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DEPARTMENT OF HORTICULTURE

ASSESSMENT OF STORAGE FACILITIES FOR COCOA BEANS IN THE ASANTE MAMPONG COCOA DISTRICT IN THE ASHANTI REGION

BY

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ASSESSMENT OF STORAGE FACILITIES FOR COCOA BEANS IN THE ASANTE MAMPONG COCOA DISTRICT IN THE ASHANTI REGION

A THESIS SUBMITTED TO THE SCHOOL OF RESEARCH AND GRADUATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE (M.Phil. POSTHARVEST TECHNOLOGY) DEGREE

BY

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JUNE, 2016

DECLARATION

I, hereby declare, that this work submitted to the school of Research and Graduate Studies, KNUST, Kumasi, with the exception of references of other researchers which have been duly acknowledged, is the result of my own research and that this thesis has never been presented anywhere for a degree.

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DEDICATION

This piece of work is dedicated to my Mum and Dad, Mr. Francis Owusu-Ansah and Madam Ama Serwaa, and to my brother Francis Owusu-Ansah and all my sisters.

ABSTRACT

This study assessed storage facilities for cocoa beans in the Asante Mampong Cocoa District of the Ashanti Region. Fifty employees with the relevant technical, operational and functional backgrounds who were involved in the handling and transportation of cocoa beans were sampled from Licensed Cocoa Buyers using snow ball sampling technique. Structured questionnaires were administered to them and personal observation was also made. Storage facilities were sampled in twenty-three communities in the district for the study. Storage problems identified were insect infestation (80%), rodent attacks (16%) and mouldiness (4%). The problem with moldiness according to the respondents was managed by drying of cocoa beans and proper sanitation in and around the storage rooms. The results of the regression test value R= 0.118 showed that there was a weak relationship between the management of storage facilities and storage problems which ultimately affects quality of cocoa beans. On the cut test, good beans recorded from the shed storage condition (50) was significantly higher than the amount recorded from the store storage condition (38.3), t (28) = 9.619, $p<0.001$. However, purple bean recorded from the store storage condition (22.52) was significantly higher than the amount recorded from the shed storage condition (15.1), t (28) = -5.993, $p<0.001$. Similarly, waste bean recorded from the store storage condition

(35.47) was also significantly higher than the amount recorded from the shed (32.3), t (28) = -2.439, $p<0.05$. Regarding chemical test, the mean free fatty acid recorded from the shed was 1.65% and the amount recorded from the store was 2.35%. The mean free fatty acid in the cocoa beans kept in the store was significantly higher than those kept in the shed, t (28) = -5.402, $p<0.001$. *Aspergillus tamari, Aspergillus niger,* Aspergillus *flavus, Penicillium spp, Rhizopus spp, Colletotrium spp, Curvularia spp,*were found on the samples, but that of the store had higher presence of the fungi than the shed. This indicated that, generally, when cocoa beans are kept in shed, the occurrence of moulds could be prevented than when they are kept in store rooms.

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CHAPTER ONE

1.0 INTRODUCTION

The chapter forms an introduction to the study on assessment of suitable storage facilities for cocoa beans in the Asante Mampong cocoa District in the Ashanti Region. It involves the background of the study and problem. The research objectives, questions, significance, scope and limitation of the study are also discussed in the chapter. It also gives a conceptual framework and methodology employed by the study.

1.1 BACKGROUND OF THE STUDY

Cocoa (*Theobroma cacao* L.), a perennial crop widely cultivated mainly in Africa, Asia and South America. The total land area for cocoa production accounts for over eight million hectares (FAO, 2009). Data from 2008 shows that the production of cocoa beans surpassed four million metric tons (MT) with almost 70% of the production allocated in Africa (FAO, 2009).West Africa is currently the dominant supplier, with three countries adding up to about 60% of global cocoa production. Côte d‟Ivoire accounts for 32%, Ghana: 16% and Nigeria accounting for 12% according to Beckett (1994). About 90% of production is used in the chocolate industry with the remaining 10% being used in the production of flavorings, beverages and cosmetics.

Cocoa is an important income earner to Ghana and contributes between 70-100% of household income of workers involved in its production and management. About 60% of agricultural labour force is employed in the cocoa industry (Appiah, 2004; COCOBOD,

1998).

Cocoa is a major source of employment, incomes and foreign exchange. Breisinger *et al*. (2008) indicated that Ghana would depend on cocoa for its socio-economic development. There are approximately 1.6 million smallholder farmers and a 3.2 million workforce producing around 700,000 Mt of cocoa. The nations‟ annual output of approaching 1million Metric tonnes of dried beans earned around 30% of foreign exchange for the country as a whole (Cooper and Cudjoe, 2012). Government‟s involvement through its Quality Control Company of COCOBOD has provided the necessary assurance for produce quality for both internal and external exports. Cocoa quality checks at the farm gate, buying centres at the village level and take-over points for storage.

Ghana is ranked second highest producer of cocoa after Cote d‟Ivoire. In terms of quality however, Ghana is recognized as the world leader in premium quality cocoa beans production. As at 2006 two million farmers and their dependents were known to be dependent on cocoa for livelihood, according to Opoku *et al.* (2006).

The quality of cocoa with respect to attributes such as taste, colour and flavour and killing of embryo is achieved through fermentation. Fermentation methods in use include heap, basket, sweat, box and tray fermentation. The most popular and frequently used in Ghana is the heap method. The most commonly used method of drying cocoa in Ghana is sun drying and this depends on climatic conditions (Motamayor, 2002).The quality of commercial beans depends very largely on how well the fermentation was carried out (Hamzat, 2004).

The period of fermentation of the cocoa bean determines the quality of the bean.

On the other hand, microorganisms such as mould whose presence is detrimental to the quality of cocoa beans gain access to them during fermentation (Hamzat *et al*., 2006). Stored cocoa is often damaged by insect, pests and most especially, by moulds (Aroyeun *et al*., 2006; Hamzat, 2004). This type of damage mostly results from the failure to dry beans properly. ICCO (2004) reported the isolation of several fungi growing on fermenting cocoa beans. Those of West African (Ghana) origin are *Aspergillus fumigatus, Aspergillus tamari* and *Mucorpusillus*. With increasing length of fermentation therefore cocoa beans have a greater chance of being penetrated by mould which grows externally on them (Opoku *et al*., 2007). After fermentation, infestation of cocoa beans starts from the drying mats and continues in storage. Climatic conditions in the tropics are characterized by high relative humidity levels of about 70 to 90% and temperatures around 30°C which are ideal for storage insects and moulds to develop on cocoa beans. Surface contamination is therefore, a major source of fungi in fermented and dried cocoa beans. According to Pitt and Hocking

(1997), species of Aspergillus are the predominant spoilage fungi in tropical areas and Penicillium spp. occur in more temperate zones. Storage beetles are attracted to cocoa beans and cause damage by burrowing holes in the beans or feeding on the nib (Jonfia-Essien *et al*., 2007). A couple of methods are applied to achieve low Free Fatty Acid content of the cocoa beans which include storing the beans at a low temperature of about 4°C or drying the beans.

Cocoa is susceptible to insect infestation, mold contamination and moisture exchange between the atmosphere and the beans during storage and transportation Villers *et al*. (2007). Once determined,

solutions to these problems could then be found to improve the crucial services of warehousing and transportation in the cocoa supply industry.

1.2 PROBLEM STATEMENT

Anecdotal data indicated that storage of cocoa beans in the cocoa growing areas in Ghana by the purchasing clerks and the cocoa shed of the various cocoa buying companies have been a source of worry and concern to major stakeholders in the cocoa industry in Ghana, especially, during the peak periods of the cocoa season (December to February) every year.

Long storage of cocoa beans has been reported to be associated with storage challenges which includes but not limited to incidence of storage pests. However, the influence of the storage facility‟s design and construction has not been reported in Ghana. Such information is, however, of utmost importance to assist in redesigning and reconstruction, if necessary to ensure good storage of cocoa beans in Ghana. The present study was therefore undertaken to assess storage facilities used and practices carried out during storage of cocoa in the Asante Mampong cocoa District to determine their impact on the quality of cocoa beans.

1.3 SIGNIFICANCE OF THE STUDY

The significance of the present study is that the cocoa industry would be able to make a lot of savings through the adoption of an efficient storage facility design and construction, which could be used to develop other equally important areas of the industry. Again, this study is expedient because with the continuous increase in the yearly output of cocoa and the critical

role of warehousing in the cocoa supply chain, it is believed that this study will address the warehousing problems that are experienced by the industry at the peak of every cocoa season.

It was anticipated that the findings and recommendations of the study will serve as a guide for management, policy makers, regulators and practitioners in the cocoa industry. The study will thus harness the monitoring, assessment and review of cocoa warehousing operations and regulation on the subject matter.

1.4 OBJECTIVES OF THE STUDY

The main objective of the study was to assess storage facilities in the Asante Mampong Cocoa District. The specific objectives were to:

1. Identify the types of storage facilities used for cocoa beans in the Asante Mampong Cocoa District.
2. Assess the storage practices carried out in the storage facilities.
3. Determine the effect of different storage types on quality of cocoa beans.
4. Identify storage problems in the Asante Mampong Cocoa District.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 INTRODUCTION

The significant role of cocoa as a driver of economic growth has gained overall acceptance in all cocoa growing economies. According to the United Nations Conference on Trade and Development, UNCTAD (2004), cocoa is a highly competitive and lucrative economic cash crop ranked highest in terms of income generation amongst other agricultural activities in the global markets. The cocoa sector for the past years has had to contend with a number of natural elements to favour its production.

Climatic factors such as rainfall, temperature, sunshine, humidity, soil moisture and wind affect cocoa production. According to the World Cocoa Foundation Report (2006), world production of cocoa beans declined to 3.3 million tons in 2004/2005 from an all-time high of 3.5 million tons produced in 2003/2004. Much of this decline in global output was due to lower production in the two leading cocoa producing countries – Côte d‟Ivoire and Ghana. These two countries suffered most from weather induced setbacks in production generally experienced in West Africa during the development of the main crop in the second half of

2004. Production in Côte d‟Ivoire fell from 1.41 million tons in 2003/2004 to 1.27 million tons in 2004/2005.

In Ghana, output fell from 740,000 to 590,000 tons in 2004/2005 despite a continued government backed mass spraying programme to contain losses from pests and diseases.

To place the issue of cocoa storage problems in context, there is the need to do an overview of the cocoa and warehousing industries in Ghana.

2.2 ORIGIN OF COCOA

The word cocoa is derived from "cacao". The cocoa tree is believed to have originated from the Americas. It is said to have originated in the foothills of the Andes in the Amazon and Orinoco basins of South America and cultivated in the tropical regions of the world (Ardhana and Fleet, 2003). However, it may have had a larger range in the past, evidence for which may be obscured because of its cultivation in these areas long before, as well as after, the Spanish arrived. It was first cultivated by the Olmec at least 1500 BC in Central

America. The cocoa tree was also introduced into the West Indies and the Philippines by the Spaniards. The Europeans also introduced it into West Africa and the rest of Asia. Commercial cocoa which is obtained from the beans originated as seeds from the ripe pods of the plant, *Theobroma cacao*, which is native to the Amazon region of South America.

2.3 ECONOMIC IMPORTANCE OF COCOA

The cocoa beans are exported from producing countries to consuming countries and these constitute the raw materials for importance industries, which manufacture semi-finished products, intended for other industries. In Ghana many uses are derived from the cocoa. The beans can be used in making cocoa drink, cocoa beverages, chocolate, detergent, cosmetics,

confectionaries, pastries and feed for livestock from the cocoa processing company. Global demand for coca increased by about 17% between 2002 and 2006, and in response to this, cocoa production hit an all-time high of 3.6 million metric tons in 2005/6 (ICCO, 2007).

2.4 NUTRITIONAL VALUE OF COCOA

Cocoa powder, bars of chocolate and confectionery are common diets and luxury in many countries. Urquart, (1992) indicated that, products contain both protein and fat in addition to a highly concentrated energy value in relation to their volume. Analysis of 100g of cocoa powder contains the following compositions: protein 20.4.g, fat 25.6g, and carbohydrate 35.0g. It contains 452 calories per 100g (Acquaah, 1999). The nutritional value of chocolate indicated that, chocolate has a complete composition of at least 800 components including useful minerals, vitamins, stimulating substances and summaries the properties of chocolate essentially as having restorative energy (Mossu, 1992).

2.5 EFFECTS OF HARVESTING TIME ON QUALITY OF DRIED COCOA BEANS

Rohan (1963) noted that it is necessary to have a controlled frequency of harvest so as to ensure uniformity of pod ripeness. According to Mossu (1992), harvesting of pods should be carried out at regular intervals of 10 to 15 days, which in any event should not exceed three weeks. In Ghana, the pods are picked at intervals greater than the recommended three weeks (Hammond, 1953). Pods should be harvested when they are ripe. If the pods are left on the tree for too long, the seeds germinate. It is even more serious to harvest the pods before they are ripe because fermentation of the seeds in this case always produces a poor quality cocoa, which is low in aromatic compounds (Knapp, 1926). Biehl (1961) recommended that the ripe cocoa should be harvested, and fermentation time increased as much as possible in order to avoid purple beans.

Unripe cocoa fails to ferment properly because it contains less Sugar than ripe cocoa (Maclean and Wickens, 1952; Saposhnikova, 1952, Rohan, 1963).

2.6 STORAGE OF COCOA

Storage is basically holding goods until they are needed. Warehousing (storage) follows directly after production. The critical role of storage in the cocoa supply chain is apparent from the fact that it precedes sale and export. An assessment of storage problems in the cocoa industry can therefore be regarded as half of the solution to problems associated with increasing profitable sales and export. Problems of cocoa storage can be denominated under space availability and quality control. Appropriate bagging and storage of the processed beans is just as important as proper fermentation and drying.

Storage is mostly done at two major levels; in the field at the production areas by farmers and LBCs and at the take-over centers by the Cocoa Marketing Company. Cocoa is brought into their village level depots by the farmers and quickly moved to larger sheds of the Licensed Buying Companies. Shed gangs build the bags of cocoa into stacks by hand or sometimes mechanically using high-mast battery-operated forklifts. Every effort is made by the dealers to avoid storing cocoa in the open to prevent problems from ground moisture, and the produce is covered immediately with a durable tarpaulin (Jonfia-Essien, 2002). The cocoa beans are then transported to warehouses where the bags are standardized to meet export regulations. The Quality Control Division is then called in to check the quality, grade and seal the bags for onward movement to terminal warehouses at the ports. Cocoa depot also referred to as a cocoa shed is also a storage facility with between 25 and 100 tonnes storage capacity.

Usually, only one or two depot/shed is found in one community. It is usually manned by trained purchasing clerks to receive large number of cocoa from various sources for temporal storage and further transport to the ports. Before transportation to the port, various quality control checks are done to achieve approved standards, notably moisture content and mould growth.

2.6.1 Storage Facilities

According to COCOBOD, a cocoa store is a storage facility with below twenty-five (25) tonnes of cocoa. Usually there are lots of stores found in a community operated by different cocoa purchasing clerks for different buying companies. A cocoa depot/shed however is a storage facility with between twenty-five and one hundred (25-100) tonnes storage capacity. Usually, only one or two depot/shed is found in one community. It is usually manned by trained purchasing clerks to receive large number of cocoa from various sources for temporal storage and further transport to the ports. Before transportation to the port, various quality control checks are done are done to achieve approved standards, notably moisture content and mold growth.

2.6.1.1 Cocoa stores

According to COCOBOD, a cocoa store is a storage facility with below 25tonnes of cocoa. Usually there are lots of stores found in a community operated by different cocoa purchasing clerks for different buying companies. There are no specifications; any room could be used as store to keep cocoa. It usually has one door with a window or none.

2.6.1.2 Cocoa sheds

A cocoa shed however, is a storage facility with between twenty-five and one hundred (25100) tonnes storage capacity. The standard dimension used by COCOBOD to build a shed is, length 72ft, width, 44ft, it has between 3-5 widows and two doors with one office and a store room. Bags of dried cocoa beans are stored in the shed on stacks. The roofs have no signs of leakages and the temperature is made favorable to enable proper storage of cocoa beans. The sheds are regularly fumigated to control insect pests. Usually, most of the sheds have a store room where they keep used sacks. It is usually manned by trained purchasing clerks to receive large number of cocoa beans from various sources for temporal storage and further transport to the ports. Before transporting to the port, various quality control checks are done to achieve approved standards, notably moisture content and mould growth.

2.8 QUALITY CHARATERISTICS OF COCOA

Quality is a combination of characteristics, attributes or properties that give a commodity value in terms of human food. Quality makes a produce what it is: the combination of attributes or characteristics of a product determining its degree of acceptability. Produce quality requirements refers to market, storage, transport, eating and processing qualities. Internationally, quality attributes of dry cocoa beans include level of total mould, slaty, purple, insect infested, flat, germinated beans, free fatty acids (FFA). Free fatty acids are influenced by oxygen, humidity, and insect infestation.

Good quality dried beans should have acceptable acidity, bitterness (astringency), less than 1% FFA, and moisture content of between 6% and 8% (Amoa- Awua *et al.*,2006). Coca quality assessment is physically done using „Cut test".

2.8.1 Physical Characteristics

This is cocoa beans on which the internal part is found to contain insects or show sign of damages by insects. Common storage pests of cocoa include *Lasioderma serricorne* (F.),

Araecerus fasciculatus (Degeer) (Jonfia-Essien, 2001; 2004), *Tribolium castaneum* (Herbst), *Cryptolestes ferrugineus (Stephens), E. cautella, L. serricorne and A. fasciculatus (JonfiaEssien, 2001; 2004).* This means cocoa beans in which mould or fungus is present and visible to the naked eye in the internal part of the beans. According to Minifie (1989), lipase (which acts best at optimum moisture levels and highstorage temperature) in cocoa is responsible for increase in FFA.

Slatty bean is one which shows slaty colour when cut lengthwise through the centre while puple bean shows grey or purple colour over half or more of the surface exposed. Other defects include clustered beans, Germinated beans, waste bean.

Good beans according COCOBOD are beans devoid of all defects, that is, slaty, purple, clustered, mouldy, germinated, insect infested and waste beans.

2.8.2 Chemical Characteristics

2.8.2.1 Free fatty acids

Free Fatty Acids are carboxylic acids. They are released from triglycerides (Selamat *et al*., 1996) by the action of lipase or oxidation. For reasons of quality therefore, the directive 73/241/EEC (EEC, 1973) limits the maximum FFA content to 1.75% oleic acid equivalent in cocoa butter. Responsible causes include black beans Fowler (1999), micro flora (Hiol, 1999) releasing lipases (Wood and Lass, 1985; Pontillon, 1998).

2.8.2.2 PH of dried cocoa beans

The degree of acidity of a solution is a property of every aqueous solution that is important in all biological systems. This property is measured as the pH (Potential of Hydrogen) of the solution (Nester, *et al.*, 1995). The quality of cocoa depends largely on its final pH since the formation of cocoa specific aroma precursors is strongly dependent on the degree of acidification of the nib during fermentation (Biehl *et al.*, 1982, 1985).

The pH for fresh cocoa beans and shells were found to be 6.5 and 3.6 respectively and these reached 5.3 and 5.9 after fermentation and drying (Takrama and Aculey, 2001). Cocoa with high cocoa specific aroma is obtained from only fermented cocoa, which results in moderate nib acidification of pH5.0-5.5. Acidification giving pH of 4.0-4.5 results in raw cocoa with low cocoa specific aroma potential (Biehl *et al.*, 1985), and therefore low quality cocoa products. Kuebutomye *et al.* (2003) reported that fermentation may be deemed successful if nib pH reaches 5.3 and total acidity is about 0.98mEq of acetic acid regardless of cultivar.

Jinap and Dimick, (1991, 1994); Lopez, (1983) also reported that preferred pH of dried beans is 5.2-5.5, and that value of pH more than 6 indicates that the beans are not well fermented and produces purple beans.

2.8.2.3 Moisture content of dried cocoa beans

Proper drying of cocoa beans should reduce moisture content from 60% to between 6–8% (Prabhakaran, 2010). Higher moisture content above 8% moisture results in mouldiness while below 5% leads to brittleness (Thompson and Lopez, 2001). Drying causes biochemical changes (Kyi *et al*., 2005) leading to the development of flavor and final bean acidity (Bonaparte, 1995).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 DESCRIPTION OF THE STUDY AREA

The Asante Mampong Cocoa District is located in the Northern part of Ashanti Region. It has a coordinates of latitude 7°4‟ North and 1°24‟ West. It covers nine Political Districts

namely Sekyere West, Sekyere East, Sekyere Kumawu, Sekyere Afram Plains, EjuraSekyedumase, Sekyere Central, Kwabre East, Afigya Kwabre and Sekyere South. The vegetation of the district includes rainforest and partly transitional zone. The mean annual rainfall is between 800 and 1500mm and is bimodal and fairly distributed. Stools, families or clans control land in the cocoa district.It covers a total land area of 782km^2 with 69 settlements, 58% being rural. According to the District progressive report, the total area of cocoa is 27912.18 hectares, while remaining 21,555.70 hectares are used for building and also other farming activities which include cassava, plantain, yam, vegetables such as cabbage, carrots, green pepper etc. The Asante Mampong Cocoa District shares boundaries with five cocoa districts in Ashanti region, namely Juaso, Nkawie, Brofoyedru, Bekwai and

Offinso, also in political region, Brong Ahafo region (to be precise, Techiman Cocoa District). Ghana Districts.com (2011)

3.2 RESEARCH DESIGN

This section discusses how data was collected and analyzed for the study. These include the data collection through questionnaire administration, sampling methods and frame and data analysis.

The study was conducted in two parts; the survey and laboratory work.

3.2.1 The Survey

Primary data was obtained from interviewing 50 Licensed Buying Companies (LBCs) through questionnaires administration and personal observations. Questionnaires were developed from the Likert scale to enable easy analysis of data. Secondary data were sourced from institutions such as COCOBOD, MOFA, Licensed Buying Companies

(LBCs), in addition to relevant articles, journals and publications and on the internet.

3.2.2 Questionnaire Design and Administration

Open and close ended questions were used in conducting the study as presented in the appendices. It was categorized into various sections with focus on the socio-demographic features, challenges faced by respondent during storage from the district. The questionnaire also sought information on, storage management as well as the challenges encountered in maintaining the quality of certified cocoa before evacuation in the study areas. Prior to the questionnaire administration, a focus group discussion was undertaken to explain the purpose of the study and the questionnaire to participants. Licensed Buying Companies and district cocoa officers who could read were given the questionnaires to complete while those who could not read and understand were interviewed. Pre-testing of the questionnaire was done at Asante Mampong Cocoa District in the Ashanti Region help fine tune the questions and improved on the questionnaire in order to have reliable and efficient data.

3.3 LABORATORY WORK

3.3.1 Physical Test (Cut test)

The cut test is a physical analysis performed on the dried cocoa beans to assess their quality. The physical test was carried out with the help of officers of the quality control division of COCOBOD. A sample of cocoa was taken from stored cocoa beans at the end of each month over a three-month period of storage from an identified cocoa storage facility with a stab sampler. About 100g of the cocoa was weighed with the cocoa scale. The sample was put in a sampling bag and bulked to mix thoroughly and quartered. A sharp cutting knife was used to cut the cocoa beans and arranged nicely to observe for mouldy beans, purple beans, slaty beans, insect infestation beans, clustered beans and waste beans.

3.3.2 Chemical Test

A laboratory chemical test was done to determine the moisture content of the beans, pH and the free fatty acid content of the sampled beans.

3.3.2.1. Determination of free fatty acids (%FFAs)

Fat from the samples was extracted with petroleum ether (40–60oC) using the Soxhlet extraction method (AOAC method 963.15). FFA of the oils extracted was determined using the International Office of Cocoa, Chocolate and Confectionery (IOCCC) method 42-1993.

Five grams of the oil was weighed into a dry 250ml stoppered conical flask and 25 ml of 95% ethanol/ether (1:1) and phenolphthalein indicator were added.
The solution was titrated with 0.1N NaOH by shaking constantly until pink colour persisted for 30 s and the percentage FFA. (as % oleic acid) was determined. The analysis was conducted in triplicates and the mean values are reported.

The %FFA (% oleic acid) was calculated using the following equation:

% FFA = volume of NaOH used x Normality of NaOH (0.1N) x Equivalent factor (28.2)

Weight of sample

3.3.2.2 Determination of pH (%)

Non-volatile acidity of the cocoa beans was determined according to the Association of Official Analytical Chemists‟ (AOAC) method 970.21 and expressed as the percentage of acetic acid by titrating juice with 0.1N NaOH. Five gram samples of beans were homogenized for 30 s in 100 ml of hot distilled water and vacuum filtered through what man filter paper No. 4. A 25 ml aliquot was pipetted into a beaker and the pH measured using a pH meter (model MP230 Mettler Toledo MP 230, Mettler Company Limited, Geneva,

Switzerland). A further 25 ml aliquot was titrated to an endpoint pH of 8.1 with 0.01N NaOH and the values reported as moles of sodium hydroxide per 100g dry nibs. The analysis was conducted in triplicates and the mean values reported.

3.3.2.3 Determination of moisture content (%)

The oven method was used to determine the moisture content of the beans at the laboratory. Thus, 10 beans of the dry commercial cocoa beans were crushed roughly in a mortar with the pestle within a minute to obtain the greatest dimension of particles not exceeding five millimeters, while avoiding the formation of a paste.

Ten grams of the crushed beans were weighed to the nearest O.0002g and poured into dry petri dishes of known weights and quickly cooled in a desiccator for an hour. The dishes with lids

containing the test samples were oven dried at 103'C in a Gallenkamp Hotbox oven (ov-160 model) without their lids for 72 hours. The dishes with the oven dried test samples were covered with their lids and quickly transferred into a desiccator until they were cooled to ambient temperature and then weighed again to the nearest O.0002g. The moisture content of the samples was expressed as the percentage loss in mass.

3.4 SAMPLE SELECTION AND DATA COLLECTION

The sample comprised employees of all stakeholders in cocoa storage, but the impracticality of surveying the entire population has been pointed out by several researchers (Dwumfour, 2006). Employees with the relevant technical, operational and functional backgrounds were therefore purposively sampled from stakeholders of LCBs in the Asante Mampong Cocoa District involved in the handling and shipment of cocoa.

The sample of the target respondents was therefore 50. Snowballing was used as the sampling technique to get to the target respondents. In this regard, individuals known by or introduced to the researcher were contacted which led to them recommending other employees the researcher could contact. This process was not only helpful, but it was necessary to gain access to individuals with relevant functionality in the study area and to overcome mistrust between researcher and participants. Respondents were assured that their responses would be kept confidential and solely used for the intended purposes.

This was done to ensure that the participants candidly expressed their views without fear or prejudice. All 50 people contacted participated (Response Rate = 100%). This high response

rate was made possible by adhering to some basic research ethics which included assuring respondents of anonymity and confidentiality, stating the contribution of the study to improving cocoa storage in Ghana.

3.5 DATA ANALYSIS

The approach of data analysis used in this study was descriptive in nature with the use of bar charts and frequency distribution tables. Statistical tools including the Statistical Package for Social Sciences (IBM SPSS) and excel sheets were used to produce graphs and frequency distribution tables with all the data pre-coded before the analysis. Statistical tests such as mode, mean, t-tests and chi-square as well multiple regressions; were also employed to analyze the questionnaires and results of analyzed cocoa samples. To improve the validity and reliability of the findings of the research study, the questionnaires were checked for errors and consistency.

CHAPTER FOUR

4.0 RESULTS

4.1 INTRODUCTION

Finding from the study has been presented in this chapter. Descriptive statistical tools including tables, percentages and bar charts were generated using SPSS while results from pesticide residue levels have been presented as tables.

4.2 DEMOGRAPHIC CHARACTERISTICS OF COCOA LICENSED BUYERS

Majority of respondents 90% were males whereas 10% were females (Table 4.1). The level of education of the respondents showed that 8% of the respondents had no education. About 40% of the respondents had completed Middle School / Junior High School and 22% had completed Senior High School. The remaining 30% have completed Tertiary level or have a Diploma. Majority of respondent were therefore Middle school leavers.

Table 4.1 Demographic Characteristics of cocoa licensed buyers

Variable	Frequency of respondents	Percent (%) of respondents
Sex		
Male	45	90
Female	5	10
Level of Education		
No education	4	8
Middle/JHS	20	40
SHS	11	22

Tertiary	15	30
Total	**50**	**100**

4.3 LICENSED COCOA BUYERS

The most dominant stakeholders in the internal marketing structure were the LBCs. Majority (28%) of the licensed cocoa buyers identified in the Asante Mampong Cocoa District were the Produce Buying Company (PBC) of COCOBOD and the least dominant buying company was Adwumapa (12%) as presented in Table 4.2.

Table 4.2 Licensed Cocoa Buyers in the Asante Mampong Cocoa District

Name of licensed cocoa buyer	Number in the Cocoa District	Percentage (%)
Adwumapa	6	12
Akuafo Adamfo	9	18
Armajaro	9	18
Kuapa	12	24
PBC	14	28
Total	**50**	**100**

4.4 TYPES AND DESCRIPTION OF STORAGE FACILITIES

Table 4.3 indicates the names of towns where storage facilities used for the study were located. In all, 50 storage facilities were identified in 23 towns during the survey. Among the towns selected for the field survey, Kofiase recorded six storage facilities, which was the highest number, with Asaam, Bomso, Akrofonso, Mprim, Nintin and Seniagya recording one storage

facility each. Two main types of storage facilities were identified during the survey. Most (62%) of the facilities were of the „store" type 38% were of the shed type (Table 4.3).

A typical COCOBOD shed had two main doors, and three to five windows. It has two separate rooms for a store and an office. The dimension of the building was: length 22m, width 13m, height 6m. Its storage capacity was between twenty-five to one hundred (25100) tonnes of cocoa beans. The store type however, had one main door with one or no window. They varied widely in terms of dimension; any room was used as a cocoa store. Its capacity is below twenty-five (25) tonnes.

Table 4.3: Existing storage facilities in selected towns in the district

LOCATION OF STORAGE FACILITY	TYPE OF STORAGE FACILITY	
	SHED	STORE
Abetenim	1	1
Agona	1	1
Akokoaso	1	1 Asaam
0 1		
Asamang	2	1
Atonsu	1	2
Atwea	0	2
Banko	0	2
Bipoa	1	1
Bomso	0	1
Dawu	1	2

Akrofonso		2	0 Juaben
1	1		
Kofiase		1	5
Kona		1	1
Kwamang		1	1
Kyebi		1	2
Kyekyewere		1	2 Mprim
1	0		
Nintin		0	1
Odoyefe		0	2
Seniagya		1	0
Wiamoase		1	1
Total		**19**	**31**
Percentage		**38**	**62**

4.5 STORAGE OF EMPTY COCOA SACKS

When respondents were asked to indicate how they stored empty cocoa sacks, 62% of them indicated that they kept used empty cocoa sacks in the storage rooms with bagged cocoa.

Thirty-eight percent (38%) said they kept the empty sacks in a separate room (Table 4.4).

Table 4.4: Storage of empty cocoa sacks

Storage of empty cocoa sacks in the store room	Frequency	Percent (%)
Yes	31	62

No	19	38
Total	**50**	**100**

4.6 MANAGEMENT OF INSECT PEST

Majority of the respondents (90%) indicated that the storage facility is sprayed with a chemical called Fast track by COCOBOD, three days before stacking of cocoa, while the remaining 10% said spraying is not done before stacking of cocoa (Table 4.5). However, all of the respondents (100%) mentioned that fogging was done with Detamost or Supergold USB, while the cocoa is in storage to control insects periodically.

Table 4.5 Management of insect pest in storage

Management of insect pest in storage	Frequency	Percentage (%)
Spraying	40	90
No spraying	10	10
Total	**50**	**100**

4.7 DURATION OF COCOA STORAGE

From the survey (Table 4.6), majority of the respondents, 78% kept the cocoa at their stores or sheds for only between 1-2 weeks, 18% stored the beans for between 3-4 weeks and 4% stored the beans for between 5-6 weeks.

Table 4.6 Duration of cocoa storage

Duration	Frequency	Percentage
1-2 weeks	39	78
3-4 weeks	9	18
5-6 weeks	2	4
Total 50	**100**	

4.8 CLEANING AND SANITATION OF COCOA STORAGE FACILITIES

From the results (Table 4.7), 50% said they cleaned their storage rooms thrice every month, 30% said they did so once every month, and 20% indicated that they cleaned their storage rooms twice every month. That is the storage facility was cleaned every month.

Table 4.7: Cleaning of storage facilities

Frequency of cleaning storage facility in a month	Frequency	Percentage (%)
None	0	0
Once	15	30
Twice	10	20
Thrice	25	50
Total	**50**	**100**

4.9 VENTILATION CONTROL OF COCOA STORAGE FACILITIES

With regards to ventilation control, it was observed that 90% of the storage facilities used wooden windows whereas 10% used moulding vents for ventilation (Table 4.8).

Table 4.8: Ventilation control of storage facilities

Type of windows	Frequency	Percentage
Wooden window	40	90
Block Moulding vent	10	10

Total	**50**	**100**

4.10. TEMPERATURE MONITORING OF COCOA STORAGE FACILITIES

According to the respondents contacted, on how they monitored temperature of the stacked cocoa, 95% indicated that quality control personnel used a device called Aqua-boy to check the temperature (moisture content) of the beans in storage, 5% said visual observations were used to indicate the temperature of the cocoa beans in storage (Table 4.9).

Table 4.9: Monitoring of temperature of bagged cocoa in storage

Method for temperature assessment	Frequency	Percentage
Use of device (Aqua-boy)	45	95
Manual (Visual)	5	5
Total	**50**	**100**

4.11 RE-DRYING OF COCOA BEANS IN STORAGE

Table 4.10 shows that 90% re-dried their cocoa beans on arrival from the farmers, whereas 10% did not re-dry their cocoa beans on arrival from the farm.

Table 4.10: Re-drying of cocoa beans

Re-dry cocoa beans	Frequency	Percentage
Yes	40	90
No	10	10
Total 50	**100**	

4.12 PACKING AND ARRANGEMENT OF BAGGED COCOA IN STORAGE FACILITIES

According to the purchasing clerks, 92% indicated that their bagged cocoa were packed on stacks in rows leaving enough spaces to ensure easy movement and ventilation in the storage room while 8% indicated that their bagged cocoa were put on the floor.

Table 4.11: Packing arrangement of bagged cocoa in storage

Arrangement of cocoa in your storage room	Frequency	Percentage
On stacks	46	92
On the floor	4	8
Total	**50**	**100**

4.13 PHYSICAL TESTS OF COCOA BEANS IN SHED AND STORE STORAGE CONDITION

Independent sample t-test was used to determine whether the mean concentration of the physical quality test (Slatty, Good, Purple, Clustered, Mouldy, Germinated, Insect infested, and waste beans) in the different storage conditions (shed and store storage condition) were the same Table 4.12. The mean good beans recorded from the shed (50%) storage condition was significantly higher than the amount recorded from the store (38.3%) storage condition, t (28) = 9.619, $p<0.001$. However, The mean purple beans recorded from the store (22.5%) storage condition was also significantly higher than the amount recorded from the shed (15.1%) storage condition, t (28) = -5.993, $p<0.001$. Similarly, the mean waste beans recorded from the store (35.47) storage condition was also significantly higher than the amount recorded from the shed (32.3) storage condition, t (28) = -2.439, $p<0.05$.

However, the mean number of slaty beans in the shed storage condition was 1.61 and the number recorded from the store was 2.26. The independent sample t-test showed that the mean number of slaty beans in the store was not significantly different from that in the shed, t (28) = -0.932, $p>0.05$. Similarly, there was no significant difference ($p>0.05$) between the mean clustered beans (shed=1.12; store = 0.56), mouldy beans (shed=0.1; store = 0.19), germinated beans (shed=0.46; store = 5.94), and insect infested beans (shed=0.04; store =

0.07) recorded from the shed and the store storage condition.

Table 4.12: Independent sample t-test for the comparison of physical test of cocoa beans (Slatty, Good, Purple, Clustered, Mouldy, Germinated, Insect, and waste beans) stored in shed and in store

Storage Condition	Slaty	Good	Purple	Clustered	Mouldy	Germinated	Insect	Waste
SHED	1.61±1.34	50±1.72	15.1±2.6	1.12±1.1	0.1±0.26	0.46±1.1	0.04±0.15	32.3±2.8
STORE	2.26±2.4	38.3±4.4	22.52±4	0.56±0.9	0.19±0.35	5.94±20.5	0.07±0.18	35.47±4.2
T-STATISTIC	-0.932	9.619	-5.993	1.544	-1.064	-1.033	-0.441	-2.439
P-VALUE/ SIG. (2-TAILED)	0.360	0.000	0.000	0.134	0.296	0.310	0.663	0.021

4.14 CHEMICAL QUALITY OF COCOA BEANS IN SHED AND STORE STORAGE CONDITION

From Table 4.13, the mean moisture content in the beans stored in the shed was 4.5 and the average moisture content in those stored in the store was 4.59%. The mean free fatty acid recorded from the shed was 1.65 and the amount recorded from the store was 2.35. The mean free fatty acid in the cocoa beans kept in the store was significantly higher than those kept in the shed, t (28) = -5.402, $p<0.001$ (Table 4.13).

However, in the independent sample t-test, the mean moisture content recorded from the beans stored in the shed and the store were not significantly different, t (28) = -1.114, $p>0.05$. Similarly, there was no significant difference ($p>0.05$) between the mean pH in the shed (5.68) and store (5.62), recorded from the shed.

Table 4.13 Independent sample t-test for the comparison of chemical test of cocoa beans (Moisture content, pH, Free Fatty Acid) stored in shed and in store

STORAGE CONDITION	MOISTURE CONTENT (%)	PH (%)	FREE FATTY ACID (%)
SHED	4.5±0.18	5.68±0.16	1.65±0.23
STORE	4.59±0.2	5.62±0.15	2.35±0.45

T-STATISTIC	-1.114	1.06	-5.402
P-VALUE/ SIG. (2-TAILED)	0.275	0.298	0.000

4.15 ASSOCIATION BETWEEN PATHOGENS AND STORAGE CONDITIONS OF COCOA

From Table 4.14a**,** it was shown that, out of the 100g of cocoa beans taken from the shed, (73.3%) of the beans tested did not show the presence of *Aspergillus tamari* and (26.7%) showed the presence of *Aspergillus tamari.* However, out of the 100g of cocoa beans taken from the store, 56.7% did not show the presence of *Aspergillus tamari* whereas 43.3% showed the presence of the pathogen. Pearson‟s chi-square test showed a significant ($\chi 2$ = 7.326, *df* = 1, *p-value* =0.007) association between the type of storage condition and the presence of *Aspergillus tamari*. From the odd ratio analysis, the odds of *Aspergillus tamari* disappearing from the beans were 2.1 times higher if kept in shed than if kept in a store. From Table 4.8b, there was a significant association between the type of storage condition and whether or not Aspergillus *niger* was present in cocoa beans $\chi 2$ (1) = 33.682, $p < .001$.

From Table 4.8, out of the 100g of the beans taken from the shed, 82.5% beans did not show the presence of *Aspergillus niger* and 17.5% showed the presence *Aspergillus niger* whereas for those taken from the store, 46.7% did not show the presence of Aspergillus *niger* and 53.3% showed the presence of *Aspergillus niger*. This seemed to represent the fact that based on the odds ratio; the odds of Aspergillus *niger* not appearing in cocoa beans in storage were 5.4 times higher if the beans were kept in shed than when kept in store. From Table, 4.8c, there

was also a significant association between the type of storage condition and whether or not Aspergillus *flavus* was present in cocoa beans $\chi 2$ (1) = 29.639, $p < .001$. From the odd ratio analysis, the odds of preventing the presence of *Aspergillus flavus* when kept in shed were 4.9 times higher than when the beans were kept in a store.

Table 4.14d also revealed a significant association between the type of storage condition and whether or not *Penicillium spp was* presenting the cocoa beans $\chi 2$ (1) = 18.134, $p < .001$. The odds of preventing *Penicillium spp* from appearing in cocoa beans were 3.4 times higher when kept in shed than when kept in store room.

There was also a significant association ($\chi 2$ (1) = 5.161, $p < .05$.) between cocoa storage condition and whether or not *Rhyzopus spp* was present. The odds of *Rhyzopus spp* not appearing in the storage cocoa beans were 1.9 times higher, when kept in a shed than when kept in store (Table 4.14e). There was a significant relationship between the presence of *Colletotrium spp* and the type of storage of cocoa beans, $\chi 2$ (1) = 12.381, $p < .001$. From the odds ratio analysis, the odds of preventing *Colletotrium spp* from appearing in cocoa storage beans were 2.7 times higher when the beans were kept in a shed than when kept in store (Table 4.14f). The relationship between the presence of *Curvularia spp* pathogen and the type of storage condition of cocoa beans was significantly different, $\chi 2$ (1) = 10.670, $p < .01$. The odds ratio analysis revealed that when the cocoa beans were kept in shed, there was 2.5 times likelihood of preventing the occurrence of Curvularia *spp* than when kept in store. This indicated that, generally, when cocoa beans were kept in shed, it is more likely to prevent the occurrence of pathogens than when they are kept in store room.

Table 4.14: Chi-square test for association between pathogens and storage conditions of cocoa

(A) ASP.TAM						
Storage Condition	**Absent (%)**	**Present (%)**	**Total**	**Odd ratio**	**x^2**	**Sig (2-sided)/ P-value**
Shed	73.3(88)	26.7(32)	120			
Store	56.7 (68)	43.3 (52)	120	2.1	7.326	0.007
(B) ASP. NIG.						
Shed	82.5 (99)	17.5 (21)	120			
Store	46.7 (56)	53.3(64)	120	5.4	33.682	0.000
(C)ASP. FLAV						
Shed	82.5(99)	17.5(21)	120			
Store	49.2(59)	50.8(61)	120	4.9	29.639	0.000
(D) PENI SPP						
Shed	80 (96)	20 (24)	120			
Store	54.2 (65)	45.8 (55)	120	3.4	18.134	0.000
(E) RHIZ SPP						
Shed	70(84)	30 (36)	120			
Store	55.8 (67)	44.2 (53)	120	1.9	5.161	0.023
(F) COLL SPP						
Shed	75.8 (91)	24.2 (29)	120			

Store	54.2 (65)	45.8 (55)		120	2.7	12.381	0.000
(G) CURV SPP							
Shed	75.8 (91)	24.2(29)		120			
Store	55.8 (67)	44.2 (53)		120	2.5	10.670	0.001

4.16 MAJOR STORAGE PROBLEMS AND MANAGEMENT

From the field survey, majority (80%) of the respondents indicated that insects were the major storage problem, 16% mentioned rodents and 4% indicated mouldiness as their major storage problem (Figure 4.1).

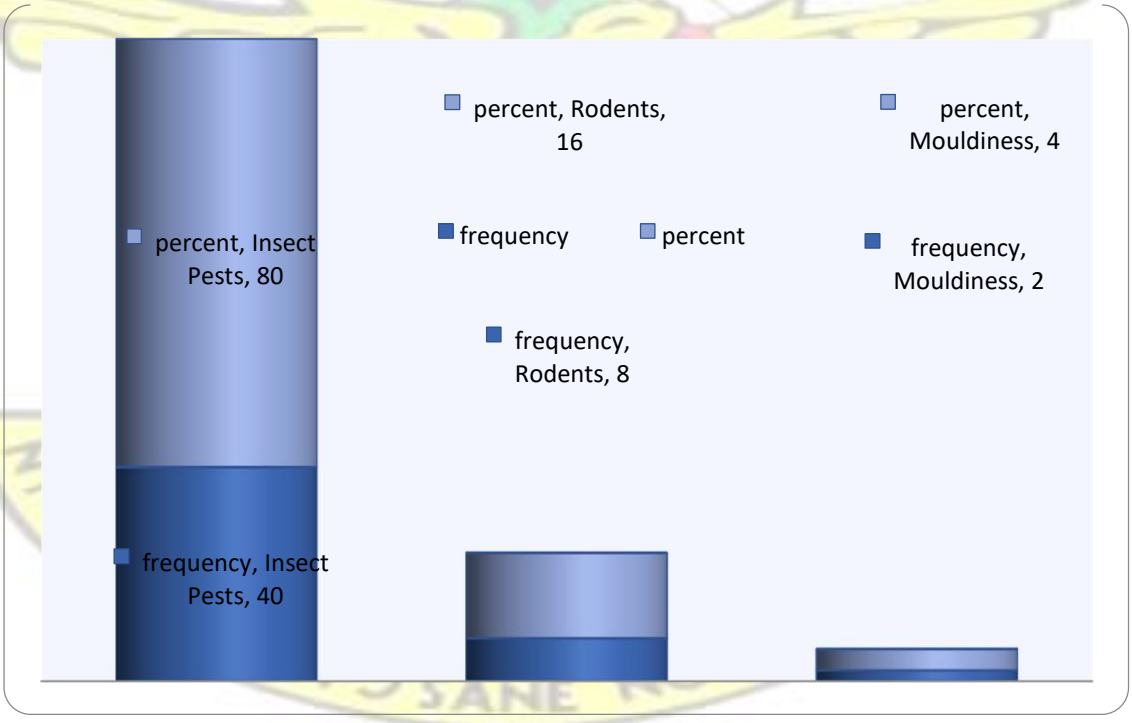

Figure 4.1: Storage Problems

4.17 MANAGEMENT OF STORAGE FACILITIES AND STORAGE PROBLEMS

From Table 4.15 below, the model summary block reports the Multiple R (0.604) and R square (0.364). The ANOVA output block in table 4.9 below shows the significance of the relationship (Sig= 0.000). From the model summary output below in table 4.9, it was realized that the management of storage facilities (good aeration, repairing of leakages, good sanitation, repair areas which habour rodents, repair areas which habour pest) explain about 36.4% of the variance in storage problems and this result is statistically significant in affecting quality of cocoa beans. With the Multiple R (0.604), it shows a strong correlation between the management of storage facilities and storage problems.

In the coefficient output block in table 4.15 below, are the slopes (B) of the Y intercept (reported as a constant of 1.492). From this information, we can build a regression equation to predict scores on storage problems. The beta for (0.659) and repairing areas which habour pests (0.284) are greater than the beta for the other storage facility management, so repairing areas which habour rodents are the most important independent variables. In other words, the two storage facility management has a positive impact on storage problems which increases quality of cocoa beans. Therefore, it can be concluded that at least for this sample, quality of cocoa beans through reduction of storage problems is more affected by repairing areas which

habour rodents, and repairing areas which habour pest than good aeration, repairing of leakages and good sanitation, as storage management facilities.

Table 4.15: Multiple Regression analysis on the effects of Management of storage facilities and storage problems

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.604[a]	.364	.329	1.101

a. Predictors: (Constant), good aeration, repairing of leakages, good sanitation, repair areas which habour rodents, repair areas which habour pest

Table 4.16: ANOVA output block showing the significance of the relationship between Management of storage facilities and storage problems

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	75.028	6	12.505	10.314	.000[b]
	Residual	130.937	108	1.212		
	Total	205.965	114			

a. Dependent Variable: Storage Problems

b. Predictors: (Constant), good aeration, repairing of leakages, good sanitation, repair areas which habour rodents, repair areas which habour pest

Table 4.17: The Coefficients table showing the regression equation to predict scores on storage problems

Model	Unstandardized Coefficients		Standardized T Coefficients	Sig.
	B	Std. Error	Beta	

	(Constant)	1.492	.649		2.297	.024
	repair areas which habour pest	.789	.226	.284	3.493	.001
1	repair areas which habour rodents	-.123	.151	-.103	-.810	.419
	repairing of leakages	.468	.083	.659	5.617	.000
	good aeration	-.006	.070	-.008	-.092	.927
	good sanitation	-.181	.133	-.158	-1.361	.176

a. Dependent Variable: Storage Problems

CHAPTER FIVE

5.0 DISCUSSION

5.1 DEMOGRAPHIC CHARACTERISTICS OF RESPONDENTS

According to the survey, majority of respondents in the lieu of 90% were males whereas 10% were females. The level of education of the respondents showed that 8% of the respondents had no education. About 40% of the respondents had completed Middle School / Junior High School and 22% had also completed Senior High School. The remaining 30% have completed Tertiary level or have a Diploma or Degree equivalent. Majority of respondent were therefore Middle school leavers.

The work of the purchasing clerks demands some level of literacy including ability to read, write and calculate, hence the need for literates to man those storage facilities. All the clerks interviewed at the sheds had attained at least Junior High School or Senior High School certificate or its equivalent; however those at the stores had a junior high school certificate or relied on their children who attended school for the writings, this according to them was a

major challenge. It would be appropriate for staff with higher level of education to be employed for both the shed and store type of storage to ensure appropriate practices carried out.

5.2 LICENSED COCOA BUYERS

The most dominant stakeholders in the internal marketing structure were the licensed buying companies which can be found in all the six cocoa growing regions in Ghana. Majority, twenty-eight percent of the licensed cocoa buyers identified in the Asante Mampong Cocoa District were of the Produce Buying Company (PBC) of COCOBOD, probably because PBC has credibility because it is a government institution. Unlike some of the private companies, they have been with the farmers and paid promptly. However, Vigneri and Santos (2007) affirmed that, LBCs target districts where they can lower operational costs and maximize profit. Under this system the operational heads assess the funding needs of these districts; monies are then lodged in the accounts of the companies at the district. The least dominant buying company found was Adwumapa, which had, twelve percent, the respondents said was due to the company establishing in the district just recently.

5.3 TYPES AND DESCRIPTION OF STORAGE FACILITIES

Fifty storage facilities were identified in 23 towns during the field survey. Among the towns selected for the field survey, Kofiase recorded the highest number of storage facilities. According to the respondents who were cocoa purchasing clerks, the high prevalence of storage facilities in an area meant high production of cocoa in that area and vice versa.

Two main types of storage facilities were identified. Cocoa depots were however interchangeably used as cocoa sheds depending on which registered company one was dealing with. Results from the study indicated that the sheds were mainly built with cement blocks and corrugated roofing. It had one or two doors and between four to six windows to enhance ventilation, unlike the stores which were found to be built with either bricks or mud with only one door and no windows. This could impede ventilation, especially, when too much cocoa is stacked in the room. The stores were found to be manned by only one personnel, whereas the sheds had one district manager, a depot keeper, and one or two manual workers.

5.5 STORAGE OF EMPTY SACKS

According to the purchasing clerks, empty sacks harbored rodents such as mice, insects, and dust which affect the quality of the beans. The insect bore holes into cocoa beans feeding on them, whereas the mice chew cocoa sacks and also destroy some of the beans. The survey revealed that, most of the buyers who kept cocoa at the stores kept empty sacks, whiles majority of the sheds had storage rooms for empty sacks. Several factors may be responsible for insect infestation in storage and of special importance is the number of flying insects searching for food (Hodges *et al*., 2002). Studies in Ghana, with experimental and real stores, have shown that the number of flying beetles during the period of storage is directly correlated with the probability that the produce in any given store will become infested (Birkinshaw *et al*., 2002).

5.6 MANAGEMENT OF INSECT PEST IN STORAGE

Cocoa weevils and cocoons were the major storage insects mentioned by the purchasing clerks. Before stacking, the storage room was cleaned of old debris and sprayed with Fast track chemical solution by COCOBOD. The chemical was mixed with water and sprinkled on the floor to kill the weevils and their eggs. This was done three days before cocoa beans were put in the storage room; to prevent the contamination of the chemical with the beans.

Periodically, fogging was done after stacking of cocoa beans with Detamost or Super gold USB in a smoke form to control the insects. Fogging is smoke-like application which suffocates and kills the insects. The infestation of cocoons according to the purchasing clerks was controlled by fumigation of the storage rooms by COCOBOD with Detia gas. In fumigation, the cocoa beans were covered with a gas proof sheet and the fumes were released to kill the cocoons.

5.7 DURATION OF COCOA STORAGE

According to the respondents, cocoa must be transported quickly to the harbour to create space for new ones from the farmers and also to avoid storage problems since there was no incentive for keeping them, especially, during the major peak season. Long storage of cocoa beans has been reported to be associated with storage challenges which includes but not limited to incidence of storage pests (Adu, 2007). However, according to Navarro *et al.*, (2007), cocoa beans are normally stored in the form of whole beans in jute sacks for relatively short periods. This affirms the current research where majority of the said bagged cocoa beans were kept only for between one to two weeks.

5.8 CLEANING AND SANITATION OF COCOA STORAGE FACILITIES

On sanitation, according to the purchasing clerks, majority did clean the storage rooms three times within one month, with none indicating that they did not clean at all within the month. Cleaning according to them was very important because failure to do so habours pest and infest the cocoa. They also regularly weed around the storage facilities to keep away rodents. Although cleaning of the shed is supposed to be done on a regular basis, Anang *et al.* (2011) acknowledged that this is a challenge which has been difficult to control.

5.9 VENTILATION OF COCOA STORAGE FACILITIES

Ventilation of cocoa storage rooms is very necessary according to the respondents interviewed during the survey. Most of the cocoa sheds were observed to have about 4 to 6 wooden windows to allow for free movement of air in and out of the storage rooms. This ensures drying of bagged cocoa in the storage rooms. The cocoa store storage facilities had one or no window or had moulded vents to allow for ventilation. Poor ventilation causes mould growth and cobwebs.

5.10 TEMPERATURE MONITORING OF COCOA BEANS IN STORAGE

According to majority of the respondents, temperature within the bagged cocoa in the storage rooms was monitored by a specialized device known as Aqua-boy, by Quality Control personnel of COCOBOD. The Aqua-boy was inserted into the bagged cocoa and readings taken to determine for Not Thoroughly Dried (NTD) beans. Others said they monitored the temperature manually by hand pressing the beans to feel the noise to determine if it was dried. This was done by an experienced person. According to COCOBOD-Ghana, the recommended moisture content of cocoa beans was 7.5% maximum. During storage and transportation, cocoa

beans are subjected to problems of insect infestation, mold contamination, and moisture exchange between the atmosphere and the beans which are hygroscopic (Villers *et al*., 2007)

5.11 RE-DRYING OF COCOA BEANS IN STORAGE

Majority of the purchasing clerks interviewed during the survey indicated that they re-dried the cocoa upon receipt from the farmers. This was because most of the farmers did not have enough time to dry the cocoa beans thoroughly before sending it to them, so they re-dry to avoid mouldiness and also get the correct weight before bagging it finally for onward transfer to the ports for shipment. According to Aroyeun *et al*. (2006) and Hamzat (2004), stored cocoa is often damaged by insect pest and most especially by moulds, and this type of damage mostly results from failure to dry beans properly.

The other minority said they did not re-dry until Quality Control Officers test for Not Thoroughly Dried (NTD) beans. Above 8% moisture, there is the danger of moulds developing within the beans while below 5% moisture, the beans are very brittle (Thompson and Lopez, 2001). Drying practices influence market quality, the development of flavor, final bean acidity, moldiness and the presence of off-flavor such as smoky notes in the beans (Bonaparte, 1995).

5.12 PACKING ARRANGEMENT OF BAGGED COCOA IN STORAGE FACILITIES

According to most of the respondents (92%), bagged cocoa was arranged on stacks in rows to allow free movement of workers and to enhance ventilation. The remaining 8% indicated that

bagged cocoa beans are sometimes left on the floor. This normally happened during the major cocoa season where cocoa is in abundance and much cocoa was brought from farmers. They however said those cocoa bags were stacked immediately there was space after there has been some evacuation from the storage rooms.

Failure to do so causes mould growth as ventilation within such pile was poor. Adu (2007) also explained that the small sizes and capacities of cocoa sheds have negatively impacted on storage as this constantly leads to the storing of cocoa outside the cocoa sheds during the peak season.

5.13 PHYSICAL TESTS OF COCOA BEANS IN SHED AND STORE STORAGE CONDITIONS

According to the Quality control Division of COCOBOD-Ghana, cocoa beans is classified as good when it is devoid of slaty, purple, clustered, mouldy, germinated, insect infested and waste beans. From the results of the study, the mean good beans recorded from the shed storage rooms were significantly higher than the amount recorded from the store storage rooms. However, the mean purple and waste beans recorded from the store rooms were significantly higher than the amount recorded from the shed storage rooms. This might be as a result of the high occurrence of the fungi (pathogens) present in the store and the level of treatment before storage. According to COCOBOD-Quality control Division, fungi helps in cocoa fermentation. After fermentation there should be absence of fungi on the beans, their presence however reduces the fat content or produces the purple colour.

According to Fowler (1999), high FFA contents in cocoa beans might result from black beans originating from rotten pods or germinated beans. Likewise, micro flora, particularly moulds, can cause similar problems during storage (Hiol, 1999). Unless storage is properly carried out there is a risk of dry cocoa beans becoming damaged from insect infestation, mould and foreign odours (Jonfia-Essien, 2001).

5.14 CHEMICAL QUALITY OF COCOA BEANS IN SHED AND STORE STORAGE CONDITIONS

According to Whitefield (2005), mouldy, rotten, and germinated cocoa beans increase the free fatty acid (%FFA) content of cocoa. However, an increase in free fatty acid content decreases the butter content of cocoa. From the study, the mean free fatty acid content in the cocoa beans kept in the store rooms was significantly higher than those kept in the shed. This may be as a result of the higher amount of waste and purple recorded from the beans kept at the store rooms. The general opinion is that higher free fatty acid content leads to a decrease in hardness of cocoa butter (Pontillon, 1998) and must be considered as a raw cocoa commercial value reducing factor both for producers and chocolate manufacturers.). Indeed, Wood and Lass (1985) and Pontillon (1998) suggested that FFA occurrence in stored cocoa beans is linked to the action of microbial lipases.

5.15 ASSOCIATION BETWEEN PATHOGENS AND STORAGE CONDITIONS OF COCOA

The results of the analysis showed that there were fungi on the cocoa beans but generally, the beans from the stores had more of the fungi, that is *Aspergillus tamari,Aspergillus niger*, Aspergillus *flavus, Penicillium* spp*, Rhyzopus* spp, *Colletotrium* spp, *Curvularia* spp, present than those kept in the sheds. These fungi play a vital role during fermentation. They feed on the slimy mucous on the cocoa beans, thereby speeding up the process of fermentation. However, over fermentation decreases the chocolate flavor of cocoa. The high presence of the fungi in the cocoa kept in the stores may be due to the fact that it was mishandled or had high moisture content.

Fungal species belonging to the *genera Aspergillus, Mucor, Penicillium* and *Rhyzopus* have been observed on mishandled or improperly dried fermented beans (Roelofsen, 1958; Broadent and Oyeniran, 1968). However, cocoa beans should be thoroughly dried before storage because, according to Moss, 1996, many fungi, especially species from the genera *Aspergillus* and *Penicillium*, produce mycotoxins that can cause acute or chronic intoxication and damage to humans and animals after ingestion of contaminated food and feed (Marasas and Nelson, 1987; Moss, 1996)

5.16 MAJOR STORAGE PROBLEMS

Insects were mainly the problem with the sheds where the area was bushy and empty sacks stored in the room with stacked cocoa. Rodents were the ranked second among the problems mentioned by the purchasing clerks. They indicated that they chewed the sacks and also the beans.

The problem with mouldiness was mainly associated with the stores. This might be due to the poor ventilation conditions as observed during the survey. Stored cocoa is often damaged by insect pests and most especially, by moulds (Aroyeun *et al.,* 2006; Hamzat, 2004). Storage beetles are attracted to cocoa beans and cause damage by burrowing holes in the beans or feeding on the nib (Jonfia-Essien *et al*., 2007).

5.17 MANAGEMENT OF STORAGE FACILITIES AND STORAGE PROBLEMS

According to the purchasing clerks, both at the stores and sheds, cocoa beans received from farmers on detection of not thoroughly dried (NTD) are re-dried and again when they see signs of mouldiness on cocoa in storage, they emptied the sacks and re-dry to reduce the moisture content. According to the purchasing clerks, poor ventilation and high relative humidity in and around the storage area causes mouldiness. Cocoa storage rooms must therefore not be stacked over its capacity to ensure proper ventilation and good storage condition. On rodents, proper sanitation, that is weeding around the storage facility and keeping away used empty sacks from the stacked cocoa beans and sealing all possible entry points were mentioned as the best way to control them.

5.18 REGRESSION ANALYSIS ON THE EFFECTS OF MANAGEMENT OF STORAGE FACILITIES AND PROBLEMS

The result confirms the report by Osei (2007) that loss of quality are as a result of challenges associated with storage, handling and transportation of the cocoa which affects the quality of the produce. Furthermore, it validates the literature that explained that the small sizes and

capacities of storage facilities have negatively impacted on storage as this constantly leads to the storage of cocoa outside the storage rooms during the peak season. This also resulted in loss of cocoa through poor handling, theft and the erratic nature of the weather. A damp environment facilitates moisture build up in the cocoa during such poor storage conditions and may cause the development of moldy beans (Adu, 2007).

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 INTRODUCTION

The chapter contains a summary of the research on assessing the suitability of cocoa storage facilities on cocoa bean quality. The study draws conclusion from the findings, and recommendations are made based on the findings and the researcher‟s opinion.

6.2 CONCLUSIONS

Below are the conclusions drawn from the result of the study;

- Two main types of cocoa storage facilities were identified in the Asante Mampong Cocoa district, and that was Cocoa Sheds and Cocoa Stores. Majority of the storage facilities were found to be of the store type. A cocoa shed was identified to have a storage capacity of between twenty-five to one hundred (25-100) tonnes of bagged cocoa beans. The cocoa stores however were found to have a maximum storage capacity of twenty-five (25) tonnes.

- Several storage practices were revealed by the study, among them were storage of empty cocoa sacks, management of insect pest, cleaning and sanitation of cocoa storage rooms, ventilation control of cocoa storage rooms, temperature monitoring of bagged cocoa, re-drying of cocoa beans, packing arrangement of bagged cocoa. • The physical quality test (cut tests) showed a significant difference in the mean good beans at the shed storage room over that of the store storage rooms.

- There was also a significant difference in the mean purple and waste beans recorded at the stores over those recorded at the sheds.
- The chemical quality test showed that the mean free fatty acid in the cocoa beans kept in the store was significantly higher than those kept in the shed.
- On the pathogenic tests, the result revealed a significant association of the presence of the pathogens (*Aspergillus tamari,Aspergillus niger,* Aspergillus *flavus, Penicillium spp, Rhyzopus spp, Colletotrium spp, Curvularia spp*), on cocoa kept under shed storage conditions and those kept under store storage conditions. Generally, from the results of the study, it can be concluded that when cocoa beans were kept under shed storage conditions, you were more likely to prevent the occurrence of pathogens than when kept under store rooms.

- Finally, it was noted that among the respondents interviewed; majority (80%) of them said insect infestation was their major storage problem. The insects were mainly the problem with the sheds where the area was bushy and empty sacks stored in the room with stacked cocoa. The results of the regression test showed that there was a weak

relationship between the management of storage facility and storage problems which ultimately affects quality of cocoa beans and that about 90% of storage problems which affect quality of cocoa beans were explained by other apart from management of storage facility.

6.3 RECOMMENDATIONS

Based on the findings of the present study, the researcher puts forward some recommendations which can inform future studies, and guide stakeholders and policy makers in the cocoa industry**.**

- Hermatic storage should be encouraged since it has provided a successful storage method for the protection of dried cocoa beans by replacing fumigants for insect control and for quality preservation.

- Cocoa beans should always be re-dried upon receipt from farmers to avoid mould growth

- COCOBOD should put in place a strict supervision mechanism in ensuring good stacking and proper management systems in the cocoa district.

- Finally, since the study showed that storage facility practices affect the quality cocoa beans to an extent, the researcher submits that further studies and measures should be

put in place to ascertain and consider other possible factors that affect cocoa bean quality especially with regards to handling and transportation.

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APPENDIX

In partial fulfillment for the award of a degree of Master of Science in Postharvest Technology in the faculty of Agriculture, KNUST, this is a research on the Assessment of suitable storage facilities for cocoa beans in the Asante Mampong cocoa District in the Ashanti Region. This research is purely for academic purposes and any information given will be treated as confidential. Absolute sincerity is required in answering the questions outlined.

Please tick [√] or write where appropriate. Thank you.

Topic: Assessment of suitable storage facilities for cocoa beans in the Asante Mampong Cocoa District in the Ashanti Region

Section A

1. Sex
   a. Male [ ] b. Female [ ]

2. Name of Licensed Buyer……

3. Type of Storage Facility
   a. Shed [ ] b. Warehouse [ ] c. Store [ ]

4. Location of Storage Facility

   a. Town / Village [ ] b. District [ ] c. Region [ ]

5. Capacity of Storage Facility

   a. Length ……

   b. Breadth ……

   c. Height ……..

   d. Tonnage ……

6. Section Drying / Parking space

   i. Adequate drying space

   a. Yes [ ] b. No [ ]

   ii. Adequate parking space

   a. Yes [ ] b. No [ ]

7. Nature of building

   a. Wooden [ ] b. Brick [ ] c. Cement [ ] d. Mud [ ]

8. Type of Floor

   a. Concrete [ ] b. Switch plaster [ ] c. Other (Specify) [ ]

9. Nature of Roof

   a. Corrugated metal b. Concrete [ ] c. Thatch [ ]

10. Ventilation

   i. Number of doors

   a. One [ ] b. Two [ ] c. More (Specify) [ ]

   ii. Number of Windows

   i. One [ ] b. Two [ ] c. More (Specify) [ ]

11. What do you use to package your beans?

a. Jute sacks [ ] b. Raphia sacks [ ] c. Other (Specify) ……

12. Do you keep used empty sacks in the store room?

a. Yes [ ] b. No [ ] Skip to 13

If yes, what problems does it pose?

…….....……

……

13. What common pest have you identified in and around the storage room?

a. Insects [ ] b. Rodents [ ] c. Other (specify) ……

14. How do you control pests in the storage room?

a. Chemical [ ] b. Biological/Cultural [ ] c. Other (Specify……

15. What is the major storage problem you face

a. Insect pest [ ] b. Rodents [ ] c. Moldiness [ ]

d. Other (specify)……

16. How do you manage each problem?

a. Chemical control [ ] b. Drying [ ] c. Proper sanitation [ ]

d. Other (specify) ……

17. How long do you keep the beans before disposal?

a. 1-2 weeks [ ] b. 3-4 weeks [ ] c. 5-6 weeks [ ]

d. Other (specify)……

18. How do you prepare cocoa beans for storage?

……

……..……

……

Storage Condition * ASP. TA Cross tabulation					
			ASP. TA		Total
			Absent	Present	
Storage Condition	Shed	Count	88	32	120
		% within Storage Condition	73.3%	26.7%	100.0%
		% within ASP. TA	56.4%	38.1%	50.0%
		% of Total	36.7%	13.3%	50.0%
	Stored	Count	68	52	120
		% within Storage Condition	56.7%	43.3%	100.0%
		% within ASP. TA	43.6%	61.9%	50.0%
		% of Total	28.3%	21.7%	50.0%
Total		Count	156	84	240
		% within Storage Condition	65.0%	35.0%	100.0%
		% within ASP. TA	100.0%	100.0%	100.0%
		% of Total	65.0%	35.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2sided)	Exact Sig. (1-sided)
Pearson Chi-Square	7.326[a]	1	.007		
Continuity Correction[b]	6.612	1	.010		
Likelihood Ratio	7.379	1	.007		
Fisher's Exact Test				.010	.005
Linear-by-Linear Association	7.295	1	.007		
N of Valid Cases	240				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 42.00.

b. Computed only for a 2x2 table

Storage Condition * ASP. NIGER Crosstabulation					
			ASP. NIGER		Total
			Absent	Present	
Storage Condition	Shed	Count	99	21	120
		% within Storage Condition	82.5%	17.5%	100.0%
		% within ASP. NIGER	63.9%	24.7%	50.0%
		% of Total	41.3%	8.8%	50.0%
	Stored	Count	56	64	120
		% within Storage Condition	46.7%	53.3%	100.0%
		% within ASP. NIGER	36.1%	75.3%	50.0%
		% of Total	23.3%	26.7%	50.0%
Total		Count	155	85	240
		% within Storage Condition	64.6%	35.4%	100.0%
		% within ASP. NIGER	100.0%	100.0%	100.0%

Chi-Square Tests

	% of Total		64.6%	35.4%	100.0%
	Value	df	Asymp. Sig. (2sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	33.682[a]	1	.000		
Continuity Correction[b]	32.134	1	.000		
Likelihood Ratio	34.878	1	.000		
Fisher's Exact Test				.000	.000
Linear-by-Linear Association	33.542	1	.000		
N of Valid Cases	240				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 42.50.

b. Computed only for a 2x2 table

Storage Condition * ASP. FLAVUS Crosstabulation

			ASP. FLAVUS		Total
			Absent	Present	
Storage Condition	Shed	Count	99	21	120
		% within Storage Condition	82.5%	17.5%	100.0%
		% within ASP. FLAVUS	62.7%	25.6%	50.0%
		% of Total	41.3%	8.8%	50.0%
	Stored	Count	59	61	120
		% within Storage Condition	49.2%	50.8%	100.0%
		% within ASP. FLAVUS	37.3%	74.4%	50.0%
		% of Total	24.6%	25.4%	50.0%
		Count	158	82	240

Chi-Square Tests

Total	% within Storage Condition	65.8%	34.2%	100.0%
	% within ASP. FLAVUS	100.0%	100.0%	100.0%
	% of Total	65.8%	34.2%	100.0%

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2sided)	Exact Sig. (1-sided)
Pearson Chi-Square	29.639[a]	1	.000		
Continuity Correction[b]	28.175	1	.000		
Likelihood Ratio	30.608	1	.000		
Fisher's Exact Test				.000	.000
Linear-by-Linear Association	29.515	1	.000		
N of Valid Cases	240				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 41.00.

b. Computed only for a 2x2 table

Storage Condition * PENI. SPP Crosstabulation

			PENI. SPP		Total
			Absent	Present	
Storage Condition	Shed	Count	96	24	120
		% within Storage Condition	80.0%	20.0%	100.0%
		% within PENI. SPP	59.6%	30.4%	50.0%
		% of Total	40.0%	10.0%	50.0%
	Stored	Count	65	55	120
		% within Storage Condition	54.2%	45.8%	100.0%

Chi-Square Tests

Total	% within PENI. SPP	40.4%	69.6%	50.0%
	% of Total	27.1%	22.9%	50.0%
	Count	161	79	240
	% within Storage Condition	67.1%	32.9%	100.0%
	% within PENI. SPP	100.0%	100.0%	100.0%
	% of Total	67.1%	32.9%	100.0%

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2sided)	Exact Sig. (1-sided)
Pearson Chi-Square	18.134[a]	1	.000		
Continuity Correction[b]	16.982	1	.000		
Likelihood Ratio	18.504	1	.000		
Fisher's Exact Test				.000	.000
Linear-by-Linear Association	18.058	1	.000		
N of Valid Cases	240				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 39.50.

b. Computed only for a 2x2 table

Storage Condition * RHIZO. SPP Cross tabulation

			RHIZO. SPP		Total
			Absent	Present	
Storage Condition	Shed	Count	84	36	120
		% within Storage Condition	70.0%	30.0%	100.0%
		% within RHIZO. SPP	55.6%	40.4%	50.0%
		% of Total	35.0%	15.0%	50.0%
	Stored	Count	67	53	120

Chi-Square Tests

	% within Storage Condition	55.8%	44.2%	100.0%
	% within RHIZO. SPP	44.4%	59.6%	50.0%
	% of Total	27.9%	22.1%	50.0%
Total	Count	151	89	240
	% within Storage Condition	62.9%	37.1%	100.0%
	% within RHIZO. SPP	100.0%	100.0%	100.0%
	% of Total	62.9%	37.1%	100.0%

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2sided)	Exact Sig. (1-sided)
Pearson Chi-Square	5.161[a]	1	.023		
Continuity Correction[b]	4.572	1	.033		
Likelihood Ratio	5.185	1	.023		
Fisher's Exact Test				.032	.016
Linear-by-Linear Association	5.140	1	.023		
N of Valid Cases	240				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 44.50.

b. Computed only for a 2x2 table

Storage Condition * COLLET. SPP Crosstabulation

		COLLET. SPP		Total
		Absent	Present	
Storage Condition	Count	91	29	120
	% within Storage Condition	75.8%	24.2%	100.0%
	% within COLLET. SPP	58.3%	34.5%	50.0%

Chi-Square Tests

	Shed	% of Total	37.9%	12.1%	50.0%
		Count	65	55	120
		% within Storage Condition	54.2%	45.8%	100.0%
	Stored	% within COLLET. SPP	41.7%	65.5%	50.0%
		% of Total	27.1%	22.9%	50.0%
		Count	156	84	240
Total		% within Storage Condition	65.0%	35.0%	100.0%
		% within COLLET. SPP	100.0%	100.0%	100.0%
		% of Total	65.0%	35.0%	100.0%

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2sided)	Exact Sig. (1-sided)
Pearson Chi-Square	12.381[a]	1	.000		
Continuity Correction[b]	11.447	1	.001		
Likelihood Ratio	12.535	1	.000		
Fisher's Exact Test				.001	.000
Linear-by-Linear Association	12.329	1	.000		
N of Valid Cases	240				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 42.00.

b. Computed only for a 2x2 table

Storage Condition * CURV_SPP Crosstabulation

		CURV_SPP		Total
		Absent	Present	
Storage	Count	91	29	120
	% within Storage Condition	75.8%	24.2%	100.0%

Chi-Square Tests

Condition	Shed	% within CURV_SPP	57.6%	35.4%	50.0%
		% of Total	37.9%	12.1%	50.0%
	Stored	Count	67	53	120
		% within Storage Condition	55.8%	44.2%	100.0%
		% within CURV_SPP	42.4%	64.6%	50.0%
		% of Total	27.9%	22.1%	50.0%
Total		Count	158	82	240
		% within Storage Condition	65.8%	34.2%	100.0%
		% within CURV_SPP	100.0%	100.0%	100.0%
		% of Total	65.8%	34.2%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2sided)	Exact Sig. (1-sided)
Pearson Chi-Square	10.670[a]	1	.001		
Continuity Correction[b]	9.799	1	.002		
Likelihood Ratio	10.788	1	.001		
Fisher's Exact Test				.002	.001
Linear-by-Linear Association	10.626	1	.001		
N of Valid Cases	240				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 41.00.

b. Computed only for a 2x2 table

PLATES

Plate 1: Ghana COCOBOD Shed at Kofiase in the Asante Mampong Cocoa District

Plate 2: COCOBOD Shed showing the back view

Plate 3: The inside of a Cocoa shed

Plate 4: Bagged cocoa beans stacked in a cocoa Shed

Plate 5: A typical cocoa store at Kyekyewere in the Asante Mampong Cocoa District

Plate 6: The inside of a cocoa store room

Plate 7: The side view of a Cocoa store at Kyekyewere

Plate 8: Another sample of cocoa store at Kwamang in the Asante Mampong Cocoa District

Plate 9: Samples of cocoa taken for the cut/physical test

Plate 10: Quality control officer performing cut/physical test on cocoa

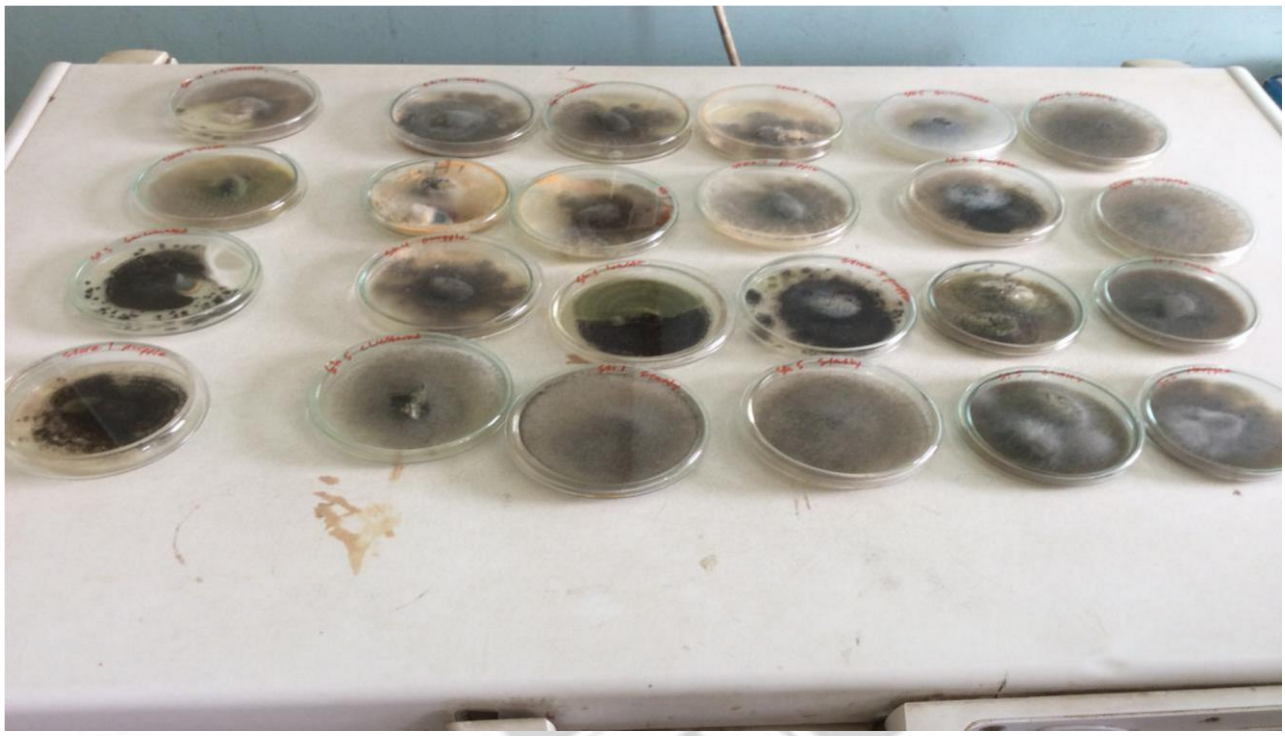

Plate 11: Mashed cocoa beans in trays at laboratory to observe for the presence of fungi

Plate 12: Mashed cocoa beans after fungi observation