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Impact of storage practices and pest on the quality of cocoa beans in warehouses in Brofoyedru Cocoa District of Ghana

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ABSTRACT

This study assessed the storage practices of five licensed buying companies (LBC) and pests which affected the quality of stored cocoa beans in the study area. The study comprised of field survey using questionnaires. Samples of stored cocoa beans were collected for periods of 0, 2 and 4 weeks of storage. Laboratory experiments were done to check physical quality characteristics using the cut test method, insect damage, purpleness and weight loss. Insects present in beans were checked using sieving net. The warehouses insects were trapped with insect pheromones (Storegard II). Survey data were analysed using IBM-SPSS version 16 and laboratory data was analyzed using Statistix statistical package 9th edition. Means separation were done using LSD at 5%. From the survey, 97% of the depot managers keep cocoa beans for 2-4 weeks before transporting. Also, 42.5% of the LBCs in the study area stored their cocoa beans in warehouse while the rest keeps them in stores or sheds. Only 17.5% removed cobwebs weekly, 30% did it monthly whiles 52.5% removed the cobwebs as and when noticed. However, 95.5%of the depot keeper's checked the moisture content of the beans before storage whiles the rest did not. Ultra-low volume fogging was the key strategy used by the LBCs to control insect infestation. The key insect pest species found were *Plodia interpunctella*, *Tribolium castaneum, Esphestia cautella* and *Rhyzopertha dominica*. No significant differences (p=0.05) were found among the LBCs depots when physical qualities of beans were assessed. It was established that all the LBCs in the study area produced standard beans. It is, therefore recommended that Pheromone traps be used for insect monitoring in warehouses.

INTRODUCTION

Cocoa is a major global commodity and a source of income for millions of smallholder farmers (Clay, 2004). Production of cocoa is dominated by three main countries: Cote d'Ivoire, Ghana and Indonesia with about 70% of the world cocoa production coming from West Africa (ECOWAS-SWAC/OECD, 2007). A report by FAO (2009) indicated that over 8 million hectares of land area had been used for cocoa production worldwide. Even though cocoa is produced in less developed nations, it's by-products are largely utilized by developed countries with the chocolate

and confectionary industries as the key buyers. The dried cocoa beans are usually refined into four main semi-finished products, specifically; cocoa powder, cocoa butter, cocoa liquor and cake, which are further processed into chocolate as a finished product. Cocoa is a rich source of vitamin A, B, C, D and E, salts and minerals (Nickless, 1996). Additionally, Cocoa beans and products from cocoa are reported to be rich in phenolic compounds which help combat free radicals that are harmful to the human body (Adamson et al., 1999). In Ghana, cocoa is the main stay of the economy, accounting to about 30% of the total earnings from export and contributes about 70-100% of yearly household incomes of the 60% cocoa farmers who are engaged in cocoa farming (Appiah, 2004; Gockowski et al., 2011; USDA, 2012). The cash crop is grown by small-scale farmers and employs over 2 million persons who are mostly engaged in production, trading, transportation, and processing (World Bank, 2007). It is mainly cultivated in the southern forest belt of the country. Importantly, Ghana's cocoa is considered premium on the global market as a result of the quality of the dried beans (Ntiamoah and Afane, 2008). The quality checks are conducted by the government through the Quality Control Division (QCD) of the Ghana Cocoa Board (COCOBOD) which offers standard protocol of quality for internal use as well as export. Purchasing of cocoa beans is done by Licensed Buying Companies after inspection by the QCD of COCOBOD at farm gate, buying centres or villages and later transported to district depots, warehouses or take-over points where other quality checks are carried out before shipment to the ports.

Despite the enormous contribution to the Ghanaian economy, the sector faces challenges such as pests and diseases on farm, as well as during storage. According to Folayan (2010), the principal cause of quality abnormalities in cocoa could be attributed to poor farm management, pest infestation, diseases, poor handling, bad fermentation, inadequate drying, mould and bacterial growth. Storage insect pest of cocoa beans has been chronicled to be associated with many challenges which include environmental factors such as relative humidity, temperature, moisture content, packaging materials which may cause deterioration as well as infestation by storage pests (Jonfia-Essien, 2004). Storage pests have over the years been a major problem to the cocoa industry. Cocoa beans are susceptible to both beetle and moth infestations.

Some of the common storage insect pests of cocoa beans are Red flour beetle (*Tribolium castaneum*), Cigarette beetle (*Lasioderma serricorne*), Coffee bean weevil (*Araecerus fasciculatus*) which are able to bore into the shell of the beans providing entrance for other insects pests, such astropical warehouse moth (*Ephestia cautella*), and opportunistic microorganisms (Jonfia-Essien, 2001; 2004). Insect pests mostly cause damage to stored beans through direct feeding. Additionally, feeding and respiration activities increase the moisture of the stored beans which consequently promote mould growth and trigger other enzymatic processes, leading to increase in free fatty acid (FFA) levels (Olabode and Adu, 2012).

Determining the effect of cocoa storage practices of licensed buying companies and storage pests on the quality of cocoa beans produced in Ghana is by far considered by decision makers or legislature to be of greatest significance. However, storage practices and storage insect pests of cocoa in Ghana have not been adequately studied and reported necessitating the current study to assess storage practices, storage insect pest and their effect on cocoa beans quality at warehouses in Brofoyedru Cocoa District in the Ashanti Region of Ghana. This is important that, Good Storage Practices are activities which generally prevent deterioration and ensure that the quality and safety of produce are also maintained.

MATERIALS AND METHODS

Assessment of storage practices

Primary data for the study were collected through the administration of structured questionnaires by interviewing depot managers, purchasing clerks and key informants in the study area. Within the cocoa district, 40 depot managers and purchasing clerks were interviewed using the snowball sampling technique. The key information the questionnaire sought to find was the storage practices and insect pest as well as the challenges encountered in maintaining the quality of certified cocoa beans before being evacuated from the study areas.

Sampling of cocoa beans from the various depots

LBCs, namely; Olam Ghana Limited (OLAM), Cocoa Merchant Ghana Limited (MERCHANT), Kuapa Kooko Limited (KUAPA), Federated Commodities Limited (FEDCO) and Nyankopa Buying Company (NYANKOPA) in the Cocoa district were selected from whom stored dried cocoa beans samples were collected after questionnaire administration. At each LBC depot, cocoa beans were collected at three different locations using a sampling horn. A total of 30 samples were collected from all the depots. Sampling of beans for quality assessments was done at two-week intervals, starting from when dried beans were initially brought to the depot until they were evacuated after four-week storage.

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Trapping of storage insects

To assess the spectrum of stored cocoa beans insect pests in the depots, STORGARD II insect pheromone lures were hanged in depots of each of the LBCs for 4 weeks. Insects collected were sent to the Entomology Laboratory of the Department of Crop and Soil Sciences, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana for identification.

Laboratory experiments

The storage Experiment was conducted at the Entomology Laboratory of the Department of Crop and Soil Sciences, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

Experimental design

The survey experiment was achieved through snow ball sampling techniques. The laboratory experimental design was a completely randomized design (CRD) with three (3) replications for all the depots.

Physical assessment of cocoa beans

From each of the five depots, 500 g of stored cocoa beans were sampled from a standard 64 kg cocoa bag using a sampling horn. Stored cocoa beans were collected from the depots at two-week intervals during the storage periods (that is, 0, 2 and 4 weeks). There were three replications for each storage periods. Beans were brought to the laboratory for initial moisture, damage and undamaged count and sieving for presence of insect. The cocoa beans were sieved with 2.00 and 0.710 mm sieves for insect pests. The cut test procedure (one of the cocoa grading schemes in Ghana; based on visual assessment of quality of cocoa relies on changes in colour of the beans (Misnawi et al., 2003) was followed for the physical assessment. Sampled cocoa beans were thoroughly mixed and then divided into four equal parts in a heap of slightly more than 300. The first 300 beans were then counted, irrespective of the size, shape and condition. The 300 beans were cut lengthways with knife and the middle and examined. In assessing for the insect damage beans, characteristic such as insect eggs, holes and chewed debris were checked in the beans according to AOAC (2005). Purpleness of the beans was determined visually. Moisture content was checked using a moisture meter (Aquaboy, Germany).

Calculations of weight loss after each storage period

Hundred grams of cocoa beans where sampled from each of the LBC's were sorted for damaged and undamaged beans as per the characteristics of damages caused by storage insect pest through the cut test. The damaged and undamaged beans were later counted and recorded. The damaged beans were those with holes or any physical defects such as surface feeding, germ feeding and tunnels. The weight loss was calculated after 2 and 4 weeks of storage using the formula:

$$\text{Weight loss (\%)} = \frac{(\text{Und}) - (\text{DNu}) \times 100}{\text{U(Nd + Nu)}}$$

Where, U, Weight of Undamaged beans; Nd, number of damaged beans; D, weight of damaged beans; Nu, number of undamaged beans (Boxall, 1986).

Data analysis

Data generated from the questionnaire was analyzed using IBM-SPSS version 16.0. The SPSS was used to perform descriptive statistics analysis. Data collected from the depots and laboratory was subjected to analysis of variance using the Statistix Software version 9.0. Means were separated using least significant difference (LSD) at 5% and (p-0.05%) level of significance.

RESULTS

Cocoa storage practices assessment

A survey conducted on five LBCs in the Brofoyedru Cocoa District showed that 42.5% of the LBCs packed their bagged cocoa beans in Warehouse, 40% in stores whilst 17.5% stored their beans under sheds until evacuation or transportation to takeover centers (Table 1). Most 87.5% of the respondents did check for roof leakage, whereas 12.5% did not check for leakages in building roof. This translates into the standard beans produced by all LBC's. No moulds were observed after the cut test (Table 1). Most (85%) of the respondents did weekly physical inventory to assess the status of beans, jute bags as well as presence of pests. Another 10% did biweekly inventory, whereas the remaining 5% embarked on a 3–4 week physical inventory (Table 1). 70% of the LBCs in the study area, after grading and bagging, answered that cocoa beans stayed at the facility for up to 2–3 week. For 25% of them, the beans stayed in the depot for over 3 weeks but up to a month depending on the season (whether main or light crop), the remaining 5% evacuated the beans within a week (Table 1). 17.5% of the respondents did removal of cobwebs in the storage facility, then on weekly basis, 30% removed them on monthly whereas 52.5% removed theirs as and when seen (Table 1.).

Table 1. Distrubution of depot keeper's response on storage practices.

Type of storage facility			No of times physical inventory is done		
	Frequency	**Percentage**	One week	34	85
Shed	7	17.5	Every 2 weeks	4	10
Warehouse	17	42.5	Every 3 weeks	1	2.5
Store	16	40	Very month	1	2.5
Total	40	100	Total	40	100
Do you check for roof leakage			**How long does cocoa beans stay after grading and sealing**		
Yes	35	87.5		**Frequency**	**Percentage**
No	5	12.5	Within a week	2	5
Total	40	100	Two to three weeks	28	70
How often do you remove cobweds			Over three weeks	10	25
Weekly	7	17.5	Over a month	0	0
Monthly	12	30	**Total**	**40**	**100**
As and when noticed	21	52.5	**Do you recondition the beans when the moisture level is not appreciable**		
Total	40	100	YES	40	100

Table 2. Distribution of depot keeper's response on storage practices.

	Frequency	**Percentage**	**What do you use in storing beans in your storage facility**		
Are there cracks in storage facility			Jute sack	40	100
Yes	10	25	**Do you leave gaps between stacks**		
No	30	75	Yes	37	92.5
Total	40	100	No	3	7.5
How often do you clean your storage facility			Total	40	100
Daily	27	67.5	**Is there evidence of nesting/feather bird/droppings?**		
Every other day	10	25	Yes	13	32.5
Weekly	3	7.5	No	27	67.5
Total	40	100	Total	40	100
Do you store other agric products with cocoa beans			**Do you cover stacks with tarpuline after fogging**		
Yes	5	12.5	Yes	15	37.5
No	35	87.5	NO	25	62.5
Total	40	100	Total	40	100

75% of the respondents did not report cracks on the walls of their building whilst the remaining (25%) reported cracks in their buildings (Table 2). Sanitation in storage facilities was done by 67.5% of the respondents indicated it to be done daily, whilst 7.5% of them mentioned that they cleaned their storage facilities every other day (Table 2). Out of the 40 respondents, 12.5% stored other agricultural commodities such as maize cowpea in their facilities together with cocoa beans whereas 87.5% stored only cocoa beans (Table 2). 97.5% of the depot keepers checked moisture contents of the cocoa beans before bagging, leaving only 2.5% who did not embark on routine moisture checks on their stored beans. All the 40 (100%) respondents from the five LBCs interviewed indicated that they kept their dry cocoa beans in jute sacks (Table 2). Other storage practice such as leaving gaps between stacks, when assessed, revealed that 92.5% did whiles 7.5% did not (Table 2). Only 32.5% responded “yes’’ to evidence of bird nesting in their facilities whiles 67.5% responded “no” (Table 2). On respondents’ request for fogging, 37.5% percent covered their cocoa beans with tarpaulin during fogging whiles majority (62.5%) did not. This translates in the insect captured in the cocoa beans collected and stored at different time intervals (Table 2).

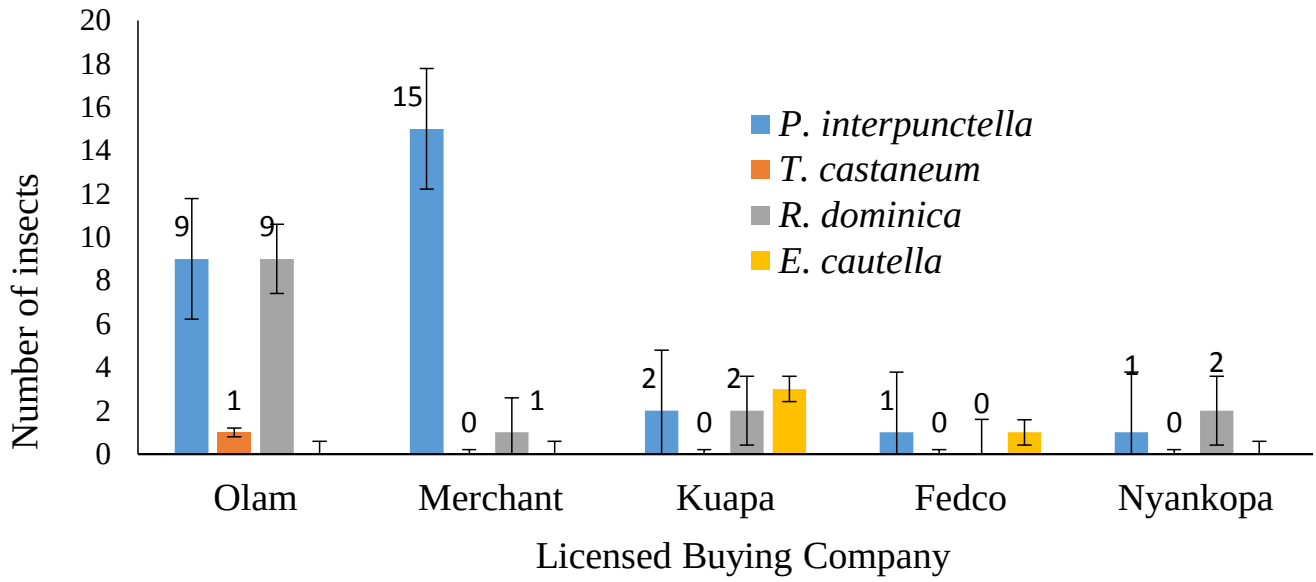

Figure 1. Insect pests captured in pheromone traps in the storage facilities of the five (5) LBCs.

Table 3. Mean number of insect pests found in cocoa beans during the four (4) weeks of storage at the facilities of the five (5) LBCs.

	Mean insect counts per LBCs					
Storage period	**FEDCO**	**KUAPA**	**MERCHANT**	**NYANKOPA**	**OLAM**	**Mean**
0	0.0^{c*}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{b}
2	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{c}	0.0^{b}
4	1.0^{b}	0.0^{c}	0.0^{c}	2.0^{a}	2.0^{a}	1.0^{a}
Mean	0.33^{ab}	0.0^{b}	0.0^{b}	0.67^{a}	0.67^{a}	

*Means followed by the same alphabet are not significantly different from each other (p=0.05).
LSD: LBCs = 0.43; Storage period = 0.33; LBCs*Storage period = 0.75.

Insect pests collected with pheromone (STORGARD II) traps

Pheromone traps that were hanged at the various depots of the LBCs caught a total of 47 insects comprising of 28 *P. interpunctella*, 1 *T. castaneum,* 4 *E. cautella* and 14 *R. dominica*. Among the LBCs, Olam had the highest number (19) whereas the least number (2) was found in Fedco followed by Merchant, Kuapa and Nyankopa had 16, 7 and 3 respectively, total number of insects, all shown in Figure 1.

Insect pests found in cocoa beans during the four (4) weeks of storage

No insect species was found in the cocoa beans from the five depots at the initial stage and 2 weeks after storage (Table 3).

Insect damaged beans (%) per 100g of cocoa beans sampled during the four (4) weeks of storage at the facilities of the five (5) LBCs

There were no significant differences (P>0.05) in the insect damaged beans between the depots. Mean numbers of insect damaged beans recorded in all the depots were <1% and ranged from 0 to 0.17. Kuapa, Fedco and Nyankopa had a mean insect damaged beans of 0.17 each whereas Olam and Merchant had 0.33 and 0.0, respectively (Table 4).

Purple beans (%) per 100g of cocoa beans sampled during the four (4) weeks of storage at the facilities of the five (5) LBCs

From the Table 5, no significant difference was observed

Table 4. Means percentage of damaged cocoa beans during the four (4) weeks of storage at the facilities of the five (5) LBCs.

LBCs	% Damaged beans (0 week of storage)	% Damaged beans (2 weeks of storage)	% Damaged beans (4 weeks of storage)	Mean
Olam	0.00[a]*	0.33[a]	0.17[a]	0.24[a]
Merchant	0.00[a]	0.00[a]	0.00[a]	0.00[a]
Kuapa	0.00[a]	0.17[a]	0.00[a]	0.09[a]
Fedco	0.00[a]	0.17[a]	0.17[a]	0.17[a]
Nyankopa	0.00[a]	0.17[a]	0.33[a]	0.24[a]
Mean	0.00	0.17	0.22	0.14
CV(%) =6.7				
LSD	0	0.8227	0.6219	0.72

*Means followed by the same alphabet are not significantly different from each other (p=0.05).

Table 5. Purple beans sampled from the five LBCs in the Brofoyedru District across the storage periods.

Storage period	FEDCO	KUAPA	MERCHANT	NYONKOPA	OLAM	Mean
0	21.67[ab]	21.33[ab]	21.10[ab]	21.90[ab]	22.23[ab]	21.65[a]
2	22.00[ab]	20.43[b]	22.57[a]	22.57[a]	21.90[ab]	21.89[a]
4	22.57[a]	21.90[ab]	22.57[a]	21.43[ab]	21.60[ab]	21.81[a]
Mean	22.078[a]	21.22[a]	21.74[a]	21.97[a]	21.91[a]	

*Means followed by the same alphabet are not significantly different from each other (p=0.05).

in the purpleness of the beans coming from the different LBCs Depots. The individual influence of the storage periods did not influence the purpleness values significantly.

Cumulative weight loss assessment

These recorded losses in weight of the cocoa beans by the five LBCs are within the acceptable range stipulated by the Ghana Cocoa Board. Little or no weight loss was observed in cocoa beans handled by the Merchant buying company throughout the storage period (percentage weight loss remained at 0%) See Figure 2 below.

DISCUSSION

Assessment of storage practices of LBCs in Brofoyedru Cocoa District

Storage is basically holding goods until they are needed. Warehousing (storage) follows directly after production. This leads to the right choice of storage structure. 42.5% of the purchasing clerks keep produce in warehouse with capacity up to 1000 tonnes which is the standard set by Ghana Cocoa Board. Few of them use structure such as stores for storage. The critical role of storage in the cocoa supply chain is apparent from the fact that it precedes sale and export. Poor structure and roofing may attract microbial growth and insect pest which will increase moisture and shelf life of the stored produce.

Good storage management plays a key role in maintaining the quality of stored cocoa beans. The quality and shelf life of stored cocoa is highly influenced by environmental factors such as temperature, relative humidity of the storage environment as well as the amount of moisture contained in the beans (Lopez and Dimick, 1995).

According to Proctor (1994), most warehouse walls may be made of a lightweight material such as fibro-cement, galvanised metal sheet, or aluminum sheeting. However, walls of this kind are easily damaged, have poor insulating properties, and are sometimes prone to erosion and cracks. They do not support good storage of produce. These cracks sometimes serve as place of niche for some insects and reptiles. From the survey, it was observed that 75% of the depot keepers and purchasing clerks checked for the presence of wall crack and only 25% did not check and even to the extent of controlling the cracks. The 25% translated to presence of insects when pheromones were hang in all the five depots used for the research work. This mean warehouse should be built by concrete as stated by Proctor.

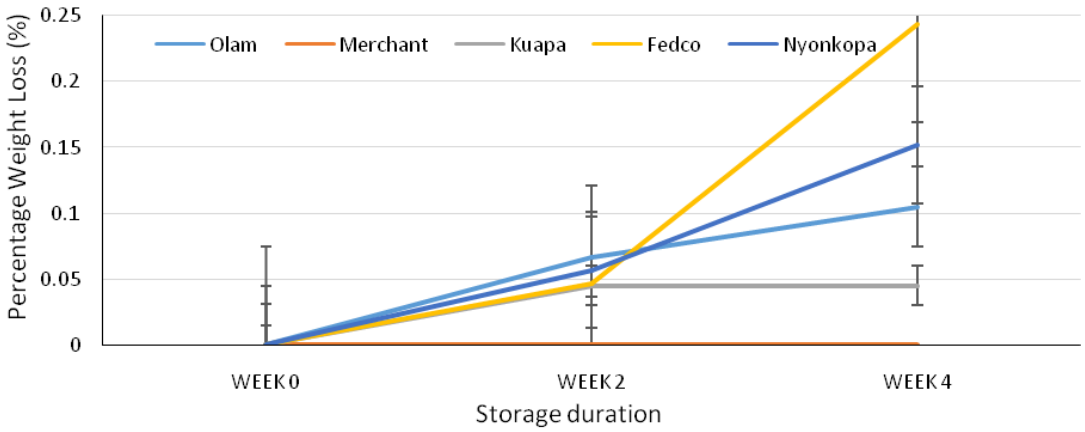

Figure 2. Cumulative weight loss.

A key factor for protecting stored products is good sanitation practices (Rotundo et al., 1995). Preventative sanitation, which is, storing beans in clean, insect-free structures with clean surroundings, is one way to ensure low initial insect population, and that the microclimate in the storage place will not be favourable for proliferation of insect pests. It could, therefore, be on this premise that the managers of the depots in the Brofoyedru cocoa district had cleaning schedules for their warehouses. Sanitation is mostly a component of several IPM-based methods designed to help manage insect pests of stored products (Hagstrum et al., 1999).

When cocoa beans are stored with other commodities they may become an alternate host for insect pests and rodents. 87.5% of the LBCs stored only cocoa, indicating that there may be no alternate food source for pests in the storage units if cocoa is evacuated. It has been established that the role of inventory management is to ensure that stock is available to meet the needs of the beneficiaries as and when required. Maximum and minimum levels are important for warehouse operations. One of the key measures to maintain a warehouse is to perform inventory daily as reported by (Saxena, 2003). This was reflected in the survey as 85% of the depot keepers took inventory on weekly basis, whereas 10% took it on a fortnightly basis. Only 2.5% of them performed inventory taking in 3 and 4 weeks.

Moisture content of a commodity is a vital physiological variable which must be regularly monitored for long term storage. Because biological and biochemical activities occur only when moisture is available, to keep cocoa beans safe during storage, the moisture content should be reduced to recommended levels 6.5 to 7.5% (Thompson et al., 2001). According to Brewbaker (2003), when moisture content is high, it generates heat which results in spoilage by moulds and insects. When beans brought to the depot are not well dried, it is essential to re-dry them. Nonetheless, commodities with abnormally low moisture become brittle and make grains or beans liable to crack which may be undesirable to consumers and processors (Hellevang, 2011). Therefore, as a good storage practice, 97.5% of the depots regularly checked moisture content of cocoa beans.

The most common method of storing cocoa beans by the LBCs was keeping dried beans in jute bags in warehouse, store or shed. It has been reported by Jonfia-Essien and Navarro (2010) that cocoa beans are stored in jute bags and stacked into warehouses, depots and sheds in Ghana. According to Jonfia-Essien (2004) proper storage material is a key to maintaining the quality of cocoa beans.

However, according to Roesli et al. (2003) and Toews et al. (2005) who stated that cleaning alone rather decreases insect numbers since patches of materials that would provide refuge for these insects and also life cycle is disturbed. Therefore, depot managers (50%) occasionally disinfested their depots by fogging. Manu et al. (2019) indicated that insect numbers in maize warehouse continued to decrease by fogging with deltamethrin, a synthetic pyrethroid insecticide with knockdown action and increases mortality of insects (Anankware et al., 2014).

The main bird species that cause problems on buildings are Pigeons, Starlings, House sparrows, Seagulls and the Indian myna. The pathogens in the bird droppings include *Salmonella*, *E. coli* and *Histoplasma,* which can then infect people handling the goods and eating contaminated food (Rentokil, 2020). The survey provided that 67.5% of the Depot keeper checked for presence of bird nesting and droppings to decreases from spreading to those handling the produce.

Insect pests in cocoa depots and management practices

Stored cocoa beans are attacked by several insect pests mostly moths and beetles. The most important insect

species found in the depots were *P. nterpunctella*, *T. castaneum*, *E. cautella* and *R. dominica*. These findings were similar to those of Jonfia-Essien (2001; 2004) indicated that *T. castaneum*, *E. cautella*, *C. ferrugineus* were among insect species associated with dry cocoa beans when the beans were monitored from 1995 to 2000. Some of these insect pests have been reported to have the ability to directly attack undamaged beans whereas others feed as secondary pests (Jonfia-Essien, 2004). The feeding activities of the insects also predisposed beans to mould attack and other infection by microorganisms thereby affecting the quantity and quality of beans (Jonfia-Essien, 2004). Additionally, some of the insects, specifically *T. castaneum,* is known to produce toxic quinones which caused unpleasant odour in beans (Mills and White, 1994).

Although quite a number of insects known to attack stored cocoa beans were found in the traps set in the depots, indicating insect presence, the very low numbers of insects (total of three) were found in the cocoa beans stored for four weeks. This could be due to the short duration of the study which did not allow eggs which might have infested the beans to develop into adults. The developmental period of these insects may range from about 26 to 32 days under favourable conditions and could prolong when condition is adverse (Mason, 2003; Chandra, 2006). Jonfia-Essien (2012) conducted physical assessment on cocoa beans coming from up-country to Take Over Centres (TOCs) and reported that cocoa beans received at all the TOCs were infested with stored product insect pests of cocoa.

It was therefore important for depot managers/keepers to conduct checks on the level of infestation in cocoa beans and disinfest before consignment are taking to storage. The Quality Control Company (QCC) of the Ghana Cocoa Board undertakes disinfestations of cocoa in storage in Ghana to ensure that only insect pest-free beans are exported. Cocoa beans may be disinfested by fogging, fumigation or spraying (COCOBOD, 2000). Usually, water-based insecticides such as fenitrothion are used for spraying, whereas oil-based insecticide like pyrethrin is used for fogging (COCOBOD, 2000). However, at the terminal ports, cocoa parcels are fumigated with phosphine gas to thoroughly disinfest them before final shipment.

The pheromone traps were able to detect more insect pest as compared to the sieving methods and this is in line with an investigations on monitoring of insect pest of stored cocoa beans in various storage facilities of cocoa done during 2010- 2011 in Tamil Nadu, India. The monitoring studies revealed that, the STOREGARD II trap detected the *T. castneum*, *L. serricorne* and *C. ferrugineus* in storedcocoa beans more effectively. The detection ratio was higher in STOREGARD II pheromone traps compared to sieving, irrespective of source of beans. Stack probe was found effective as a monitoring tool in the detection of stored product insects mainly, *T. castaneum* and *C. ferrugineus* and *Carpophilus spp*. in bag storage of cocoa beans. Pheromone traps were found to be the ideal tools for detection of *P. interpunctella* and *E. ellutella* stored product insects in stack storage of cocoa beans (Shrikant et al., 2014).

Physical assessment of cocoa beans

The result of insect feeding is increased in insect damaged beans. The larvae of primary insects fed inside infested beans, and when they exited as adults live highly visible exit holes inevitably increasing the percentage of insect damaged beans (Hagstrum et al., 2012). In the study, percent insect damaged beans were very low (<1%) in all the cocoa bean samples. This could be because cocoa beans were not attacked by insect pests probably due to the short duration of the study and also proper fumigation (fogging) procedures. It therefore stands to reason that if the time of transportation of cocoa beans from up-country to terminal ports is reduced, insect pest attack might be reduced because there will be insufficient time to complete their developmental cycle. This also resulted in a significantly negligible loss in the weight of the stored beans over the stored periods in all the five LBCs. Typically; higher insect damaged beans will be associated with higher weight loss (Paudyal et al., 2017; Manu et al., 2019). Because percent insect damaged beans were very low, there was a corresponding low percent weight loss.

A purple cocoa bean shows purple colour on half or more of the surface of the cotyledon. Generally, there was a variation in percentage of purple beans during storage. Jonfia-Essien et al. (2008) reported that there was reduction in the total purple colour of cocoa beans but differences were not significant enough to cause any change in the grade. However, in this study, there was neither decrease nor an increase in the percentage of purple beans after days of storage. The polyphenol content in cocoa beans is among the factors responsible for the purple colour, thus if the polyphenol content is high, the percentage of purple beans will be high. Aikpokpodion and Dongo (2010) determined the polyphenol content of cocoa beans during fermentation and recorded a decrease in the polyphenol content as fermentation period prolonged, a corresponding decrease in percentage of purple coloured beans was also recorded. His finding suggested that fermentation led to gradual reduction of polyphenol in cocoa beans. Polyphenols are mostly responsible for the astringent sensation as well as bitter taste and colour (Misnawi et al., 2003).

Adzaho (2011) also reported a decrease in anthocynins (polyphenolic compound) content with increase in fermentation period. Therefore determination of polyphenol content during storage should be studied. At the beginning of the storage period there was high

percentage of purple beans in cocoa beans stored for 0, over 2 weeks and up to 4 weeks. Although there were variations in the percentage of purple beans, the grade of the beans was not affected. However, according to Misnawi et al. (2003) countries, such as Malaysia, are making use of the unfermented and under-fermented cocoa beans for cocoa liquor, powder and cocoa butter production, but due to its excessive astringency and bitterness, purple beans are undesirable in West Africa. In the study, there was no significant difference in the purpleness of the beans. This could be attributed the short duration of the storage.

Conclusion

It is evident that 42.5% of the LBCs store cocoa beans in warehouse. Results indicated that 97% of depot managers/keepers checked moisture content in cocoa beans before storage. More over 100% of the all the LBC stored or package cocoa beans in Jute sacks. In the process of maintaining moisture level and moldiness in the storage environment, majority of the depot managers checked for roof leakages and cracks on the storage walls. All LBCs practiced fogging to control insect pests. Pheromones traps were hanged in all the depots to tarp insects. The key insect pest species found in the depots were *P. interpunctella, T. castaneum, E. cautella and R. dominica*. In the study percentage damage to dry cocoa beans by insects was very low. Percentage purple, insect damage and weight loss had no significant effect on the quality of beans over the storage period. There were no significant differences in the proximate composition of the beans, however, moisture content was in the acceptable range of 6.5 – 7.5%. We conclude that the LBCs in the Brofoyedru Cocoa District ensured that quality of cocoa beans were high and graded “A” due to their good handling practices at their depots.

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