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TITLE

ASSESSMENT OF POST HARVEST HANDLING PRACTICES OF MAIZE AT ODUMASE IN THE SUNYANI WEST DISTRICT OF THE BRONG AHAFO REGION

A THESIS SUBMITTED IN FULFILMENT OF THE REQUIREMENTS FOR THE MPHIL IN FOOD AND POST HARVEST ENGINEERING

BY

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DECLARATION

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

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ABSTRACT

Aflatoxin contamination levels were measured in samples collected from selected maize stores at the beginning and at the end of the storage period to examine the incidence of aflatoxin in Odumase (a major maize producing and marketing centre) and the effect of different storage practices. A mean contamination level of 61.6ppb was found in the 25 samples collected with 72% of the samples having contamination levels in the 20-100ppb range. The mean contamination level in the beginning of storage samples was 26.7ppb and increased to 56.7ppb in the end of storage samples after a period of 3 to 5 months. A survey conducted through the administration of a questionnaire to 42 farmers showed that storage of ears in traditional cribs was the predominant practice with 88.1% of respondents using this storage practice. Storage of husked maize in the traditional cribs showed no increase in aflatoxin contamination levels but storage of dehusked ears in the traditional cribs recorded a mean change of 90ppb over the storage period. The survey identified good handling and storage practices in the research area, such as the sorting out of mould infected and insect damaged ears as well as treatment of both maize and storage structures with insecticide. High increases in insect infestation in most stores at the end of the storage period suggested lack of professionalism in the use of good storage and handling practices. The research identified low patronage of certified seed (14.3%) and fertilizer (7%) among farmers and the undue delay in conveying harvested maize from the farm gate to the farmers' store or the market (average of 11.6 days) as situations contributing to the high pre-storage aflatoxin level of 26.7ppb. Fungal evaluation in maize samples also showed the presence of *Aspergillus flavus* in all but two of the

beginning of storage samples. Analysis of climatic data of the research area and moisture content data on maize from the Odumase market indicated the existence of unfavourable climatic conditions for maize handling during the harvesting period of July to September/October. Relative humidities of above 80% leave harvested maize with moisture contents between 26.8% and 18% and make sun drying of little effect. The survey revealed that mechanical drying was not practiced by farmers themselves but some poultry farmers and traders who buy maize from the Odumase market. The research concluded that mechanical drying would be the most effective way of dealing with the high aflatoxin contamination levels, in view of the unfavourable climatic conditions especially during the major season harvest. It was also concluded that strict observance of good agronomic and post harvest handling and storage practices could significantly reduce the aflatoxin contamination level even without mechanical drying.

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LIST OF ABBREVIATIONS

AF	Aflatoxin
AFB1	Aflatoxin B1
AFM1	Aflatoxin M1
DI	Deterioration Index
D_p	Drying Potential
ERH	Equilibrium Relative Humidity
EMC	Equilibrium Moisture Content
GMP	Good Management Practice
GWSP	Good Warehouse Storage Practice
HACCP	Hazard Analysis Critical Control Points
MC	Moisture Content
MDSF	Mechanical Drying and Storage Facility
P_a	Partial Vapour Pressure of air
P_g	Internal Vapour Pressure of grain
P_{sat}	Saturated Vapour Pressure of air
PWSP	Poor Warehouse Storage Practice
RH	Relative Humidity
RSD	Room Storage Dehusked
RSH	Room Storage Husked
TCD	Traditional Crib Storage – Dehusked
TCH	Traditional Crib Storage – Husked

CHAPTER 1 INTRODUCTION

1.1 Outline of the thesis

The thesis is presented in five chapters. Chapter one, after this outline, continues with the background to the research and then makes a case for the justification of the study. The objectives of the study are then outlined.

Chapter 2 reviews the factors affecting the production of aflatoxin in maize and goes on to outline the health and economic implications of the toxin. The chapter also reviews the control and management of aflatoxin in maize. Two approaches are examined, the preventive approach and the detoxification of contaminated products. The chapter ends with an examination of the regulatory control of the toxin.

Chapter 3 reports on the study of handling/storage practices in Odumase and aflatoxin contamination. The study area is introduced and the results of a survey conducted to identify the handling and storage practices in the area are presented and discussed. Results of investigations into insect infestation, fungal infection and associated aflatoxin contamination are presented and discussed in chapter 3. Related work done by other authors on aflatoxin in maize in Ghana is discussed in this chapter.

The effect of the Odumase climate and different handling practices on the MC of harvested maize is the subject of the fourth chapter. The potential impact of the climate

is assessed through calculation of various relevant indices using some standard equations. The resulting MC regime over the harvesting period is examined vis-à-vis the climate and handling practices in the research area. This is facilitated by data collected on the climate and MC. The MC regime in maize from Yamfo, another important production/marketing centre is presented for comparison. The chapter ends with an analysis of the drying potential of the research area and an examination of the effectiveness of sun drying in the post harvest chain.

Chapter 5 presents general conclusions and recommendations in the light of the results of the work as a whole. Suggestions are also made as to what further investigations need to be done to enhance knowledge on the aflatoxin contamination situation confronting the maize industry in the research area and beyond.

1.2 Background

Maize is a major staple in Ghana. It is widely cultivated all over the country. The economic importance of maize and its role in ensuring food security in Ghana cannot be overemphasized. The annual production has been more than 1,000,000 MT since 2000, averaging 1,282,000MT over the period 2002 to 2004 (MOFA, 2007). Brong Ahafo and Ashanti regions, in the middle belt of the country, are the leading producing regions.

Human consumption of maize is greatest in the Southern parts of the country where it is used to prepare a wide variety of maize meals including *kenkey, banku, tuozafi and akple.* Consumption of maize in the poultry sector is as important as human consumption with

the grain constituting about 50% or more of most poultry feeds. The major poultry farms are located in the South of the country as well as in the Ashanti and Brong Ahafo regions. This maize production and consumption pattern is responsible for the regular flow of the commodity from major markets such as Techiman, Nkoranza and Odumase in the Brong Ahafo region as well as Asawasi in the Ashanti region to the Southern parts of the country all year round.

The importance of maize in Ghana suggests that serious efforts must be made to reduce crop losses at all levels, especially in the post harvest sector. Dzisi *et al.* (2007) identified field and post harvest losses as the most important constraints limiting maize production in Ghana. They reported losses in the field and post harvest sectors as 5-10% and 15-20% respectively. Edusah (2006) reported losses of 15 to 30%. This suggests that intensified efforts to mitigate losses in the post harvest sector may lead to salvaging significant portions of our production.

Losses in harvested produce may be quantitative or qualitative and may occur separately or together (Hall, 1970). Appert (1987) noted that qualitative losses are more difficult to determine but may be just as important, if not more important than quantitative losses, particularly if deterioration of the produce makes it unfit for consumption. An aspect of qualitative loss is the contamination of the produce by harmful metabolic by-products of fungi called mycotoxins. There are many mycotoxins of worldwide importance by virtue of their impact on human health and animal productivity observed in a variety of countries. These include the aflatoxins, fumonisin and ochratoxin (FAO, 2001). The

commodities with the highest risk of aflatoxin contamination are maize, groundnuts and cottonseed. Cottonseed and maize feature extensively in poultry feeds in the country as well as groundnut cake. The study of aflatoxin contamination in maize during handling and storage is the objective of this thesis.

Maize may become contaminated with aflatoxin in the field, at harvest or after harvest. This is because of the presence of the toxin producing fungi, *Aspergillus flavus* and related fungi (or their spores) along the maize commodity chain. The hot and humid environmental conditions prevalent in the tropics and sub-tropics are favourable for the growth and development of most fungi including *Aspergillus flavus* and *Aspergillus parasiticus*, aflatoxin producing moulds. Given that *A.flavus* produces aflatoxin over the temperature range of 15-37ºC (FAO, 2001), it is not surprising that aflatoxin contamination of maize and other susceptible crops and feedstuffs is commonplace in Ghana and most other tropical countries. The contamination is also favoured by harvesting maize at high moisture contents of above 22% which is common on most farms in Ghana, especially during the major crop season when farmers need to prepare the land for the minor season crop.

Aflatoxins are known to have detrimental effects on both human and animal health. Associated with these effects are important economic implications, the immediate impact being experienced most in the animal production industry. The poultry industry in particular suffers the aflatoxin menace most because of the use of maize as a major feed ingredient.

1.3 Justification of research

In view of the fact that maize is a major staple in Ghana, it is important for all stakeholders in the country, especially the government (working through the Ministry of Food and Agriculture (MOFA) and other relevant ministries and agencies) to ensure that maize consumed in the country is of premium quality with zero or minimal levels of aflatoxin and other contaminants. This is because people are as healthy as the food they eat. In addition to this, maize stands the chance of becoming an economically important export commodity for Ghana but unacceptable aflatoxin levels could pose a threat to this opportunity.

Wareing (1993) and Kpodo (1996) reported high levels of aflatoxin in maize samples and fermented maize products in Ghana. This constituted a wake up call demanding the fashioning of a national program to manage the aflatoxin menace in view of the health and economic implications. Neither MOFA nor the Food and Drugs Board who could play leading roles in this direction have come up with any such program. Some of the countries in the Far East which produce maize as food crop and cash crop have undergone programs through which they have managed to bring levels of aflatoxin contamination in the commodity to within internationally acceptable limits and successfully traded on the international maize market. A case in point is Thailand (Anon, 1989) where a range of strategies and programs have been deployed after much research in an effort to effectively manage the aflatoxin contamination in maize as well as groundnuts. Intensive research was carried out over more than 10 years (and is still on going) with the government spearheading efforts. The efforts have enjoyed support from

some Western Developed countries but the initiative was from Thailand. The scope of activities in the Thailand initiative went beyond research to education, publicity, training, legislation and monitoring of aflatoxin contamination levels. A National Committee on Mycotoxin Control in Agricultural Commodities was set up with the following terms of reference:

1. To publicize the nature and importance of aflatoxin, especially with regard to export commodities;
2. To devise and evaluate effective aflatoxin control measures applicable to each stage in the marketing chain, and then vigorously promote these techniques through radio, television, newspaper advertisements, leaflets and posters;
3. To coordinate aflatoxin research and maximise collaborative studies to increase efficiency and reduce excessive duplication of projects;
4. To encourage mechanical drying of maize upcountry to minimize delays in drying wet grain to a safe moisture content, and hence reduce the risk of aflatoxin contamination; and
5. To regularly monitor the aflatoxin content of maize and peanuts intended for export, so that any problems can be recognized early and remedial action can be taken promptly.

Any effort to manage the maize aflatoxin menace in the nation would require an in depth survey of what levels of aflatoxin contamination we have on our hands, especially in the major maize producing areas such as Techiman, Odumase and Nkoranza which constitute an important source of maize supply in the country. Beyond that it is very necessary to identify what handling and storage practices pertain in these areas and what levels of aflatoxin contamination those practices contribute to the maize post harvest chain. This will enable scientists, engineers and policy makers design interventions that would bring

the aflatoxin contamination in maize to within acceptable limits over the shortest period of time. These are the questions that this research seeks to address.

Odumase was chosen as the research area because it is one of the major maize producing and marketing centres in Brong Ahafo Region. It was also chosen because of proximity to the researcher's base station, Sunyani, the distance between the two towns being just about 3.5km. Techiman and Nkoranza, on the other hand are located 64km and 92km respectively from Sunyani. Thus travelling cost could be kept low in view of the limited financial resources available for the work at this level. More importantly, the researcher's long standing relationship with the Odumase maize market, its operators and industry as a whole stood to facilitate good cooperation from the key players in the Odumase maize industry.

1.4 Objectives

The main objective of the research was to find out what levels of aflatoxin contamination were contributed by the various maize storage practices employed in the research area with a view to identifying which practices may be encouraged, modified or discouraged. The effect of climate and different handling practices on MC in maize was also examined. The specific objectives of the work are listed below:

1. To identify the types of storage facilities in use at Odumase.
2. To identify the storage practices in use at Odumase
3. To determine the insect infestation associated with various storage practices.

4. To determine the fungal infection associated with various storage practices
5. To determine aflatoxin contamination associated with various storage practices.
6. To examine the effect of climate and different handling practices on the moisture content (MC) in harvested maize.

CHAPTER 2 LITERATURE REVIEW

2.1 General challenges to maize storage in Ghana

Storage of harvested maize in Ghana is mainly done by farmers themselves. This takes place at the farm gate, the village level, or at the farmer's residence. A number of challenges are encountered during storage. These are mainly due to the country's location within the humid tropical zone, among others. Farmers have to grapple with losses in quantity by way of insect infestation and rodent attack. In addition to this mould infection is another challenge. All together these losses reduce the food value as well as the economic value of the crop. An aspect of the quality loss that is not appreciated by most farmers and traders as well as users is the contamination with aflatoxin resulting from mould infection. This is because most consumers place little or no emphasis on the issue of aflatoxin contamination. The situation is a reflection of the low levels of awareness of aflatoxin contamination and its health implications on man and animals consuming the commodity. James *et al* (2007) found poor baseline knowledge of aflatoxin and health risks during a public information campaign on aflatoxins in Benin, Ghana and Togo.

The poultry industry in Ghana has some awareness of aflatoxin contamination in maize and its effect on poultry production but the industry's approach adopted in dealing with the aflatoxin situation has not focused on the preventive side. The use of toxin binders has rather been the strategy. In some cases this has not helped because aflatoxin levels encountered have been beyond the capacity of the toxin binders available on the market.

2.2 Introductory notes on aflatoxin

Aflatoxins are potent carcinogens that are produced as secondary metabolites of strains of the fungi *Aspergillus parasiticus* and *Aspergillus flavus* on important food crops such as groundnuts, maize and other oil seeds (Gourama and Bullerman, 1995). Aflatoxin is one of the most widely occurring and dangerous mycotoxins (C.A.S.T., 1989). It is probably the best known and most intensively researched mycotoxin in the world.

Aflatoxins were first discovered in England in 1960 when more than 10,000 turkeys and ducks died within a few months. The disease contracted by these animals was called Turkey X disease and its cause was traced to *Aspergillus flavus* contamination of peanut meal that had originated in Brazil. The toxin was named for the short hand of its causative agent: *A. fla*. (Austwick, 1978; Sassoon, 2007).

There are 4 major aflatoxins, namely B1, B2, G1 and G2, each with its own molecular formula and structure. The B prefix refers to the blue fluorescence and the G refers to the yellowish-green fluorescence under ultraviolet light. Aflatoxins M1 and M2 are so-called because they were first isolated from the milk of lactating animals fed aflatoxin preparations, hence the M designation.

2.3 Factors affecting the production of aflatoxin in maize

Several factors are responsible for the infection of maize with Aspergillus fungi and aflatoxin contamination. Diener *et al.* (1987) classified them into 3 categories: climatic, agronomic and biotic factors. These are briefly discussed below.

2.3.1 Climatic factors

A number of authors have reported on the effect of various climatic factors such as temperature, relative humidity and drought on the infection of maize with fungi such as *Aspergillus flavus* and the contamination with aflatoxin (Widstrom, 1992; Payne, 1987). *A.flavus* is reported to grow within the temperature range of 10-43ºC. The optimal growth rate occurs at a little above 30ºC. The aflatoxins are produced by *A.flavus* over the temperature range 15-37ºC, at least. It is not possible to specify the optimum temperature for the production of the toxins, although production between 20-30ºC is reported to be significantly greater than at higher or lower temperatures (FAO, 2001).

Commodities stored at humidities between 75 and 85% are susceptible to fungal attack within the normal storage time (Hell, 1997). Calderwood and Schroeder (1968) showed that *A.flavus* growth was optimal in freshly harvested maize with a moisture content of 20-28%, particularly at high temperatures of 20-30ºC. Aflatoxin can be formed at a RH of 88, 90 and 99%, common in the Southern parts of West Africa (Lillehoj, 1983). It must be noted that mould growth and aflatoxin contamination are not informed by the climatic factors in isolation but depend also on the moisture content of the maize.

Kawasugi *et al.* (1988) showed that maize harvested early showed the highest levels of aflatoxins, i.e. when moisture content was around 30.3%

2.3.2 Agronomic factors

Since the 1970s it has been accepted that corn kernels become infected with fungi and contaminated with aflatoxin while in the field. (Widstrom, 1992). Cotty (1994) identified plant stress, irrigation, cropping pattern, variety, date of planting, date of harvesting and storage conditions as agronomic factors that may influence aflatoxin development. Physical and chemical characteristics of husk and grain also render maize susceptible to mould infection (Barry *et al.,* 1986; Cardwell *et al.,* 2000).

The variety of maize planted is an important factor in fungal infection and toxin development. Nwogu *et al.* (1979) found that yellow maize was more susceptible to microbial and fungal attack than white maize. Lokesha *et al.* (1987) investigated vulnerability of 12 hybrids to Aspergillus infection and aflatoxin contamination and found some of them more susceptible with increasing RH. In studying the resistance of various varieties to *A.flavus* and aflatoxin contamination, Kang *et al.* (1990) noted that though several varieties were less susceptible, none with full resistance could be selected.

Planting and harvesting dates may be managed to reduce aflatoxin contamination (Jones and Duncan, 1981). Contrary to Jones and Duncan (1981), Nagler *et al.* (1992) reported

that late harvesting in Thailand did not lead to an increase in aflatoxin contamination. Tanboon-ek (1989) noted that field drying followed by mechanical drying is the most effective means of reducing aflatoxin contamination in maize in the same region.

Growth under stress due to low fertilization and dense plant population has been reported (Payne *et al.,* 1989; Schmitt and Hurburgh, 1989). However, Bucio-Villalobos *et al*. (2001) reported an insignificant effect of nitrogen fertilization on aflatoxin synthesis in the field. Wilson *et al.* (1989) found that high amounts of applied nitrogen increased aflatoxin levels in corn. Many authors have reported that water stress, especially in the terminal growth stages, lead to high aflatoxin contamination (Jacques, 1988; Davis *et al.*, 1986; Williams and McDonald, 1983; Kumar *et al.,* 2000). The presence of a woody canopy also enhances aflatoxin production (Lillehoj, 1983; Sander *et al.,* 1985) and so does planting maize in fields after cropping with peanuts (Cole *et al.,* 1982; Grifin *et al.,*1981). Spores of *Aspergillus flavus* have been known to remain in the soil in stalks and leaves of harvested maize. According to Payne *et al.* (1986), deep ploughing in North Carolina reduced aflatoxin contamination.

2.3.3 Biotic factors

The relationship between insect damage and aflatoxin development has been studied by many authors. (Fortnum, 1986; Borgemeister *et al.,* 1997; Lynch *et al.,* 1991; Gormang and Kang, 1991). Insect-attack in the field or store facilitates easy fungal infection. Thus

varieties with high resistance to ear-infesting insects and tough kernels are less susceptible to *A.flavus* infection and aflatoxin contamination.

Cracks and breaks in the mazie may be produced during harvesting, and by insect activity both in the field and in store (Zuber *et al.*, 1986). Post harvest operations such as shelling and various handling operations such as mechanical drying and cleaning could also account for wounding of kernels. Insects also act as vectors of fungal spores (McMillian *et al.*, 1990) and help the infection process. Sinha and Sinha (1992) observed that the rapid multiplication of insects lead to increased moisture content, dust production, *A .flavus* infection and aflatoxin contamination. Competition with other organisms could lead to slowing down of the development of *A. flavus* in the substrate. However, the growth of *A. flavus* was observed to be fastest at 30ºC.

2.4 Health and economic implications of aflatoxins

Aflatoxin contamination in maize, groundnuts and other crops carry important consequences in its wake. In the developing countries where nothing or little is being done to manage the aflatoxin menace, both producers and consumers of crops are at serious risk. In the developed countries where management and control systems are in place and operative, the consuming populace is protected. However, the contamination has economic implications for farmers who are producing the crops as well as for the countries as a whole where export of maize is an important source of foreign exchange.

2.4.1 Aflatoxin effects on human health

Afllatoxins are known to be hepatotoxic, carcinogenic, and teratogenic. A positive correlation has been established between the consumption of aflatoxin-contaminated foods and the increased incidence of liver cancer worldwide (Aly, 2002). Aflatoxins are also mutagenic, and immunosuppressive to most animal species (Chiavaro *et al.,* 2005). Both AFB1 and AFM1 have been shown to have potent hepatocarcinogenic activity (Eaton and Gallagher, 1994). The International Agency for Research on Cancer (IARC) has classified AFB1 as Group 1 carcinogen and AFM1 as a Group 2 carcinogen on account of their potential hazard to humans and animals (IARC, 1993).

Dietary exposure to aflatoxins is one of the major risk factors for hepatocellular carcinoma (HCC), (Sun *et al.,* 2002). Although chronic infection with hepatitis B virus (HBV) is now regarded as the major cause of HCC in high-incidence areas (Yeh *et al.*, 1989; Chen *et al.,* 1991; Ryder *et al.,* 1992), ingestion of aflatoxin B1 (AFB1) has also been implicated as another major contributor to risk (Yeh *et al.,* 1989; Ross *et al.,* 1992; Wang *et al.,* 1996a,). Many studies have shown how AFB1 is converted to its carcinogenic forms. (International Agency for Research on Cancer, 1992; Gallagher *et al.,* 1994; Guengerich *et al.*, 1998).

Ankrah *et al.* (1994a) studied the relationship between a diet containing aflatoxins and liver inflammation in Ghana. The major carbohydrate sources of the subjects were cassava (as *konkonte*), or maize (as *kenkey*), or a mixture of the two (as *akple*). Their results were indicative of liver inflammation, not liver cancer. However, in their study,

Bulatao-Jayme *et al.* (1982) concluded that the risk of developing primary liver cancer increases with the aflatoxin load of the ingested food. Similar evidence is reported by Yu *et al.* (1989) who studied significant correlation between the primary liver cancer mortality rates and aflatoxin intake in the local foods in five villages in China.

In order to establish a close relationship of human mycotoxicoses with that of the aflatoxin content in the diet intake, it is very important to employ a comprehensive screening programme. For this purpose, daily consumption of aflatoxin is needed to analyse a large number of foodstuffs collected from market and domestic households. Rensburg (1977) reports a significant statistical relationship between the incidence of liver cancer and the intake of aflatoxin as shown in Table 2.1.

Table 2.1: Incidence of liver cancer (cases per 100,000 people per annum) and aflatoxin intake (mg/kg body weight per day) in Africa and Asia.

Region	Incidence of liver cancer	Aflatoxin content
Kenya- highlands	0.7	3.5
Thailand – Songkhal	2.0	5.0
Swaziland – highlands	2.2	5.1
Kenya - medium altitude	2.9	5.8
Swaziland - medium altitude	4.0	8.9
Kenya – lowlands	4.2	10.0
Thailand – ratburi	6.0	45.0
Swaziland – lowlands	9.7	43.1
Mozambique – inhambane	13.0	222.4

Source: Rensburg (1977).

The immunosuppressive properties of AFB1, particularly on cell mediated immunity, have been demonstrated in various animal models (Ali *et al.*, 1994; Silvotti *et al.*, 1997; Sharma, 1993). After the examination of the cellular immune status of 64 Ghanaians in relation to aflatoxin B1 – albumin adduct in plasma, Jiang *et al*. (2005) found alterations in immunological parameters of participants with high AFB1 levels which they pointed out, could result in impairments in cellular immunity that could decrease the host's resistance to infections.

Other health conditions in which aflatoxin has been implicated are Kwashiorkor and Reye's syndrome, sicknesses that are more prevalent in Africa than in other parts of the world (Wild *et al.*, 1991). Coulter *et al.* (1986) biopsied the liver of 27 Sudanese children suffering from Kwashiokor and reported the detection of aflatoxin B1 , B2 and aflatoxicol in the organs of the children. Stora *et al.* (1983) found aflatoxin B1 levels of between 120 and 180µg/g in the livers of 5 infants suffering from Reye's syndrome.

2.4.2 Aflatoxin effects on animal health

Toxic and especially carcinogenic effects of aflatoxins have been reported in several different animals, but susceptibility to these toxins varies greatly with sex, age, species and strain within a species (Busby, 1984; CAST, 2003). Aflatoxins cause liver damage, decreased milk and egg production, recurrent infection as a result of immunity suppression, in addition to embryo toxicity in animals consuming low dietary concentrations (Saad, 2007).

Aflatoxicosis is a disease caused by the consumption of aflatoxins. Aflatoxin B1 is the most potent mycotoxin to affect cattle. When significant quantities of B1 are consumed, the metabolite M1 appears in milk within 12 hours. Various countries and communities therefore have regulatory limits on the level of aflatoxin allowable in animal feeds. The EEC limits as reported by Goyal (1989) are presented in the Table 2.2 below.

Table 2.2: EEC Tolerance limits for aflatoxin B1 in animal feed

Commodity	**Aflatoxin B1 tolerance not more than (µg/kg) or ppb.**
Produce for processing into mixed feed	50
Complete feed for cattle, sheep and goats (with the exception of dairy animals, calves and lambs)	50
Complete feed for pigs and poultry (with the exception of infant pigs, chicks, ducklings and turkeys).	20
Animal feed supplements for dairy animals	20
Other complete feeds.	10

Source: Goyal (1989)

Young animals of all species are more susceptible than mature animals to the effects of aflatoxin. Pregnant and growing animals are less susceptible than young animals, but more susceptible than mature animals. Feed refusal, reduced growth rate and decreased feed efficiency are the predominant signs of chronic aflatoxin poisoning. In addition, listlessness, weight loss, rough hair coat and mild diarrhoea may occur (Cassel, 2001).

2.4.3 Economic implications of aflatoxin contamination

Kumar *et al.* (2000) identified 3 reasons why aflatoxins cause economic losses:

- Humans and animals fed on aflatoxin contaminated food result in ill health and lowered animal production.
- Commodities contaminated with aflatoxins lower their market value and export potential.
- They add to the management and monitoring costs.

Since its discovery in numerous feedstuffs, aflatoxin, has caused much concern among consumers and producers alike. This toxin poses a serious economic threat to maize producers of the southeastern and midwestern regions of the United States (Gardner *et al.*, 2007). Stringent regulations have been put into effect by the U.S. Food and Drug Administration limiting the amount of aflatoxin allowable in grain intended for human and animal consumption. Currently, grain having a concentration of aflatoxin B1 exceeding the threshold of 20 ng/g is banned from interstate trade (NGFA, 1992). The EU has set a maximum admissible level of 0.05g/l in raw milk, heat-treated milk and milk for the manufacture of milk-based products (European Communities, 2001). These restrictions have caused substantial economic losses among maize growers.

Aflatoxin contamination of cottonseed and corn costs agriculture in the U.S. millions of dollars each year. In Arizona alone, aflatoxin contamination of cottonseed costs the cotton industry $3 million to $8 million per year. Currently, agricultural profits are

severely curtailed and the burden of aflatoxin contamination has been increasingly difficult to bear. Aflatoxins are a major factor limiting international trade of several U.S. commodities. Economically viable aflatoxin management is needed to ensure the stability of agriculture in several regions of the U.S. (Cotty *et al.*, 2006).

It has been estimated that annual losses in the USA and Canada, arising from the impact of mycotoxins on the feed and livestock industries, are of the order of $5 billion. In developing countries, where the food staples (e.g. maize and groundnuts) are susceptible to contamination, it is likely that significant additional losses will occur amongst the human population because of morbidity and premature death associated with the consumption of mycotoxins (FAO, 2001).

2.5 Control and management of aflatoxin in maize

The health and economic implications of aflatoxin contamination are such that, though the contamination may be considered unavoidable and unpredictable (Park and Stoloff, 1989; FAO, 1997), serious efforts must be made to bring the menace under control. A recent outbreak of aflatoxicosis in May 2004 in Kenya (CDC, 2004) has reminded us that the aflatoxin problem, although being known for decades, has not been solved. In Thailand, aflatoxin has been a great problem in maize, a major foreign exchange earner for the country. Thai maize faced marketing difficulties among her regular buyers in the 1990s due to a high incidence of aflatoxin (Tangthirasunan, 1989;Yoshiyama, 1989). Because of this, maize was traded at $10-$20 per ton below that of maize from other

sources. The annual cost to Thailand of the aflatoxin and related quality problems, was not less than US$50 million. (Nagler *et al.,* 1992; Van Egmond, 1987a; RIO, 1988).

Methods of aflatoxin control have been grouped into two major categories (Riley and Norred, 1999; Mishra and Das, 2003). They are:

1. Prevention of mould contamination and growth and
2. Detoxification of contaminated products

2.5.1 Prevention of mould contamination and growth

Since aflatoxin contamination is a result of mould infection, strategies in this category are based mainly on the management of factors that are responsible for mould development in maize from planting through the post harvest stage until consumption. They involve both biotic and abiotic factors. Action points in this respect have been captured by Kumar *et al*., (2000) along 3 main fronts as follows:

a) Training programmes for farmers in major maize growing areas in the following:
   - Good agronomic practices
   - Proper storing and drying of grain
   - Maintaining grain quality
   - Sanitizing grain handling equipment

b) Reducing the risk of aflatoxin contamination in maize: pre harvest

- Plant maize hybrids with first possible rains and harvest crop at correct maturity.
- Remove dead plants and plants showing severe stress due to pest or pathogen attack.
- Remove weeds and protect crop from corn borer damage.
- Avoid excessively high plant populations and excessive application of nitrogen.
- Visually inspect cobs for fungal infections / damage on the grain and discard the affected cobs.

c) Reducing the risk of aflatoxin contamination in maize: post harvest

- Avoid mechanical damage to seed during harvesting, drying and storage.
- Rapidly dry the grain down to 13.5% moisture content and store the seeds.
- Clean grain bins/storage areas before putting in the new crop.
- Stock cobs or seeds in bags on wooden plank and store them in a well aerated waterproof area.
- Avoid stacking of harvested crop with cobs intact.

A recent post harvest intervention, incorporating a package of activities focused on improved crop drying and storage techniques, successfully demonstrated a greater than 50% reduction in aflatoxin albumin adducts in a rural population in West Africa, naturally exposed to AFB1 through diet (Turner *et al.*, 2005). In the outbreak of

aflatoxicosis in Kenya, improper home storage of maize was identified as a risk factor for jaundice (CDC, 2004). Thus primary management and control measures such as good agronomic, harvesting and post harvest practices constitute an important tool in the effort to tame aflatoxin contamination.

2.5.2 Detoxification of contaminated products

Among physical treatments, cleaning and sorting of grain or peanuts as well as segregation are promising but incomplete methods (Riley and Norred, 1999). The use of adsorbents added to animal feed is one approach, using hydrated sodium calcium aluminosilicate (HSCAS) to reduce the bioavailability of aflatoxins (Phillips *et al.,* 2002; CAST, 2003). HSCAS binds and immobilizes aflatoxins in the gastrointestinal tract of animals, resulting in a major reduction in bioavailbility. Recently, HSCAS have also been demonstrated to be safe for humans (Wang *et al.,* 2005), which would allow the use of this technique for products intended for human consumption. Tanboon-ek (1989) commented that maize with high aflatoxin content can be detoxified efficiently with ammonia and the resulting grain is safe and can be fed for cattle and swine but not suitable for human consumption. Sodium bisulphite has also been found to be able to degrade aflatoxins like ammonia does.

Novel strategies in detoxification are being researched in the area of biocontrol of *A.flavus* infection and aflatoxin contamination. Abas *et al.,* (2006) assessed the ability of two non-aflatoxigenic *Aspergillus flavus* Link isolates (CT3 and K49) to reduce aflatoxin contamination of corn. Results of the 4-year study indicate that non-aflatoxigenic,

indigenous *A.flavus* isolates such as strain K49, have potential use for biocontrol of aflatoxin contamination in southern US corn.

2.5.3 Regulatory control

Aflatoxin levels beyond certain concentrations lead to various health problems in humans and animals. Kumar *et al.*, (2000) list the general levels permitted and the consequences of ingestion beyond those levels as in Table 2.3.

Table 2.3: Aflatoxin ingestion limits and health effects

Aflatoxin level (parts per billion)	Limitation / consequence
20	Highest level allowed for humans
50	Highest level allowed for animals
100	Slowed growth of young ones
200-400	Slowed growth of adults
Beyond 400	Liver damage and cancer

Various countries have set their own limits for aflatoxins which have to be observed by those who trade internally or internationally. The limits are rather low in the developed countries and some other countries have not set any limits at all, especially the developing and the less developed countries.

A number of survey and monitoring programs have been carried out in several countries attempting to obtain the general pattern of extent of food contamination (Abdulkadar *et al.*, 2000; Aycicek *et al.*, 2002; Galvano *et al.*, 1996; Oruc & Sonal, 2001; Rastogi *et al.*,

2004). China, India, Malaysia, Philippines and Thailand have established national maximum levels for aflatoxin (FAO, 1987). The European Commission and the Turkish government have also set limits for various aflatoxins in various types of food products (Codex Alimentarius Commission, 2001; Commission Regulation, 2002; Turk, 2002). These are presented in Table 2.4.

Table 2.4: Established maximum levels for aflatoxins in some countries/communities

Country/community	Product	Aflatoxin	Max. level permitted	Source
China	Maize & products	Total	20 ppb	FAO, 1987
	Rice	Total	10 ppb	
	Legumes	Total	5 ppb	
	Infant food	Total	0 ppb	
India	Food	Total	30 ppb	
	Peanut meal (export)	Total	120 ppb	
Malaysia	Food	Total	35 ppb	
Philippines	Food	Total	20 ppb	
	Feed	Total	200 ppb	
Thailand	Food	Total	20 ppb	
European Commi-Ssion & Turkish Government	Groundnuts, nut, dried fruit & their products (retail sale)	Total	4µg/kg	Codex Alimentarius Commission, 2001; Commission Regulation, 2002; Turk Gda Kodeksi Teblig, 2002
	Groundnuts, nut, dried fruit & their products (retail sale)	AFB1	2µg/kg	
	Nuts & dried fruit to be subjected to sorting, or other physical treatment before human consumption or use as ingredient in foodstuffs	Total	10 µg/kg	
	Nuts & dried fruit to be subjected to sorting, or other physical treatment before human consumption or use as ingredient in foodstuffs	AFB1	5 µg/kg	
EU Commission	AFM1 in milk, butter and cheese	AFM1	0.05 µg/l	
Turkish Government	AFM1 in milk, butter and cheese	AFM1	0.25 µg/l	

CHAPTER 3 ODUMASE HANDLING/STORAGE PRACTICES AND AFLATOXIN CONTAMINATION

3.1 Introduction

The incidence of AF in any post harvest system is best studied by identifying the commodity flow pattern and determining the levels of contamination at strategic points in the post harvest chain. This chapter reports on the survey conducted to identify the major handling and storage practices characterizing the study area. The results of studies conducted on insect infestation, fungal infection, and aflatoxin contamination in the major storage practices identified are presented and discussed. The results of other authors' work on AF contamination, particularly in Accra are compared to what was found in the study area. This was of interest because an important quantity of maize bought from the Odumase market is transported to Accra.

3.2 Materials and methods

The survey to identify handling and storage practices was conducted through questionnaire administration and personal interviews. Maize samples were collected from storage facilities of farmers who were willing to cooperate with the researcher. The various analyses were carried out in Sunyani and at laboratories in KNUST and Accra.

3.2.1 The study area

Odumase is the capital of the newly created Sunyani West District of the Brong Ahafo region. Until the creation of the new district in October 2007 Odumase was part of the

Sunyani Municipality. The town is located about 3km to the North of Sunyani and had a population of over 10,000 as at 1999.

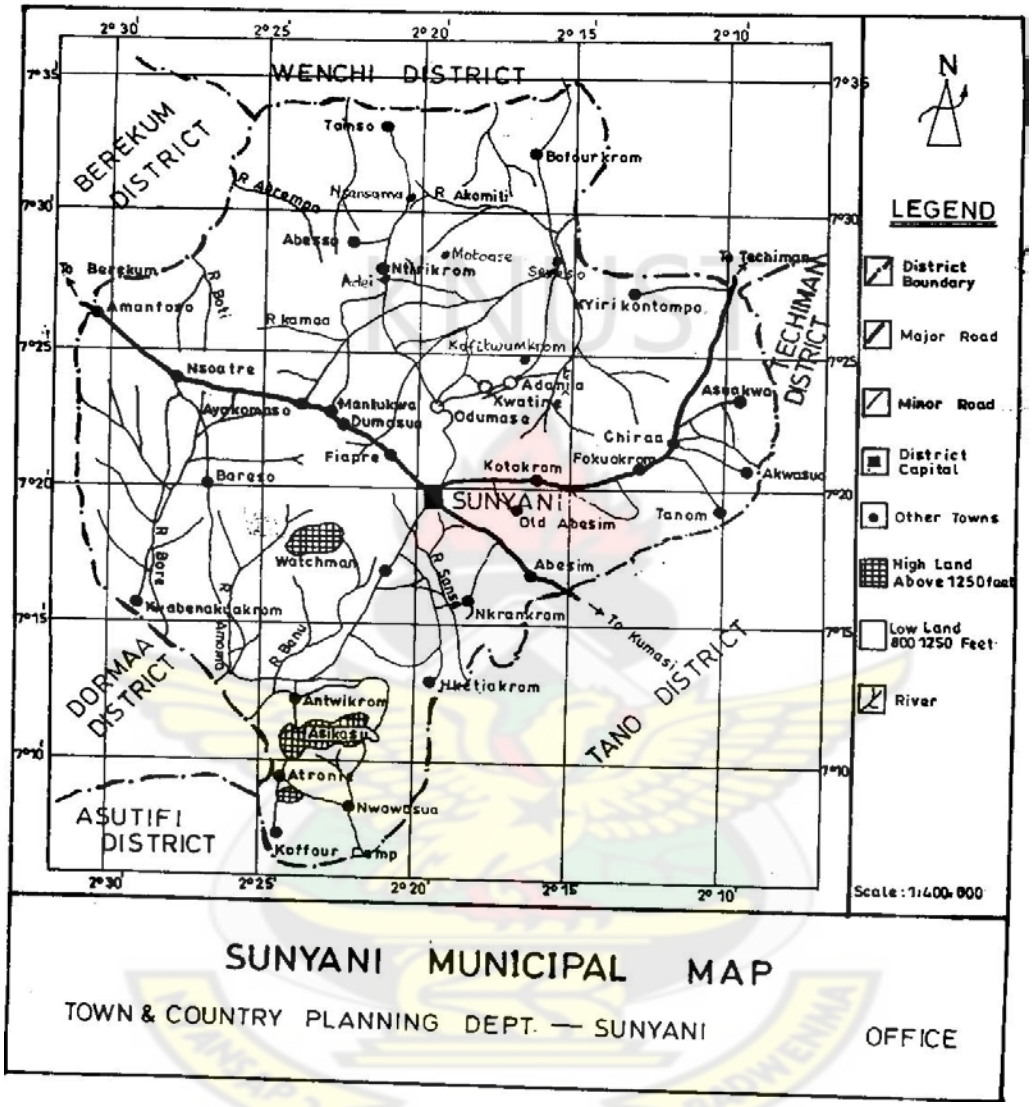

Fig. 3.1 Map of Sunyani Municipality.

The Odumase community is made up of two towns – Odumase no. 1 and Odumase no. 2. This is by virtue of the fact that the town has two chiefs, each owning a section of the town with its associated farmlands and economic activity. The main occupation of the

working populace is farming, the major crop being maize. Cassava, plantain and yam are also cultivated as well as pepper.

The study area is located in the humid savanna agro ecological zone. The area enjoys a bimodal seasonal rainfall pattern with peaks occurring in April – June for the major season and in October for the minor season. This governs the two farming seasons in the area. Harvesting of the major season maize crop takes place mainly in August and September when the minor season rains are about peaking. Relative humidity in the area during this period is in excess of 80%. This is a major challenge to moisture content management in harvested maize. Chapter 4 of this work looks at the effect of climate on the moisture content of harvested maize in the study area vis-à-vis the post harvest handling practices. Harvesting of minor season maize coincides with the long dry spell which lasts from December until February-March. This greatly helps field drying and sun drying.

The post harvest handling and storage of maize in the study area is indicated by the commodity flow pattern between harvesting and marketing shown in Fig.3.2. The main flow path is from field to the marketplace (point 1 to point 4) from July to October. Flow along path 1 – 2 – 3 – 5 (maize ends up in storage) begins to feature in October when some amount of field drying has taken place. Depending on the farmer's economic circumstances maize may be stored for up to 9 or 10 months or released in bits to the market over a period of time. Flow to the Mechanical Drying and Storage Facilities (MDSF) from the market is remarkable between July and October/November when

moisture content in harvested maize is high and the climate is not conducive for effective sun drying. Each flow path poses peculiar challenges to handling and storage of maize.

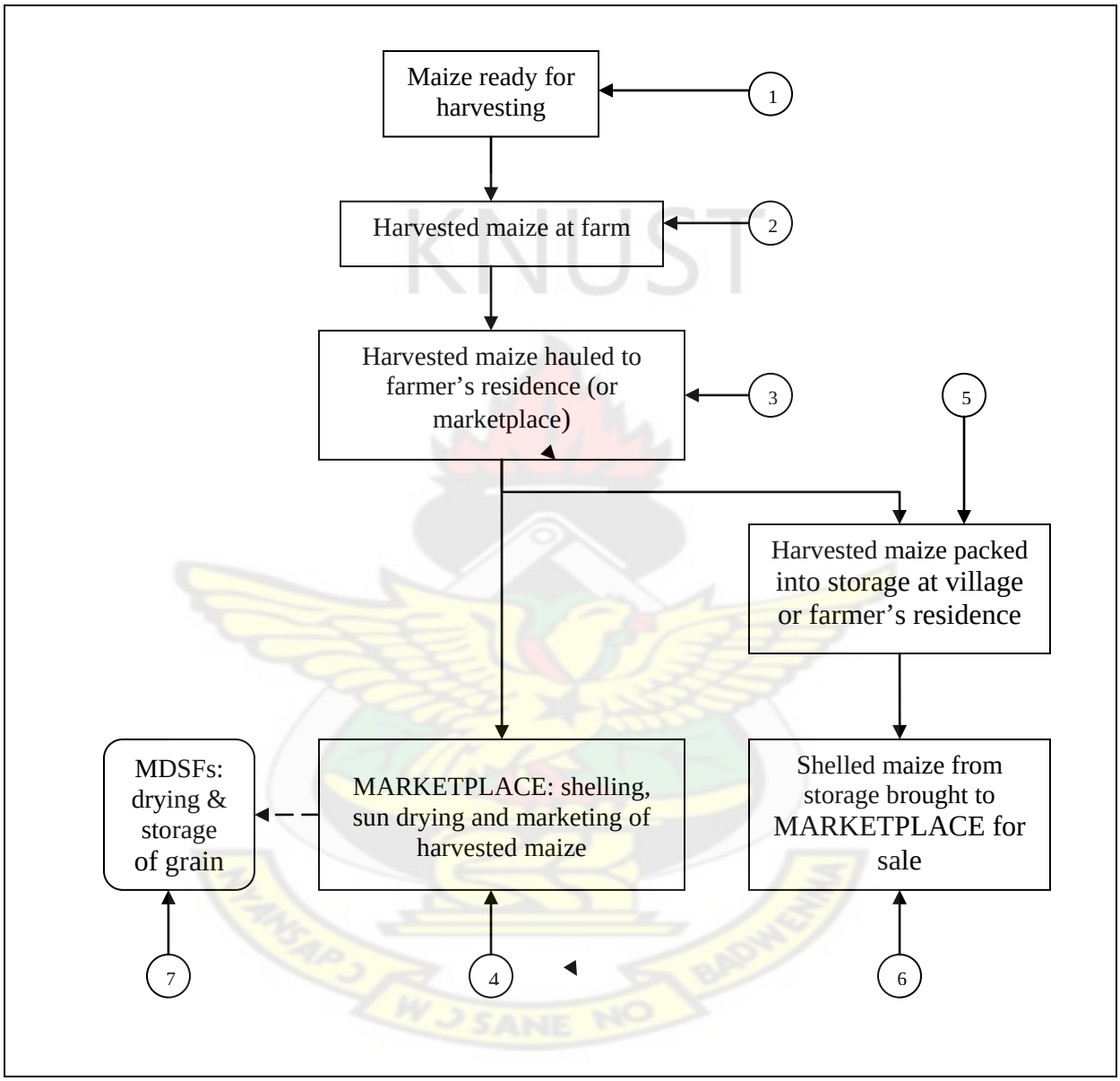

Fig.3.2 Maize flow pattern between harvesting and marketing

There are two maize markets, one belonging to each of the two traditional councils and serving as important sources of revenue for the councils. Almost all the maize produced by Odumase citizens are marketed through the two markets. The traditional authorities

are very keen about their markets because of the Traditional Council tax on every bag of maize passing through the markets and indeed every bag of maize produced on Odumase lands for commercial purposes. Some Odumase citizens cultivate farmlands outside Odumase territory but sell the produce through the Odumase market because of the market's importance nationally and beyond. Traders come from as far as Burkina Faso and Niger to buy maize from the Odumase market.

A good portion of the vehicular traffic in Odumase is made up of trucks of various sizes and capacities hauling maize in different forms from one place to another. Medium sized trucks of 3 – 5 MT capacities conveying harvested ears of maize from the farm gates to the markets for shelling, sun drying and marketing or for storage on cribs erected in the houses of the farmers pending future sale is commonplace in Odumase. Odumase is also home to big trucks of 20 – 30 MT capacities, which are used in hauling bagged grains from the maize market to the Southern parts of the country. Occasionally 50MT capacity articulated trucks are encountered in this category.

3.2.2 Survey of maize handling and storage practices

This was done through the administration of a questionnaire by the researcher. The questionnaire was structured in a manner similar to that used by Hell (1997) in a study of the factors contributing to the distribution and incidence of aflatoxin producing fungi in stored maize in Benin. The questionnaire was administered to 42 people from Odumase who were maize farmers. 23 out of the 42 farmers (54.76%) were maize market

operators as well. The general structure of the questionnaire is shown below and the full questionnaire contained in appendix I.

General structure of survey questionnaire:

I General background of respondent

- Personal information
- Background in maize farming and trading

II Maize cropping/production

III Harvesting practices

IV Storage Practices

- Transit Storage
- Pre-storage sorting
- Post-storage sorting
- Preparation of facilities for storage
- Storage structures, practices and losses

3.2.3 Selection of storage practices for the study

Maize storage by farmers in Odumase is generally done in traditional cribs with ears husked or dehusked. Storage in rooms of uncompleted buildings or a spare room in the farmer's house is not uncommon. The practice of storing in rooms may also involve husked or dehusked ears.

Another practice to which maize from the locality is subjected is the storage of shelled maize at mechanical drying and storage facilities (MDSFs). This is mainly by poultry

farmers, processors, stockists or traders who buy the grain from the Odumase market and take it to the MDSF for drying and storage. Here the practice is to dry the grain and store it bagged in warehouses under varying storage conditions. Good warehouse storage practice (GWSP) would involve:

- Regular fumigation of stocks at 3-month intervals (maximum)
- Spraying of stocks and the general warehouse area with a suitable insecticide, usually actellic
- Observation of good warehouse sanitation

Poor warehouse storage practice (PWSP) does not involve the practices associated with GWSP.

In the light of the above the storage practices listed in Table 3.1 were selected for the study. Two farmer stores were selected for each practice depending on their experience and readiness to cooperate with the researcher. Unfortunately one farmer in the dehusked room storage category sold off his maize without informing the researcher.

Table 3.1: Maize storage practices selected for the study

Maize storage practice	No. of stores selected

Traditional crib, husked (TCH)	2
Traditional crib, dehusked (TCD)	2
Room storage, husked (RSH)	2
Room storage, dehusked (RSD)	1
Warehouse: good storage practice (WGSP)	2
Warehouse: poor storage practice (WPSP)	2

3.2.4 Sampling from storage structures and other facilities

Where possible stream sampling was used. This refers to the process by which a sample from particulate material is obtained by taking portions of the material (known as cuts) at regular intervals as it flows on a conveyor belt. Stream sampling has been judged the most effective sampling method in the analysis of maize for aflatoxin (Ware, 1989). Where stream sampling was not possible, the sampling procedure adopted was made to approach stream sampling as much as possible. The procedures are explained in the sections below. Samples were also taken from batches/lots so as to obtain a grain sample size in the region of 5kg.

3.2.4.1 Sampling from cribs and rooms – beginning of storage

i. A number of ears were collected randomly from the farmers' harvest as they were packing their maize into storage. A minimum number of 30 ears were collected, depending on the farmer's level of co-operation. The aim was to obtain a minimum quantity of 5kg of shelled grain for analysis.

ii. Ears collected were put in a paper bag and quickly sent to the improvised laboratory at the premises of Grainplus Ltd. Here the maize was hand shelled and the moisture content and insect infestation level determined. Afterwards, three sub-samples weighing 1kg each were obtained from the shelled maize using the coning and quartering method to ensure good mixing and representation. One of the samples was used for a physical assessment of mould infection. The other two were tightly packed in a polythene bag with minimal air space and kept in a deep freezer (at -5ºC). One of them was used for fungal evaluation and aflatoxin measurement while the other was stored as a retained sample. (Herman, undated)

3.2.4.2 Sampling from cribs and rooms – end of storage

The same sampling procedure employed in the collection of beginning of storage samples was used. In the case where the farmer was not ready to off-load his maize onto the market, the sample was obtained by digging into the store and randomly picking ears from various positions and at different depths. This was done to facilitate the composition of a sample that was sufficiently representative of the maize in the store.

3.2.4.3 Sampling from MDSF – beginning of storage

The MDSF at Grainplus Ltd. employs batch handling and bagged storage in its drying and storage operations. The grain flow at the plant is represented in a simplified diagram in Fig. 3.3.

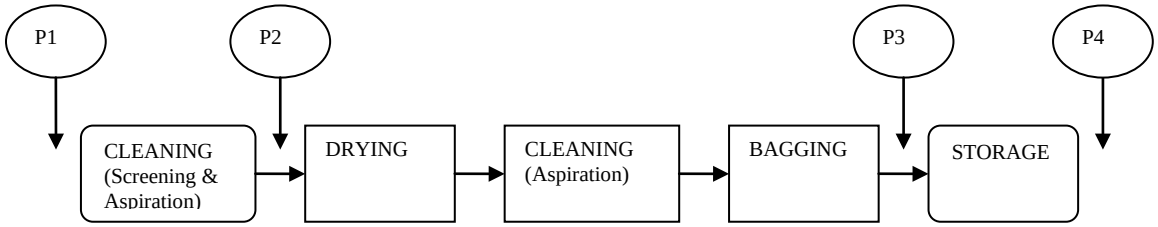

Fig. 3.3 Simplified diagram of grain flow at Grainplus Ltd.

The actual sample used as the beginning of storage sample in these practices was taken at sample point P3, at bagging of the dried maize. A handful of grain was caught from the stream flowing into each alternate bag during bagging off after drying. This was put into a paper bag and labelled. Samples were also taken at P1 and P2 to observe the effect of cleaning on aflatoxin contamination in maize obtained from the market. In the case of P1 small portions were taken by hand from the flowing contents of each alternate bag as it was emptied into the intake pit. At P2 similar portions were taken from the cleaner exit stream at two minute intervals over the period the batch was being cleaned and loaded into the dryer.

3.2.4.4 Sampling from MDSF – end of storage

Maize stored for investigation under GWSP and PWSP consisted of stacks of 30 mini bags, each mini bag weighing 50kg. In each 30 mini bag stack, 12 out of the 30 bags were selected from different regions of the stack. In each of the 12 bags selected, maize

was drawn from the top, middle and bottom portions of the bag using a grain probe fabricated at a local workshop.

3.2.5 Determination of sample moisture content (MC)

MCs of the samples collected were measured using a FARMEX Moisture Meter. The instrument was calibrated using a new DOLE Moisture Meter at the Agricultural Engineering Department, KNUST. For each sample, the grain was thoroughly mixed and 3 MC readings taken and the average of the 3 computed and used as the MC of the sample. The grain used in each measurement was discarded and a fresh quantity taken from the sample for the subsequent measurement.

3.2.6 Determination of insect infestation level

A no. 8 Tyler sieve was used to sieve out insects in each of the samples collected just after the MC had been determined and the sample weighed. Small portions of the sample were sieved at a time until the whole mass of the sample had been sieved. This was to facilitate vigorous shaking and the removal of as many insects as possible. The count was made of insects sieved out (live and dead together) and the number for each sample recorded. The level of infestation was computed as no. of insects per kg of grain.

3.2.7 Determination of mould infection and fungal evaluation

Mould infection was determined by sorting out all visibly moulded grain from a 1-kg sub sample. The sorted out moulded grain was weighed using an electronic scale and expressed as a percentage of the 1-kg sub sample.

The fungal evaluation in samples collected was done at the Pathology Lab. of the Agriculture Faculty of the KNUST. A medium of Potato Dextrose Agar sterilized in an autoclave at 121ºC for 3 hours was used. Petri dishes were sterilized in an oven for 3 hours at a temperature of 160ºC. The table was also sterilized with 70% ethanol.

Kernels were selected randomly for incubation and they were sterilized in a 1% sodium hypochlorite solution for two minutes and then washed twice in sterile water. 5 grains were plated on each Petri dish and the dishes were covered and stored at room temperature (25ºC) for the fungi to grow. Each grain was examined under the microscope after 5 days for identification of the colonising fungi. The no. of grains colonised by various fungi detected was recorded and the no. of kernels germinated also recorded.

3.2.8 Determination of aflatoxin levels

The 1 kg sub-samples stored in the deep freezer were used for the measurement of aflatoxin in the various samples. The samples were milled one after the other at a corn mill, the mill being dismantled and cleaned after the milling of each sample. The AF levels were measured at the laboratory of the Veterinary Services Division Headquarters in Accra using a semi quantitative method. The laboratory's 12-step procedure is presented below:

1. Weigh 10g of sample into a blender
2. Add 100mls of 70% Methanol and blend for 3-5 minutes
3. Pour out sample into a jar and allow to stand and settle completely

4. Transfer 11-15mls of the supernatant into another clean flask
5. Add 10mls of benzene and 20 mls. of distilled water
6. Sake vigorously to obtain a homogeneous solution
7. Transfer the mixture into another clean bottle, eg. A universal bottle
8. Leave standing on the bench for some time. Clear benzene will collect on top of a milky solution
9. Pipette off a few mls. of benzene into a Petri dish and evaporate in a hot air oven or in air
10. Place 3 drops of fresh benzene into the dry Petri dish and place an already cut strip of filter paper in it.
11. With a clean forceps or applicator stick, wipe out everything in the Petri dish. Allow the strip to dry (This is the test sample.)
12. View the test sample together with a clean strip of filter paper (as control) for fluorescence in the UV chamber.

3.3 Results and discussion

3.3.1 Survey Results: the farmer, farm size and yield

Average values of age, number of children, level of education and years of farming are presented in Table 3.2 to give background information on the average farmer in the research area.

Table 3.2: Background information on the average Odumase maize farmer

Age	39.6
Number of children	3.7
Level of education	Senior Secondary School
Years of maize farming	13.1

An analysis of the age distribution among the respondents showed that 76.2% of the farmers are between age 31 and 50 with only 14.3% found in the age bracket of less than 31 years. This suggests that the youth who are more energetic shy away from farming. A similar trend was found in the Ejura Sekyere-Dumase district (Agyarko *et al*., 2007) with only 12.5 % of farmers falling below age 31. A rather encouraging observation that came out from the survey was the relatively high educational background of the average farmer in Odumase. 50% of the respondents had Senior Secondary School education. This augurs well for adoption of technologies or practices introduced by extension agents as observed by La Anyane (1986).

Appendix III shows the distribution of the average farm size and yield for 2005/06 and 2004/05 farming years.

The analysis shows that the bulk of the farmers cultivate parcels of land less than 12 acres during the major seasons. In the 2005/06 farming year 85% of the respondents fell in this range of farm size and the figure was 86.8% in the 2004/05 year. With respect to yield trends, 80% and 78.4% of the respondents experienced yields of up to 7.0 bags/acre in 2005/06 and 2004/05 respectively. The trend is indicative of the fact that the bulk of

maize in the area is produced by farmers with relatively small farms and any intervention to tackle aflatoxin contamination must focus on such farmers.

3.3.2 Agronomic practices and pre-harvest infestation

The survey results showed that Odumase farmers have generally moved from planting local varieties. Over 90% of the respondents indicated that they use improved varieties introduced by the extension agents. 57.1% of the respondents said they planted the Obatanpa variety and the rest planted other varieties. Whereas there has been successful adoption of introduced improved varieties, only 14.3% of the farmers use certified seed. 45.2% reported that they use uncertified seed obtainable from previous season's stocks, either from their own farms or friend's farms. This situation could lead to a reduction in the plants ability to resist the attack of pests such as mould and insects while offering the grain reduced protection from external water or moisture.

Fertilizer use among Odumase farmers was found to be as low as 7%. Payne *et al.*(1989) reported that AF development was reduced by improved nitrogen levels in soils. Thus encouraging farmers in the research area to use fertilizer is likely to help in the management of AF contamination in the Odumase area.

The analysis of the survey results showed that 95.2% of the respondents use weedicide to control weeds at one or more stages of cultivation with 31% employing weedicide at all stages (Fig.3.4). Atrazine is used in the post planting weed control stage while Roundup is used at the land clearing and preparation stage to kill all plants growing on the land before planting. In view of the extent of weedicide use plant stress due to soil nutrient

competition from weeds may not be a serious problem on Odumase farms. However plant stress due to low soil moisture cannot be ruled out because farming in Odumase area is 100% rain fed. Thus plant stress due to insufficient water provision could be an important factor in AF contamination in maize at Odumase.

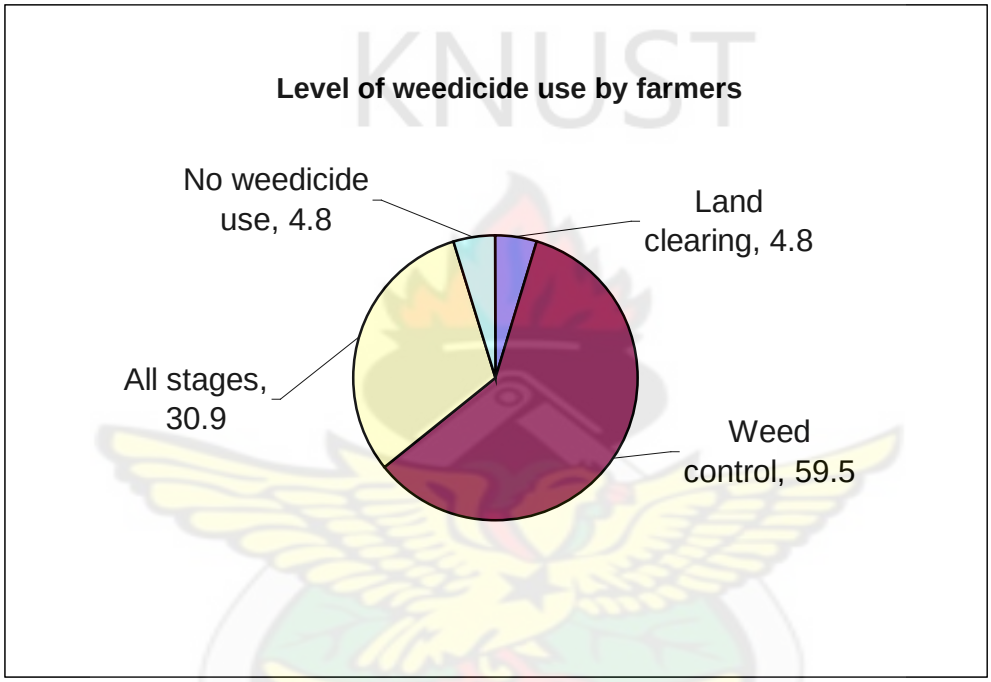

Fig.3.4 Extent of weedicide use by farmers

The farmers interviewed identified several common field pests of importance on their farms but ranked them differently. The pest mentioned were grass cutters, birds, insects, moulds, squirrels, rats and termites. Grass cutters, birds and mould received the highest rankings by most farmers. Table 3.3 shows the percentage of respondents giving various rankings to various pests.

Table 3.3: Respondent's rankings of various pests

Rank	Field Pest			
	Grass Cutters	Birds	Mould	Insects
1st	61.9	23.8	0.0	4.8
2nd	31.0	28.6	2.4	4.8
3rd	2.4	19.0	11.9	14.3
4th	0.0	0.0	21.4	9.5

The results show that 85.7% of the respondents had grasscutters or birds as the most troublesome pests while 59.6% of them considered these pests as the second pest of importance. Only 12.0% of them ranked mould and insects among the two most important pests. The farmers set traps, clear patches of weeds around the farm and use guns to control the grasscutters. Unfortunately, little or nothing is done to control the mould and insects which are of greater consequence by way of AF contamination.

3.3.3 Storage structures in use within the research area

The traditional crib used for dry-storing maize after harvesting was found to be the predominant storage structure in use at Odumase. 88.1% of the farmers interviewed used this structure while 7.1% stored in rooms. 76.1% of the farmers had their cribs located in the Odumase town, mostly beside their houses while 19.1% had their cribs in villages close to their farms.

Materials used in the construction of the cribs are mainly lumber, tree bark and bamboo obtained from within the research area. These materials are used for the floors and walls of the crib. Thatch grass, iron sheets and veneer waste from the plywood industry are

used for roofing. Figures 3.5 to 3.7 show the extent of use of the various materials for the roofing, walls and floors as obtained from 30 cribs examined.

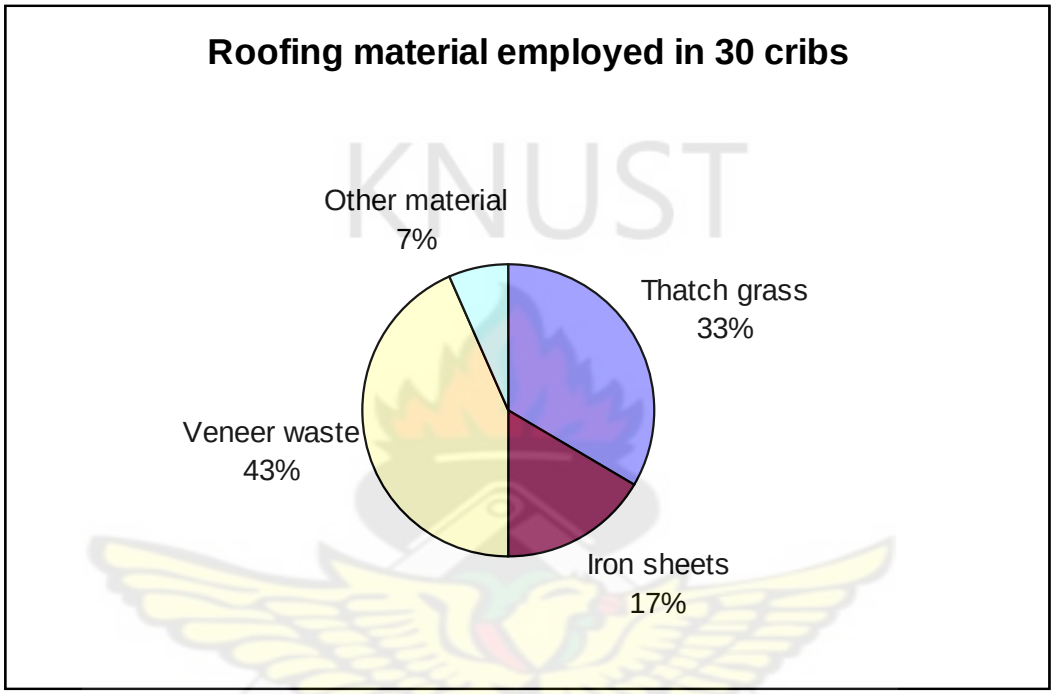

Fig. 3.5 Roofing materials used in Odumase cribs

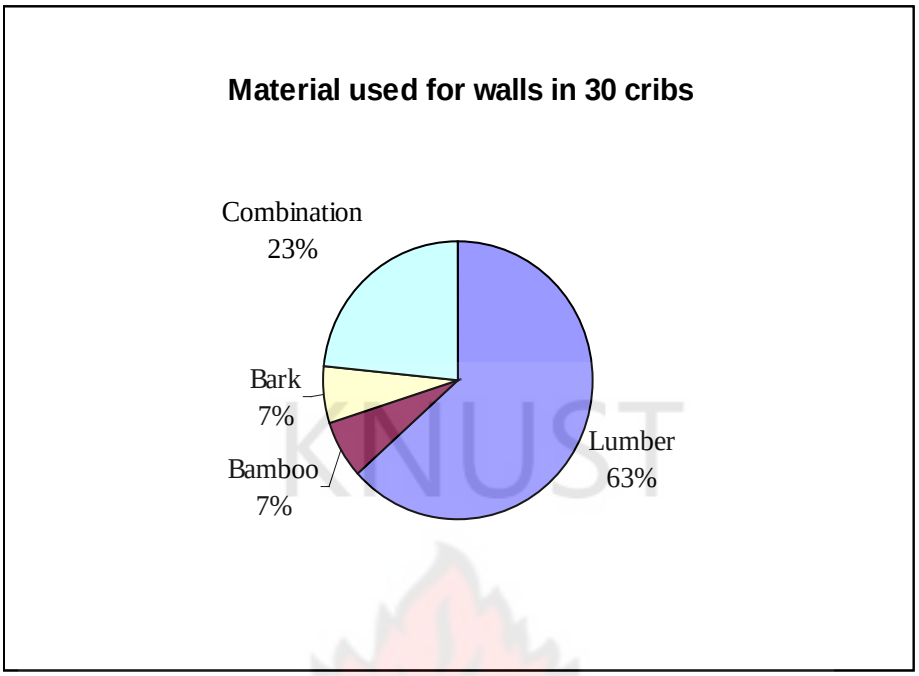

Fig. 3.6 Walling materials used in Odumase cribs

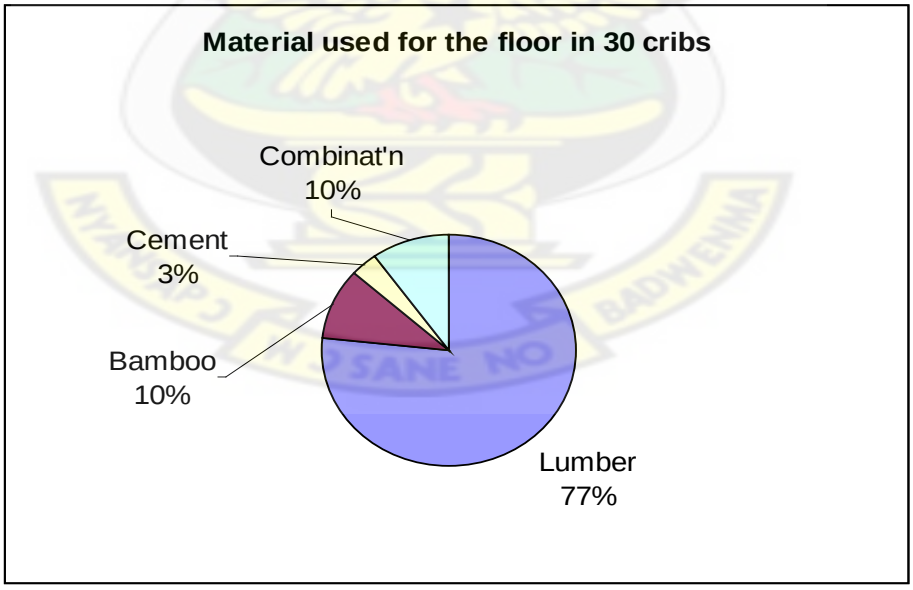

Fig. 3.7 Floor materials used in Odumase cribs

Various dimensions of the crib were also measured. Measurements were taken of the length (L), width (W), clearance from the ground (C), depth of the crib (D) (i.e. height from the floor of the crib to the lintel level) and the total height (H), i.e. the distance from the ground to the highest point of the crib. The measurements were taken on 26 different cribs. The mean values of these measurements are presented in Table 3.4.

Table 3.4: Mean values of crib dimensions (m)

Length, L	5.84
Width, W	3.18
Ground clearance, C	0.34
Depth, D	1.81
Total height, H	3.00

Figures 3.8, and 3.9 show the distribution of the crib width and ground clearance.

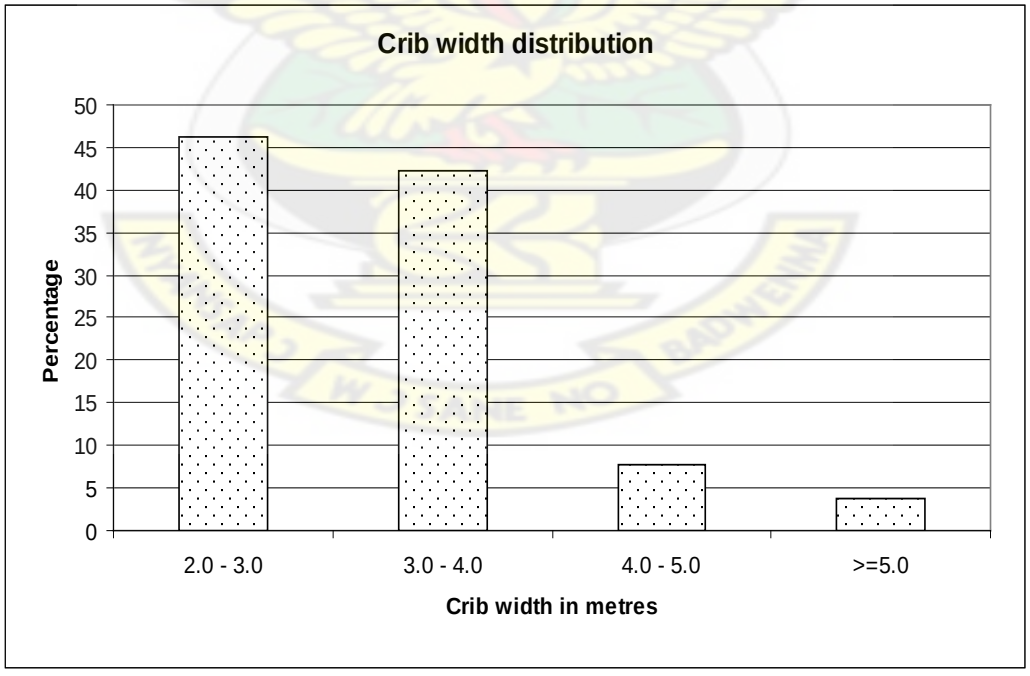

Fig. 3.8 Distribution of crib width in 26 cribs

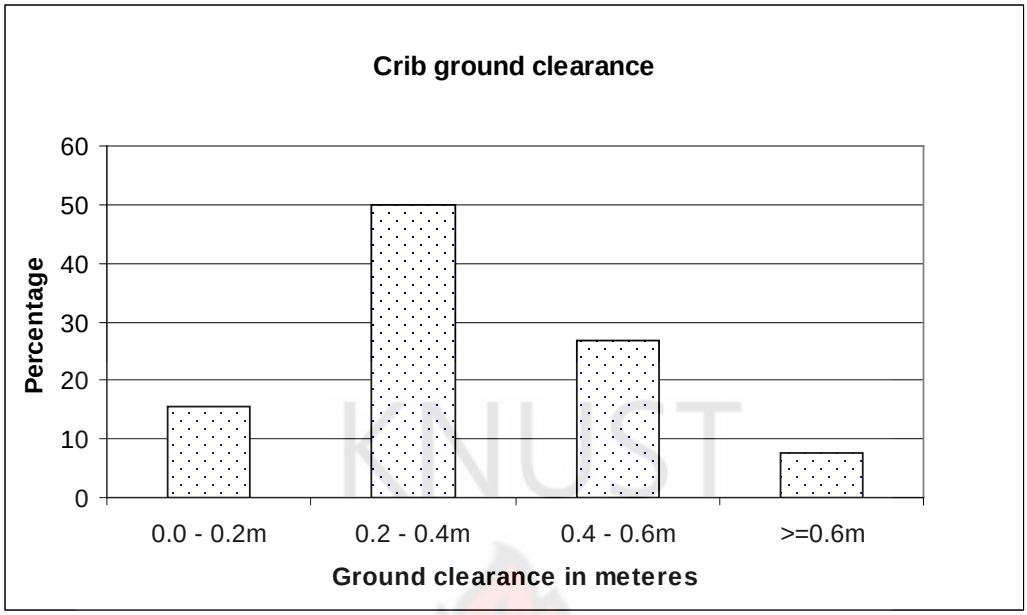

Fig 3.9 Distribution of ground clearance in 26 cribs

Almost 90% of the cribs measured had their width measuring between 2-4m, the lowest being 2.1m. This is far wider than the width of 0.6 m prescribed by the FAO (1985) for humid areas. Coupled with the wide width, the low clearance from ground and little or no space left between wall members do not make for effective ventilation of maize kept in the cribs used in the research area.

Some typical examples of the storage structures used in the Odumase area are shown in Figs. 3.10a, 3.10b, 3.10c and 3.10d. The use of bamboo for the walls and the floor with thatch grass as roofing material can be seen in Fig.3.10a.

Fig. 3.10a

Fig. 3.10b

Fig. 3.10c

Fig. 3.10d

Figs.3.10b and 3.10c are cases of poor ground clearance which makes ventilation difficult. From the pictures it can also be seen that there is little space left between adjacent wall members during the construction. This makes ventilation all the more difficult. Some farmers mentioned that they had to construct the crib to protect the maize from thieves and goats who would take advantage of the small spaces between wall members. Fig.3.10d shows the use of veneer waste from the plywood industry.

3.3.4 Pre-storage sorting practice

3 main criteria are used in sorting at this stage by various farmers. Table 3.5 shows the percentage of respondents using various criteria.

Table 3.5: Criteria used by farmers in sorting out maize

Criterion	Percentage of respondents using criteria
Cobs protruding out of husk	97.6
Ear size	54.8
Damaged ears	61.9
All 3 criteria	26.2

With respect to the 2005/06 major season harvest, about 52% of the respondents said they encountered just a few ears with protruding cobs while 35.7% encountered many. 7.1 % had about a third of their ears protruding while 2.4% experienced it in about half of their harvest. Another 2.4% said they did not have any such experience.

Ears with protruding cobs are very likely to be harbouring high loads of fungal spores which will develop under favourable conditions. The way such ears are handled will therefore have a bearing on AF contamination in the maize. Table 3.6 reports on this. 23.8% of the farmers go on to store such maize with the majority of them (14.3%) taking no precaution to arrest insect or mould attack that might have started in the field. The ideal option for such ears would have been shelling and immediate mechanical drying to the safe MC level for storage but this practice is far from commonplace among Odumase farmers.

Table 3.6: Handling of husk protruding cobs

Practice	% Practicing
Store as others	14.3
Treat before storage	9.5
Sell off	69.0
Domestic consumption	2.4
Other use	4.8

The survey revealed that farmers sort out different types of damage in maize. These are insect, bird, rodent and mould damaged maize. Fig. 3.11 shows the proportion of respondents who sort out the various damage types. Various farmers dispose of the damaged maize sorted out in different ways. The ears are consumed domestically, shelled and sold or thrown away if it is obviously bad. Table 3.7 shows how the farmers handle the different damage types sorted out at this pre-storage stage.

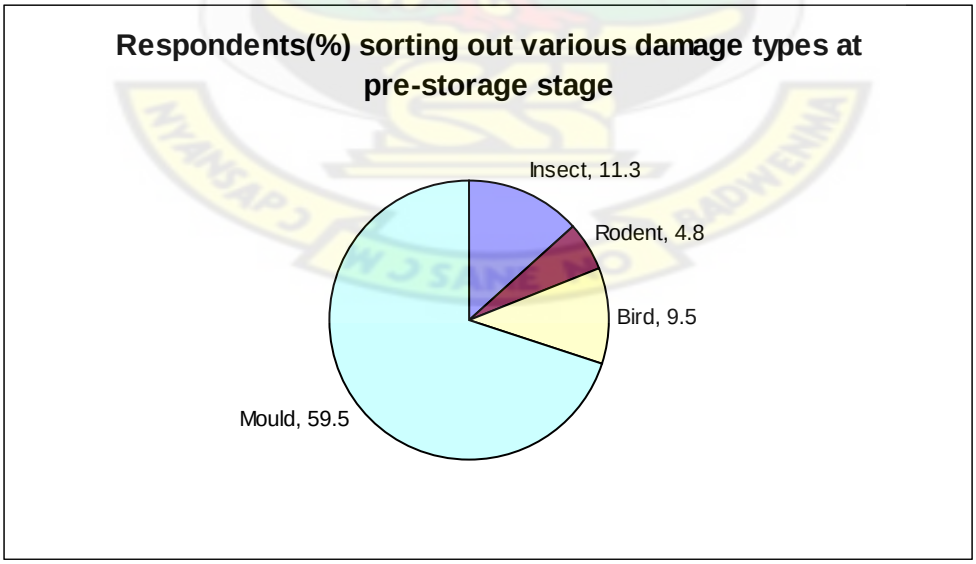

Fig. 3.11 Proportion of respondents (%) who sort out various damage types at pre-storage stage.

Table 3.7: Farmers' handling of sorted out damaged ears at the pre-storage stage (numbers represent percentage of farmers)

Handling	Type of damage			
	Insect	Rodent	Bird	Mould
Throw away	16.7	0.0	25.0	80.0
Shell and sell	18.3	100.0	75.0	20.0
Domestic consumption	0.0	0.0	0.0	0.0

3.3.5 Post-storage sorting practice

Fig. 3.12 shows the proportion of respondents sorting out various damage types at post-storage stage. Table 3.8 shows how various farmers handle the different damaged types sorted out at the end of the storage period.

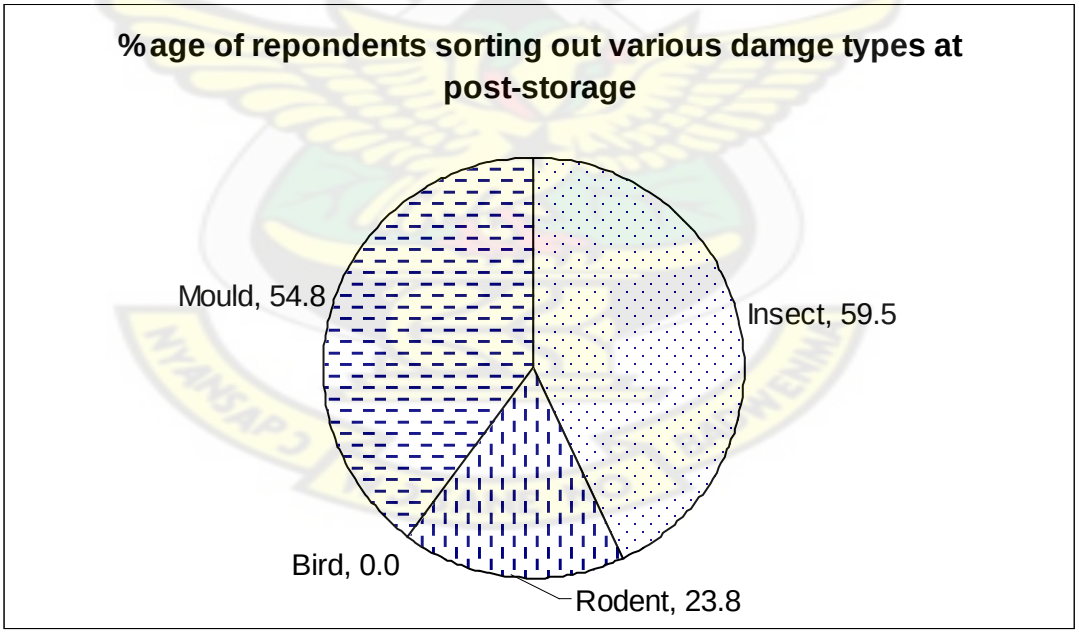

Fig.3.12 Proportion of respondents (%) who sort out various damage types at post-storage.

Table 3.8: Farmers' handling of sorted out damaged ears at the post-storage stage (numbers represent percentage of farmers)

Handling	Type of damage			
	Insect	Rodent	Bird	Mould
Throw away	4.0	0.0	0.0	78.3
Shell and sell	84.0	90.0	0.0	21.7
Domestic consumption	12.0	10.0	0.0	0.0

A comparative study of tables 3.7 and 3.8 shows that sorting out mould damage is important to farmers both at the beginning and end of storage. However, sorting of insect infested ears becomes widespread at the end of storage with 59.5% of farmers sorting out insect damaged ears (characterized by powdering and holing) as against 11.3% sorting at the beginning of storage. The sorting out of moulded ears at the end of storage is done by 54.8% of the farmers, a figure not too different from the 59.5 % of the beginning of storage. This suggests that a lot of moulding has developed during storage. The above observations also indicate that the storage systems and practices do not sufficiently arrest insect infestation and fungal development during storage.

Even though a greater portion of farmers throw away their sorted out moulded ears, an important fraction go on to shell and sell theirs on the market (Tables 3.7 and 3.8). This moulded maize still enjoys good patronage in times of scarcity. The two tables show that a lot more farmers sell insect infested maize than throw it away. However, insect infested maize also carries the risk of AF contamination. A few farmers reported that when their maize was not 'obviously mouldy' they would shell it along with the rest together and sell it on the market as such. The researcher is of the opinion that this practice is rather commonplace in the Odumase maize farming community.

3.3.6 Infestation control practice

Infestation control in the research area was found to be carried out on two fronts. First on the storage facility itself and secondly in the maize stored. The use of pesticides was found to be widespread with some using the herbal insecticide, *Chromolaena Odarata*, known locally as "Acheampong". Table 3.9 shows the extent of pesticide use by farmers in infestation control.

Table 3.9: Extent of pesticide use by respondents in infestation control

	% of respondents involved	
	On storage facility	**On maize**
Uses pesticide	76.19	92.86
Does not use pesticide	23.81	7.14

All the farmers had a common objective of getting rid of or reducing insect infestation. Those who did not disinfect their storage facility said nothing would happen because they would treat their maize with insecticide as they put it into store.

83.3% of the respondents indicated that they clean their cribs with brooms before storage. While 17.4% of them said they did this to get rid of debris, 74.3% indicated that it was to avoid early infestation of their stored maize. In response to the question of how old maize was handled, 69.1% of the farmers indicated that their stores would be empty by the time of the new harvest. However, 11.9% of the farmers said they took out their old maize (if there was still some available), citing avoidance of cross infestation and spoilage of the old maize as reasons. Another 11.9% of the farmers said they kept their

old maize in store and packed it on top of the new, separating the two with a layer of "Acheampong" leaves. Some in this category indicated that they left the maize in store because of poor market prices and because they did not own a second crib.

Fig. 3.13 presents the results on the means of chemical insecticide application employed in the research area while Fig. 3.14 shows the frequency of insecticide application during storage.

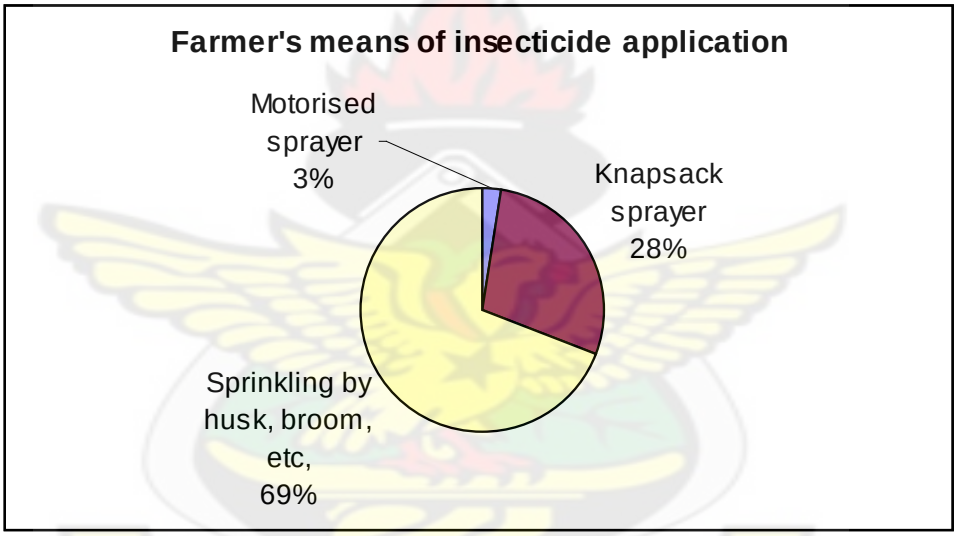

Fig. 3.13 Farmers' means of insecticide application

It is encouraging to observe that most farmers in the research area (56.4%) use Actellic because it is a proven effective insecticide in grain storage. Insecticide application is done mainly by sprinkling (69%).

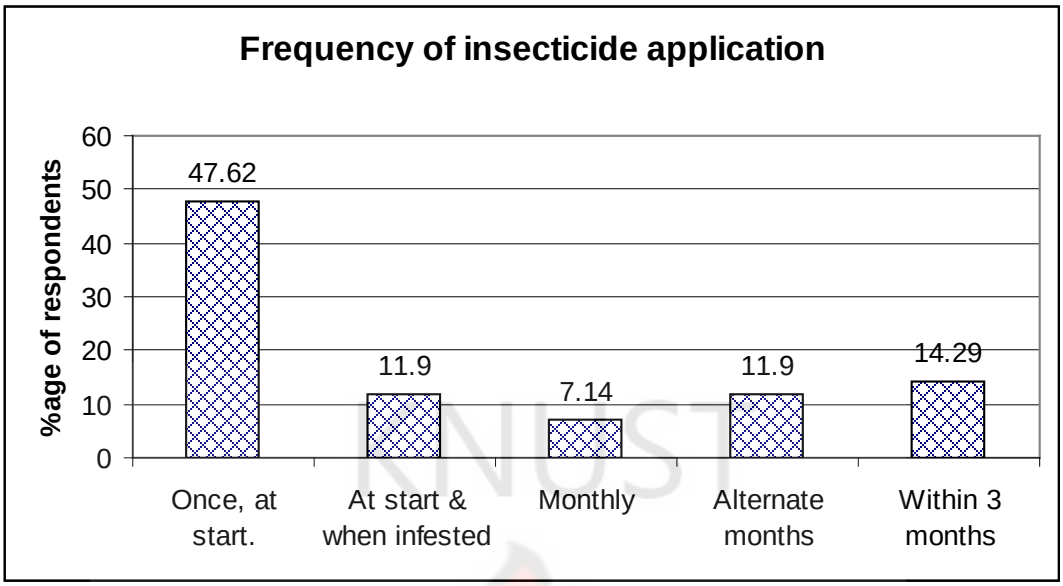

Fig. 3.14 Frequency of insecticide application

This is done mainly using maize husk, brooms, small tree branches, etc. Unfortunately, this method does not facilitate a good contact with the ears and insects for a good kill. Even where a knapsack or motorised sprayer is used the spray of chemical may not be able to penetrate successfully the centre of a 2-4m width crib with ears packed tightly. Yet almost 90% of the cribs visited had widths in this range. The above discussion suggests that infestation control in Odumase maize storage by the use of pesticides, though popular, may not be as effective as desired. However, there is promise of significant improvement with increased education and training on the role of proper insecticide application methods since the need for the practice is widely appreciated by farmers. To this end, workshops for farmers in the area on the theory and practice of infestation control would go a long way to assist.

3.3.7 Insect infestation in various storage practices

All the storage practices led to an increase in the level of insect infestation with the storage of dehusked ears in the traditional crib (TCD) recording the highest average change of 245 insects/kg of shelled maize as can be seen in Table 3.10.

Table 3.10: Beginning, end and change in levels of insect infestation during storage for various storage practices

Storage practice	Insect infestation levels (%)		
	Beginning (A)	End (B)	Change (B-A)
TCH	8.64	74.85	66.21
TCD	15.05	260.20	245.15
RSH	9.74	205.10	195.37
RSD	15.70	156.20	140.50
GWSP	2.20	7.00	4.80
PWSP	2.20	42.35	40.15

This storage practice also recorded the greatest increase in AF level over the storage period. This however, was no indication of a positive correlation between insect infestation and AF contamination because in both RSH and GWSP practices which recorded an average change in AF contamination of 10ppb each, change in insect infestation was 195/kg and 4.8/kg in RSH and GWSP respectively. Nevertheless, the results were in agreement with the observation by Richter *et al*. (1997) that insecticide treatment was less effective in cribs than in shelled grain stored in sacks.

3.3.8 Mould infection and fungal evaluation in various storage practices

It must be stated at the beginning of the discussion here that the fungal infection measured at the beginning of storage is a reflection only of the infection resulting from handling practices and the environment to which the crop has been exposed until the beginning of storage, i.e. the pre-storage history of the crop. (This is true also for the results obtained in insect infestation). Table 3.11 shows the beginning of storage (A), end of storage (B) levels of mould infection in stores and the change experienced over the storage period.

Table 3.11: Beginning, end and change in levels of mould infection over storage for various storage practices

Storage practice	Mould infection levels (%)		
	Beginning (A)	End (B)	Change (B-A)
TCH	0.80	1.99	1.19
TCD	11.04	8.43	-2.62
RSH	2.92	3.39	0.47
RSD	2.11	7.97	5.86
GWSP	10.14	11.35	1.22
PWSP	10.14	10.24	0.11

Except for the TCD practice, there was an increase in mould infection in all the other storage practices. A computation of the mean percentage mould infection across all practices shows an increase from 6.19% by 1.04 percentage points to 7.23%, indicating a general increase in moulding of maize in the research area during storage.

Results from the fungal evaluation revealed the presence of *A. flavus* in all but two of the beginning of storage samples. It was present in all the end of storage samples. Other fungal species identified in samples were *A. Niger, Fusarium, Penecillium* and *Rhizopus*. In all the storage practices investigated there was an increase in *A. flavus* contamination over the storage period but a decrease in the other fungal species in most of the storage practices. This observation suggests that *A. flavus* may have an inhibitory effect on the development of the other fungal species when they occur together in stored maize, a rather unfortunate possibility since *A. flavus* metabolism is key in the formation of AF in maize.

3.3.9 Aflatoxin contamination in various storage practices

The 25 samples collected from the research area had AF levels ranging from 0 to 200ppb as per the Fluorescent Standard Range used. A mean of 61.6ppb was computed. The intervention level recommended by the World Health Organisation is approximately 20 ppb. Only 4% of the samples had the below 20ppb contamination level permitted in food in countries like China, Philippines and Thailand. The bulk of the samples (72%) had AF levels between 20 and 100 ppb. (Fig.3.15). It must be pointed out that all the samples came from the major season crop and involved maize stocks that had been stored for various periods, the longest storage period lasting for about 5 months. They were obtained between September 2006 and February 2007.

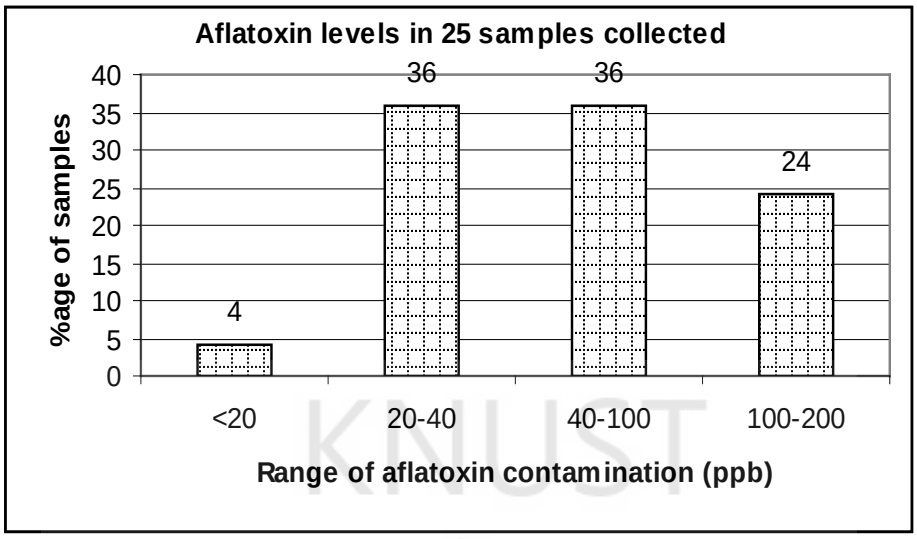

Fig. 3.15 Distribution of AF in 25 samples collected from Odumase.

Table 3.12 shows AF contamination levels of between 20 and 30 ppb for various practices. A computation of the mean aflatoxin level across all the storage practices gives a value of 26.7ppb at the beginning of storage. At the end of storage the

Table 3.12: Beginning, end and change in levels of AF over storage for various storage practices

Storage practice	Aflatoxin level (ppb)		
	Beginning (A)	End (B)	Change (B-A)
TCH	20.00	20.00	0.00
TCD	30.00	120.00	90.00
RSH	30.00	40.00	10.00
RSD	20.00	20.00	0.00
GWSP	30.00	40.00	10.00
PWSP	30.00	100.00	70.00

AF level ranges between 20 and 120 ppb with a mean of 56.7 ppb across all practices. Thus the mean AF contamination in stored maize more than doubled over a period of 3-5 months in the Odumase area.

In view of the fact that the maize in each of the stores had their peculiar post harvest and pre-storage histories, the research was more interested in the change in AF level that occurred over the storage period. Traditional crib storage of maize in the dehusked form, TCD, recorded the highest change in AF levels followed by PWSP with changes of 90 and 70 ppb respectively. The TCH and RSD practices showed the lowest change in AF level over storage. The TCH practice, incidentally turned out to be the predominant one in the research area.

Apart from the practice of storing dehusked ears in a room (RSD) in which the second observation failed because the farmer sold off his maize without notice, two stores were observed for each of the other 5 storage practices. The changes in AF in different practices were not significantly different ($p>0.05$).

3.3.10 Aflatoxin contamination in Accra by other authors

The Greater Accra Region has been the leading producer of commercial poultry in Ghana (MOFA, 1996). Consequently the region has been an important consumer of maize produced in the middle belt of the country including areas like Odumase and the Sunyani West District as a whole. AF levels in maize in Accra and surrounding areas is therefore of some interest to this work.

In a study on fusaria and fumonisins in maize from Ghana and their co-occurrence with aflatoxins, Kpodo *et al.* (2000) found AF contamination in 8 out of 15 maize samples collected from 15 major maize processing sites in Accra. Contamination in the 8 samples ranged from 2 – 662ppb with an average of 176ppb. An observation of grave concern arising from this research is the levels of AFB1 encountered in the contaminated samples. This ranged from 2 – 338ppb with an average of 102ppb. The concern is in view of the role of AFB1 in aflatoxicoses as discussed in Section 2.4.2 and the permissible limit of as low as 2ppb in groundnuts, dried fruit and their products for retail sale pertaining in the European Economic Commission (Table 2.4).

In a work carried out to assess the effect of applying GMP and HACCP to traditional food processing in a semi-commercial kenkey production plant in Ghana (Amoa-Awua *et al*., 2007), the authors reported that AF levels in kenkey produced was brought down from 64.1-196ppb to 14.5-17.2ppb. This represents a reduction of 77.4-91.2%. The results indicate that the observation of good management practices and implementation of a good HACCP plan are potent tools in the management of AF contamination. It can

therefore be argued that insisting on the adoption of the less vulnerable storage practices (TCH) and the observation of good hygiene are steps that have a good chance of reducing the incidence of AF contamination in maize stored in the research area.

A summary of the results of AF measurements at the laboratory of the Veterinary Headquarters in Accra (personal communication) was compiled in the course of this work to enable examination of AF contamination in and around Accra. The laboratory is much patronized by poultry farmers and the records of AF testing give some indication of poultry farmers' experience with AF contamination in feedstuffs within the Accra area. Such information is necessary in designing interventions to deal with the AF menace.

The detailed records of the laboratory are summarized and presented in Appendix IV. It shows the AF levels measured in maize and feed mash samples brought to the laboratory from January 2004 to June 2007. The number of measurements made in each month is reported with the minimum, maximum and average levels indicated. The levels are also averaged out for each year. AF measurements in maize and feed mash were of particular interest to this work. Fig.3.16 shows a graphical representation of the trend of the average level of AF encountered over the period. A major trend seen in Fig. 3.17 is the decline towards the 30ppb level of contamination after the peaking in 2005 and 2006.

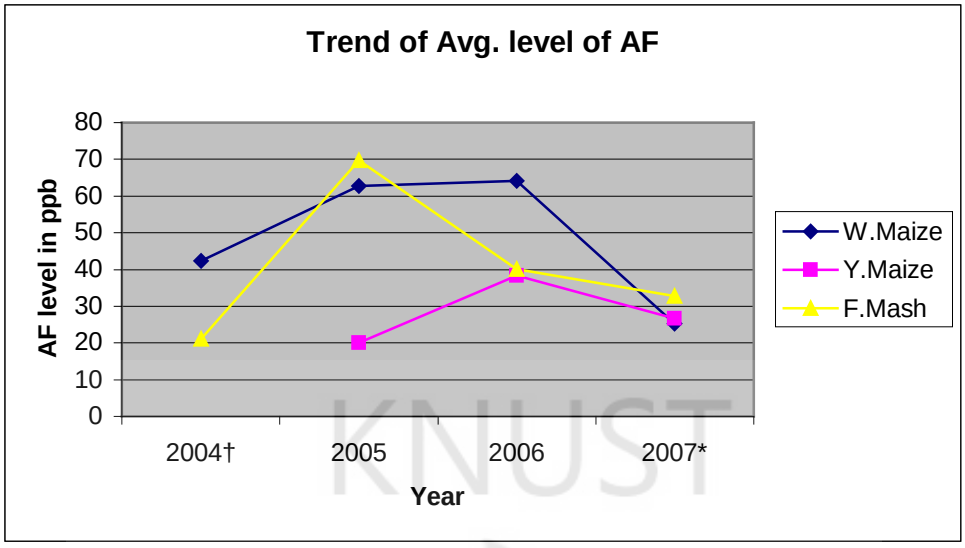

Fig. 3.16 Graphical representation of the trend of average AF contamination in certain feedstuffs as obtained from the records of a laboratory in Accra.

Though Fig.3.16 shows a decline in the average AF level in the feedstuffs beginning from 2005, the situation still calls for more research into how AF contamination in maize may be reduced. Two reasons that are particularly related to the Accra situation are presented below:

1. The 30ppb contamination level about which the feedstuffs were hovering in 2007 may be acceptable for poultry but this is above the limit for human consumption. This is a concern because in Ghana there is no clear distinction between poultry grade maize and maize meant for human consumption. Thus the 30ppb average AF level recorded by the laboratory is very well representative of the maize on the market in and around Accra, irrespective of its end use.

2. The past few years have seen large quantities of both yellow and white maize imported into the country from various sources around the world. The imports were undertaken by both the government and private sector in view of anticipated shortfalls in local production. A lot of these imports were consumed by poultry farmers and feed manufacturers in the Greater Accra Region and surrounding areas. It is likely therefore, that most of the maize brought to the laboratory for AF testing originated from outside the country and in places where probably measures are in place to ensure that AF levels are maintained within acceptable limits. The declining trends in average AF levels indicated in Fig. 3.17 is therefore not a very reliable picture of the local maize production. This is particularly so in the case of the yellow maize since yellow maize has not been produced in Ghana until very recent times.

It must be pointed out that the records of AF contamination levels obtained from the laboratory in Accra and analyzed to produce the results discussed here were not obtained from any particular experimental design. No information is obtained from the farmers about the source of their maize or feedstuffs brought for testing. The conditions under which the maize had been kept is not necessarily a concern of the laboratory, though these are factors that affect AF contamination. Therefore the discussion of AF contamination in and around the Greater Accra Region should be viewed against this background.

3.4 Conclusion

The mean AF level obtained in samples collected from the research area was 61.6ppb. The mean beginning of storage and end of storage levels stood at 26.7 and 56.7ppb respectively. Between the two major practices of storage in traditional cribs, husked storage (TCH) recorded no change in AF contamination levels while a 3-fold increase was observed in the dehusked storage practice in traditional cribs (TCD). An increase of 33% (from 30 to 40ppb) was observed in the good warehouse storage practice (GWSP) as against 233% in the poor warehouse storage practice.

The fungal evaluation showed that all but two of the beginning of storage samples showed the presence of *A .flavus*, indicating the widespread presence of the AF producing fungus. Thus storage practices that entail direct exposure of the grain to the environment should be discouraged in the research area. It may be concluded that the storage in traditional cribs with the husk on performed better because of limited exposure of the grain to the environment during storage.

The high pre-storage contamination level of 26.7ppb is indicative of the fact that much AF is formed in maize before the storage begins. Steps should be taken to control the contamination in this segment of the post harvest chain. These may include the strict use of certified seed and the complete sorting out and disposal of husk protruding cobs. The work of Amoa-Awua *et al*. (2007) strongly suggest that good post harvest management practices could go a long way to reduce the AF levels in the research area to acceptable levels.

CHAPTER 4 EFFECT OF CLIMATE AND POST HARVEST HANDLING ON MOISTURE CONTENT IN HARVESTED MAIZE

4.1 Introduction

The survey conducted revealed that an important portion of the major season harvest is not stored but shelled immediately after harvesting and put on the market while being sun dried. Table 4.1 shows the proportions of maize disposed of via this route by the respondents over two farming years. Whereas an average of 22.9% of the minor season harvest was disposed of through this route as much as 43.75 of the major season harvest was disposed of.

Table 4.1: Proportion (%) of maize harvested and shelled immediately for sale by farmers without storage

Farming year	Farming season	
	Major	Minor
2004/05	39.1	26.7
2005/06	47.2	19.1
Average	43.7	22.9

In view of the high MCs usually associated with freshly harvested maize, the research sought to examine the effectiveness of the sun drying practices in controlling the MCs in the shelled maize put on the market. This was considered important because of the effect of high MCs on aflatoxin contamination reported by Kawasugi *et. al.* (1988) and also because of the significant quantities of maize subjected to the practice.

The MC in shelled maize during sun drying is impacted by two main factors. These are the climate and the sun drying practice itself. In this chapter the theoretical impact of the climate on MC is examined by computing relevant indices such as the Equilibrium Moisture Content (EMC), the Drying Potential (Dp), and the Deterrioration Index (DI). The sun drying practice in Odumase is examined and compared with that of Yamfo, another important maize productionand marketing centre some 20km away. The MC regime in shelled maize while being sun dried is also examined for both Odumase and Yamfo.

4.2 Materials and methods

4.2.1 Data collection on climate and maize MCs

Climate data on the research area was obtained from the Metrological Services Agency weather station at the Sunyani Airport. The weather station was most appropriate because of its location some half a kilometre from Odumase. Data was obtained from 1997 to 2006. The Metrological Services Agency does not have a weather station at Yamfo. However, the data obtained from the Sunyani Airport was applied because of the location of the two towns within the same agro-ecological area and their separation by a distance of 20km. The climate data was processed to obtain various graphs presented in the results.

Data on the harvesting period moisture regime was obtained from Grainplus Ltd., a maize drying and storage facility which buys maize from the Odumase, Yamfo and other markets in the area during the harvesting period for drying. At the drying facility several

batches of shelled maize are delivered each week for drying from the various markets. The MC in each batch is determined by taking a sample from different points in each bag during weighing, mixing all the samples and measuring the MC with a moisture meter. The average of 3 different moisture content readings from each sample is computed and recorded. (This is used for computing the drying fee for each batch of maize delivered to the centre).

From the records of the company, MC data for maize delivered from Odumase and from Yamfo was sorted out and the mean MC for each month obtained using the batch weight and the average MC for each batch. Data was obtained for five seasons, beginning from the 2002/03 season. This was used in assessing the effect of different handling practices on MC.

4.2.2 Computation of Equilibrium Moisture Content (EMC) and Deterioration Index (DI)

Methods similar to what was used by Seidu (2005) in the assessment of functional capabilities of the improved narrow cribs in a humid area were used in these calculations. The Chung-Pfost equation as presented in the American Society of Agricultural Engineering (ASAE) Standards (ASAE D245.4) was used to obtain the EMC. The equations are as follows:

$$M = E - F \cdot ln[-(T+C) \cdot ln(RH)] \qquad \text{(eq.1)}$$

$$RH = \exp\left[-A^{-(T+C)} \exp(-B.M) \right] \qquad \text{(eq.2)}$$

where M = Grain Moisture Content, decimal dry basis

RH = Relative Humidity, decimal

T = Temperature, °C

The Chung-Pfost equation constants for corn are given as:

A = 312.30

B = 16.958

C = 30.205

E = 0.33872

F = 0.058970

The Deterioration Index was calculated based on the value for atmospheric RH (Brook,1950) as:

$$DI = (RH\% - 65) \times P_{sat}.10^{-4}$$

Where P_{sat} = calculated Saturated Vapour Pressure of air in Pascals, Pa, and is obtained by the formula $P_{sat} = 214(T) – 2240$ (Brook,1950; Teter, 1987).

4.2.3 Computation of the Drying Potential (D_p) of ambient air in the research area

The drying potential refers to the ability of the maize to get rid of some moisture and depends on the difference between the internal grain vapour pressure, P_g and the partial vapour pressure of the surrounding air, P_a. Thus

$$D_p = P_g - P_a$$

$P_g = ERH \times P_{sat}$ and $P_a = RH \times P_{sat}$

Where ERH = equilibrium relative humidity computed from the Chung-Pfost equation (eq.2). ERH was calculated using the mean grain MC at harvest computed from Table

4.5 as 22.1%. RH is the average monthly relative humidity of air. For drying to take place $P_g > P_a$.

4.2.4 Post harvest handling of maize shelled immediately after harvesting for sale in the Odumase and Yamfo markets.

The interviews held with farmers and market operators in the research area served as a source of information in understanding the post harvest handling of maize in Odumase. In addition, the researcher's experience of the maize industry in the research area, as well as in the Yamfo area, a period spanning more than ten years, served as a source of information. A special visit was made to Yamfo and 7 farmers/market operators purposively selected and interviewed to obtain detailed information on the handling of maize shelled immediately after harvesting for marketing. The results of the interviews have been summarized and presented in the discussion section.

4.2.5 Climatic conditions and MC regimes during harvesting

The MC regime in the research area during harvesting was also matched to the processed climate data and the portions of the harvest stored and the portions shelled (and sun dried) and disposed of. Data on the portions of the harvest sold or stored for each month was obtained from the analyses of the survey conducted.

4.2.6 Effectiveness of sun drying of shelled maize within the research area.

The effectiveness of sun drying in humid areas was investigated by FAO (1980). Effectiveness of the practice in the research area was reviewed in the light of this work

because the FAO experiments were carried out in climate similar to that of the research area. Shelled maize from the harvest was spread out in plastic roofed trays (Fig.4.9) for drying and the number of days taken to reach 15% and 12% moisture content respectively noted. This was done for maize harvested during the wet season and also during the dry season.

4.3 Results and discussion

4.3.1 Equilibrium Moisture Content and Deterioration Index

Table 4.2 shows the mean temperature and RH values for various months in the research area and alongside is presented the computed EMC, P_{sat} and DI values.

Table 4.2: Equilibrium MC (EMC), Saturated Vapour Pressure (P_{sat}) and Deterioration Index (DI) of maize in the research area

Month	Air Temp. (°C)	RH (%)	EMC (%)	P_{sat} (kPa)	Det. Index
Jan	26.6	57.5	13.5	3.45	-2.6
Feb.	28.3	59.3	13.7	3.82	-2.2
Mar.	28.7	67.3	15.3	3.90	0.9
Apr.	27.7	76.1	17.6	3.69	4.1
May.	27.0	78.7	18.4	3.54	4.8
Jun.	25.9	81.6	19.5	3.30	5.5
Jul.	25.5	83.3	20.2	3.22	5.9
Aug.	24.6	83.4	20.3	3.02	5.6
Sep.	25.3	83.9	20.4	3.17	6.0
Oct.	26.0	81.2	19.4	3.32	5.4
Nov.	26.6	78.3	18.4	3.45	4.6
Dec.	26.1	70.2	16.2	3.35	1.7

From the table, it can be seen that it is only in January and February that the EMC reduces to levels at which maize can be stored safely. This is due mainly to the harmattan dry winds which are at their peak influence in the country about this time.

Records from Grainplus Ltd., the maize handling and marketing outfit, indicated that MCs of maize obtained from the research area as well as from Yamfo were between 13.5 and 14.1% during the period from January to April each year. This can partly be seen from Fig.4.7. The deterioration index of the maize is also lowest during the months of January and February. This is because the grain MC and the RH of the ambient air at this time are unfavourable for the activities of the agents of deterioration. In practice maize MCs do not approach the 17-20% range indicated by the computed values in the Table 4.2. This is because even though the RH of the ambient air rises, the storage systems do not permit the amount of interaction between the air and the grain that will lead to the calculated MCs shown in the table. Thus the January – February MCs attained are increased only slightly over any long term storage because of the limited ventilation permitted by the storage structures within the research area as discussed in section 3.3.3.

4.3.2 Drying Potential (Dp) of ambient air in the research area

The computed drying potential of the ambient air in the research area is presented in Table 4.3. The results confirm the discussion in section 4.3.1 above. Drying potential is highest in January – February and to some extent in March. The drying potential is lowest in July to September which is the harvesting period for the major season crop. This again underscores the need for mechanical drying of maize at this time. Seidu

(2005) reported similar trends of drying potential at the Sefwi Wiawso area where his study was carried out.

Table 4.3: Drying potential (D_p) of the ambient air in the research area

Month	P_{sat} (kPa)	P_g (kPa)	P_a (kPa)	D_p
Jan	3.45	302.1	198.5	103.5
Feb.	3.82	333.9	226.3	107.6
Mar.	3.90	341.4	262.6	78.8
Apr.	3.69	322.6	280.6	42.0
May.	3.54	309.5	278.4	31.1
Jun.	3.30	288.9	269.5	19.5
Jul.	3.22	281.5	268.0	13.5
Aug.	3.02	264.6	252.2	12.4
Sep.	3.17	277.7	266.3	11.4
Oct.	3.32	290.8	269.9	20.9
Nov.	3.45	302.1	270.3	31.7
Dec.	3.35	292.7	234.8	57.8

4.3.3 Post harvest handling of shelled maize in Odumase and Yamfo

Post harvest handling of shelled maize in the Odumase market goes through a series of steps and gets sold while sun drying is taking place. In situations of high market demand the maize is sold off via a second route. The commodity flow is presented in Fig.4.1.

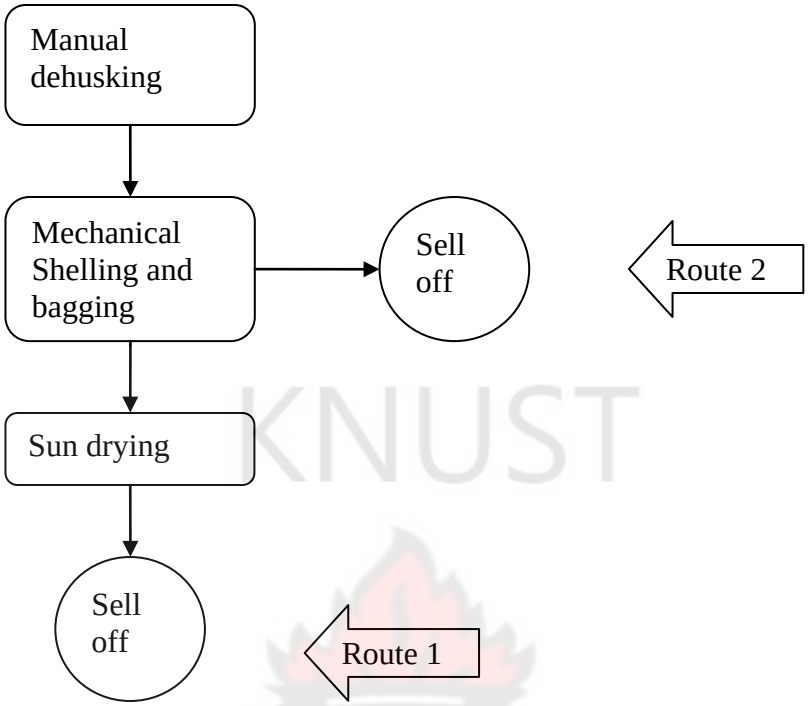

Fig. 4.1 Diagram showing the handling of maize sold immediately after harvesting without storage.

Each of the sell off routes imparts particular MC changes with peculiar mould infection implications. Maize leaving Odumase would typically be loaded in bags into containerized trucks which undertake a day or two's trip to Accra. The route 2 exit does not involve sun drying and exposes the commodity to high risk of fungal development.

Mechanical shellers are available which can dehusk and shell simultaneously but this is seldom employed in the Odumase area. This is because mechanical dehusking renders the maize husk unsuitable for use in preparation of the famous *Ga Kenkey*, a type of food prepared from fermented corn dough. The husk is therefore removed manually in a process involving the skilful use of a kitchen knife to end up with an unshredded husk. Most farmers would seek out women with these skills to undertake the dehusking.

After obtaining the husk through manual dehusking, the dehusked maize ears are carried in basketfuls and fed into a mechanical sheller. The shelled maize is discharged from the sheller into bags and carried to the market operator's *plot* in the market. The shelling at Odumase is generally done at the back side of the maize market where one would always find shellers lined up shelling various batches of maize. At the *plot* sun drying and marketing take place or marketing directly takes place without sun drying (route 2) depending on the demand in the market.

The sun drying practice consists of opening the bags of maize that have been shelled and brought to the market operator's *plot* and spreading it out on tarpaulins or other sheets on the ground as shown in Fig. 4.2. The depth of maize spread out during sun drying in Odumase may range from about 2-10 cm. Maize spread out in the open would be stirred every couple of hours or so to aid the drying process. The effectiveness of sun drying is affected by a number of factors:

1. The prevailing weather conditions i.e. the RH, temperature and wind speed.
2. The time allowed by the market operator for sun drying.
3. The space available for the market operator to undertake sun drying.
4. The depth of maize spread out in the sun.
5. The frequency of stirring of maize spread out in the sun.
6. The quantity of maize at the market operator's *plot* awaiting sun drying.
7. The demand for maize in the market indicated by the number of buyers present at the market.

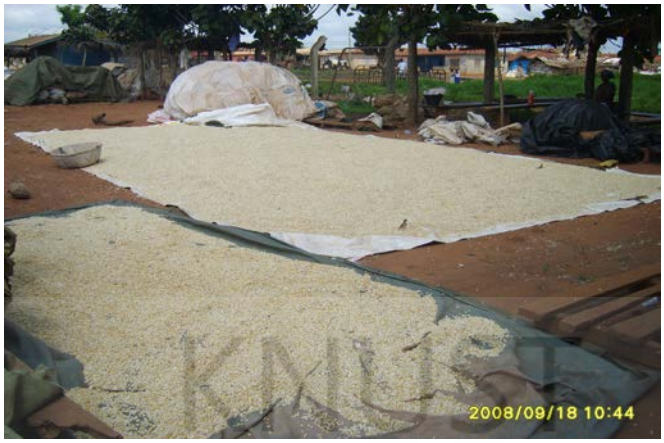

Fig. 4.2 Shelled maize being sun dried at Odumase

Whereas the prevailing weather conditions cannot be controlled, the depth of maize spread out is affected by the space available to the operator on his *plot*, the pressure on him/her to sun dry shelled maize stacked on his pallet so as to make room for more stocks (thus increasing his stock turnover and consequently his profit), as well as the demand for the commodity prevailing in the market. The drudgery of stirring of maize spread out in the open for sun drying puts off many a market operator, except when the premium on relatively dried maize in the market at a particular time is significantly higher. But again, the desire to increase his throughput pushes the operator to sell off just after a few rounds of stirring.

The steps involved in the handling procedure for maize in Yamfo are essentially the same as those in Odumase, namely manual dehusking (usually), mechanical shelling and bagging, sun drying followed by selling off. Shelling takes place at the farm gate or at the farmer's residence from where the market operators take the maize into their custody

for marketing. While waiting for traders to come and buy the maize the market operators keep the grain in their store rooms. The store rooms (or operation centre) of the market operators are not all located at a common centre, but are scattered in different places in the township. These scattered stores together constitute the physical market place in Yamfo, a situation quite different from the Odumase market. Selling off via a route 2 does not happen here because of the structuring of the maize market.

While they wait for traders to purchase the grain from their hands, the market operators keep the grain spread out on the floor in their stores. What is called sun drying in the Yamfo area is the opening of stores' doors and windows to facilitate aeration of shelled maize spread out on the floor. This is accompanied with frequent stirring. Fig. 4.3 shows typical market operators' stores in the Yamfo township with maize being sun dried. Such conditions do not augur well for sun drying of shelled grain.

Fig. 4.3 Typical maize market operators' stores encountered in the Yamfo township.

An interview with seven purposively selected market operators during a visit to the Yamfo area threw more light on the sun drying practice. The information gathered is presented in Table 4.4

Table 4.4: Information from 7 Market Operators interviewed on their sun drying operations at Yamfo.

Mkt. Operator	Years of operation	Av. No. of bags handled each major season	Room size			Maximum grain depth (m)	Mould encountered during sun drying
			Length (m)	Breadth (m)	Area (m^2)		
1	15	500	4.60	3.10	14.30	0.30	Yes
2	4	150	5.23	3.85	20.12	0.36	Yes
3	15	1500	5.23	4.15	21.73	1.22	No
4	15	1000	4.15	2.77	11.50	1.22	Yes
5	3	1000	3.69	3.54	13.06	0.91	Yes
6	24	2000	5.54	4.92	27.26	1.83	Yes
7	8	800	3.08	2.92	8.99	1.22	Yes
Mean	12.0	992.9	4.503	3.607	16.709	1.009	
*SD	6.9	568.5	0.841	0.708	6.024	0.499	

***SD = Standard Deviation

According to the 7 market operators interviewed, various batches of maize brought to their stores could remain there for about a week or more before it is bought off. The depth of grain in the store averages 1.0m, reaching as high as 1.83m in the case of the 6th interviewee. It is therefore not surprising that except for one person, all the interviewees reported that they encountered moulding in their stores during the peak of the harvesting season when their stores held the maximum quantities of maize.

4.3.4 Climatic conditions and MC regimes during harvesting

Figures 4.4, 4.5 and 4.6 show graphs of the processed climate data for the research area indicating the mean monthly rainfall, temperature and relative humidity respectively.

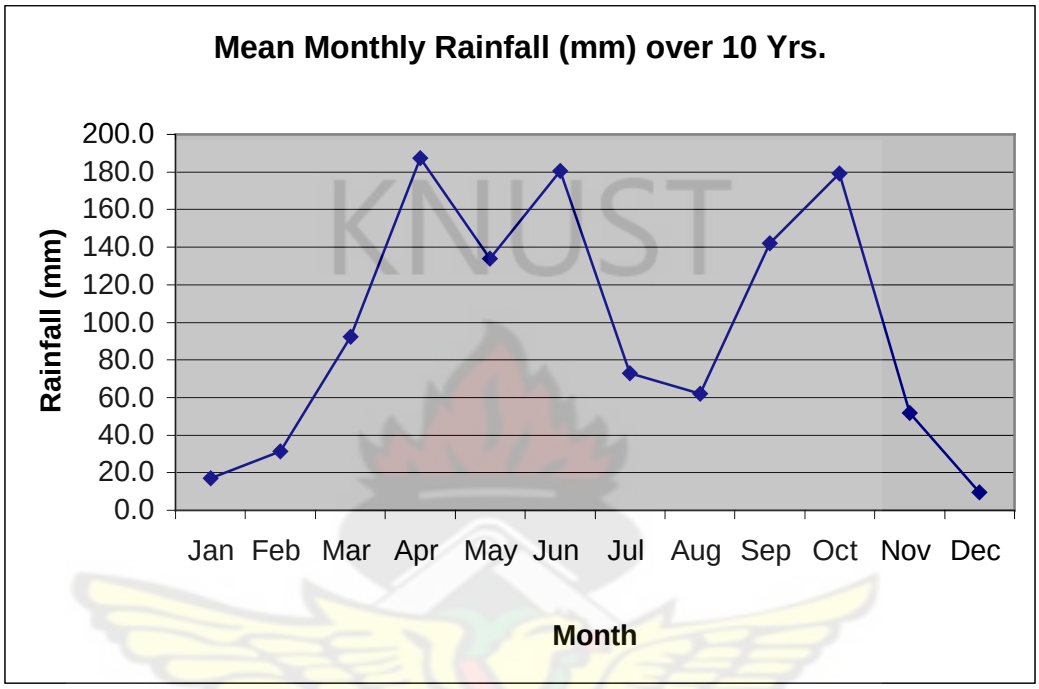

Fig.4.4 Mean monthly rainfall of the research area

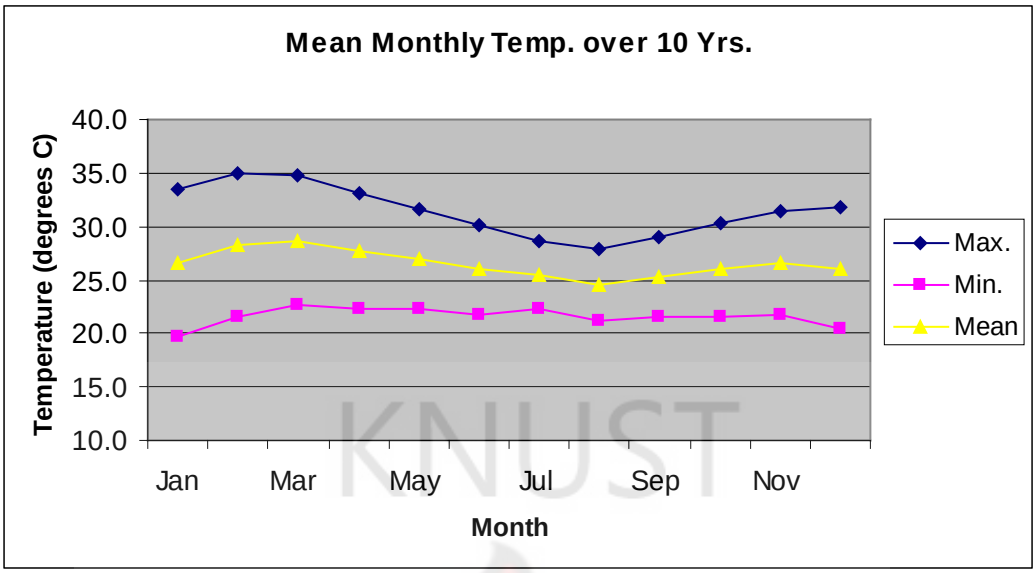

Fig.4.5 Mean monthly temperature of the research area

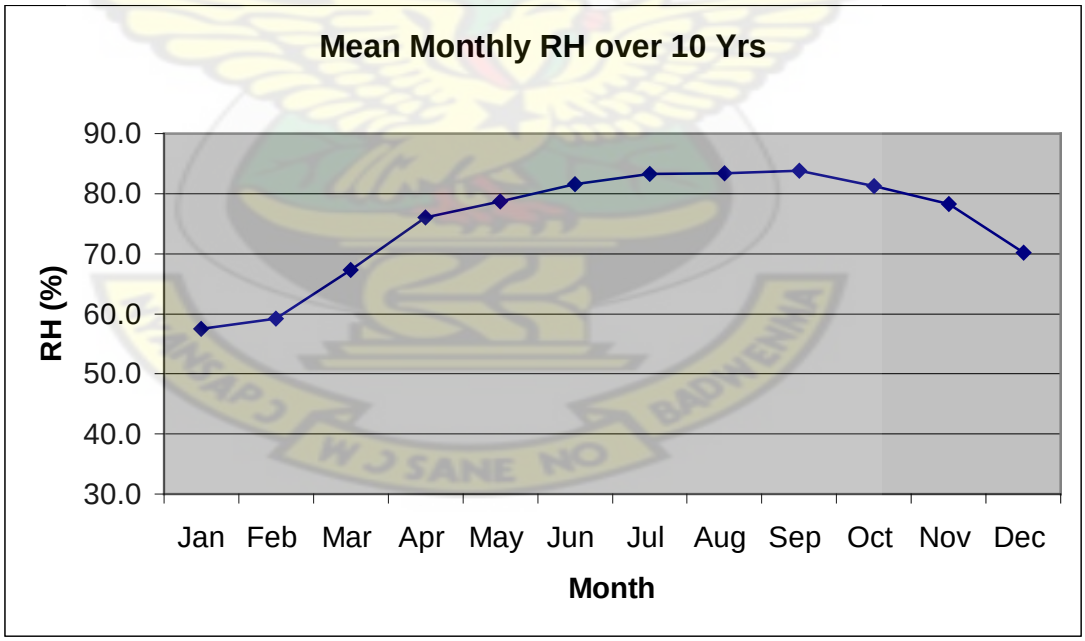

Fig.4.6 Mean monthly RH in the research area

The processed data on MC regimes during the harvesting period for both the research area and Yamfo are presented together on the same graph in Fig.4.7 to facilitate comparison and to assess the effect of different handling practices. The graphs compare differently over 3 distinct sections of the harvesting period:

1. From July to September
2. Between September and November
3. Beyond November

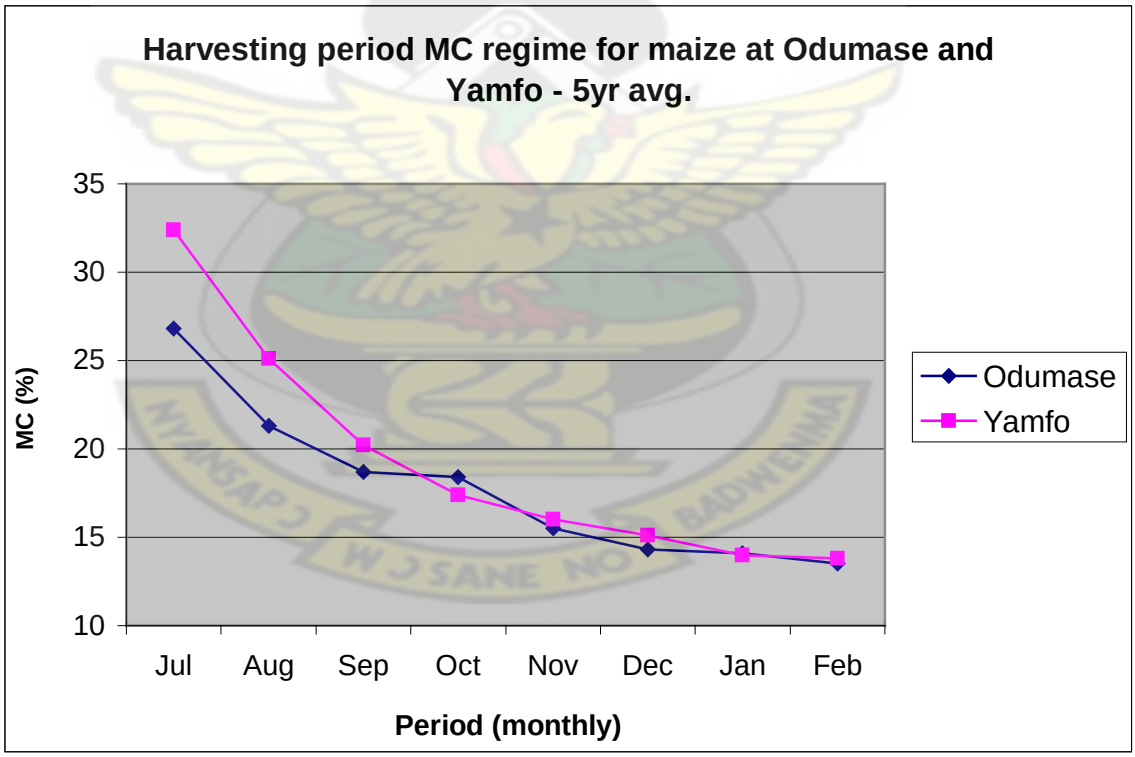

Fig.4.7 Comparison of Odumase and Yamfo MC regimes in harvested maize

From July to September

During this period Yamfo MCs are higher than Odumase MCs. The difference however reduces towards the end of September. Given the assumption that climatic conditions are similar, the difference in handling practices, particularly the sun drying practice, may be identified as the reason for this observation.

It may be argued that sun drying by spreading out in the open as is done in Odumase is a more effective means of reducing MC in maize harvested and released immediately onto the market than sun drying by spreading out in store rooms as is done in Yamfo. The reducing difference in MCs towards September can be explained by the fact that ears harvested late would have reduced MCs irrespective of where they were grown due to field drying.

Between September and November

During this period the rate of MC reduction in Odumase maize slows down sharply to the extent that by October Odumase MCs are higher than Yamfo MCs. This is contrary to the observed trend from the beginning of harvesting where Yamfo MCs are always higher. One would have expected that the trend would remain the same since handling practices and climatic conditions have not changed. The situation may be explained by the interplay of a number of factors during the period. These are outlined below:

1. October marks the end of harvesting of the major season crop and the supply rate to the Odumase market is reduced, with about half of the season's crop sold

already and the other half in storage (Table 4.5) in anticipation of higher prices. Also around this time, farmers are working on their minor season farms and would give little attention to bringing out and shelling what is in store.

2. In view of the situation in (1), stocks arriving at the market are subjected to sun drying for very little time due to the increased demand. The exit of maize from the market through route 2 (Fig.4.1) becomes important., a situation that does not come into play much in Yamfo because of the market structure where traders do not have direct access to maize while it is being shelled.

3. In addition to the above mentioned factors, it is to be noted that September – October is characterized by high RH values in excess of 80% (Fig.4.6). Even though the equilibrium MC for the observed RH values during the period are in the range of 16-17% (Hayma, 1995), the grain is scarcely permitted enough time to interact with the surrounding air to bring about the natural drying process – in the case of the Odumase market. Results from experiments on sun drying by FAO (1980) at IITA in Ibadan (discussed in section 4.3.5) indicate that a long period of time is needed to reduce MCs in maize through sun drying with such relative humidities.

4. Finally, it is to be noted that rainfall is on the increase between September – October. Market Operators at Odumase who may be sun drying keep their maize covered most of the time to avoid it being soaked by the rains. At the Yamfo

centre, however, the increasing rainfall is not a serious challenge because grain is not spread in the open but in rooms. Thus the doors and windows are easily closed or opened to manage the effect of the weather on the natural drying of maize.

Beyond November

Very little difference exists in MC of maize from the two centres during this period. The over-riding factor in the environment at this time is the low relative humidity characteristic of the harmattan winds which about equally influences Yamfo and Odumase. The RH takes a dive from around 76% in November to below 60% in January and February (Fig.4.6). Coupled with this, rainfall is at its lowest levels during this period (Fig. 4.3). As these climatic conditions persist, MC in maize all over the middle and northern parts of the country continue to head for the 11-13% level which is the equilibrium for RH of 60-70% (appendix VI).

Table 4.5: Harvested maize disposal, climate and MC regime for Odumase

Season	Month of harvest	Month's Harvest			Max. Temp (°C)	Rainfall (mm)	Av. RH (daytime) (%)	Av. MC (%)
		% of season's	% stored	% dis-posed				
Major	Jul	11.9	26.9	73.1	28.6	72.8	83.3	26.8
	Aug	62.6	64.5	35.5	28.0	62.2	83.4	22.0
	Sep	25.5	56.9	43.1	29.0	142.0	83.9	20.0
	Season	100.0	49.4	50.6				
Minor	Dec	17.1	63.8	36.2	31.8	9.7	70.2	13.9
	Jan	79.1	80.9	19.1	33.4	17.0	57.5	13.8
	Feb	3.8	73.6	26.4	35.0	31.2	59.3	13.8
	Season	100.0	72.8	27.2				

Table 4.5 shows the proportion of each month's harvest that is stored and that is disposed of (by shelling, sun drying and marketing). It also indicates what proportion of the season's harvest each month's harvest represents. It can be seen that whereas 50.6% of the major season's harvest is disposed of, only 27.2% of the minor crop is disposed of. Unfortunately however, the rainfall and RH during the major season harvesting is most unfavourable for the sun drying that accompanies the disposal. This situation makes up a good case for mechanical drying.

Given the MC range of 20.0-26.8% in maize on the market and the temperature regime of above 27°C that pertains during the harvesting period, harvested maize in the research area in the major season stands a high risk of deterioration through fungal and insect activity. This can be seen from the correlation of temperature and MC values for cereals indicating their influence on germination, insect and fungal development (Hayma, 1995) as shown in Fig.4.8. The curve labeled C shows that maize at a moisture content of 20-25% should be kept at temperatures of 5°C and below to aboid deterioration. Unfortunately, temperature in the research area when MCs are this high is above 27°C. curve A also shows that for the observed MC range of 20 – 26.8%, insect heating will take place, except the temperature is below 18°C.

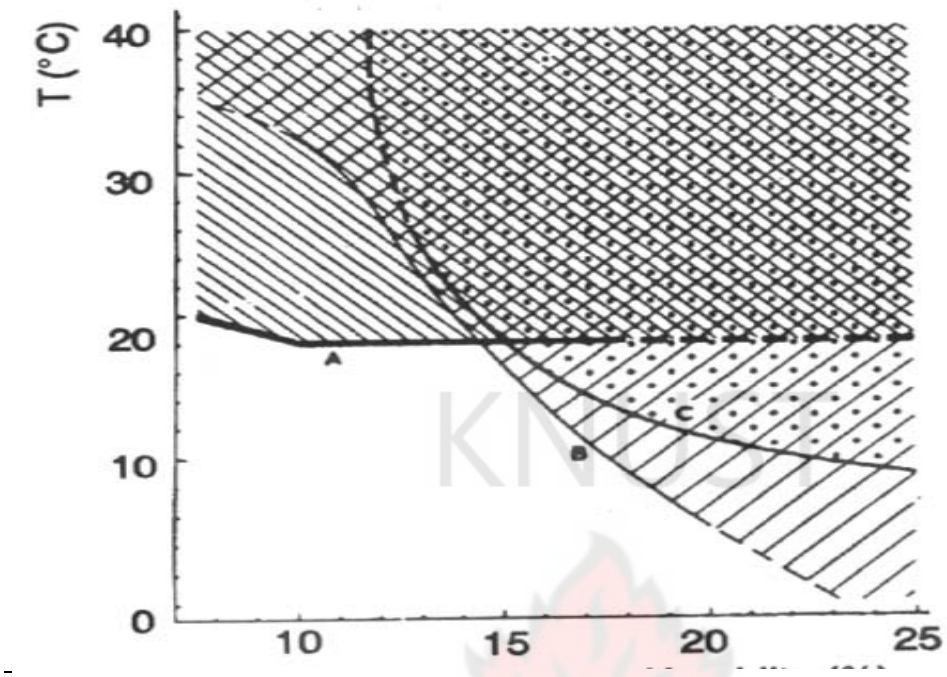

Fig.4.8 Correlation of temp., RH and MC values for cereals indicating their influence on germination, insect and fungal development. A: Lower limit for insect heating; B: Lower limit for germination; C: Lower limit for fungal development.

A concern expressed by most farmers which is worth mentioning here is the undue delay in hauling harvested maize from the farm to their stores at Odumase as a result of impassable roads in the event of any slightly heavy downpour. Some lamented that their farms became inaccessible if their harvest was not at home by September because when some of the streams overflowed their banks it could take a week or more before the waters would recede to allow trucks to ply the roads to the farms. In the event that harvested maize was left at the farm in such rainy conditions for such a period, most of

the ears went completely bad with some germinating. This is a challenge faced by farmers in the research area.

4.3.5 Effectiveness of sun drying of shelled maize

Maize sold off immediately after harvesting is usually processed and consumed not too long after leaving the markets. The final condition of the maize is the cumulative effect of post harvest handling up to the marketing stage and the handling of the commodity thereafter until processing for consumption. Particularly, sun drying immediately after harvesting is critical to the quality of the maize at the time of processing and consumption, whether used in the food or feed industry.

Experiments conducted at IITA on the drying of shelled grain in plastic roofed trays (Fig. 4.9) and solar dryers gives an indication of the effectiveness of sun drying vis-à-vis the time required to reduce MCs to desirable levels before bagging (FAO, 1980). Table 4.6 is culled from the results of the work for the discussion in this section.

Fig. 4.9 Sun drying of maize under plastic roofed trays at IITA, Ibadan.

Table 4.6: Time taken to reach various MCs during sun drying of shelled maize in trays.

Season / Period	Initial MC (%)	Days taken to reach	
		15%	12%
Wet Season (Aug – Nov)	30 - 35	35	70
Dry Season (After Dec.)	25	4	9

The sun drying system consisted of plastic roofed trays (Fig.4.9) of size 1.5m by 0.65m holding 40kg of shelled maize. Using a bulk density of 718kg/m^3, the depth of grain in the tray is computed to be 5.7cm for the experiment. The climate of Ibadan, Nigeria where the experiment was conducted is somewhat similar to the climate in Odumase. Appendix VI shows the rainfall and mean monthly relative humidity for Ibadan as presented in the results of the work.

Two differences exist between the experiment mentioned above and the sun drying practice in the Odumase and Yamfo centres discussed in this chapter which need to be taken into account in discussing the effectiveness of sun drying in the various situations.

1. No roof of any sort is used in sun drying at Odumase. At Yamfo, the roofs of store rooms provide some covering during the drying but this is much unlike the plastic roofs used in the IITA experiment shown in Fig. 4.9

2. No stirring of the maize was done in the IITA experiment as is done during sun drying in Odumase and the other centres.

The results of the IITA experiment suggest that sun drying may not be relied on as an effective means of reducing MCs in shelled grain for storage or even to low levels to permit temporary storage in polythene bags for any lengthy period of time. This is especially so for the major season harvest which comes in at high MCs and therefore takes over a month to dry down to 15%. However, it may be that the sun drying practice employed by the Odumase market operators may be a more effective means of reducing MCs, inferring from the comparative trends between Odumase and Yamfo shown in Fig.4.7. Except for the period around October, Odumase MCs are always lower than Yamfo MCs.

4.4 Conclusion

Theoretical calculations of the EMC, DI and D_p all point to the fact that harvested maize can only be stored safely without mechanical drying in January and February. The major season harvest is at risk of AF contamination and deterioration because of the climate and its effect on harvested maize as well as the handling practices pertaining to the research area. This is particularly so in the case of maize which gets shelled immediately after harvesting for marketing.

About half of the major season harvest is not stored but immediately shelled for sun drying/marketing upon the arrival of the maize at the market from the farm gate. In view of the unpopularity of mechanical drying, management of MCs in such stocks is critical to preservation of the maize to prevent undue fungal activity which may lead to AF production. The MC range of 20-26.8% and temperature range of 28-29°C are most conducive for the growth of *A.flavus* and AF formation, according to Calderwood and Schroeder (1968). Harvesting in July poses a serious maize quality threat because of the high MC of 26.8% and the shelling of 73.1% of the harvest. It may be worthwhile conducting a survey of AF levels in maize that is not stored but disposed of during the major season.

The practice of sun drying in the open at Odumase is a relatively better method of handling freshly harvested and shelled maize than the in-door maize handling practiced in Yamfo. This is so until October when the Yamfo practice of spreading out maize on floors in rooms with open windows and doors seems more effective in reducing MC in freshly harvested and shelled maize. This can be seen in the differences in mean monthly MC in maize from the two areas as shown in Table 4.7.

Table 4.7: Difference in mean monthly MC (%) between Yamfo and Odumase maize production/marketing centres

	Jul	Aug	Sep	Oct
Yamfo	32.4	25.1	20.2	17.4
Odumase	26.8	21.3	18.7	18.4
Difference	5.6	3.8	1.5	-1.1

The chief factor responsible for this turn around is the sudden increased demand in the Odumase market resulting from the disposal of 50.6% of the major season crop by the end of September. Other factors that aid this trend include farmers' engagement with their minor season farming activities and consequent unreadiness to bring out maize from their stores for shelling and marketing. Also the near-scramble for maize arriving at the market from the farm gate by traders does not give room for any serious sun drying. Coupled with all these factors is the rainfall which is heading for the seasonal peak by the end of September.

CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

5.1.1 Handling and storage practices and AF contamination in the research area

The mean aflatoxin level obtained for the 25 samples collected was 61.6ppb. 72% of the samples recorded levels between 20ppb and 40ppb, beyond the highest level allowed for humans (Kumar *et al.*, 2000). The mean AF contamination across the storage practices investigated increased over the 3-5 month storage period from 26.7ppb to 56.7ppb. Among the 6 main practices identified in the survey, storage of harvested ears in the traditional crib was found to be predominant, practiced by 88.1% of the respondents. Storage in traditional cribs with the husk showed no change in AF level over time while storage without the husk recorded an increase of 90ppb (300%).

The mean AF level of 26.7ppb observed at the beginning of storage shows that some intervention is needed to deal with the incidence of contamination in the pre-storage segment of the post harvest chain. Areas that would have to be dealt with include the low level (14.3%) of certified seed use and of fertilizer application (7%). Others are the labour and transportation (of harvested maize from the farm gate to Odumase) challenges which culminate in unduly long lapse of time between harvesting and storage (an average of 11.6 days).

A worthwhile practice discovered through the survey to be widespread was the sorting out of damaged maize by farmers both at the beginning and end of storage, especially the

sorting out of visibly moulded and insect infested maize. Whereas 90.5% of respondents sorted out visibly moulded maize at the beginning, 61.9% sorted at the end of storage. As against 14.2% at the beginning, 59.5% of the respondents sorted out insect damaged ears at the end of storage, an indication that insect infestation in the research area is not effectively controlled. The conclusion drawn from this is that the storage practices employed in the research area are ineffective in reducing moulding in the stored maize. Neither do they effectively deal with insect infestation irrespective of the infestation control measures employed. Chances are that if sorting is done more critically and insect infestation control carried out more efficiently, AF contamination may be reduced.

5.1.2 Natural and socio-economic challenges to AF management in Odumase

The 10 year analysis of climatic data of the research area revealed an average daytime RH of 83% between July and September, the time for harvesting of the major season crop. Mean monthly minimum temperatures during the same period are in excess of 21ºC. These natural characteristics of the area militate against effective sun drying and result in the high MC regime (26.8% to 18.7%) over the harvesting period, making the harvest prone to fungal infection and consequent AF contamination. The remedy for this situation is good handling and storage practices with mechanical drying immediately after harvesting.

It must be pointed out that the non patronage of mechanical drying services is due, among others to the socio-economic circumstances of the farmer. After harvesting the major season crop, most farmers sell part of it immediately to raise money to pay outstanding

debts and also finance the minor season crop production. They do this because of difficulties associated with obtaining financial assistance from the financial institutions. Thus incurring further cost on the harvested maize by way of mechanical drying is something most farmers are not ready to do.

5.2 Recommendations

An obvious option in the post harvest management of the maize industry in reducing AF contamination is the provision of sufficient mechanical drying capacity close to or within the production centres. The techno-financial implications of such an option and its management constitute important challenges to the search for a solution to the AF menace. In view of this the following recommendations are presented along with some suggestions on further research required in the quest for a high performing post harvest sector in the maize industry.

i. Continued education and training of farmers on the importance of simple post harvest practices such as sorting and infestation control as well as how they may be best practiced. This holds good prospects in view of the fact that the bulk of farmers in the research area have been through Senior Secondary School education (Section 3.3.1)

ii. Improvement of maize haulage services from the farm gate to the storage facilities (usually located in the Odumase township) during the harvesting period. Two approaches are recommended here – maintaining feeder roads

and farm tracks as harvesting approaches and empowering haulers to expand the service. These are interventions needing government support to help reduce the time lapse between harvesting and packing into store.

iii. There is a need to conduct a survey of AF contamination in the research area at cardinal points in the maize post harvest cycle over the year. This has been done in several countries (Ayicek *et al*., 2005) and it provides for good understanding of the extent and level of contamination. Such a database is an indispensable tool in the design of any project, programme or intervention purposed to effectively manage the aflatoxin menace.

iv. AF testing laboratories need to obtain and keep records on the source of maize samples tested for AF contamination. Information must also be obtained on post harvest handling and storage histories of samples brought for testing where possible.

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APPENDICES

APPENDIX I: QUESTIONAIRE

QUESTIONAIRE STRUCTURE

I. GENERAL BACKGROUND OF RESPONDENT
II. MAIZE CROPPING/PRODUCTION
III. HARVESTING PRACTICES
IV. STORAGE PRACTICES
V. DRYING PRACTICES

I. GENERAL BACKGROUND OF RESPONDENT

Personal information

1. Agro ecological zone:
2. Name:
3. Age:
4. Sex: male / female
5. Marital status: single / married
6. Number of children:
7. Educational background: no formal education / middle school / 'O' level / 'A' level / Training college / Technical school / Polytechnic / University

Background in maize farming and trading

8. What is your main and financially most important occupation? Maize farming / maize trading / other (specify) ……..
9. What is your second most important occupation (financially)? …….
10. How many years have you been a maize farmer? …… years.
11. How many years have you been a trader in the market? ….. years.
12. Please provide the information below on your maize production and trading activities:

ITEM	MAIZE SEASON					
	2003/04		2004/05		2005/06	
	MAJOR	MINOR	MAJOR	MINOR	MAJOR	MINOR
Acreage cropped Maxi bags harvested Month of harvesting						
Quantity sold: Immediately After 2 months After 4 months After 6 months After 8 months After 10 months						
Maize traded						

II. MAIZE CROPPING / PRODUCTION

1. List the crops you produce in order of importance. Indicate "F" or "S" against the crop to indicate whether it is for food or sale

a) (F / S)
b) (F / S)
c) (F / S)
d) (F / S)
e) (F / S)

2. Do you ever grow maize in the same field year after year? (Yes / No)
3. If yes how many years is it to date?
4. If no what crop do you grow between the maize crops?
5. About how long does the cropping between the maize crops last? (3 months / 6 months / 9 months / 12 months)
6. Information on seed used in farming:

a) Name of variety: ……..
b) Variety: (Local / Improved)
c) Certification: (Certified / Uncertified)
d) Source: ……..
e) Do you treat seed before planting? (Yes / No)
f) Chemical used for seed treatment: ……

7. Do you apply fertilizer on your farm? (Yes / No)
8. Type of fertilizer used: ……..
9. Weed Control method used (manual / chemical / both)
10. Which stage(s) do you employ chemical weed control? ……
11. Name the weedicide you use in weed control ……
12. Which of the following pests attack maize in the field?
    (insects mice/rats birds moulds other)
13. Indicate the remedial action employed against the field pest attacks:
    Insects:
    Mice/rats:
    Birds:
    Moulds:
    Other:

III. HARVESTING PRACTICES

1. When is maize ready for harvesting?
   - silk falls out - cobs and husk are completely dry
   - cobs fall down - grain can't be scratched with the fingernail
   - other
2. Are you able to harvest as soon as the crop is mature? (Yes / No)
3. If no why not? (No labour available / Other activities in this period / Other)
4. How do you harvest? (cut the whole stalk / collect the ears / bend the stalk before harvest to let it dry then harvest / other)
5. Why do you particularly use the harvest procedure indicated?
6. Do you harvest your maize all at once or in bits ……
7. If you harvest in bits why is this so? (labour problem / non-uniform drying / other reason ……)
8. Do you harvest green maize? (Yes / No)
9. If yes what percentage of your maize crop is harvested green? ……..%
10. What percentage of the portion harvested green is consumed in the house?.....%
11. What percentage of the portion harvested green is sold?
12. Do you leave the cobs on the plant to dry before harvesting? (Yes / No)
13. If yes how long do you leave the cobs on the plant to dry? ……. Weeks

IV. STORAGE PRACTICES

Transit storage

1. After harvesting do you put maize directly into storage or you keep it elsewhere before? Directly into storage / Kept elsewhere for a while.
2. If you keep maize elsewhere before storage, why do you do so?
   ……
3. For how long do you keep the maize elsewhere?

Pre-storage sorting

4. Do you encounter cobs that are not well covered by the husk in your harvest? Yes / No
5. What proportion of your 2005/06 major season harvest was like this? None / Few / Many / about a third of the harvest / half the harvest / more than half the harvest.
6. What do you do with these cobs?
   - fed to animals (eg……..) - consumed domestically
   - sold - other (specify)
7. After harvesting do you sort out certain cobs? Yes / No
8. Indicate the criteria for sorting and the reason.
   Colour: ……
   Cob size: …….
   Grain size: ……...
   Damage: ……..
   Other (specify) ……
9. Indicate the types of damage you usually sort out.
   Insect / Rodents / Birds / mould (discolouration) / other (…….)
10. What do you do with the damaged cobs?
    - throw them away - feed them to animals (which animals? ……)
    - domestic consumption - sell them
    - other (specify)
11. Indicate what you do with the cobs sorted out by the following criteria:
    Colour: ……
    Cob size: …….
    Grain size: ……...
    Other: ……..
12. Where do you sort the maize after harvesting? On farm / at the village / at your Odumase residence / at the site of the storage facility
13. Is there any particular reason for the choice of site for sorting after harvesting?
    ……

Post-storage sorting

14. Do you do any sorting at the end of the storage period? Yes / No

15. Indicate the criteria for sorting and the reason.
    Colour: ……
    Cob size: …….
    Grain size: ……...
    Damage: ……..
    Other (specify) ……
16. Indicate the types of damage you usually sort out.
    Insect / Rodents / Birds / mould (discolouration) / other (…….)
17. What do you do with the damaged cobs?
    - throw them away - feed them to animals (which animals? ……)
    - domestic consumption - sell them
    - other (specify)

Preparation of facilities for storage

18. Do you clean your facility before storage of maize? Yes / No
19. Give reason(s) ……..
20. Describe the cleaning process. ……
21. Do you remove old maize from the facility before storage?
22. Give reason(s) ……..
23. Do you treat the storage facility in any way before storage? Indicate the method.
    - ash - sand - smoke
    - manure - neem - insecticide/pesticide
    - other (specify)
24. What happens if you do not treat the facility before use?
    ……
25. What maintenance works do you carry out on the storage facility before use?
    ……

Storage structures, practices and losses.

26. What facility do you use for storage? Traditional crib / improved crib / a room / other (specify) ……
27. Where is the storage facility located? On farm / village / Odumase residence
28. Over the past 3 years have you been storing maize in the facility every year? Yes/No
29. If no give reason(s) ……
30. Do you use the facility to store any other foodstuffs? Yes / No
31. If yes what other foodstuffs?
    .....
32. Please provide information on your storage facility as applies :

A. CRIB

i) Crib Structure

a) Dimensions (length x width x height (to eaves)): …….m x …….m x …….m.
b) Clearance from the ground: …….m
c) Material used for roof:
d) Material used for walls:
e) Materials used for floor:
f) Ventilation (%age of crib perimeter available for ventilation):
g) Provision for rodent-proofing:
h) General sanitation around crib:

ii) Storage Practice

a) In what state do you store your maize? Husked / Dehusked / Shelled
b) Do you use chemicals to treat your maize in storage? Yes / No
c) If yes, what chemicals do you use?
d) How often do you apply the chemical?
e) By what means or method do you apply the chemical?
f) Are there any other things you do during storage to ensure your maize keeps well?

iii) Experience with losses:

Indicate the duration of storage and nil / minimal / moderate / high against each of the parameters mentioned:

ITEM	MAIZE SEASON			
	2004/05		2005/06	
	MAJOR	MINOR	MAJOR	MINOR
Duration of storage Insect-holed Live insect infestation Mould (discolouration) Rodent infestation				

B. STORAGE ROOM

i) Room Structure

a) Room dimensions (length x width x height (to eaves)): …….m x …….m x …….m.
b) Material used for roof:

c) Material used for walls:
d) Materials used for floor:
e) Number of windows:
f) Size(s) of windows:
g) Door size:
h) General sanitation around:

ii) Storage Practice

a) In what state do you store your maize? Husked / Dehusked / Shelled
b) Do you use chemicals to treat your maize in storage? Yes / No
c) If yes, what chemicals do you use?
d) How often do you apply the chemical?
e) By what means or method do you apply the chemical?
f) Are there any other things you do during storage to ensure your maize keeps well?

iii) Experience with losses:

Indicate the duration of storage and nil / minimal / moderate / high against each of the parameters mentioned:

ITEM	MAIZE SEASON			
	2004 / 05		2005 / 06	
	MAJOR	MINOR	MAJOR	MINOR
Duration of storage Insect-holed Live insect infestation Mould (discolouration) Rodent infestation				

C. OTHER STORAGE FACILITY

If you use any other structure or facility for storage please supply the following information with respect to that facility:

- The physical dimensions of the structure and materials used
- The storage practices observed in the use of the facility

- Your experience with losses while using the facility

APPENDIX II

Distribution of average maize farm size and yield for 2005/06 and 2004/05 farming years in Odumase

Year	Major Season						Major Season					
	Farm size			Yield			Farm size			Yield		
	acres	Freq.	% of Far-mers	Bags per acre	Freq.	% of Far-mers	acres	Freq.	% of Far-mers	Bags per acre	Freq.	% of Far-mers
2005/06	<4.0	2.0	5.0	<3.0	0.0	0	<4.0	7.0	17.5	<3.0	17.0	42.5
	4.0-8.0	20.0	50.0	3.0-5.0	14.0	35.0	4.0-8.0	12.0	30.0	3.0-5.0	16.0	40.0
	8.0-12.0	12.0	30.0	5.0-7.0	18.0	45.0	8.0-12.0	14.0	35.0	5.0-7.0	3.0	7.5
	12.0-16.0	4.0	10.0	7.0-9.0	4.0	10.0	12.0-16.0	3.0	7.5	7.0-9.0	4.0	10.0
	16.0-20.0	0.0	0.0	>9.0	4.0	10.0	16.0-20.0	2.0	5.0	>9.0	0.0	0.0
	>20.0	2.0	5.0				>20.0	2.0	5.0			
Total			100.0		40.0	100.0		40.0	100		40	100.0
2004/05	<4.0	7.0	18.4	<3.0	4.0	10.5	<4.0	9.0	26.5	<3.0	7.0	20.6
	4.0-8.0	19.0	50.0	3.0-5.0	7.0	18.4	4.0-8.0	16.0	47.1	3.0-5.0	17.0	50.0
	8.0-12.0	7.0	18.4	5.0-7.0	15.0	39.5	8.0-12.0	6.0	17.6	5.0-7.0	6.0	17.6
	12.0-16.0	2.0	5.3	7.0-9.0	7.0	18.4	12.0-16.0	1.0	2.9	7.0-9.0	2.0	5.9
	16.0-20.0	1.0	2.6	>9.0	5.0	13.2	16.0-20.0	1.0	2.9	>9.0	2.0	5.9
	>20.0	2.0	5.3				>20.0	1.0	2.9			
Total			100.0		38.0	100.0		34	100.0		34.0	100.0

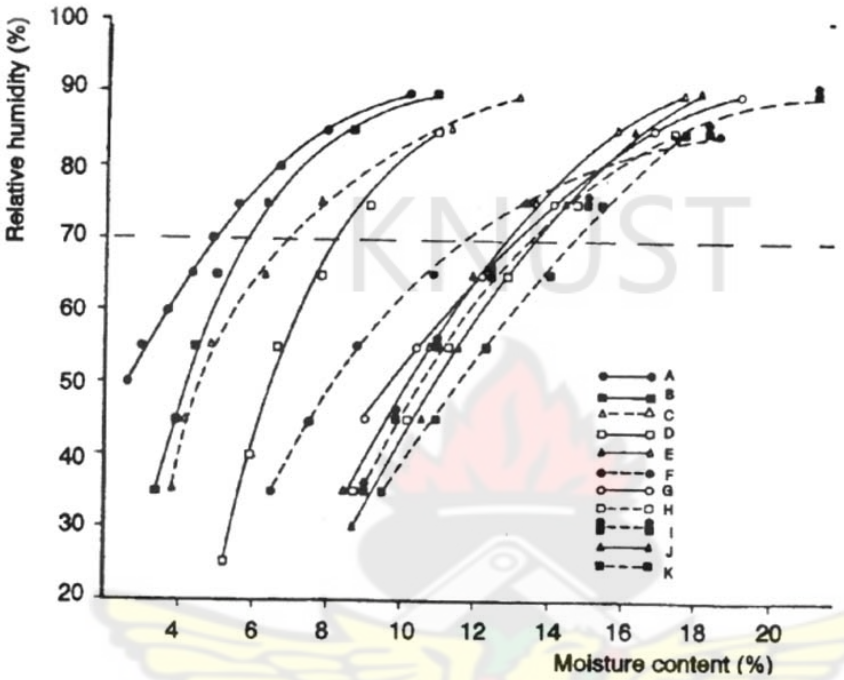
APPENDIX III

SUMMARY OF RESULTS OF AF MEASUREMENTS (PPB) IN MAIZE AND FEED MASH OBTAINEDBY THE VETERINARY HEADQUARTERS LABORATORY IN ACCRA FROM 2004 TO 2007.

	WHITE MAIZE				YELLOW MAIZE				FEED MASH			
	No. of tests	Min. Level	Max. Level	Avg. Level	No. of tests	Min. Level	Max. Level	Avg. Level	No. of tests	Min. Level	Max. Level	Avg. Level
YEAR: 2007												
JAN	1	20	20	20.0	1	40	40	40.0	5	20	100	52.0
FEB	2	20	20	20.0	2	20	20	20.0	7	10	40	25.7
MAR	2	10	40	25.0	2	20	20	20.0	9	10	100	42.2
APR	4	10	100	35.0					2	20	20	20.0
MAY	3	10	40	26.7					5	10	80	40.0
JUN	2	10	40	25.0					3	10	20	16.7
SUM	14				5				31			
MEAN		13.33	43.33	25.28		26.67	26.67	26.67		13.33	60	32.77
YEAR: 2006												
JAN	3	80	200	126.7	1	80	80	80.0	2	20	50	35.0
FEB	9	20	200	108.9	1	40	40	40.0	2	10	100	55.0
MAR	2	80	100	90.0	1	20	20	20.0	2	20	150	85.0
APR	4	40	100	85.0					3	10	20	16.7
MAY	1	100	100	100.0	2	20	20	20.0	2	20	50	35.0
JUN	7	10	100	35.7	1	75	75	75.0	4	10	40	25.0
JUL	1	10	10	10.0	2	20	60	40.0	9	20	100	47.8
AUG												
SEP	14	20	100	35.7	1	20	20	20.0	5	10	100	42.0
OCT	1	40	40	40.0	1	30	30	30.0	3	20	20	20.0
NOV	3	20	40	33.3	1	20	20	20.0	10	20	100	40.0
DEC	1	40	40	40.0					4	20	60	40.0
SUM	46				11				46			
MEAN		41.82	93.64	64.12		36.11	40.56	38.33		16.36	71.82	40.13
YEAR: 2005												
JAN									2	20	100	60.0
FEB									1	100	100	100.0
MAR	1	100	100	100.0					2	40	100	70.0
APR	2	40	40	40.0								
MAY									1	40	40	40.0
JUN	1	100	100	100.0								
JUL	1	20	20	20.0					5	80	100	92.0
AUG									2	80	100	90.0
SEP									5	10	100	60.0
OCT	2	20	100	60.0					5	10	80	36.0
NOV					1	20	20	20.0				
DEC	4	5	100	56.3					1	80	80	80.0
SUM	11				1				24			
MEAN		47.5	76.67	62.71		20	20	20		51.11	88.89	69.78
YEAR: 2004												
JAN												
FEB												
MAR												
APR												
MAY												
JUN												
JUL												
AUG												
SEP	8	10	230	56.3					3	10	40	23.3
OCT	7	10	200	55.7					2	20	20	20.0
NOV									1	20	20	20.0
DEC	2	10	20	15.0								
SUM	17								6			
MEAN		10	150	42.32						16.67	26.67	21.11

APPENDIX IV

MOISTURE CONTENT / RELATIVE HUMIDITY CURVES

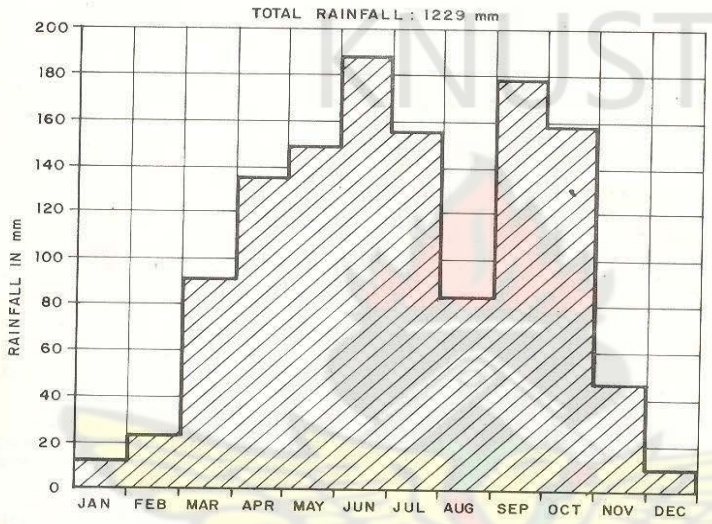


Moisture content/relative humidity equilibrium curves; A: Copra, B: Palm kernels, C: Shelled groundnuts, D: Cocoa beans, E: Paddy, F: Soybeans, G: Yellow Maize, H: White Maize, I: Coffee beans, J: Sorghum, K: Rice, polished.

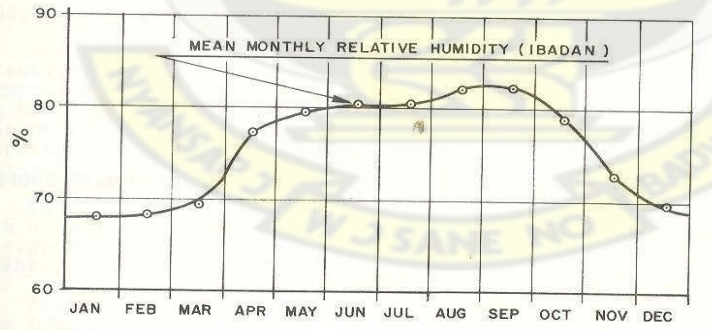
Source: Hayma, 1995

APPENDIX V

MEAN MONTHLY RAINFALL AND RH AT IBADAN



MEAN MONTHLY DISTRIBUTION OF RAINFALL AT IBADAN



MEAN MONTLY RELATIVE HUMIDITY AT IBADAN

Source: FAO, 1980