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QUALITY RESPONSE OF COCOA BEANS TO DIFFERENT STORAGE MATERIALS IN THE SAMREBOI DISTRICT OF GHANA COCOBOD IN THE WESTERN REGION

BY

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DECLARATION

I hereby declare that, except for references to work of other people which have been duly acknowledged, this write up submitted to the School of Research and Graduate Studies, KNUST, KUMASI is the result of my own original research and that this thesis has not been presented for any degree elsewhere.

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DEDICATION

I dedicate this work to my late mother Margaret Maku Teinor, my wife Mrs. Comfort Awuku Doku and my children Linda Adjarkie Doku, Ophelia Adjarkuor Doku, Emmanuel Adjartey Doku and Benjamin Adjarnor Doku.

ABSTRACT

A study was conducted to evaluate the performance of different storage bags over different storage periods on the quality of dried cocoa beans. The study was conducted at Samreboi Cocoa District which is part of Wassa Amenfi West District of Western Region of Ghana. The study was made up of two parts namely survey using questionnaire and laboratory analysis. In all 70 cocoa purchasing clerks were sampled and interviewed using convenient sampling technique on the qualities, forms of defects and problems in cocoa beans storage in the district with the help of closed and opened questionnaires. Their responses were analyzed with the help of SPSS. The experiment was a 3×7 factorial arrangement laid out in a randomized complete design (RCD) with three replications. The factor A was made up of jute sack, woven nylon and hermetic bag. Factor B was also varying time of storage (0, 1, 2, 3, 4, 5 and 6 months). Cut test was conducted to assess effects of the experimental treatments on the physical attributes of the stored cocoa beans. Proximate analysis was carried out at the KNUST Biochemistry department laboratory. Analysis of Variance was carried out on the data using Statistix Student Version 9. Tukey's HSD was used for mean separation at probability level of 0.01. The survey revealed that wet beans (65.7%) followed by mouldy beans (35.7%), slaty beans (27.1%), impurities (38.1%) and purple beans (42.9%) were the five most common forms of defects in cocoa beans in the district. The results indicated that cocoa beans stored hermetically recorded the least mould, germinated and other defects except slate and purple, among the methods of storage used in this study. Hermetic bag recorded the lowest moisture content of 6.80% whilst the jute sack and woven nylon recorded 8.59% and 7.47% respectively. The jute sack and woven nylon recorded higher fat, nitrogen free extract, free fatty acids and pH compared with hermetic bag. The use of hermetic sacs resulted in superior quality stored beans. It is recommended that hermetic storage material should be used by stakeholders for storage of cocoa to increase shelf-life.

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CHAPTER ONE

1.0 INTRODUCTION

Theobroma cacao L., commonly called Cocoa had its origin in the Amazon of Brazil. It has spread to the tropics especially in Ghana, Ivory Coast, Nigeria, Brazil, Venezuela, Malaysia and Indonesia (Beckett, 1994) in limited ecozone around the equator (Buijsse *et al*., 2006). Cocoa is rich in vitamin A, B, C, D and E, minerals and salts (Nickless, 1996).

Cocoa, which is an important cash crop of Ghana, contributes significantly to the total foreign exchange earnings and livelihoods along its value chain (Essegbey and Ofori-Gyamfi, 2012)

Ghana's cocoa is considered premium on the world market. Top brands of chocolate and confectionery are branded with Ghana Cocoa for premium pricing.

The storage of cocoa beans and its attendant problems have been reported by many researchers (Wood, 1986). Temperature, moisture, relative humidity and packaging environment are agents of deterioration of cocoa during storage. The deleterious effect of mould, microflora and oxidation are particularly problematic in cocoa bean storage.

High moisture content (MC) in cocoa beans triggers an enzymatic process in the beans leading to high respiration rate resulting in destruction of the beans. It also leads to increase in free fatty acid (FFA) levels (Olabode and Adu, 2012).

The use of several pesticides in controlling pests in cocoa has raised concerns on health risks. Several have taken specific action via sanitary and phytosanitary (SPS), legislative and regulatory measures to stop importing cocoa beans with pesticide residues and other harmful substances. Such changes can hamper market access among producing countries, particularly if those countries are unprepared to respond (World Bank, 2007a). Recently, over 2,000 metric tonnes of Ghana's cocoa beans, famous all over the world for its very high quality, has been rejected by Japan. The Chocolate and Cocoa Association of Japan appealed to the Ghanaian authorities to take immediate steps to reverse the excessive agro-chemical residues found in some cocoa beans exported to the Asian countries (Naotada, S. 2006).

Cocoa beans are of great economic importance and in other to maintain its quality, suitable bags must be used to prevent both pest and moisture penetration (Aroyeun *et al*., 2006). Unless storage is properly carried out there is the risk of dried cocoa beans becoming damaged from insect infestation, mould and foreign odours (Jonfia-Essien, 2001).

Although various authors have worked on the storage of dried cocoa beans using various storage materials (Gerhardt and Lindgren, 1954), to date no in depth work has been done to evaluate the performance of hermetic storage bags for storing cocoa beans produced in Ghana (Villers *et al*., 2007).

The Cocoa industry has put emphasis on free fatty acids (FFA) content of cocoa beans, known to be affected by humidity, oxygen and insect infestation. Consequently hermetic storage could be helpful in the management of FFA, insect control and quality preservation (BCCCA, 1996).

Hence, in other not to hamper market access due to these defects, the need for this chemical free storage environment (HS) to mitigate the risk.

The main objective of this study was to evaluate the performance of different storage bags in keeping the quality of dried cocoa beans. The specific objectives were:

i. To identify cocoa farmers, purchasing clerks and the different storage materials applied in the study area, ii. To identify the commonest form(s) of defects in cocoa beans in the district, iii. To determine the influence of the different storage bags and periods of storage on cut test attributes of dried cocoa beans, iv. To determine the influence of the different storage bags and periods of storage on the proximate composition of dried cocoa beans and

v. To determine the level of microbial contamination of the dried cocoa beans in the different storage bags over the different storage periods.

CHAPTER TWO

2.0 LITERATURE REVIEW

This chapter gives history of cocoa in Ghana and its contribution to the economy. It also presents information on hermetic storage. Lastly not the least, chemical composition of cocoa bean was also presented here.

2.1THE HISTORY OF COCOA IN GHANA

The Bassel Missionaries first introduced cocoa in Ghana in 1857, by planting the seeds they received from Surinam at Akropong (Grossman-Greene and Bayer, 2009).

Unfortunately, these seeds could not survive hence they tried again with seeds from Cape Palmas the following year (Grossman-Greene and Bayer, 2009). By 1861 these seeds have turned to ten young trees but only one survived by 1863 due to action of termites and beetles. Pods from this tree were distributed to other Basel mission stations at Aburi, Mampong and Krobo-Odumase in the Eastern Region where most of these plants survived (Grossman-Greene and Bayer, 2009). The Dutch, Swiss, and English though played various roles. Ghanaians believe that it was through the instrumentality of Tetteh Quarshie, a Ga blacksmith from Christiansburg that the crop was disseminated and later developed in Ghana (Dand, 1997; Grossman-Greene and Bayer, 2009; Leiter and Harding, 2004). Quarshie is believed to have introduced the crop from Fernando Po to Ghana around 1879. He established cocoa nursery (of about 300 healthy trees) in Mampong- Akwapim and when matured sold pods and seedlings to local farmers (Leiter and Harding, 2004; Grossman-Greene and Bayer, 2009). These trees became the parent trees for Ghana‘s cocoa industry (Grossman-Greene and Bayer, 2009). From Akwapim, cocoa farming spread to Ashanti, Brong Ahafo, Central and Western Regions, and Ghana exported her first batch of cocoa beans 80 pounds worth in 1891. By 1910-1911 Ghana was the leading producer of cocoa, producing about 40,000 tons per year (Grossman-Greene and Bayer, 2009).

Cocoa farms in Ghana are mostly small in size, on individual or family owned plots rarely exceeding three acres till date; there are no large plantations owned by expatriates, multinationals or corporate entities in Ghana (Grossman-Greene and Bayer, 2009). There are also few but very large plantations, owned by local individuals who have employed caretaker farmers in various parts of the Country where, cocoa production is favourable. Perhaps the area where the colonial government had to work hard to develop the growth of the crop was Ashanti (Leiter and Harding 2004). Men in Ashanti did not engage in farming, the women engaged in subsistence farming; so as an inducement the colonial government established model farms allowing anyone who put in 1000 plants the opportunity to buy a Dane gun, one keg of gunpowder and two lead bars (Leiter and Harding, 2004). This contributed to the success in the cocoa sector around 1910-1911 as stated above; by 1939, cocoa accounted for about 80% of the country's total exports (Leiter and Harding, 2004).

The country continued to be the leading producer of cocoa, producing about 570,000 tons annually in the mid-1960s (Raffaelli, 1995; Leiter and Harding, 2004). This success was without recourse to extension services and other infrastructural development, it is difficult to understand why the British were eager to advance the production of the cash crop yet unwilling to create the necessary conditions for this success to be achieved,

Berry in 1992 described the colonial administrators as having―lived on a shoe-string (Leiter and Harding, 2004). They posted limited personnel to the sector, yet they were expected to raise enough revenue to cover their administrative cost since they were not prepared to subsidize recurrent or capital cost (Leiter and Harding, 2004). The administrators did not understand that the traditional method of production used by indigenes was well adapted to plentiful supply of land coupled with inadequate labour; they therefore characterized these practices as unskillful, uninventive, crude, neglectful and disorganized hence believed they resulted in the production of poor quality produce leading to low pricing of commodities from Africa in Europe (Leiter and Harding, 2004). Official policy therefore, wavered between encouraging and limiting export crop production, cocoa production was further confused and constrained with colonial policies, and problems associated with land tenure system; to bring about justice they established a rigid judicial system in Ghana (Berry, 1992; Leiter and Harding, 2004). In a bid to secure good price for the produce, coastal tradesmen, producers and wealthy farmers staged a boycott from 1937-1938 to as they call it ―break the hold European (mainly British) expatriate firms had on the marketing of peasant-produced cocoa overseas (Grossman-Greene and Bayer, 2009). A group of officials who were charged to investigate the drastic decline in cocoa production around 1943 reported that, farmers only collected available crops from the trees without maintaining their farms because they were poorly compensated for their produce. This led to the spread of two major diseases (capsid pest and cocoa swollen shoot virus disease) (Danquah, 2004; Grossman-

Greene and Bayer, 2009). It was so serious that the colonial government‗s report on the Gold Coast in 1947 projected that ―if left unchecked, the cocoa industry would disappear in 20 years (Danquah, 2003; Grossman-Greene and Bayer, 2009).

The quality of Ghana's cocoa beans is not only the issue of taste but also due to low pesticide use compared with what pertains to other big plantations in other producing countries elsewhere in the world (Leiter and Harding, 2004). Small-holders in Ghana cannot afford many pesticides; they therefore resort to traditional methods of pest control as careful weeding, pruning, and waste disposal (Cox, 1993; Leiter and Harding, 2004). Besides, the Ghana COCOBOB monitors the introduction of new pesticides so as to control any possible introduction of new crop contaminants now and then into the industry (Leiter and Harding, 2004).

2.2IMPORTANCE OF COCOA TO THE ECONOMY OF GHANA

Cocoa positioned itself as Ghana's premier cash and principal means of foreign exchange earnings in the 20th century. It therefore, became a focal point in many national policies. Nkrumah's government had an ambitious plan of industrializing Ghana and attempted to use cocoa to bankroll his program (Grossman-Greene and Bayer, 2009). GrossmanGreene and Baryer reported that the period of political instability in the country is due in part to sharp decreases in cocoa prices from 1964-65; emanating from pressure to pay interest on international loans and eagerness to increase funding for education and other developmental projects (Grossman-Greene and Bayer, 2009). Cocoa continued to follow a downward trend in production levels and by 1978-79 seasons Ivory Coast had replaced Ghana as the Worlds' leading producer of cocoa (Ridler, 1993; Grossman-Greene and Bayer, 2009). Grossman-Greene and Bayer of Tulane University have reported that ―as the cost of labour started to increase, government increased its siphoning of cocoa revenue (Grossman-Greene and Bayer, 2009). This indicates that cocoa was the backbone of most of the government developmental projects.

High cocoa production by the nation implies much resources or revenue for the nation to sponsor government policies and projects. Cocoa positioned itself as the main drive for the nation‘s economy; pricing for the commodity was therefore a motivating factor for ensuring higher production. Prices were increased from $34 in 1982 to $471 per ton by the government in 1988/89 season. This was further increased to $640 per ton in 1990. Overall production of the commodity by Ghana subsequently increased to 300,000 tons in 1989/90 crop season (Danquah, 2004; Grossman-Greene and Bayer, 2009). In line with the Structural Adjustment Agreement with the World Bank and the IMF, liberalization of the cocoa sector in 1992/93 season was done with the introduction of private and quasi-private exporting companies; this introduced competition into the sector as reported by Wilcox and Abbott in 2004 (Grossman-Greene and Bayer, 2009). In a

World Bank report by Essegby 2009; on ―Agribusiness and Innovation Systems in Africa, the national goal of Ghana in the 2006/2007 season was ― to produce one million metric tons of cocoa by 2010 by increasing from the 700,000 tons levels in 2007. The Crop Research Institute (CRI) of the COCOBOD was therefore, charged to conduct research into and provide support services to farmers including; distribution of seedlings resistant to CSSV, fertilizers and technical training on farm management practices and in 2008, the COCOBOD was reported to have spent $87,488,569 on CODAPEC free cocoa spraying for cocoa farmers and a further $31,800,000 on solar powered deep wells in farming communities all aimed at boosting farmers‘ morale to enhance quality and high levels of cocoa production(Owusu-Amankwah, 2009; Grossman-Greene and Bayer, 2009).

The construction of Ghana‘s second major hydroelectric power generation dam at Bui is widely believed to have received the financial sponsorship based on some collateralization of the country's cocoa of some kind. The cocoa sector has played significant role in the nation's economic achievements and over the past few years has been the major source of foreign exchange earnings (McKay and Aryeetey, 2004; Begotic *et al.*, 2007; Breisinger *et al.*, 2007; Bulir, 1998). Based on these circumstances the government of Ghana made an announcement on its development vision; declaring the goal of reaching the middle income status by 2015 and reducing the number of poor people beyond the Millennium Development Goal (MDG) level, while emphasizing the importance of the cocoa sector by setting target of a million metric ton production by 2010 (Breisinger *et al.*, 2007; Bulir, 1998; IITA, 2007). While expressing doubts about these goals, skeptics argued that it might not materialize based on the fact that the growth in the cocoa sector is driven by land expansion and increased use of labour rather than by productivity growth (Breisinger *et al.*, 2007; Vigneri, 2007). They also think increase in production level has direct linkage with price incentive to farmers but not removal of constraints to production and productivity enhancing measures (Vigneri 2007; Teal and Zeitlin, 2006). Once again critics believe COCOBOD's operations have not been efficient enough questioning their expenditure in 2006 as representing about eighty five (81%) percent of total agricultural expenditure for that year in Ghana (Breisinger *et al.*, 2007).

The World Bank, however, believed that cocoa can continue to play an important role in Ghana's economic growth toward MIC status (Breisinger *et al.*, 2007; World Development Report by World Bank, 2007). Again, it is believed that Ghana's cocoa production is below international average, suggesting the potential for productivity driven growth (Breisinger *et al.*, 2007; FAO, 2005; ICCO, 2007). New scientific evidence emphasizes health benefits for cocoa consumers which potentially can further boost demand (Breisinger *et al.*, 2007; FAO, 2005). Furthermore, the Government of Ghana has indicated its willingness to carry through its continued liberalization of buying companies to contribute to output and productivity growth (Breisinger *et al.*, 2007; Varangis and Schreiber, 2001; Laven, 2007). Cocoa indeed plays a large role in Ghana‘s economy and employs many small scale farmers (Breisinger *et al.*, 2007). Cocoa production hit all-time high of 3.6 million metric tons in 2005/6 year with West African countries including Ghana accounting for over 70 percent of the world production (ICCO, 2007).

Ghana planned to increase its production by 100,000 tons per annum and due to combination of factors as mass spraying programmes, fertilizer credits, government backed rehabilitation programmes, partial liberalization, establishment of price stabilization policy, higher producer prices; the country has been the most successful of all cocoa exporters (Breisinger *et al.*, 2007; FAO, 2005, Laven, 2007). Cocoa production more than doubled from 395,000 tons in 2000 to 740,000 tons in 2005, contributing 28 percent of agricultural growth in 2006 (Begotic *et al.*, 2007; Breisinger *et al.*, 2007). This makes the sector‘s performance more impressive following the country‘s earlier elasticity in production (Abdulai and Rieder, 1995). The boost led to an increase in agricultural GDP from 13.7 percent in 2003/2004 to 18.9 percent in 2005/2006 (Breisinger *et al.*, 2007). Producer price rose by about $260 between 2000 and 2006. The FAO and Ministry of Food and Agriculture (MOFA) estimates that achievable yields for cocoa is about 1-1.5 tons per hectare per year; more than double the average yields in 2005 (Breisinger *et al.*, 2007; FAO 2005). In 2005, cocoa beans (24.3%) and cocoa products (3.8 %) together contributed about 28 percent of total exports accounting for about half of agricultural exports (Breisinger *et al.*, 2007). Africa processed on the average 15 percent of cocoa products. However, Ghana's processed cocoa is below Africa's average ranging from 8 to 12 percent. Domestic food industries that use cocoa as raw material is small hence value addition are low limiting its contribution to economic growth (Breisinger *et al.*, 2007). There is, however, an encouraging development, the value of processed beans went up from US$83.6 million in 2004 toUS$152.9 million in 2006 (MoFA, 2007 and Breisinger *et al*., 2007). Levy on export tax on cocoa has, however, declined over the years, reducing from 16 percent in 1960s to 12 percent in 1990s and to about 5 percent in 2005(BoG, 2007 and ISSER, 2001 in Breisinger *et al.*, 2007). National poverty reduced from 51.7 percent in 1991 /92 to 39.5 in 1998/99 and then to 28.5 in 2005/2006 (Breisinger *et al.*, 2007). Poverty among cocoa farmers is also believed to have reduced drastically; from 60.1percent or over 281,600 cocoa farmers in 1991/92 to 23.9 percent or 112,000 cocoa farmers in 2006 (Coulombe and Wodon, 2007; Breisinger *et al.*, 2007).

The cocoa sector offers many economic and social advantages to the Ghanaian economy due to the high quality standard of Ghana's cocoa. Canatus and Aikins, (2009), argue that the cocoa industry is the backbone of Ghana's economy. Again, contrary to economic indices which label gold as the largest foreign exchange earner, Tutu (2011), cited by the Ghana News Agency, (2011), 15th February edition, observes that cocoa is the largest foreign exchange earner for Ghana. He posits that an investment of one dollar ($1.00) in the minerals sector earns two dollars while the same amount of investment in the cocoa sector earns about seventeen dollars ($17.00).

A major problem here is that cocoa production is geographically concentrated and its contribution to poverty reduction is not evenly distributed (Breisinger *et al.*, 2007). From Ghana Living Standard Survey-5 (GLSS-5) about two-thirds (2/3) of the country's cocoa is produced in the forest zone, where rural poverty levels are below the national average and about 30 percent in the Southern Savanna zone (mainly Brong-Ahafo Region) and the Coastal zone takes the rest (GSS Survey, 2005/2006).

In the North where poverty is endemic, natural conditions are not suitable for cocoa production (Breisinger *et al.*, 2007). The rural household generates only 30 percent of their Agriculture income from cocoa with the rural poor getting about 10 percent of income from cocoa (Breisinger *et al.*, 2007).

2.3 QUALITY OF COCOA BEANS

Ghana cocoa is subjected to a minimum of three stages of quality inspection prior to shipment. This gives added assurance and confidence to the customers to buy Ghana Cocoa at all times. Quality Control Company (QCC) of COCOBOD's monitors the quality of the beans along the cocoa value chain from production to export. QCC provides all the inspection, grading and certification services. First inspection takes place at the society/village level before purchase is done by the Licence Buying Companies (LBC's) marketing clerks (MC). A second inspection is carried out at the District depots by QCC before movement to take-over points at Kaase in Kumasi, Tema and Takoradi ports. A third inspection is carried out at the port before the cocoa is taken-over by CMC and a final inspection, before shipment/export. All such quality checks are done to ensure that the quality, as seen during original inspection and certification is maintained and consistent.

2.3.1 Quality Control

It is very important that exported cocoa beans are of good quality since this will affect the quality of the final cocoa product. 60 % of Ghana's exported cocoa beans go to Europe, and the chocolate companies favor to buy the best quality of cocoa beans (Amoa-Awua, 2007; Mankatah, 2010).

Cocoa beans of good quality are free from insect holes, smoky and flat beans. They are not excessively acidic, bitter or astringent, and they have uniform sizes. They should also be well fermented, have a moisture content of maximum 7.5 %, a free fatty acid content maximum 1.5 % and a cocoa butter content between 45 and 60 %. Finally, too high levels of foreign matters, insects and harmful bacteria and pesticides residues are not allowed (Mankatah, 2010).

International standards are made to measure quality of cocoa beans. This is performed via a cut test where the cocoa beans are cut lengthwise and visually divided after quality. Purple beans, slaty beans and beans with all other defectiveness are grouped. Defectiveness among cocoa beans includes flat, moldy and geminated beans (Asare, 2010, Lockhart, 2010). Table 2 shows the causes of defected beans.

Definition and perceptions of cocoa bean quality the international cocoa market defines quality in four main ways, as applied and certified in exporter buyer contracts: (1) physical quality; (2) biochemical quality; (3) process quality; and (4) origin quality (Asuming Brempong *et al.*, 2008; Paulsen *et al.*, 1996).

Process quality refers to the production process of cocoa: whether organic or inorganic methods are employed; whether child labour is used; and whether the production process and subsequent rewards benefit the farmer and his community (fair trade) (Ponte and Gibbon, 2005). The farmers and the LBCs interviewed did not consider that process quality was an important component of cocoa bean quality. COCOBOD is, however, interested in maintaining Ghana's good quality image on the international market and has taken steps to include process quality control into its policies. For instance, child labour on cocoa farms in Ghana has been minimized. Some cocoa districts have been marked as organic cocoa zones, while Kuapa Kokoo Ltd has been certified as a fair trade LBC. In general, however, the results from the interviews with farmers revealed that the majority of the respondents (71%) acknowledged the importance of cocoa bean quality to the development of the sector. Also, all of the LBC staff interviewed regarded cocoa bean quality as being important to the sector (Ponte and Gibbon, 2005).

Table 2.1: Causes of defective beans

Defective Beans	Cause

Slaty	A dark color indicates that the bean has not been fermented. Slaty beans have not developed the characteristic chocolate aromas and brown color.
Purple	The beans are under fermented. Glycosides have not yet broken down.
Dark	Too slow drying of the beans, or drying on metal. Beans from black pod diseased pods.
Flat	The beans are collected from immature pods.
Mouldy	Develops when moisture content has not been reduced to less than 7.5 %.
Germinated	Fermenting in holes in the ground. Not turning the beans during fermentation. Leaving unharvested, ripe pods on the trees for several days.

Source: Asare, 2010.

CHAPTER THREE

3.0 MATERIALS AND METHODS

The study conducted to find out common forms of defects in cocoa beans from the view of purchasing clerks and influence of storage of cocoa beans in different storage materials at varying time interval on the quality of cocoa beans. It was in two parts namely, a questionnaire survey and laboratory investigations.

3.1 DESCRIPTION OF STUDY AREA

The study was conducted at Samreboi Cocoa District which is part of Wassa Amenfi West District of Western Region of Ghana. The region is situated between Latitude

400’N and 500˚40’N and Longitudes 10˚45’ W and 20 10’W. Asankraguah is the administrative capital and shares boundries with Aowin, Wassa Amenfi East, BibianiAnhwiaso-Bekwai and Wassa Amenfi Central Districts with a total land area of 2354 sq. km.

3.2PHASE ONE: FIELD SURVEY

Part one of the studies was a questionnaire survey conducted in the cocoa district on randomly selected Purchasing Clerks (PCs) of Licensed Buying Companies (LBCs) to find out about qualities of cocoa beans they purchase, common form of defects and problems associated with storage cocoa beans they purchased in cocoa beans in the district. The main objective of the preliminary survey was to validate the methods used in cocoa beans storage in the district. It was also to find out the knowledge of the PCs in post-harvest processing of cocoa beans over the years. The findings were to form the basis for the laboratory investigations.

3.2.1Questionnaire Survey

A validated pre-tested questionnaire (Appendix I) was administered to Purchasing Clerks (PCs) of Licensed Buying Companies (LBCs). The questionnaire for PCs was made up of two sections mainly background information of the respondents (Purchasing Clerks) and qualities, forms of defects and problems in cocoa beans storage.

3.2.2Technique for Sample Selection

The convenient randomized sampling technique was used since the exact number of Purchasing Clerks in the district could not be quantified. Sampling was done until 70 Purchasing clerks were interviewed.

3.3PHASE TWO: COCOA BEANS PREPARATION

3.3.1 Harvesting

Ripe cocoa (*Theobroma cacao* L.) pods of which all the matured pods turned from green to yellow-of mixed- hybrids were harvested by hand during the main 2013/14 cocoa season in October 2013 from a farm in Samreboi in the Wasa Amenfi West District in the Western Region of Ghana. Hands reached pods were harvested with the aid of cutlass, while those at the top of the trees were harvested with "Go-to-Hell". With the aid of baskets, the pods were assembled at conveying point for the pods to be broken.

3.3.2 Cocoa Pod Breaking

Cocoa pods were broken using cutlass (small and short). The beans were removed from the husks. All germinated, black or diseased beans or pieces of shell fragments were discarded.

3.3.3 Cocoa Fermentation

The beans were fermented by the heap method. Fresh banana leaves were laid on the ground and the mass of beans, heaped on it. The heaped wet cocoa beans were then covered with other fresh banana leaves and held in position with pieces of wood and banana pseudostem. The heaped beans remains under this condition for six consecutive days and turned twice (2nd and 4th days) to facilitate adequate aeration of fermenting mass and to ensure that beans from the top and bottom are thoroughly mixed together. Whilst turning, the placenta, pieces of shell fragments and any other foreign materials were removed. A fresh layer of banana leaves were added to the original leaves after each turning to ensure adequate insulation.

3.3.4 Drying Method - Sun Drying Methods

From the fermentation point on the seventh day, the cocoa beans were brought and spread on a raised mat - 1m above ground level. Natural or sun drying process was used. The spread beans were turned in an hourly interval to ensure uniformity in the drying process. During turning, the beans were cleansed by picking or removing pieces of pod husk, placenta, defective beans, and foreign material as well as separating beans which stick closely together. In the process, beans were heaped and covered when it threatened to rain; same was done in the evenings. With little experience, the characteristic features of dried beans were determined after 7 days by the feel and rattling of beans when hand was thrust into it. The dried state was confirmed at 7% moisture content with the aid of Acqua-Boy moisture meter. Beans were weighed and allotted into the various treatments.

3.3.5 Sampling of Dry Cocoa Beans

Dried cocoa beans were removed from sacks packed in lots of 30 bags. The beans were removed from the sides, front and back of each bag by a stabbed metal horn. The horned beans were bulked, mixed thoroughly and quartered. One opposite quarter was rejected and the process repeated until a final sample of slightly more than 15 kilos of beans were obtained.

3.4 EXPERIMENTAL DETAILS

3.4.1 Treatment

The experiment consisted of 3 storage materials (Factor A) with seven levels of periods of storage (Factor B).

The three storage materials were:

Jute sack - T_1

Woven nylon - T_2

Hermetic bag - T_3

Levels of period of storage (month(s))

0 - ST_0 (Control)

1 - ST_1

2 - ST_2

3 - ST_3

4 - ST_4

5 - ST_5

6 - ST_6

3.4.2 Design and Layout of Experiment

The design was a 3×7 factorial arrangement laid out in a completely randomized design (CRD) with three replications. There were 24 combinations of experimental treatments in the set up. The hermetic block was made up of 18 small bags where 3 were taken at each sampling time to avoid alteration in gases as soon as the bags are opened and resealed.

3.5CUT TEST

Average bean weight is expected to be 1.0 - 1.2 g with 1.0 g as a minimum. These figures are equivalent to 83-100 beans per 100 g (Wood, 1986) and this is placed in category (Cat) "A". Beans for this experiment were placed in Cat. A.

The cut test which is a cocoa grading scheme based on visual assessment of quality of cocoa and which relies on changes in colour of the beans is the standard test used to assess the suitability of cocoa beans at all the sampling periods. Points were given for bean dimension. colour, odour and the absence of imperfect beans. The procedure involved filling three equal sized white calico clothed sampling bags ($5.7dm^3$) with wellmixed beans. The mixed beans were quartered leaving a heap of slightly more than 300 beans, which were used to fill the sampling bags. Each sampling bag was left with 300 beans and was cut length-wise through the middle to expose the internal surface of the two cotyledons of which a half was laid out on a board.

The cut beans were examined in good daylight and the percentage total purple (deep, pale and partly brown/partly purple) beans were determined (this involves counting 3 purple surface scoring 1 point and this defects should not exceed 3 points or 9 surfaces in a lot) and recorded. Percentages of other defective categories (mouldy, slaty, insect infested, flat and germinated beans) were also determined with same principle (Appendix 7). Purity test (PTY) was determined using the formular

PTY= (100-M+G+S+P+W+OD) where M=mould, G=germinated, S=slate, P=purple, W=weevil, OD=other defects.

The beans were GRADE I as the defective beans did not exceed the following percentages: Mould – maximum 3 per cent by count, Slaty beans – maximum 3 per cent by count and Insect damaged, germinated or flat beans total maximum 3 per cent by count.

3.6CHEMICAL ANALYSIS OF THE COCOA BEAN

The cocoa beans (test samples) were subjected to proximate analysis by the methods outlined by Pousga *et al.,* (2007). The Atomic Absorption Spectrophotometer (AAS) was used to determine the mineral content of the by-product. All analyses were done in triplicate. All laboratory analyses were done at KNUST biochemistry laboratory in triplicates.

3.6.1 Determination of Moisture Content

This method was based on moisture evaporation used by Pousga *et al.,* (2007). In this method, aluminum dishes were washed dried in oven and desiccators for cooling. The weight of each dish was taken. Hundred grammes (100 g) of each sample of cocoa powder were weighed into a sterile aluminium dish; weight of the dish and weight of sun dried sample (in triplicate) were taken. This was transferred into an oven and set at 100ºC and less than 100 mm Hg for approximately 5 hours after which the dish was removed from the oven, covered, cooled in desiccator, and weighed. Then the weight was measured using a measuring scale balance. It was transferred back into the oven for another one hour and then reweighed. The process continued until a constant weight was obtained. The difference in weight between the initial weight and the constant weight gained was taken as the moisture content. The loss in weight multiplied by 100 over the original weight is percentage moisture content. The formula used is presented below:

$$\text{Moisture content (g/100g)} = \frac{\text{Lost in weight } (W_2 - W_1)}{\text{Original weight of sample } (W_2 - W_1)} \times 100\%$$

Where W1= initial weight of empty crucible, W_2 = weight of crucible + SNC before drying, W_3 = final weight of crucible + SNC after drying. % Total solid (Dry matter) (%) = 100 - moisture (%)

3.6.2 Ash Content

The ash represents the inorganic component (minerals) of the sample after all moisture has been removed as well as the organic material. The ash content was determined according to Pousga *et al.*, (2007). Approximately 1g of finely ground sample was weighed into porcelain crucible which had been ignited. The crucible was placed in a muffled furnace and heated at 500ºC for four hours, removed and cooled. The ignited residue was moistened with 2 ml distilled water and slowly and carefully 5 ml of 8 N HCl (2 parts of conc. HCl was mixed with one part of water). It was transferred again into the cool muffle furnace and the temperature was increased step wise to 550 ± 5°C. The temperature was maintained for 8 hours until white ash was obtained. It was then brought out and allowed to cool in a desiccator and weighed again. Percentage weight was calculated as weight of ash multiplied by 100 over original weight of the samples used.

The formula used is presented as:

$$\text{Ash content (\%)} = \frac{\text{Weight of ash}}{\text{Weight of original sample}} \times 100\%$$

3.6.3 Crude Fiber

Crude fiber content was determined according to methods adopted by Pousga *et al.*, (2007). Twenty grams (20 g) of each ground cocoa beans powder samples were defatted separately with Diethyl ether for 8 hours and boiled under reflux for exactly 30 min with 200 ml of 1.21% H_2SO_4. It was then filtered through cheese cloth on a fluted funnel. This was later washed with boiling water to completely remove the acid. The residue was then boiled in a round bottomed flask with 200 ml of 1.21% Sodium hydroxide (NaOH) for another 30 min and filtered through previously weighed couch crucible. The crucible was then dried with samples in an oven at 100°C, left to cool in a desiccator and later weighed. This was later incinerated in a muffle furnace at 600°C for 3 hours and later allowed to cool in a desiccator and weighed. The formula used is presented as:

$$\text{Fibre content (\%)} = \frac{\text{Weight of fibre}}{\text{Weight of original sample}} \times 100\%$$

3.6.4 Crude Protein Determination

Total protein was determined by the Kjeldahl method as modified by Pousga *et al.*, (2007). The analyses of protein content in a compound by Kjeldahl method is based upon the determination of the amount of reduced nitrogen present. Thirty grams (30 g) of each sample was weighed into a filter paper and put into a Kjedahl flask, 10 tablets of Na2SO4 were added with 1 g of $CuSO_4$ respectively. Twenty millilitres (20 ml) of concentrated

H_2SO_4 were added and then digested in a fume cupboard until the solution became colourless. It was cooled overnight and transferred into a 500 ml flat bottom flask with 200 ml of distilled water. This was then cooled with the aid of packs of ice block. About 70 ml of 40 percent NaOH were poured into the conical flask which was used as the receiver with 50 ml of 4 percent boric acid using methyl red as indicator. The ammonia gas was then distilled into the receiver until the whole gas evaporated. Titration was done in the receiver with 0.1 N H_2SO_4 until the solution became colourless. The formula used was presented as:

$$\text{Protein content (\%)} = \frac{Vs - Vb \times 0.01401 \times N\ acid\ (6.25)}{\text{Weight of original sample used}} \times 100\%$$

Where Vs = Volume (ml) of acid required to titrate sample; Vb = Volume (ml) of acid required to titrate blank; N acid = normality of acid.

3.6.5 Determination of pH

The pH determination was in accordance with the procedures of the Office International du Cacao et du Chocolat (OICC) (1972). Ten grams of ground cocoa beans was extracted with 90 ml boiling de-ionized water. The cocoa was extracted for 10 min, cooled to 25°C, and the pH was determined using a Mettle-Toledo pH meter.

3.6.6 Determination of Free fatty acid

Free fatty acid content was determined using titration method (ISC, 1998). Fat obtained from extraction is dissolved in warm ethanol and then titrated using alkali solution (NaOH 0.1N). Free fatty acid was calculated and expressed as the percentage of mass per mass using the following formula:

$$\% \text{ free fatty acid content} = \frac{V \times N}{M} \times \frac{100}{100 - mc}$$

V = the volume, in ml, of NaOH

N = the normality of NaOH solution

M = the mass, in grams, of cocoa bean lipid and Mc = moisture content

3.6.7 Determination of Fat Content

The method employed was the Soxhlet extraction technique adopted by Pousga *et al.*, (2007). Twenty grams of the samples were weighed and carefully placed inside a fat free thimble. This was covered with cotton wool to avoid loss of the sample. The loaded thimble was put in the Soxhlet extractor and about 200 ml of petroleum ether poured into a weighed fat free soxhlet flask with the flask attached to the extractor. The flask was placed on a heating mantle such that the petroleum ether in the flask refluxed. Cooling was achieved by a running tap connected to the extractor for at least 6 hours after which the solvent was completely siphoned into the flask. Rotary vacuum evaporator was used to evaporate the solvent leaving behind the extracted lipids in the soxhlet. The flask was removed from the evaporator and dried to a constant weight in the oven at 60°C. The flask was then cooled in a desiccator and weighed. Each determination was done in triplicate. The amount of fat extracted was calculated by the formula presented below:

$$\text{Ether Extract (EE) \%} = \frac{\text{Weight of extracted lipids (g)}}{\text{Weight of dry sample (g)}} \times 100\%$$

3.6.8 Nitrogen- free Extracts (NFEs)

Nitrogen-free extracts (NFEs) represents the soluble carbohydrate of a feed, such as starch and sugars. This is determined by subtracting each of the other components (percent crude protein, crude fat, crude fibre, moisture and ash) from 100 (Crampton *et al.*, 1969).

3.7 FUNGAL ISOLATION AND IDENTIFICATION

Fungi population was determined by dilution method followed by pure plate method using Dichlorane 18% Glycerol Agar (DG18) (Pitt and Hocking). Fungi species were identified using works done by (Samson *et al.*, 1996, Pitt and Hocking) as the main references.

3.8 DATA ANALYSIS AND INTERPRETATION

The data gathered from the field survey were coded and analyzed using descriptive statistics of the Statistical Package for Social Sciences now known as Statistical Product and Service Solutions (SPSS) software (version 19.0). The descriptive statistics used were frequencies, percentages, means and statement form.

Square root transformation was used to transform data collected from cut test, weevil population and microbial contamination before subjecting them to analysis. The transformed data of the cut test, weevil population, and microbial contamination and data from the proximate analyses were subjected to analysis of variance (ANOVA) using Statistix Student Version 9. Tukey's HSD (Honest Significant Difference) was used for mean separation at probability level of 0.01.

CHAPTER FOUR

4.0 RESULTS

This chapter gives the results of the study. It comprises 2 components: field survey and laboratory analysis (cut test and proximate analysis).

4.1 FIELD SURVEY

4.1.1 Background information of respondents

Table 4.1 presents the background information of respondents. On average, there was a clear dominance of males (85.7%), as against females (14.3%). With regards to age of respondents, majority (45.7%) of them were aged 30 – 40 years followed by 41 – 50, less than 30, 51 – 60 and over 60 years with 27.2, 21.4, 4.3 and 1.4% respectively. Most (97.1%) of the respondents have had a form of formal education. Moreover, majority (92.9) of the respondents had at least two (2) years' experience in cocoa purchasing business.

Table 4.1: Background information of purchasing clerks (PCs)

Item	Frequency	Per cent
Sex		
Male	60	85.7
Female	10	14.3
Total	**70**	**100**

Age (years)		
Less than 30	15	21.4
30–40	32	45.7
41–50	19	27.2
51–60	3	4.3
Over 60	1	1.4
Total	**70**	**100**
Level of education Non-formal	2	2.9
Primary	12	17.1
MSLC	9	12.9
JSS	5	7.1
SSS	25	35.7
Tertiary	17	24.3
Total	**70**	**100**
No. of years in business as PC		
Less than 2	5	7.1
Above 2 to 4	14	20
Above 4 to 6	12	17.1
Above 6 to 8	8	11.4
Over 8	31	44.4
Total	**70**	**100**

4.1.2 Preference of Cocoa License Buying Companies (LBCs) on quality of cocoa beans to purchase

Table 4.2 gives the responses of Cocoa License Buying Companies on their perception of quality of cocoa beans. The study showed that 37.1% indicated that they preferred mould free cocoa beans whilst 25, 14.2 and 12.1% reported that they preferred well dried, impurities free and purple free beans respectively. However, 10.8% preferred insects free and uniform colour cocoa beans.

Table 4.2: Preference of License Buying Companies (LBCs) on quality of beans to purchase

Qualities	Frequency	Per cent
Well dried	30	25.0
Purple free	15	12.5
Impurities free	17	14.2
Mould free	45	
Others (Specify)		
Insects free	5	4.2
Uniform colour	8	6.6
Total	**120**	**100**

NB: Total N is greater than sample size because some respondents chose more than one quality

4.1.3 A Ranking of different forms of defects observed in cocoa beans purchased Table 4.3 shows that the five most common forms of defect observed in cocoa beans purchased were wet beans (65.7%) followed by mouldy beans (35.7%), slaty beans (27.1%), impurities (38.1%) and purple beans (42.9%).

Table 4.3: A Ranking of different forms of defects observed in cocoa beans purchased

Defectives and ranks	Frequency	Per cent
First rank defectives		
Wet beans	46	**65.7**
Mouldy beans	1	1.4
Purple beans	23	32.9
Total	**70**	**100**

Second rank defectives Wet beans	16	22.9
Mouldy beans	25	**35.7**
Purple beans	8	11.4
Impurities	12	17.1
Poorly polished beans	2	2.9
Insect attack	2	2.9
Small size beans	5	7.1
Total	**70**	**100**
Third rank defectives Wet beans	1	1.4
Mouldy beans	7	10
Purple beans	17	24.3
Slaty beans	19	**27.1**
Impurities	10	14.3
Poorly polished beans	6	8.6
Small size beans	10	14.3
Total	**70**	**100**
Forth rank defectives Mouldy beans	10	14.3
Purple beans	5	7.1
Slaty beans	19	27.1
Impurities	27	**38.7**
Poorly polished beans	4	5.7
Small size beans	5	7.1
Total	**70**	**100**
Fifth rank defectives Mouldy beans	6	8.6
Purple beans	30	**42.9**
Slaty beans	6	8.6
Impurities	13	18.5
Insect attack	4	5.7
Small size beans	11	15.7
Total	**70**	**100**

4.1.4 Problems encountered by Cocoa License Buying Companies during Storage of

Cocoa Beans

Table 4.4 showed the result of problems encountered by cocoa LBCs during storage of purchased cocoa beans. Most (72.9%) of the cocoa LBCs indicated that they encountered problems during storage of cocoa beans purchased whilst 27.1% indicated that they did not encounter any problem. Major problems during storage were mouldy beans (37.3%), rotten beans (17.6%) and insects attack (15.7%). Others include loss of weight (13.7%); theft (9.8%) and rodent attack (5.9%).

Among those who encountered problems during storage, 49% indicated that they did additional drying to ensure extended shelf life. Again, 45.1% reported that they fumigated to minimize pest infestation. Whilst 5.9% reported the use of other strategies such as application of pesticides (insecticides or rodenticide) to manage the problems associated with storage of cocoa beans.

Table 4.4: Problems encountered by Cocoa License Buying Companies during storage of cocoa beans.

Item	Frequency	Per cent

Do you encounter problems		
Yes	51	72.9
No	19	27.1
Total	**70**	**100**
Major problems Mouldy beans	19	37.3
Insect attack	8	15.7
Rotten beans	9	17.6
Loss of weight	7	13.7
Stealing	5	9.8
Rodent attack	3	5.9
Total	**51**	**100**
Measures adopted to forestall above problems		
Fumigation	23	45.1
Drying	25	49
Application of pesticide	3	5.9
Total	**51**	**100**

4.2 CUT TEST

4.2.1 Effect of storage materials and period of storage on mouldiness of beans Storage materials had significant ($p \leq 0.01$) effect on mould development among the cocoa beans stored. Jute sack produced 0.91% mould which was similar to the effect of woven nylon (0.93%) but effect of either jute sack or woven nylon was significantly higher than effect of hermetic bag which recorded 0.78% (Table 4.5).

Duration of storage of cocoa beans resulted in significant ($p \leq 0.01$) impact on mould development of beans stored. Storage at 0, 1, and 3 months were statistically similar in mould development but significantly different ($p \leq 0.01$) and lower than storage at 2, 4, 5 and 6 months. The 5th and 6th months recorded 1.09% and 1.14% mould respectively which were statistically similar but effect of either was different from storage at 2nd and 4th month (0.84 and 0.87% mould respectively) (Table 4.5).

Storage materials and duration of storage interacted significantly ($p \leq 0.01$) resulting in mould development. Hermetic bag recorded 0.71% of mould throughout the sampling periods except at the 2nd month of storage which recorded 1.11% mouldiness. However, beans stored in Jute sack and woven nylon recorded similar mould of 0.71% from 0 to 4 and 0 -3 months respectively and these were similar to hermetic bag in the various months except the 2nd month of storage. Again, jute sack at the 6th month and woven nylon at the 5th month had similar mouldiness but the effect of jute sack at the 6th month was statistically different from jute sack at the 5th month, woven nylon (at 4th and 6th months of storage) and hermetic bag at the 2nd month. Jute sack at the 5th month storage and woven nylon at 5th and 6th months of storage produced similar mouldy cocoa beans but were statistically different from woven nylon at the 4th month (1.11%) of storage and hermetic bag at the 2nd month (1.11%) of storage. The latter two interactive effects were statistically similar (Table 4.5).

Table 4.5: Effect of storage materials and periods of storage on mouldiness of cocoa beans

Storage material	Initial (0)	1	2	3	4	5	6	Mean (SM)
	Duration of storage (DS) (months)							
	Mouldiness (%)							
Jute sack	0.71	0.71	0.71	0.71	0.81	1.23	1.48	**0.91**
Woven nylon	0.71	0.71	0.71	0.71	1.11	1.34	1.22	**0.93**
Hermetic bag	0.71	0.71	1.11	0.71	0.71	0.71	0.71	**0.73**
Mean	**0.71**	**0.71**	**0.84**	**0.71**	**0.87**	**1.09**	**1.14**	

HSD (0.01) SM = 0.06 (s) DS = 0.11 (s) SM×SP = 0.22 (s)
CV (%) = 7.18

"s" means significant at probability level of 1%

4.2.2 Effect of storage materials and period of storage on germination of cocoa beans

Germinated beans in the stored cocoa beans were significantly ($p \leq 0.01$) influenced by storage materials. The effect followed in order of woven nylon (0.90%), jute sack (0.79%) and hermetic bag (0.77%). Storage materials used were statistically different from each other (Table 4.6).

Table 4.6: Effect of storage materials and periods on germination habits of cocoa beans

Storage material	Initial (0)	1	2	3	4	5	6	Mean (SM)
	Duration of storage (DS) (months)							
	Germinated beans (%)							
Jute sack	0.71	0.71	0.71	0.71	0.71	1.11	0.89	**0.79**

Woven nylon	0.71	1.09	0.71	0.71	1.10	1.11	0.89	**0.90**
Hermetic bag	0.71	0.71	0.71	0.71	0.71	0.71	1.10	**0.77**
Mean	**0.71**	**0.84**	**0.71**	**0.71**	**0.84**	**0.98**	**0.96**	

HSD (0.01)	SM = 0.03 (s)	DS = 0.06(s)	SM×SP = 0.13 (s)
CV (%) = 4.44			

"s" means significant at probability level 1%

Duration of storage of cocoa beans had significant ($p \leq 0.01$) influence on germinated beans in the stored beans. Storage at 0, 2 and 3 months were statistically similar (0.71%) which were significantly different and lower than storage at 1 and 4 months (0.84%), 5 months (0.98%) and 6 months (0.96%). Storage at 1 and 4 months produced similar germinated beans but were statistically different and lower than storage at 5 and 6 months. The latter two were also similar in germinated beans (Table 4.6).

Storage materials and duration of storage had significant ($p \leq 0.01$) influence on germinated beans. Jute sack at 0, 1, 2, 3 and 4 months, woven nylon at 0, 2 and 3 months and hermetic bag at 0 to 5 months maintained similar number of germinated beans of 0.71% but these were different from germinated beans recorded in jute sack at 5 and 6 months produced (1.11% and 0.89% respectively), woven nylon at 1, 4, 5 and 6 months (1.09%, 1.10%, 1.11% and 0.89% respectively) and hermetic bag at 6th month which produced 1.10% germinated beans. However, the germinated beans recorded in jute sack at 5 months and those in woven nylon at 1st, 4th and 5th months and hermetic bag at 6th month were similar but effect of either was statistically different and higher than jute sack and woven nylon at the 6th month (Table 4.6).

4.2.3 Effect of storage materials and period of storage on slatiness of cocoa beans Slate development of stored cocoa beans was significantly ($p \leq 0.01$) different among the storage materials. Beans stored in jute sack had the highest significance (1.08%) followed by hermetic bag (1.02%) and woven nylon recorded the least significance (0.99%) but woven nylon and hermetic bag recorded no significant difference (Table 4.7).

Duration of storage of cocoa beans resulted in significant development ($p \leq 0.01$) among all the storage times. Storage at 1st and 6th months produced 1.18% of slaty beans which were statistically different from storage at 0, 2, 3, 4 and 5 months (1.10%, 1%, 1.10%, 0.71% and 0.94% respectively). Storage at 0 and 3 months slaty beans were similar but statistically different from 2, 4 and 5 months. Effect of storage at 2 and 5 months were similar however, effect of either on slaty beans development was higher and different from at 4 months (Table 4.7).

Storage materials and duration of storage interacted significantly ($p \leq 0.01$) resulting in slaty beans development in the stored cocoa beans. Jute sack at 0, 1, 2, 3,5 and 6 months, woven nylon at 0, 1, 3 and 6 months and hermetic bag at 0, 1, 3 and 6 months produced slaty beans in the range of 1.10 – 1.22% which were similar but statistically different from storage in woven nylon at 2 months (0.89%) and hermetic bag at 2 and 5 months each producing 0.89% of slaty beans and these (woven nylon at 2 months and hermetic bag at 2 and 5 months) were different from jute sack at 4 months, woven nylon at 4 months and hermetic bag at 4 months which produced similar slaty beans of 0.71% (Table 4.7

Table 4.7: Effect of storage materials and periods of storage on slatiness of cocoa beans

Storage material	Duration of storage (DS) (months)							
(SM)	Initial (0)	1	2	3	4	5	6	**Mean**

	Slaty beans (%)							
Jute sack	1.10	1.10	1.22	1.10	0.71	1.22	1.09	**1.08**
Woven nylon	1.10	1.22	0.89	1.10	0.71	0.71	1.22	**0.99**
Hermetic bag	1.10	1.22	0.89	1.10	0.71	0.89	1.22	**1.02**
Mean	**1.10**	**1.18**	**1.00**	**1.10**	**0.71**	**0.94**	**1.18**	
HSD (0.01)	SM = 0.04 (s)		DS = 0.08 (s)		SM×SP = 0.17 (s)			
CV (%) = 4.50								

“s” means significant at probability level of 1%

4.2.4 Effect of storage materials and period of storage on purple beans incidence

Incidence of purple beans was not significantly ($p \geq 0.01$) influenced by storage materials. Purple beans incidence ranged between 1.19% and 1.43% (Table 4.8).

Duration of storage of cocoa beans had no significant ($p \geq 0.01$) influenced on purple beans (Table 4.8).

Interactive effect of storage materials and time of storage had no significant ($p \geq 0.01$) influence on purple beans development in the stored dried cocoa beans (Table 4.8).

Table 4.8: Effect of storage materials and periods of storage on the incidence of purple beans

Storage material (SM)	Duration of storage (months)							
	Initial (0)	1	2	3	4	5	6	**Mean**
				Purple bean (%)				
Jute sack	1.48	1.22	1.22	1.10	1.22	1.22	0.89	**1.19**
Woven nylon	1.48	1.22	1.34	1.36	1.22	1.57	1.34	**1.32**

Hermetic bag	1.48	1.48	1.48	1.34	1.47	1.71	1.22	**1.43**
Mean	**1.48**	**1.15**	**1.35**	**1.27**	**1.30**	**1.50**	**1.15**	
HSD (0.01) CV (%) = 1.89	SM = 0.24 (s)		DS = 0.43 (ns)		SM×SP = 0.89 (ns)			

4.2.6 Effect of storage materials and period of storage on incidence of weevil infestation in cocoa beans

Storage materials significantly influenced (*$p \leq 0.01$*) percentage of beans with weevils. Woven nylon produced weevil population of 0.90% which was similar to jute sack with 0.85%. Effect of either was different from hermetic bag which recorded 0.71% (Table 4.10).

Duration of storage had significant (*$p \leq 0.01$*) effect on beans with weevils in the stored cocoa beans. 0, 1, 2, 3 and 5 months produced similar weevil beans of 0.71% which was different and lower than storage times of 4 and 6 months which produced 1.14% and 1.01% (Table 4.10).

Storage materials and duration of storage had significant (*$p \leq 0.01$*) influence on beans weevils. Jute sack at 4 and 6 months and woven nylon at 4 and 6 months produced beans with weevils in the range of 1.17 – 1.56% which were similar but statistically different from the other interactive effects (Table 4.10).

Table 4.10: Effect of storage materials and periods of storage on incidence of weevil infestation in cocoa beans

Storage material (SM)	Duration of storage (months)							
	Initial (0)	1	2	3	4	5	6	**Mean**
	Weevil population							

Jute sack	0.71	0.71	0.71	0.71	1.17	0.71	1.22	**0.85**
Woven nylon	0.71	0.71	0.71	0.71	1.56	0.71	1.22	**0.90**
Hermetic bag	0.71	0.71	0.71	0.71	0.71	0.71	0.71	**0.71**
Mean	**0.71**	**0.71**	**0.71**	**0.71**	**1.15**	**0.71**	**1.05**	
HSD (0.01)	DS SM = 0.11 (s) = 0.20 (s)				SM×SP = 0.42 (s)			
CV (%) = 4.50								

"s" means significant at probability level of 1%

4.2.7Effect of storage materials and period of storage on purity test of cocoa beans

Purity of stored cocoa beans was significantly ($p \leq 0.01$) influenced by storage materials. The effect followed in order of hermetic bag (94.24%), jute sack (93.69%) and woven nylon (93.65%). Effect of jute sack and woven nylon were similar but either was statistically different from effect of hermetic bag (Table 4.11).

Duration of storage of cocoa beans had significant ($p \leq 0.01$) influence on purity of stored beans. Storage at 1, 2 and 3 months recorded purity test 93.96, 94.21 and 94.41% respectively but only the 3rd month was statistically different from purity of stored cocoa beans at 0, 4, 5 and 6 months (93.81, 93.52, 93.52 and 93.52% respectively). Storage at , 1 and 2 months had similar purity of the stored cocoa beans but were statistically different from storage at 4, 5 and 6 months. The latter three storage times were similar in the range of 93.52 – 93.52% (Table 4.11).

Storage materials and duration of storage had significant ($p \leq 0.01$) influence on purity of stored cocoa beans. Jute sack at 0, 1, 2 and 3 months, woven nylon at 0, 1, 2 and 3 months and hermetic bag at all the storage times produced cocoa beans with the purity in the range of 93.81 – 94.81% which were similar in effect but statistically different from storage in jute sack at 4, 5 and 6 months (92.66, 93.15 and 93.52% respectively) and woven nylon at 4, 5 and 6 months (93.09, 93.22 and 92.87% respectively). Storage in jute sack at 4, 5 and 6 months and woven nylon at 4, 5 and 6 had similar purity in the stored cocoa beans (Table 4.11).

Table 4.11: Effect of storage materials and periods of storage on purity test of cocoa beans

Storage material (SM)	Duration of storage (DS) (months) Initial (0)	1	2	3	4	5	6	**Mean**
	Purity test (%)							
Jute sack	93.81	93.98	94.33	94.35	92.66	93.15	93.52	**93.69**
Woven nylon	93.81	93.82	94.42	94.32	93.09	93.22	92.87	**93.65**
Hermetic bag	93.81	94.09	93.88	93.88	94.81	94.18	94.33	**94.24**
Mean	**93.81**	**93.96**	**94.21**	**94.41**	**93.52**	**93.52**	**93.52**	
HSD (0.01)	SM = 0.27 (s)		DS = 0.49 (s)		SM×DS = 1.01 (s)			
CV (%) = 0.30								

"s" means significant and "ns" means non-significant at probability level of 1%

4.3PROXIMATE COMPOSITION

4.3.1 Moisture content of beans

Moisture content was significantly (*$p \leq 0.01$*) influenced by storage materials. Jute sack recorded percent moisture content of 7.51% which was similar to woven nylon of 7.48% but effect of either was higher than that of hermetic bag with 6.80% (Table 4.12).

Duration of storage significantly (*$p \leq 0.01$*) affected moisture content of stored cocoa beans. The initial moisture content of 6.00% was the lowest and significantly different from the storage times. Storage at 1 month recorded statistically different moisture content of 6.50%

from storage at 2, 3, 4, 5 and 6 months with 7.27, 7.47, 7.73, 8 and 7.90% respectively. 2 and 3 months storage moisture content were statistically similar but different from storage at 4, 5 and 6 months. Moisture content of cocoa beans stored for 4 and 6 months were similar but the effect of the former was also similar to storage at 5 months (Table 4.12).

Table 4.13: Effect of storage materials and periods on percent moisture content of beans

Storage material (SM)	Duration of storage (DS) (months)							
	Initial (0)	1	2	3	4	5	6	**Mean**
	Moisture content (%)							
Jute sack	6.00	6.50	7.50	7.90	8.00	8.40	8.30	**7.51**
Woven nylon	6.00	6.50	7.30	7.50	8.20	8.50	8.40	**7.48**
Hermetic bag	6.00	6.50	7.00	7.00	7.00	7.10	7.00	**6.80**
Mean	**6.00**	**6.50**	**7.27**	**7.47**	**7.73**	**8.00**	**7.90**	
HSD (0.01)	DS SM = 0.12 (s) = 0.22 (s)				SM×DS = 0.45 (s)			
CV (%) = 1.73								

"s" means significant at probability level of 1%

Storage materials and duration of storage significantly (*p≤0.01*) influenced moisture content in stored cocoa beans. Jute sack at 5 and 6 months and woven nylon at 4, 5 and 6 months produced moisture content in the range of 8.20- 8.50% which was different from the other combined effects except jute sack at 4 months with 8% which was similar to woven nylon at 4 and 6 months and jute sack at 6 months. Jute sack at 3 months produced moisture content of 7.90% which was similar to jute sack at 4 months. Jute sack at 2 and 3 months had similar moisture content to woven nylon at 2 and 3 months and hermetic bag at 5 months. Storage in woven nylon at 2 months had similar moisture content to storage in hermetic bag at 2, 3, 4, 5 and 6 months. All the storage materials at 1-month storage had moisture content of 6.50% each which were different from the initial moisture content of 6% (Table 12).

4.3.2 pH content of cocoa beans pH of cocoa beans stored was significantly (*p ≤ 0.01)* influenced by storage materials. Jute sack recorded pH of 5.63% which was similar to woven nylon with 5.60% but different from hermetic bag which had 5.45% (Table 4.13).

Duration of storage significantly (*p ≤ 0.01)* affected pH of stored cocoa beans. Storage at 4 and 6 months had pH of 5.68% and 5.73% respectively and theses were statistically different from storage at 0, 1, 3 and 5 months (5.50%, 5.58%, 5.23% and 5.55% respectively). Storage at 2 and 4 months had similar pH in the range of 5.65% – 5.68%. Storage at 1 month had similar pH to storage at 5 months. Storage at 0 and 5 months also had similar pH (Table 4.13).

Storage materials and duration of storage significantly (*p≤0.01)* influenced pH. Jute sack and woven nylon at 2 months had similar pH of 5.95% and 5.97% respectively but only jute sack at 2 months was similar to storage in jute sack at 5 months and woven nylon at 6 months with 5.83% each. The latter two, and storage in jute sack at 6 months, woven nylon at 4 months and hermetic bag at 5 months had similar pH in the range of 5.74% – 5.83%. Storage in jute sack at 1, 4 and 6 months had similar pH to woven nylon at 3 and 4 months and hermetic bag at 4 months in the range of 5.65% – 5.77%. Initial pH in all the storage materials had similar pH to storage in hermetic bag at 1 and 6 months and woven nylon at 1 month. Storage in jute sack at 3 months had similar pH to woven nylon at 5 months and hermetic bag at 2 and 3 months (Table 4.13).

Table 4.13: Effect of storage materials and periods on percent pH of beans

Storage material (SM)	Duration of storage (DS) (months)							
	Initial (0)	1	2	3	4	5	6	**Mean**
				pH				
Jute sack	5.50	5.66	5.95	5.04	5.66	5.83	5.77	**5.63**
Woven nylon	5.50	5.49	5.97	5.65	5.74	5.05	5.83	**5.60**
Hermetic bag	5.50	5.60	5.04	5.01	5.65	5.78	5.60	**5.45**
Mean	**5.50**	**5.58**	**5.65**	**5.23**	**5.68**	**5.55**	**5.73**	
HSD (0.01)	SM = 0.03 (s)		DS = 0.06 (s)		SM×DS = 0.13 (s)			
CV (%) = 4.50								

"s" means significant at probability level of 1%

4.3.3 Ash content of cocoa beans

Percent ash content was not significantly (*p ≥0.01)* influenced by storage materials. However, it followed in order of jute sack (3.19%), hermetic bag (3.07%) and woven nylon (3.06%) (Table 4.14).

Duration of storage significantly (*p ≤ 0.01)* influenced percent ash content of stored cocoa beans. Storage at 0 month had 2.69% which was statistically different from storage at 2 months which had 3.50%. Storage at 1, 3, 4, 5 and 6 months had in the range of 2.93 – 3.26% and these were similar to effect of storage at either 0 month or 2 months (Table 4.14).

Storage materials and duration of storage had no significant (*p≥0.01)* influenced on percent ash content. The initial ash content (0 month) was 2.70%. Jute sack at 1 - 6 months had ash content in the range of 2.67 – 3.80%. Woven nylon at 1 – 6 months storage recorded ash content of 2.67 – 3.60%. Hermetic bag at storage times 1 - 6 months recorded ash content 2.78 – 3.80% (Table 4.14).

Table 4.14: Effect of storage materials and periods on percent ash content of beans

Storage material (SM)	Duration of storage (DS) (months)							
	Initial (0)	1	2	3	4	5	6	**Mean**
	Ash content (%)							
Jute sack	2.69	2.80	3.50	2.80	3.77	3.80	3.00	**3.19**
Woven nylon	2.69	3.00	3.60	3.60	3.00	3.20	2.90	**3.06**
Hermetic bag	2.69	3.00	3.40	3.00	2.80	2.70	3.80	**3.07**
Mean	**2.69**	**2.93**	**3.50**	**2.93**	**3.19**	**3.26**	**3.23**	
HSD (0.01)	DS SM = 0.31 (ns)			= 0.57 (s)	SM×DS = 1.18 (ns)			
CV (%) = 10.60								

"ns" means non-significant and "s" means significant at probability level of 1%

4.3.4 Fat content cocoa beans

Percent fat content was significantly (*p ≤0.01)* influenced by storage materials. Jute sack recorded percent fat content of 55.46%, woven nylon had 54.76% and hermetic bag had 53.73%. Effect of either was statistically different from each other (Table 4.15). Duration of storage significantly (*p ≤0.01)* affected percent fat content of stored cocoa beans. The initial fat content was 52% which was statistically different from storage from 1 – 6 months which had 54.75 – 55.47% (Table 4.15).

Table 4.15: Effect of storage materials and periods on percent crude fat content beans

Storage material (SM)	Duration of storage (DS) (months)							
	Initial (0)	1	2	3	4	5	6	**Mean**
	Crude Fat content (%)							
Jute sack	52.00	54.80	56.50	56.00	56.40	56.40	56.00	**55.46**
Woven nylon	52.00	54.50	55.50	54.25	56.00	55.40	55.63	**54.76**
Hermetic bag	52.00	55.00	53.40	54.00	53.20	54.50	54.00	**53.73**
Mean	**52.00**	**54.77**	**55.13**	**54.75**	**55.20**	**55.47**	**55.21**	
HSD (0.01)	SM = 0.49 (s)		DS = 0.91 (s)		SM×DS = 1.86 (s)			
CV (%) = 0.95								

"s" means significant at probability level of 1%

Storage materials and duration of storage significantly (*$p \leq 0.01$*) influenced percent fat content. The initial fat content was 52%. Storage in jute sack at the various months (1 – 6) had 54.8% – 56.5% fat and these were similar. Woven nylon at 1 – 6 months had 54.5% – 56% fat and these were similar. Cocoa beans stored in the hermetic bag for 1 – 6 months had fat content of 53.2% – 55.0% and these were similar (Table 15).

4.3.5Fiber content of cocoa beans

Percent fiber content was significantly (*$p < 0.01$*) influenced by storage materials. The effects were in order of Jute sack, hermetic bag and woven nylon which recorded 2.83%, 2.81% and 2.70% respectively (Table 4.16).

Duration of storage significantly (*$p \leq 0.01$*) affected percent fiber content of stored cocoa beans. Storage at 0 and 1 month had fiber content of 2.90% and 2.81% respectively which were similar but each was different from storage at the 6th month which had

2.68%. Storage at 1 – 5 months had 2.73% – 2.81% fiber content which were similar.

Also, storage at 2 – 6 were similar (Table 4.16).

Fiber content was significantly (p*≤0.01)* affected by storage materials and duration of storage. The initial fiber content in the dried cocoa beans was 2.90%. Jute sack at 1 – 4 and 6 months and hermetic bag at 1 – 5 months had 2.75% – 2.92% fiber content and these were similar to the fiber content at the initial reading. Storage in jute sack at 5 months had 2.70% fiber, woven nylon at 1 – 6 months had fiber content of 2.60% – 2.72% and hermetic bag at 6 months had 2.60% which were similar (Table 4.16).

Table 4.16: Effect of storage materials and periods on percent crude fibre content beans

Storage material (SM)	Duration of storage (DS) (months)							
	Initial (0)	1	2	3	4	5	6	**Mean**
	Crude Fibre content (%)							
Jute sack	2.90	2.80	2.89	2.92	2.82	2.70	2.75	**2.83**
Woven nylon	2.90	2.72	2.65	2.65	2.65	2.60	2.70	**2.70**
Hermetic bag	2.90	2.92	2.78	2.75	2.80	2.90	2.60	**2.81**
Mean	**2.90**	**2.81**	**2.77**	**2.77**	**2.76**	**2.73**	**2.68**	
HSD (0.01)	SM = 0.01 (s)		DS = 0.10 (s)		SM×DS = 0.20 (s)			
CV (%) = 2.00								

"s" means significant at probability level of 1%

4.3.6Protein content of cocoa beans

Protein content was not significantly (*p ≥ 0.01)* influenced by storage materials. Jute sack, woven nylon and hermetic bag had 10.55%, 10.55% and 10.90% protein content respectively (Table 4.18).

Duration of storage significantly (*p ≤0.01)* affected percent protein content of stored cocoa beans. Storage at 0 month (initial) had 12.00% protein which was statistically different from storage from 1 – 6 months (10.23% – 10.73%) (Table 4.17).

Storage materials and duration of storage significantly (*p≤0.01)* influenced percent protein content. The initial reading (0 month) had 12% protein. Jute sack at 1, 2 and 6 months, woven nylon at 2, 3 and 6 months and hermetic bag at all the storage times recorded protein content 10.44%-11% which were similar. Only the initial protein content at the on-set was statistically different from jute sack at 3, 4 and 5 months and woven nylon at 1, 4 and 5 months (9.89% – 10.21%) (Table 4.17).

Table 4.18: Effect of storage materials and periods on percent crude protein content of beans

Storage material (SM)	Duration of storage (DS) (months)							
	Initial (0)	1	2	3	4	5	6	**Mean**
	Crude Protein content (%)							
Jute sack	12.00	10.63	10.56	9.98	10.01	9.89	10.72	**10.55**
Woven nylon	12.00	10.25	10.64	10.44	9.95	10.13	10.45	**10.55**
Hermetic bag	12.00	10.79	11.00	10.56	10.69	10.69	10.60	**10.90**
Mean	**12.00**	**10.56**	**10.73**	**10.33**	**10.23**	**10.24**	**10.59**	
HSD (0.01)	SM = 0.42 (s)			DS = 0.77 (s)		SM×DS = 1.58 (s)		
CV (%) = 4.12								

“s” means significant at probability level of 1%

4.3.7Free Fatty Acid content on cocoa beans

Free fatty acid content was significantly (*p ≤0.01)* influenced by storage materials. Woven nylon recorded 2.03% free fatty acid which was statistically different and greatest among the storage materials. Jute sack recorded 1.84% which was statistically different and greater than hermetic bag effect on free fatty acid of 1.51% (Table 4.18).

Duration of storage significantly ($p \leq 0.01$) affected free fatty acid content of stored cocoa beans. The initial free fatty acid (0 month), storage at 1 and 3 months had similar free fatty acid (1.67% – 1.80%). Storage at 3 and 4 months also had similar free fatty acid (1.76% and 1.61% respectively). Storage at 5 and 6 months had 2.07% and 2.16% free fatty acid respectively and these were similar but different from the other periods (Table 4.18).

Storage materials and duration of storage significantly ($p \leq 0.01$) influenced free fatty acid content. Storage in woven nylon at 5 months had 2.80% free fatty acid which was statistically different from the other combinations. Storage in woven nylon and jute sack at 6 months had 2.24% and 2.45% respectively which were similar. Storage in jute sack at 3 – 6 and woven nylon at 1 and 3 months had 1.92% – 2.24% free fatty acids which were similar. Storage in jute sack at 3 – 5; woven nylon at 1 and 3 months; initial free fatty acid and hermetic bag at 6 months had 1.80% – 2.10% free fatty acid and these were similar. The initial free fatty acid content, jute sack at 3 months, woven nylon at 2 months and hermetic bag at 6 months were similar (1.65% – 1.92%). The initial free fatty acid content, storage in jute sack at 1 month, woven nylon at 2 months and hermetic bag at 1 and 6 months were similar (1.50% – 1.80%). Storage in jute sack at 1 and 2 months; woven nylon at 2 and 4 months; and hermetic bag at 1 and 5 months had free fatty acid of 1.42% – 1.65% and these were similar. Storage in jute sack at 1 and 2 months; woven nylon at 4 months; and hermetic bag at 1, 2, 3, 4 and 5 months had free fatty acid of

1.27% – 1.50% and these were similar (Table 4.18).

Table 4.18: Effect of storage materials and periods on percent free fatty acid content beans

Storage material	Duration of storage (DS) (months) Initial (0)	1	2	3	4	5	6	**Mean** (SM)
	Free fatty acid content (%)							
Jute sack	1.80	1.50	1.42	1.92	2.00	2.00	2.24	**1.84**
Woven nylon	1.80	2.00	1.65	2.10	1.43	2.80	2.45	**2.03**
Hermetic bag	1.80	1.50	1.29	1.27	1.29	1.42	1.80	**1.51**
Mean	**1.80**	**1.67**	**1.45**	**1.76**	**1.65**	**2.07**	**2.16**	
HSD (0.01)	SM = 0.08 (s)		DS = 0.15 (s)		SM×DS = 0.31 (s)			
CV (%) = 0.95								

"s" means significant at probability level of 1%

4.3. 8 Nitrogen Free Extracts content of cocoa beans

Percent nitrogen free extracts content was significantly (*p ≤ 0.01)* influenced by storage materials. Jute sack and woven nylon had 19.30% and 19.42% which were similar but different from effect of hermetic bag which had 21.18% (Table 4.19).

Duration of storage significantly (*p ≤ 0.01)* affected percent nitrogen free extracts content of stored cocoa beans. Storage at 0 and 1 months had similar nitrogen free extracts (22.60% and 22.50% respectively) but different from storage at 2, 3, 4, 5 and 6 months. Storage at 3 and 4 months had 19.99% and 19.24% respectively which were similar and lower than the 2 month which recorded 21.04%. Storage at 5 and 6 months had nitrogen free extracts of 18.22% and 18.23% which were similar (Table 4.19).

Storage materials and duration of storage significantly (*p≤0.01)* influenced percent nitrogen free extracts content. The initial nitrogen free extracts content together with storage in Jute sack at 1 and 2 month, woven nylon at 1 and 2 month and hermetic bag at 1, 2, 3, 4 and 5 months had 20.60% – 22.00% which were similar. Storage in jute sack at 3 month, woven nylon at 3 and 4 months and hermetic bag at 6 months had 20.20% – 18.48% which were similar. Storage in jute sack at 3 months; woven nylon at 2, 3 and 4 months; and hermetic bag at 1 and 6 months had 18.48% – 22.61% and these were similar. Storage in jute sack at 2, 3, 4, 5 and 6 months; and woven nylon at 2, 3, 4, 5 and 6 months had nitrogen free extracts of 16.71% and 18.77% and these were similar (Table 4.19).

Table 4.19: Effect of storage materials and periods on percent nitrogen free extracts content of beans

Storage material (SM)	Duration of storage (DS) (months)							
	Initial (0)	1	2	3	4	5	6	**Mean**
	Nitrogen free extracts content (%)							
Jute sack	22.60	22.30	20.97	18.48	16.96	16.71	16.99	**19.30**
Woven nylon	22.60	22.60	21.03	20.06	18.77	17.47	17.47	**19.42**
Hermetic bag	22.60	22.60	21.13	21.42	22.00	20.60	20.20	**21.18**
Mean	**22.60**	**22.50**	**21.04**	**19.99**	**19.24**	**18.23**	**18.22**	
HSD (0.01)	SM = 0.55 (s)		DS = 1.01 (s)		SM×DS = 2.08 (s)			
CV (%) = 0.95								

“s” means significant at probability level of 1%

4.4DETERMINATION OF MICROBIAL LOAD OF COCOA BEANS

4.4.1 Effect of storage materials and period of storage on contamination of cocoa beans by *Aspergillus niger* and *Mucor pusillus*

Contamination of cocoa beans by *Aspergillus niger* and *Mucor pusillus* were not significantly (*p≥0.01)* different among the storage materials (Tables 4.20a and 4.20b).

Duration of storage had no significant (*p≥0.01)* influence on microbial contamination by *Aspergillus niger and Mucor pusillus* (Tables 4.20a and 4.20b).

Storage materials and duration of storage did not have significant (*p≥0.01)* influence on microbial contamination (noticeably *Aspergillus niger* and *Mucor pusillus*). The hermetic bag at varying time of storage recorded the least and stable microbial contamination compared to the other two materials (Tables 4.20a and 4.20b).

Table 4.20a: Effect of storage materials and storage periods on contamination of cocoa beans by *Aspergillus niger*

Storage material (SM)	Duration of storage (DS) (months)							**Mean**
	Initial (0)	1	2	3	4	5	6	
	Aspergillus niger count							
Jute sack	0.88	1.17	0.71	0.71	0.71	0.71	1.22	**0.87**
Woven nylon	0.88	0.71	0.71	0.71	1.17	0.71	0.71	**0.80**
Hermetic bag	0.88	0.71	0.71	0.71	0.71	0.71	0.71	**0.73**
Mean	**0.88**	**0.86**	**0.71**	**0.71**	**0.86**	**0.71**	**0.88**	
HSD (0.01)	SM = 0.16 (ns)		DS = 0.30 (ns)		SM×DS = 0.62 (s)			
CV (%) = 2.54								

“ns” means non-significant and “s” means significant at probability (p)=0.01

Table 4.20b: Effect of storage materials and periods of storage on contamination of cocoa beans by *Mucor pusillus*

Duration of storage (DS) (months)

Storage material (SM)	Initial (0)	1	2	3	4	5	6	**Mean**
	Mucor pusillus count							
Jute sack	0.88	1.17	0.71	0.71	0.71	1.22	0.71	**0.87**
Woven nylon	0.88	0.71	1.22	0.71	0.71	0.71	1.71	**0.87**
Hermetic bag	0.88	0.88	0.88	0.71	0.71	0.71	0.71	**0.76**
Mean	**0.88**	**0.92**	**0.88**	**0.71**	**0.71**	**0.88**	**0.86**	
HSD (0.01)	SM = 0.17 (ns)		DS = 0.31 (ns)		SM×DS = 0.63 (ns)			
CV (%) = 2.15								

"ns" means non-significant and "s" means significant at probability (p)=0.01

CHAPTER FIVE

5.0 DISCUSSION

5.1 FIELD SURVEY INFORMATION

5.1.1 Background Information on the License Buying Companies (LBCs) Purchasing Clerks (PCs)

The study revealed that most of the LBCs purchasing clerks (PC) were males. The male dominance is an indicative of the physical and labour intensive nature of the LBCs job. Most (67.1%) PCs of the LBCs were aged 50 years and below supporting the perception of labour intensiveness. The nature of such jobs requires strength and endurance which the youth and middle adulthood afford.

It was observed that the LBCs had considered formal education as an important requirement. This explains why majority had higher education above the Junior High School level. The ability to read and write is very essential in the LBCs work since data collection and records keeping are required. A good majority was well experienced in the business and consequently could provide good responses to the study. The level of experience above six years is indicative of their ability to provide extension services to farmers.

5.1.2 Perception of LBCs on quality of beans to purchase

The respondents, ranked mould free beans as desirable followed by well dried, impurities free, purple free, uniformity of colour and insect free. This perception is in conformity to recommended criteria for grading cocoa beans. Poor quality beans attracts lower price and therefore the desire of LBCs to buy beans of desirable attribute is commendable.

5.1.3 Five Common Forms of Defect in Cocoa Beans Purchased in the District

Defective beans does not attract premium price. The study revealed that wet beans were the commonest defect. Wet beans come about as a result of improper drying. There could be several reasons for the high level of wet beans purchased, including competition among the LBCs for beans. Due to the proliferation of LBCs as a result of the liberalization of the industry, the LBCs, are allegedly accepting beans that are not thoroughly dried. Consequently, farmers come to deliver improperly dried beans which could go mouldy during storage, an undesirable condition that must be avoided.

Purpleness and slaty beans comes as a result of under-fermentation and non-fermentation respectively. Wood and Lass (1985) stated that under-fermentation will produce beans with more purple pigment, and greater bitterness and astringency will be expected in the final product. Quesnel (1958) noted that purple beans constitute a serious defect of cured cocoa. Wood and Lass (1985) stated that, beans which are dried without being fermented at all have a characteristic slaty-colour of the cotyledons and cheesy textured. Such beans have been killed by drying instead of by the heat and acid arising during fermentation so that none of the changes which take place as a result of the breakdown of the internal cell structure has occurred. Such bean characteristics are objectionable categories of defective beans and have serious effects on the quality of the finish product. These situations can also be attributed to the competitiveness of the LBCs for beans. In their attempt to buy more leads to compromising of quality.

Foreign material found in purchased cocoa beans devalues the product. Again, Wood and

Lass 1985, describes it as any substances other than cocoa beans, broken beans, fragments and pieces of shell. These can be substances such as pieces of wood, stones, broken bottles and others. Producers appear to be neglecting good production practices as they face a number of buyers competing to buy the beans. This situation can lead to reduction of price and can even renders the cocoa beans unsaleable if found in large numbers.

5.1.4 Problems Encountered During Storage

Results from the studies indicated that most 72.9% of the PCs encountered problems during storage. One of such problems was mould development. These can be attributed to the competitiveness of their business. In an attempt to purchase more, they allegedly give more regard to quantity than quality. LBCs, competing with each other, are allegedly accepting beans that are not thoroughly dried or properly sorted into bean size categories resulting in mould development during storage. It is a known fact that high moisture content results in mould infection (Wood and Lass, 1985; Pontillon, 1998).

The next challenge was insect infestation. Insect infested beans cannot meet international standard, as a result, such beans would be rejected leading to reduction of price or total loss of the product. Infestation of dry cocoa beans in the postharvest sector starts from the drying mats and continues during storage. At the farm, insects in drying mats are an important source of infestation. At the end of the season they are usually rolled up and stored under the eaves but they often carry pupae from which *Ephestia cautella* (Walker) may emerge to infest the new crop(Wood and Lass, 1985, Jonfia-Essien, 2004). Unless storage is properly carried out - such as hermitic storage - there is a risk of dry cocoa beans becoming damaged from insect infestation, mould and foreign odours (Jonfia- Essien, 2001). Rotten beans can lead to total loss. This situation occurred as a result of very bad nature of road condition in the Samreboi area which worsens during the rainy season making it very difficult for evacuation of cocoa beans.

Loss of weight resulted in 13.7%. In an attempt to forestall wet beans problem to avoid mould development, they did additional drying to ensure extended shelf life, which resulted in weight lost. Theft challenge recorded 9.8%. This was as a result of very poor states of their storehouses. Lastly, rodent attack recorded 5.9%. They applied pesticides (insecticides or rodenticide) to manage the situation.

5.2 INFLUENCE OF DIFFERENT STORAGE MATERIALS AND STORAGE PERIODS ON CUT TEST ATTRIBUTES OF DRIED COCOA BEANS

5.2.1Effect of Different Storage Materials on Mouldiness of Dried Cocoa Beans

Moulds are undesirable features in the chocolate manufacturing industry. Wood and Lass 1985 stated that internal mould is the most important cause of off-flavour because it cannot be removed during manufacturing. Again, there is the possibility of some moulds giving rise to the presence of mycotoxins. Mould can lead to total loss of produce if care is not taken. Though, dried beans will inevitably bear fungal spores and under suitable conditions these will develop and may enter the beans (Wood and Lass, 1985). On the other hand, good storage management such as the use of hermitic sac with its associated modified atmosphere will be able to arrest this situation by making it unfavourable for spore development.

5.2.2 Incidence of Germinated beans

Germinated beans are also a source of fungal development. Germinated beans comes as a result of fermenting in holes in the ground, not turning the beans during fermentation and leaving unharvested, ripe pods on the trees for several days (Asare, 2010). This situation can be avoided by regular harvesting of ripe pods of 2-3 weeks interval, proper fermentation by turning the heaped beans any other day for six days to prevent the occurrence of germinated beans.

5.2.3 Incidence of Slatiness

Slaty beans are those that are dried without being fermented at all and having a characteristic slaty-colour of the cotyledons and a cheesy texture. The study revealed presence of slatiness. Such beans have been killed by drying instead of by the heat and acid arising during fermentation so that none of the changes which take place as a result of the breakdown of the internal cell structure has occurred. Slaty beans have none of the precursors of chocolate flavour and chocolate made from them has a bitter, astringent and thoroughly unpleasant flavor (Wood and Lass, 1985). Beans with such characteristics may face marketing (value) challenge since consumers may find it reluctant to patronized such products because of their unpleasant flavour. To avoid this situation proper fermentation must be practiced for better yield to attract premium.

5.2.4 Purpleness of beans

Purple beans are undesirable characters and as such are unacceptable in the chocolate manufacturing industry as their end product gives off-flavoured products. Rohan, 1963 stated that beans which are under-fermented will have some chocolate flavour but they will also have bitter and astringent flavours. This is due to the presence of unchanged anthocyanin which confers a bright purple colour on the cotyledons. A change in flavour is associated – directly or indirectly – with this change in colour and chocolate made from them would have a harsh and bitter taste. Producers are allegedly diverting from the normal fermentation period (6-7 days) and are drying beans which are fermented less than the specified period resulting in this avoidable situation which if not checked would have a repercussion on the country's image.

5.2.5 Incidence of all Other Defects

The study revealed that there were other defect beans such as flat beans, broken beans, diseased/insect-damaged beans and others. Such beans if not sorted out become very difficult to work with. Wood and Lass (1985) stated that when such condition exceeds 6 per cent, it is considered as sub-standard. It is alleged that producers are attaching less important to the drying process whereby all these defects are sorted out in the cause of drying. Producers need to adhere to the drying process to achieve better results.

5.2.6 Incidence of Weevil Population

Similar weevil contamination occurred in woven nylon and jute sac as revealed by the study. The occurrences of these insects in these two sacs were as a result of favourable environment created in those sacs due to gas exchange. Wood and Lass (1985) stated that, drying mats are an important source of infestation. At the end of the season they are usually rolled up and stored under the eaves but they often carry pupae from which insects may emerge to infest the next crop. Infested beans are a major threat to chocolate manufacturers as they are dangerous to the quality of chocolate products. This incidence of pest is a worldwide phenomenon which cannot be completely eradicated but can be curbed through pragmatic measures (Jonfia-Essien, 2001). The use of hermetic sac with its associated modified atmosphere (lethal to insects) can be employed to control such situation.

5.2.7 Purity of Stored Beans

Beans purity has direct bearing on its value. The study revealed that hermetic sac recorded the highest percentage of purity test. These might have been the absence of mould and insect beans as well as less percentage of other defects recorded. Though the other materials recorded some sort of defects, their recorded purity percentages were within the acceptable standard.

5.3 INFLUENCE OF DIFFERENT STORAGE MATERIALS AND STORAGE PERIODS ON PROXIMATE COMPOSITION OF DRIED COCOA BEANS

5.3.1Moisture Content of Beans

The study revealed that moisture content was high and similar in jute sac and woven nylon. High moisture content - above 8 percent - triggers enzymatic process in the beans leading to high respiration rate resulting in consumption of the bean constituent to water, carbon dioxide and energy (Olabode and Adu, 2012). Therefore, increase in moisture content can lead to total loss. Concerted effort must be made to store beans that are properly dried and stacked in a standardized storehouse to curb insect infestation, mould contamination and moisture exchange between atmosphere and the beans, which are hygroscopic (Villers *et al*., 2007).

For save storage the moisture content of cocoa beans should be between 6 and 7 per cent. Above 8 per cent there is danger of mould developing within the beans, below 5 percent the beans will be very brittle (Wood and Lass, 1985).

5.3.2 Incidence of pH

Results from the data analyzed revealed that pH was high in jute sac and woven nylon than that of the hermetic sac. Beans with acid level below pH of 5 gives a product which is unacceptable to consumers. Cocoa beans with high degree of acidity tend to be weak in chocolate flavor (Wood and Lass, 1985). As pH is mostly influenced by fermentation, its processes must be adhered to, to yield good results.

5.3.3 Ash Content

Ash content in cocoa beans is indicative of mineral levels present. Cocoa is known to be rich in potassium and magnesium. There were no significant differences between the ash values of the various materials used in the study. This indicates that irrespective of the method of packaging for storage, ash levels remained the same. Consequently, regarding ash levels any of the bagging materials could be used without adversely affecting the ash content.

5.3.4 Fat Content

The study revealed that crude fat was high in jute sac and woven nylon. Fat content is influence by bean weight which is also under the influence of rainfall. Doyne and Voelcker1939 stated that decline in fat content in the bean is due to rainfall, the low fat content being associated with beans that developed during the dry season.

5.3.5. Incidence of Fibre Content

Fibre content was significantly influenced by storage materials. Though, there were significant differences in the parameter studied, they conformed to the observed values. As a result, per the crude fibre content levels, any of the bagging materials could be used without having any negative affect on the fibre content.

5.3.6 Percentage Crude Protein

Storage materials had no significant impact on percentage crude protein in the study. Though there were sharp decline in the values from the initial 12.00%, figures during the duration (10.23%-10.73%) were consistent and conformed to the observed values. Although cocoa is not a traditional source of proteins, the levels recorded were appreciable and could contribute to nutrition.

5.3.7 Incidence on Free Fatty Acid (FFA)

From the study, it was observed that free fatty acid was least recorded in hermetic sac. Free fatty acids level is influence by factors such as humidity, oxygen and insects (Wood and Lass, 1985).High levels of FFA can render the beans unsuitable for chocolate and butter production. Again, Nickless1994 stated that cocoa butter with high level of FFA tends to be soft, have poor crystallization properties, contains off-flavour and have a poor shelf-life. Since hermetic bags had the least FFA, it would be more suitable for controlling FFA levels in stored cocoa beans.

5.3.8 Nitrogen Free Extracts (NFE)

Percentage nitrogen free extract was significantly influenced by storage materials.

Though, there were significant differences in the parameters studied, they conformed to the observed values. Consequently, regardless of any of the bagging materials used there would be no adverse effect on nitrogen free extract content.

5.4INFLUENCE OF DIFFERENT STORAGE MATERIALS AND STORAGE PERIODS ON INCIDENCE OF MICROBIAL CONTAMINATION OF DRIED COCOA BEANS

Though there was no significant ($p \geq 0.01$) impact on microbial contamination in the study, hermetic sac recorded the least. According to Wood and Lass (1985), there is the possibility of some moulds giving rise to the presence of mycotoxins. Microbial contamination of stored cocoa beans is of prime interest to stakeholders in the cocoa industry as some strains can be toxic to consumers. This indicates that care must be taken in handling cocoa beans in the supply chain to avoid development of any fungal. The result indicates that, irrespective of the storage materials used or the storage month, the cocoa beans were microbiological safe. However, storage in the hermetic sac was desirable to use.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSION

From the study, wet beans (65.7%) were the commonest defect followed by mouldy beans (35.7%), slaty beans (27.1%), impurities (38.1%) and then purple beans (42.9%). Majority (72.9%) of the Purchasing clerks also encountered storage problems such as mouldy beans, rotten beans, insects attack, weight loss, theft and rodent attack. However, drying of beans, fumigation and application of pesticides were used to extend shelf-life of beans during storage.

The effect of different storage bags on cut test attributes of dried cocoa beans showed significance. From the results, Hermetic bag, throughout the storage period, recorded less mould content (0.71%) except the second month of storage which recorded 1.11% mouldiness. High mouldiness was recorded in Jute sack on the sixth month. For incidence of germination, the highest was recorded in Jute sack and woven nylon on the fifth month while the least (0.71%) was recorded in hermetic bag during the entire storage period (from month one to the fifth) except on the sixth day when it recorded 1.10% of germinated beans.

Cocoa beans stored in the three storage materials; jute sack, woven nylon and hermetic bag had percent slaty beans between 0.71% and 1.22. Effect of storage materials and time of storage had no significant ($p \geq 0.01$) influence on purple beans development in the stored dried cocoa beans. However, the purple beans ranged from 0.89% to 1.57% in the cocoa beans. All other defects in stored cocoa beans were also significantly ($p \leq 0.01$) affected by duration of storage and storage materials. Jute sack on the fourth month recorded the highest other defects in beans while hermetic bags on the third and fourth month had the least other defects. Weevil infestation in cocoa beans stored in the three storage materials was between 0.71% and 1.22%.

Regarding the chemical properties of the dried cocoa beans, the moisture content ranged from 8.50% to 6.50% with the highest recorded in woven nylon stored for 5 months and the least recorded in jute sack, woven nylon and hermetic bag stored for one month. The highest pH (5.83%) was recorded in beans stored in jute sack and stored for jute sack while the least (5.49%) was recorded in woven nylon stored for a month. The ash content in the cocoa beans showed no significance but ranged from 2.70% to 3.80%. Storage of cocoa beans in the jute sack for 6 months had 54.80 – 56.50% of fat, beans stored in the woven nylon stored for 6 months had 54.50 – 56.0% fat while beans stored in the hermetic bag for 6 months had fat content of 53.20 – 55.00% with each of the storage material significantly similar. Fibre content in cocoa beans stored in the three materials and stored for 6 months were significantly different and ranged from 2.60% to 2.92%. Protein content in beans also ranged from 9.98% to 10.79% and showed significant difference. Storage materials and duration of storage significantly ($p \leq 0.01$) influenced free fatty acid content and ranged from 1.27% to 2.80%.

Storage materials and duration of storage did not have significant ($p \geq 0.01$) influence on microbial contamination (*Aspergillus niger* and *Mucor pusillus*).The hermetic bag storage recorded the least and stable microbial contamination compared to the other two materials.

The use of hermetic sacs resulted in superior quality stored beans as compared to the jute sacs and the woven nylon sacs.

6.2Recommendations

The achievement and maintenance of stored quality cocoa beans largely depends on cocoa farmers who are the primary producers and the purchasing clerks who are handlers in the cocoa value chain. Farmers need to pay special attention to the cultural practices that are needed to ensure quality cocoa beans for storage and the purchasing clerks need to employ maximum effort to use quality storage materials in a standard storage environment (store house) to ensure shelf life. The uses of any unstandardised storage material will mare the beauty of quality cocoa beans. Cocoa beans handlers in the value chain must also seek expert advice from COCOBOD on the use of chemicals in the control of pest and diseases to avoid chemical residue in the beans. Cocoa is highly hygroscopic and so purchasing clerks and other handlers during storage must avoid stacking on floors or leaning stacks on walls as well as keeping chemicals close to where cocoa is stored, they can be absorbed leading to high moisture content and chemical residue respectively in the cocoa which will affect its quality.

The controls of insect pest and diseases as well as humidity have been the main challenges to handlers of cocoa in the value chain industry. To mitigate these risk, hermetic storage have proofed to be sole mechanism which when employed can curb these challenges being phased by these handlers. Hermetic storage creates lethal environment for pest survival and modified atmosphere which makes it difficult for diseases development.

Based on the result of this research, it is recommended that, hermetic storage material should be used by stakeholders for storage of cocoa to increase shelf-life. Again, further study should be conducted to evaluate the knowledge and perception of stakeholders in the cocoa industry on the use of hermetic bag.

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APPENDICES

APPENDIX 1: QUESTIONNAIRE FOR LICENCE BUYING COMPANIES (LCBs)

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY (KNUST). KUMASI

Questionnaire №: ……………………. Date: …………… Time Started: ……………………….. Time ended: …………………… Name of LBC: ………………………

Name of Society: ……………... Designation of Respondent: ( ) PC. ( ) DO. ( ) Specify

Dear Sir/Madam

This questionnaire is aimed at evaluating the quality response of cocoa beans to different storage materials in the Samreboi District of Ghana COCOBOD in the Western Region.

The information is intended solely for academic purposes and shall be treated with strict confidentiality.

Answers to these questions are by provision of appropriate answers to the open-ended questions or ticking the appropriate options provided.

HoYour response is voluntary.w long have you been buying cocoa?
…………………………………………………..

Thank you.1.

DOKU ALLAN BEN (student)
2.

Others: ………………….

SECTION A: BACKGROUND INFORMATION

1. Sex: ( )Male ( )Female

2. How old are you?1) Less than 30 years 2)30-40yrs ( ) 3) 41-50yrs ( ) 4) 51-60yrs ( ) 5) over 60 yrs. ( )

3. Educational Qualification:

( ) No formal education ( )Primary ( )MSLC ( )JSS ( )SSS ( )Tertiary

4. Marital status: ( )Married ( )Single ( )Divorced ( )Widow ( )Widower

5. Number of years' in this business (Cocoa purchasing).

   1) Less than 2 year 2) Above 2 to 4 yrs( ) 3) Above 4 to 6 yrs( ) 4) Above 6 to 8 yrs( ) 5) over 8 yrs. ( )

SECTION B: QUALITIES, FORMS OF DEFECTS AND PROBLEMS IN COCOA BEANS STORAGE

1 How many cocoa communities do you serve?

……………………………………………

2 How many farmers do you serve?

………………………………………………………

3 How many tones do you buy during a season?

…………………………………………

4 What qualities do you look for in cocoa beans before you buy? ( )Well dried ( )Purple free ( )Impurities free ( )Mould free ( )Specified others.

5 Do farmers at times present defective beans for sale? ( )Yes ( )No

6 If Yes, do you reject them? ( )Yes ( )No

7 If No, do you work on the poor beans to add to the lot? ( )Yes ( )No

8 If Yes, does it have effect on the stored beans? ( )Yes ( )No 9 If Yes in what form?

……………………………………………………………………

10 If the defective beans in No.6 are rejected, do you sell to special buyers

(Abinkyi)? ( )Yes ( )No

11 What are the commonest defects you get in cocoa beans presented for sale? *(Rank: 1, 2, 3 With 1 being the most occurring problem encountered)* ( )Wet beans (Rank …..) ( )Mouldy beans (Rank ……) ( )Purple beans (Rank……) ( )Slaty beans (Rank….) ( )Impurities (Rank….) ( )Poorly Polished beans (Rank…) ( )Insect attack (Rank ….) ( )Small size bean (Rank …) ( )Germinated beans (Rank …) ( ) Specify others (Rank.)

12 In what containers do farmers present their cocoa for sale? ( )Jute sacks ( )Poly sacks ( )Woven nylon sacks ( )Baskets ( )Specify others ………………………………………

13 In what materials do you store your cocoa beans? ( )Jute sacks ( )Poly sacks ( )Woven nylon sacks ( )Baskets ( )Specify others ……………………………………………….

14 Do you at times short storage sacs during the season? ( )Yes ( )No

15 If Yes, what do you do? ……………………………………………………………………

16 How long do you store the cocoa beans before evacuating? ( )6 months ( )9 months ( )12 months ( )specify others ………………….

17 Do you encounter problems during storage? ( )Yes ( )No

18 If yes, what are some of the storage problems do you encounter? *(Rank: 1, 2, 3 With 1 being the most occurring problem encountered)* ( )Mouldy beans (Rank ……) ( )Insect attack (Rank ….) ( )Rotten beans (Rank …) ( ) Specify others (Rank ….)

19 What measures do you take to forestall such problem(s)? ( )Fumigation ( )Drying

( ) Specify others

……………………………………………………………………………….

APPENDIX 2: ANOVA OF CUT TEST, PROXIMATE ANALYSIS AND MICROBIAL COUNT

Analysis of variance

Fact A = Storage material (SM) Fact B = Storage time (ST)

ANOVA OF CUT TEST

Analysis of Variance Table for Mouldiness

Source	DF	SS	MS	F	P
Rep	2	0.01832	0.00916		
SM	2	0.32447	0.16223	41.72	0.0000
ST	6	1.78637	0.29773	76.57	0.0000
SM*ST	12	1.83387	0.15282	39.30	0.0000
Error	40	0.15554	0.00389		
Total	62	4.11857			

Grand Mean 0.8681   CV 7.18

Analysis of Variance Table for Germinated beans

Source	DF	SS	MS	F	P
Rep	2	0.01681	0.00841		
SM	2	0.22372	0.11186	84.12	0.0000
ST	6	0.73289	0.12215	91.86	0.0000
SM*ST	12	0.77197	0.06433	48.38	0.0000
Error	40	0.01319	0.00133		
Total	62	1.79857			

Grand Mean 0.8206   CV 4.44

Analysis of Variance Table for Slaty beans

Source	DF	SS	MS	F	P
Rep	2	0.00486	0.00243		
SM	2	0.07911	0.03955	18.45	0.0000
ST	6	1.47813	0.24636	114.93	0.0000
SM*ST	12	0.60178	0.01015	23.40	0.0000
Error	40	0.08574	0.00214		
Total	62	2.24962			

Grand Mean 1.0289   CV 4.50

Analysis of Variance Table for Purple beans

Source	DF	SS	MS	F	P
Rep	2	0.43143	0.21571		
SM	2	0.61692	0.30846	5.02	0.0113
ST	6	1.08564	0.18094	2.94	0.0178
SM*ST	12	0.77012	0.06418	1.04	0.4298
Error	40	2.45777	0.06144		
Total	62	5.36189			

Grand Mean 1.3138   CV 1.89

Analysis of Variance Table for All Other Defects

Source	DF	SS	MS	F	P
Rep	2	0.0093	0.00463		
SM	2	1.8586	0.92931	70.71	0.0000
ST	6	3.0019	0.50031	38.07	0.0000
SM*ST	12	4.9574	0.41311	31.43	0.0000
Error	40	0.5257	0.01314		
Total	62	10.3529			

Grand Mean 1.2905   CV 8.88

Analysis of Variance Table for Purity

Source	DF	SS	MS	F	P
Rep	2	0.6501	0.32505		
SM	2	4.5306	2.26530	28.50	0.0000
SP	6	6.7327	1.12212	14.12	0.0000
SM*SP	12	9.1905	0.76588	9.64	0.0000
Error	40	3.1791	0.07948		
Total	62	24.2830			

Grand Mean 93.859   CV 0.30

Analysis of Variance Table for Weevil population

Source	DF	SS	MS	F	P
Rep	2	0.01539	0.02770		
SM	2	0.41871	0.20935	15.54	0.0000
ST	6	1.97444	0.32907	24.43	0.0000
SM*ST	12	1.17945	0.09829	7.30	0.0000
Error	40	0.53887	0.01347		

Total	62	4.16686

Grand Mean 0.8208 CV 1.41

ANOVA FOR PROXIMATE ANALYSIS (CHEMICAL COMPOSITION)

Analysis of Variance Table for Moisture

Source	**DF**	**SS**	**MS**	**F**	**P**
Rep	2	0.0317	0.01587		
SM	2	7.3956	3.69778	232.96	0.0000
ST	6	28.0619	4.67698	294.65	0.0000
SM*ST	12	4.2267	0.35222	22.19	0.0000
Error	40	0.6349	0.01587		
Total	62	40.3508			

Grand Mean 7.2825 CV 1.73

Analysis of Variance Table for pH

Source	**DF**	**SS**	**MS**	**F**	**P**
Rep	2	0.01720	0.00860		
SM	2	0.37692	0.18846	147.05	0.0000
ST	6	1.48289	0.24715	192.84	0.0000
SM*ST	12	3.38597	0.28216	220.17	0.0000
Error	40	0.01126	0.00128		
Total	62	5.31424			

Grand Mean 5.5627 CV 0.64

Analysis of Variance Table for Ash content

Source	**DF**	**SS**	**MS**	**F**	**P**
Rep	2	0.1110	0.01552		
SM	2	0.2287	0.11433	1.06	0.3576
ST	6	3.9239	0.65398	6.04	0.0001
SM*ST	12	4.5830	0.38192	3.52	0.0013
Error	40	4.3340	0.10835		
Total	62	13.1806			

Grand Mean 3.1056 CV 10.60

Analysis of Variance Table for Fat content **Source DF SS MS F P**

Rep	2	0.915	0.4577		
SM	2	31.741	15.8703	59.13	0.0000
ST	6	77.075	12.8459	47.86	0.0000
SM*ST	12	21.847	1.8206	6.78	0.0000
Error	40	10.736	0.2684		
Total	62	142.314			

Grand Mean 54.647 CV 0.95

Analysis of Variance Table for Fibre content

Source	**DF**	**SS**	**MS**	**F**	**P**
Rep	2	0.00174	0.00087		
SM	2	0.20701	0.10351	33.63	0.0000
ST	6	0.24815	0.04136	13.44	0.0000
SM*ST	12	0.27888	0.02324	7.55	0.0000
Error	40	0.12313	0.00308		
Total	62	0.85891			

Grand Mean 2.7760 CV 2.00

Analysis of Variance Table for Protein content

Source	**DF**	**SS**	**MS**	**F**	**P**
Rep	2	0.2984	0.14919		
SM	2	1.7645	0.88227	4.57	0.0163
ST	6	20.6223	3.43706	17.82	0.0000
SM*ST	12	1.6773	0.13977	0.72	0.7191
Error	40	7.7158	0.19290		
Total	62	32.0783			

Grand Mean 10.668 CV 4.12

Analysis of Variance Table for Free Fatty Acid

Source	**DF**	**SS**	**MS**	**F**	**P**
Rep	2	0.02150	0.01075		
SM	2	2.90231	1.45116	200.50	0.0000
ST	6	3.32437	0.55406	76.55	0.0000
SM*ST	12	3.05329	0.25444	35.16	0.0000
Error	40	0.28950	0.00724		
Total	62	9.59097			

Grand Mean 1.7952 CV 4.74

Analysis of Variance Table for Nitrogen Free Extracts

Source	DF	SS	MS	F	P
Rep	2	0.091	0.0457		
SM	2	73.939	36.9697	110.16	0.0000
ST	6	125.332	20.8887	62.24	0.0000
SM*ST	12	42.858	3.5715	10.64	0.0000
Error	40	13.425	0.3356		
Total	62	255.646			

Grand Mean 19.726   CV 2.94

ANOVA FOR MICROBIAL COUNT

Analysis of Variance Table for *Aspergillusniger*

Source	DF	SS	MS	F	P
Rep	2	0.08960	0.04480		
SM	2	0.20180	0.10090	3.38	0.0441
ST	6	0.40574	0.06762	2.26	0.0165
SM*ST	12	1.16480	0.09707	3.25	0.0025
Error	40	1.19500	0.02988		
Total	62	3.05694			

Grand Mean 0.8024   CV 2.54

Analysis of Variance Table for *Mucorpusillus*

Source	DF	SS	MS	F	P
Rep	2	0.22434	0.11217		
SM	2	0.18286	0.09143	2.96	0.0630
ST	6	0.40817	0.06803	2.21	0.0624
SM*ST	12	1.60534	0.13378	4.34	0.0002
Error	40	1.23366	0.03084		
Total	62	3.65437			

Grand Mean 0.8348   CV 2.15