO Commission of the United Republic of Tanzania (2010). *Agriculture: Green Revolution to Improve Productivity*. <http://www.natcomreport.com/Tanzania/pdf-new/agriculture.pdf>(Accessed 2010 November 12).

UNGEI, 2006.*Information by Country: Tanzania, United Republic of: Press Release*. <http://www.ungi.org/news/tanzania_1121.html> (Accessed 2010 December 15).

United Nations Statistics Division, 2010. *United Republic of Tanzania*. <http://data.un.org/countryprofile.aspx?crName=United%republic%20of%20Tanzania> (Accessed 2010 July 1).

Vasal, S.K., 2002. Quality Protein Maize: Overcoming the Hurdles. *Journal of Crop Production*. 6, 35, 193 - 122.

Webb, G.P., 1995. *Nutrition. A Health Promotion Approach*. Edward Arnold, London.

Welch, R.M. 2002. Breeding Strategies for Biofortified Plant Foods to Reduce Micronutrient Malnutrition Globally. *Journal of Nutrition*. 132: 4955 - 4995.

WFP, 2009. *Comprehensive Food Security and Vulnerability Analysis Handbook*. WFP, Rome.

APPENDICES

Appendix 3.1: An illustration of a sample size calculator

Entering the population size into the designated space automatically reflects the sample sizes required at different precision levels at 95 % confidence level and 100 % confidence level.

Population size.................		Reset	
Plus or minus:			
1 percentage point...........		6 percentage points..........	
2 percentage points.........		7 percentage points..........	
3 percentage points.........		8 percentage points..........	
4 percentage points.........		9 percentage points..........	
5 percentage points.........		10 percentage points........	

Appendix 3.2: The questionnaire that was used to collect data

1 Is the household head male or female? (a) Male (b) Female

2 How many years of formal education does household head have?

(i) None (ii) One (iii) Two (iv) Three (v) Four (vi) Five (vii) Six (viii) Seven

(ix) Eight (x) Nine (xi) Ten (xii) Eleven (xiii) Twelve xiv) Thirteen (xv) Fourteen (xvi) More than fourteen

3 What is the marital status of household head?

(a) Single (b) Married (c) Divorced (d) Widowed

4 For how many years have you been farming? -------------------

5 For how many years have you (or other person) been the decision maker of your farming activities? ---

6 What is the composition of your household?

Gender group	**Number of members of gender group**	**Age in years**	**Number of years of formal education**
Male adults			
Female adults			
Male children			
Female children			

7 What type of maize meal do you often use? ------------------------------

8 How many days per week do you eat maize meals in your household? ----------------days

9 How many times do you eat maize meals in a day in your household? ----------------times

10 What are the reasons for your answers to questions 7 - 9?

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11 How much maize meal do you consume per meal in your household? ----------

12 How many meals does your household have in a day? ----------------------meals

13 During which month in a year does stored maize start running out in your household? ----------
----

14 How do you deal with maize shortages when your maize harvests run out?

(a) Buy more maize (b) Use other types of food

(c) Beg for maize from close relatives (d) other (specify**)……………….**

15 In your household, what do you often eat maize meal with?(i) Beans (ii) Meat (iii) Fresh fish (iv) Fresh green leafy vegetables (v) Dry green vegetables (vi) Sour milk/*Maziwa ya mgando* (*Maas*) (vii) Eggs (viii) Green peas (ix) Dry peas(x) Cabbage (xi) Other (specify) -----------

16 How much land has your household allocated to growing maize? ---------------------------------

17 How much land is allocated to other types of food crops that you grow?

Type of food crop	**Size of land allocated to food crop**

18 When do you start consuming your maize? (a) When it is still green (b) Immediately after harvest (c) Other (specify) -------------------------------------

19 Do you run out of maize? (a) Yes (b) No

20 What month in the year do you start applying the strategies you have indicated in question 14? (please put a blue sticker in the box that corresponds with the relevant month).

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	OTHER (specify)

21. During which month of the year does stored maize completely run out in your household? (Please put a red sticker in the box corresponding to the relevant month)

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	OTHER (specify)

22 Do you think your household is food secure? (a) Yes (b) No

23 What are the reasons for your answer to question 22? --

Appendix 3.3: Statistics for Characteristics of heads of farm households

		Household head's age	**Household head's years of farming experience**	**Household head's years of formal education**
N	Valid	260	260	260
	Missing	0	0	0
Median		45.00	20.00	7.00
Std. Deviation		12.344	12.867	3.080
Variance		152.386	165.571	9.489
Range		51	51	16
Minimum		27	4	0
Maximum		78	60	16

Appendix 3.4: Household heads' years of formal education in four groups

Years of formal education		Frequency	Percent	Valid percent	Cumulative percent
Valid	0 - 0	27	10.4	10.4	10.4
	1 - 7	178	68.5	68.5	78.8
	8 - 12	49	18.8	18.8	97.7
	13- 16	6	2.3	2.3	100.0
	Total	260	100.0	100.0	

Appendix 3.5: Age of heads of farm households in six groups

Age	Frequency	Percent	Valid percent	Cumulative percent
<= 35	50	19.2	19.2	19.2
36 - 40	46	17.7	17.7	36.9
41 - 45	39	15.0	15.0	51.9
46 - 52	39	15.0	15.0	66.9
53 - 60	45	17.3	17.3	84.2
61+	41	15.8	15.8	100.0
Total	260	100.0	100.0	

Appendix 3.6: Statistics for the importance of maize in Katumba ward

		Number of days per week during which maize meal is consumed	Number of maize meals per day	Total number of meals per day
N	Valid	260	260	260
	Missing	0	0	0
Mean		6.16	1.77	2.82
Std. Deviation		1.450	0.482	0.389
Range		6	2	1
Minimum		1	1	2
Maximum		7	3	3

CHAPTER FOUR

MAIZE STORAGE PROBLEMS AND THE QUALITY OF MAIZE IN RUNGWE DISTRICT, TANZANIA: IMPLICATIONS ON HOUSEHOLD FOOD SECURITY

Abstract

Maize storage problems in Katumba ward, Rungwe district, Tanzania were investigated through interviewing 260 farm households and studying the quality of maize samples that was collected from the same farm households in the ward. The quality of maize was studied by investigating levels of insect infestation using the incubation method on maize samples that were collected from a sub-sample of 130 farm households in the ward. It was found that 228 tonnes of maize that the farm households harvested annually were stored using roof and sack storage methods, and that 34.5 % of the maize was lost to insect infestations during storage. Through studying the farm households' perceptions, it was found that the farm households were ignorant of the negative effects that moulds can propagate in maize and on the consumers. Lack of association between the farm household and the agricultural institutions, especially extension and research institutes was also noted. After 90 days of incubation 25 % of the maize samples that were collected at harvest were infested by either *Sitophilus zeamais* (Motschulsky) or *Sitotroga cerealella* (Olivier) or both in a range of 0 - 52 insect pests per 120 maize kernels. Likewise, after 90 days of incubation, 93 % of the maize samples that were collected from the same farm households after five months of storage were found to be infested by the insect pests, ranging from 0 - 210 insects per 51 g, amounting to 1569 insects per kg of maize. The means were 80 insects for the maize sample that were collected from the roof storage facilities and 79 insects for the maize samples that had been collected from the sack storage facilities. The presence of the large numbers of insects in stored maize suggests that both grain quality and yield were compromised. It was concluded that methods that farm households in Katumba ward used to fight against infestations in stored maize were not effective.

Key words: Maize, Storage, Perceptions, Household Food security.

4.1 Introduction

Moulds, insect pests and rodents have been acknowledged as the main storage pests that cause loss of stored maize worldwide (De Groote, 2004). In Africa, *Sitophilus zeamais* and *Sitotroga cerealella* have been reported as the main insect pests (Capinera, 2008; Brink and Belay, 2006). It is estimated that rodents cause loss of 15 % of stored maize per year in Africa, while *S. zeamais* can cause up to 20 % of maize losses in three months of storage (Boxall, 2002, as cites by Tefera *et al*., 2011), which amounts to millions of tonnes of maize loss.

Apart from reducing the mass of the grain through feeding on the grain (Lewis *et al.*, 2008), pests also reduce the nutritional content of the infested grain (Jood *et al.*, 1992) and contaminate the grain with waste products (Lewis *et al.*, 2008). Pests also cause unpleasant odours in the foods made from the infested crops (Hansel *et al.*, 2004). They may also cause unpalatability of the foods (Mejia, 2003) and loss of marketability of the infested food crops (Hill, 2008). While insect activity in the grains increases the temperature in the grain, it also increases moisture content through perspiration and condensation, which create favourable conditions for development and growth of moulds (Williams, 2004).

Characterised by wetness throughout the year, the climatic conditions in some parts of Tanzania such as Rungwe district create favourable conditions for moisture content problems to occur in stored grain, which further leads to infestations. The climatic conditions together with the insect activity in the grain further create favourable conditions for attack of the grains by secondary insect pests and moulds (Mejia, 2003; Sallam, 1999). Moreover, insect pests transmit micro-organisms such as bacteria and fungal spores in the crops (Hill, 2008) thus, increasing the magnitude of infestations. Through the indicated means, insect pests interfere with the food security of the consumers and put the consumers at risk of ill health.

Therefore, it is of utmost importance that there be no insect pests in maize prior to or during storage. Storage technologies play a major role in determining the extent to which stored maize is safe from infestation, but also in determining availability and safety of food for the consumers. Prior to this study no one had attempted to investigate storage problems and the capacity of maize storage methods in the ward to protect stored maize from infestations. Methods that farm households used for long term storage of maize were identified. Storage problems that they encounter when storing maize were studied and the quality of maize stored using methods that farm households used to store maize were investigated through the ecohealth approach. The ecohealth approach aims at improving health of the people being studied, thus, it involves studying roles that men and women play in specific contexts in order to identify key persons for initiating change in the community under investigation (De Plaen and Kilelu, 2004). This study is concerned with maize storage problems at household level, and roles that individuals in the farm households play when storing maize.

4.1.1 Main objective

To identify maize storage methods and investigate the associated storage problems such as pest infestation of stored maize and subsequent losses, and their implications on the farm households' food security.

4.1.2 Specific objectives

(i) To study storage methods, factors influencing their selection and assess quantities of maize that farm households harvested and stored.

(ii) To determine the levels of insect infestations and fungal infections in maize stored using each of the storage methods and the prevalence of the infestation by rodents.

(iii) To study control methods used to protect the maize and persons responsible for protection of stored maize, selecting and managing storage methods in the households, who can be targeted for future improvement of the storage methods in the ward.

4.2 Materials and Methods

4.2.1 Sampling of the farm households

Farm households were sampled using the procedure indicated in Chapter Three, Section 3.2.1.

4.2.2 Sampling of maize samples

Maize samples were randomly collected from a sub-sample of 130 households drawn from the 260 sample householdsbetween February and March, 2009. Half of the sample households was considered large enough to provide reliable findings. In order to eliminate bias and sampling error, maize sample units were randomly sampled as follows:After thoroughly mixing the maize grain 2.5 kg of maize were collected from storage facilities using the method recommended by Pitchler (2006). Where maize was in the form of cobs the cobs were mixed thoroughly ten randomly picked followed by shelling. The maize kernels were evenly distributed on a 1x1.5 m mat and divisions were made on the mat using ropes as shown in Figure 3.1, and the ropes were secured in position using nails. Maize for insect pest quantification was collected from the mat on spots represented by green circles in Figure 4.1 situated about 30 cm from each other. This procedure was used to collect maize from the sub-sample of farm households immediately after maize was harvested in March 2009, and later repeated after the same farm households had stored maize for five months.

Since the maize samples were randomly sampled it was expected that the results would be reliable.

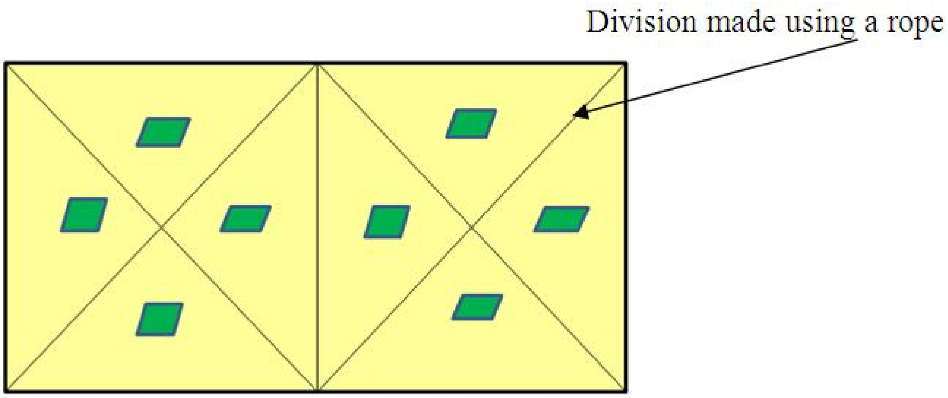

Figure 4.1: Sampling of the maize sample units
Source: Pitchler, 2006

Due to the fact that a larger proportion of the farm households stored maize using the roof storage method than the sack storage method (Section 6.1), Forty two out of the 130 maize samples were gathered from the sack storage facilities and 88 were collected from the roof storage facilities. Moreover, the number of maize samples for each maize variety collected depended upon the varieties that the farm households had at that particular moment. Thus, 87 out of the 130 maize samples were of the improved varieties, 43 were of the indigenous types. Each of the maize samples was zip-locked in a separate zip-lock plastic bag in order to prevent movement of insects from one maize sample to another.

4.2.3 Data collection techniques

Semi-structured and structured face-to-face interviews were administered to 260 sample households in Katumba ward by the researcher with the help of research assistants.interviews were carried out in February - March 2008 and repeated in February - March 2009 in order to gather information which was inadequately collected in 2008. Semi-structured face -t o - face interviews were used in order to make possible the participation of those who cannot read or write (Trochim, 2006). The questionnaire that was used is shown in Appendix 4.1. The survey was later split into different sections that were used to answer the research objectives that made the chapters of this thesis. The interviews were conducted at the participants own homes or venues of their choice to make easier the participation of women. In Rungwe district most of the farming activities including processing and crop storage are done by women (FAO, 1994). Data collected included the types of storage methods that the farm household used, the length of time during which maize was stored, the quantities of maize that the farm households stored and the farm households' perceptions concerning the capacity of the storage method to protect the stored maize from infestations and infections.

Data set concerning farm households' experiences of maize losses due to pests, types of insects, moulds and rodents that they observed in stored maize and control methods that they used against the infestations and infections was collected. Pictures of different types of maize insect pests, rodents and ear rots symptoms (Appendix 4.1) were attached to the questionnaire and the farmers were asked to view the pictures and identify the types of insect pests, rodents and moulds that they observe in stored maize. Data set concerning the types of maize seeds that the farm households grew, whether the farm households bought or used some of their own saved maize seeds for planting was also collected. Places where they bought the seeds from, other storage problems apart from infestation and infection and means that the farm households used to dry maize was were recorded. Details concerning the collected data are shown in Appendix 4.1.

Levels of insect infestations in the maize samples were studied using the incubation method described by Derera *et al*. (2001). Grain samples were each placed in a 250 ml glass jar for insect detection. The glass jars were covered with nylon mesh screen lids to prevent insects from escaping while allowing free ventilation. The glass jars were also labelled for identification of the source and maize variety and were kept at room temperature at 25 - 30 ^{0}C and 75 - 80 % relative humidity.

Insects that came out of the maize samples were counted after 90 days of incubation period. The 90 days incubation period was considered long enough to allow growth of the insects pests especially during the cold season at the University of KwaZulu-Natal, Pietermaritzburg, South Africa, where the trials were conducted. The above procedure was repeated using maize samples that were collected from the same households after five months of storage in September 2009. Forty two out of the 130 maize samples were gathered from the sack storage facilities, whereas 88 were collected from the roof storage facilities. While 43 out of 130 maize samples were local varieties, 87 out of 130 were improved varieties.

4.2.4 Statistical analyses

Statistical analysis was performed using the Statistical Programme for Social Sciences (SPSS) version 15, 2005 software. In order to find out the number of scores per response, descriptive statistics were performed using frequencies for each response. Cross tabulations were also performed in order to explore trends between variables. Part of the statistical output is shown in Appendix 4.2 - 4.7. The amounts of maize that the farm households lost to infestations and infections were obtained by subtracting the amount that the farm households used for consumption and non-consumption purposes from the total estimated amount of maize that the farm households harvested per year[4].

The estimated amount of maize produced in Katumba ward was obtained through multiplying the average amount of maize that each farm household produced per annum by the number of households in the ward, which was 2649 households. The percentage of farm households in

[4]Moisture content of the maize was not measured thus, changes in the grain due to changes in moisture content were not accounted for.This may affect the accuracy of the calculations.

Katumba ward for whom insect infestation of maize started during storage was obtained through subtracting the percentage of maize samples that were found to be infested by the insect pests prior to storage from the percentage of maize samples that were found to be infested by the insect pests during storage.The average number of insect pests per kilogram (kg) of maize, were derived from the mean quantity of insect pests per 120 maize kernels (or 51 g) of maize.

The independent t-tests were performed in order to evaluate the performance of different storage methods through comparing average numbers of insect pests that came out of the incubated maize samples from each of the storage facilities. Levels of insect infestation in the landraces and improved varieties of maize were compared by conducting the independent t-test using the SPSS programme.

4.3 Results

4.3.1 Maize Storage methods and quantities of stored maize

Farm households in Katumba ward harvested maize between February and March depending on the time when it was planted. For long-term storage of maize, the farm households stored maize using either the roof storage method exclusively or sack storage method exclusively or both. Sacks[5]were mainly made from sisal and synthetic fibers. Maize grains were packed in the sacks and sealed before storing in a place of the farmer's choice. Where roof storage was used, farm households piled maize cobs in a designated storage space in the roof of the house (Appendix 4.3). The findings revealed that 43.1 % of the respondents used the roof storage method exclusively, 8.1 % used sack storage exclusively and 48.9 % used both sack and roof storage methods. It was also found that the farm households that took part in this study normally harvested an estimated total of 235 tonnes of maize annually, 277 tonnes were harvested during a good year, and 173 tonnes were harvested during a bad year. The mean for the total amount of maize that the 260 farm households harvested annually was 228 tonnes. Therefore, since there were 2649 farm households in Katumba ward, it was estimated that a total amount of 2323 tonnes of maize were harvested in the ward per annum.

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[5] One sack can accommodate an estimate of 100 kg of maize, which also equals five tins of 3785.41 cm^3volume each. A tin is a unit measure commonly used in Katumba ward.

Furthermore, 52 % of the maize that the farm households harvested was stored using the roof storage method exclusively, 10 % was stored using the sack storage method exclusively and 38% was stored using roof storage at harvest and later shelled and stored using the sack storage method. The time in a year, during which maize was shelled and stored using the sack storage method differed from farm household to farm household. Thus, at some stage 90 % of the harvested maize was stored using the roof storage method, while 48 % was stored using the sack storage method. While the farm households that used roof storage method stored maize harvests in the roofs for two to 14 months, the farm households that stored maize using sack storage method stored maize harvests in the sacks for five to 14 months. Other storage technologies such as storing maize using clay pots, storage baskets and the practice of hanging maize cobs in the kitchen were found to be only used for short term storage or for storing seeds for planting, thus, were not further pursued.

4.3.2 Factors influencing selection maize storage method

The majority of the farm households indicated that they used the roof storage method in order to enhance drying of the stored maize (Table 4.1). While 35.8 % of the farm households indicated that they stored maize using the sack storage method in order to be able to easily monitor infestations, 18.8 % of the farm households said that they stored maize using the sack storage method in order to accommodate large quantities of maize and easily monitor infestations. Only 1.5 % of the farm households said that they used the sack storage method for maize storage because they did not have an appropriate roof that they could use. Thus, a larger proportion of the farm households that used the sack storage method used it in order to be able to easily manage and monitor infestations. Farm households' responses in Table 3.1 imply that the farm households that used the roof storage method, stored maize before it was dry enough, and that they believed in the capacity of the roof storage method to dry the stored maize.

Roofs of 83.8 % of the houses in which maize was stored were made of corrugated iron sheets, whereas 16.2 % were thatched. Thus, for the 78.4 % of the farm households that stored maize using the roof storage method exclusively the houses in which maize was stored were roofed using corrugate iron sheets and 21.6 % were thatched. Furthermore, for only 12.6 % of the farm households that stored maize using both the roof and the sack storage method houses in which maize was stored were thatched, whereas 87.4 % of the houses were roofed using corrugated iron sheets. Therefore, more than three quarters of the farm households that stored maize using the roof storage method stored maize in houses roofed using corrugated iron sheets.

Table 4.1: Reasons that the farm households provided for using the roof storage method

Reason	Percent of farm households (n=260)
To accommodate large quantities of maize	0.4
To protect from infestations	1.5
To enhance the drying process and protect from insect infestation	5.8
To enhance the drying process and accommodate maize	78.8
To accommodate maize and protect from insect infestation	0.8
It is our traditional method used for many years	1.9
Used to this method	0.4
Relatively cheaper	2.3

Number of responses per respondent ≥ 1

A Chi square test (Appendix 4.7) revealed a significant relationship ($\alpha<0.05$) between farm households' size and the type of storage method that the farm households used. The practices of storing maize using the roof storage method exclusively or using the roof and the sack storage methods concurrently were applicable to relatively larger farm households. There was no significant association between the types of storage methods that the farm households used and the farm households' level of formal education.

4.3.3 Maize storage problems in Katumba ward

4.3.3.1 Maize loss due to insect pests, moulds and rodents

While 87.7 % of the farm households that participated in this study indicated having experienced maize loss due to storage pests, 75.0 % of the farm households reported having encountered maize loss due to insect pests, 69.6 % to rodents and 8.8 % to moulds. The farm households used an average of 57 tonnes (25 % of the harvested maize) annually for consumptionpurposes, ranging from 0.08 - 0.4 tonnes per household with 0.2 tonnes mean. The farm households used 92 tonnes of maize (40.4 % of the harvested maize) for non-consumption purposes such as marketing for raising income. Thus, the farm households used an estimated total of 149 tonnes (65.4 %) of maize for consumption and non-consumption purposes.

The amount of maize that each farm household lost to pests ranged from 0 - 0.1 tonnes and the mean was ± 0.3 tonnes. The total amount of maize that the respondents lost to infestations was estimated to be 78.8 tonnes, equivalent to 34 % of the total harvests.Since there were 2649 farm households in Katumba ward, the amount of maize that was lost to infestations in the ward was through multiplying 78.79 by 2649 followed by dividing by 260, which equals 800 tonnes after rounding off.

4.3.3.2 Types of insect pests observed in stored maize

The farm households that took part in this study identified from the pictures 10 types of insect pests that they saw in stored maize (Table 4.2). Also, in relation to the insect pests that the farm households identified as resembling those that they saw most in stored maize, *S. zeamais* had the majority of the scores, followed by *S. cerealella* which had more than half of the total scores. Proportions of farm households that observed *S. zeamais* in stored maize most of the time were almost equally high for each of the two storage methods, whereas a highest percentage of the farm households that used both of the storage methods observed *S. cerealella* most of the time (Table 3.3). Furthermore, 48.2 % of the total number of farm households that used the roof storage method exclusively observed *S. cerealella* most of the time as opposed to 38.1 % of the total number of farm households that stored maize using the sack storage method exclusively and observed *S. cerealella* most of the time (Table 4.3). Thus, maize stored using the roof storage method was possibly almost equally affected by *S. zeamais*, whereas *S. cerealella* affected maize stored using the roof storage method exclusively more than maize stored using the sack storage method exclusively.

Table 4.2: Types of insect pests that farm households identified as the ones that attack stored maize

Type of insect pest	Percent of farm households that saw the insect pests in stored maize	Percent of farm households that saw the insect pest most in stored maize (n=260)
Cryptolestes ferrugineus	0.40	0.00
Laemophiloeus pusillus	0.40	0.00
Oryzaephillus surinamensis L	0.40	0.00
Prostephanus truncatus	1.90	0.80
Sitotroga cerealella	65.40	59.20
Sitophilus granarius	26.50	16.90
Sitophilus zeamais	81.50	76.20
Tribolium destructor	1.20	0.80
Trogodema granarium	15.40	11.50

Number of responses per respondent ≥ 1

Table 4.3: Insect pests that were observed most of the time and the associated storage method

Insect pests that the household observed most of the time	% households that used both roof and sack storage method (n=127)	% households that used roof storage method exclusively (n=112)	% households that used sack storage method exclusively (n=21)
Plodia interpunctella	8.7	2.7	4.8
Prostephanus truncatus	0.0	1.8	0.0
Sitotroga cerealella	72.4	48.2	38.1
Sitophilus granarius	15.7	20.5	4.8
Sitophilus zeamais	74.8	76.8	71.4
Tribolium destructor	1.6	0.0	4.8
Trogodema granarium	3.1	18.8	23.8

Number of responses per respondent ≥ 1

4.3.3.3 Methods used to control insect infestations in stored maize

While 21.20 % of the farm households that took part in this study indicated that they did not control the insect pests in stored maize, the majority of the farm households controlled insect pests using pesticides (Table 4.4). Farm households use either actellic super dust or *shumba* dust. These two types of pesticides are the ones sold in agricultural shops in the research area. Furthermore, 71.4 % of the farm households that stored maize using the sack storage method exclusively used pesticides to control the insect pests as opposed to 66.1 % of the farm households that used the roof storage method exclusively and used pesticides to fight against the insect pests (Table 4.5).

Table 4.4: Methods that farm households used for controlling insect infestations in stored maize

Method	Percentage of farm households that used the method (n=260)
No application of control measures	21.2
Removing the affected kernels from the lot	0.4
Using pesticides	71.5
Dehulling the maize	2.6
Using traditional plant powders	1.2
Putting maize in the sun as soon as the infestation begins	2.3
Using wood ash	0.8
Total	100.0

The fact that 71.50 % of the farm households usedpesticides, yet stored maize was infested by insect pests imply that the nutritional content of the stored maize was compromized. This would reduce the amounts of available maize and compromise the safety of maize contrary to the food security definition which requires that all people at all times be able to access safe and nutritious food. Thus, it would seem that the use of pesticides in Katumba ward fell short of helping the farm households to achieve food security.

Table 4.5: Methods that farm households used for controlling insect infestations in stored maize and the associated storage methods (n=260)

Control method	Storage method		
	Roof storage method exclusively (n=112)	**Sack storage method exclusively** (n=21)	**Both roof and sack storage method** (n=127)
No method	28.6	9.5	15.7
Removing the affected kernels from the lot	0.9	0.0	0.0
Using pesticides	66.1	71.4	77.2
Dehulling the maize	1.8	9.5	2.4
Using traditional plant powders[6]	0.0	0.0	2.4
Putting maize in the sun as soon as the	1.8	4.8	2.4
Using woo dash	0.9	4.8	0.0
Total	100	100	100

[6] The plant powders were made from plants known as *inunganunga* in Nyakyusa. The Swahili and Scientific names for the plants were not found.

4.3.3.4 Types of fungi observed in maize

Through viewing the pictures of ear rots that were attached to the questionnaire, the farm households identified the types of moulds that they saw in stored maize. Since each of the ear rots is caused by a specific type of fungus, the types of ear rots that the farm households identified as resembling the types of moulds that they saw in stored maize gave an indication of the possible types of moulds that infest stored maize in Katumba ward. The farm households identified *Aspergillus*, *Diplodia*, *Gibberella*, *Fusarium* and *Penicillium* ear rots as similar to the types of moulds that they saw in stored maize (Table 4.6). *Gibberella* ear rot was identified as the type of fungi which was seen most of the time followed by *Diplodia* ear rot (Table 4.7).

Table 4.6: Types of moulds that farm households in Katumba ward observed in stored maize

Type of ear rot	Percent of farm households that observed the ear rot in maize (n=260)
Aspergillus ear rot	44.6
Diplodia ear rot	70.0
Fusarium ear rot	20.8
Gibberella ear rot	87.7
Penicillium ear rot	28.5

Number of responses per respondent ≥ 1

Table 4.7: Frequencies at which the identified moulds were observed in maize (%)

Type of ear rot that resembles the mould seen in stored maize	**Seen most of the time** (n=260)	**Seen sometimes** (n=260)	**Seen least** (n=260)
Aspergillus ear rot	12.3	25.4	7.7
Diplodia ear rot	30.4	18.5	21.2
Fusarium ear rot	10.4	9.2	1.2
Gibberella ear rot	41.5	35.8	10.0
Penicillium ear rot	9.6	9.60	8.8

Number of responses per respondent > 1

A higher proportion (95 %) of the farm households that stored maize using the sack storage method exclusively observed *Gibberella* ear rot in maize compare to the 87 % of the farm households who stored maize using the roof storage method exclusively and the 85.8 % of the farm households who stored maize using both of the two storage methods (Table 4.8). However, the proportions of farm households who observed *Gibberella* ear rot in maize were high for all of the storage methods used.

Table 4.8: Types of fungi observed and the associated storage method

Types of ear rot observed	Type of storage method used to store maize		
	Roof storage exclusively (n=112)	**Sack storage exclusively** (n=21)	**Both roof and sack storage** (n=127)
Fusarium ear rot	14.3	30.0	24.4
Gibberella ear rot	87.5	95.2	85.8
Aspergillus ear rot	47.3	47.6	40.2
Penicillium ear rot	21.4	14.3	37.0
Diplodia ear rot	69.6	85.7	67.7

Number of responses per respondent ≥ 1

4.3.3.5 Methods used by the farm households to control moulds in stored maize

Seventy three percent of the farm households indicated that they did not use any means of controlling moulds in stored maize, 26.2 % indicated that they removed the infested maize kernels from the lot and 0.8 % indicated that they dehulled the maize.

4.3.3.6 Types of rodents that the farm households saw in stored maize

For the 69.6 % of the farm households that participated in this study infestation of stored maize by rodents was common. The types of rodents that attacked stored maize in Katumba ward included black rats, brown rats and house mice which had 32.7 %, 88.5 % and 6.5 % of the total scores, respectively. In general, the percentage of farm households that saw brown rats in stored maize was more than three quarters of the total percentage followed by black rats which had significantly lower scores.

4.3.3.7 Methods that the farm households used in order to control rodents in stored maize

While 14.7 % of the farm households that participated in this study did not apply any means in order to control rodents that attack stored maize, 36 % of the farm households indicated that they controlled rodents by keeping cats that killed the rats, 28.5 % used rat traps and 20 % applied rat poison. Keeping a cat for the purpose of killing the rodents in the homestead had the highest frequency counts. The latter was due to the fact that the control method was cheap.

4.3.3.8 Persons responsible for controlling infestations and infections of stored maize in the farm households

4.3.3.8.1 Persons responsible for controlling the insect pests

It was also found that for 84.20 % of the farm households the tasks of controlling insect pests in stored maize were normally done by specific persons in the households, whereas in 15.8 % of the farm households no specific person was responsible for the above indicated task. Tables 4.9 and 3.10 provide details of individuals in the households who were responsible for controlling insect pests in maize and reasons for the persons being responsible for the task.

Table 4.9: Scores for the persons responsible for controlling insect pests in stored maize

Persons responsible for controlling insect pests	**% of farm households** (n=260)
No specific person	15.8
Female household head	13.5
Male household head	26.9
Both of the parents	41.5
Female parent (male headed household)	1.9
Male adult	0.4
Total	100

Table 4.10: Factors that influenced selection of the persons responsible for controlling insect pests in stored maize

Factors	**Percent of farm household for whom the response was applicable** (n=260)
It is one of the female parent's responsibilities	4.20
The parents in the household practice team work thus, both of them are responsible	23.80
The person(s) is/are the leader(s) of household (s) hence the responsibility	46.90
The person is most involved with farming activities than the others in the household	9.20
Total	84.20

15.8 % of the farm households did not assign this task to anyone

4.3.3.8.2 Persons responsible for controlling moulds in stored maize

Scores for the persons in the households who were responsible for controlling moulds in stored maize were as follows: 'female household head had' 11.5 %, 'male household head' had 12.7 %, 'both of the parents' had 21.2 % and 'female parent in a male headed household' had 0.8 % of the total scores. Table 4.11 presents factors that led to the persons being responsible for controlling moulds in the households.

Table 4.11: Factors that led to the particular persons being responsible for controlling moulds

Factors	**% of farm households for whom the response was applicable** (n=260)
The person is the household head hence the responsibility	21.9
It is one of the female parent's responsibilities	1.2
The parents practice team work, thus, they share the responsibility	21.2
The person is most involved in farming activities than the others	1.9
Total	46.2

53.8 % of farm households did not assign this task to anyone

4.3.3.8.3 Persons responsible for controlling rodents in stored maize

The farm households named the individuals shown in Table 4.12 as being responsible for controlling rodents in the households and they also provided the reasons presented in Table 4.13 for the named individuals being responsible for the task mentioned above. About 6 % of the farm households indicated that they had not assigned the responsibility to anyone.

Table 4.12: Persons in the households who are responsible for controlling rodents in stored maize

Person	**Percent of farm households for whom the response was applicable** (n=260)
No one has been assigned this responsibility	6.9
Female household head	14.6
Male household head	28.8
Both parents	48.1
Female parent (male headed household)	1.2
Male adult (elder son)	0.4
Total	100

Table 4.13: Factors that led to the named persons being responsible for controlling rodents

Factor	**Percent of farm households for whom the response was applicable** (n=260)
Controlling rodents is one of the female parent's responsibilities	3.1
Parents practice team work thus, both of them are responsible	29.6
The person (s) is/are leader(s) of the household hence the responsibility	57.3
The person is most involved in farming activities than the rest of the household members	0.8
Total	90.8

Number of responses per respondent ≥ 1
The responses do not apply to the 6.9 % farm households who did not assign this task o anyone

4.3.4 Maize loss in relation to the varieties of maize seeds grown by the farm households

The findings also revealed that 63 % of the farm households in Katumba ward often grew improved varieties of maize, which they bought mostly from seed retail outlets (Table 4.14), while 37 % often grew local types of maize. Out of the 63 % that grew improved varieties, 60 % grew improved varieties only, while 3 % often grew both improved and local types of maize. The improved varieties included PANNAR, Uyole hybrid, Kenya hybrid and Seed-Co seeds. One of the two local types of maize that farm households grew was named '*katumbili*'[7]. Farm households referred to the other local variety of maize as *kienyeji*, which simply means 'local' in Swahili. Farm households that grew local varieties of maize got the seeds from their own maize harvests.

Table 4.14: Place where the household buys maize seeds

Place	**Percent of farm households (**n=260)
Seed retail outlet	61.9
From other farmers	0.8
Agricultural research station	0.4
Total	63.1

The responses are not applicable to the 37 % of the farm households who grew local types of maize

[7] The meaning of the term "katumbili" was not found

The farm households reported having lost both local and improved varieties of maize mostly to insects and rodents infestations, and very few of them to fungal infection (Table 4.15). However, it seems that the improved maize varieties were more susceptible to both insect pests and rodents compared to local maize landraces as attested by the percentage of respondents that had experienced losses.

Table 4.15: Maize loss in relation to maize varieties

	Local varieties of maize (n=260)	**Improved varieties of maize** (n=260)	**Both improved and local varieties of maize** (n=260)	**Total**
Percent of farm households that had experienced maize loss due to insect pests	28.08	44.23	2.69	75.00
Percent of farm households that had experience maize loss due to rodents	26.50	40.33	3.08	69.62
Percent of farm households that had experienced maize loss due to moulds	5.00	3.85	0.00	8.85

Number of responses per respondent≥1

3.3.5 Other storage problems in Catawba ward

Maize being insufficiently dry at the time of storage was the other main problem that the farm households encountered. About 96 % of the farm households indicated that maize was not dry enough at the time of harvest, all of the farm households said that it took more than two weeks for them to dry maize. Thus, 88.8 % of the farm households would put all of the maize in the roof storage facilities as a means of drying and storing it at the same time, 7.4 % dried maize exclusively in the sun and 3.8 % used both of the methods indicated. Theft and germination of stored maize were listed among the storage problems. However, only 1.2 % and 0.8 % of the farm households, respectively reported having come across such problems. While theft of the stored maize was associated with the maize being stored in houses that were separated from the main houses, germination of the stored maize was associated with the farm households failing to get the maize to be sufficiently dried before storage.

4.3.6 Uses of mouldy maize and the farm households understanding of the possible negative effects of moulds on stored maize

In general, almost all of the farm households used maize that had been affected by moulds for purposes related to consumption (Table 4.16), whereas more than half of the participants were not aware of any problems associated with consuming mouldy maize. Thus, 52.7 % of the farm households said that moulds were not pathogenic, 5.8 % did not know whether moulds could be pathogenic or not, and only 41.5 % were confident that moulds could be pathogenic. This is detrimental to the food security of the farm households because it creates possibilities for the farm households to consume maize which is infected by pathogenic moulds. This would compromise utilization of the maize meals and promote the farm households' vulnerability to diseases.

Table 4.16: Different uses of mouldy maize by farm households in Katumba ward

Mouldy maize use	**% of farm household for whom the response was applicable (**n=260)
Throw it away	0.8
Animal feed	38.4
Brewing beer	0.4
Throw away if very badly affected otherwise dehull and use for food	58.8
Use as animal feed if badly affected, otherwise dehull for food	1.2
Sell to beer brewers	0.4

4.3.7 Access to information on maize storage

4.3.7.1 Involvement with maize storage associations

It was found that none of the farm households that participated in this study was a member of a maize farming association, and that 20.8 % of the farm households were members of the tea farmers association. The former would hinder the farm households from making collective attempts to improve the tatus quo, thus, it impacts negatively on the farm households' food security.

4.3.7.2 Distance from the farm household's residences to agricultural institutions

The farm households' responses concerning the distance of their residences to the locations of the agricultural institutions were as follows: 0.2 - 13 kilometers (km) to the agricultural extension office, 7 - 84 km to the agricultural research station, 65 - 84 km to the seed producing company and 1 - 76 km to the grain and livestock marketing outlet. Other details concerning the distance from the farm households' homes to where the agricultural institutions were located are as indicated in Tables 4.17 and 4.18. The availability of the agricultural institutions is expected to contribute to enhancing the food security of the farm households through delivering the necessary services. However, it seems that farm households were under were ignorant of the actual locations of the agricultural offices situated in Kikuba. About 55 % of the farm households also provided incorrect names for the location of the agricultural extension office. Only 3.5 % of the farm households mentioned the seed retail outlet in Kikuba, whereas 5 % mentioned the grain/livestock outlet also in Kikuba (Table 4.18)

Table 4.17: Distance (Km) from the farm households' homes to the agricultural institutions/markets (n=260)

	Mean	Std. Deviation	Minimum	Maximum
Distance from the agricultural extension office	6.83	3.69	0.20	13.00
Distance from the agricultural research station	74.54	3.19	66.00	84.00
Distance from the seed producing company	74.53	3.21	65.00	84.00
Distance from the seed retail outlet	9.32	6.22	0.40	72.00
Distance from the grain or livestock marketing outlet	9.45	4.99	1.00	76.00

Table 4.18: Names of agricultural institutions/markets and places where they are located (n=260)

Name of agricultural institution	Location	Percent of farm households that named the institution
Agricultural extension office	Tukuyu town	55.8
	Kikuba	42.3
	Itagata	1.2
Agricultural research station	Uyole	100.0
Seed production company	Uyole	100.0
Seed retail outlet	Uyole	0.8
	Tukuyu town	95.8
	Kikuba	3.5
Grain/livestock outlet	Tukuyu town	91.9
	Kikuba	5.0
	Kiwira	3.1

4.3.7.3 Number of times in a year that the farm households in Katumba ward visited the agricultural institutions

It was found that 20 % of the farm households that partook in this study visited the agricultural extension office in a range of 1 - 12 times per year for the purpose of seeking advice regarding farming in general. It was also found that only 1.20 % visited the agricultural research station in a range of 1 - 3 times annually in order to seek advice concerning maize farming or to buy seeds and that 60.40 % of the farm households visited the seed retail outlet once annually in order to buy seeds. For the same purpose of seeking advice regarding maize farming or buying seeds, 1.9 % visited the seed retail outlet twice per year and 0.80 % visited the seed retail outlet three times per year. Furthermore, 20 % of the farm households that took part in this study visited the grain or livestock market outlet in a range of 1 - 48 times per year for the purpose of selling or buying crops. In general, more than half of the farm households visited the seed retail outlets, but very few of them visited the agricultural extension office and the agricultural research station and the reasons for the visits were not related to maize storage.

4.3.7.4 Number of times in a year that staff from the agricultural institutions visited the farm households in Katumba ward

About 20 % of the farm households that participated in this study reported that they had been visited by the agricultural extension staff one to four times per year, whereas the reasons for the visits were not related to maize storage. About 7 % of the farm households received advice concerning maize farming during the visits, 15 % received advice related to livestock keeping. Moreover, only 0.4 % of the farm households reported having been visited by staff from the agricultural research station on matters concerning to maize seeds. In addition, the entire group of farm households indicated that staff from the seed production company, the seed retail outlet and the grain or livestock marketing outlet had never visited them. Almost all of the farm households had never been visited by staff from the agricultural research station. Efforts to contact the agricultural extension staff for interviews were not successful.

4.3.8 The quality of maize stored using roof and sack storage methods

4.3.8.1 The incidence of insect infestations in grains at harvest

After 90 days of incubation, 25 % of the maize samples that were collected from freshly harvested maize were infested by either *S. zeamais*, *S. cerealella* or both. *S. Zeamais* was identified based on physiological characteristics. It has been noted that S. zeamais can be differentiated from *S. oryzae* in that *S. zeamais* adults reach a length of 3 - 3.5 mm (Kgware *et al*., 2005), whereas adults *S. Oryzae* are shorter, with average length of 2.5 mm (Pest control expert, 2007), and unlike *S. oryzae*, *S. zeamais* readily fly (Kgware, 2005). The *Sitophilus* pests found in the maize had the characteristics of *described* in this paragraph, thus, were identified as *S. zeamais*.

About 23 % of the maize samples that had been collected from the farm households immediately after harvest were found to be infested by *S. zemais only,* 0.77 % had *S. cerealella* only, and 0.77 % had both *S. zemais* and *S. cerealella*. The total number of insects in the maize samples ranged from 0 - 52 per 120 maize kernels (Table 4.19), the mean was 2.23, standard error of mean was 0.59, and standard deviation was 6.731.

Table 4.19: Number of insects in the freshly harvested maize (*S. zeamais* + *S. cerealella*)

Total number of insects	Percent of Landraces (n = 43)	Percent of Improved maize varieties (n=87)
0.0	72.09	75.86
1-4	16.3	9.2
5-9	4.7	9.2
10-20	4.7	3.4
31-34	0.0	2.3
35-52	2.3	0.0
Total	100.0	100.0

None of the indigenous varieties of maize were concurrently infested by both *S. zeamais* and *S. cerealella* prior to storage, whereas 1.5 % of the improved varieties of maize samples were concurrently infested by *S. zeamais* and *S. cerealella* prior to storage. Furthermore, 25.9 % of the indigenous varieties of maize samples collected at harvest were infested by *S. zeamais* only, whereas 20.7 % of the improved varieties were infested by *S. zeamais* only. These findings show that in Katumba ward a large number of farm households faced insect infestation of maize prior to storage, and that *S. zeamais* is the main insect pest in the ward, followed by *S. cerealella*. Whether the agricultural extension staff members in Katumba ward are aware of the extent of these infestations is not known because the extension staff members were not interviewed. Likewise, efforts to contact the Vulnerability Assessment Programme in Tanzania were not successful, whether they are aware of the infestations or whether they are implementing any mitigation strategies is not known.

4.3.8.2 The incidence of insect infestations in the maize samples that were collected after five months of storage

About 93.1 % of the maize samples collected from the farm households after five months of storage were infested by either *S. zeamais* or *S. cerealella* or both. The infestation ranged from 0-210 insects per 120 maize kernels. About 43 % of the maize samples were infested by both *S. zeamais* and *S. cerealella* and 50 % were infested by *S. zeamais* only. The mean for the number of insect pests per 120 maize kernels was 80 insect pests, standard deviation was 51.44. A greatest proportion of the maize samples were infested by more than 50 insect pests per 120 maize kernels (Table 4.20).

The findings also showed that 68.5 % of the maize samples were became infested during storage. Thus, the percentage of infested maize samples increased from 24.6 % for the maize samples that were collected from freshly harvested maize to 93.1 % after the five months of storage. Furthermore, after five months of storage, the number of insects in the maize samples collected from the same farm households where the 33 maize samples that were found to be infested at harvest were collected had increased tremendously (Figure 4.2). The mean quantities of insect pests from the maize samples that were collected at harvest was two insect pests per 120 maize kernels, amounting to 39 insects per kg of maize, and the average number of insect pests per 120 kernels of maize which was collected after five months of storage period was 80, amounting to 1569 insects per kg of maize. This implies that most of the insect infestation of maize took place during storage, and for the maize that was infested by the insect pests prior to storage the infestation intensified during storage. Through performing a Chi square test (Appendix 4.2) it was found that 88 % of the maize samples that were infested by insect pests were also infected by moulds.

Table 4.20: Levels of insect infestations per 120 kernels of maize which was collected after five months of storage period

Total number of insects per 120 maize kernels	**Percent of infested maize samples** (n = 130)
0	7.9
<10	7.7
11-50	15.4
51-100	33.1
101-200	34.6
>200	2.3
Total	100

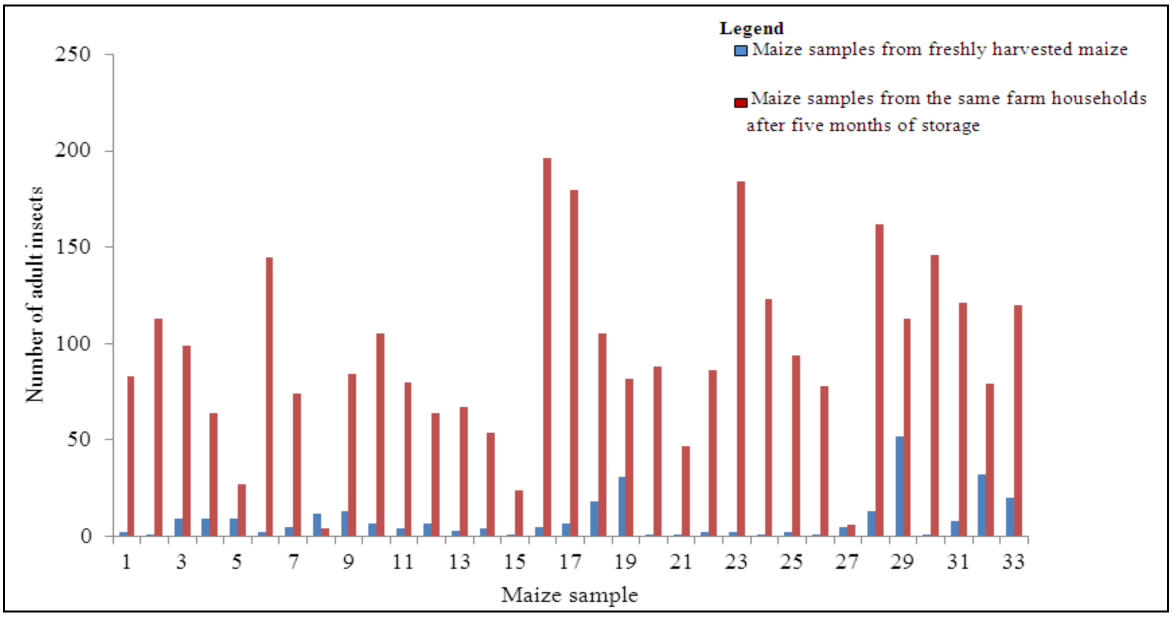


Figure 4.2: Comparison of levels of insect infestation on maize samples infested prior to storage with that of maize collected from the same farm households after five months of storage

It seems that the extension services in Katumba ward have not paid attention to the problem of maize infestation during storage. Consequently, this creates room for fungal infection of maize, and maize losses to occur, which can lead to the vulnerability of the farm households to hunger, undernourishment and disease.

4.3.8.3 The percentage ofinfested maize in relation to maize variety

It was found that 93.4 % of the indigenous varieties were also infested by the insect pests, while 92 % of the improved varieties of maize samples were also found to be infested by the insect pests. The infestation ranged from 0 - 210 insects per 120 kernels for the local varieties and 0 - 184 per 120 kernels for the improved varieties.

Moreover, 39.5% of the infested indigenous varieties were infested by *S. zeamais* only and 55.8 % were infested by both *Sitophilus zeamais* and *S. cerealella*. Out of the infested maize samples of the improved varieties, 55.2 % were infested by *S. zeamais* only and 36. 8 % were infested by both *S. zeamais* and *S. cerealella*. The mean number of insects per 120 maize kernels in the maize samples of the indigenous maize types was 91.26 and standard deviation was 52.69. The mean number of insects per 120 maize kernels in the maize samples of the improved varieties was 74.37 and standard deviation was 50.22. For both the landraces and the improved varieties of maize, more than 50 % of maize samples had more than 50 insect pests per 120 kernels. (Table 4.21). T - tests results showed that there was no significant difference between the means for the maize samples for the improved varieties and landraces (Appendix 4.6).

Table 4.21: The Level of infestation of the maize samples in relation to the types of seeds

Levels of insect s	**Frequency Local varieties**(n=43)	**Frequency Improved varieties**(n=87)	**Total**
0	4.7	8.0	12.7
1-10	2.3	10.3	7.7
11-50	16.3	14.9	15.4
51- 100	34.9	31.0	32.3
101-200	37.2	35.6	36.2
>200	4.7	0.0	1.5
Total	100	100	100

4.3.8.4 Effect of storage facilitieson percentage of maize infestation

About 90 % of the maize samples that had been collected from the roof storage facilities were infested by insect pests, 95 % of the maize samples collected from the sack storage facilities were also found to be infested by the insect pests. The number of insects in the maize samples from the roof storage facilities ranged from 0 - 203, while the number of insects in the maize samples from the sack storage facilities ranged from 0 - 210. The mean number of insects on maize samples from the roof storage facilities was 80.18, and standard deviation was 49.34. The mean number of insects on maize samples from the sack storage facilities was 79.67, and standard deviation was 55.24. The high infestation rate of maize stored using the two most popular storage methods in Katumba ward imply that the farm households are vulnerable to food insecurity. Furthermore, 42 % of the maize samples collected from the roof storage facilities were infested by both *S. zeamais* and *S. cerealella* and 50 % were infested by *S. zeamais* only. Also 45.2 % of the maize samples that were collected from the sack storage facilities were infested by both *S. zeamais* and *S. cerealella* and 50 % of the maize samples collected from the sack storage facilities were infested by *S. zeamais* only. T-test results revealed that there was no significant difference between the mean number of insect pests in the maize samples from the roof and sack storage facilities (Appendix 4.5). Other details regarding the number of infested maize samples in relation to the storage facilities from which they were taken are as shown in Table 4.22.

Table 4.22: The level of infestations of the maize samples in relation to the storage facilities (n=130)

Number of insects	Roof storage facilities	Sack storage facilities	Total number of infested maize samples
<10	4	6	10
11- 50	15	6	20
51- 100	33	9	43
101- 200	29	17	45
>200	1	2	3
Total	81	40	121

4.3.9 Level of formal education of heads of farm household

More than half of the heads of farm households that took part in this study had up to seven years of formal education (Figure 4.3). The mean for the heads of farm households' years of formal education was 6.57 and standard deviation was 3.1. When grouped into four categories of years of formal education, it was found that 10.4 % of the farm household heads had no formal education at all, 68.5 % had one to seven years of primary education and 18.8 % had secondary education and only 2.3 % had college education.

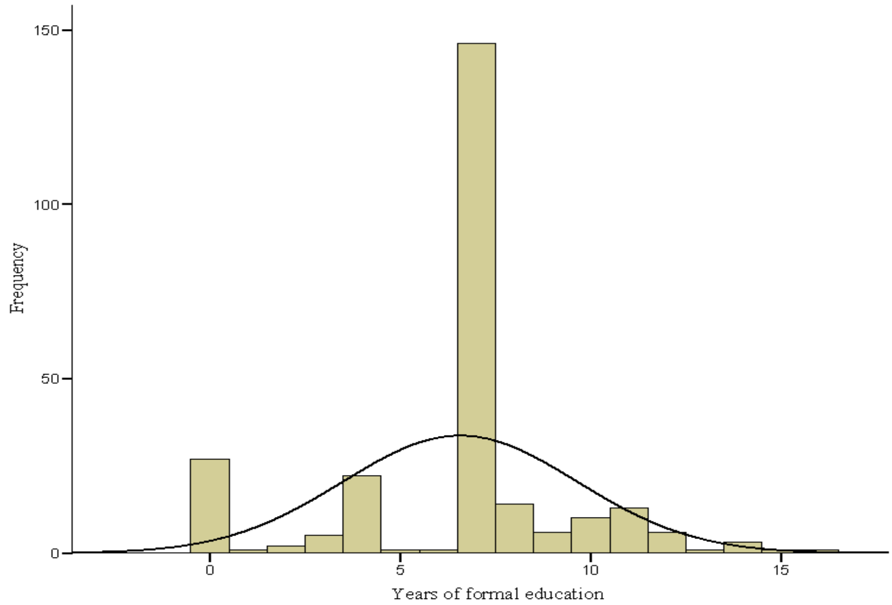


Figure 4.3: Household heads' years of formal education in Katumba ward

4.3.10 Age of heads of farm households and size of farm household

When grouped into five categories 41.9 % of the heads of farm households were aged 35 - 45, which was the highest percentage (Figure 4.5), followed by the group of farm household heads aged 46 - 56 which had 22.3 % of the total number of farm households. These numeric figures show that while heads of farm households of various age groups in Katumba ward were involved in maize farming, the majority of the heads of farm households were aged 35-56 years. Farm household size ranged from 2 to 16, with 5.61 mean and 2.08 standard deviation.

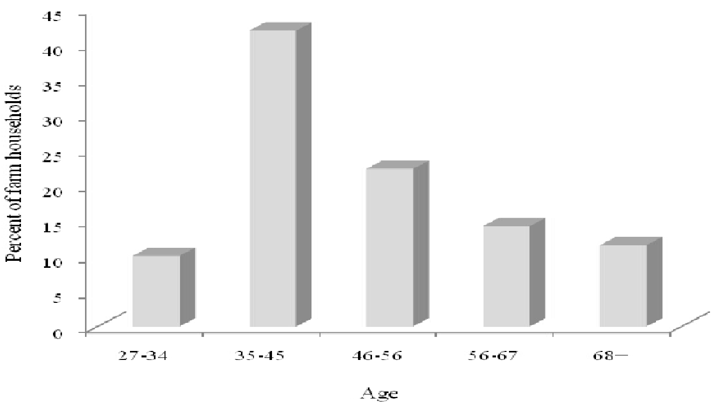


Figure 4.5: Age of farm household heads in Katumba ward

4.4 Discussion

4.4.1 Long term maize storage methods in Katumba ward

In the light of the findings in section 3.2, roof and sack storage methods are the only long term storage methods that the farm households in Katumba ward used to store maize. The quantities and quality of maize available to the farm households in Katumba ward depended on the degree of efficiency of the two storage methods indicated above, which implies that the two storage methods were very important in the ward. While the use of roof and sack storage methods for storing maize is common in Africa, they have been associated with exposure of stored maize to infestations (UNIFEM, 1995).

In Katumba ward the farm households preferred roof and sack storage methods mainly because the roof storage method helped them to dry maize while storing it; whereas the sack storage method made it easier for them to monitor infestations. However, the fact that 90 - 95 % of maize stored using these storage methods was infested by insect pests supports the claim that the two storage methods expose stored maize to infestations. The implication of the extremely high infestations is that almost all of the farm households would experience reduction of the amounts of maize that they can access and the length of time during which the maize can be accessed. Thus, the roof and sack storage methods reduced stability, promoted vulnerability and increased food insecurity of the farm households. Intervention by the Vulnerability Assessment Committee in Tanzania is required for mitigations.

Factors such as the cost of building and running the storage method, availability of the materials and expertise for building the storage facility, climatic conditions of the area and the types of pests problems in the area, the quantities of crops to be stored and the expected quality of the stored crops are known to affect the farmers' choice of the storage methods (FAO 1985). However, while the farm households in Katumba ward were concerned with amounts of maize that they could store and protect against insect pests, it seems that they did not take into consideration the effect of climatic conditions in the ward on the performance of the roof and sack storage methods or on the expected quality of stored maize. This calls for the extension officers in Katumba ward to educate the farm households concerning maize storage and factors that can lead to poor quality of stored maize, and the preventive measures that the farm households should be applying.

Moreover, the practices of storing maize using the roof storage method exclusively or using both the roof and the sack storage methods were practiced by relatively larger farm households. This shows that selection of the roof storage method was influenced by the size of farm households rather than heads of households' level of formal education. Also, no significant relationship was observed between the tendency for farm households to store maize using the sack storage method exclusively and the size of farm households. However, since the practices of storing maize using the roof storage method and the roof storage together the with the sack storage method were applied by relatively larger farm households, smaller households must have used the sack storage as an alternative method.

4.4.2 The implication of the quantities of maize lost to infestations by farm households that used roof and sack storage methods

The estimated 800 tonnes of maize lost to pests in Katumba ward per annum was quite huge especially considering the fact that the farm households were only subsistence farmers who produced an average of 877 kg of maize each annually. The estimate of 35.4 % of maize that the farm households lost to the infestations was within the estimated amount of maize that is lost to pests in Tanzania. Up to 34 % of on-farm maize loss due to insect pests has been reported to occur within three months of storage in the country (CIMMYT and Dubin, 2010). Considering that maize is the most preferred food crop in Katumba ward, the percentage of maize that was lost to the insect pests reduced not only the amount of food, but also the length of time during which the food can be available to the farm households, thus, increasing their vulnerability. Consequently, this scenario impacted negatively on the farm household's food security. It is necessary that the Vulnerability Assessment Committee in Tanzania and the extension services make effort to ensure that the problem of insect infestation of maize is given adequate attention so that maize losses caused by the infestations can be stopped or minimized.

4.4.3 Predominant pests of maize in Katumba ward and their implications

4.4.3.1 Predominant insect pests

Findings in Tables 3.2 revealed that the majority of the farm households in Katumba ward experience storage problems due to the infestation of maize by *S. zeamais* and *S. cerealella*. The high numbers of insects observed through laboratory tests in 93 % of samples of stored maize confirmed the above perceptions. Therefore, *S. zeamais* and *S. cerealella* were the most important insect pests that infested stored maize in Katumba ward. Weevils, especially *S. zeamais* (Mulungu *et al.,* 2007), and beetles, mainly *Tribolium* species (Katinila, 1998) have been reported as the main insect pests that cause post-harvest maize loss in Tanzania. However, the farm households in Katumba ward perceived *S. cerealella* as next to *S. zeamais* in relation to its importance where infestation of maize by insect pests is concerned. The findings corroborate with the reports from other places such Western Africa (Tadasse, 1996) and Kenya (Oduor, 2000) where *S. cerealella* has been named among the major insect pests of stored maize.

There was no significant difference between the proportions of infested maize samples for the local varieties and the improved maize varieties. The independent samples T-test (α>0.05) further confirmed that there was no significant difference between the mean numbers of insect pests per 120 maize kernels for the maize samples of the indigenous and improved varieties alike. This implies that farm households in Katumba ward experienced infestations of insect pests, especially *S. zeamais* and *S. cerealella* species in stored maize regardless of the type of seeds that they grew. The fact that the insect infestation occurred on both the improved and local varieties of maize is an indication of the poor resistance to insect infestation of the maize varieties that the farm households grew. This corroborates with the concern that in Tanzania maize breeding is done mainly for the purpose of increasing yield rather than for improving resistance of the food crops to infestations (Kaliba *et al.,* 1998). Thus, among other factors, maize seeds that are resistant to insect infestations both in the field and in storage in Katumba ward were also required by the farm households. Therefore, it is important that the maize breeding programmed in Tanzania be encouraged to produce maize seeds that are resistant to infestations.

The climatic conditions such as temperatures and relative humidity that characterize Katumba ward play a role in promoting growth of the insect pests. In general temperatures between 15 -40

^{0}C are known to promote insect activity in cereals (Semple *et al.,* 1992). Thus, the 10^{0}C-25^{0}C that characterizes the temperatures in Katumba ward (Anon, 2008) are within the range in which insect activity in grains takes place. However, the temperatures in Katumba ward are cooler than other parts of Tanzania such as Dodoma, where temperatures are within the range of 18 - 31 ^{0}C (Government of the United Republic of Tanzania, 2003). Thus, the temperatures in Katumba ward may not be as much supportive of infestations as the temperatures in the warmer areas.

The presence of insect pests in the maize confirmed that the quality of the maize in Katumba ward was poor. The fact that 88 % of the maize samples that were tested for insect infestation were also found to be infected with moulds suggested that there was an interaction between the insect infestation and fungal infection. A chi square test ($\alpha<0.05$) confirmed that there was an association between the infested and the infected maize samples (Appendix 4.2). Thus, the insects influenced the development of moulds. It has been noted that while feeding on the maize the insect pests make holes in the maize kernels, which in turn cause maize to be susceptible to fungal infections (Sallam, 1999) and other micro-organisms such as bacteria (Hill, 2008).

Insect activity in stored grain has also been associated with the increase in heat and moisture content in the storage facilities, which further leads to moisture content problems (Williams, 2004). Thus, the insect pests in the maize in Katumba ward possibly led to moisture content production and fungal growth in the maize. Apart from the insect pests causing the reduction of maize by weight through feeding on it (FAO, 1985), it has been noted that contamination of maize by waste products produced by the insect pests in stored maize are also inevitable where maize is infested by insect pests (Mejia, 2003). Thus, the presence of large numbers of insect pests in stored maize in Katumba ward implies that maize would possibly be contaminated, and that the health of the consumers and household food security of the farm households were being compromised.

4.4.3.2 The implication of the presence of high levels of insect pests in stored maize on the capacity of roof and sack storage methods to protect stored maize from insect infestation

More than half of the farm households in Katumba ward experienced infestation of maize by the insect pests during storage, which implies that sack and roof storage methods did not offer adequate protection to stored maize against insect pests. The fact that 95 % of the maize samples from the sack storage facilities and 90 % of the maize samples from the roof storage facilities were infested by insect pests shows that the percentage of infested maize samples from the two storage systems was not significantly different. The independent samples T-test ($\alpha > 0.05$) further confirmed this. Thus, maize stored using roof and sack storage technologies in Katumba ward was equally susceptible to infestation by insect pests. Furthermore, the performance of both sack and roof storage technologies with respect to protecting stored maize from insects infestation in Katumba ward was equally poor.

The poor performance of the roof storage method in Katumba ward is contrary to the general view concerning roof and sack storage methods, whereby the former is regarded as capable of drying and protecting stored grain from insect infestation; while the latter is considered as capable of cooling the stored grain from the heat that comes as a result of the perspiration of the grain (UNIFEM, 1995). This can be explained in terms of the climatic conditions in Katumba ward, which are characterized by wetness and low temperatures (Anon, 2008) , which most likely made it impossible for maize in the roof storage facilities to become dry fast and therefore, created favourable conditions for insect infestation to occur. Insect activity takes place especially at 15 -40 ^{0}C (Yigezu *et al*., 2010). Thus, the increase in the intensity of the insect infestation in maize that was collected from the roof and sack storage facilities after five months of storage implies that the temperatures in the storage facilities was within the range of temperatures which are conducive to the growth of insect pests. The 2 - 14 months duration for which the farm households stored maize using the roof storage method would also have a negative impact on the extent of damage and loss by the insect pests.

One of the characteristics of a perfect storage method is that it shoud be suitable for use in the climatic conditions of the place where it is being used (Coulter and Schneider, 2004). The roof and sack storage methods in Katumba ward did not fulfill this requirement, thus, are not ideal for use in this ward.

4.4.3.2 Types of rodents that infest stored maize in Katumba ward

Three types of rodents attacked stored maize in Katumba ward, namely: brown rats, black rats and house mice. Brown rats were the most predominant type followed by house mice. Like the insect pests named above, the rodents that infest maize in Katumba ward reduced not only the amounts of maize and nutrients that could have been available to the farm households, but also posed a health threat the farm households through consumption of maize which may be contaminated with diseases that the rodents transmit. The diseases that are transmitted by brown rats include the weil disease, cryptosporidiosis, viral hemorrhagic fever (VHF), Q fever and hantavirus pulmonary syndrome, while house mice transmit lyme disease, chloromeningitis, and aseptic meningitis (Public Health of Canada, 2008, Mills and Childs, 2001). Thus, maize which is infested by brown rats and house mice puts the consumers at risk of suffering from the indicated diseases.

The fact that rodents are hosts to many emerging viral diseases that are fatal to humans and animals in Africa has been acknowledged (Merck, 2011). Studies conducted on humans and rodents in several urban and per-urban areas in Tanzania in 2003 - 2006 associated the occurrence of the following deadly bacterial infections with rodents: plague caused by *Yersinia pestis*, and leptospirosis caused by *Leptospira* (University of Greenwich, 2006). The occurrence of taxoplasmosis a parasitic infection caused by *Toxoplasma gondii* was also associated with rodents (University of Greenwich, 2006). No research has been conducted in Rungwe district to investigate the occurrence of diseases transmitted by rodents, thus, people may be suffering from these unnoticed. Therefore, more research should be conducted in Katumba ward and Rungwe district in general, to investigate the occurrence of the diseases transmitted by rodents. Furthermore, it is also possible that the rodents made holes in the storage containers, which would allow movement of moisture from outside into the containers. The infestation of stored maize by rodents also implies that the occurrence of rodents' excretions in the maize would be inevitable. Consequently, this would contaminate the maize, create moisture problems in the stored maize as well as create conditions that are favorable for the growth of moulds and other micro- organisms such as bacteria (FAO, 1985; De Groote, 2004).

4.4.3.4 Predominant fungi species in Katumba ward and the farm households' understanding of moulds

The findings imply that for the majority of the farm households in Katumba ward stored maize was exposed to infection by moulds which cause *Gibberella* and *Diplodia* ear rots, namely, *Gibberella zeae,* synonym *Fusarium graminearum* and *Diplodia maydis* (Van Rensburg and Flett, 2010) synonym *Stenocarpella maydis* (Moremoholo and Shimelis, 2009), respectively. The findings also imply that for a significant number of farm households in Katumba ward stored maize was infested by *Aspergillus* and *Penicillium* species of fungi which caused *Aspergillus* and *Penicillium* ear rots, respectively (Moremoholo and Shimelis, 2009). Furthermore, the findings suggested that for a small percentage of farm households maize was infested by *Fusarium* species responsible for causing *Fusarium* ear rot of maize such as *F. verticillioides* (Parsons and Munkvold, 2010) and *F. proliferatum* (Robertson-Hoyt *et al*., 2007). These fungal infections could reduce the nutritive value of the infested maize and their metabolic activities in the infested maize could produce mycotoxins, chemical compounds that are harmful to the consumers.

At least half of the farm households that took part in this study were not aware of health problems that are associated with mouldy maize. This explains the majority of the farm households' failure to acknowledge maize loss due to moulds regardless of the fact that the infection of maize by moulds was common to them. It also explains the farm households' use of mouldy maize for human consumption or feed purposes. The use of mouldy maize for consumption purposes could subject the consumers, both human and animals to ill health due to the associated mycotoxins (Van Rensburg and Flett, 2010; Sweeney *et al.*, 2000; Atkins and Norman, 1998). Thus, the importance of the extension officers in this ward to educate the farm households on these issues cannot be overemphasized.

The farm households' ignorance regarding moulds is further revealed through the fact that at least 50 % of the farm households simply threw away mouldy maize if they felt that it was very badly damaged. The practice of simply throwing away mouldy maize would accelerate the problem as the moulds would continue to grow where conditions are favorable. Katumba ward is known to be characterized by wetness throughout the year and cool temperatures ranging from 10 - 25 ^{0}C (Anon, 2008), which naturally leads to high humidity. High humidity and temperatures ranging from 10 - 43 ^{0}C allow growth of fungi (FAO, 2003). Thus, the temperatures in Katumba ward are within the range of temperatures which in combination with high humidity favours the growth of moulds. Thus, the fungi in the mouldy maize that the farm households threw away in Katumba ward could easily multiply and intensify the problem of fungal infection of maize. The farm households' ignorance in relation to moulds also explains the farm households' reluctance to control moulds in stored maize. Thus, the role of the extension officers as educators is critical for ensuring that the farm households are informed concerning health problems associated with pathogenic moulds and for preventing the infection of stored maize by moulds.

4.4. 4 The relationship between maize loss and maize variety in Katumba ward

Both the farm households that grew the improved varieties of maize and the farm households who grew the local varieties of maize almost equally experienced maize loss due to rodents, insect pests and moulds. A Chi-Square test ($\alpha>0.05$) confirmed that there was no significant association between specific maize variety and the farm households' losing maize to insect pests, rodents or moulds.

4.4.5 The association between maize loss and drying prior to storage in Katumba ward

The practice by the majority of the farm households of storing maize insufficiently dried maize in the roof storage facilities, together with the fact that it took more than two weeks for the maize to dry, impacted negatively on the safety of the stored maize. Moist grain perspires faster than dry grain leading to increase in temperature and an increase in moisture content of the grain through condensation (Williams, 2004), which creates favorable conditions for pests especially insect pests, moulds and other micro-organisms and subsequent contaminations. To prevent infestations and infections from occurring it is recommended that maize be adequately dried prior to storage (De Groote, 2004) rather than during storage. Weinberg *et al.*, (2008) and Reed *et al.* (2007) recommend rapid drying of maize followed by cooling and treating with fungicides to prevent it from being infested by moulds. However, unless storage facilities are moisture proof, dry maize stored in climatic conditions which are characterized by high humidity can still take in some of the moisture from the storage area. The prolonged rainfall that characterizes the climatic conditions in Katumba ward (Anon, 2008) leads to high humidity, which can subject maize stored in sacks or in roofs of houses to moisture content problems. The farm households' complaint that maize was not dry enough at harvest, and the fact that for the majority of the farm households maize was infested by moulds during storage, are indications that the sources of heat that the farm households depended on for drying maize were inadequate. Consequently, it took a lot more than 48 hours to become dry enough for storage, which led to growth of moulds n the stored maize. Accumulation of the moulds in the roof storage facilities over time was also possible. Thus, an efficient alternative method for drying maize rapidly prior to storage is a basic need for the farm households in the ward, whereas the sack and roof storage methods need to be made moisture proof for better performance against the climatic conditions in the ward. The Vulnerability Assessment Committee and the agricultural extension staff in Katumba ward could assist with finding and implementing efficient methods of maize drying.

4.4.6 The implication of the inadequacy of the methods used by the farm households to control infestations and infections in stored maize

It can be deduced that for the 21.2 % of farm households that did not apply any means of controlling insect pests, insect pests would continue to multiply, consume and contaminate stored maize causing losses in weight and quality of the maize as opposed to the 71.5 % of the farm households who used pesticides. It would have been expected that the experiences of maize loss due to insect pests would be rare in Katumba ward considering that the majority of the farm households used pesticides or other means such as applying plant powders or ash or sunning control the insect pests in maize. Contrary to the above, the infestation of insect pests on maize was reported alike by the farm households who used means and those who did not use any means. This suggests the occurrence of underlying factors such as conditions in the storage facilities being favorable for development and growth of the insect pests, inadequacy of the substances used for controlling the insect pests, moisture content of the maize kernels being high and maize not being resistant to insect infestation.

It has been noted that plant powders that are used for protecting maize from insect infestation become inactive if applied to maize which has high moisture content (Kimondo, 2008). This probably explains the occurrence of insect infestations on stored maize in Katumba ward regardless of the insecticidal dusts that the farm households applied on maize. Furthermore, the occurrence of high levels of insect infestation on stored maize regardless of the use of pesticides raised questions regarding the types of pesticides that the farm households used, the method of application and rates, and the shell life. It also raised questions concerning whether the insects were developing resistance to the pesticides used. Detailed studies need to be conducted in order to find answers to these questions. Thus, the government and the Vulnerability Assessment Committee in Tanzania should fund research on the issues raised in this section so that farm households can be better served. In addition, the problem of insect infestation of stored maize in Katumba ward could have been avoided through ensuring good sanitation of the storage facilities prior to storage, ensuring that maize is dry prior to store, age and growing maize varieties that are resistant to insect pests. The latter has potential to increase yield and minimize maize loss (Abebe *et al*., 2009; Mugo *et al*., 2002).

Furthermore, the use of pesticides has been criticized for exposing the consumers to health hazards especially where inappropriate handling is the case (Owusu *et al.,* 2007). 2004). The use of maize seed which is resistant to insect infestation provides a safe, reliable alternative way for fighting against insect infestation (Bergvinson, 2000). It is a preventive method which the farm households in Katumba ward could have used without being exposed to health risks. Investing in centralized high technology storage is another option that the government in Tanzania should also consider for ensuring high quality of maize. This can also create market access to the farm households.

Similarly, the methods that were used for controlling rodents that infest stored maize in Katumba ward, namely: applying rat poison, using rat traps and keeping cats in order to kill the rodents in the homesteads were found to be inadequate. The inefficiency of using a rat trap to control rodents in the whole homestead is quite obvious because a rat trap would be restricted to one place and can only kill one rodent at a time. This, together with the fact that rodents' multiply fast (Bayer, 2007) makes a rat trap incapable of eliminating the entire rat population in a homestead. The application of rat poison to control rodents in stored maize may be effective. However, rat poison may also be harmful to the consumers if it comes into contact with the stored maize (De Groote, 2004). As with insect pests, the most effective way for controlling rodents is to prevent the rodents from entering the storage facilities (Hill, 2008). The occurrence of loss of stored maize to rodents in Katumba ward indicates that the storage structures in which maize was stored were not rodent proof or soundly built. To control moulds in stored maize 26.2 % of the farm households separated the affected maize kernels from the lot, which is incapable of eliminating moulds or preventing the unaffected maize from being infected. Elimination of the factors that promote growth of moulds in stored maize is the best way to protect the stored maize from getting mouldy. It includes ensuring that storage facilities are clean, dry, and not infested with insect pests or rodents (De Groote, 2004). Thus, mere removal of the affected maize from the lot is inadequate especially where the above conditions have not been met, which was the case in Katumba ward.

4.4.7 Access to maize storage knowledge

The agricultural extension office that deals with maize farming in Katumba ward is situated in Kikuba area in the middle of Katumba ward. However, more than half of the farm households that took part in this study were under the impression that the agricultural extension office is situated in Tukuyu town where most of the government offices for Rungwe district are located. The farm households' ignorance concerning the location of the agricultural extension office implies that more than half of the farm households were not in touch with this office. This ignorance was also portrayed by the farm households' perceptions that the maximum distance from the farm households' homes to the agricultural extension office was 13 km, which would be the correct distance for a significant number of the farm households if the agricultural extension office was situated in Tukuyu town. Kikuba, the place where the agricultural extension office is located is within walking distance for almost all the farm households in Katumba ward, which would make it possible for the farm households to visit the agricultural institutions such as the agricultural extension office and vice versa.

The lack of interaction between the farm households and agricultural extension officers is common in developing countries especially Africa, in most cases due to low wages, inefficient technical expertise, (Dulle, 2000) and the extension officers lacking necessary resources (Swanson and Samy, 2002). The main role of agricultural extension systems is to link agricultural research with the farmers so that the knowledge obtained from research institutions can be adopted by the farmers for improved productivity (Subair, 2002). Thus, although information dissemination between the farmers and the Agricultural Research Institutes is central to the role of an agricultural extension system, the inefficiency of extension systems, the gap between the extension officers and the farmers, hinders the flow of the necessary information. In turn, the above further hinders agricultural development. Thus, closing the gap between the farm households and the agricultural extension system in Katumba ward is key to strengthening the partnership between the extension institutes, the farm research households and the research institute at Uyole. The lack of partnership between the agricultural institutions and the farm households was also confirmed through the failure by the majority of the farm households to name the agricultural institutions that were situated within the ward. The farm households rightly named the locations for the agricultural research station and the seed production company in Uyole, but very few of them mentioned the seed retail outlet located in Kikuba, which was closest to them. Moreover, while the majority of the farm households mentioned Tukuyu town as the place where the grain or livestock outlet is situated, very few of them mentioned Kiwira grain or livestock marketing outlet, which is about 13km from the centre of Katumba ward, and the grain market at Kikuba, which is in the middle of the ward.

The above implies that while all of the farm households were aware of the location of the seed production company, the agricultural research station and the grain or livestock marketing outlet located in Tukuyu town, very few were aware of the agricultural institutions available in Katumba ward. This further confirms the claim that the farm households were working in isolation from the agricultural extension institution in the ward, and it also implies that the farm households were working in isolation from each other. This, together with the fact that none of the farm households reported having ever been visited by staff from the seed production company, seed retail outlet and the grain or livestock outlet imply that the Agricultural Institutions have not implemented any strategic plans to help the farm households to access information regarding maize storage. Likewise, the fact that the farm households visited the agricultural institutions for reasons that are not related to maize storage indicates that the farm households' did not seek advice concerning maize storage from the agricultural institution. In general, none of the farm households had ever received training or information regarding maize storage from the agricultural institutions, which explains the farm households' ignorance concerning moulds and the use of inefficient methods to control the maize storage pests.

In developing countries, the need for partnerships among farmers and between farmers and agricultural institutions for better flow of information, skills and agricultural technology is widely acknowledged (Subair, 2002). Strengthening the interaction among farmers through associations is recommended in order for the farmers to be able to voice their needs and close the indicated gap (Combe, 1997). Farmers associations create a friendly environment for the farmers to voice their concerns, to share and exchange information, knowledge and skills, to lobby, to raise funds and to access services in an organized manner (Combe, 1997). As a result, the farmers' awareness and understanding of issues around farming is raised. Success stories in terms of increased income and improved food security of small scale farmers functioning under umbrellas of associations have been reported in places such as Mviwata, Arusha, Tanzania and in other countries such as Zambia and Malawi (Pinto, 2009).

Thus, the farm households in Katumba ward could have solved most of the maize storage problems had they worked in partnerships with institutions indicated above. In view of the above discussion, the farm households in Katumba ward have no access to maize storage information, hencethey lack appropriate technical skills for combating the maize storage problems in the ward. Thus, strengthening the partnership between the research institutes available to the farm households in Katumba ward and encouraging the farm households to form a maize farming association are crucial to solving the storage problems.

4.4.8 The implication of the level of formal education of heads of farm households on maize storage in Katumba ward

The low level of education of the majority of the farm households in Katumba ward raises concern regarding the degree to which the heads of farm households understand scientific issues involving food security and ecological factors that influence maize storage. The influence that heads of farm households may have had on the members of their households with respect to the scientific issues mentioned above is also questionable. The understanding of scientific issues around food security and ecological factors that influence maize storage is crucially important for understanding ways in which maize should be handled for maximum safety and quality. Thus, it is important that extension literature on maize farming and storage be compatible with the low level of the farm households in Katumba ward. Moreover, farmers' level of formal education has been reported to influence the farmers use of modern technology (Phanhpakit, 2009) such that the higher the level of formal education that a farmer has, the more likely the farmer is to adopt modern technologies. Thus, in the case of Katumba ward where the heads of farm households' level of formal education is low, efficient extension services are necessary for ensuring that the farm households receive the necessary skills and knowledge regarding maize production and storage for the best quality and safety of maize.

4.4.9 The implication of the age of heads of farm households on maize storage in Katumba ward

Although heads of farm households of different age groups were involved in maize farming and storage, a relatively greater number of the farm household heads that were involved in farming were aged 35 - 45. The United Nations reports indicate that currently, life expectancy in Tanzania is 54 years (United Nations Statistics Division, 2010), thus, 35 - 45 years is prime age. The fact that more of the farm household heads were involved in maize farming at their prime age suggests that maize farming in Katumba ward was important both as a source of livelihood and as a source of food, thus, it should not be ignored.

4.5 Conclusions and recommendations

Roof and sack storage methods, the only storage methods that the farm households in Katumba ward use to store maize, expose the maize to pests and moulds. The methods that the farm households used in order to control the infestations and infections were not adequate. Storage problems in Katumba ward were mainly due to insect pests, especially *S. zeamais* and *S. cerealella*, rodents, especially the brown rats and *Fusarium*, *Diplodia*, *Aspergillus* and *Penicillium* species of moulds. As a result of the pests, individual farm households that participated in this study lost an estimate of 302 kg of maize annually, amounting to 78.64 tonnes (or 34 %) of maize. Thus, an estimate of 800 tonnes of maize was lost to pests in the ward. This amount is very large for the subsistence farmers to lose considering that the farm households produced an average of 877 kg of maize per annum.

It was also concluded that *S. zeamais* was the most predominant insect pest of maize in Katumba ward followed by *S. cerealella*. The presence of high levels of the insect pests in the maize samples that were collected from the farm households confirmed that the quality of maize stored using sack and roof storage technologies in Katumba ward was low and that these technologies were ineffective in protecting maize from insect pests. The fact that about 25 % of the farm households experienced maize infestation by insect pests prior to storage may indicate that the infestation began in the fields prior to harvest or during harvest due to poor handling. However, for more than half of the farm households in Katumba ward the infestation of maize started during storage, which confirms the inadequacy of sack and roof storage methods to protect stored maize from the infestations.

The high population of the insect pests in maize stored using sack and roof storage methods rendered the maize susceptible to infestations by moulds, which eventually leads to mycotoxin contamination of the maize and possible ill health or even premature death of the consumers. Thus, the presence of high levels of insect pests in maize in Katumba ward put the farm households at risk of food insecurity in a number of ways. These include reducing the quantities of available food for the farm households, rendering meals made from the infested maize unpalatable and encouraging micro - organisms and mould spores in the stored maize thus, rendering the maize unsafe for consumption.

The farm households attributed much of the maize loss to rodents and insects and were ignorant of the negative impact that moulds could have on the health of the consumers. As a result the farm households tended not to associate moulds infestation with loss of stored maize, and showed reluctance and negligence in controlling the moulds in stored maize. These attitudes put the farm households at risk of ill health and created room for further multiplication of the moulds in the places where they were disposed such as in the fields.

The methods that the majority of the farm households used in order to control pests were either inefficient or harmful especially where controlling rodents and insect pests are concerned, thus, they contributed to enhancing household food insecurity and putting the consumers at risk of ill health. The best way to store maize includes ensuring that infestations and infections do not occur at all, which findings have shown that the majority of the farm households failed to achieve. The lack of interaction between the farm household and the agricultural institutions also contributed to the farm households' use of inadequate means to control the infestations. Generally, the lack of extension services concerning maize storage in Katumba ward promotes the poor performance of the farm households with respect to maize storage. Lastly, the low level of formal education of heads of farm households in Katumba ward indicates the need for production of extension manuals that are readily available and compatible with the farm households' education. This will help the farm households to understand ecological issues involved in maize storage and food security. Thus, it was recommended that:

- Efforts should be made by the government and the Vulnerability Assessment Committee in Tanzania in order to provide extension education to ensure that the farm households' are informed on the implications of pest infestations of stored maize on the lives of the consumers. Strengthening the partnership between agricultural extension officers and the farm households in Katumba ward, and ensuring that the agricultural institutions that are within reach by the farm households deliver necessary services and skills to the farm households efficiently are crucial for raising the farm households' awareness.
- Farm households be encouraged to form maize farmers associations so that they can benefit from shared information and other resources, and that an alternative way of drying maize thoroughly prior to storage be implemented in Katumba ward in order to eliminate the chances of the moulds and insect pests to easily infest stored maize.
- The farm households should be encouraged to handle maize with care prior to storage such that the infested maize cobs are not disposed of or left unattended in the fields. This will help to control the multiplication of the insect pests.
- Storage facilities should be cleaned and disinfected prior to storage in order to eliminate insect pests or their eggs. The use of new sacks should be encouraged for maize storage while old sacks can be disinfested by simply washing and boiling them in hot water before use.
- Storage facilities should be kept dry in order to avoid creating favourable conditions for infestations.
- Farm households should be encouraged to inspect the storage facilities regularly in order to detect and control the infestations using effective pesticides.

- The government of Tanzania should make deliberate efforts to ensure that maize varieties that are particularly resistant to *S. zeamais* and *S. cerealella* are made available to the farm households in Katumba ward.
- The government of Tanzania should implement appropriate agricultural policy in order to control the infestation of stored maize by the insect pests. For instance passing a law which insists on maize being adequately dried prior to storage may help the farmers to adopt new ways of drying maize adequately before storing it.

References

Abebe, F., Tefera, A., Mugo, S., Beyene, Y., Vidal, S., 2009. Resistance of Maize Varieties to the Maize Weevil *Sitophilus zeamais* (Motsch.) (Coleoptera: Curculionidae). *African Journal of Biotechnology*. 8, 21, 5937 - 5943.

Anon, 2008. *Weather in Katumba*. <http://freemeteo.com/default.asp?pid=180lta=1&sid=639320&gid=151851&alls=2>(Accessed 2008 August 01).

Atkins, D., Norman, J., 1998. Mycotoxins and Food Safety. *Nutrition and Food Science* 5, 260 - 266.

Bayer (Pty), 2007. *Rodents, their Biology and Control*. <http://www.bayerhome.co.za/docs/Rodents/%20editorial%20complete.pdf> (Accessed 2011 August 28).

Bennett, S.M. 2008. *The Black Rat (Rattus rattus)*. <http://www.the-piedpiper.co.uk/thlb.htm> (Accessed 2008 January 18).

Bergvinson, D.J., 2000. *Storage Pest Resistance in Maize*. <http://apps.cimmyt.org/Research/Maize/results/mzhigh99-00/mrhigh99-00stor.pdf>(Accessed 2011 August 27).

Brink, M., and Belay, G., 2006.*Cereals and Pulses. Volume 1 of Plant Resources of Tropical Africa*. Plant Resources of Tropical Africa (PROTA), Wageningen.

Capinera, J.L., 2008. *Encyclopedia of Entomology*, Vol. I. Springer, Berlin.

CIMMYT, Dubin, J. 2010. *Insects - Maize*. <http://cropgenebank.sgrp.cgiar.org/index.php?option=com_contents&view=articles&id=496&Itemid=678&lang=english> (Accessed 2010 November 01).

Combe, D. 1997. *The Role of Farmers Associations in commodity Price Risk Management and Collateralizes Commodity Finance.* <http://www.unctad.org/infocomm/francis/1docs/farmers.pdf> (Accessed 2010 December 02).

Coulter, J., Schneider, K. 2004.*Feasibility Study of Post Harvest Project in Mozambique and Tanzania*.Consultancy Report to the Swiss Agency for Development and Cooperation (SDC) <http://www.postcosecha.net/en/home/Knowledge_Network/ongoing_POSTCOSECHA_Programs/Eastern_andsouthern_Africa> (Accessed 2010 September 02).

Dattalo, P., 2008. *Determining sample size: Balancing Power, Precision and Practicality*. Oxford University, Oxford.

De Groote, I., 2004. *Protection of Stored Grains and Pulses*, fourth ed. Agromisa Foundation, Wageningen.

De Plaen, R., Kilelu, C., 2004. From Multiple Voices to Common Language: Ecosystem Approaches to Human Health as an Emerging Paradigm. *Ecohealth*.1, 2, 8 - 15.

Derera, J., Denash, G., Pixley, K.V, 2001. Resistance of maize to the maize weevil:1. Antibiosis. *African crop Science Journal*.9, 2,431 - 440.

Dulle, F.W., 2000. The Extension Triad Approach in Disseminating Agricultural Information to Extension Workers: Some Experience from the Southern Highlands Dairy Development Project, Tanzania. *Journal of Information Science*. 26, 2, 121 - 128.

FAO, 1985. *Prevention of post- harvest food losses: a training manual*. FAO, Rome.

FAO, 1994. *Grain Storage techniques-Evolution and Trends in Developing Countries*. FAO, Rome.

FAO, 2003. *Maize Post- Harvest Operation: Chapter 1*. <http://www.fao.org/inpho/content/compend/text/ch23_01.htm> (Accessed 2010 June 21).

GISG, 2008. *Trogodema Granarium*. <http://www.issg.org/databasespecies/ecology.asp?Si=1428fr=1&sts=&lang=EN> (Accessed 2008 January 01).

Government of the United Republic of Tanzania, 2003. *Dodoma Region*. <http://www.tanzania.go.tz/regions/dodoma/zones> (Accessed 2011 August 28).

Harney, M., 1993. *A Guide to the Insect Pests of Stored Grain in South Africa*. Plant Protection Research Institute, Pretoria.

Hansel, L.S., Skovgård, H., Hell, K., 2004. Life Table Study of *Sitotroga cerealella* (Lepidoptera: Gelichiidae), a strain from WestAfrica. *Journal of Economic Entomology*. 97, 4:1484 - 1490.

Hill, D.S., 2008. *Pests of Crops in Warmer Climates and Their Control*. Springer, Lincs.

Hall, D. W., 1970. *Handling and Storage of Food grains in Tropical and Subtropical areas.* Rome: Food and Agriculture Organisation of the United Nations.

Jood, S., Kapoor, A.C., Singh, R., 1992. Biological evaluation of Protein Quality of Maize as Affected by Insect Infestation. *Journal of Agricultural and Food Chemistry*.40, 12, 2439 - 2442.

Kaliba, A.R.M., Verkuijl, H. Mwangi, W. Mwilawa, A.J.T. Anandajayasekeram, P. 1998. *Adoption of Maize Production Technologies in Central Tanzania*. <http://www.cimmyt.cgiar.org/Research/Economics/PDFs/CentralTnz.pdf> (Accessed 2007 February 18).

Katinila, N., 1998. Adoption of Maize Technologies in Southern Tanzania. CIMMYT, Mexico

Kgware, M., Maniram, J., Maharaj, P.P.,2008.*Public Vectors and Pests*. <http://www.kznhealth.gov.za/environ/vector/brownrat.htm> (Accessed 2008 December 04).

Kimondo, M., 2008.*Post Harvest Handling and Protection of Maize*. <http://www.kari.org/fileadmin/publicationsii/Post_harvest_handling_and_protection.pdf >Accessed 2010 December 21).

Laden, G., 2008. *When the Corn Weevil Knocks, we are all Doomed*. <http://www.Scienceblogs.com/gregladen/2008/11/whenthe_corn_weevil_knocks_we.php>(Accesse 2008 Januaty 01).

Lewis, D., Hahn, J., Pelliteri, P., 2008. *Insect Pests of Store Foods*. <www.extenxion.umn.edu/distribution/nutrition/DJ1000.html> (Accessed 2010 January 22).

Mason, L.J., 2008. *Grain Mite*. <http://extension.entm.purdue.edu/publications/E-222.pdf (Accessed 2008 January 15).

Mejia, D., 2003. *Maize Post- Harvest Operation chapter 4*. <http://www.fao.org/inpho/content/compend/text/ch23_03.htm#TopOfPage> (Accessed 2010 February 20).

Merck, 2011. *Zoonoses: Introduction*. <http://wwwmerckvetmanual.com/mvm/index.jsp?cfile=htm/bc/220100.htm> (Accessed 2011 August 27).

Mills, J.N., Childs, J.E., 2001. Rodent borne Hemorrhagic fever. In Williams, E.S. (Ed). *Infectious diseases of wild mammals*, third ed., pp. 254 - 267.

Moremoholo, L., Shimelis, H., 2009. Stability analysis of Grain Yield and *Stenocarpella maydis* Ear rot Resistance in Maize.*African Crop Science Conference Proceedings*. 9, 425 - 433.

Moshi A.J. 1998. *Adoption of Maize Production Technologies in Central Tanzania*. CIMMYT/ Government of the United Republic of Tanzania/The Southern Africa Centre for Cooperation in Agricultural Research (SACCAR), Mexico.

Mugo, S., De Groote, H., Songa, J., Mulaa, M., Odhiambo, B., Taracha, C., Bergvinson, D., Hoisington, D., Gethi, M., 2002. Advances in Developing Insect Resistant Maize Varieties for Kenya within the Insect Resistant Maize for Africa (IRMA) Project. In Friesen, D.K., Palmer, A.F.E. (Eds). *Integrated approaches to Higher Maize Productivity in the New Millenium. Proceedings of the 7th Eastern and Southern Afrrica Regional Maize Conference, Nairobi, Kenya, 11 - 15 February 2002*. CIMMYT, Mexico, PP. 31 - 37.

Mulungu, L.S., Lupenza, G., Reuben, S.O.W.M., Misangu, R.N., 2007. Evaluation of Botanical Products as Stored Grain Protectant Against Maize Weevil *Sitophilus zeamais* (L.) on maize. *Journal of Entomology*. 4, 3, 254 - 262.

Oduor, G.I., Smith, S.M., Chandi, E.A., Karanja, L.W., Agano, J.O., Moore, D., 2000. Occurrence of *Beauveria bassiana* on insect pests of stored maize in Kenya *Journal of Stored Products Research*. 36, 2, 177 - 185.

Ogendo, J.O., Deng, A.L., Belmain, S.R., Walker, D.J., Musandu, A.A.O., 2004. Effects of Insecticidal Plant Materials*, Lantana camara* L. and *Tephrosia vogelii* Hook, on the Quality Parameters of Stored Maize Grains. *The Journal of Food Technology in Africa*. 9, 1, 29 - 35.

Owusu, E.O, Osafo, W.K., Nutsukui, E.R., 2007. Bioactivity of Candlewood, Zanthoxylum Xanthoxyloides (LAM0 Solvent Extracts Against Two Stored=Product Insect Pests. *African Journal of Science and Technology (AJST*). 8, 1, 17 - 21.

Parsons, M.W., Munkvold, G.P., 2010. Association of Planting Date, Drought Stress and Insects with *Fusarium* Ear Rot and Fumonisn B_1 Contamination in California Maize. *Food Additives and Contaminants*: Part A. 27, 5, 591 - 607.

Pinto, A.C., 2009. *Agricultural Cooperatives and Farmers Organizations; Role in Rural Development and Poverty Reduction*. <http://www.un.org/esa/socdev/egms/docs/2009/cooperatives/Pinto.pdf>(Accessed 2010 December 05).

Pitchler, E., 2006. *Sampling for mycotoxins- do we care enough?*<www.romerlabs.com> (Accessed 2008 December 14).

Public health of Canada, 2008. *Lyme Disease*. <http://www.publichealth.gc.ca> (Accessed 2008 December 10).

Reed, C., Doyungan, S., Loerger, B., Getchell, A., 2007.Response of Storage Molds to Different Initial Moisture Contents of Maize (Corn) Stored at 25^{0}C, and effect on respiration rate and nutrient Composition. *Journal of Stored Products Research*, 43, 443 - 458.

Robertson-Hoyt, L.A., Betran, J, Payn, G.A., White, D.G., Sakeit, T., Maragos, C.M., Molnar, T., Holland, J.B. 2007. Relationships among resistances to *Fusarium* and *Aspergillus* Ear rots and Contamination by Fumonisin and Aflatoxin in Maize. *Phytopathology*. 97, 3, 311 - 317.

Sallam, M.N., 1999. *Chapter II Insect Damage on Post - harvest*. <http://www.fao.org/inpho/content/compend/text/ch02.htm> (Acessed 2010 January 22).

Semple, R.I., Hichs, P.A., Lozare, J.V., Castermans, A., 1992. *Towards Integrated Community and Pest Management in GrainStorage*. <http://www.fao.org/inpho/content/documents/vlibrary/x00484/x0048E00.htm> (Accessed 2009 December 18).

Subair, S.K., 2002.Improving Extension-Research Linkages through On-Farm Adaptive Research (OFAR) Philosophy in Southern African Countries. *Journal of International Agricultural and Extension Education*. 9, 1, 85 - 91.

Swanson, B.E., Samy, M.M., 2002. Developing an Extension Partnership among Public, Private, and Non Government Organizations. *Journal of International Agricultural and Extension Education*. 9, 1, 5 - 10.

Sweeney, M.J., White, S., Dobson, A.D.W., 2000. Mycotoxins in agriculture and food safety**.** *Irish Journal of Agriculture and Food Research*. 39, 2, 235 - 244.

Tadasse, A. Insects and other Arthropods Recorded from Stored Maize in Western Ethiopia. *African Crop Science Journal*. 4, 3, 339 - 349.

Tenuta, A., 2006. *Identifying Corn Ear Molds*. <http://www.mkap.com/index.cfm?show=108mid=12> (Accessed 2007 November11).

Trochim, W. M. K., 2001. *The Research Methods Knowledge Base*. Atomic Dog, Cincinnanti.

UNIFEM. 1995. *Storage*: *Food Cycle Technology Source Books*. Intermediate Technology and UNIFEM, London.

United Nations Statistics Division, 2010. *United Republic of Tanzania*. <http://data.un.org/countryprofile.aspx?crName=United%republic%20of%20Tanzania> (Accessed 2010 July 1).

University of Delaware Kent County Agricultural Extension. 2007. *Aspergillus Fungus that Produces Aflatoxin in Corn*. <http://kentagextension.blogspot.com/2007/08/aspirgillus-fungus-that-produces.html> (Accessed 2008 January 25).

University of Greenwich, 2006. *Rats and Human Health in Africa: Proceedings of an International Workshop on Rodent-borne Diseases and the RatZooman Research Project*. <http://www.nri.org/projects/ratzooman/docs/workshop_proceedings.pdf> (Accessed 2011 August 26).

University of Michigan, 2008. *Mus muscullus (House mice).* <http://animaldiversity.ummz.umich.edu/site/accounts/pictures/musmuscullus.html> (Accessed 2008 January 20).

Van Rensburg, J.B.J., Flett, B.C., 2010. A Review of Research Achievements on Maize Stem Borer, Busseola fusca (Fuller) and Diplodia Ear rot Caused by *Stenocacarpella maydis* (Berk. Stutton). *South African Journal of Plant Soil*. 27, 1, 74 - 80.

Weinberg, Y.Y., Chen, Y., Finkelman, S., Ashbell, G., Navarro, S., 2008. The Effect of Moisture Level on High-moisture maize (*Zeamays* L.) under hermetic storage conditions- in vitro Studies. *Journal of Stored Products Research* 44:136 - 144.

Tefera, T., Muo, S., Likhayo, P., 2011. Effects of Insect Population Density and Storage Time on Grain Damage and Weighrt Loss in Maize due to the Maize Weevil *Sitophilus zeamais* and the Larger Grain Borer *Prostephanus truncates*. *African Journal of Agricultural Research*. 6, 10, 2249 - 2254.

Wyffels Technical Bulletin, 2006. *Ear Rot in the 2006 Corn Crop*. <http://www.wyffels.com/images/pdf/ear_rot_2006-pdf> (Accessed 2007 December 07).

Williams, J .H., 2004. Human aflatoxicosis in developing countries: a review of toxicology, exposure, potential health consequences and interventions. *The African Journal of Clinical Nutrition*. 80, 1106 - 1122.

Yigezu, Y.A., Alexander, C.E., Preckel, P.V., Mailer, D.E., Mason, L.J., Woloshuk, C., Lawrence, J., Moog, D.J., 2010. Economics of Integrated Insect Management of Stored Corn. *Journal of Entomology*. 103, 5 : 1896 - 1908.

APPENDICES

Appendix 4.1: The questionnaire that was used for collecting the necessary information for the study

1. Have you ever experienced loss of maize during storage? (i) Yes (ii) No

2. If your answer to question one is yes, what was the cause of the loss?

(i) Infestation by insects (ii) Infestation by rodents (iii) Infestation by moulds (iv) Infestation by insects and rodents (v) Infestations by insects and moulds (vi) Infestation by rodents and moulds (vii) Other (specify)----------------------------

3. If you have had an experience of loss of maize during storage due to insect infestation, which type of insects do you see in your stored maize? (Please put a tick against the letter and number corresponding to the picture of insect relevant to you. You may select more than one insect if necessary).

(a). A (i) *Trogodema granarium* (b). A (ii) *Oryzaephilus surinamensis* L

(c). A (iii) *Tribolium destructor* (d). A (iv) *Cryptolestes ferrugineus*

(e). A (v) *Laemophiloeus pusillus* (f). A (vi) *Prostephanus truncatus*

(g) B (i) *Sitophilus oryzae* (h). B (ii) *Sitophilus granarius*

(i). C (i) *Sitotroga cerealella* (j). C (ii) *Plodia interpunctella*

(k). C (iii) *Corcyra cephalonica* (l). D Grain mites

4. Which type of insects do you see most in your stored maize?

(a). A (i) *Trogodema granarium* (b). A (ii) *Oryzaephilus surinamensis L*

(c). A (iii) *Tribolium* destructor (d). A (iv) *Cryptolestes ferrugineus*

(e). A (v) *Laemophiloeus pusillus* (f). A (vi) *Prostephanus truncatus*

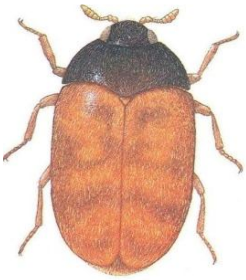
(g) B (i) *Sitophilus oryzae* (h). B (ii) *Sitophilus granarius*

(i). C (i) *Sitotroga cerealella* (j). C (ii) *Plodia interpunctella*

(k). C (iii) *Corcyra cephalonica* (l). D Grain mites

A. Beetles (Harney, 1993; Hall 1970; The Global Invasive Species Group of the IUCN Species Survival Commission (GISG), 2008)

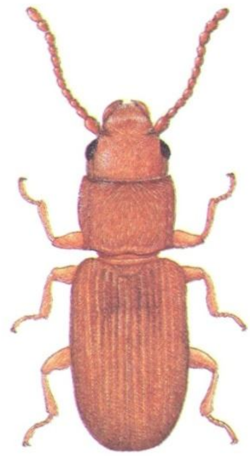
(i) *Trogodema granarium* (Everts)



(ii) *Oryzaephilus surinamensis* L

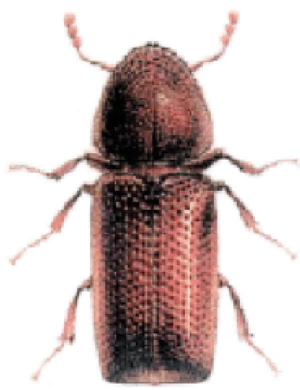
(iii) *Tribolium destructor* (Uytt)

(iv) *Cryptolestes ferrugineus* (Stephens)



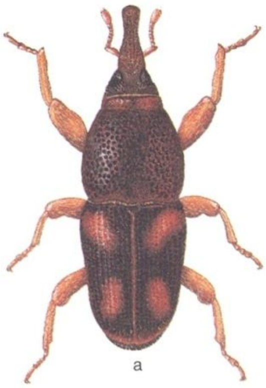
(v) *Laemophiloeus pusilus* (Schönher)

(vi) *Prostephanus truncates* (Horn)

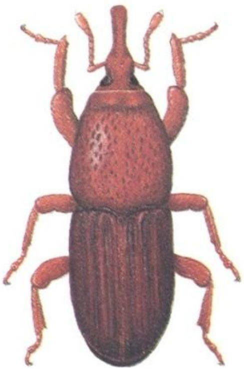


B. Weevils (Harney, 1993)

(i) *Sitophilus oryzae* (Linnaeus)



(ii) *Sitophilus granarius* (L.)

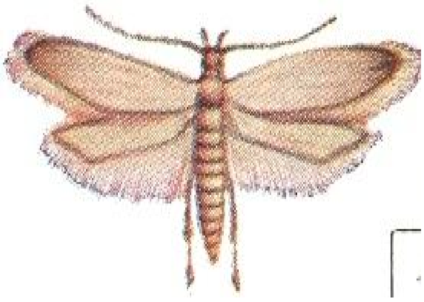


(iii) *Sitophilus zeamais* (Motschulsky)

brown or black (Laden, 2008)

C. Moths (Harney, 1993; Hall, 1970)

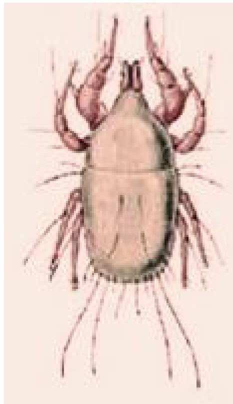
(i) *Sitotroga cerealella* (Olivier)



(ii) *Plodia interpunctella* (Hübner)

(iii) *Corcyra cephalonica* (Stainton),

D. Grain mites (Degesch America, as cited by Mason, 2008).



5. What methods do you use to control insects that infest your stored maize? ------------------------
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6. In your household, whose responsibility is it to control insects that infest stored maize?

Person responsible for controlling insects	Why is it that particular person's responsibility?
Female household head	
Male household head	
Both parents	
Female parent (Male headed household)	
Other (specify) --	

7. Which type of rats attack your stored maize? (Please put a tick on the answer corresponding to the relevant type of rat shown in the pictures. You may put a tick on more than one type of rat if necessary).

Type of rat	Attacks most	Attacks sometimes	Attackes least
(i). Brown rats (*Rattusnarvegicus*)			
(ii). Black rats (*Rattus rattus*)			
(iii). House mice (*mus musculus*)			

(i). Brown rats (*Rattus narvegicus*)

Long tail

Brown in colour (Kgware *et al*., 2008; Hall 1970)

(ii) Black rats (*Rattus rattus*) Similar to black rats but a bit slender

Tail longer than brown rat's tail

Ears bigger than brown rat's

Black/gray in colour

(Hall 1970; Bennett, 2008)

(iii). House mice (*mus musculus*)

Smaller than the other types of rats. Small, black protruding eyes. Large, lightly haired ears. Almost hairless tail with scale rings. Slightly pointed nose (University of Michigan, 2008).

8. How do you deal with the problem of rats? --

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9. In your household who is responsible for controlling rats that infest stored maize?

Person responsible for controlling rats	**Why is it that particular person's responsibility?**
Female household head	
Male household head	
Both parents	
Female parent (Male headed household)	
Other (specify) ---	

10. Which type of moulds do you see in your stored maize? (Please put a tick on the numeral corresponding to the picture the relevant type representing the type of rot).

Mould	**Seen most**	**Seen sometimes**	**Seen least**
(i) *Fusarium* ear rot			
(ii) *Gibberella* ear rot			
(iii) *Aspergillus* ear rot			
(iv) *Penicillium* ear rot			
(v) *Diplodia* ear rot			

(i) *Fusarium* ear rot caused by *Fusarium moniliforme*
Scattered infection. White to pink or salmon colored mould. Kernels turn brown, and they may have white streaks (Tenuta 2006; Wyffels technical bulletin 2006)

(ii) *Gibberella* ear rot
Red or dark pink mould. Usually it starts at ear tips (University of Delaware Kent County Agricultural extension 2007)

(iii) *Aspergillus* ear rot

Black or grayish yellow mould on and between kernels (University of Delaware Kent County Agricultural extension 2007)

(iv) *Penicillium* ear rot

Green or bluish green powdery mould. Can infect embryos of kernels and turn them blue (University of Delaware Kent County Agricultural extension 2007; Tenuta 2006)

(v) *Diplodia* ear rot (Tenuta, 2006)

Thick white mould usually starts at the base of the ear It later changes to grayish brown or black growth over the husks and kernels. Entire ear may be shrunken. Infected kernels appear glued to the husks. Infected ears are very light and may be totally rotten

11. How do you control ear moulds in maize?

Type of ear rot	Methods used to control
(i) *Fusarium* ear rot	
(ii) *Gibberella* Ear rot	
(iii) *Aspergillus* ear rot	
(iv) *Penicillium* ear rot	
(v) *Diplodia* ear rot	

12. Do you think moulds could have harmful effects? (a) Yes (b) No

13. In your household who is responsible for controlling moulds?

Person responsible for controlling ear rots	Why is it the particular person's responsibility?
Female household head	
Male household head	
Both parents	
Female parent (Male headed household)	
Other (specify) ---------------------------------	

14. What do you use rotten/moldy maize for? ---

15. Apart from infestations, are there other storage problems that you come across?

a) Yes (b) No

16. If your answer to question 15 is yes, what are the problems? ---------------------------------------

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17. What was the cause of the problems?

Type of problem	Cause of problem	Methods used to control the problem

18. What maize varieties do you normally grow?

19. Do you buy seeds or use some of your own maize for planting?

Maize variety	Indicate whether you buy or use your own maize	If you buy seeds, where do you buy them from?

20. Are you a member of any farmers' association? (a) Yes (b) No

21. If your answer to question 20 is yes, please name the farmers' association(s) you belong to ---

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22. How far are you from the following services?

Institution	Name of location	Distance from village
Agricultural extension		
Agricultural research station		
Seed production company		
Seed retail outlet		
Grain/livestock marketing outlet		

23. How many times do you visit these institutions in a year?

Institution	**Number of times you visit per year**	**What do you visits the institutions for?**
Agricultural extension		
Agricultural research station		
Seed production company		
Seed retail outlet		
Grain/livestock marketing outlet		

24. How many times does staff from the institutions visit you annually?

Institution	**Number of times you are visited per year**	**What do they visit you for?**
Agricultural extension		
Agricultural research station		
Seed production company		
Seed retail outlet		
Grain/livestock marketing outlet		

25. Are you a beneficiary of any government or non government organisation (NGO) programs? (a) Yes (b) No

26. If your answer to question 25 is yes, for how long have you been a beneficiary?

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27. If your answer to question 25 is yes, what is the main function of the organisation that you are a beneficiary of?

Name of organisation	**Function of the organisation**

Appendix 4.2: Chi square test: Exploring the relationship between maize samples being infested by insect pests and being infected by pathogenic fungi

		Infected with insect pests		
		No	Yes	Total
The sample is infested by pathogenic fungi	No	4	14	18
	Yes	5	107	112
Total		9	121	130

α significant level = 0.021

Appendix 4.3: Estimated amounts of maize produced, consumed or lost to pests annually

	Average amount of maize harvested per annum (Tonnes)	**Total amount of maize(in sacks) that household consumed annually**	**Estimated amount of maize (in sacks) used for other purposes**	**Total estimated amounts (in sacks) that households used annually**	**Estimated amount of maize (in sacks) lost to pests**
Total	227.91	57.48	91.74	149.27	78.64
Mean	0.88	0.22	0.35	0.57	0.31
Std Dev	140.69	35.44	56.88	92.25	48.53
Min	0.10	0.08	0.00	0.08	0.00
Max	6.33	0.39	6.00	6.30	0.99

Appendix 4.4: Estimated number of maize sacks that the farm households harvested per annum (n=260)

Normal year		Good year		Bad year		Average no. of maize sacks per year			
No. of maize sacks	Frequency (Households)	No of maize sacks	Frequency (Households)	No. of maize sacks	Frequency (Households)	No. of maize sacks	Frequency (Households)	No. of maize sacks	Frequency (Households)
1	1	1.5	1	0.5	1	1.00	1	9.67	6
1.5	1	2	1	1	4	1.50	1	10.00	7
2	3	2.75	1	1.5	5	2.00	1	10.33	2
2.5	5	3	6	2	22	2.17	2	10.50	1
2.75	1	3.5	2	2.5	3	2.33	2	10.67	1
3	14	4	14	3	42	2.50	3	11.00	5
3.5	1	5	20	3.5	2	2.83	2	11.33	3
4	20	6	29	4	32	3.00	10	11.67	3
4.5	3	7	29	4.5	3	3.17	3	12.00	9
4.7	1	8	16	5	25	3.33	1	12.33	5
5	27	8.5	2	6	18	3.67	7	12.67	3
5.5	5	9	17	6.5	1	4.00	13	13.00	2
5.7	1	9.5	1	7	24	4.17	1	13.67	2
6	23	10	25	7.5	1	4.50	3	14.00	2
6.5	1	10.5	1	8	18	4.57	1	14.33	1
7	19	11	9	9	10	4.67	11	14.67	8
7.5	1	11.5	1	10	18	4.83	2	15.33	1
8	23	12	13	12	9	5.00	15	16.33	2
9	20	13	13	13	4	5.17	2	16.67	1
9.5	1	14	5	14	4	5.33	6	17.00	2
10	21	15	18	15	5	5.57	1	17.33	1
10.5	1	16	1	16	1	5.67	8	18.00	1
11	7	17	11	19	1	6.00	9	18.67	1
12	20	18	5	20	3	6.17	1	19.00	1
13	5	19	1	29	1	6.33	6	19.33	2
14	3	20	4	38	1	6.50	1	20.00	1
15	10	21	1	45	1	6.67	6	23.67	1
16	2	23	3	55	1	7.00	9	24.00	1
17	2	25	1			7.17	1	24.33	2
18	4	28	3			7.33	5	27.33	1
20	5	30	1			7.50	4	34.00	1
25	3	32	1			7.67	5	41.00	1
28	1	38	1			8.00	7	50.00	1
30	1	45	1			8.33	3	63.33	1
35	1	55	1			8.67	11		
40	1	70	1			9.00	6		
50	1					9.33	5		
65	1					9.50	3		

Appendix 4.5: Independent t-tests scores: The difference between the means for the number of insects per 120 maize kernels for the maize samples that were collected from the roof and sack storage facilities

	t-test for Equality of Means						
						95% Confidence Interval of the Difference	
	Sig.	t	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Upper	Lower
Equal variances assumed	0.277	0.054	0.957	0.515	9.622	-18.523	19.553
Equal variances not assumed		0.051	0.959	0.515	10.016	-19.446	20.476

Appendix 4.6: Investigating the difference between the means for the number of insect pests per 120 maize kernels for the indigenous and improved maize samples

	t-test for Equality of Means						
						95% Confidence Interval of the Difference	
	Sig.	t	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Upper	Lower
Equal variances assumed	0.837	1.778	0.078	16.796	9.448	-1.898	35.490
Equal variances not assumed		1.744	0.085	16.796	9.632	-2.373	35.965

Appendix 4.7: Chi square test for the relationship between farm households' sizes and the types of storage methods that the farm households used to store maize

		Type of storage method that the farm household use			
		Roof storage	Sack storage exclusively	Both roof and sack storage	Total
Household size in groups	1-3 people	19	1	19	39
	4-5 people	58	5	35	98
	More than 5 people	39	11	73	123
Total		116	17	127	260

Significant at 0.001

CHAPTER FIVE

THE IMPORTANCE AND CHARACTERISTICS OF ROOF AND SACK STORAGE METHODS IN RUNGWE DISTRICT, TANZANIA

Abstract

The importance and characteristics of roof and sack storage methods in Katumba ward were studied using the matrix for scoring and ranking tool and through administering face-to-face semi-structured and structured interviews to 260 farm households that were randomly sampled for the study. Farm households' perceptions concerning roof and sack storage methods' capacity to protect stored maize from insects, moulds and rodents infestations were also studied. The houses in which the storage facilities were located were built using low quality bricks, which makes it easy for invasions of stored maize by rodents to occur. Due to the materials from which roof and sack storage methods were made, the two storage methods had the capacity to allow entrance of moisture from the storage areas, which creates possibilities for growth of fungi and moulds in stored maize. The farm households wrongly believed that roof and sack storage methods offered very good and good protection to stored maize against fungal infestation, respectively. The farm households' overall ranking for the roof storage method was that it was good; while 59.2 % of the farm households considered the storage roof storage method excellent in the protection of stored maize against fungal infestation. The overall ranking for the sack storage method was that it was an average storage method, while at least three quarters of the farm households that took part in this study linked sack storage with good protection against insects and moulds infestations. It was concluded that farm households' perceptions concerning roof and sack storage methods impacted negatively on ways in which they responded to the infestations, which put them at risk of food insecurity and ill health. It was recommended that farm households' awareness concerning maize storage should be raised, and that roof and sack storage methods be improved for more efficiency.

Key words: Roof, Sack, Maize Storage, Rungwe district, Tanzania

5.1 Introduction

Insect activity in stored maize (Danilo, 2003; Lewis *et al.,* 2008), waste products produced by rodents (Brooks and Fiedler 1999) and the metabolic activities of fungi in the stored maize are known to lead to serious contaminations in maize (Sallam 1999; Pitt and Hocking, 2009), which can further lead to ill health of the consumers (Pitt 2000; Bennett and Klich, 2003; Wood *et al*., 2003). Efficient storage methods play a major role in ensuring the safety of the stored crops, and can impact positively on the quantity of safe food available to the consumers (Thamaga *et al*., 2004).

On the contrary, inefficient storage technologies play a major role in reducing food security to the farm households (Infonet-biovision, 2010). In Katumba ward roof and sack storage methods are commonly used for storing maize, hence the focus on the two storage methods. In the context of Katumba ward, the roof storage method entails pilling maize cobs in the space between the lower and the upper part of the roof, thus, is different from the roof-top storage method (Chapter 2: Figure 2.7). Maize stored using roof and sack storage methods was stored for 2 - 14 and 5 - 14 months, respectively. Thus, the characteristics of the sack and the roof storage methods played a crucial role in determining the amount and quality of maize that could be available to the farm households in this ward. In this chapter, farm households' perceptions on the characteristics and usage roof and sack storage methods for maize storage in Katumba ward and their implications on the farm households' food security were explored.

5.1.1 Main objective

To characterize, explore the usage and probe the farm households perceptions' regarding the importance of roof and sack storage methods in Katumba ward, Rungwe district, Tanzania, and determine the implications on the quality of stored maize and household food security in the ward.

5.1.2 Specific objective

To explore the characteristics, usage and farm households' perceptions of the importance of roof and sack storage methods and their implications on the quality of stored maize and household food security in Katumba ward.

5.2 Materials and Methods

Both qualitative and quantitative methods were used for studying a sample of 260 farm households in Katumba ward (Chapter Three, Section 3.2.1). The research tools that were used included face to face semi- structured and structured interviews and the matrix tool for scoring and ranking described in section 5.3.1. Data collected using the above indicated research tools included: type of buildings in which the farm households stored maize, places where the storage facility were located in the buildings and the characteristics of sack and roof storage methods. Other data sets collected included the form in which maize was stored such as shelled grain or unshelled maize cobs, reasons for storing maize in the specified forms and the farm households' perceptions of the efficiency of sack and roof storage methods. Data set on the advantages of roof and sack storage methods and the person responsible for selecting the storage method used by farm households was also collected (Appendix 1).

5.2.1 The procedure for the scoring and ranking matrix

The matrixtool for scoring and ranking though simple, promotes discussion, thus,FAO (1994) recommends its use in order to obtain full participation of participants and to facilitate gathering the views of the group. Based on the participants' perceptions, the performance of sack and roof storage methods used by farmers in Katumba ward were tabulated as follows:

10 Scores - Excellent

8 - 9 - Very good

7- Good

6 - Average

5 - Very poor

The total scores were calculated and used to rank the storage methods in the order of their importance to the farm households. Details concerning the procedure for the scoring and ranking matrix is presented in Appendix 5.1.

5.2.2 Sampling of the farm households

The farm households were sampled as indicated in Chapter Thee, Section 3.2.1.

5.2.3 Statistical analyses

The data collected for this study was analyzed using the Statistical Programme for Social Sciences (SPSS) version 15, by Pallant (2005), complemented by the Excel package. The farm households' perceptions regarding the performance of roof and sack storage methods were explored through calculating frequencies, performing cross tabulations and comparing means using the indicated statistical packages.

5.3 Findings

5.3.1 Types of buildings used by the farm households to store maize

The majority (98.8 %) of the farm households that participated in this study stored maize in their main houses, and only 1.2 % stored maize in the kitchens which were separate from the main houses. Furthermore, for 64.2 % of the farm households, the main house was built using mud bricks and roofed with corrugated iron sheets. More details on the types of main houses owned by the farm households who participated in this study are given in Table 5.1.

Table 5.1: Types of walls and roofs of the main houses in Katumba ward (n=260)

Types of walls and roofs	Percent of farm households whose houses had the specified walls and roofs
Mud bricks thatched roof	13.1
Baked bricks (fire burnt)and thatched roof	4.2
Mud bricks (sun dried) corrugated iron sheets	64.2
Baked bricks corrugated iron sheets	15.4
Cement bricks corrugated iron sheets	3.1

5.3.2 Characteristics of the roof storage method in Katumba ward

As indicated in Table 4.1, the roofs of houses in Katumba ward were either thatched or made of corrugated iron sheets, and as Table 4.2 reveals, 77.3 % of the farm households in Katumba ward built the lower part of the roofs of their main houses using mud bricks and heavy wooden logs. While the heavy wooden logs made it possible for roofs to bear the heavy weight of maize, they were also strategically placed from one wall to the other in order to accommodate the stored maize. Other materials that the farm households in Katumba ward used to build the lower parts of the roofs are shown in Table 5.2.

Table 5.2: Materials that farm households in Katumba ward used for constructing the lower parts of roofs (n=260)

Materials used	Percent of farm households that used the specified building materials
Mud bricks (sun dried) + wooden logs	**77.3**
Baked bricks (fire burnt) + wooden logs	**4.2**
Cement bricks + wooden logs	**2.7**
Baked bricks + light weight timber	**15.4**
Cement bricks + light weight timber	**0.4**

5.3.3 Characteristics of the sack storage method in Katumba ward

Findings revealed that all of the farm households that used sacks for storing maize bought the sacks and that the sacks were either made of sisal or synthetic fibres. While 20 % of the farm households used sacks that were made of sisal exclusively, 35.8 % used sacks made of sisal and sacks made of synthetic fibres. All of the farm households that used sack storage method piled the sacks of maize on top of wooden planks wherever there was space in the houses that they lived in.

5.3.4 Maize drying prior to storage

The farm households that stored maize using sack storage exclusively dried prior to storage by spreading it on mats made of local grasses, placed on the ground in the sun (Table 5.3). Moreover, 88.46 % of the farm households depended on the heat from the burning firewood below the storage facilities, which they lit for routine purposes and from the sun above the roof to dry maize stored in the roofs during storage. All of the farm households reported that it took more than two weeks for maize to dry.

Table 5.3: Methods that the farm households used to dry maize in relation to type of storage method used (n=260)

Methods used to dry maize	Household used roof storage method exclusively (%)	Households used sack storage method exclusively (%)	Households used both roof and sack storage method (%)
Sun: drying by spreading maize on mats in the sun on the ground prior to storage	0	6.92	0.77
Drying in the roof: using heat from the burning wood and from the sun during storage	44.23	0	44.23
Sun: through spreading maize on the mats in the sun + roof: using heat from the burning wood and from the sun during storage	0	0	3.85

5.3.5 The form in which maize was stored

Farm households in Katumba ward stored maize in the form of unshelled cobs with or without husks or as shelled grain (Table 5.4). Those that used the roof storage method exclusively stored maize in the form of unshelled cobs with or without husks, and the percentages of those that stored maize without husks exclusively or initially without husks, were higher than those that stored it the other forms (Table 5.4). Almost all of the farm households that used the sack storage method exclusively stored maize in the form of shelled grain (Table 5.4). Other details regarding the form in which the farm households in Katumba ward stored maize and the reasons for which maize was stored in the specific forms are indicated in Tables 5.4 - 5.6.

Table 5.4: Form in which maize was stored in relation to storage method used (n=260)

Form in which maize was stored	Roof storage method exclusively (%)	Sack storage method exclusively (%)	Both roof and sack storage (%)	Total
Shelled grain	0.38	6.54	0.38	7.31
Unshelled without husks	29.62	0	0	29.62
Unshelled with husks	13.85	0	0.38	14.23
Unshelled without husks, later shelled grain	0.38	0	33.85	34.23
Unshelled with husks, later shelled grain	0.38	0	11.54	11.92
Some unshelled without husks, some with husks, latter shelled grain	0	0	1.15	1.15
Some of it shelled grain, some unshelled without husks	0	0	1.54	1.54

The farm households that stored maize in the form of unshelled cobs without husks stored it in that specific form in order to easily monitor infestations and for the maize to dry faster in the roof storage facilities. While the former reason had 13.1 % of the total score, the latter had 65.4 % of the scores. A highest percentage of farm households that stored maize in the form of unshelled cobs with husks, stored it in that particular form to protect it from smoke (Table 5.5).

Table 5.5: Reasons for storing maize in the form of unshelled cobs with husks (n=260)

Reasons for storing unshelled maize cobs with husks	Percent of farm households that stored unshelled maize cobs with husks
To protect from insect infestations	5.40
To protect from smoke in the kitchen roof	12.70
It is a traditional method used for many years	2.70
To reduce workload	2.70
To protect from smoke and insects	3.50

Responses apply only to farm households that stored unshelled maize cobs with husks

Table 5.6: Reasons for storing maize in the form of shelled grain (n=260)

Reasons for storing shelled maize	Percent of farm households that stored shelled maize
Makes it easy to monitor and control infestations	12.3
It is already shelled at the time of storage (for fast sun drying prior to storage)	5.4
Easier to manage and store in the sacks	37.7
No specific reason	0.4

Responses apply only to farm households that stored maize in the form of shelled grain

5.3.6 Advantages of roof and sack storage methods: Farm households' perceptions

More than half (70 %) of the farm households that took part in this study perceived roof storage as advantageous based on the reason that it helped to further dry the stored maize (Table 4.7). Other advantages that the farm households attributed to roof and sack storage methods are presented in Table 5.7.

Table 5.7: Advantages of roof and sack storage methods to the farm households in Katumba ward (n=260)

Storage method	Advantages	Percent of farm households for whom the response is applicable
Roof storage method	Helps to dry maize while storing	70.0
	Accommodates large volumes of maize and dries at the same time	25.8
	Helps to minimize insect infestation and dries maize	0.4
Sack storage method	It accommodates large quantities of harvests	2.7
	It is makes it easy to reach maize and monitor it for infestations	53.1

No. of response(s) per respondent ≥ 1

The most important attribute of the roof storage method to the farm households was that it helped them to store maize while drying it; whereas the sack storage method made it easy to reach maize and monitor it for infestations.

5.3.7 General capacity of roof and sack storage methods to protect stored maize against infestations

Only 7.4 % of the farm households considered the roof storage method as poor for protecting stored maize from infestations as opposed to a total of 53.4 % of the farm households who regarded the sack storage method as poor (Table 5.8).The general mean scores for roof and sack storage methods were 7out of 10 and 6 out of 10 after rounding off, which stood for 'good' and 'average', respectively. Thus, in general, the majority of the farm households perceived the roof storage method as a good method; while the sack storage method was perceived as an average storage method (Table 5.8).

Table 5.8: Farm households' perceptions concerning the general performance of the roof and sack storage methods to protect stored maize against infestations (n=260)

Roof storage method		Sack storage method	
Rating	**Percent of households**	**Rating**	**Percent of households**
Very poor	2.0	Very poor	5.4
Poor	5.4	Poor	48.0
Average	29.2	Average	30.0
Good	39.2	Good	11.2
Very good	24.2	Very Good	5.4

5.3.8 The farm households' rating of roof and sack storage methods with respect to their capacity to protect stored maize from insect pests, rodents and moulds

Generally, about 56 % of the farm households perceived the sack storage method as having a good capacity to protect stored maize against infestations (Table 5.9). More than 50 % of the farm households viewed the roof storage method as an excellent storage method for protecting stored maize against moulds; while more than 50 % had the view that it was not a good storage method as far as offering stored maize protection from rodents is concerned (Table 5.10). Only 13.5 % of the farm households had the view that the roof storage method did not offer stored maize protection against insect infestation, whereas more than 50 % of the farm households perceived the sack storage method "as not good" in relation to protecting stored maize from rodents.

Table 5.9: Sack storage method's rating: Farm households' perception concerning the capacity of the sack storage method to protect stored maize against infestation by insects, rodents and moulds (n=260)

Protection from rodents		Protection from insect pests		Protection from moulds	
Rating	**Percent of households**	**Rating**	**Percent of households**	**Rating**	**Percent of households**
Very poor	21.9	Very poor	6.5	Very poor	00.0
Poor	43.1	Poor	16.9	Poor	13.8
Good	29.6	Good	56.9	Good	54.6
Very good	4.6	Very good	15.1	Very good	18.5
Excellent	0.8	Excellent	4.6	Excellent	13.1

Table 5.10: Roof storage methods' capacity to protect stored maize against rodents, insect pests and moulds (n=260)

Protection from insect pests		Protection from moulds		Protection from rodents	
Rating	**Percent of farm households**	**Rating**	**Percent of farm households**	**Rating**	**Percent of farm households**
Very poor	1.2	Very poor	0.4	Very poor	19.6
Poor	12.3	Poor	0.0	Poor	33.8
Good	45.0	Good	8.9	Good	33.1
Very good	33.0	Very good	31.5	Very good	11.6
Excellent	8.5	Excellent	59.2	Excellent	1.9

In addition, less than one third of the farm households had the view that the sack storage method was not a good method for protecting stored maize against insect infestation; while only 13.8 % thought that the sack storage method offered stored maize poor protection against moulds. The mean scores for the performance the roof and sack storage methods based on the protection attributes on stored maize are presented in Table 5.11.

Table 5.11: Ranking and Scoring Matrix mean scores for the capacity of roof and sack storage methods to protect stored maize against pests

	Mean	Std. Deviation
Roof storage's capacity to protect stored maize against insects	6.71	1.692
Roof storage's capacity to protect stored maize against moulds	8.98	1.378
Roof storage's capacity to protect stored maize against rodents	4.85	1.986
Sack storage's capacity to protect stored maize against insects	5.88	1.749
Sack storage's capacity to protect stored maize against moulds	6.62	1.737
Sack storage's capacity to protect stored maize against rodents	4.38	1.715

After rounding off, the mean scores in Table 5.11 are equivalent to seven, nine, five, six, seven and four, respectively, and as indicated in Section 5.3.1, nine scores stood for 'very good', seven for 'good', six for 'average' and four - five for 'poor". Thus, in general, the farm households viewed the roof storage method as very good for protecting stored maize against moulds and also viewed it as good for protecting stored maize against insect pests, whereas they viewed the sack storage as good for protecting stored maize against moulds.

5.3.9 Persons responsible for selecting storage method and preparing/ building storage facilities in the farm households

For 64.6 % of the farm households the male household heads made decisions regarding the storage method which the farm household should use; while for 15.8 % of the farm households the responsibility of selecting the storage method which the farm household should use was upon female household heads. Also, for 58.4 % of the farm households the storage facilities were built or prepared by the male household heads. Other details regarding persons that were responsible for making decisions and building or preparing the storage facilities are as shown in Table 5.12 and 5.13.

Table 5.12: Person(s) in charge of selecting storage methods in the farm households (n=260)

Decision maker	Percent of the farm households
Female household head	15.8
Male household head	64.5
Male adult (elder son)	1.2
Female parent (Male headed household)	8.5
Both parents	10.0

Table 5.13: Person responsible for building or preparing the storage facility for the household (n=260)

Person(s) responsible for building/preparing the storage facility	Percent of the farm households for whom the specified person is applicable
Male household head	58.4
Female household head	16.2
Female parent (Male headed household)	6.5
Male adult (Elder son)	1.2
Both of the parents	17.7

5.4 Discussion

5.4.1 The implications of the characteristics of the buildings in which maize was stored on the performance of the storage facilities

Since the majority of the farm households that took part in this study stored maize in houses that they lived in, and the majority of the houses were made of mud bricks, the storage facilities in the houses were at risk of being attacked by the rodents. Rodents can easily make holes through the mud bricks thus, gain access to the maize stored in the roofs of the houses or in sacks. Thus, the materials that were used for building houses in Katumba ward determined the characteristics of the roof storage facilities and also contributed to influencing the performance of the roof and sack storage methods.

5.4.2 Characteristics and usage of roof and sack storage methods, and their effects on the quality of maize and household food security in Katumba ward

Although the wooden logs made it possible for the farm households to store maize securely in the roof storage facilities, two characteristics, namely: the mud bricks with which the majority of the farm households used to build the lower parts of the roof storage facilities and the thatched roofs which characterized 17.3 % of the houses in which the farm households stored maize, were loopholes for easy infestation of stored maize by rodents. The tendency for poor farmers in Africa to use storage methods that are inadequate to protect stored grain from rodents among other storage pests has been acknowledged (Payne, 2002). It is recommended that ways of equipping farm households in Katumba ward to improve the inadequacy of the storage structures be found.

Basically, in Rungwe district the roof storage method is a traditional technique which has been passed on from one generation to another, hence its use in Katumba ward. This perhaps contributes to the farm households' reluctance to build maize storage facilities separate from the living houses. When using the roof storage the farm households expect the heat from the firewood that they burn in the houses for routine cooking to help dry the maize. The roofs of the houses were constructed using iron sheets, and the majority of the farm households depended on the heat that comes up when the corrugated iron sheets got hot as a result of exposure to the sun to assist with the drying of the stored maize. However, the fact that it took more than two weeks for the entire group of farm households to dry maize after harvest implies that the sources of heat for the farm households that stored maize in the roof storage facilities was inadequate to dry the maize within the 48 hours that Semple *et al*. (1992) recommends. This can lead to fungal and insect infestations of the maize. Thus, the farm households need to be informed regarding the negative implications that the roof storage method could have on stored maize and they should be encouraged to adopt better maize storage methods. The government could help the farm households by making available the resources for construction of good quality storage structures.

The above scenario applies to the farm households that dried maize in the sun for more than two weeks prior to storing the maize using the sack storage method. The sack storage method is commended for helping stored grain to lose moisture through ventilation (De Groote, 2004), which would somehow assist in controlling moisture problems, insect infestations and mould infections. However, even where the farm households rightly placed maize sacks on top of planks to prevent maize from absorbing moisture from the floor, the characteristics of the materials from which the storage facilities were made have the capacity to allow moisture from the storage areas to enter into the storage facilities, which would impact negatively on the moisture content of the stored maize. The high humidity perpetrated by the prolonged wetness and cool temperatures that characterize Katumba ward (Anon, 2008) and the low quality of the houses in which the majority of the farm households lived and stored maize would naturally lead to the atmosphere in the houses being humid. Rungwe district receives rainfall throughout the year in a range of 800 mm in the low land areas and up to 2,700 mm in the areas with higher altitude such as where Katumba ward is situated, (Meoweather, 2009). During the 2009 harvest season minimum and maximum temperatures in Katumba ward were 11.1 ^{0}C and 17.8, respectively, in February, whereas in March minimum and maximum temperatures were 10.8 ^{0}C and 18.9 ^{0}C, respectively. On average, temperatures are coolest in May to July and slightly rises in August - December (Appendix 5.2) As a result, it took the farm households in Katumba ward longer to dry maize than recommended even where the roof of the house was made of corrugated iron sheets. The above would in turn create conditions favourable for growth of insect pests and moulds, which would have a negative impact on the quality of maize and household food security.

5.5.3 The influence of the form in which maize was stored on maize loss and on the length of time that it took the farm households to dry maize

It seems that for the majority of the farm households in Katumba ward the major concern was to get maize to dry while monitoring it for infestations. While the farm households who stored maize in the form of unshelled cobs without husks did so in order to easily monitor infestations and to assist the maize to dry faster, the fact that it took more than two weeks for the farm households to dry maize contradicts the farm households’ expectations. The practice of storing maize cobs in piles while they are not dry enough for storage has been identified as a risk factor which promotes fungal growth and mycotoxins contamination {Somali Agriculture Technical Group Training Guide (SATG), 2009}. Thus, the farm households’ practice of stacking maize cobs which are not dry enough for storage in the roof storage facilities exposed the maize to pests and mycotoxins contamination rather than protecting it. In general, storing maize in the form of unshelled cobs with husks is said to offer stored maize some protection from insect infestations (UNIFEM, 1995). However, as indicated above, the characteristics of the materials from which the storage facilities were made, the climatic conditions that are characterized with wetness in Katumba ward together with the fact that maize was not dry enough at harvest created conditions that encouraged infestations even on maize stored undehusked. There is also concern that maize cob storage promotes attack of the maize by *Prostephanus truncatus,* which prefer grain on cobs rather than shelled grain (Infonet-biovision, 2011), thus, causing greater damage and loss to the unshelled maize (FAO, 1994). Severe grain damage and loss of maize stored on cobs due to *P. truncatus* (Richter *et al*., 1997) and *S. cerealella* (Nepal Institute of Agriculture and Animal Science, 2006) were reported in Togo and Nepal, respectively. Thus, the practice of storing maize cobs in Katumba ward could attract attack of the maize by *P. truncates*. Finding an alternative method of drying maize prior to storage, and ensuring that maize is stored in the form of shelled grain could reduce the infestation prevalence for the farm households in Katumba ward.

5.4.4 Farm households' perceptions concerning roof and sack storage methods' capacity to protect stored maize from infestations

Perceptions by the majority of the farm households that both roof and sack storage methods offered stored maize poor protection against rodents can be due to the low quality of bricks that were used to build the houses in which the farm households stored maize. As indicated above, mud bricks are easy to break, thus, rodents can easily make holes through them and infest stored maize. Rodents do not only damage the maize kernels and make the infested maize susceptible to infestation by insect pests and moulds, but also make holes in the storage facilities, which in turn allow movement of moisture from outside into the storage facilities (De Groote, 2004). Thus, the use of the sack storage method for maize storage in mud brick houses exposes stored maize to rodent attack, which can lead to moisture content problems as well as insect and moulds infestations. Therefore, rodent proof structures that are sorely for maize storage are necessary for protecting stored maize from rodents in Katumba ward.

5.4.5 Key persons responsible for building or preparing the sack and roof storage technologies in Katumba ward

While more than half of the male household heads were the decision makers as far as selection of storage method was concerned, the total percentage of females who were also decision makers was less than one third of the overall percentage of the farm households that participated in this study. For more than 50 % of the households, males were involved in building or preparing the maize storage technologies, whereas less than 50 % of the females were involved in selecting the storage technologies. This was quite unbecoming considering the fact that women perform most of the activities involved with crop processing and storage in Rungwe district (Anon, 2008**).** For the improvement of maize storage in Katumba ward, all of the groups of people that play a role in selecting the storage method for use, building or preparing the storage facilities in the farm households in Katumba ward should be targeted. These include all of the male and female household heads, all of the female parents in male headed households and others such as male adults, where applicable.

5.5 Conclusions and recommendations

The ease of managing and monitoring stored maize for infestations was the main motivation for the use of the sack storage method by the farm households in Katumba ward. Most of the farm households in Katumba ward use the roof storage method in order to enhance drying of the maize while storing it at the same time. However, since the farm households depend on the heat produced by the fire that they light for routine cooking, the heat produced is inadequate for drying maize in the roofs. This can lead to development of moulds and insect pests in the maize. Furthermore, most of the farm households are aware that roof and sack storage methods expose stored maize to infestation by rodents, a problem which, as discussed above, was hastened by the low quality of the buildings in which the farm households stored maize.

Moreover, the farm households in Katumba ward viewed sack and roof storage methods as having ‘average’ and ‘good’ capacity to protect the stored maize from insect pests, respectively. While they wrongly regarded the roof storage method as having ‘excellent’ capacity to protect stored maize from fungal infections, they also believed that the sack storage method offered good protection of the stored maize against infestation by moulds. Farm households’ perceptions concerning the capacity of roof and sack storage methods to protect stored maize from moulds and insect pests would have a negative influence on the means that the farm households applied to fight against the pests. This put the farm households at risk of food insecurity and ill health. It is recommended that the government of Tanzania should make efforts to educate farm households on effective maize storage, the effects of pests on the quality of maize and health risks associated with consuming infested maize. The roof and sack storage methods in Katumba ward should be improved for better protection of stored maize against pests.

References

Anon, 2008. *Weather in Katumba* <*http://freemeteo.com/default.asp?pid=180lta=1&sid=639320&gid=151851&alls=2*> (Accessed 2008 August 01).

Bennett, J.W., Klich, M., 2003. Mycotoxins. *Clinical Mycrobiology Reviews* 16 (3): 497- 516.

Brooks, J.E., Fiedler, A., 1999. Chapter III Vertebrate Pests: Damage on Stored Foods. <http://www.fao.org/inpho/compend/text/ch03.htm> (Accessed 2009 August 14).

Danilo, J., 2003. *Maize Post- Harvest Operation chapter 4* <http://www.fao.org/inpho/content/compend/text/ch23_03.htm#TopOfPage> (Accessed 2010 February 2010).

De Groote, I., 2004. *Protection of Stored Grain and Pulses*, fourththed. Agromisa Foundaton, Wageningen.

FAO, 1994. Grain Storage techniques - Evolution and trends in Developing Countries. FAO, Rome.

FAO, 2001, Manual on the Application of the HACCP system in Mycotoxin Prevention and Control.

FAO, 2004. *Mycotoxin Regulations in 2004 and 2003 and current Developments*. <http://www.fao.org/docrep/007/y5499e07.htm#bm07> (Accessed 2010 August 02).

Infonet - Biodivision, 2010. *Storage Pests*. <http://www.infonetbiovision.org/default/ct/220/pests> (Accessed 2010 July 05).

Infonet - biodivision, 2011.*Larger Grain Borer (LGB).* <http://www.infonet-biodivision.org/default/ct/91/pests>. (Accessed 2011, September 01).

Israel, G. D., 1992. *Sampling the Evidence of Extension Program Impact.* <http://edis.ifas.ufl.edu/PD005> (Accessed 2008 July 19).

Lewis, D, Hahn, J. and Pelliteri, P. 2008. *Insect Pests of Stored Foods*. <www.extenxion.umn.edu/distribution/nutrition/dj1000.html> (Accessed 2010 January 21).

Meoweather, 2009. *Weather History fo Katumba, Mbeya, United Republic of Tanzania*. <http://www.meoweather.com/history/Tanzania,%20United%Republic%20of/na/-9.2333333/33.6166667/Katumba.html?speed=k4> (Accessed 2011, August, 21).

Nepal Institute of Agriculture and Animal Science, 2006. Efficacy of Indigenous Plant Materials and Modified Storage Structures to Insect Pests of Maize seed during on-farm Storage. *Journal of Institute of Agriculture and Animal Science*. 27, 69 - 76.

Pallant, J., 2005. *SPSS Survival Manual. A Step by Step Guide to Data Analysis using SPSS for Windows (Version 12),* second ed. Open University Press, Philadelphia.

Payne, T.S., 2002. *Harvest and Storage Management of Wheat*. <http://www.fao.org/docrep/006/y40iieou.htm> (Accessed 2010 December 21).

Pitt, J.I., 2000. Toxigenic Fungi and Mycotoxins. *British Medical Bulletin*. 56, 1, 184 - 92.

Pitt, J., Hocking, A.D., 2009. *Fungi and Food Spoilage*, third ed. Springer, New York.

Richter, J, Biliwa, A., Henning-Helbig, S., 1997. Losses and Pest Infestation in Different Maize Storage Systems with Particular Emphasis on *Prostephanus truncatus* (Horn) (Col. Bstrichidae) in Togo. ANZEIGER FÜR SCHÄDLINGSKUNDE. 70, 6, 112-116.

Sallam, M.N., 1999. *Chapter II Insect Damage on Post-harvest.* <http://www.fao.org/inpho/content/compend/text/ch02.htm> (Acessed 2010 January 22).

SATG, 2009. Post-Harvest and Grain Storage Losses: Training Module. SATG: Somalia.

Semple, R.I., Hichs, P.A., Lozare, J.V., Castermans, A., 1992. *Towards Integrated Community and Pest Management in Grain Storage*. <http://www.fao.org/inpho/content/documents/vlibrary/x00484/x0048E00.htm> (Accessed 2009 December 18).

Thamaga- Chitja, J.M., Hendriks, S.L., Ortmann, G.F. and Green, M.G., 2004. Impact of maize storage on rural household food security in Northern KwaZulu-Natal. *Journal of Family* Ecology and Consumer Sciences, 32: 8 - 15.

Wood, G.E., Trucksess, M.W and Henry, S.H, 2003. Major Fungal Toxins of Regulatory Concern. In Miliotis, M.D. and Bier, J.W., *International Handbook of Foodborne Pathogens*. Marcel Dekker, New York.423 - 443.

APPENDICES

Appendix 5.1: The questionnaire which was used to gather the required information for the study

1.What is the type of your main house?

(i) Round hut with thatched roof (ii) Multiple rooms made of mud bricks, with thatched roof (iii) Multiple rooms made of mud bricks with corrugated iron roof (iv) Multiple rooms made of cement bricks with corrugated iron roof (v) Multiple rooms made of baked mud bricks with corrugated iron roof (vi) Other (specify)-----------------------

2. What is the lower part of the roof of your house made of? ---------------------------------

3. In which house do you store maize? (a) main house (b) Kitchen separate from the main house (c) Other (specify)---------------------------------------

4. If you use roof or sack storage method for storing maize, where do you store them after filling them with maize? (a) On the floor (b) On top of planks (c) Other (specify) --------------------------
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5. If you use roof or sack storage method to store maize, why do you use the particular storage method?--
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6. If you store maize using the sack storage method, what are the sacks that you use made of?

7. Is maize dry enough for storage at harvest? -----------------------------

8. If maize is not dry enough at harvest, how do you dry it?

9. In what form do you store your maize?

Maize form	**Why do you store maize in the storage form you have indicated?**
Shelled grain	
Unshelled without husks	
Unshelled with husks	
Other (specify)-------------------------------	

10. Which of the following storage methods do you consider very good, good, poor or very poor with respect to providing stored maize with the indicated protection? (To answer this question

place a sticker with number ten on it for the best storage method, a sticker with number nine or eight on it for a very good storage method, a sticker with number seven for a good storage method, six for an average storage method, five or four for a poor storage method and a sticker with number three, two or one on a very poor storage method).

Storage method	**Protection against insects**	**Protection against moulds**	**Protection against rodents**
Sack storage			
Roof storage			

11. What are the advantages of the storage method if you have ranked it as very good or good in your answer to question 10?

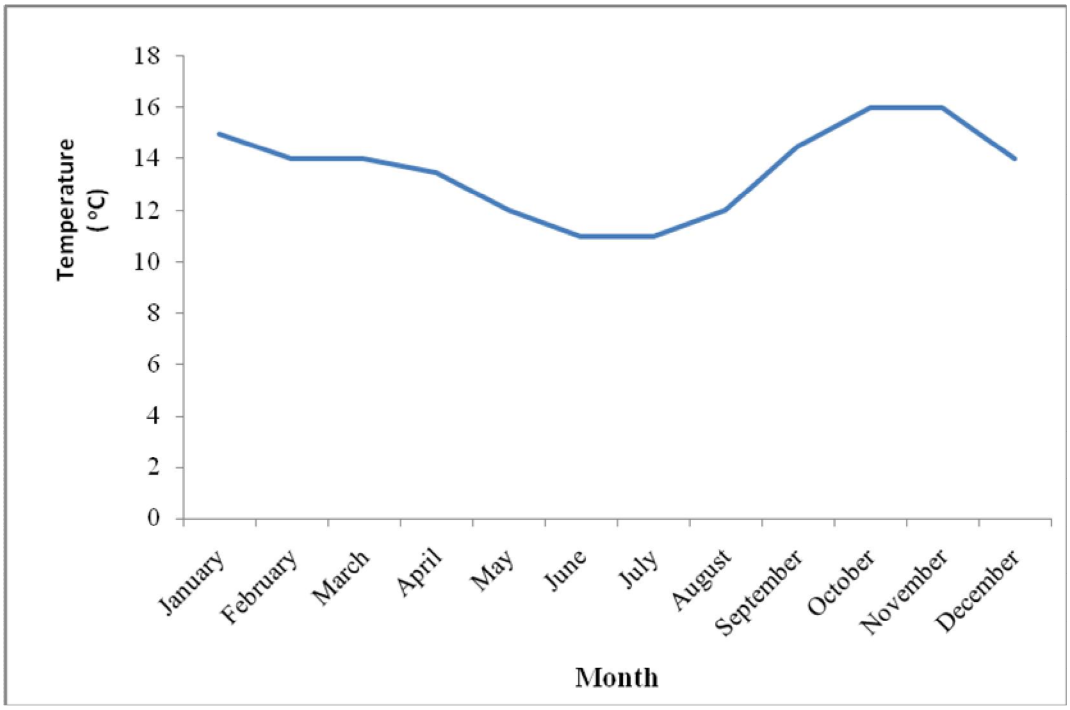
Storage method	**Advantages**
Sack storage method	
Roof storage method	

12. In your household, whose responsibility is it to select storage method for use?

(a) Household head (b) Male adult other than household head (c) Female adult other than household head (d) Other (specify) ---

13. In your household, who is responsible for building or preparing the storage facilities for storing maize?(a) Household head (b) Male adult other than household head (c) Female adult other than household head (d) Other (specify)---

Appendix 5.2: Average temperatures for Katumba ward in 2009



Source: Meoweather, 2009

CHAPTER SIX

THE EFFECTS OF LEVELS OF FUNGAL INFECTION AND MYCOTOXIN CONTAMINATION ON THE QUALITY OF MAIZE STORED USING ROOF AND SACK STORAGE METHODS IN RUNGWE DISTRICT, TANZANIA

Abstract

The quality of maize was studied through conducting mycological analysis on 130 maize samples collected from a sample of 130 farm households that participated in this study in Katumba ward, Rungwe district, Tanzania. The study was conducted by investigating the presence of *Fusarium*, *Aspergillus* and *Penicillium* species and by studying the levels of the corresponding mycotoxins using qualitative and quantitative methods on a sub-sample of 77 maize samples that developed more fungal colonies than the others. About 86 % of the maize samples studied were infected by one, two or three types of the pathogenic fungi investigated and 88 % of the sub-samples of maize were contaminated by one, two or three of the following mycotoxins: fumonisins, aflatoxins, ochratoxins and T-2 toxins. All of the maize samples that had been collected from the sack storage facilities were contaminated by the mycotoxins, 83 % of the sub- samples of maize that had been collected from the roof storage facilities were also contaminated by the mycotoxins. The quantities of mycotoxins in the maize samples ranged from 0 - 354 mg/kg fumonisins, 0 - 1 mg/kg aflatoxins, 0 - 3 mg/kg ochratoxins and 0 - 62 mg/kg T-2 toxins. The means for the quantities of fumonisins, aflatoxins, ochratoxins and T-2 toxins were 87 mg/kg, 0.6 mg/kg, 0.7 mg/kg and 2 mg/kg, respectively. While there are no set standards for T-2 toxins, the amounts of aflatoxins, fumonisins and ochratoxins were a lot higher than the internationally accepted levels per kg of maize, namely: 20 µg/kg for aflatoxins, 4 mg/kg for fumonisins and up to 50 µg/kg for ochratoxins. It was concluded that in Katumba ward, maize stored using roof and sack storage methods was exposed to infection by *Fusarium*, *Aspergillus* and *Penicillium* species, and that the farm households were at risk of ill health due to the unacceptable levels of mycotoxins. It was recommended that ways of ensuring that maize stored using sack and roof storage method in Katumba ward is free from infection by moulds be implemented.

Key words: Maize, Storage, Quality, Fungi, Mycotoxins

6.1 Introduction

In Katumba ward, farm households stored maize using the roof and sack storage methods (Chapter Four, Section 4.3.1), and consumed an average of one kg and a minimum of 500 g of maize flour per meal (Chapter Three, Section 3.3.3.1). The farm households preferred maize meals such that two out of three meals that the farm households consumed in at least six days per week were made from maize (Chapter Three, Section 3.3.2.3). Although maize is such an important staple food crop in Rungwe district, its quality with respect to it being free from pathogenic fungi and mycotoxins has never been studied before in this district. The study of the quality of maize in Katumba ward is expected to shed light on the quality of maize in Rungwe district in general. Reports show that maize is susceptible to fungal infection especially under favourable conditions such as high humidity, inadequate storage technologies and insect activity, which are known to increase the moisture content of maize (Chelkowski *et al.,* 2007; Tachin, 2008; Weinberg *et al.,* 2008; Williams, 2004). In general, the whole of Rungwe district is characterized by climatic conditions such as rainfall throughout the year, ranging from 900 mm to 2,700 mm and cool temperatures ranging from 10 ^{0}C to 25 ^{0}C (Anon, 2008; Administrator, 2010), which are known to promote fungal infection of maize grain.

Fusarium, *Penicillium* and *Aspergillus* species have been identified as the most important fungi that attack stored maize, and have been associated with production of mycotoxins that can cause serious health problems to both human beings and animals (Sweeney *et al*., 2000; Montes *et al*., 2009) and reduction of the nutrient content of maize (Jood *et al*., 1992). These facts raised questions regarding the quality of maize stored using roof and sack storage methods in Katumba ward in terms of its nutritional value, the degree to which it was safe for consumption and its implications on household food security.

The interest in this study was on moulds that attack stored maize and produce mycotoxins that are harmful to both humans and animals, thus, mycotoxins produced by *Fusarium*, *Aspergillus* and *Penicillium* species were studied in maize grain that was collected from farm households in Katumba ward. The mycotoxins produced by the named fungi include fumonisins which are produced by *Fusarium* species (Cousin *et al*., 2005; Arora, 2004; Wood *et al*., 2003), especially *F. verticillioides* (synonym *F. moniliforme*) and *F. proliferatum* (Öhlinger *et al*., 2004)and aflatoxins which are produced mainly by the following *Aspergillus* species: *A. flavus*, *A. parasiticus* (Cousin *et al.*, 2005; Pitt, 2000), *A. nomius* (Sweeney *et al.*, 2000; Wood *et al.*, 2003), *A. ochraceoroceus*, *A. pseudotamari* (Bennet and Klich, 2003) and *A. bomycis* (Peterson *et al.*,2001). Ochratoxins are mainly produced by *Penicillium* species and some *Aspergillus* species (Wood *et al.*, 2003) such as *A. niger*, *A. carboinarius*, and *A. ochraceous* (Cousin *et al*., 2005; Bennett and Klich 2003, Pitt, 2000); whereas T-2 toxins are also produced by *Fusarium* species(Pitt, 2000). Whether all of these fungal species occur in parts of Tanzania is not known. However, in 2005 fumonisins and aflatoxins were found in maize samples from Ruvuma, Iringa and Kilimanjaro regions in Tanzania, which imply that *Aspergillus* and *Fusarium* species that produce aflatoxins, and fumonisins respectively, occurred in these regions.

Fumonisins are specifically associated with cancer of the esophagus (Pitt 2000), T-2 toxins are associated with aleukia, a disease of the alimentary canal (Pitt, 2000), aflatoxins are particularly associated with cancer of the liver (Munkvold *et al.*, 2009; Wood *et al.*, 2003) and ochratoxins are associated with kidney problems (Hayes, 2001). While there are no set acceptable standards for T-2 toxins in maize, the international regulatory limits for fumonisins and aflatoxins are 4 mg/kg (Wu, 2004) and 20 µg/kg (Munkvold *et al*., 2009), respectively. Different countries have set different acceptable levels of ochratoxins in cereals, and 50 µg/kg is the highest acceptable level for a number of countries (The Food and Agriculture Organization of the United Nations (FAO), 2004). The above implies that levels above 50 µg/kg ochratoxins in maize may be harmful to consumers.

6.1.1 Main objective

To examine the quality of maize stored using sack and roof storage methods in Katumba ward, Rungwe district, Tanzania, and its implication on household food security.

6.1.2 Specific objective

To investigate the presence of *Fusarium*, *Penicillium*, and *Aspergillus* and the mycotoxins that these fungal species produce in maize samples from farm households in Katumba ward, Rungwe district, Tanzania and their implication on the quality of maize and household food security.

6.2 Materials and methods

Both qualitative and quantitative methods were employed in this study using structured face to face interviews and Laboratory tests. Agar methods commonly used in laboratories such as the mid-West Seed Services laboratory (2006), and also recommended by Neergaard (1977) for testing health of seeds was applied during isolation and identification of fungi. Unlike other mycological methods such as blotter methods, this agar method is said to be relatively faster thus, less time consuming (Mid- West Seed Services laboratory, 2006). The mycological analysis for *Fusarium, Penicillium,* and *Aspergillus* species required the use of maize samples that were collected from the research areas. The maize samples for these studies were sampled as follows:

6.2.1 Sampling of maize sample units

Maize sample units for mycological analysis were collected from a sub-sample of 130 households drawn from 260 farm households using the procedure described in Chapter Four, Section 4.2.2, whereas the maize samples were randomly collected through the procedure descibed in Chapter Four, Section 4.2.2. A larger proportion of the farm households stored maize using the roof storage method than the sack storage method (Section 6.1), thus,88 out of the 130 maize samples were collected from the roof storage facilities, whereas 42 were collected from the sack storage facilities. The types of maize varieties that the farm households were in possession of at the time of the study determined the number of maize samples per variety collected, thus,87 out of the 130 maize samples were of the improved varieties, 43 were of the indigenous types.

6. 2. 2 Preparation of the maize samples for mycological analysis

Each of the maize samples was mixed thoroughly followed by randomly sub- sampling two cups[8] from each of the samples. The sub- samples of maize were ground by coarsely pounding each of the maize samples using a pestle and mortar and then transferring the coarsely ground maize into a blender for finer grinding. The apparatus used in the grinding process were washed thoroughly with a dish - washing liquid followed by 3.5 % sodium hypochlorite solution before grinding each maize sample. This was done in order to minimize chances of contamination between the maize samples. After washing, the drying of the grinding facilities was facilitated by the use a

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[8]One cup of dry maize is equivalent to 250 g

clean cloth and a dry paper towel. Each of the ground maize samples was transferred into zip-lock plastic bag, labeled and stored in a cold room below 5 ^{0}C.

6.2.3 Preparation of maize sample dilutions for mycological analysis

The maize samples dilutions were prepared using the procedure described by Machin (2003). Thus, eight McCathy bottles for each maize sample were prepared for each maize sample and autoclaved for 15 minutes at 121 ^{0}C. After completion of the autoclaving, the distilled water was allowed to cool overnight then for each maize sample one gram of ground maize was added to the first McCathy bottle followed by gently swirling the mixture to form a homogenous solution. Serial dilutions (10$^{-7)}$ were made for each maize sample**.**

6.2.4 Pre-test for identifying the best medium for mycological analysis of the maize samples

A pre- test was done prior to conducting mycological analysis for the study of fungi in the maize samples. The pre-test was performed in order to identify the best medium and dilution that should be used for the study.

6.2.4 .1 Method

In general, the manufacturer's instructions (Merck Laboratories) were followed when preparing the media. Serial dilutions (10^{1}-10^{7}) for each maize sample were plated on Malt Extract Agar (MEA) and Potato Dextrose Agar (PDA) using the sterile spread plate technique. Two replicate plates were made for each maize sample. Plates were incubated at 28 ^{0}C and monitored each day for five days and the colonies that developed were counted. The medium that allowed development of more colonies of fungi than the other was considered to be the best medium. On the other hand, the dilution that constantly produced less than 100 colonies per petri dish was selected for ease of counting the colonies.

6.2.4.2 Pre-test results

Fungal colonies grew from all dilutions on the PDA plates, whereas no colonies grew at 10^{7}dilution on MEA plates. Sample dilution 10^{-6}on both PDA and MEA constantly formed colonies that were well dispersed thus, could be counted. Thus, dilution 10^{-6} of each sample and PDA were selected for growing fungi from the maize samples.

6.2.5 Studying the presence of *Penicillium*, *Aspergillus* and *Fusarium* species in the maize samples

A qualitative study was carried out in order to study the presence of fungi on 130 freshly harvested maize samples from Katumba ward, Rungwe district, Tanzania. The study was repeated on another 130 maize samples that were collected after the farm households had stored maize for five months.

6.2.5.1 Methodused for preparation of medium

As per manufacturer's instructions, (Merck Laboratories), 39 g of PDA were dissolved in one litre of distilled water in a two litre flask. The flask containing the mixture was covered with cotton wool and aluminium foil and autoclaved for 15 minutes at 121 ^{0}C. Upon completion of autoclaving, the media was allowed to cool to 45 ^{0}C, before pouring it into 90 mm diameter Petri dishes. The media was allowed to set for 48 hours and after the agar had set, three replicate plates of the sample dilution (10^{-6}) were made by plating 1 ml of the sample dilution onto the PDA medium using the sterile plate techniques. The plates were incubated at 28 ^{0}C for 7 days.

The plates were monitored daily for growth of fungal colonies and changes were recorded. Fungal colonies were observed under the light microscope using a wet mount for morphological characteristics of *Penicillium*, *Fusarium* and *Aspergillus* in order to confirm their presence in the maize samples. The procedure for the identification of fungi was repeated for the 130 maize samples that were collected after the sample households had stored maize for five months. *Fusarium* species took longer time to grow on PDA than *Penicillium* and *Aspergillus* species. In order to maximize the growth of *Fusarium* species the maize samples were further studied for the presence of the *Fusarium* species using the *Fusarium* selective media originally prescribed by Nash and Snyder (1962). The media was then poured into the petri dishes and allowed to set for 48 hours. After the agar had set, three replicate plates of the sample dilution (10^{-6}) were made by plating one millilitre of the sample dilution onto the *Fusarium* selective medium using sterile spread plate techniques. The plates were incubated at 28 ^{0}C for seven days. The following characteristics were used to confirm the presence of *Fusarium*, *Penicillium,* and *Aspergillus* species in the maize samples:

6.2.5.2 Criteria for identifying the presence of *Fusarium* species

Colonies: Fruity smell or no smell, hyaline and cotton like (Pitt and Hocking, 2009) initially white, turning dull, pale pink, pale purple or red, white, with maturity, or white throughout. Under the microscope: macroconidia are septate, straight or slightly curved to form sickle like shapes (Moss and Smith, 1982).

6.2.5.3 Criteria for identifying the presence of *Penicillium* species

Colonies are filamentous or powdery, grow rapidly, and are cotton like in texture. Colonies are initially white in colour but turn blue green with maturity (De Hoog *et al.*, 2000). Under the light microscope long conidiophores with broom like structures carrying chains of round or spherical conidia at the tips are seen. Conidia resemble glass beads (De Hoog *et al.*, 2000).

6.2.5.4 Criteria for identifying the presence of *Aspergillus* species

Colonies appear as powdery masses of pale or dark yellow green or pale yellow colonies that turn brown to black with maturity. Under the microscope globose fruiting bodies that carry flask shaped phialides which may be attached directly to the versicles or via a supporting cell are seen (Eltem *et al.* 2003). Chains of conidia are formed on the phialides. *Aspergillus* species were also identified by their mouldy smell as described by Eltem *et al.* (2003).

After confirming the presence of *Fusarium, Penicillium,* and *Aspergillus* species in the maize samples, these fungal species were further studied with respect to the mycotoxins that they produce. Of interest to this study were the mycotoxins that have been confirmed to affect both animals and human beings, thus, fumonisins (Miliotis and Bier 2003) and T- 2 toxins (Pitt, 2000) both produced by *Fusarium* species. Other mycotoxins of interest to this study include ochratoxins which are mainly produced by *Penicillium* species and some *Aspergillus* species such as *A. carbonarius* and *A. niger* (Bennett and Klich, 2003, Pitt, 2000), and aflatoxins which are produced by *Aspergillus* spp. (Pitt, 2000). The mycotoxins were investigated using Elisa kits.

6.2.6 Tests for mycotoxins in the maize samples

Due to limited budget only the sub- samples of maize that had formed more colonies than the others and those which were found to be infected with two or three out of the three species of fungi of interest to this study were selected for further investigation. Thus, 77 out of the 112 maize samples that were found to be infested with the pathogenic fungi were further studied with respect to the quantities of mycotoxins in them. Seventy seven maize samples equal 68.8 % of the infected maize samples, and was a good representative of the maize samples.

The number of maize samples that were tested for a particular mycotoxin depended upon the number of maize samples that each Elisa kit could accommodate. Thus, 38 maize samples that had more *Fusarium* colonies than the others were selected for the study of fumonisins and T-2 toxins. Likewise, 38 maize samples were tested for levels of ochratoxins and 40 maize samples were tested for levels of aflatoxins. Some of the maize samples were tested for the presence of more than one type of mycotoxin. Thus, in general a total number of 154 tests were conducted on the specified sub- samples of maize for the study of the indicated mycotoxins.

Thirty two out of the 40 maize samples that were tested for the presence of aflatoxins had been taken from the roof facilities, and eight from the sack storage facilities. Likewise, out of the 38 maize samples that were studied for the presence of fumonisins and T-2 toxins, 25 were collected from the roof storage facilities and 13 were collected from the sack storage facilities. Moreover, 30 out of the 38 maize samples that were studied for the presence of ochratoxins were taken from the roof storage facilities and 8 out of 38 were collected from the sack storage facilities. Altogether, 56 out of the 77 maize samples that were studied for the levels of mycotoxins had been collected from roof storage facilities and 21 had been collected from sack storage facilities. Prior to the tests, the maize samples were brought to room temperature at 25 ^{0}C followed by extracting solutions from them using methanol as shown in section 6.2.7.

The selection of the 77 maize samples studied for levels of mycotoxin contamination was based on the understanding that only maize which infected by fungi has potential for mycotoxin contamination. However, mere fungal infection does not necessarily mean that the maize is contaminated by mycotoxins. Thus some kind of purposeful sampling was necessary in order to identify maize samples that may be contaminated. Purposeful sampling is acceptable for in depth study of cases that have potential to provide greater knowledge of issues of central importance to the purpose of the research than others, and the cases are selected based on the degree to which they meet specific criteria (Patton, 2001).In this study maize samples that made more fungi colonies than the others, and those that were infected by more than one type of mycotoxin were considered as having potential for being contaminated by mycotoxins, hence their selection. The maize samples were gathered from the same 130 randomly selected maize samples studied for fungal infection, thus the results were expected to be reliable.

6.2.7 The procedure for obtaining maize sample extracts

Methanol, which is one of the most commonly used extraction solvents (FAO, 1989) was used for the extraction of sample extracts from maize. The sample extracts for quantification of fumonisins, T-2 toxins and aflatoxins were prepared by adding 3 g of ground sample to 15 ml of 70 %[9] methanol solution (Neogen Corporation, 2009 a, 2009 b), while the sample extracts for quantifying ochratoxins in the maize samples were prepared by adding two grams of ground sample to 8 ml of 50 %[10] methanol solution (Neogen Corporation, 2008). Prior to extraction each of the ground maize samples was mixed thoroughly followed by weighing the required amount of the sample. The mixture in each of the bottles was shaken vigorously for three minutes and filtered using 99 mm Whatman # 1 filter paper. 100μl of each maize sample extract was used for the mycotoxins assay.

6.2.8 Quantification of fumonisins, aflatoxins, ochratoxins and T-2 toxins

The concentration of aflatoxins, fumonisins, ochratoxins and T-2 toxins in the maize sample extracts was determined by direct competitive enzyme-kits supplied by Neogen Corporation. The procedure followed for analysis and quantification of the various mycotoxins was as described by the kits' manufacturer (Neogen Corporation, 2007, 2008, 2009 a, 2009 b). The reactions between the antibodies and the mycotoxins in the maize sample extracts produced a blue colour, the intensity of which was read using a microplate reader with a 650 nm filter at room temperature.

Graphs plotted using the values for the mycotoxins concentrations in the control samples against the corresponding wavelengths in order to obtain the equations for calculating concentrations of mycotoxins in the maize samples (Appendix 6.1). Two strips were used for each mycotoxin test, and the microplate readings for the strips differed significantly, therefore, two graphs for each

[9] 70 % methanol solution was prepared by mixing seven parts of methanol with three parts of sterile distilled water.
[10] 50 % methanol solution was prepared by mixing one part of methanol with one part of sterile distilled water

type of mycotoxins tested were plotted. In order to achieve the highest degree of linearity the graphs for studying the concentration of aflatoxins, T-2 and ochratoxins were plotted using values of the concentrations of the mycotoxins concerned in the form of logarithm to the base ten ($\log_{10}$)[11] followed by converting the $\log_{10}$ values into their respective antilog_{10} values. The equations in Table 5.1 were obtained from the graphs in Appendix 6.1:

Table 6.1: Equations obtained from plot graphs of concentration of mycotoxins in the control samples against the corresponding wavelengths

Type of mycotoxin studied	Equation from the first strip control sample extracts	Equation from the second strip control sample extracts
Fumonisins	y = -1.885*x* + 1.901	y = -1.6078*x* + 1.737
Aflatoxins	y = -0.907*x* + 2.01	y = -201*x* + 2.530
T-2 toxins	y = -1.880*x* + 3.608	y = -1.73*x* + 3.679
Ochratoxins	y = -1.0561x + 1.959	y = -0.648*x* + 1.629

In the equations, 'y' stands for the concentration of fumonisins; aflatoxins, ochratoxins or T-2 toxins, while *x* stands for the wavelengths corresponding to the concentration of the mycotoxins in the control samples. The estimated quantities of fumonisins, aflatoxins, ochratoxins and T-2 toxins in the maize sample extracts were calculated by replacing '*x*' in the above equations with the wavelength value obtained from the microplate reader for each maize sample extract. The maize sample extracts for quantifying aflatoxins, fumonisins and T-2 toxins were derived from only three grams of each of the maize samples tested, while the sample extracts for quantifying ochratoxins were derived from only two grams of each of the maize samples tested. Thus, the equations in Table 6.1 were used for calculating the estimated concentrations of fumonisins, aflatoxins and T-2 toxins, respectively, per three grams of maize, while the estimated concentration of ochratoxins was calculated per two grams of maize. The values that resulted from the calculations were used to calculate the estimated quantities of the mycotoxins per kg (µg/kg) of each maize sample. Imagining that the quantities of fumonisins, aflatoxins and T-2 per

[11] The values for the concentration of the mycotoxins were a lot bigger than the values for the corresponding wavelengths, thus, $\log_{10}$ of the values of the concentration of the mycotoxins were used for more accuracy with respect to obtaining the required equations and for the ease of plotting the graphs.

three grams of each maize sample that were tested was equal to ‘*x*’, the quantity of the mycotoxins per kg of each of the maize samples was calculated as follows:

$$x \equiv 3\text{g of maize}$$

$$\frac{x}{3}\ \mu\text{g} \equiv 1\ \text{g of maize}$$

$$\frac{x}{3}\ \mu\text{g} \times 1000 \equiv 1\ \text{kg of maize}$$

The same procedure was followed to estimate the concentration of ochratoxins per two grams of maize.

6.2.9 Statistical analyses

By using the Statistical Package for Social Sciences (SPSS) version 15, frequency counts, percentiles, means, minimum and maximum values, and standard deviations were obtained in order to study the quantities of maize samples that were infested by *Fusarium*, *Aspergillus* and *Penicillium* species and those which were contaminated by the mycotoxins they produce. Since the maize samples for the study were collected from the sack and roof storage facilities, cross tabulations and the independent samples T-tests were performed to study their performance of the sack and roof storage methodsby comparing means for the quantities of mycotoxins in maize samples that were collected from the roof and sack storage facilities. The Chi-square test was performed to compare the ratios of mycotoxin contaminated maize samples from each of the storage facilities and between maize stored in various forms. One way between groups ANOVA tests were performed to compare the mean quantities of mycotoxins in maize inrelation to the different forms in which maize was stored. Part of the outputs for the statistical analyses is shown in Appendix 6.2 - 6.6.

6.3 Results

Only 3.8 % of the maize samples that collected from the farm households at harvest were found to be infected by the pathogenic moulds compared to 86.2 % of the maize samples collected after five months of maize storage. Thus 82.3 % maize samples were infected during storage.

6.3.1 Types of pathogenic fungi in the maize samples

The number of fungi colonies in the infected maize samples collected at harvest and after five months of storage ranged from 0 - 23 and 0 - 99, respectively. For the maize samples collected after five months of storage period, the percentage of maize samples that showed concurrent presence of *Fusarium, Aspergillus* and *Penicillium s*pecies was the highest compared to the number of maize samples that had one or two pathogenic fungi each (Figure 6.1).

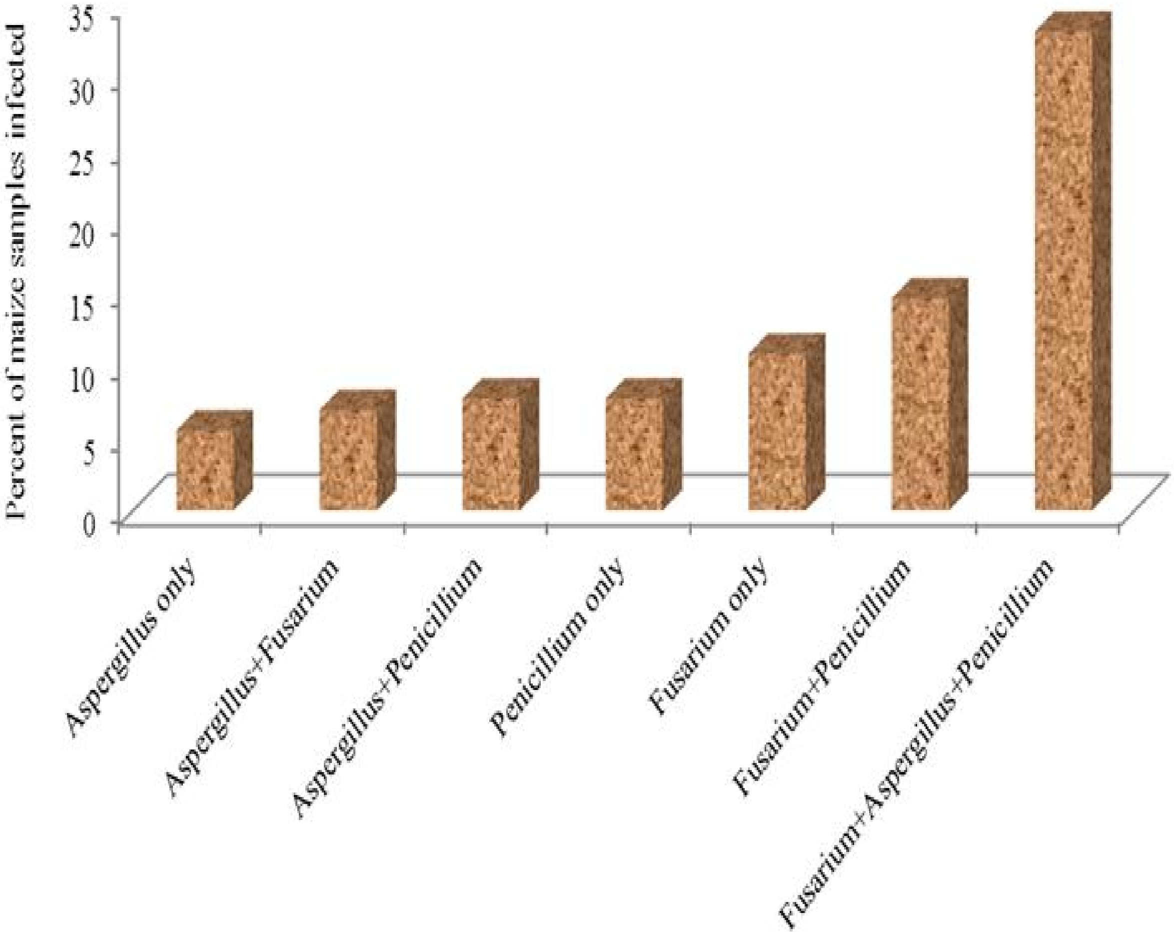


Figure 6.1: Types of pathogenic fungi identified in the maize samples

Examples of the colonies that were observed in the plated petri dishes are shown in Figure 6.2, while the morphological characteristics of the moulds as observed under the microscope are shown in Figure 6.3 - 6.6.

Aspergillus + other spp

Fusarium + other spp

Penicillium spp

Fusarium spp

Figure 6.2: Fungi colonies observed in the maize samples

Figure 6.3: *Fusarium* conidia viewed under the light microscope

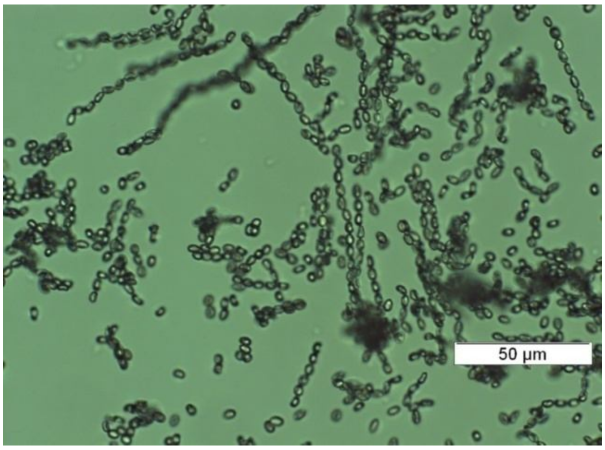


Figure 6.4: ***Penicillium*** **spores viewed under the light microscope**

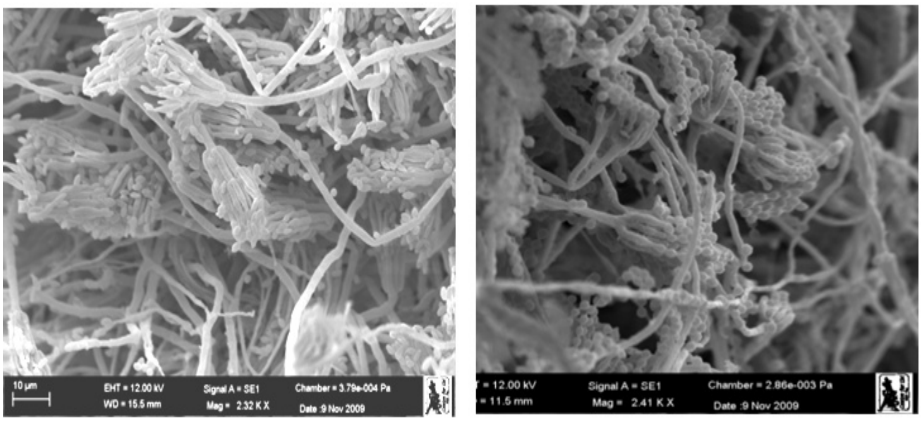


Figure 6.5: ***Penicillium*** **species viewed under the electronic microscope**

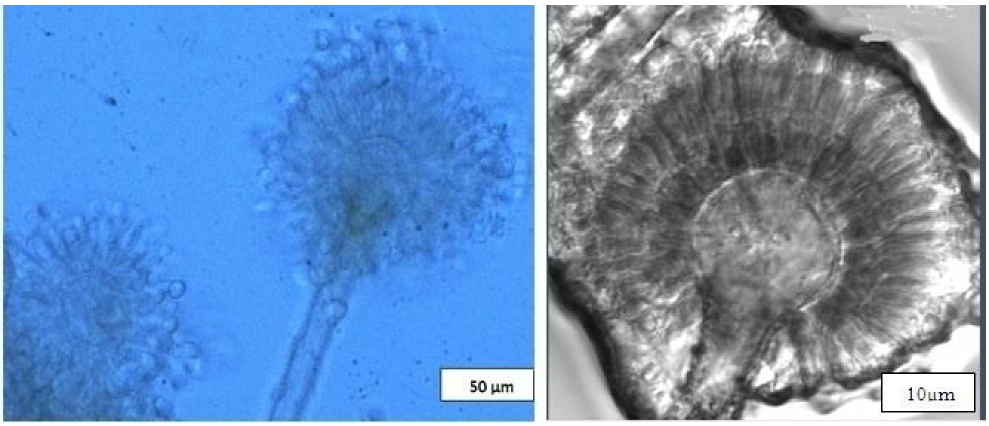


Figure 6.6: ***Aspergillus*** **species viewed under the light microscope (left) and the Zeis LSM 710 (Confocal) DIC imager (right)**

6.3.2 Further morphological and molecular identification of fungal species

Further morphological and molecular identification of the fungal species conducted by the Biosystematics Division, Mycology Unit of the Agricultural Research Council-Plant Protection Research Institute (ARC), Pretoria, South Africa, confirmed the presence of the following species in the maize samples:

1. *Aspergillus ochraceus* G. Wilh
2. *Aspergillus parasiticus* Speare
3. *Penicillium waksmanii* K.M. Zalessky
4. *Penicillium oxalicum* Currie & Thom
5. *Penicillium decumbens* Thom
5. *Penicillium raistikii* G. Sm
6. *Penicillium verruculosum* Peyronel
7. *Fusarium verticillioides (sacc)*
8. *Fusarium subglutinans* (Wollenweber. and Reinking) P.E. Nelson, Toussoun and Marasas

6.3.3 Storage facilities where the infected maize samples were collected

While 86.36 % of the maize samples that were collected from the roof storage facilities were infected by the pathogenic fungi of interest to this study, 85.71 % of the maize samples that were collected from the sack storage facilities were also infected by the fungi. Likewise, 31.82 % of the maize samples from the roof storage facilities were infected by all of the three types of the pathogenic fungi studied compared to 35 % of the maize samples from the sack storage facilities which were also infested by all of the three types of fungi. The performance of the roof and sack storage facilities with respect to the rest of the maize samples is shown in Table 6.2.

A chi-square test ($\alpha>0.05$) revealed that there was no significant difference between the proportions of the infected maize samples to the uninfected ones for the maize samples collected from the roof and sack storage facilities.

Table 6.2: Proliferation of fungi in the infested maize samples collected from the roof and sack storage facilities (n=130)

Number of types of fungi in the maize samples	**Percent of infected maize samples from the roof storage facilities** (n=88)	**Percent of infected maize samples from the sack storage facilities** (n=43)
Not infested	13.64	14.29
One type	20.45	30.95
Two types	34.09	19.05
Three types	31.82	35.71
Total	86.36	85.71

Each maize sample represents a specific farm household

6.3.4 Percentage of the indigenous types and improved varieties of maize infected by the pathogenic fungi

It was found that 97.67 % of the maize samples of the indigenous types were infected by the pathogenic fungi and 90.7 % of the maize samples of the improved varieties were also infected by the fungi.

6.3.5 Types of fungi that infected maize and maize form

Maize stored in the form of cobs without husks had the highest incidence of concurrent infection by *Fusarium*, *Aspergillus* and *Penicillium*, followed by maize stored in the form of cobs without husks and later stored in the form of shelled grain (Table 6.3). However, the Chi - square tests showed that there was no significant difference between the proportions of maize samples infected by each of the three types of fungi or by combinations of the fungi in the various maize forms.

Table 6.3: Maize form and types of pathogenic moulds that infected the maize (n=112)

Types of moulds	Percent of farm households that stored maize in the specific form						
	Shelled grain	**Unshelled without husks**	**Unshelled with husks**	**Unshelled without husks, later shelled**	**Unshelled with husks, later shelled**	**Some unshelled without husks, some with husks, later shelled**	**Total**
Aspergillus only	0.0	1.8	0.0	1.8	1.8	1.6	7.0
Fusarium only	1.8	1.8	4.4	3.5	0.9	0.8	13.2
Penicillium only	0.0	1.8	0.9	3.5	1.8	1.6	9.6
Aspergillus + *Penicillium*	0.9	2.7	0.9	3.5	0.0	0.0	8.0
Aspergillus + *Fusarium*	0.9	3.5	0.9	1.8	0.9	0.8	8.8
Fusarium + *Penicillium*	0.9	4.5	3.5	5.4	2.6	2.3	19.1
Aspergillus + *Fusarium* + *Penicillium*	0.9	13.4	7.0	9.8	1.8	1.6	34.5
Total	5.4	29.4	17.6	29.2	9.7	8.7	100.0

6.3.6 The number of maize samples contaminated by mycotoxins

The findings revealed that 68.4 % of the 38 maize sample extracts that were studied for the presence of fumonisins and T-2 toxins were contaminated by fumonisin, whereas 94.7 % were contaminated by T-2 toxins. About 55 % of the 40 maize sample extracts that were studied for the presence of aflatoxins were contaminated and 76.3 % of the 38 maize sample extracts that were studied for the presence of ochratoxins were contaminated by this particular mycotoxin. The number of the different types of mycotoxins that were found in each of the 77 maize samples that were tested is indicated in Table 6.4. Maize samples contaminated by combinations of T-2 toxins and Fumonisins were more frequent followed by those contaminated by ochratoxins only and those contaminated by aflatoxins only (Figure 6.7).

Of the 77 maize samples tested for mycotoxin contamination, a larger proportion had been collected from the roof storage facilities compared to those collected from the sack storage facilities. This was due to the fact that the number of farm households that stored maize using the roof storage method was higher than that of those who stored it using the sack storage method, thus more maize samples were collected from the roof than the sack storage facilities.

Table 6.4: Number and types of mycotoxins in each of the maize sample (n=77)

Types of mycotoxins	Percent of maize samples that were contaminated with the mycotoxins
One type	41.5
Two types	37.7
Three types	7.8
Four types	1.3
Total	88.3

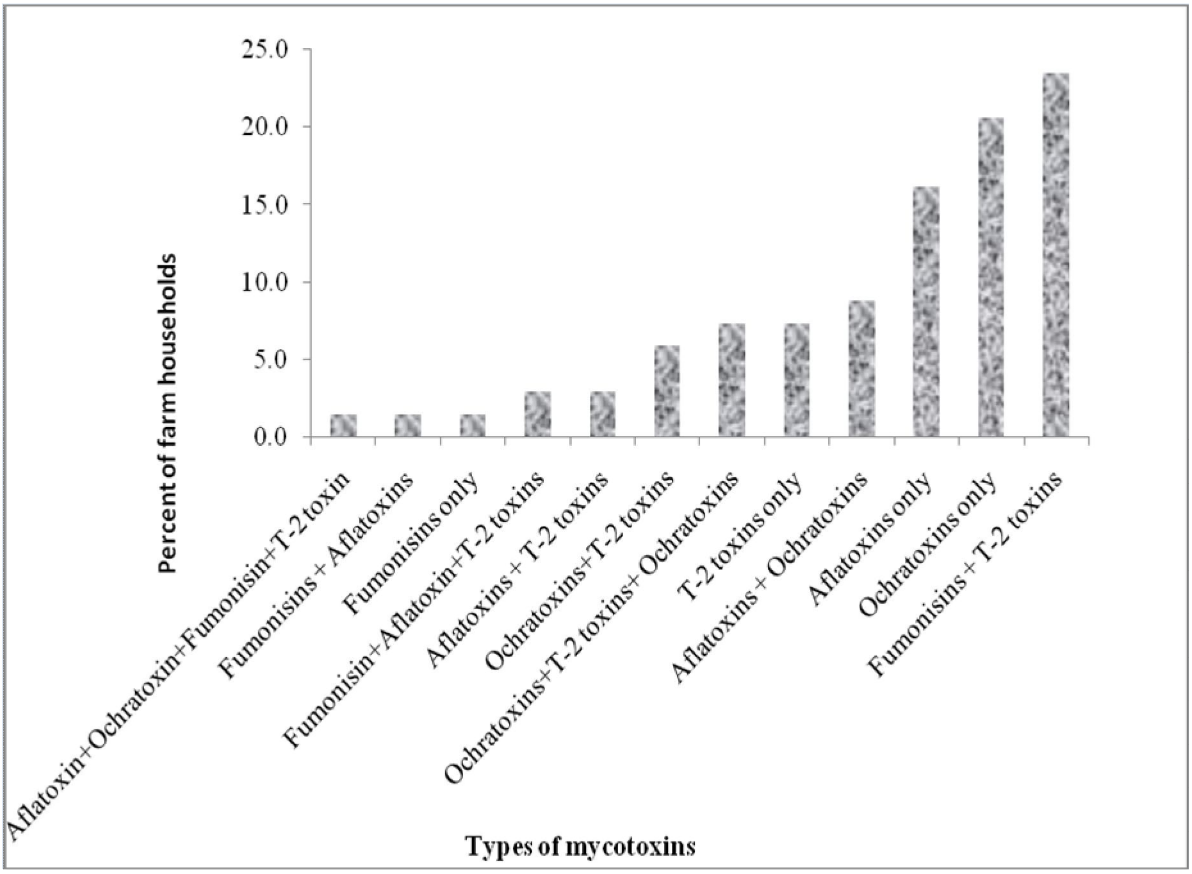


Figure 6.7: Types of mycotoxins in the maize samples

The presence of mycotoxins was detected in 83.9 % of the sub- samples of maize collected from the roof storage facilities, whereas all the sub- samples of maize collected from the sack storage facilities tested positive for the mycotoxins. Table 6.5 shows highest level of contamination of the maize samples with T-2 toxins followed by fumonisins and ochratoxins for maize samples from both the roof and from sack storage facilities.

Table 6.5: Percent of maize samples contaminated by the mycotoxins in relation to the storage methods

Contaminated maize samples	**Fumonisins** (n=38)	**Ochratoxins** (n=38)	**Aflatoxins** (n=40)	**T-2 toxins** (n=38)
Number of maize samples collected from roof facilities for the test	25	30	32	25
Number of maize samples collected from sack facilities for the test	13	8	8	13
Percent of contaminated maize samples from roof storage facilities	96	73.3	50	96
Percent of contaminated maize samples from sack storage facilities	92.3	87.5	96	93.3

Only maize samples that made more fungi colonies than the others were tested for mycotoxins, hence the lack of uniformity in the number of maize samples tested from each of the storage facilities.

Table 6.6 reveal that the percentage of maize samples that were concurrently contaminated with two types of mycotoxins was the highest for maize samples from the sack storage facilities, whereas maize samples that were contaminated by one type of mycotoxins had the highest percentage for the maize samples collected from the roof storage facilities. However, a Chi square test ($\alpha>0.5$) revealed that there was no significant difference between the proportions of contaminated maize samples from the roof and sack storage facilities.

Table 6.6: A Comparison of the incidence of mycotoxin contaminated maize samples from the roof and sack storage facilities after five months of storage

Types of mycotoxins in the maize sample	**Percent of contaminated maize samples from the roof storage facilities**(n=56)	**Percent of contaminated maize samples from the sack storage facilities**(n=21)
One type	42.90	38.10
Two types	32.10	47.62
Three types	7.10	14.28
Four types	1.80	0.00
Total	83.90	100.00

6.3.7 Maize form and types of mycotoxins that contaminated the maize

Maize stored in the form of cobs without husks, latter stored in the form of shelled grain had the largest proportion of maize samples contaminated concurrently by fumonisins and T-2 toxins (Table 6.7), whereas the proportion of maize samples from maize stored in this particular form and contaminated by ochratoxins only was also greater compared to the proportions of maize samples from maize stored in the other forms.

Table 6.7. Maize form and types of mycotoxins detected in the maize samples (n=68)

Mycotoxins	**Maize form**						
	Shelled grain (%)	Unshelled without husks (%)	Unshelled with husks (%)	Unshelled without husks, later shelled (%)	Unshelled with husks, later shelled (%)	Some unshelled without husks, some with husks, later shelled (%)	Total
Aflatoxins only	2.9	2.9	2.9	4.4	1.5	1.5	16.1
Fumonisins only	0	0	0	0	0	1.5	1.5
Ochratoxins only	0	7.4	1.5	8.7	4.4	0	22
T-2 toxins only	0	0	0	4.4	0	1.5	5.9
Aflatoxins and fumonisins	1.5	0	0	0	0	0	1.5
Aflatoxins and ochratoxins	1.5	2.9	0	2.9	1.5	0	8.8
Aflatoxins and T-2 toxins	0	1.5	0	1.5	0	0	3
Ochratoxins and T-2 toxins	0	0	2.9	2.9	0	0	5.8
Fumonisins and T-2 toxins	1.5	7.4	1.5	10.2	2.9	0	23.5
Fumonisins + Ochratoxins + T-2 toxins	0	1.5	1.5	4.4	0	0	7.4
Fumonisins + aflatoxins + T-2 toxins	1.5	1.5	0	0	0	0	3
Aflatoxins + Ochratoxins + Fumonisins + T-2 toxins	0	0	0	1.5	0	0	1.5
Total	8.9	25.1	10.3	40.9	10.3	4.5	100

The Pearson correlation revealed a strong positive relationship between storing some of maize cobs unshelled without husks, some with husks and latter in the form of shelled grain with contamination of maize by fumonisins only (Table 6.8). The association was significant at 0.570**. The tendency for maize to be concurrently contaminated by fumonisins, aflatoxins and T-2 toxins decreased with storing maize in the form of shelled grain (Table 6.8). No significant relationship was observed between mycotoxin contamination and maize stored in the form of unshelled cobs without husks exclusively or which was later shelled and stored in the form of grain. Likewise, no significant relationship was observed between mycotoxin contamination and maize stored as cobs with husks and latter shelled and stored in the form of grain.

Table .6.8: Pearson Correlation between maize form and types of mycotoxins that contaminated maize

	Fumonisins + aflatoxins	Fumonisins + aflatoxins + T-2 toxins	Ochratoxins + T-2 toxins	Fumonisins only
Shelled grain exclusively	0.363**	-0.232*	ns	ns
Unshelled with husks exclusively	ns	ns	0.333**	ns
Some unshelled without husks, some with husks, later shelled grain	ns	ns	ns	0.570**

* Significant at 0.05 level
** Significant at 0.01 level
ns = no significant relationship observed

6.3.8 The concentrations of fumonisins, aflatoxins, ochratoxins and T-2 toxins in the maize samples

As indicated in Section 6.2.7, the protocol for preparation of maize sample extracts for quantification of ochratoxins required the use of two grams of ground maize, whereas the protocols for the rest of the mycotoxins required the use of three grams of ground maize. The quantities of aflatoxins, fumonisins, T-2 toxins per three grams of ground maize, and the quantity of ochratoxins per two grams of ground maize are shown in Table 6.9 - 6.12. No significant difference was observed between the mean quantities of each type of mycotoxins for the maize samples from the roof and sack storage facilities (Appendix 6.3 - 6.6).

Table 6.9: Concentration of fumonisins in the maize sample extracts (mg/3 g of maize)

Maize Sample ID	Fumonisins (mg/3 g)	Maize Sample ID	Fumonisins (mg/3 g)	Maize Sample ID	Fumonisins (mg/3 g)
2	-	29	-	70	0.082
5	0.032	32	-	81	0.484
6	-	36	-	85	0.423
7	-	38	-	95	1.009
10	-	44	0.096	97	0.053
12	0.156	48	0.047	99	1.062
13	0.290	50	-	105	0.205
15	0.070	51	0.137	108	0.269
19	0.048	54	0.401	118	-
23	-	55	0.254	120	0.113
24	0.006	65	0.423	122	0.205
26	-	66	0.592	127	0.098
27	0.021	68	0.266		

Findings in Table 6.9 shows that Maize sample ID 66 had the highest concentration of fumonisins, whereas maize sample ID 24 had the lowest concentration.

Table 6.10: Quantities of aflatoxins in the maize samples (µg/3 g of maize)

Maize Sample ID	Aflatoxins (µg/3 g)	Maize sample ID	aflatoxins (µg/3 g)	Maize sample ID	Aflatoxins (µg/3 g)	Maize sample ID	Aflatoxins (µg/3 g)
1	1.026	22	1.490	42	3.904	79	2.738
5	-	23	2.789	45	2.322	80	-
8	-	25	1.297	47	-	84	2.990
9	1.684	28	-	49	-	89	-
10	1.364	30	1.260	50	-	95	-
12	1.164	31	1.163	51	-	97	-
15	1.226	32	-	54	-	99	-
16	1.101	33	1.265	58	-	100	-
18	1.993	38	1.695	72	1.897	103	-
21	1.382	41	1.366	75	2.253	121	-

Maize sample ID 42 had the highest concentration of aflatoxins (Table 6.10), whereas maize sample ID 127 had the highest concentration of T-2 toxins (Table 6.11) and maize sample ID 106 had the highest concentration of ochratoxins per 2 g of maize (Table 6.12). The blanks in Tables 6.9 – 6.12 represent uncontaminated maize sample.

Table 6.11: Quantities of T-2 toxins in the maize samples (µg /3 g of maize) (n=38)

Maize sample ID	T-2 toxins (µg/3g)	Maize sample ID	T-2 toxins (µg/3g)	Maize sample ID	T-2 Toxins (µg/3g)
2	2.676	29	7.105	70	3.457
5	2.550	32	2.915	81	6.823
6	1.401	36	-	85	11.216
7	2.231	38	1.401	95	3.857
10	2.059	44	6.335	97	3.990
12	6.448	48	4.420	99	2.125
13	1.508	50	4.557	105	9.046
15	2.113	51	3.688	108	11.640
19	-	54	3.173	118	15.686
23	2.044	55	4.242	120	8.589
24	3.023	65	2.583	122	17.997
26	4.457	66	2.351	127	18.602
27	5.939	68	2.560		

Table 6.12: Quantities of ochratoxins in the maize samples (µg /2 g of maize)

Maize sample ID	Ochratoxins (µg /2g)	Maize sample ID	Ochratoxins (µg /2g)	Maize sample ID	Ochratoxins (µg /2g)
1	1.872	37	7.234	80	0.798
5	-	38	-	84	1.080
15	-	39	-	90	1.123
16	-	42	-	97	0.965
18	0.880	43	-	99	0.814
22	1.136	46	-	101	0.866
23	0.896	47	-	105	1.270
24	0.998	51	-	106	2.717
29	1.217	55	1.208	108	1.355
31	0.898	64	-	115	1.430
33	-	65	1.513	116	1.666
35	0.809	72	-	121	1.876
36	-	74	1.174		

6.3.9 Quantities of mycotoxins that each of the farm households could consume per meal

In Katumba ward, a farm household consumed an average of 1kg and a minimum of 0.5 kg or 500 g of maize meal per meal (Section 6.1), thus, the estimated amounts of mycotoxins that a farm household could consume per meal are equivalent to the amounts of mycotoxins that were detected per kg of maize flour shown in Table 6.14. Since the farm households consumed maize meals in an average of two times per day, individuals in an average farm households composed of six people that consumed an average of one kg of maize flour per meal could be exposed to the amounts of mycotoxins in Table 6.13 per day. Likewise, individuals in farm households that consumed 500 g of maize flour per meal could be exposed to the amounts of mycotoxins indicated in Table 6.13per day through contaminated maize meals.

Table 6.13: The quantities of the mycotoxins (μg) that an individual in a farm household in Katumba ward could consume per meal/ per day

	Quantity of mycotoxin	Aflatoxins	Ochratoxins	Fumonisins	T-2 toxins
Individual in a household which utilize one kg of maize flour per meal	per meal	99.58	122.84	14622.59	300.63
	per day	199.16	245.67	29245.18	601.25
	per week	1194.96	1474.02	175471.10	3607.50
Individual in a household which utilize 500g of maize flour per meal	per meal	49.79	61.42	7311.30	150.31
	per day	99.58	122.81	14622.59	300.61
	per week	597.48	737.01	87735.55	1803.75

Table 6.13 shows that levels of fumonisins that individuals in farm households were exposed to were highest compared to the rest of mycotoxins, whereas T-2 toxins were second in the order of importance with respect to the concentrations that individuals in the farm households were exposed to.

The amounts of mycotoxins in Table 14 are far above the international regulatory standards per kg of maize indicated in Section 6.1, thus are harmful to the maize consumers.

Table 6.14: The estimated quantities of mycotoxins per kg of maize

ID	Aflatoxins (µg/kg)	ID	Ochratoxins (µg/kg)	ID	Fumonisins (µg(/kg)	ID	T-2 toxins (µg/kg)
1	342.00	1	936.00	2	-	2	892.00
5	-	5	-	5	10666.67	5	850.00
8	-	15	-	6	-	6	467.00
9	561.33	16	-	7	-	7	743.67
10	454.67	18	440.00	10	-	10	686.33
12	388.00	22	568.00	12	52000.00	12	2149.33
15	408.67	23	448.00	13	96666.67	13	502.67
16	367.00	24	499.00	15	23333.33	15	704.33
18	664.33	29	608.50	19	16000.00	19	-
21	460.67	31	449.00	23	-	23	681.33
22	496.67	33	-	24	2000.00	24	1007.67
23	929.67	35	404.50	26	-	26	1485.67
25	432.33	36		27	7000.00	27	1979.67
28	-	37	3617.00	29	-	29	2368.33
30	420.00	38	-	32	-	32	971.67
31	387.67	39	-	36	-	36	-
32	-	42	-	38	-	38	467.00
33	421.67	43	-	44	32000.00	44	2111.67
38	565.00	46	-	48	15666.67	48	1473.33
41	455.33	47	-	50	-	50	1519.00
42	1301.33	51	-	51	45666.67	51	1229.33
45	774.00	55	604.00	54	133666.67	54	1057.67
47	-	64	-	55	84666.67	55	1414.00
49	-	65	756.50	65	141000.00	65	861.00
50	-	72	-	66	197333.33	66	783.67
51	-	74	587.00	68	88666.67	68	853.33
54	-	80	399.00	70	27333.33	70	1152.33
58	-	84	540.00	81	161333.33	81	2274.33
72	632.33	90	561.50	85	141000.00	85	3738.67
75	751.00	97	482.50	95	336333.33	95	1285.67
79	912.67	99	407.00	97	17666.67	97	1330.00
80	-	101	433.00	99	354000.00	99	708.33
84	996.67	105	635.00	105	68333.33	105	3015.33
89	-	106	1358.50	108	89666.67	108	3880.00
95	-	108	677.50	118	-	118	5228.67
97	-	115	715.00	120	37666.67	120	2863.00
99	-	116	833.00	122	68333.33	122	5999.00
100	-	121	938.00	127	32666.67	127	6200.67
103	-						
121	-						
Mean	596.50		745.73		87717.95		1803.77
Std Dev	245.72		650.75		92369.53		1486.49
St Error	38.85		105.57		14984.32		244.56
Maximum	1301.33		3617.00		354000.00		6200.67

6.3.10 Comparing means for the concentrations of mycotoxins in maize samples from the roof and sack storage facilities

The average amounts of mycotoxins in maize samples from the roof and sack storage methods are as indicated in Table 6.15.

Table 6.15: Comparing the difference between the mean scores for the quantities of mycotoxins per kg of maize stored using the roof and the sack storage methods

Mycotoxins	Storage method	No. of samples tested	Mean µg/kg	Standard Deviation	Standard error of mean	Significant level (Independent sample T-test)
Fumonisins	Roof	25	58419.62	81853.72	16370.74	ns (α>0.05)
	Sack	13	65054.17	97149.32	26944.37	
T-2 toxins	Roof	25	1795.27	1486.99	297.40	ns (α>0.05)
	Sack	13	1542.57	1635.55	453.62	
Aflatoxins	Roof	32	334.33	365.91	64.682	ns (α>0.05)
	Sack	8	305.76	367.95	130.09	
Ochratoxins	Roof	30	568.48	668.68	122.08	ns (α>0.05)
	Sack	8	539.87	281.72	99.60	

ns = "not significant"

While the concentrations of fumonisins were highest in the maize samples, the concentration of fumonisins was higher in the maize samples collected from the sack storage facilities than in those collected from the roof storage facilities. The concentration of T-2 toxins was higher in the maize samples from the roof storage facilities than in the maize samples from the sack storage facilities. However, t tests results in Table 6.15 reveals that there were no significant differences between the mean concentrations for each of the mycotoxin tested in the maize samples stored using the roof and sack storage methods.

6.3.11 Maize form and the concentration of mycotoxins in the maize samples

The mean concentrations of aflatoxins and ochratoxins were highest in maize stored in the form of unshelled cobs with husks latter shelled and stored in the form of grain, whereas the mean concentration of fumonisins was highest in maize stored in the form of unshelled cobs without husks (Table 6.16). T-2 toxins concentration was highest in maize stored in the form of shelled grain. However, the one way between groups ANOVA tests ($\alpha > 0.5$) showed that there were no significant differences between the mean quantities of each type of mycotoxin in maize stored in the various forms.

Table 6.16: Comparing the mean quantities of mycotoxins in maize stored in different forms

Form in which maize was stored	Concentration of mycotoxins (μg/kg)								ANOVA
	Aflatoxins		Ochratoxins		Fumonisins		T-2 toxins		Significance level
	Mean	Standard error of mean	Mean	Standard error of mean	Mean	Standard error of mean	Mean	Standard error of mean	
Shelled grain	285.17	90.46	0.00	0.00	45,833.33	22,500.00	3,351.67	2,647.34	α > 0.05 (ns)
Unshelled without husks	305.97	95.21	399.23	113.10	138,000.00	49365.38	1,735.92	373.75	α > 0.05 (ns)
Unshelled with husks	448.33	263.59	492.63	173.64	56,583.34	29,696.42	1,490.25	463.80	α > 0.05 (ns)
Unshelled without husks latter shelled	258.37	93.32	499.32	206.14	36,916.67	12,598.54	1,779.52	364.00	α > 0.05 (ns)
Unshelled with husks latter shelled	873.84	122.84	761.75	199.15	52,166.67	36,500.00	1,163.33	310.00	α > 0.05 (ns)
Some unshelled without husks, some with husks, latter shelled grain	561.33	0.00	0.00	0.00	8,000.00	8,000.00	233.50	233.50	α > 0.05 (ns)

n = not significant

6.4 Discussion

6.4.1 The presence and implication of the pathogenic fungi in the maize samples

The laboratory findings confirmed the farm households' perceptions that *Aspergillus*, *Fusarium* and *Penicillium* species attack stored maize in Katumba ward. In general, the results show that more than half of the maize samples studied were infected with pathogenic fungi. Furthermore, 72 % of the maize samples infected by the pathogenic fungi had more than one type of the fungi, whereas 27 % had only one type of the fungi. This implies that for at least half of the farm households that participated in this study, their stored maize was infected by more than one type of fungi.

7.. *ochraceus* and *A. Paraciticus* confirmed to be present in the maize samples are associated with production of ochratoxins and aflatoxins (Pitt, 2000), respectively, whereas *P. Verrucosum* and *P. Nordicum* are said to be the main *Penicillium* species that produce ochratoxins (Cabañes *et al.*, 2010). The presence of pathogenic fungi in the maize samples implies that the quality of maize in Katumba ward was poor and that the farm households were exposed to pathogenic fungi through maize consumption. This would not only have a negative effect on the palatability of the corresponding maize meals, but it also implies that stored maize could be contaminated by ochratoxins, aflatoxins and other mycotoxins. This would compromise the utilization of food, increase vulnerability of the farm households and render them food insecure.

6.4.2 The association between maize form and fungal infection

Maize stored in different forms was equally affected by moulds infection. The Chi-square tests ($\alpha > 0.05$) confirmed this claim. This suggests that the infection of maize by moulds in Katumba ward was not influenced by the form in which maize was stored.

6.4.3 The Implication of the incidence of fungal infections on the capacity of roof and sack storage technologies to protect stored maize from infection

A slightly higher percentage of maize samples that were collected from the sack storage facilities tested positive to all the three types of pathogenic fungi compared to the percentage of maize samples from roof storage facilities. However, a higher percentage of the maize samples from the roof storage facilities had two types of the pathogenic fungi than the percentage of maize samples from the sack storage facilities. In addition, although a higher percent of the indigenous types of maize samples were affected by the fungi species compared to the maize samples from the improved varieties, in both cases, more than three quarters of the maize samples were infected by the pathogenic fungi. A chi-square test ($\alpha>0.05$) showed that there was no significant difference between the proportions of the infected maize samples to the uninfected ones for maize samples collected from the roof and sack storage facilities, which implies that maize stored using the roof and the sack storage methods was equally infected by moulds.

Both the indigenous and the improved varieties of maize stored using roof and sack storage methods in Katumba ward were equally affected by the pathogenic fungi, hence the poor quality of stored maize. The fact that both the landraces and the improved varieties of maize were infected by the pathogenic fungi during storage also implies that the tendency for the stored maize to be infected by fungi in Katumba ward was a storage technology problem and that the maize varieties' lack of resistance to the infections also played a role in allowing the fungal infections to occur. Furthermore, wetness and high humidity that characterize the climatic conditions in Katumba ward (Anon, 2008) create conditions that favour the growth of fungi in stored maize. This, together with the findings discussed in the previous paragraph imply that sack and roof storage technologies in Katumba ward were not adequate for protecting stored maize against the climatic conditions indicated above and against fungal infection. Thus, they fell short of the characteristics of an ideal storage method described by Coulter and Schneider (2004), which include among others, the suitability of the storage method for use in the climatic conditions of the place where it is being used.

6.4.4 The incidence of mycotoxins in the maize samples and its implications on the consumers

The 68 maize samples that were found to be contaminated by the mycotoxins are equivalent to 52.3 % of the 130 maize samples subjected to mycological analysis. Since each of the maize samples was collected from a specific farm household, 52.3 % is also equivalent to the percentage of farm households where maize samples were collected. The above implies that for half of the farm households in Katumba ward, stored maize was contaminated by aflatoxins, fumonisins, ochratoxins or T-2 toxins. The mycotoxins compromised the safety and nutritional value of the contaminated maize, thus rendered the farm households vulnerable and food insecure.

Since the presence of *A. paraciticus* and *A. ochraceus* confirmed in the maize samples, the aflatoxins in the maize must have been produced by these particular species. *P. verrucosum and P. nordicum* have been reported to be the main *Penicillium* species that produce ochratoxin A. The former produces ochratoxin A in cereals and the latter produces ochratoxin A in meats (El Khoury and Atoui, 2010). However, *P. Verrucosum* was not detected in the maize samples. Therefore, since *A. Ochraceus* also produces ochratoxin A, (El Khoury and Atoui, 2010), the ochratoxin detected in the maize samples might have been produced by this particular fungi species. *Fusarium verticillioides* (sacc), synonym *F. moniliforme* is one of the main producers of fumonisins (Pitt, 2000). Thus, fumonisins that were detected in the maize samples must have been produced by *F. verticillioides* which was confirmed to be present in the maize samples. Furthermore, T-2 toxin is known to be produced by several *Fusarium* species such as *F. tricinctum*, *F. equiseti, F. sporotrichioides* (Ohlinger *et al*., 2004) and *F. poae* (Bennet and Klich, 2004). Thus, the T-2 toxins detected in the maize samples were possibly produced by the *Fusarium* species named above, which were not studied. The occurrence of two or more mycotoxins per maize sample raises questions concerning the effects that the interaction between the mycotoxins may have on the stored maize and on the health of the consumers. Moreover, 41.1% of the maize samples were contaminated by only one type of mycotoxin compared to 46.8% of the maize samples that were contaminated by more than one type of mycotoxin. This implies that at least one third of the farm households in Katumba ward were exposed to more than one type of mycotoxin per maize meal.

The above findings indicate that, for at least half of the farm households in Katumba ward stored maize was likely to be contaminated by aflatoxins, ochratoxins, fumonisins or T-2 toxins, or a combination of two, three of four of the mycotoxins named above. In addition, for the half of the farm households that experienced contamination of stored maize by the mycotoxins indicated above, every 22 out of 40 of the farm households, stored maize was likely to be contaminated by an average of 596.48±38.85 µg/kg of aflatoxins and for 29 out of 38 farm households stored maize was likely to be contaminated by 745.73± 105.57 µg/kg of ochratoxins. Also, for 29 out of 38 farm households, stored maize was likely to be contaminated by 87717.95±14984.32 µg/kg (or 87.2± 15mg/kg) of fumonisins and for every 36 out 38 farm households, stored maize was likely to be contaminated by 1803.77±244.56 µg/kg(or 1.8±0.241 mg/kg) of T-2 toxins.

The amounts of mycotoxins detected per kg of maize in Katumba ward are far above the international regulatory standards of 4 mg/kg for fumonisins (Wu, 2004), 20 µg/kg for aflatoxins (Munkvold *et al.,* 2009) and 50 µg/kg for ochratoxins even for households that utilize only 500 g of maize flour per meal. The amounts of fumonisins and aflatoxins were also much higher than the 11048 µg/kg and 158 µg/kg of these mycotoxins, respectively, reported by Kimanya *et al.* (2008) in home stored maize from Iringa, Kilimanjaro and Ruvuma regions in Tanzania. However, higher quantities of up to 212000 µg/kg (or 212 mg/kg) of aflatoxins have been reported before in maize in Kenya (Probst, 2007) and up to 300 mg/kg (or 300000 µg/kg) were reported in Italy (Rittieni *et al*., 1997). Reports of amounts higher than the maximum amounts of 3617 µg/kg (or 361.7 mg/kg) of ochratoxins and 6200.67 µg (or 620 mg/kg) of T-2 toxins in food or feed were not found. Thus, perhaps this was the first time such high amounts of ochratoxins and T-2 toxins were detected in stored maize. The high quantities of mycotoxins in maize in Katumba ward put the farm households in the ward at risk of suffering from a combination of health problems from the mycotoxins, which include: interference with neurons function, interference with protein synthesis, mutagenesis, suppression of the immune system, and retarded growth. Furthermore, the large quantities of mycotoxins also put the maize meal consumers at risk of being vulnerable to attack by other diseases such as malaria and HIV due to the possible suppression of the immune system caused by the mycotoxins. Maize consumers in Katumba ward may be suffering or dying unnoticed from consuming maize meals that are contaminated with the indicated mycotoxins, especially since there are no reported investigations of the mycotoxin effects Rungwe district. In general, the mycotoxins interfere with the utilization of the foods made from the contaminated maize, thus, they increase the farm households' vulnerability and render them food insecure.

6.4.5 The association between maize form and mycotoxin contamination of maize

Storage of maize cobs with husks seemed to increase the risk for maize to be contaminated by combinations of ochratoxins and T-2 toxins, whereas maize stored in the form of shelled of grain was more exposed to concurrent contamination by fumonisins and aflatoxins and concurrent contamination by fumonisins, aflatoxins and T-2 toxins. Pearson correlations significant at $\alpha < 0.01$, $\alpha < 0.05$ and $\alpha < 0.01$, respectively. However, the mean quantities for each type of mycotoxin were equally high in maize stored in each of the various maize forms. The one way ANOVA tests ($\alpha > 0.05$) confirmed that there was no significant difference between the quantity of each type of mycotoxin in each of the maize form. Thus maize form may have influenced the incidence and types of mycotoxis that contaminated maize, the quantity of mycotoxins produced was not influenced by it.

6.4.6 The implication of the high levels of mycotoxins regarding the capacity of roof and sack storage technologies to protect maize from mycotoxins contamination

The fact that all the maize samples collected from the sack storage facilities and that 83 % of the maize samples from the roof storage facilities for mycotoxins tests were contaminated show poor effectiveness of both storage methods to prevent contaminations from occurring. A Chi-square test ($\alpha > 0.05$) confirmed that there was no significant difference between the two storage methods with respect to the proportions of mycotoxin contaminated maize samples. The fact that maize samples from both roof and sack storage facilities were contaminated by one or more than one type of mycotoxins (Table 5.4) indicate that both storage methods could not prevent the production of mycotoxins in the stored maize.

The highest percentage of the maize samples from the roof storage facilities were contaminated by T-2 toxins and fumonisins, while maize ssamples from the roof storage facilities recorded very high concentrations of the T-2 toxins and maize samples from the sack storage facilities had highest concentration of fumonisins. This implies that both roof and sack storage methods were not effective in preventing production of T-2 toxins and fumonisins in stored maize. Moreover, the fact that more than half of the maize samples that were concurrently contaminated by two types of mycotoxins had been collected from the sack storage facilities implies that maize stored in sacks in Katumba ward was more exposed to contamination by more than one type of mycotoxins than the maize stored in the roof storage facilities.

However, T-test results for each of the storage methods revealed that there were no significant differences between the means for the quantity of each of the mycotoxin studied, which shows that there was no difference between the roof and sack storage methods concerning the capacity to regulate the quantities of mycotoxins produced in stored maize. Both the roof and sack storage methods exposed stored maize to very high quantities of mycotoxins. Therefore, both the roof and sack storage methods exposed the farm households to vulnerability and food insecurity.

Lastly, the high quantities of mycotoxins in the maize samples from roof and sack storage facilities could only be produced in the presence of moisture and optimum temperatures. At 15-37 ^{0}Cochratoxins A, the type of ochratoxins which is mostly found in food are produced (FAO, 2004), while at 25 – 30 ^{0}C and 15 – 43 ^{0}C fumonisins and aflatoxins, respectively are also produced (Marin *et al.,* 1995; FAO, 2001). In addition, according to Munkvold (2003), conditions that are favourable for growth of fungi are also favourable for production of fumonisins. Thus, since the quantities of aflatoxins, ochratoxins, fumonisins and T-2 toxins in the maize samples collected from the roof and sack storage facilities alike were high, it is inferred that the temperatures in the storage facilities from which the maize samples were taken were favorable for the growth of fungi and production of the mycotoxins.

Rapid drying (Reed *et al.,* 2007), cooling followed by treating the maize with antifungal chemicals (Weinberg *et al*., 2008) are recommended for preventing growth and development of fungi in maize, whereas the latter is usually recommended for maize seeds for planting. However, due to the wetness and high humidity that characterize the climatic conditions in Katumba ward maize which is thoroughly dried can still take in moisture from the surrounding area. Therefore, apart from ensuring that maize is dry enough prior to storage, there is a need for roof and sack storage technologies in Katumba ward to be improved so that they can prevent stored maize from taking in moisture from the surroundings. While lining storage sacks with moisture proof liners may be helpful in preventing moisture from entering, finding ways of improving the roof storage method requires that more research.

6.5 Conclusions and recommendations

The majority of farm households in Katumba ward, the quality of maize stored using roof and sack storage methods was low due to the infections by *Fusarium*, *Aspergillus* and *Penicillium* species which are pathogenic in nature. The presence of the pathogenic fungi in maize in Katumba ward would in turn render maize meals probably not only unpalatable, but also puts at least half of the farm households at risk of ill health or even premature death due to daily exposure to high levels of mycotoxins. The mycotoxins include fumonisins and T-2 toxins, aflatoxins, and ochratoxins, respectively. Most of the fungal infection of maize in Katumba ward occurred after harvest, in both the landraces and improved varieties of maize. The infection of fungi on maize in Katumba ward is more of a post-harvest problem rather than a pre- harvest one and it calls for extension education by the extension officers and the VAC in Tanzania. Sack and roof storage methods, which are the only storage methods that are used in Katumba ward for long term storage of maize, are inadequate in protecting stored maize from fungi attack, thus, they promote food insecurity of the farm households. Raising the awareness of the farm households and extension workers in Katumba ward with respect to the implication of the presence of the pathogenic fungi and the corresponding mycotoxins on the quality of maize and on the health of the consumers is strongly recommended. Furthermore, it is also recommended that more research be done in Katumba ward and other parts of Rungwe district in order to find out if there are diseases or deaths that can be linked to the contamination of maize meals by the above mycotoxins. Furthermore, ways of ensuring that maize stored using roof and sack storage methods is protected from infections by fungi should be implemented in this ward. These should include encouraging the farm households to do the following:

- Ensuring that the storage facilities are clean prior to use
- Ensuring that none of the maize is infected by moulds prior to storage
- Ensuring that maize is dry enough prior to storage
- Ensuring that maize is dried within 48 hours prior to storage
- To grow maize varieties that are particularly resistant to infection by moulds and insect pests in order to reduce chances of maize grain to be infected during storage.

The Tanzanian government should encourage agricultural engineers to design driers such as bio-fuel driers that farm households in humid places such as Katumba ward can use for rapid drying of maize and other food crops that need to be dried prior to storage. Furthermore, the maize breeding program in Tanzania should be adequately funded and encouraged by the government to develop maize varieties that are resistant to fungal infections so that contamination of stored maize by mycotoxins can be avoided in Katumba ward and other areas with similar climatic conditions. Additionally, appropriate policy should be implemented by the government in Tanzania in order to control the quality of stored maize especially in areas that have the same climatic conditions as Katumba ward. Lastly, the hygroscopic nature of maize requires that studies centered on finding ways of keeping maize dry during storage be conducted.

References

Adminstrator, 2010. *Agriculture – Rungwe*. http://www.mbeya.go.tz/index.php?option=com_content&view=article&id=174&Itemid=192> (Accessed December 2010 November 25).

Anon, 2008. *Weather in Katumba* <*http://freemeteo.com/default.asp?pid=180lta=1&sid=639320&gid=151851&alls=2*>(Accessed 2008 August 01).

Arora, D.K., 2004. *Fungal Biotechnology in Agricultural, Food and Environmental Applications Vol 21*. Marcel Dekker, New York.

Bennett, J.W., Klich, M., 2003. Mycotoxins. *Clinical Microbiology Reviews*. 16 3, 497-516.

Cabanes, F.J., Bragulat, M.R., Castella, G., 2010. Ochratoxin A Producing Species in the Genus Penicillium. *Toxins*. 2, 1111 – 1120.

Chelkowski, J, Ritieni, A., Wisniewska, H., Mule, G, Logrieco, A., 2007. Occurrence of Toxic Hexadepsipeptides in Preharvest Maize Ear Rot Infected by *Fusarium* poae in Poland. *Journal of Phytopathology*. 155, 8 – 18.

Coulter, J., Schneider, K. 2004.*Feasibility Study of Post Harvest Project in Mozambique and Tanzania*. Consultancy Report to the Swiss Agency for Development and Cooperation (SDC) <http://www.postcosecha.net/en/home/Knowledge_Network/ongoing_POSTCOSECHA_Programs/Eastern_andsouthern_Africa> (Accessed 2010 September02).

Cousin, M.A., Riley, R.T., Pestka, J.J., 2005. Foodborne mycotoxins: Chemistry, Biology, Ecology and Toxicology, in Fratamico, P.M., Bhunia, A.K., Smith, J.L. *Foodborne Pathogens: Microbiology and Molecular Biology*. Caister Academic Press, Wymondham, 163 – 226.

De Hoog, G.S., Guarro, J., Gene, J., Figueras, M.J., 2000. *Atlas of Clinical Fungi,* second ed. Centraal Bureau voor Schmmelcultures, Ultrecht.

El Khoury, A., Atoui, A., 2010. Ochratoxin A: General Overview and actual Molecular Status. *Toxins*. 2, 4, 461 – 493.

FAO, 1989. *Overview of analytical methods for mycotoxin contamination of maize and peanuts*. <http://www.fao.org/docrep/x5036Eoc.htm>. (Accessed 2010 July 05).

FAO, 2001. *Manual on the Application of the HACCP System in Mycotoxin Prevention and Control*. FAO and The International Agency for Atomic Energy (IAEA).

FAO, 2004. *Worldwide Regulations of Mycotoxin in Food and Feed in 2003*. FAO, Rome..

Hayes, A.W., 2001. *Principles and Methods of Toxicology*, fourth ed. Taylor and Francis, Philadelphia.

Jood, S., Kapoor, A.C., Singh, R., 1992. Biological evaluation of Protein Quality of Maize as Affected by Insect Infestation. *Journal of Agricultural and Food Chemistry*. 40. 12, 2439 – 2442.

Kimanya, M.E., De Meulenaer, B., Tiisekwa, B., Ndomondo-Sigoda, M., Devlieghere, F., Van Camp, J., and Kolsteren, P., 2008. Co- occurrence of fumonisins with aflatoxins in home-stored maize for human consumption in rural villages of Tanzania. *Food Additives and Contaminnts*. 11, 12, 1353-1364.

Machin, B.D., 2003. *Serial Dilutions*. <<http://www.elp.manchester.ac.uk/pub_project/1999/machin/BRYNserl.HTM> (Accessed 2010 January 12).

Marin, S., Sancis, V., Vinas, I., Canela, R. and Magan, N., 1995.Effect of water activity and temperature on growth and fumonisin B_1 and B_2 production by *Fusarium proliferatum* and *Fusarium moniliforme* on maize grain. *Letters in Applied Microbiology*. 21, 5, 298 – 301.

Mbogoro, K. D., 2003. *2002 Population and Housing Census: 2002 Regional Census Results: Mbeya: District Census Data*. <http://www.tanzania.go.tz/census> (Accessed 2007 March 23).

Mid – West Seed Services, 2006. *Seed Health Testing*. <http://www.bpi.da.gov.ph/Services/seedtesting.html> (Accessed 2007 August 15).

Miliotis, M.D, Bier, J.W., 2003. *International Handbook of Foodborne Pathogens*. Marcel Dekker, New York.

Montes, G.N., Reyes, M.C.A., Montes, R.N., Cantu, A.M.A., 2009. Incidence of Potentially Toxigenic Fungi in Maize (*Zea mays* L.) Grain used as Food and Animal Feed. *Journal of Food*. 7, 2, 119 – 125.

Munkvold, G. P., 2003. Epidemiology of Fusarium Diseases and their Mycotoxins in Maize, in Xu, X., Bailey, J.A. and Cooke, B.M. (Eds.), *Epidemiology of mycotoxins producing fungi*. Kluwer Academic Publishers, Dordrecht, pp. 705-713.

Munkvold, G., Hurburgh, C, and Meyer, J, 2009. *Aflatoxins in Corn*. <http://www.extension.iastate.edu/publications/pm1800.pdf> (Accessed 2010 April10).

Nash, S.M., Snyder, W.C., 1962. Quantitative Estimations by Plate counts of Propagules of the Bean Root Rot of *Fusarium* in Field Soils. *Phytopathology*. 52: 567 – 572.

Neergaard, P., 1977. *Seed Pathology, vol. I and II*. John Willey and Sons, New York.

Neogen Corporation, 2007. Veratox Quantitative Fumonisin 5/10 Test. Unpublished Elisa kit Insert. Neogen, Lansing.

Neogen Corporation, 2008.Veratox Quantitative Ochratoxin Test. Unpublished Elisa kit Insert. Neogen, Lansing.

Neogen Corporation, 2009 a. Veratox Aflatoxin Quantitative Test. Unpublished Elisa kit Insert. Neogen, Lansing.

Neogen Corporation, 2009 b.Veratox for T-2/HT-2 Toxin. Unpublished Elisa kit Insert. Neogen, Lansing.

Öhlinger, R., Adler, A., Kräutler, O. And Lew, H., 2004. Occurrence of toxigenic fungi and related mycotoxins in cereals, feeds and foods in Austria, in: Logrieco, A., and Visconti, A (Eds). *An overview on Toxigenic Fungi and Mycotoxins in Europe*, Kluwer publishers, Dordrecht, pp.1 – 10.

Patton, M., 2001. *Qualittive Methods and Evaluation Methods*. Thousand Oaks. Sage Publications, CA.

Peterson, S.W., Ito, Y., Horn, B.W., Goto, T., 2001. *Aspergillus bombycis*, a new aflatoxigenic species and genetic variation in its sibling species, A. Nomius. *Mycologia*. 93, 4, 689 – 703.

Pitchler, E., 2006. *Sampling for mycotoxins-do we care enough?* <http://www.romerlabs.com>(Accessed 2008 December 14).

Pitt, J.I., 2000. Toxigenic Fungi and Mycotoxins. *British Medical Bulletin*. 56, 1, 184 – 192.

Reed, C., Doyungan, S., Loerger, B., Getchell, A., 2007.Response of Storage Molds to Different Initial Moisture Contents of Maize (Corn) Stored at 25 ^{0}C, and effect on respiration rate and nutrient Composition. *Journal of Stored Products Research*, 43, 443 – 458.

Rittieni, A., Moretti, A., Logrieco, A., Bottalico, A., Randazzo, G., Monti, S.M., Ferracane, R., Fogliano, V., 1997. Occurrence of Fusaproliferin, Fumonisin B_1 and Beauvericin in Maize from Italy. *Journal of Agricultural and Food Chemistry*. 45, 10, 4011 – 4016.

Sweeney, M.J., White, S., Dobson, A.D.W., 2000. Mycotoxins in agriculture and food safety**.** *Irish Journal of Agriculture and Food Research*. 39, 2, 235 – 244.

Tachin, E. S., 2008. *Aflatoxins in maize, human life and economy system are in trouble*. Script of the Audio Document No 6. IITA- Ibadan, Ibadan.

Weinberg, Y.Y., Chen, Y., Finkelman, S., Ashbell, G., Navarro, S., 2008. The Effect of Moisture Level on High-moisture maize (*Zea mays* L.) under hermetic storage conditions- in vitro Studies. *Journal of Stored Products Research* 44:136 – 144.

WHO, 2006. *Nutrition and Food Security*.<http://euro.who.int/nutrition/security/sectop> (Accessed 2006 October 17).

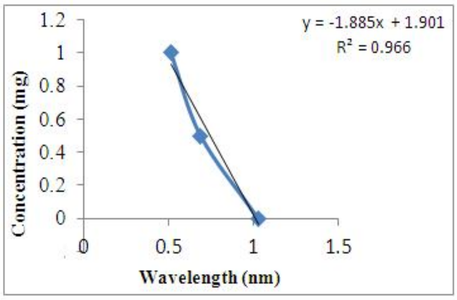
Williams, J .H., 2004. Human aflatoxicosis in developing countries: a review of toxicology, exposure, potential health consequences and interventions. *The African Journal of Clinical Nutrition*. 80, 1106 – 1122.

Wood, G.E., Trucksess, M.W., Henry, S.H, 2003. Major Fungal Toxins of Regulatory Concern. In Miliotis, M.D., Bier, J.W, *International Handbook of Foodborne Pathogens*. Marcel Dekker, New York, 423 – 443.

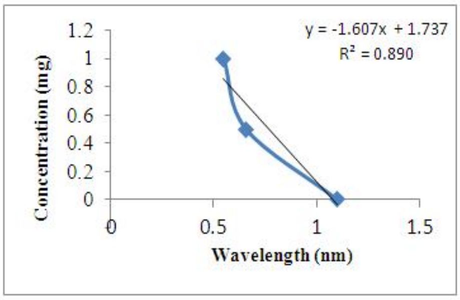
Wu, F., 2004. Mycotoxins Risk Assessment for the purpose of Setting International Regulatory Standards. *Environmental Science and Technology*. 38, 15, 4049 – 4055.

APPENDICES

Appendix 6.1: Concentration of fumonisins, aflatoxins, ochratoxins and T-2 toxins in the control samples

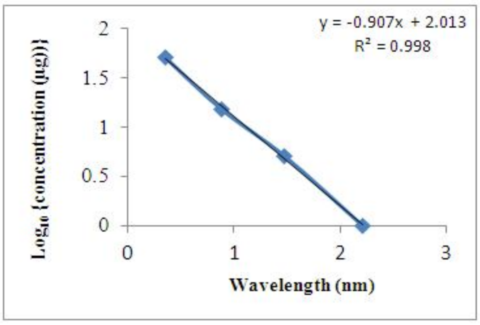


Graph 1a: 1st strip

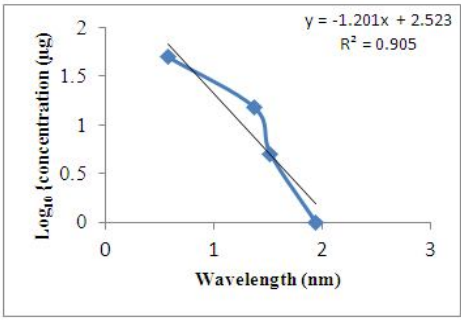


Graph 1b: 2nd strip

7.. Fumonisins in the control samples

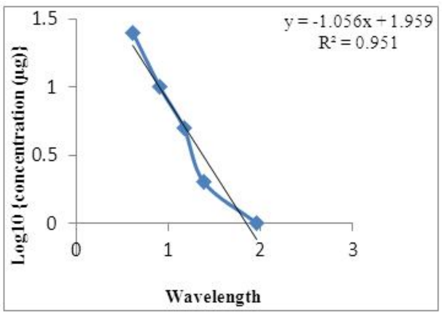


Graph 2a: 1st strip

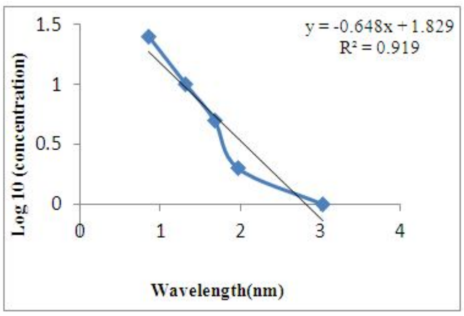


Graph 2b: 2nd strip

(ii) Aflatoxins in the control samples

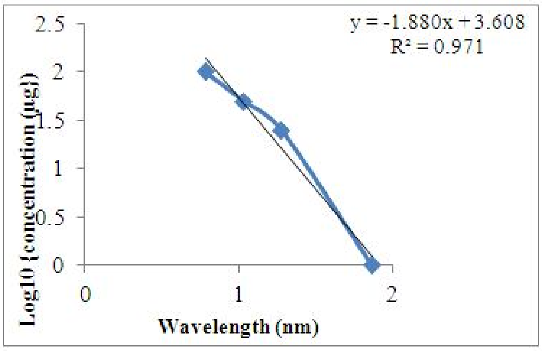


Graph 3a: 1st strip

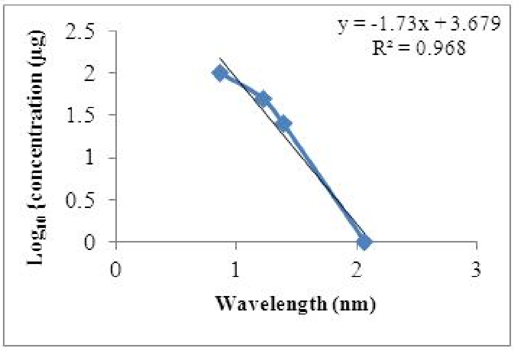


Graph 3b: 2nd strip

Ochratoxins in the control samples



Graph 4a: 1st strip



Graph 4b: 2nd strip

T-2 concentration in the control samples

Appendix 6.2: Number of contaminated maize samples in relation to the storage facilities from which they were collected

Number of maize samples studied for presence of mycotoxins		**Number of contaminated maize samples**				**Total number of tested maize samples**	**Total number of contaminated maize samples**	**Percent of contaminated maize samples**
Sack	Roof	Sack	Percent	Roof	Percent			
21	56	21	100.00	47	83.93	77	68	88.31

Appendix 6.3: Independent samples T-tests: Investigating the difference between the means for the quantities of aflatoxins in the maize samples from the roof and sack storage facilities

Quantity of aflatoxins	**Levene's Test for Equality of Variances**	**t-test for Equality of Means**					
	Sig.	t	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Upper	Lower
Equal variances assumed	0.872	0.197	0.845	28.569	144.787	-264.537	321.676
Equal variances not assumed		0.197	0.848	28.569	145.284	-292.142	349.280

Appendix 6.4: Independent samples T-tests: Investigating the difference between the mean quantities of ochratoxins in the maize samples from the roof and sack storage facilities

Quantity of ochratoxin	Levene's Test for Equality of Variances	t-test for Equality of Means					
	Sig.	t	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Upper	Lower
Equal variances assumed	0.470	0.117	0.907	28.602	243.874	-465.997	523.201
Equal variances not assumed		0.182	0.857	28.602	157.560	-293.953	351.157

Appendix 6.5: Independent samples T-tests: Investigating the difference between the mean quantities of fumonisins in the maize samples from the roof and sack storage facilities

Quantity of Fumonisin	Levene's Test for Equality of Variances	t-test for Equality of Means					
	Sig.	t	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Upper	Lower
Equal variances assumed	0.849	-.222	0.825	-6634.543	29834.518	-67141.750	53872.665
Equal variances not assumed		-.210	0.835	-6634.543	31527.774	-72188.787	58919.702

Appendix 6.6: Independent samples T-tests: Investigating the difference between the mean quantities of T-2 toxins in the maize samples from the roof and sack storage facilities

Quantity of T-2 toxin	Levene's Test for Equality of Variances	t-test for Equality of Means					
	Sig.	t	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95 % Confidence Interval of the Difference	
						Upper	Lower
Equal variances assumed	0.980	0.480	0.634	252.700	525.941	-813.959	1319.359
Equal variances not assumed		0.466	0.646	252.700	542.418	-870.877	1376.2769

CHAPTER SEVEN

THE FARM HOUSEHOLDS' FOOD SECURITY STATUS MEASURED USING THE HOUSEHOLD FOOD SECURITY SCALE, AND THE FARM HOUSEHOLDS' UNDERSTANDING OF FOOD SECURITY IN RUNGWE DISTRICT, TANZANIA

Abstract

Food security status of farm households in Katumba ward and their understanding of food security were investigated through studying a sample of 260 farm households that were randomly selected in the ward. The farm households' food security status was studied using the Household Food Security Scale. The necessary information for the study was collected through conducting face to face structured and semi-structured interviews. It was found that 66.6 % of the farm households were food insecure without hunger, 0.8 % were food insecure with hunger and 32.3 % were food secure. The farm households were very poor such that individuals in the farm households lived below the poverty line of 1.25 US Dollars per day. This limited their cash and food flows, which further rendered them vulnerable to hunger, diseases and food insecurity. It was also found that farm households in Katumba ward preferred maize meals above the other types of food that were available in the ward, which hindered them from accessing necessary nutrients from the foods that they did not prefer. Thus, this contributed to the food insecurity status of the farm households. Although farm households in Katumba ward were food insecure, 83.8 % of the farm households perceived themselves food secure for the reason that they had sufficient food to eat. This contradicted the food insecurity conditions that existed among them, such as the application of coping strategies such as the use of foods that they did not prefer when their proffered food ran out and reducing the number of meals that they took per day in order to cope with food shortages. It was concluded that the majority of the farm household in Katumba ward were food insecure, and that the farm households' understanding of food security was limited. Thus, it was recommended that effort be made by the government in Tanzania and development practitioners to raise the farm households' awareness regarding food security and issues around it, through effective extension services.

Key words: Food security status, perceptions, Katumba ward

7.1 Introduction

In this study, FAO's (2009) definition of food security applies (Chapter 1: Section 5.1). Food security carries aspects that influence health, namely: availability of food, the capacity for people to access food, the quantities of food that the people can access, the nutritive value and safety of the food. Thus, whether a farm household is food secure or not depends on the degree to which the farm household fulfills these factors.

While the nutritive value (Hubbard, 1995) and safety of food play an important role in determining the health of the consumers, wealth in terms of income level and assets that households own sheds light on the degree of purchasing power of the household or individuals (WFP, 2011).Assets provide farm households the capacity to purchase products that they do not produce (Maxwell and Smith, 1992; Hubbard, 1995). They can also be converted into food through marketing when food supplies run out or when farm households are faced with severe scarcity {Guo, 2010; Maxwell and Smith, 1992; World Food Programme (WFP), 2011}. Assets ownership also determines the capacity of a farm household or individual to access formal credit (WFP and WHO, 2006). The value of the assets that a household or individual owns is regarded as evidence of the person or household's capacity to be able to pay a loan back. Thus, a household which owns valuable assets is more likely to access credit than a household which does not own valuable assets.

Prior to this study, food security reports in Tanzania focused mainly on amounts of food crops harvested. Due to this reason, Mbeya, the region in which Katumba ward is situated is recognized among the important regions that produce surplus food crops in Tanzania (Government of the United Republic of Tanzania, 2007), thus is traditionally regarded as food secure. Likewise, the most part Rungwe district is considered important for high agricultural productivity (The Planning Commission and Mbeya Regional Commissioner's Office, (2011). In 2006 the Tanzania Food Security and Comprehensive Vulnerability Assessment (CFSVA) report (Mckinney, 2006) showed that 81 % of the households in Mbeya Region were food secure, 14.1 % were moderately vulnerable to food insecurity, 3.4% were highly vulnerable and 0.7 % were food insecure. The CFSVA's report was established based on findings obtained through investigating households' access to food, types of food that the households' consumed, health and types of livelihoods that the households depended on (Mckinney, 2006). There is no evidence in this report that instances of food crops being infested by pests or being contaminated by mycotoxins were among the conditions used to study food insecurity among the investigated households. In this study an attempt was made to explore the general food security status of the farm households in Katumba ward using the Household Food Security Scale tool (Bickel *et al*, 2000) using conditions that are specifically applicable to the population being studied. Thus, instances of the staple food crop being infested by pests were included in the conditions that were used to determine the farm households' food security status. Basically, this tool assesses the severity of food insecurity based on the respondents' experiences, perceptions and anxieties concerning meeting basic food needs and ways in which they respond to these experiences or perceptions (Bickel *et al*, 2000). It is easy to use and is commonly used in the United States of America (Bickel *et al*, 2000).

The current study explored the general food security status of the farm households, their understanding of food security and the implications on the farm households' health. The study was conducted through investigating 260 farm households that were randomly selected in Katumba ward. A guiding questionnaire was used for gathering the required information.

7.1.1 Main objective: To explore the general food security status of the farm households in Katumba ward, Rungwe district, Tanzania using the Household Food Security Scale tool and assess the farm households' understanding of food security from an ecohealth perspective.

7.1.2 Specific Objectives

1. To investigate the types and quantities of assets that the farm households were in possession of and the implications on household food security in Katumba ward.

2. To explore the farm households' income, its sources and the implications on the farm households' food security in Katumba ward.

3. To explore the farm households consumption behavior and their understanding of food security, and determine the implications on the farm households' food security status in Katumba ward.

7.2 Materials and Methods

7.2.1 Sampling of the farm households

The procedure described in Chapter 1: Section 1.9 was used for sampling of the farm households.

7.2.2 Data collection techniques

Semi-structured and structured interviews were used for collecting the necessary data. The questionnaire used to collect the necessary data is shown Appendix 1. Data sets collected includes the types of houses that the farm households' lived in, types and quantities of plough assets, transportation assets, livestock that the households owned, whether the farm households owned private water facilities such as tap water or water pump and the types and quantities of transport and transportation assets. Data sets collected also included the persons who owned the different types of assets in the farm households was also collected, types of legume crops that the farm households grew, other types of food that the farm households utilized for consumption purposes and types of food that the farm households often utilized concurrently with maize meals was also collected. Other data sets collected includes farm households coping strategies for the time in a year when they faced food shortages, month in a year when the households applied strategies in order to cope with maize scarcity, types of food that the farm households utilized when they faced maize shortages and farm households' perceptions concerning their food security status.

7.2.3 Determining the food security status of the farm households using the Household Food Security Tool

The Household Food Security Scale tool was used to measure the severity of the food insecurity of the households. In line with Bickel *et al*, (2000), the following conditions of food insecurity were identified among the farm households' responses:

- Anxiety that the household food supply may be insufficient to meet basic needs

  This involved perceptions that preferred food will not last long, perceptions that pests may contaminate food and the perception that pesticides that the farm households use to store their preferred food crop may endanger their lives
- Instances of staple food (maize) being infected by pathogenic moulds
- Instances of staple food being infested by insect pests or rodents
- The experience of running out of food without money to buy more
- Perceptions that the food eaten by the household members was inadequate in quality or quantity
- Adjustment to normal food use such as skipping meals or using less preferred cheaper foods
- Reducing amount of food per meal

The responses to the food insecurity conditions named above were coded "affirmative" or "negative" depending on whether the food insecurity conditions were present or absent, respectively, in the respondent's responses. The total number of responses coded "affirmative" was recorded per household, whereas the absence of the conditions was assigned a scale value of zero. The scores were weighted and interpreted using the standard scale score values in Table 7.1 A total of 0 – 2.22 scores means that the household is food secure, 2.3 – 4.6 scores means that the household is food insecure without hunger, 4.7 – 6.5 scores means the household is moderately food insecure, and a total of 6.6 – 10 scores means the household is severely food insecure (Bickel *et al*., 2000).

Table 7.1 Food security score standard values

Number of affirmatives	Standard value scores	Food security status
0	0.00	Food secure
1	2.04	Food secure
2	2.99	Food insecure without hunger
3	3.77	Food insecure without hunger
4	4.50	Food insecure without hunger
5	5.38	Food insecure with hunger
6	6.06	Food insecure with hunger

Source: Bickel *et al.*, 2000

The food security status of the farm households was also studied through investigating the wealth of the farm households. Types and quantities of assets that the farm households owned and their income were investigated. The types of food crops that the farm households' grew, coping strategies that they used to combat food shortages and their consumption behavior were also important for studying the farm households' food security status. The farm households' annual income and household food security status were correlated in order to explore the relationship between the two variables.

7.2.4 Statistical analyses

Frequency counts, percentiles, means, standard deviations and standard error means were calculated using the Statistical Programme for Social Sciences (SPSS) version 15 in order to explore magnitudes and significances. A Chi square test was performed in order to explore the relationship between the size and composition of households, and the time in a year during which the farm households ran out of maize. The average quantity of specific assets owned was calculated as follows:

Average quantity of specific asset in the household=mean value for the specific asset ± standard error of the mean.

Furthermore, the estimated percentages of the annual earnings that each source of income contributed to the total annual income made by the 260 farm households were calculated by dividing the values for the estimated yearly earnings from each of the different sources of income by the estimated overall income followed by multiplying by 100. The estimated amount of money that a farm household lived on per day was calculated by dividing the total annual income by 365[12]. Also, since the average size of a farm household in Katumba ward is five or six people the average amount of money that an individual in a farm household lived on per day in Katumba ward was calculated by dividing the amount of money that a farm household lived on per day by five or six. Furthermore, at the time of the study one US Dollar(USD) was equivalent to

[12] 365 is the number of days in a year.

Tanzanian shillings (TS) 1491.60 (OANDA, 2010), thus, the average amount of money in USD that a farm household in Katumba ward earned annually was based on the exchange rate.

7.3 Results

7.3.1 Assets that the farm households owned

7.3.1.1 Types of houses that the farm households in Katumba ward lived in

More than half of the farm households in Katumba ward live in houses that are made using mud bricks and corrugated iron sheets (Chapetr Five, Table 5.1). Mud bricks are low quality bricks and they shed light on the poor status of the farm households that used them to build houses.

7.3.1.2. **Implements ownership**

All of the farm households that participated in this study were in possession of at least one hand hoe, and the maximum number of hand hoes in a household was nine. The mean and standard error of the mean for the number of hand hoes that the farm households owned were 2.58 and 0.072, respectively. Only 0.4 % of the farm households were in possession of pairs bullock ploughs, which means the farm households did most of the land tillage using hand hoes.

7.3.1.3 **Transport and transportation facilities**

Very few of the farm households were in possession of transport or transportation facilities such as vehicles and tractors. Bicycles are the only transport facilities that about one third of the farm households owned (Table 7.2); while only fractions of the farm households owned motor vehicles or tractor trailers, which is an indication of the poor status of the farm households.

7.3.1.4 Ownership of communication facilities

While radios are the only communication facilities that more than half of the farm households owned (Table 7.3), only fractions of the total number of the farm households that owned relatively expensive communication facilities such as cell phones or televisions. This is an indication of the poor status of the majority of the farm households.

Table 7.2: Transport facilities that the farm households were in possession of (n=260)

Facility	Quantity	Percent of the farm households that possessed transportation facilities
Motor vehicle for commercial use	1	0.4
Motor vehicle for non commercial use	1	0.8
Bicycle	1	35.0
	2	0.8
	3	0.4
Motor cycle	1	2.7
Tractor	1	0.4
Tractor trailer	1	0.4

Responses apply to farm households that owned transport facilities. Number of responses per respondesnt ≥ 1

Table 7.3: Communication facilities that the farm households owned (n=260)

Communication facilities	Quantity	Percent households that possess the facilities
Television	1	10.0
Radio	1	63.8
	2	1.2
Cell phone	1	7.3
	2	1.2

Responses apply to farm households that owned communication facilities. Number of responses per respondesnt ≥ 1

7.3.1.5 Facilities for running water in the farm households

It was found that only 8.8 % of the farm households had tap water facilities in their homes. Thus the majority of the farm households depended on streams for water supplies. Distance to water sources was not considered important because in Rungwe district there is plenty of water in the form of streams, thus the residents in this district do not walk long distances in search of water. The concern though, is whether water from the streams is clean and safe.

7.3.1.6 Livestock that the farm households were in possession of

More than 90 % of the farm households owned chickens in a range of 0 - 74 per household, with mean of 7.78, and standard error 0.478. When divided into groups, it was found that the majority of the farm households owned up to ten chickens (Figure 7.1), which further illustrated the poor status of the farm households. A number of farm households owned cows, goats and pigs in the quantities indicated in Table 7.4. The means and standard errors of the means for the quantities of livestock owned by the farm households are also presented in Table 7.4.

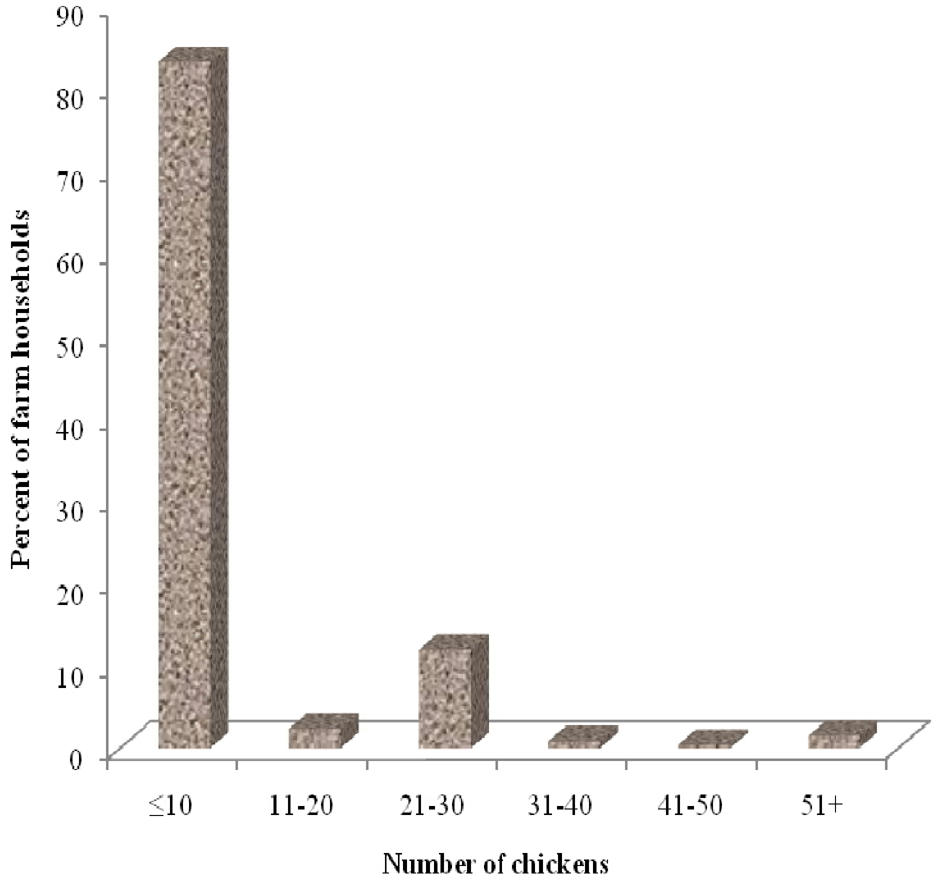


Figure 7.1: Number of chickens per household in Katumba ward

Table 7.4: Quantities of cows, goats and pigs that farm households owned (n=260)

Type of livestock	Quantity	Percent of households that posses the livestock	Mean	Standard error of the mean
	1	31.5		
	2	30.0		
	3	10.8		
Cows	4	2.3	1.43	0.77
	5	0.4		
	6	0.4		
	8	0.8		
	1	2.3		
Goats	2	1.9	0.13	0.03
	3	2.3		
Pigs	1	29.2		
	2	9.2		
	3	1.6	0.58	0.53
	4	0.8		
	6	0.4		

Thus, an average farm household in Katumba ward owned an average of seven or eight chickens, one or two cows, one or no pig and no goat.

7.3.1.7 Mode of transportation used forcarrying maize from the fields to their homes at harvest

About 73.5 % of the farm households transported maize from the fields to their homes by head portage (Table 7.5).

Table 7.5: Means that farm households used for transporting maize from the fields (n=260)

Means of transportation	Percent of farm households
Head portage, bicycle and wheel barrow	3.8
By bicycle	1.2
By commercial vehicle	3.5
By motorcycle	0.4
By head portage	73.4
By head portage and bicycle	14.2
Own wheel barrow	1.5
Commercial tractor trailer	0.8
Own tractor trailer	0.4
Commercial wheel barrow	0.8
Total	100.0

7.3.1.8 Persons who owned the assets within the farm households

In male headed farm households the number of males who owned hand hoes was slightly higher than that of females (Table 7.6). However, the overall number of females who owned hand hoes was greater than that of males (Table 7.6). There was no statistical difference between the percentage of females and males who owned bicycles (Table 7.7).

Table 7.6: Persons in the farm households who own the hand hoes (n=260)

Person	Percent of farm household for whom the response was applicable
Female household head	20.4
Male household head	44.2
Female parent (male headed household)	34.6
Both parents	0.8
Total	100.0

Table7.7: Persons who owned transport and transportation facilities in the farm households (n=260)

Facility	Owner	Percent of farm households that own transport facilities
Commercial use motor vehicle	Male household head	0.4
Non commercial motor vehicle	Male household head	0.4
	Female parent (male headed household)	0.4
Bicycle	Female household heads	3.84
	Male household heads	16.54
	Female parent (male headed household)	15.38
	Both of the parents	0.4
Motor cycle	Male household heads	0.4
	Both of the parents	2.3
Tractor	Male household head	0.4
Tractor trailer	Male household head	0.4

Responses applicable to farm households that owned transport facilities.

More males than females owned communication facilities; while less than one third of the female parents in male headed households shared ownership of radios with the male parents (Table 7.8).

The proportion of female household heads who owned tap water facilities equaled 1.2 % of the total percent of farm households that participated in this study; while the proportion of male household heads was 3.1 % and the proportion of female parents in male headed households who owned tap water facilities equaled 4.6 % of the total percent of farm households.

On the issue of livestock keeping, in general, more males than females in the farm households owned livestock (7.9). The findings in Tables 7.2 - 7.9 show that the majority of farm households in Katumba ward did not own expensive assets, which sheds light on their poor status. The findings also reveal that within the farm households, except for livestock and radios and hand hoes, the proportion of females who had ownership of assets was very small compared to the male counterparts. This shows that females were poorer than males.

Table 7.8: Persons who owned communication facilities in the farm households (n=260)

Communication facilities	Persons who own the facilities	Percent of farm households
Television	Female household head	1.50
	Male household head	3.80
	Both of the parents	4.60
Radio	Female household head	7.30
	Male household head	28.80
	Both of the parents	26.9
	Female parent (male headed household)	0.40
	Male adult (Male child)	0.40
Cell phone	Female household head	0.40
	Male household head	6.50
	Both of the parents	1.50

Table 7.9: Persons in the households who owned livestock (n=260

Type of livestock	Owner of livestock	Percent of farm households that owned the livestock
Cows	Female household heads	10.4
	Male household heads	36.2
	Female parents (male headed households)	29.2
	Both of the parents	0.4
Goats	Female household heads	1.2
	Male household heads	4.6
	Female parents (male headed households)	0.8
Pigs	Female household heads	8.1
	Male household heads	20.0
	Female parent s(male headed households)	13.1

7.3.2 Farm households' estimated annual income from different sources

The majority of the farm households that participated in this study depended on crop sales as a source of income (Table 6.10 and 6.11)and they earned a minimum of TS 15000.00 (or USD 10), a maximum of TS 6,866,000.00 (or USD 4,480.26), and an average of TS 598,113.47 (or USD 390.29) per annum. However, most of the income was generated from livestock sales. Standard deviation for the average income was 840,444.61 and the standard error for the mean was 52,122.16. The percentage of income that each of the sources of income contributed is shown in Table 7.11.

Table 7.11: Farm households' estimated yearly income {(TS) (n=260)}

		Estimated income in TS		Estimated income in US Dollars (USD)		
Source of income	**Percent of farm households**	**Maximum Income (TS)**	**Total Income from source (TS)**	**Maximum Income(USD)**	**Total income from source (USD)**	**Percentage of contribution to the total annual income**
Crop sales	84.20	4,000,000	40,762,266	2,610	27328	26.53
Livestock sales	46.50	6,000,000	45,930,000	3,915	30792	29.89
Fish sales	3.10	450,000	1,220,000	293	818	0.79
Petty trade	45.40	3,000,000	28,506,111	1,957	19111	18.55
Paid employment	5.80	2,500,000	13,370,000	1,631	8964	8.70
Self employment	3.80	6,000,000	16,690,000	3,915	11189	10.86
Remittances	4.20	600,000	1,840,000	391	1234	1.20
Timber sales	1.90	3,000,000	4,420,000	1,957	2963	2.88
Firewood sales	1.50	250,000	590,000	1633	396	0.38
Piece work	1.20	150,000	320,001	98	215	0.21

Exchange rate as at 14/09/2010: USD 1 = TS 1,491.60

7.3.3 Estimated amount of money that a farm household lived on per day

A farm household which consisted of five people in Katumba ward lived on TS 319.20 or USD 0.21 per day, while those made up of six people lived on TS 267 or USD 0.17 per day. The correlation between the farm households income and food insecurity severity revealed a weak, negative correlation (-122) significant at 0.05 (Appendix 7.3), implying that the farm household’s food insecurity severity slightly decreased with increase in income.

7.3.4 Farm households’ consumption behaviour

While 81.5 % of the farm households consumed three meals per day and 18.5 % consume two meals per day, 60.8 % of the farm households consumed three or two meals per day throughout the year. About 39.2 % of the farm households changed the number of meals that they consumed per day from three to two at a certain time during the year in order to cope with the decreasing food supply (Figure 7.2). The percentage of farm households that changed the number of meals from three in September-January was 9.2, and was higher than the percentages of farm households that changed the number of meals during months other than September - January. The

Chi-square test (α > 0.5) showed that there was no significant relationship between the size and composition of farm households, and the time in a year during which maize ran out.

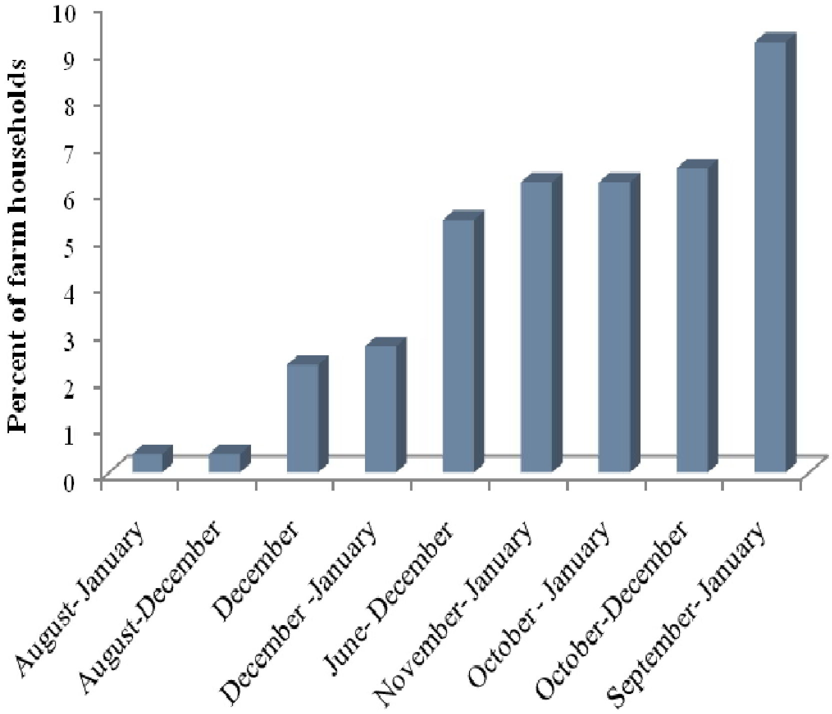


Figure 7.2: Time in a year during which farm households changed the number of meals that they take per day

7.3.4.1 Legume crops that the farm households grew

It was found that 96.6 % of the farm households grew at least one type of legume crop, namely: beans, peas, *mbaazi* and *njugu*[13]. The other types of legume crops that the farm households grew are presented in Table 7.12.

[13] "*Mbaazi*" and "*njugu*" are Swahili common names.

Table 7.12: Legume crops that farm households grew (n=260)

Legume	Percent of farm households
Beans	85.8
Peas	0.4
Beans and peas	8.8
Beans, peas and *mbaazi (pigeon peas)*	0.8
Beans and *njugu (Vignea subterranea)*	0.8

Also, the entire group of farm households that participated in this study grew at least one type of vegetable among the vegetables indicated in Table 7.13.

Table 7.13: Types of vegetables grown by the farm households grew (n=260)

Types of vegetables	Percent of farm households
Pumpkin leaves	93.1
Mchicha[14]	81.9
Bean leaves	95.4
Spinach	1.9
Cabbage	11.5
Chinese cabbage	24.6

7.3.4.2 Types of food often utilized concurrently with maize meals

Almost all of the farm households often consumed maize meals with beans, fresh leafy vegetables, dry fish and cabbage (Table 7.14).

[14]*Mchicha* is a Swahili common name for one of the local types of green leafy vegetable

Table 7.14: Types of food that farm households often ate together with maize meals (n=260)

Type of food	Percent of farm households that used the type of food
Beans	99.2
Meat	84.6
Fresh fish	15.5
Dry fish	95.4
Fresh green leafy vegetables	96.9
Dry vegetables	5.8
Sour milk (*Maziwa ya mgando /maas*)	82.7
Eggs	48.8
Green peas	14.6
Dry peas	6.5
Cabbage	95.8

7.3.4.3 Alternative types of food that the farm households utilized when they faced maize shortages

When the farm households in Katumba ward experienced maize shortages, they used the other types of food listed in Table 7.15, which they either purchased or grew (Table 7.16).

Table 7.15: Types of food that the farm households utilized in times of maize scarcity (n=260)

Type of food	Percent of farm households that utilized the type of food
Green bananas and plantains	99.6
Potatoes	20.8
Rice	11.2
Magimbi (*Colocasia esculenta*)	93.1
Cassava	27.7
Sweet potatoes	85.0

Table 7.16: Sources of the other types of food that farm households utilized when maize was scarce (n=260)

Type of food	Percent of farm households that bought the type of the food	Percent of farm households that grew type of the food
Green bananas and plantains	1.2	98.4
Potatoes	5.8	15.0
Rice	11.2	0
Magimbi (*Colocasia esculenta*)	3.5	89.6
Cassava	14.2	13.5
Sweet potatoes	3.8	81.2

Farm households grew/consumed more than one type of food crop each

Table 7.17 presents details concerning strategies that the farm households in Katumba ward used in order to cope with maize scarcity.

Table 7.17: Strategies used by the farm households when maize was scarce (n=260)

Strategy	Percent of farm household that applied the strategy
Buys more maize	18.8
Uses other types of food	6.2
Buys more maize and uses other types of food	67.7
Minimize maize use so that it may last long	0.8

7.3.4.4 Month in a year when the farm households applied strategies to cope with maize scarcity

Farm households in Katumba ward started applying strategies as early as in May of the same year in which maize was harvested in order to cope with maize shortages (Figure 7.3).

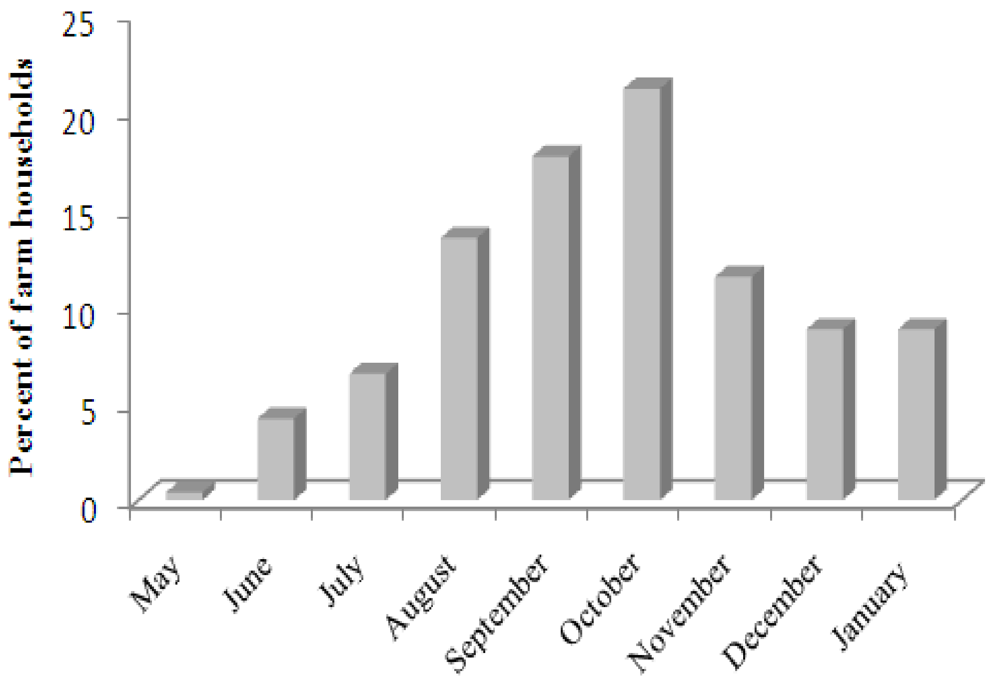


Figure 7.3: Month in a year when farm households applied strategies to cope with maize scarcity

Table 7.18 provides details concerning the time in the year when the farm households used other types of food as a strategy for coping with maize shortages and the length of time during which they used the other types of food, respectively.

7.3.5 The severity of the farm households food insecurity: Results obtained through using the Household Food Security scale

The findings obtained through the Household Food Security scale tool revealed that 86.5% of the farm households were food insecure without hunger, 10.4 % were food insecure with moderate hunger, 0.4 % were food insecure with severe hunger and 2.7 % were food secure. The condition of being food insecure without hunger could mislead the farm households into perceiving themselves food secure, thus, failing to take effective measures to fight against the status quo.

Table 7.18: Time in a year when farm households started using other types of food in order to cope with maize shortages (n=260)

Time in a year	Percent of farm households	Length of time in months during which the farm households used the other types of food more regularly per year
One month after maize harvest	0.4	10
Two months after maize harvest	4.4	9
Three months after maize harvest	6.8	8
Four months after maize harvest	13.8	7
Five months after maize harvest	17.8	6
Six months after maize harvest	21.2	5
Seven months after maize harvest	11.5	4
Eight months after maize harvest	8.8	3
Nine months after maize harvest	8.8	2

7.3.6 Farm households' perceptions concerning their food security status

About 83.8 % of the farm households perceived themselves food secure as opposed to only 16.2 % of the farm households that considered themselves food insecure. The main reason for which more than half of the farm households that took part in this study perceived themselves food secure was that they felt that they got enough food to eat (Table 6.19). Reasons for which the farm households perceived themselves food insecure are indicated in Table 6.20.

Table 7.19: Reasons that the farm households provided for perceiving themselves food secure (n=260)

Reasons for which the farm households perceived themselves food secure	Percent of farm households that provided the specific response
Our maize harvests last long enough	2.3
We get enough food to eat	55.4
We ensure cleanliness of the food	5.8
We manage to get maize all the time	1.9
We are satisfied with the food that we get	2.3
We ensure that we have all of the necessary types of food for a healthy diet for each meal	1.2
We get all of the necessary meals	0.4
We eat the type of food that we like	0.4
We store our food crops in a safe place	8.1
We grow other food crops apart from maize and get good harvests	20.4
We fight against infestations	0.4
We eat different varieties of food	23.8

Table 7.20: Reasons that the farm households provided for perceiving themselves food insecure (n=260)

Reasons for which the farm households perceived themselves food insecure	Percent of farm households that provided the specific response
Our maize supply does not last long enough	10.8
When maize supply runs out we are forced to eat other types of food which we do not like	0.4
We do not have access to adequate food	4.6
Insects and rodents that infest stored food contaminate it	0.8
We use pesticides in order to protect stored maize from insect infestations, thus, we are worried that the pesticides may endanger our health	0.4

7.4 Discussion

7.4.1 Implications of the types and quantities of assets that the farm households were in possession of on household food security

The poor status of the farm households in Katumba ward manifested itself through the possession of inexpensive assets or lack of assets which characterized the majority of the farm household. They include the low quality houses in which the majority of farm households lived in and the use of hand hoes for land tillage by the majority of the farm households. The fact that most of the land tillage was done using hand hoes also sheds light to the farm households'degree of limitation in terms of the sizes of land they could till and grow crops and ultimately to the amount of crops they could produce per harvest season.

Thus, since hand hoes are the only plough instruments that the majority of the farm households owned, it was necessary that the farm households be able to maximize output from the crops that they grew. This could have been done through preventing crop losses in the fields and during storage through growing crop varieties that are resistant to infestations (Ajala *et al.*, 2009) and infections, planting and harvesting on time (Obetta and Daniel, 2007), proper handling to reduce waste and grain damage at harvest and during processing (International Rice and Research Institute (IRRI) and International Maize and Wheat Improvement Centre (CIMMYT), 2009) and using efficient storage technologies (Thamaga-Chitja, 2004). Other factors that revealed the poor status of the farm households include the fact that only 3 % of the farm households were in possession of motor vehicles, and that radios are the cheapest communication facilities, yet about one third of the farm households did not own them.

Likewise, the fact that only 8.8 % of the farm households that participated in this study were in possession of tap water facilities further demonstrated the poor status of the farm households. It has been noted that in rural areas, people's access to water affects the people's food security (Hubbard, 1995). The time and effort that the households put into fetching water hinder them from spending more time in income generating activities (Hubbard, 1995), which leads to low income, and impacts negatively on their food security status. Lack of running water facilities may also lead to hygiene problems, which may encourage diseases such as diarrhoea, which may impact negatively on the capacity of the consumer's body to assimilate the required nutrients from food (Hubbard, 1995). Thus, lack of running water facilities may lead to nutrition problems and food insecurity for the majority of the farm households in Katumba ward. The fact that the majority of farm households used head portage for transportation of maize from the fields and the extent to which the numbers of the different types of livestock the farm households in Katumba ward owned were small also confirm the poor status of the farm households. This also means that the livestock that the farm households owned cannot be considered as constant sources of meat for the majority of the farm households. It also suggests that for the majority of the farm households meat was purchased rather than produced.

In addition, the fact that the farm households owned very few basic assets also shed light to the degree to which it would be difficult for the farm households to access formal credit to boost their farming input or income generating activities. Although access to formal credit is among factors that are recommended for better agricultural input and productivity (WFP, 2007), lack of valuable assets has been a constraint to accessing formal credit in several places (Diagne and Zeller, 2001; WFP and WHO, 2006).

7.4.2 Implications of the sources of income and the amount of income on the farm households' food security

While the majority of the farm households in Katumba ward depended on crop sales as a source of income, livestock sales and petty trade were sources of income for significant percentages of the farm households (section 6.4.2). Livestock sales contribute the highest percentage to the total annual income followed by crop sales (Table 11). This implies that although the majority of the farm households depended on crop sales for income, the percentage of the farm households that depended on livestock sales generated more money from livestock sales than the amount of money generated from crop sales.

Petty trade, self employment and paid employment made a relatively higher contribution to the total annual income than remittances and timber sales, whereas fish sales, firewood sales and piece work contributed least to the income. The importance of remittances as a source of income has been acknowledged worldwide (The World Bank, 2010). In 2005 Remittances contributed 36.9 % of the Gross Domestic Product (GDP) in Guyana and 34.5 % of the GDP in Haiti. Thus, in Katumba ward remittances played a minor role as sources of income since their contribution to the total income in the ward amounted to only 1.20 %. Although there were several sources of income that the farm households depended on in Katumba ward, the amount of money that the farm households earned annually from different sources of income was very low, such that the amount of money that an individual in a farm household lived on was a lot lower than the World Bank's poverty line, which is USD 1.25 per day per individual (Crocodila, 2010). This further demonstrated the poor status of the farm households. However, the weak association between the farm households' income and their food insecurity severity as revealed by the Pearson correlations suggests that other underlying factors influenced the farm households' food insecurity. Thus other factors such as farm households' experiences of infestations, fungal infections and mycotoxin contaminations of maize included in measuring the farm households' food security status played important roles in determing the latter.

Poverty may lead to illness and hunger, which is partly due to the poor people's cash flows and their very limited capacity to purchase adequate amounts of nutritious food when their food supplies diminish. Income plays a role in determining the capacity of the farm households or individuals to make purchases (Anslinger, 1997). The lower the household's income, the lower the household's capacity to purchase food products that the household does not produce on-farm and the lower the household's capacity to purchase food when the household's food supply diminishes. Thus, income determines the food security status of a household (Hubbard, 1995).Therefore, the very low income of the farm households in Katumba ward was an indication of their food insecurity. In general, farm households in Katumba ward depended heavily on farm produce for income, while very few had non- farm sources (Table 6.10). Strengthening farm and non-farm sources of income in Katumba ward was a necessity for sustainable livelihoods.

7.4.3 Ownership of assets within the farm households and its implications on the farm households food security

A higher percentage of females who participated in this study owned facilities that were used for land tillage than males did, which imply that more women were more involved in tillage activities than men. This was in agreement with the general understanding that in Tanzania (Government of the United Republic of Tanzania, 2006) and particularly Rungwe district (Anon, 2008); women are the main food producers. The fact that women were more involved in agricultural activities yet were poorer than men in Katumba ward, concurs with Hunter-Gault's report (2006) concerning the status of women in Africa.

7.4.4 Food consumption behavior and its implications on the farm households' food security

7.4.4.1 The implication of the number of meals that the farm households consumed per day

The 39 % of the farm households that reduced the number of meals from three to two per day at a certain time within a year in order to cope with the decreasing food supply was quite large. The option by the farm households to consume less numbers of meals than entitled to per day in order to cope with the food shortages are indications of food insecurity, which as Maxwell and Smith (1992) reported determines the level of vulnerability and food insecurity of the individuals concerned.

The reduction of the number of meals that individuals take per day as a strategy for coping with food shortages has been acknowledged in Africa (Quaye, 2008; Nzomoi, 2008). In Katumba ward, the majority of the farm households that reduced the number of meals from three to two did so in September-January (Figure 6.2); while a few farm households did so from as early as August to January. Although the 39.2 % of farm households that reduced the number of meals to two was less than half of the total percentage, it shed light on the existence of vulnerability to hunger for a significant number of farm households in Katumba ward. The fact that there was no significant relationship between size and composition of farm households and the time in a year during which the farm households completely ran out of maize imply that the time during which maize shortages occured was not influenced by the size and composition of the farm households.

7.4.4.2 The implications of the types of food that the farm households consumed on health

The 11 types of food eaten together with maize meals in Katumba ward, namely: beans, meat and fresh fish, fish, green vegetables, dry vegetables, sour milk eggs, green peas, dry peas and cabbage offered the farm households diversification in relation to the nutrients that the farm households could access. Green leafy vegetables are good sources of vitamins, minerals and roughage (Singh *et al*., 2001; Flyman and Afolayan, 2006), whereas dry fish, eggs, and sour milk, also eaten with maize meals on a regular basis are good sources of protein (FAO, 1999; Ofuya and Akhidue, 2005). Thus, it is possible that farm households were able to access some of the required protein minerals and vitamins from these foods on a regular basis, depending on the quality and quantities of the foods. However, since the other types of food eaten together with maize meals are taken in small amounts, it implies that only small amounts of nutrient could be accessed from the foods, which may not satisfy the basic minimum daily requirements of these nutrients among the farm households.

7.4.4.3 The implications of the other food types consumed during maize scarcity on the farm households' nutrition

Six types of food crops were also grown in Katumba ward, namely: green bananas/ plantains, sweet potatoes, potatoes, cassava, and *magimbi*. These crops served as food especially when maize was scarce, and they provided the farm households with diversification options, thus, impacting positively on their food security status. While 100 g of maize can provide 287 mg of potassium, bananas (The George Mateljan Foundation, 2011 a), sweet potatoes (The George Mateljan Foundation, 2011 b), potatoes (Botanical online, 2011) and *magimbi* (Anon, 1999) can provide a lot more potassium per 100 g of edible matter. Furthermore, bananas (The George

Mateljan Foundation, 2011 a), potatoes (The George Mateljan Foundation, 2011 b; Botanical online, 2011) and cassava (Anon, 2002) are good sources of vitamin C, whereas sweet potatoes are very good sources of A-Beta carotene (The George Mateljan Foundation, 2011 b), which are deficient in common maize (Nuss and Tanumihardjo, 2010).

Although more than 60 % of the farm households bought more maize when their maize supplies diminished (Table 6.17), about 73 % of the farm households also used other types of food as a strategy for coping with maize shortages till the next maize harvest season. A total 49 % used the other types of food more regularly than they normally did for less than six months, 31 % used the other types of food more regularly for six to seven months and only 11 % of the farm households increased the frequency at which they used the other types of food for more than seven months. In the light of the above, it is evident that for more than six months, 48.6 % of the farm households deprived themselves nutrients that they could otherwise obtain from the other types of food, which could impact negatively on their nutrition. Similarly, 31 % of the farm households deprived themselves of the nutrients discussed above for five to six months in a year, and only 11 % that used the other types of food for more than eight months they deprived themselves of the nutrients for only one to three months in a year. Therefore, due to their preference for maize meals above the other types of food, the majority of the farm households denied themselves nutrients that they could otherwise have obtained from the diversity of the food crops that they grew. While this would have a negative effect on the farm households' nutrition, those that experienced maize scarcity for longer periods of time used the other types of food more frequently, and this created opportunities for diversification of food sources and possible better nutrition than farm households that experienced maize scarcity for only a short period of time in a year, and thus, could be more food secure.

7.4.5 The implications of the farm households' understanding of food security and their perceptions regarding their food security status

Almost all of the farm households were food insecure, yet 83.8 % of the farm households incorrectly perceived themselves food secure. The farm households perceived themselves food secure for several reasons, of which the idea of having enough food to eat had the highest scores which amounted to 75.8 %[15] of the total scores. This is perhaps understandable considering the fact that 86.5 % of the farm households were food insecure without hunger[16]. Thus, regardless of the existence of food insecurity conditions such as the tendency to skip meals in order to cope with food shortages, the farm households perceived themselves food secure based on the fact that they managed to have something to eat. As far as food security is concerned, sufficient food has a lot to do with the capacity of individuals to constantly access safe, nutritious food for a healthy and active life (Maxwell and Smith, 1992; The World Bank, 1986; Guha-Khasnobis *et al.,* 2007), which was not the case for the majority of the farm households in Katumba ward. Although Mbeya region as a whole is regarded as a food secure region, the opposite may be the case when issues of food safety are incorporated into the conditions that are used for determining household food insecurity.

Furthermore, the quality of food in terms of nutrition (Guha-Khasnobis *et al.,* 2007; Webb and Thorne-Lyman, 2007) and safety plays a major role in influencing health of the consumers, thus, food quality is an important aspect of food security. However, it seems that farm households in Katumba ward were not aware of this fact. Thus, the farm households' perception that they have sufficient food was incorrect for the majority of the farm households. For the 16 % of the farm households that perceived themselves food insecure, the proportion of those whose perception was based on the fact that their maize supply did not last long enough was larger than the proportion of those whose perception was due to other reasons than the above. Very few farm households were able to link food security with its other aspects apart from availability of food.

While only 0.8 % of the farm households linked food insecurity with the contaminations caused by insects and rodents infestations on the stored maize, none of the farm households linked fungal infections on stored food crops, particularly maize with household food insecurity. Therefore, it is inferred that the majority of the farm households in Katumba ward incorrectly perceived themselves food secure, mostly because they felt that they had access to enough quantities of food to eat. The farm households that perceived themselves food insecure did so

[15]The numeric figure '75 %' was obtained after adding together scores for 'we have enough food to eat' and 'we grow other food crops apart from maize and we get good harvests', which carry the same sense of having enough food to eat.
[16]Appendix 7.2

mostly due to the reason that their maize harvests did not last long. This also justifies argument that the majority of the farm households understood food security as having adequate quantities of food regardless of its quality in terms of nutritive value and the degree to which it was safe for consumption, which is a limited understanding of food security.

7.5 Conclusion and recommendation

As per Household Food Security Scale tool, the main conclusion in this chapter is that 86.5 % of the farm households in Katumba ward were food insecure without hunger, 10.40 % were moderately food insecure with hunger, 0.4 % were severely food insecure with hunger and 2.7 % were food secure. This is partly based on the fact that the majority of the farm households in Katumba ward were poor, a state which revealed itself through the very few assets that the farm households owned, and the very little income which led to them to live below the World Bank's poverty line of 1.25 USD per day per individual. Consequently, the poor status of the farm households in Katumba ward would limit their capacity to purchase food when food supplies diminish. This renders them vulnerable and food insecure. Furthermore, for the majority of the farm households in the ward, maize, which is their most preferred food crop did not last till next harvest season, which forced about 39 % of the farm households to cut down on the number of meals that they took per day at a certain time in a year, which is an indication of vulnerability to food insecurity. The farm households' preference for maize meals than other types of food that they grew such as green bananas/plantains, and sweet potatoes impacted negatively on their food security status because it hindered them from accessing nutrients from the foods.

In addition, for the majority of the farm household, their understanding of food security was limited because it only focused on the availability or quantities of available food and it ignored the safety and nutritive value of the available food. For a farm household to be food secure, each individual in the household must have constant access to safe and nutritious food among other factors, which was not the case for the majority of the farm households in Katumba ward. In the light of the above, it was recommended that efforts be made by the government in Tanzania and development agents to raise the awareness of farm households in Katumba ward on issues of food security and its implications on the well - being of the people.

References

Ajala, S.O., Aroga, R., Odiyi, A., Olaye, G., 2009. Screening and Breeding for Resistance to Maize Stem Borers and Eldana in West and Central Africa. *African Crop Science*. 9, 559 - 564.

Anon, 1999. *Nutrition information on Taro, raw.* <http://www.elook.org/nutrition/vegetables/3390.html>(Accessed 2011 January 02).

Anon, 2002. *Composition and Nutrition Value*. <http://www.bicolida.gov.php/opportunities/cassava%20profile/topic1.htm>(Accessed 2011 January 18).

Anon, 2008. *Weather in Katumba* <*http://freemeteo.com/default.asp?pid=180lta=1&sid=639320&gid=151851&alls=2*>(Accessed 2008 August 01).

Anslinger, B, 1997. Outcomes of Microcredit Programs: Sustainability, Social Development, Economic Development and Food Security. *Middle States Geographer*. 30, 105 - 111.

Bickel, G., Nord, M., Price, C., Hamilton, W., Cook, J., 2000. *Guide to Measuring Household Food Security*. Http://www.fns.usda.gov/fsec/files/fsguide.pdf (Accessed 2011 August 17).

Botanical online, 2011. *Potatoes* <http://www.botanical-online.com/potatasangles.htm> (Accessed 2011 February 15).

Crocodila, 2010.*World leaders ready for a summit on MDGs*. <http://www.allvoices.com/contributed-news/6751701-world-leaders-ready-for-un-summit-on-mdgs> (Accessed 2010 September 14).

Dattalo, P., 2008. *Determining sample size: Balancing Power, Precision and Practicality*. Oxford University, Oxford.

Diagne, A., Zeller, M., 2001. *Access to Credit and its Impact on Welfare in Malawi*. International Policy Research Institute, Washington.

FAO, 1999. *Fish is Good for the Brain as well as Good Protein*. <http://www.fao.org/focus/e/fisheries/nutr.htm> (Accessed 2010 October 19).

FAO, 2010. *The State of Food Insecurity in the World. Addressing Food Insecurity in Protracted Crises*. FAO, Rome

Flyman, M.V., Afolayan, A.J., 2006. The Suitability of Wild Vegetables for Alleviating Human Dietary deficiencies. *Journal of Botany*. 72, 4, 492 - 497.

Government of the United Republic of Tanzania, 2006. *Agriculture*. <http://www.tanzania.go.tz/agriculture/htm> Accessed 2010 May 19).

Government of the United Republic of Tanzania, 2007. *Mfano wa Tovuti ya Mkoa bado Inaendelezwa* . <http://www.kagera.go.tz/kurasa/halmashauri/1ga1/dc/index.php> (Accessed 2010 February 27).

Guha-Khasnobis, B., Acharya, S.S., Davis, B., 2007. *Food Insecurity, Vulnerability and Human Rights Failure.* PALGRAVE MACMILLAN, New York:.

Guo, Baorong, 2010. *Household Assets and Food Security.Evidence from the Survey of Program Dynamics*. <http://www.springerlink.com/content/j458260324160672/fultext.html>. (Accessed 2011 January 1).

Hubbard, M., 1995. *Improving Food Security . A guide for rural development managers*. Intermediate Technology Publications, London.

Hunter-Gault, C., 2006. *In Tanzania Women see a Path out of Poverty*. <http://www.npr.org/templates/story/story.php?storyid=5632059> (Accessed 2011 January 1).

IRRI, CIMMYT), 2009. *Maize Seed Management-Post - harvest Treatment and Storage*. <http://www.knowledgebank.irr.org/ckb/index.php/post-harvest/maize-seed-management- > (Accessed 2011 January 1).

Maxwell, S, Smith, M, 1992. *Household Food Security: A Conceptual Review*, in Maxwell, S., Frankenberger, T.R., Household Food Security- Concepts, Indicators and Measurements- A Technical Review. UNICEF/IFAD, New York, pp. 1-72.

McKinney, P. 2006. *Tanzania: Comprehensive Food Security and Vulnerability Analysis (CFSVA).* <http://documents.wfp.org/stellent/groups/public/documents/vam/wfp118341.pdf> (Accessed 2011 August 20).

Nuss, E., Tanumihardjo, S.A. 2010. Maize: A Paramount Staple crop in the Context of Global Nutrition. *Comprehensive Reviews in Food Science and Food Safety*. 9, 4, 417 - 437.

Nzomoi, J.N., 2008. *Agricultural Commodity Price Fluctuation, Poverty and Food Issues in* Kenya. <http://www.cerdi.org/uploads/sfCmsContent/htm/258/Nzomoi.pdf> (Accessed 2011 January 1).

OANDA. 2010. *Currency converter* <http://www.oanda.com/currency/converter> (Accessed 2010 September 14).

Obetta, S.E., Daniel, C., 2007. Preliminary Investigation into some Quality Control Indices for Selected Stored Grains in Makurdi, Nigeria. *Nigerian Food Journal*. 25, 1, 117 - 129.

Ofuya, Z.M., Akhidue, V. 2005. The Role of Pulses in Human Nutrition: A Review. *Journal of Applied Sciences and Environmental Management*. 9, 3, 99 - 104.

Orozco, M., 2007. *The Role of Remittances in Leveraging Sustainable Development in Latin America and the Caribbean*. <http://www.thedialogue.org/PublicationFiles/sustainable_development1.pdf> (Accessed 2011 August 17).

Quaye, W., 2008. Food Security Situation in Northern Ghana, Coping Strategies and Related Constraints. *African Journal of Agricultural Research*. 3, 5, 334 - 342

Singh, G., Kawartra, A., Sehgal, S., 2001.Nutritional Composition of Selected Green Leafy Vegetables, herbs and Carrots. *Plant Foods for Human Nutrition*. 56, 359 - 364.

Thamaga- Chitja, J. M., Hendriks, J., Ortmann, G.F., Green, M., 2004.Impact of Maize Storage on rural household food security in Northern KwaZulu- Natal. *Journal of Family Ecology and Consumer Sciences*. 32, 8 - 15.

The George Mateljan Foundation, 2011 a. *Bananas*. <http://www.whfoods.com/genpage.php?tname=nutrientprofile&dbid=92>(Accessed 2011 January 02).

The George Mateljan Foundation, 2011 b. *Sweet Potatoes. Whats' New and Beneficial about Sweet Potatoes*. <http://www.whfoods.com/genpage.php?tname=nutrientprofile&dbid=128> (Accessed 2011 January 02).

The Planning Commission and Mbeya Regional Cmmissioner's Office. 2011. *Mbeya Region, Socio - econoomic Profile*. <http://www.tzonline.org/pdf/mbeyareg.pdf> (Accessed 2011 August 14).

The World Bank, 1986. Poverty *and Hunger: Issues and Options for Food Security in Developing Countries*. World Bank Policy Study, Washington D.C.

The World Bank, 2010. *Migration and Remittances*. <http://siteresources.worldbank.org/TOPICS/Resources/214970-1288877981391/Annual_Meetings_Report_DEC_IB_MigrationAndRemittances_Update24Sep10.pdf> (Accessed 2011 August 18).

Trochim, W. M. K., 2001. *The Research Methods Knowledge Base*. Atomic Dog, Cincinnanti

Webb, P., Thorne-Lyman, A., 2007.Entitlement Failure from a Food Quality Perspective: The life and Death role of Vitamins and Minerals in Humanitarian Crises. In Guha-Khasnobis, B., Acharya, S.S. and Davis, B. (Eds). *Food Insecurity, Vulnerability and Human Rights Failure*. PALGRAVE MACMILLAN, New York, pp 243 - 265.

WFP/WHO, 2006.*Greater Monrovia Comprehensive Food Security and Nutrition Survey (CFSNS).* <http://www.unliberia.org/doc/MonroviaCFSNS_July%202007.pdf> (Accessed 2011 January 1).

WFP, 2007. *Home - Grown School Feeding. A Framework to Link School Feeding with Local Agricultural Productivity and Food Availability*. WFP, Rome.

WFP, 2011. *Assets*. <http://foodsecurityatlas.org/bhn/country/asets> (Accessed 2010 December 30).

APPENDICES

Appendix 7.1: Questionnaire that was used for gathering required information

1. What is the type of your main house?

(i) Round hut with thatched roof (ii) Multiple rooms made of mud bricks, with thatched roof (iii) Multiple rooms made of mud bricks with corrugated iron roof (iv) Multiple rooms made of cement bricks with corrugated iron roof (v) Multiple rooms made of baked mud bricks with corrugated iron roof (vi) Other (specify)

2. How many of the following assets do you own in the household?

Item	Unit (or pairs of unit)	Owner	Item	Unit (or pairs of unit	Owner
Motor vehicle (Commercial use)			Tractor plough		
Motor vehicle (private use)			Pairs of bullock		
Motor cycle			Bullock plough		
Bicycle			Bullock harrow		
Television			Bullock cart		
Radio			Chickens		
Private tap water			Cows		
Water pump			Goats		
Tractor			Other (specify) --------------------		
Tractor trailer					

Owner codes: (i) Household head (ii) Spouse ((iii) parents (iv) siblings (vi) Children (vii) Other (specify) ---------------------------

3. How do you transport your farm produce from the farm to the house?

(i) By bicycle (ii) By private vehicle (iii) By commercial vehicle (iv) By bullock cart (v) By head portage (vi) Other (specify)

4. What are the sources of income for your household?

Sources of income	What is your estimated yearly income from the sources you have indicated?
Crop sales	
Livestock sales	
Fish sales	
Petty trading	
Paid employment	
Remittances	
Self employment	
Other (specify)- -----------------	

5. How many meals does your household consume in a day? ----------------------meals

6. Does your household have the number of meals you have indicated in your answer to question six throughout the year? (a) Yes (b) No

7. If your answer is 'No' to question 6, what months in the year do you have a number of meals other than the number of meals you have indicated in your answer to question 5?

Month	Number of meals

8. If your answer is "No" to question 6, what are the reasons for changing the number of meals?

9. Which legume crops do you grow?

Legume crop	How much land is allocated to growing legumes?

10. Which vegetables do you grow?

Type of vegetable crop	How much land is allocated to growing vegetables?

11. When you do not have maize, what other types of food do you eat?

Type of food	Reasons for using the indicated type of food

12. Do you grow or buy the type of food you have indicated in your answer to question 11?

Type of food	Do you buy or grow the type of food you have mentioned?

13. Do you think your household is food secure? (a) Yes (b) No

14. What are the reasons for your answer to question 13?---

Appendix 7.2: The food security status of farm households

		Frequency	Percent	Cumulative Percent
Valid	Food secure	7	2.7	2.7
	Food insecure without hunger	225	86.5	89.2
	Food insecure with hunger (Moderate)	27	10.4	99.6
	Food insecure with hunger (Severe)	1	.4	100.0
	Total	260	100.0	

Appendix 7.3: Exploring the association between food insecurity severity and farm households' income

		Food insecurity severity	Total income per year(USD)
Food insecurity severity	Pearson Correlation	1	-.122*
	Sig. (2-tailed)		.049
	N	260	260
Total income per year(USD)	Pearson Correlation	-.122*	1
	Sig. (2-tailed)	.049	
	N	260	260

*. Correlation is significant at the 0.05 level (2-tailed).

CHAPTER EIGHT

OVERVIEW OF RESEARCH FINDINGS AND RECOMMENDATIONS

The following hypotheses were tested in this study:

(i) Due to the climatic conditions in Rungwe district, maize storage methods may be inadequate for keeping stored maize safe from pests and subsequent contaminations, thus, the quality of stored maize may be poor, and the farm households may be at risk of ill health, thus vulnerable and foood insecure.

(ii) Traditionally, green bananas/plantains are the preferred food crop in Rungwe district. However, maize production is gaining significance in this district, thus, maize consumption may also be rising, whereas farm households may not be well equipped with skills for achieving and maintaining high quality of stored maize.

The hypotheses were largely addressed and achieved using Katumba ward as a reflection of the other parts of Rungwe district. However, more insights into the study could have been gained through involvement of the agricultural extension staff. The main conclusion was that the quality of maize stored using roof and sack storage methods in Katumba ward was very low. Furthermore, maize was the most important food crop in Katumba ward. This claim was based on the fact that the farm households in Katumba ward preferred maize meals compared to other types of food, and as a result they consumed an average of two out of three meals per day in an average of six days per week. Through consuming maize meals the farm households in Katumba ward could access 63 - 65 % of the total energy required, 83 - 90 % of the total required protein and smaller quantities of necessary minerals such as calcium and phosphorus daily. Also maize contributed to enabling the farm households in Katumba ward to access nutrients from the other types of food that were consumed concurrently with maize meals such as meat, fish and vegetables.

However, although the above was the case, roof and sack storage methods that the farm households in Katumba ward used to store maize were not effective enough to protect stored maize from infestations by rodents and insect pests and from moulds. As a result, 34.5 % of the total maize harvests in Katumba ward were lost to the pests annually, which is quite significant considering the fact that they were subsistence farmers. While *Sitophilus zeamais* and *Sitotroga cerealella* are the main insect pests that attacked stored maize in Katumba ward, rodents, especially the brown rats and fungal pathogens, namely: *Fusarium*, *Diplodia*, *Aspergillus* and *Penicillium* species also attacked stored maize regularly in the ward. The presence of moulds and insect pests in the stored maize would render maize unpalatable, whereas the storage pests reduced the amounts of maize that could be available to the farm households, thus, promoting food insecurity.

Furthermore, the pathogenic moulds produced high quantities of mycotoxins in stored maize such that the farm households in Katumba ward were exposed to averages of 596.50 ± 38.85 µg/kg of aflatoxins, 1803.77 ± 244.56 µg/kg (or 18.04 ± 0.24 mg/kg) of T-2 toxins 87717.95 ± 14984.32 µg/kg (or 87.72 ± 15 mg/kg) of fumonisins and 745.73 ± 105.57 µg/kg of ochratoxins per meal. The amounts of aflatoxins, ochratoxins and fumonisins per kg of maize in Katumba ward were very much higher than the internationally accepted standards, which are: 20 µg/kg aflatoxins, 50 µg/kg ochratoxins and 4000 µg/kg for fumonisins. This put the consumers at risk of suffering from the diseases that are caused by the mycotoxins such as the suppression of the immune system, cancer of the esophagus, cancer of the liver, kidneys problems, interference with protein synthesis and interference with the neuron function (Hayes, 2000; Munkvold *et al*., 2009). At the time of this study no research had been done in order to find out whether the above indicated diseases were real in Katumba ward or Rungwe district in general, thus, people may have been dying unnoticed due to the diseases. Roof and sack storage methods are the only storage methods that the farm households in Katumba ward used for long term storage of maize, thus, they played a major role in determining the quality and quantity of maize that could be available to the farm households in the ward. Farm households in Katumba ward wrongly perceived roof and sack storage methods as having high capacity to protect stored maize from insect infestations and moulds infections, a perception which the findings that were obtained through conducting laboratory experiments on maize samples from the research area proved incorrect.

Factors that contributed to the low performance of the roof and sack storage method in Katumba ward include the climatic conditions in the ward which lead to high humidity and the poor quality of the buildings in which maize was stored, which allowed rodents to enter the storage facilities. The poor quality of the buildings in which maize was stored in Katumba ward and the nature of the storage facilities also promoted the development of the pests and moulds. The low level of education of heads of farm households and farm households' lack of access to maize storage information also impacted negatively on the farm households understanding of maize storage problems and handling of maize in general. As a result of the ignorance the farm households in Katumba ward utilized mouldy maize for consumption purposes or simply threw away maize which was badly affected by the moulds. In turn, the above tendencies created possibilities for illnesses caused by the mycotoxins and the multiplication of the moulds in the fields.

Poverty, the infestation of the staple food with insect pests, rodents and moulds and their related contaminations compromised the food security status of the farm households. Consequently, 86.5 % of the farm households were food insecure without hunger, 10.4 % were moderately food insecure with hunger, 0.4 % were severely food insecure with hunger.

The following was recommended:

- Roof and sack storage mechanisms in Katumba ward be improved so that they can protect stored maize from absorbing moisture from the storage areas. This will help in ensuring that the storage facilities do not create favourable conditions for growth of moulds, and that the nutritional value, availability and safety of maize are not compromised.
- Programs that aim at raising the farm households' and extension workers'awareness concerning maize storage and the implications of infestations and infections in stored maize on the health of the consumers be implemented in Katumba ward.
- Programs that aim at equipping the farm households with necessary skills for maize storage should also be implemented in the ward.
- An alternative, simple and cost effective way of ensuring that maize is rapidly and sufficiently dried and is dry enough prior to storage be found and introduced to the farm households.
- The farm households in Katumba ward be encouraged to do the following:
    - To establish a maize farming association for easier access to maize storage knowledge
    - To grow maize varieties that are particularly resistant to insect pests and moulds

- Ensure that the storage facilities are clean and disinfected prior to storage in order to eliminate insect pests and their eggs, moulds and spores that may have accumulated in the storage facilities.
- Ensure that the storage facilities are dry at all times
- Use local herbs that can control insect pests instead of expensive pesticides which the farm households may not be able to afford.
- Inspect the storage facilities at regular intervals in order to detect and control the infestations and infections.
- Avoid disposing maize cobs and infested maize in the fields but incinerate them instead in order to control the multiplication of the insect pests and moulds in the fields.

- Appropriate agricultural policy be implemented by the government of Tanzania in order to control the quality of stored maize especially in areas that have the same climatic conditions as Katumba ward. Passing a law which insists that maize should be adequately dried prior to storage may push farm households into adopting faster ways of drying maize prior to storage.
- The government of Tanzania should encourage the plant breeders in the country to produce maize varieties that are particularly resistant to insect pests and moulds. This will reduce both the incidence and severity of mycotoxin accumulation in maize grain. They should also emphasize selection for resistance of maize varieties to contamination by mycotoxins as a larger program for ensuring food safety in rural communities such as Katumba ward.
- Maize breeding for higher content of nutrients such as protein, vitamins, zinc, iron and other mineral elements should also be encouraged.
- More research should be conducted in order to investigate the existence of diseases or deaths that are related to consumption of foods that are contaminated by mycotoxins in Rungwe district and other places that have the same climatic conditions as Katumba ward.