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EFFECT OF DIFFERENT STORAGE PERIODS ON THE QUALITY OF DRY COCOA BEANS OF AMELONADO AND MIXED HYBRID VARIETIES CULTIVATED AT WASSA AMENFI WEST DISTRICT OF WESTERN REGION

BY

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SEPTEMBER, 2016

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A THESIS SUBMITTED TO THE SCHOOL OF RESEARCH AND GRADUATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF MASTER OF PHILOSOPHY (POSTHARVEST TECHNOLOGY) DEGREE

BY

DOMINIC AMANKWAH

SEPTEMBER, 2016

DECLARATION

I hereby declare that this submission is the result of my own work and that it has not been submitted either in part or whole for any other degree elsewhere. Works by other authors have been duly acknowledged.

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DEDICATION

This thesis is dedicated to the Glory of God, my family, my siblings and all my loved ones through their toil and prayers my education materialized.

May God bless you all.

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ABSTRACT

A study was conducted to investigate the effect of different storage periods on the quality of stored dry cocoa beans of Amelonado and mixed hybrid varieties. The study comprised two components mainly field survey and laboratory experiment. The field survey was conducted at Wassa Amenfi West District in the Western Region of Ghana to identify storage practices of farmers and cocoa purchasing clerks. Structured questionnaires were used to interview 150 farmers using simple random sampling technique and 75 PCs using purposive sampling technique. Data obtained from the field survey were analyzed using SPSS. The laboratory analysis was 2 x 5 factorial laid in a completely randomized design. The Factor „A" was cocoa variety with two levels (Amelonado and mixed hybrid) and Factor „B" was storage period with five levels (i.e. initial (control), 30, 60, 90 and 120 days) and replicated three times. Data were collected on cut test, moisture content, pH, fat and free fatty acid contents and were analyzed using Statistix statistical package 9^{th} edition. Treatment means were compared using HSD at 1% level of probability. The study revealed that 82% of farmers stored dried cocoa beans for less than 7days during the main season whereas 18% of farmers stored for more than7 day, however in the minor season 62% farmers stored dried cocoa beans for less than 7 days whereas 38% of farmers stored for more than 7 days. On the contrary 28% of PCs stored dried cocoa beans for less than 14 days whereas 72% of PCs stored for more than 14 days during the main season, however in the minor season 33% of PCs stored dried cocoa beans for less than 21days, whereas 67% stored for more than 21days. Most of the farmers (40%) stored their dried cocoa beans in jute sacks whilst others stored in baskets (23%), fertilizer bags (19%), hermetic bags (10%), polythene bags (5%) and rubber bowls (3%). Mixed hybrid varieties had more slaty beans (0.54%) than

Amelonado variety (0.20%). Amelonado variety had 99.45% purity which was higher than that of mixed hybrid varieties (98.65%). Fat content in the cocoa beans did vary significantly between the Amelonado variety (38.34%) and mixed hybrid varieties (34.10%). Free fatty acid in Amelonado variety was 1.69% which was statistically lower and different from that of the mixed hybrid varieties (1.98%). Free fatty acid recorded at the initial period (control), 30, 60, 90 and 120 days were 2.12%, 1.98%, 1.57%, 1.43% and 2.09% respectively. Interaction of cocoa variety and storage period had significant effect on moisture, fat and free fatty acid contents. Amelonado variety maintained relatively good physical qualities during the various storage periods than the mixed hybrid variety therefore; it is recommended that Amelonado variety could be stored for longer periods (60 days) than the mixed hybrid varieties (30 days).

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CHAPTER ONE

1.0 INTRODUCTION

Ghana has systematically grown the cocoa industry which is a major foreign exchange earner. Measures used include improving product quality since according to Osei (2007), quality determines the value of a product. There are approximately 1.6 million smallholder farmers and with 3.2 million workforce producing around 700,000 Mt of cocoa. Currently, the annual output of approaching 1million Metric tonnes of dried beans earns around 30% of foreign exchange for the country as a whole (Cooper and Cudjoe, 2012).

Government"s involvement through Quality Control Company of COCOBOD has provided the necessary assurance for produce quality for the Internal and External exports. Quality of exported cocoa has been promoted through quality checks at the farm gate, buying centres at the village level and take-over points for storage and subsequently. However, quality of Ghana"s cocoa can be compromised with increased competition on both the local and international markets.

The effort to increase market share by competing buyers of cocoa could lead to reduced produce quality (Anang *et al*., 2011). Typical instance in Ghana was in 1997/98 cocoa season, when Licenced Buying Companies (LBCs) bought improperly dried beans from farmers which resulted in mould growth resulting in lower grading on the international market leading to economic losses (Bank of Ghana, 2003). Storage, primary and secondary evacuation of cocoa have been a source of concern to LBCs especially during peak seasons of the year. There have been many instances where originally graded and sealed cocoa failed to meet quality standards at the take- over centres (TOCs) and therefore was rejected (Adu, 2007). Shepherd and Farolfi (1999), indicated that challenges of liberalized markets include maintenance of bean quality in storage and transportation Vigneri and Santos (2007) also identified that the liberalization of the cocoa industry has contributed to a decline in quality of cocoa beans for export and the local market. This is expected to affect cocoa earnings in terms of the premium payment on the international commodity market and therefore there is the need to look into how the cocoa beans are stored and recommend appropriate measures in order not to compromise the quality of beans.

Osei (2007) reported that premiums are determined by markets using factors such as quality perceptions. The author indicated that although Ghana‟s premium cocoa ia a benchmark for quality persistently new challenges requires constant improvement to satisfy processors including chocolate producers.

Farmers and Purchasing Clerks (PCs) store cocoa for longer period particularly during the minor season due to anticipation for price increases during the reopening of the new season at the expense of quality (Osei, 2007). According to Ghana Cocoa Board industry regulation, storage of cocoa when thoroughfully dried should be offered immediately for purchase by LBCs for primary and secondary evacuation to port for shipment to foreign buyers to avoid deterioration in quality (Ghana COCOBOD Industry Regulation, 1968). As such, it is crime and prosecutable to store or hoard in anticipation for price increase and subsequent profit. However, another challenge is posed by poor road networks delay the evacuation of dried cocoa beans in storage with PCs and LBCs. According to Wood and Lass (2001), the storage of cocoa in the tropics presents two potential challenges; development of mould and spread of storage pests. It is in this line that the study was conducted to investigate effect of storage periods on the quality of Amelonado and mixed hybrid varieties of dry cocoa beans. Cocoa marketing companies that receive cocoa on behalf of COCOBOD based on the findings of this study would in conjunction with the Quality Control Division put in place appropriate measures to ensure cocoa beans are stored in ideal environment by farmers and PCs. Finally, the result of this research study would add up to existing literature on quality control practices in the cocoa industry in Ghana.

The main aim of the study was, therefore, to examine effect of different storage periods on the quality of dry cocoa beans of Amelonado and Mixed Hybrid varieties.

The specific objectives of the study were;

i. To identify cocoa storage practices of cocoa farmers and cocoa PCs.
ii. To determine the effect of cocoa variety on some physical (slaty, mould, purple, and other defects) and chemical (moisture, pH, Fat content, and free fatty acid) quality attributes of stored dry cocoa beans.
iii. To determine the effect of storage period on some physical (slaty, mould, purple, and other defects) and chemical (moisture, pH, Fat content, and free fatty acid) quality attributes of stored dry cocoa beans.
iv. To determine the interactive effect of cocoa variety and storage period on some physical (slaty, mould, purple, and other defects) and chemical (moisture, pH, Fat content, and free fatty acid) quality attributes of stored dry cocoa beans.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin and classification of cocoa

Cocoa (*Theobroma cacao*) is known to have originated from Southern and Central America and is native to the Amazon and Orinoco valleys of South America (Thompson *et al*., 2001, Beckett, 2009; Afoakwa, 2010). History has it that about 600 AD ago the Maya and Aztecs were the first to grow and consume cacao, what is now widely known as cocoa (Beckett, 2009). The word *Theobroma* means food of the gods thus *theos* meaning "god" and *broma* meaning "food" (Afoakwa, 2010; Nair, 2010). The Spanish introduced cocoa to Europe and also to Fernando Po now called Bioko, an island in Equatorial Guinea in 1840 and by 1897 Tetteh Quarshie a Ghanaian, brought cocoa from Bioko and successfully cultivated it in Ghana. Cocoa grown in other West African countries such as Nigeria, Togo, Ivory Coast and others originated from Ghana (Nair, 2010).

There are about twenty-two (22) species of the genus *Theobroma* (Nair, 2010), out of which only one, *Theobroma cacao*, a member of the family *Sterculiaceae* is of economic importance (Thompson *et al*.,2001, Afoakwa, 2010; Nair, 2010). Other species according to Nair (2010), including *Theobroma bicolor, Theobroma angustifolium and Theobroma grandiflorum* are usually cultivated and consumed because of their sweet edible pulp and used as drinks in some parts of Brazil. Currently, there are four (4) types of commercial cocoa (*Theobroma cacao*) belonging to the family Sterculiaceae that are cultivated and these include; Forastero, Criollo, Nacional and Trinitario (Fowler, 2009; Afoakwa, 2010; Nair, 2010). The cocoa of commerce is grouped under two (2) broad umbrellas; the "bulk" and "fine" cocoa, which according to Lopez and Dimick (1995), the ForasteroAmelonado variety make up the "bulk" cocoa because of their strong cocoa flavour and "fine" cocoa constitutes Criollos, Nacional and Trinitarios which have mild and floral flavours.

The Criollo variety has a mild nutty cocoa flavour but is highly susceptible to diseases while Trinitario, a hybrid of Forastero and Criollo is more disease resistant (Beckett, 2009). The Forastero cocoa and its varieties are ubiquitous and widely grown, accounting for approximately 95% of the world cocoa production (Thompson *et al*., 2001; Afoakwa, 2010). The Forastero variety is also referred to as Amelonado because of the melon shape of its seeds. The cultivation of the Nacional cocoa variety is restricted to Ecuador. It is noted for its fine "Arriba" flavour (Beckett, 2009; Afoakwa and Paterson, 2010).

2.2 Cocoa Cultivation

Prior to planting, certain environmental and edaphic conditions must be at their optimum for a successful growth of the cocoa plant. Temperature, rainfall and humidity are the three most important environmental factors that affect growth. According to Afoakwa (2010) and Fowler (2009), cultivation of cocoa requires temperatures ranging between 18–32˚C and rainfall within 1500 and 2500 mm well distributed throughout the year. During dry seasons or rainfall below 100 mm other sources for replenishing water lost via transpiration of the plant such as irrigation must be seriously considered to prevent the cocoa plant from wilting and from rapid senescence. During the early stages of the growth of cocoa plants they are mostly intercropped with other food crops such as plantain and oil palm to act as windshields and also for shade provision. The cocoa trees are grown to cover a total density of 600–1200 trees/acre (1500–3000 trees/ha), this ensures that humidity is typically maintained between the ranges of 70–80% during the day and 90–100% at night (Fowler, 2009; Afoakwa, 2010). Cocoa can grow in a vast array of soils, however edaphic factors such as pH must be neutral to partially acidic with a range of 5–7.5, and the soil must also possess a good drainage and well aerated system (Fowler, 2009; Afoakwa, 2010). The rooting of cocoa is that of the tap root system with few lateral roots hence the soil must be approximately 1.5 m deep or more to facilitate the uptake of water and nutrients (Fowler, 2009; Nair, 2010). Cocoa husbandry, pest and disease control should be done meticulously to achieve substantial yield (Fowler, 2009; Afoakwa, 2010). Some pests and diseases include black pod, witches" broom, frosty pod rot, swollen shoot, capsids and mirids, and the cocoa pod borer.

Squirrels, rats and monkeys also consume and destroy a chuck of ripe pods (Fowler, 2009; Nair, 2010).

The cocoa tree comes into fruition after two to three years of maturity and reach their full yield potential when it"s six to seven years old (Fowler, 2009). With a growing height of approximately 10 m at maturity, harvesting is usually difficult especially with fruits growing at its apex. Afoakwa (2010) stated that "modern breeding methods have led to the development of trees to a standard of approximately 3 m tall to allow for easy harvesting". The cocoa plant is said to have an economic viable life span of about 25 – 30 years (Fowler, 2009).After a successful pollination and fertilization, the pods reaching maximum and fully mature about 140 days. The fruits are then allowed to ripen for about 10 days and the pods are harvested (Afoakwa, 2010; Fowler, 2009).The matured cocoa fruits measure between 100 and 350 mm long and have a wet weight of approximately 200 g to 1 kg (Fowler, 2009). Colour change is a major factor in determining the ripeness of cocoa pods. However, due to genotypic differences there are considerable variations in the shape, surface texture and colour. Cocoa colour generally varies from green or purple to various shades of red, orange or yellow pods (Afoakwa, 2010).

2.3 Primary processing of cocoa beans

Before cocoa beans attain its commercial viability it must have gone through some major post-harvest processes that have a profound impact on the quality of the cocoa beans. Harvesting, pulp pre-conditioning, fermentation and drying and the major and most critical primary processing that must be done meticulously to avert under fermented and astringent beans.

2.3.1 Harvesting

The transformation from raw cocoa beans into dried cocoa beans begins with the primary process of harvesting which is normally carried out over a period of 3 to 4 days, at intervals of 3 to 6weeks. This practice will vary according to the size of the farm and pod yield (Lopez and Dimick, 1995). Ripe pods, which the farmer must assess via the external colour, are detached from the bark of the tree using sharp knives, secateurs and machetes. Those out of arms reach are harvested with special long-handled tools with a sharp edge. Care is taken to avoid damage to the flower cushions that would reduce future yields.
The harvested pods are transported to the a fermentary where they are broken most often in Ghana with machetes to open and reveal the seeds for removal (Knight, 2001) in Ghana, harvesting is done in two main batches with October to February being the main crop and from May to August which is the mid-crop (Amoa-Awua *et al.,* 2006).

Ripeness of the pods is a very important factor for proper fermentation as a lack of control thus poor judgment of the maturity and ripeness of the pods will lead to the harvesting of immature and not fully ripen will cause variations in the quality of cocoa beans after fermentation and drying.

2.3.2 Pulp-Preconditioning

There are three basic treatments that have been evaluated for the post-harvest treatment of cocoa beans prior to fermentation. This includes pod storage, mechanical de pulping and enzymatic de pulping (Schwan and Wheals, 2004). Due to high acidity of beans from some producing areas such as Malaysia these treatment methods were developed in an attempt to reduce the problem of acidity in dried fermented cocoa beans. This problem of high acidity has been linked to the excessive production of lactic and acetic acid resulting from fermentation (Rohan, 1963). From earlier research conducted, the removal of a portion of the pulp thus the fermentable sugar content of the bean results in the production of less acids during fermentation and subsequently less acidic beans after drying (Rohan, 1963; Wood and Lass, 1985).

Pod storage is quite different from mechanical de pulping and enzymatic de pulping and the chemistry of the outcomes of the three different forms of pulp preconditioning are highly different. While stored pods for 5 – 7 days as shown by earlier researchers enhances pre-fermentation activity inside the pods during this dormant stage helps to facilitate rapid rise in temperature during fermentation, reduces acidity, and imparts stronger chocolate flavour (Schwan and Wheals, 2004; Nazaruddin, 2006; Afoakwa 2010; Afoakwa *et al.,* 2011ab; Afoakwa *et al.,* 2012ab) that cannot be said for mechanical de pulping.

The principle for mechanical de pulping is to separate pulp from fresh beans via the action of a de pulper and this might cause bruising of the beans and its inherent cell structures leading to activation of enzymes that might influence the biochemical processes during fermentation. Apart from reducing acidity, de pulping also shortens fermentation Period and makes available excess pulp in the manufacture of jams and cocoa liquor (Buamah *et al.,* 1997; Dias *et al.,* 2007).

2.3.3 Pod-Breaking

Pods are usually split open with a sharp machete to reveal and remove the seeds. In Ghana most of the farmers crack open the pods with the machete by making a sharp incision on the longitudinal section of the pod is made then a second on the opposite side of the pod and a third incision made at the base for easy removal of the husk (Quao, 2010). The beans are then scooped out with fingers or the cutlass and this is an important process as there is the transfer of microorganisms from the farmer‟s hands or tools to the beans. The beans are extracted without placenta and fermentation follows immediately (Afoakwa, 2010). Only mature, well-developed pods contain good beans. The colour of the pulp is a good indication of suitability as damaged pods show discoloration but pods showing symptoms of damage from black pod on the surface need not be discarded if the beans inside are unaffected (Knapp, 1937;Nair, 2010).

2.3.4 Fermentation

Fermentation plays a pivotal role in the formation of flavour harbingers, colour and aroma due to biochemical and chemical changes that occur during the process. However these are also affected not just by fermentation but also by genetic variation of the cocoa varieties (Lopez and Dimick, 1995; Afoakwa and Paterson, 2010). During and after opening of the cocoa pods the cocoa beans are spontaneously inoculated with a variety of microorganisms from the farmer‟s hands and the tools involved (Nielsen, 2006; Thompson *et al.,* 2001). The usual recommendation for fermentation is to start immediately following pod breaking. It is the norm but in exceptional cases such as to reduce acidity, seeds may be spread out for several hours before being fermented (Biehl *et al.,* 1990); another method also recommends partial removal of the seed mucilage prior to fermentation (Lopez and Dimick, 1995).

Typically fermentation involves the confinement of freshly scooped out beans be it in a heap or any of the other fermentation systems for a duration of 6 day with a maximum of 7days depending on the variety of the cocoa (Lopez and Dimick, 1995). As fermentation continues, various yeasts, lactic acid bacteria, acetic acid bacteria and other microorganisms such as *Bacillus* spp. (Nielsen, 2005) develop in a form of succession which is not entirely distinct but rather overlap with other microorganisms occurring throughout the fermentation process (Thompson *et al.,* 2001; Ardhana and Fleet, 2003; Schwan and Wheals, 2004).

The fermentation process involves microorganisms catabolizing fermentable pulp sugars to alcohols (ethanol) and through exothermal reactions some of the alcohols are oxidized to acetic acid resulting in the liberation of pulp juices known as sweating"s (Thompson *et al.,* 2001). The penetration of the ethanol and acetic acid into the core of the beans and its associated heat emanating from the reaction causes the beans to swell up and destroy the embryo or the germ. The heat generated can reach a high of 45 – 50˚C from an initial of 25˚C and is very typical of heap fermentations (Senanayake *et al.,* 1995). This leads to a loss of germinating ability of the seed. This process also brings about the destruction of cellular integrity and break down of the cell walls within the bean allowing the interactions of enzymes and substrates freely. This continued process leading to well fermented beans (Roelofsen, 1958; Thompson *et al.,* 2001; Beckett, 2009; Afoakwa, 2010). The production of acids and alcohols by various yeasts, lactic acid bacteria, acetic acid bacteria and other microorganisms causes the pH of the beans to decrease from about 7.0 to 5.0 – 5.5 (Beihl *et al.,* 1985; Thompson *et al.,* 2001).

Other metabolic processes occurring simultaneously within the bean will cause the increase in flavour precursors such as amino acids and reducing sugars as well as the reduction on total polyphenols leading to a less bitter and astringent beans and other complex chemical processes will also take place. The fermentation process produces typical alcoholic, lactic and acetic acids in the external pulp enveloping the seed. These changes take place within the tissue, resulting in the formation of flavour precursors (Lopez and Dimick, 1995).

2.3.5 Drying

Drying is an all-important process after fermentation. After fermenting the beans for the required duration, the beans are removed from their respective types of fermentation systems employed for drying. Drying can be done in two ways thus natural or sun drying and artificial drying. Drying is done to ensure to removal of moisture and also some major biochemical processes such as flavour development, reduction in bitterness and astringency occur and also develop the chocolate brown colour of well fermented cocoa beans (Fowler, 2009; Afoakwa 2010). During drying a considerable amount of moisture is lost and has been estimated that moisture is reduced from approximately 50% to about 7 – 8%. This is important as moisture content above 8% might yield mould growth during prolonged storage and moisture of below 5% is very brittle (Lopez and Dimick, 1995). Regions or countries where the weather is hot and dry the fermented beans are spread on flat surfaces dried in the sun. In countries where the weather is humid and makes natural drying difficult, mechanical drying is employed (McDonald *et al.,* 1981;

Lopez and Dimick, 1995; Nair, 2010).

2.3.6 Storage of Cocoa Beans

Traditionally cocoa beans are packed into jute bags of 65 kg and subject to sanitary certification in warehouses prior to shipment. During longer storage periods, the quality of the cocoa beans can seriously be affected if proper care is not taken. Some bagged cocoa beans undergo a brief period of storage in warehouses on the farms, at the buying agencies and on the dockyards before and after shipping and at the factories before processing into cocoa products (Jonfia-Essien, 2004).

During prolonged storage relative humidity of 65 – 70% will generally maintain the moisture content of the beans about 7 – 8% this prevents insect and mould attacks. According to earlier literature by Thompson *et al.* (2001), during the initial storage period slow oxidation and loss of volatile acids may improve flavour but prolonged periods will eventually lead to staling of the beans. The quality of cocoa beans can change during storage depending on temperature, relative humidity and ventilation
(Lopez and Dimick, 1995; Thompson *et al.,* 2001; Jonfia-Essien, 2004).

2.4 Cocoa Pulp Composition

The pulp is white, sweet and a mucilaginous substance surrounding the beans. It is the fermentation substrate and its composition is therefore a critical factor on the outcome of fermentation (Beckett, 2009; Thompson *et al.*, 2001; Nielsen, 2006; Afoakwa, 2010). Water dominates its composition with about 82 – 87% with the remaining percentage consisting of approximately 10 – 15% sugars (glucose, fructose and sucrose), 2 – 3% pentosans, 1 – 3% citric acid and 1 – 1.5% pectin (Fig. 4) (Lopez and Dimick, 1995;

Afoakwa, 2010). This composition clearly makes the pulp an ideal medium for a medley of microorganisms to proliferate. Proteins, amino acids, vitamins (predominantly vitamin C) and minerals are in the minority.

According to Nielsen (2006), chemical characteristics for Ghanaian *Forastero* cocoa for fresh bean were 5.4 – 6.6% glucose, 6.3 – 7.4% fructose and about 0.3% sucrose. According to Afoakwa *et al.* (2012) storage of pods results in variation in pulp characteristics.

2.5 Cocoa Production, Supply and Consumption

2.5.1 Global Production of Cocoa

Global production of cocoa beans was reported to be 3.6 million tonnes in the 2009/2010 fiscal years, a marginal increase compared with the previous seasons (ICCO, 2012). Production also increased to about 4.3 million tonnes in 2010/2011 and a marginal decline in 2011/2012 with 3.9 million tonnes. According to statistics from ICCO (2012), cocoa beans from smallholder farms account for approximately 90–95% globally. In Ghana, mainly smallholder farmers undertake production of cocoa with only about 5% from large plantations such as those owned by the Government subsidiary, Ghana Cocoa Board (COCOBOD) via its institutions and some private investors. It is estimated that Ghana has a market share of about 28 - 31% second to the Ivory Coast which, has a market share of over 46.8% and thus Africa produces about 70 - 75% of the world"s cocoa (ICCO, 2012).

ICCO (1997) stated that the *El Niño* weather events reduced cocoa production, on average, by 2.4% at world level however due to this reduction, world cocoa prices increased by

1.66% on average. The impact of the *El Niño* event is not homogenous across cocoa producing countries. Cocoa production in Ghana, Nigeria and Cameroon are not systematically affected by *El Niño* events (IRI, 2009).

2.5.2 Cocoa Production in Ghana

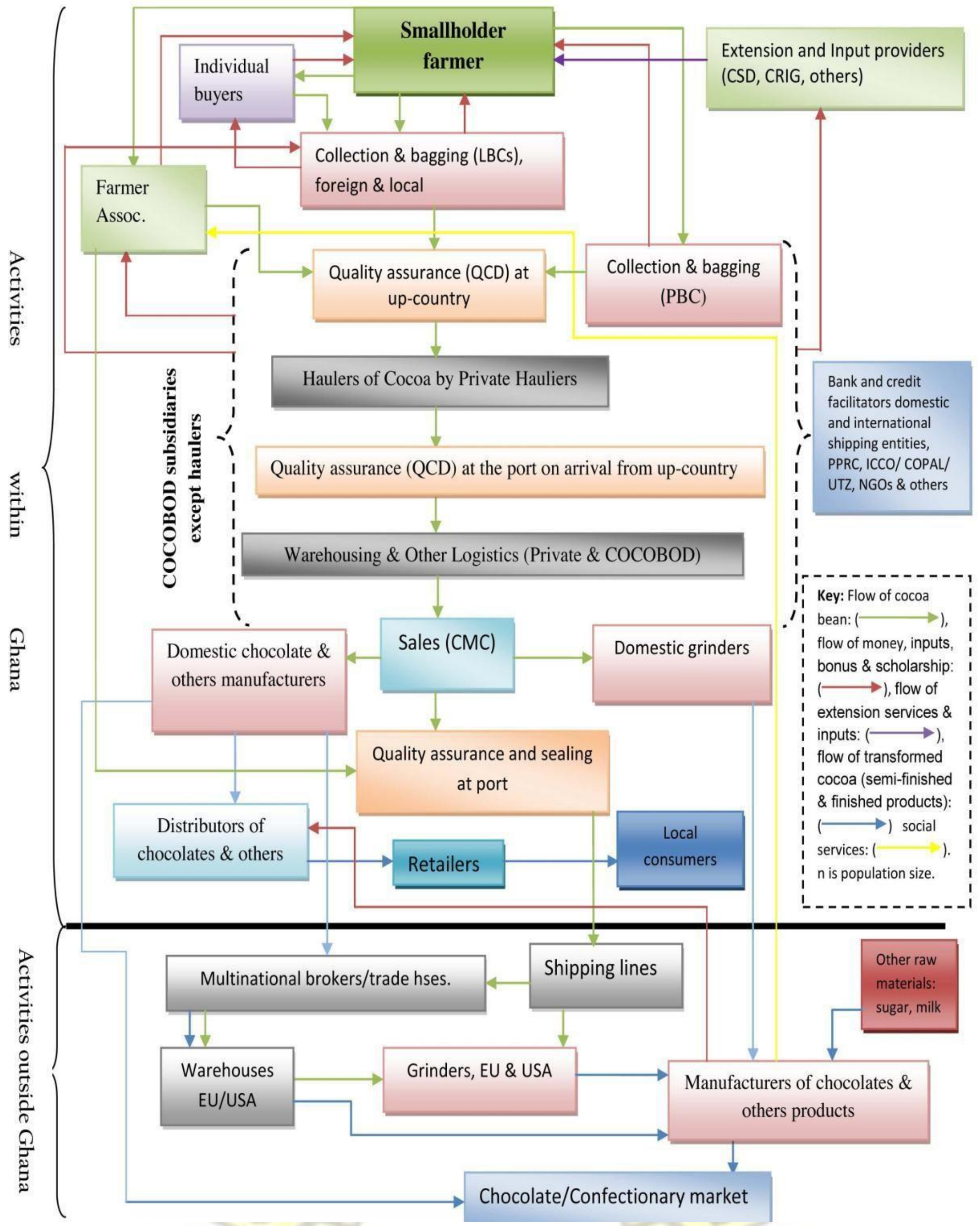
Cocoa is produced in Ghana mainly in the forest areas, thus, Western, Ashanti, BrongAhafo, Central, Eastern, and Volta regions, where the rainfall is usually between 1,000 and 1,500 mm per year (Ashitey, 2012). In a bid to establish sustainable ways to increase yield and improve quality of cocoa beans, the government of Ghana via concerted efforts has empowered its institutions such as COCOBOD and its subsidiaries including Cocoa Research Institute of Ghana (CRIG) and major stakeholders including farmers and some private bodies to provide extension services to the farmers (Ashitey, 2012).The purpose of these extension services is to improve agronomic practices, provide fertilizer and chemicals for pest and disease control. The Government is also committed to higher remuneration for farmers as an incentive for high production and also providing funds for the rehabilitation and replanting of old farms. As well, institutions such as CRIG and other research stations have the mandate to develop hybrid cocoa seedlings with higher yields.

2.5.3 Cocoa Supply Chain in Ghana

Despite several interventions by the government of Ghana, cocoa farmers in Ghana continue to rely on the traditional methods such as the use of hoes and cutlasses for farming. Mohammed *et al*. (2012) reported that competition among farmers is nonexistent because government of Ghana is the sole exporter of cocoa. Ghana cocoa value chain consists of three (3) main players; farmers, license buying companies (LBCs) and COCOBOD. Like most cocoa producing nations in Africa and Asia, cocoa is a major contributor to Ghana"s gross domestic product (GDP) and foreign exchange earner for the country.

Cocoa production in Ghana and most West African countries is mainly on smallholder or family farms using labour-intensive methods. The vast majority of labour employed on cocoa farms in Ghana is adult and it can be either full period or casual basis (Beckett, 2009). During busy harvest periods children are made to help with farm work such as plucking of cocoa pods and carrying baskets of cocoa pods to breaking sites. In as much as cocoa growing provides significant benefits to the Ghanaian rural economies and the national economy at large, much can be done to improve the conditions and livelihood of cocoa farmers since majority of these farmers continue to use primitive farming methods (Mohammed *et al*., 2012).

From the detailed map of Ghana"s cocoa value chain (Figure 2.1), the smallholder farmers after fermentation and drying of their cocoa beans sell their dried cocoa beans to the cocoa marketing company (CMC) via the license buying companies (LBCs). However, there are some individuals (middle men) who are not aligned to any institution who buy from the farmers when they need money and they intend sell to the LBCs.
Quality control checks are conducted on all cocoa by the Quality Control Company of COCOBOD.



Source: Mohammed *et al.* (2012)

Figure 2.1: Value Chain of Ghana cocoa

2.5.4 Cocoa Commerce: Demand, Consumption and Market for Cocoa

Grindings of cocoa beans serves as a proxy for the estimation of the demand for the commodity across the world. Cocoa processing, or grinding, entails the transformation of dried cocoa beans into a variety of processed products including cocoa paste or liquor, cake, powder and butter (Afoakwa, 2010). The foregoing discussion gives a view that two-thirds of the world total grindings and consumption of cocoa beans occurs outside the production zones, demand is highest in Europe with 39.1% and the Americas with 21.8% (www.worldcocoafoundation.com). Nonetheless due to the increase in demand and consumption, grindings has also increased in some producing countries such as

Ghana and Ivory Coast of which has necessitated the expansion of Cargill Cocoa and Chocolate processing factory in the later (www.cargill.com). Due to a growing number of Fairtrade and organic crop organizations around the world especially in Europe and America, there has been a marked increase in the demand and consumption of specialty cocoa products. Current market trend shows that Fairtrade cocoa commands a very small share of the cocoa market (0.5%). The typical significance of Fairtrade cocoa is that the farmers via their respective organizations receive a higher price for their cocoa beans. It is calculated on the basis of world market prices, plus Fair trade premiums. The Fairtrade premium for standard quality cocoa is US$ 150 per tonne. The minimum price for Fair trade standard quality cocoa, including the premium, is US$ 1,750 per tonne. However, based on the steady growth of Fairtrade and support from activists and the general public, some Fair trade participants claim that the idea were eventually grown from a niche market and become more mainstream (ICCO, 2013).

The organic cocoa market represents a very small share of the total cocoa market, estimated at less than 0.5% of total production. ICCO (2012) projections for production of certified organic cocoa at 15,500 tonnes, mainly from the following countries:

Madagascar, Tanzania, Uganda, Belize, Bolivia, Brazil, Costa Rica, Dominican Republic, El Salvador, Mexico, Nicaragua, Panama, Peru, Venezuela, Fiji, India, Sri Lanka and Vanuatu.

However, similar to Fairtrade cocoa, the demand for organic cocoa products is growing at a very strong pace, as consumers are increasingly concerned about the safety of their food supply along with other environmental issues chiefly global warming. Certified organic cocoa producers must comply with all requirements associated with the legislation of importing countries on production of organic products. The benefit for cocoa farmers is that organic cocoa commands a higher price than conventional cocoa, usually ranging from US$ 100 to US$ 300 per tonne. It is inspiring to note that originating countries with smaller volumes can fetch much higher premiums. This premium should cover both the cost of fulfilling organic cocoa production requirements and certification fees paid to certification bodies (ICCO, 2012).

Ghana processes about 215 thousand tonnes (Table 2.1) (about 40 per cent of its cocoa bean production) domestically and exports the processed materials (ICCO, 2012).

Table 2.1: Processing of cocoa beans in thousand tonnes from 2009 to 2012

Grinding Regions	2009/ 2010		Estimates 2010/2011		Forecasts 2011/2012	
Europe	**1524**	**(40.8%)**	**1615**	**(41.1%)**	**1536**	**(39.0%)**
Germany	361		439		420	
Netherlands	525		540		510	
Others	638		636		606	
Africa	**685**	**(18.3%)**	**658**	**(16.7%)**	**717**	**(18.2%)**
Côte d'Ivoire	411		361		440	
Ghana	212		230		215	
Others	61		67		62	
America	**815**	**(21.8%)**	**860**	**(21.9%)**	**839**	**(21.3%)**
Brazil	226		239		240	
United States	382		401		385	
Others	207		219		214	
Asia & Oceania	708	19.0%	795	20.2%	850	21.6%
Indonesia	130		190		240	
Malaysia	298		305		295	
Others	280		299		315	
World total	3731	100.0%	3927	100.0%	3941	100.0%
Origin grindings	1527	40.9%	1598	40.7%	1693	43.0%

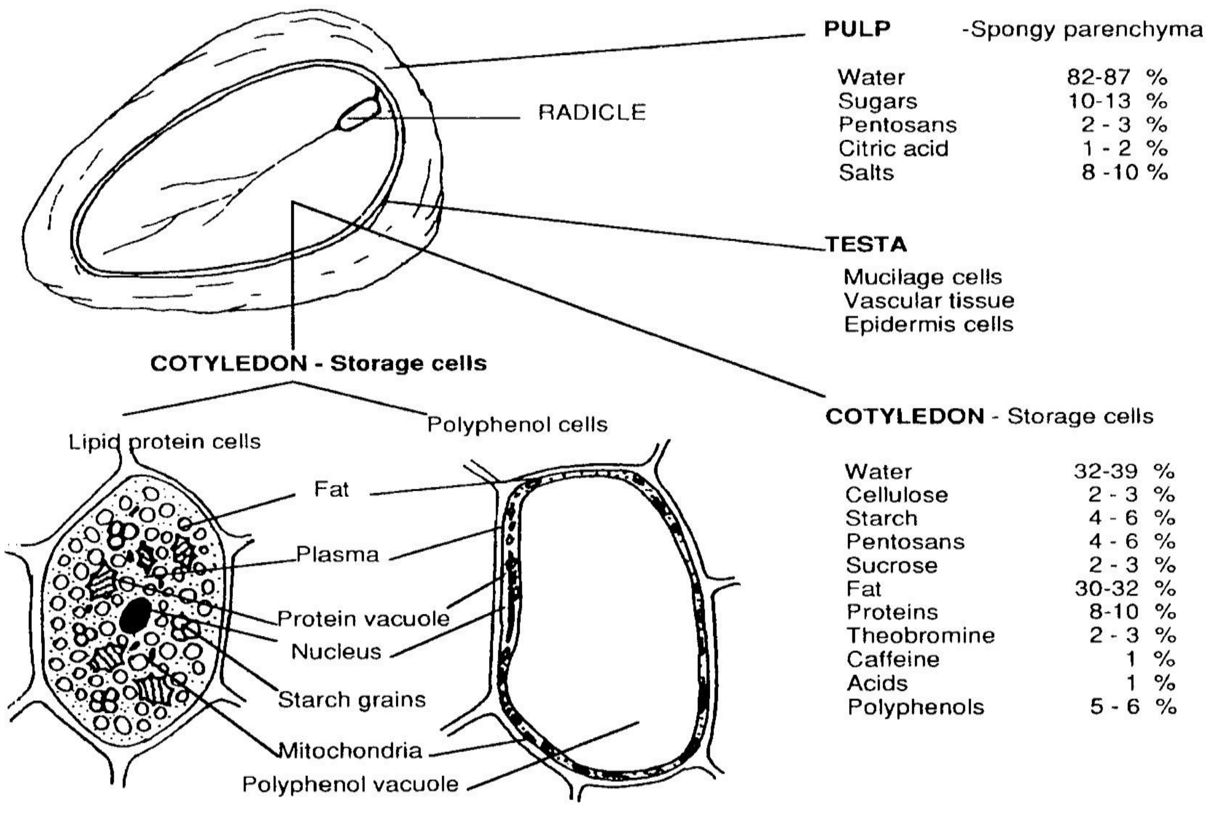
Source: ICCO (2012). Note: Totals may differ from sum of constituents due to rounding.

2.6 Challenges faced by Licensed Buying Companies (LBCs) in Ghana

Various challenges are faced by LBC"s in Ghana. These include lower margins, excessive market power of COCOBOD, poor financial management, high finance cost, competition in volumes instead of price, and poor infrastructural facilities (Zeitlin, 2006; Vigneri and Santos, 2007; Adu, 2007; Kusi, 2006; Laven, 2007).

2.7 Cocoa Bean Composition

The size of cocoa beans is of practical significance as flat beans are not viable. The minimum average bean size is 1 g (Nair, 2010). A transverse section via a cocoa bean reveals two cotyledons (nibs) and a small germ or embryo, all enclosed in a leathery seed coat or testa (shell) (Figure 2.2), which is impermeable to large molecules however, small molecules such ethanol and acetic acid are capable of diffusing into the bean. The cotyledons have two main functions, as the storage organs containing nutrients for the development of the seedling and as the premier leaves of the plant when the seed germinates (Nielsen, 2006; Nair 2010; Afoakwa, 2010).



Source: Lopez and Dimick (1995)

Figure 2.2: Anatomy of the cocoa seed

Fresh Forastero beans are violet in cross-section but upon proper fermentation attain the deep brown colour, which give chocolate its colour and produces a strong cocoa flavour upon proper processing (Lopez and Dimick1995; Nielsen, 2006; Afoakwa, 2010).The cotyledons are basically made up of different types of storage cells, polyphenolic cells contain a single large vacuole filled with polyphenols and alkaloids and on the other hand, cells tightly packed with multiple small protein and lipid vacuoles and other components such as starch granules (Figure 2.2). All these components serve as a harbinger for cocoa flavour and aroma characters (Nazaruddin *et al*., 2001; Afoakwa, 2010).

2.7.1 Quality of Cocoa Beans Production in Ghana

The credibility, reputation and price of cocoa beans is highly dependent on the quality. Ghana‟s success story on cocoa quality is highly dependent on quality systems developed by COCOBOD. The existing pricing is attributable to forward sales contracts as collateral for discounted international loans leading to the possibility of setting a fixed producer price and other profit margins (Laven, 2005) and consequently sustained quality.

Cocoa beans produced in Ghana are rated to be of premium quality as a result of the following: the fixed producer prices in Ghana that results in farmers not being pressured to sell their produce too early (or too late) by a fluctuating price, but at moments when quality is optimal, and; the methodical infrastructure of QCC in Ghana that checks the quality of the purchased cocoa on three different points in the chain before shipment. If quality compliance fails, the cocoa is sent back to the LBC, using a good system of traceability. This system enables the LBCs to blacklist recalcitrant farmers.

CHAPTER THREE

3.0 MATERIALS AND METHODS

The study was conducted to determine the effect of different storage periods on the quality of Amelonado and Mixed Hybrid varieties of dry cocoa beans: a case study at Wassa Amenfi west District of Western Region. The study comprise two components mainly field survey and laboratory experiment.

3.1 Description of Study Area

The study was conducted at Samreboi, Asankrangwa and Akyekyere Cocoa Districts which are part of Wassa Amenfi West District of Western Region of Ghana. The Wassa Amenfi West District located between Latitude 400‘‘N and 500 40‘‘N and Longitudes 10 45‘‘ W and 20 10‘‘W.

Average annual rainfall tapers off from 173 mm at the south to 140 mm at the north. The district experiences bimodal rainy season i.e. March to July and September to early December. Two dry spells separate the seasons. Temperatures are generally high ranging from 24 degrees Celsius to 29 degrees Celsius. Maximum temperatures were recorded in March and Minimum in August.

The study was conducted at Asankrangwa, Samreboi and Akyekyere in the western region. The three towns are cocoa growing Districts in the Wassa Amenfi West Districts. The districts are situated in tropical rainforest ecological zone with average temperature of 24-29% degree Celsius.

Generally the annual rainfall is between 1500-1,650mm. The vegetation within the ecological zone is made up of forest reserves, rubber plantation, sacred mangroves, mahogany, odum, Dhomeatcenta tree of great economic importance (www.ghanadistrict.com).

3.2 Field Survey

The main objective of the field survey was to identify storage practices among farmers and Purchasing Clerks (PCs) of License Buying Companies (LBCs) in the cocoa districts and challenges they face.

3.2.1 Questionnaire Survey

A structured questionnaire was used to collect data from farmers and PCs. The questionnaires were pre-tested at Enchi cocoa district using ten farmers and five PCs. A modified questionnaire (Appendix I) were used to interview cocoa farmers and PCs. The questionnaire was made up of two sections mainly background information of respondents and storage practices.

Simple random sampling technique was used in selecting farmers to participate in the study. In the course of Sampling, One hundred fifty (150) farmers were contacted and interviewed with fifty (50) farmers from each cocoa districts (Samreboi, Asankrangwa and Akyekyere districts respectively). Seventy five (75) PCs in the cocoa districts were selected and interviewed using purposive sampling technique with twenty five (25) PCs from each district.

3.3 Laboratory Studies

3.3.1 Experimental Design and Treatment Details

A 2 x 5 factorial design in a completely randomized design was used. There were two factors. Factor „A" was varieties with two levels (Amelonado and mixed hybrid) and factor

„B" was storage period with five levels (i.e. initial (control), 30, 60, 90 and 120 days). There were ten treatments combinations (H_0, H_{30}, H_{60}, H_{90}, H_{120}, A_0, A_{30}, A_{60}, A_{90} and A_{120} where H and A stand for mixed hybrid and Amelonado varieties respectively and subscripts represent storage periods in days) and the experiment was replicated three times.

3.3.2 Experimental Procedure

Cocoa pods (Amelonado and mixed hybrid) of uniform ripeness (when the pods was 180 days from flowering as pods turned from greenish to yellowish or orange in colour) were harvested from Amelonado variety and also from Mixed hybrid variety in June 2015. The harvesting was done by traditional methods using sickle and machette (under ambient temperature during the day, 28-30 °C) and the pods transported to the fermentation station where they were stored for 3 days to ensure pulp preconditioning. Pod breaking was done using wooden billet which involved one or two sharp blows with the edge of the billet.

Two hundred kilogrammes (200 kg) of extracted cocoa beans from Amelonado pods and mixed hybrid pods respectively were fermented separately using the heap fermentation method with plantain leaves. Fermentation lasted for 6 days with consecutive opening and turning every 48 hours.

Sun drying technique was employed to dry the fermented beans on raised platforms with a raffia mat. Cocoa beans were dried until they reached moisture content of 7% with the help of aqua boy device (KAM 1113005071, Germany). The beans were mixed thoroughly to ensure uniformity. Cocoa beans from each variety (Amelonado and mixed hybrid) were dried separately and stored in Jute sack for 30, 60, 90 and 120 days in triplicates.

3.4 Parameters Studied

Before the storage, i.e. when sampled cocoa beans were dried and attained moisture content of 7%: cut test, moisture content, pH, fat and free fatty acid contents were determined as initial data. At the same Period, samples were subjected to different treatments (storage periods). The room temperature and relative humidity were measured at each sampling period with temperature and humidity data logger device. Details of cut test and other laboratory analysis carried out at the various storage periods are given below.

3.4.1 Determination of some physical factors that affect the storage quality of dry cocoa beans

3.4.1.1 Purity Test

The cut test is a visual assessment quality characteristic of cocoa 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 thus contained hundred beans and were cut length-wise through the middle to expose the internal surface of the two cotyledons.

The cut beans were examined in good daylight and the percentage total purple (deep, pale and partly brown/partly purple) beans were determined and recorded. Percentage defective beans (i.e. mouldy, slaty, all other defects (germinated, weevil infested, flat, beans) were determined through hand picking. Defective percentage beans were calculated out of the three hundred beans split open and recorded.

Purity test (PTY) was determined using the formula.

PTY= 100-M+S+OD (G+W+F) where M=mouldy beans, G=germinated beans, S=slaty beans, W=weevil infested beans, F=Flat beans OD=other defects.

Figure 3.1: Beans under the cut test process

3.4.2 Determination of some chemical factors that affect the storage quality of dry cocoa beans

Cocoa beans were milled into powder with ceramic mortar and pestle after which the milled beans were defatted. The powders obtained were directly used for proximate analysis by the methods outlined by AOAC (2005) and Pousga *et al.,* (2007). All the laboratory analysis was carried out at Horticulture Department laboratory of KNUST,

3.4.2.1 Determination of moisture content

Empty crucible was dried in an oven, cooled and weighed. About 2g of the sample was put in this crucible and heated in the oven at 105^{0}C for 5 hours. The sample was cooled and weighed. The process was repeated until a constant weight was obtained. The percentage moisture content was calculated as loss in weight of the original sample.

$$\% \text{ moisture} = \frac{(B - C) - (D - C)}{A} \times 100\%$$

Where

A = weight of sample (g)

B = weight of crucible + sample before oven drying (g)

C = weight of crucible (g)

D = weight of crucible + dry sample after oven drying (g)

3.4.2.2 Determination of pH

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

3.4.2.3 Determination of fat content

The method employed was the Soxhlet extraction technique adopted by Pousga *et al.* (2007). Twenty grams (20g) 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:

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

3.4.2.4 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

3.5 Data Analysis

The data gathered from the field survey were coded and analysed using descriptive statistics of Statistical Product and Service Solutions (SPSS) software (version 19.0). The descriptive statistics used were frequencies, percentages and means.

The data recorded from cut test and laboratory analysis were subjected to Analysis of Variance (ANOVA) using Statistix statistical package 9th edition. Treatment means were compared using the honest significant difference (HSD) at 1% level of probability.

CHAPTER FOUR

4.0 RESULTS

This chapter gives the results of the study. It comprises 2 components: field survey and laboratory studies (physical and chemical analysis).

4.1 Field Survey

4.1.1 Farmers' Background and Storage Practices

4.1.1.1 Background information of farmers

Table 4.1 presents the background characteristics of farmers. There was a clear dominance of males (82%) as against females (18%). With regards to age of farmers, majority (46%) of them were aged above 59 years followed by 50 -59, 40 -49, 30 – 39 and 20 – 29 years with 27, 13, 11 and 3% respectively. In relation to highest educational level, majority being 56% have had no formal education, 18% of them have had primary education, 12% of them have had tertiary education, 8% have had Middle School Leaving Certificate (MSLC) /Junior Secondary School (JSS)/ Junior High School (JHS) and the remaining 6% have had secondary/technical/vocational education. Moreover, 33% of the farmers have had respondents have had 31 – 40 years' experience in cocoa farming, 30% of them have had 11 – 20 years, 20% have had 1 – 10 years and 17% have had 21 – 30 years.

Table 4.1: Background information of farmers

Items	Frequency	Percentage
Sex		
Male	123	82
Female	27	18
Total	**150**	**100**
Age (years)		
20-29	5	3
30-39	17	11
40-49	19	13
50-59	40	27
Above 59	69	46
Total	**150**	**100**
Highest education		
No formal	84	56
Primary	27	18
MSLC/JSS/JHS	12	8
Secondary	9	6
Tertiary	18	12
Total	**150**	**100**

Experience in cocoa farming (years)		
1-10	30	20
11-20	45	30
21-30	26	17
31-40	49	33
Total	**150**	**100**

4.1.1.2 Storage practices of farmers

Storage practices of farmers are shown in Figure 4.1, 4.2 and 4.3. Figure 4.1 indicates that majority of the farmers being 52% use experience / hand feel, visual assessment/ colour and sound in determining the dryness of their cocoa beans. Followed by 22% of them that use only sound to determine the level dryness of their cocoa beans. 18% of them use experience / hand feel whereas 8% use visual assessment /colour (Figure 4.1).

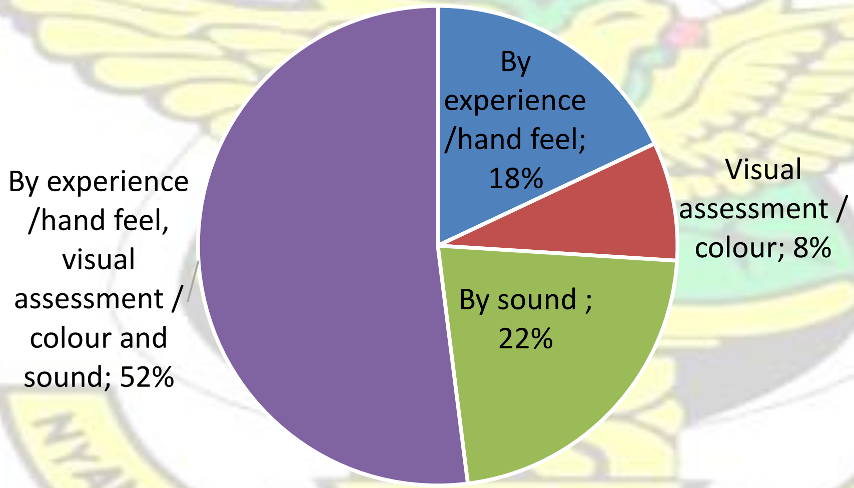


Figure 4.1: Farmers ways of determining level of dryness appropriate for storing their cocoa beans

In responding to duration of storage of dried cocoa beans by farmers in both main and minor seasons as shown in Figure 4.2, 123 farmers representing 82% indicated to store dried cocoa beans during the main season for less than 7 days whereas 10% and 8% store for between 7 – 14 and 14 – 21 days respectively. In the minor season, 62% of the farmers indicated to store dried cocoa beans during the main season for less than 7 days whereas 26% and 12% store for between 7 – 14 and 14 – 21 days respectively (Figure 4.2).

Table 4.2: Duration of storage of dried cocoa beans by farmers

Duration (Days)	Main season		Minor season	
	Frequency	Percentage	Frequency	Percentage
Less than 7	123	82	93	62
7 – 14	15	10	39	26
14 – 21	12	8	18	12
Total	**150**	**100**	**150**	**100**

Forty per cent (40%) of the farmers reported to store their dried cocoa beans in jute sack whilst 23%, 19%, 10%, 5% and 3% of the farmers store in baskets, fertilizer bags, hermetic bags, polythene bags and rubber bowls respectively (Figure 4.2).

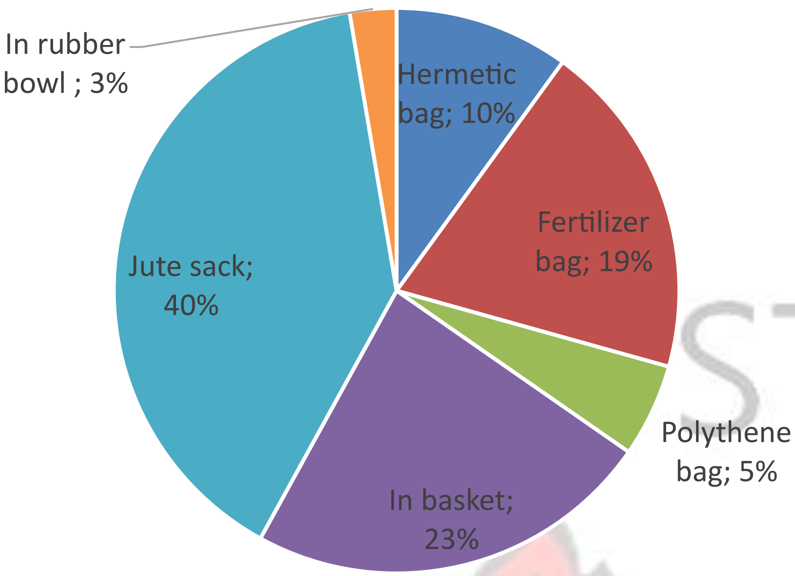


Figure 4.2: Storage structures used by farmers for their dry cocoa beans

4.1.2 Purchasing Clerks (PCs) Background and Storage Practices

4.1.2.1 Background information of PCs

Background characteristics of PCs are shown in Table 4.3. Majority of the PCs being 92% were males whereas 8% were females. With relation to age of PCs, 39% were aged 30 – 39 years followed by 25%, 18%, 13% and 6% in the age group of 50 – 59, 40 – 49, 20 – 29 and above 59 respectively. With regard to highest educational level, 32% of the farmers have had MSLC / JSS / JHS, 22% of them have had secondary / technical / vocational education, 21% have had primary education, 17% have had no formal education and 8% have had tertiary education.

Table 4.3: Background information of Purchasing Clerks

Items	Frequency	Percentage
Sex Male		
	69	92
Female	6	8
Total	**75**	**100**

Age (years) 20-29	10	12
30-39	29	38
40-49	14	18
50-59	19	25
Above 59	5	6
Total	**75**	**100**
Highest education No formal	13	17
Primary	16	21
MSLC/JSS/JHS	24	32
Secondary	17	22
Tertiary	6	8
Total	**75**	**100**
Number of years in cocoa purchasing 1-10 years	49	65
11-20 years	10	13
21-30years	9	12
31-40 years	8	10
Total	**75**	**100**

Moreover, 33% of the PCs have had respondents have had 1 – 10 years‟ experience in cocoa purchasing business, 13% of them have had 11 – 20 years, 12% have had 21 – 30 years and 10% have had 31 – 40 years (Table 4.3).

4.1.2.2 Storage practices of Purchasing Clerks

Figures 4.3 and Tables 4.4, 4.5 and 4.6 present information on the storage practices of Purchasing Clerks (PC) whereas Table 4.7 gives information on the conditions of storage facilities of PCs.

Majority of the PCs being 34% use only experience / hand feel to determine dryness of cocoa beans from farmers before they purchase, 21% use combination of experience / hand feel, visual assessment/ colour and sound, 17% use only visual assessment /colour, 16% use aqua boy moisture meter (device) and 12% use only sound (Figure 4.3).

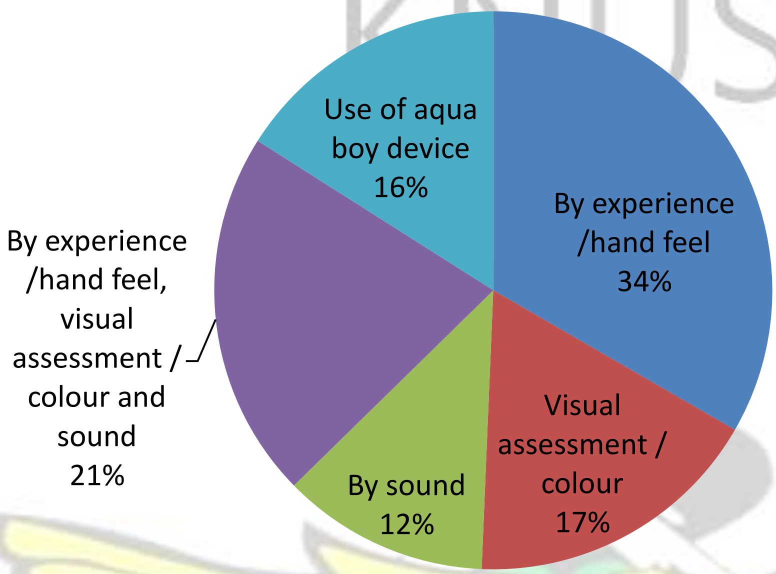


Figure 4.3: Methods PCs use to assess dryness of cocoa from farmers

With regards to duration of storage of dried cocoa beans by PCs in both main and minor seasons as shown in Figure 4.5, twenty one (21) out of 28% of the PCs indicated to store dried cocoa beans during the main season for less than 14 days whereas 29%, 23% and 20% store for between 14 – 21, 21 – 28 and more than 28 days respectively.

In the minor season, 35% of the PCs indicated to store dried cocoa beans for between 21 - 28 days, 28% store for more than 28 days, 25% store for between 14 – 21 days and 12% store for less than 14 days (Table 4.4).

Table 4.4: Duration of storage of dried cocoa beans by Purchasing Clerks (PCs)

Duration (Days)	Main season		Minor season	
	Frequency	Percentage	Frequency	Percentage
Less than 14	21	28	9	12
14 – 21	22	29	19	25
21 – 28	17	23	26	35
More than 28	15	20	21	28
Total	**75**	**100**	**75**	**100**

Concerning materials for storage of purchased dried cocoa beans, 92% of the PCs reported to store in jute sack whereas 8% store in hermetic bag (Table 4.5). However, 49% indicated to re-dry once a while, 20% said they re-dry whenever necessary, 16% mentioned to re-dry frequently whereas 15% said they do not re-dry (Table 4.5).

Among those PCs who re-dry their purchased beans, 33% of them re-dry on cemented floor, 30% use raise mat platform for re-drying, 23% of them use tarpaulin for the redrying whilst the remaining 14% use black polythene sheet for re-drying (Table 4.5).

Minority of the PCs (16%) do grading of their cocoa beans during storage whereas the majority being 84% do not grade. However, those PCs who do grading during storage, 58% grade according to uniform state of dryness, 17% use uniform size, 17% use uniform colour for the grading and 8% use uniform quality (Table 4.5).

Table 4.5: Storage practices of Purchasing Clerks

Items	Frequency	Percentage
Material for storage before transfer to depot Jute sack	69	92
Hermetic bag	6	8
Total	**75**	**100**

Frequency of re-drying purchased cocoa Once a while	37	49
Frequently	12	16
Whenever necessary	15	20
Do not re-dry	11	15
Total	**75**	**100**
Place use for re-drying		
Cemented floor	21	33
Raise mat platform	19	30
Plastic polythene sheet	9	14
Tarpaulin	15	23
Total	**64**	**100**
Grading of cocoa beans during storage Yes	12	16
No	63	84
Total	**75**	**100**
Procedure for grading		
Uniform size	2	17
Uniform colour	2	17
Uniform state of dryness	7	58
Uniform quality	1	8
Total	**12**	**100**

Minority of the PCs being 31% determine moisture content in their store cocoa beans whilst 69% reported not to determine moisture content (Table 4.6). Among those who determine moisture content during storage, 48% of them indicated to know the recommended moisture content of 5 – 6 %, 22% of the PCs know less than 5% moisture content, 9% of the PCs know above 6% to 8% moisture content, 4% of them know moisture content above 8% – 10% (Table 4.6). The methods PCs use in determining moisture content during storage followed in of by experience (48%) > by sound (39%) > aqua boy device (13%).

Table 4.6: Moisture content of cocoa during storage by Purchasing Clerks

Items	Frequency	Percentage
Determination of moisture content during storage		
Yes	23	31
No	52	69
Total	**75**	**100**
Moisture content (%) perceived as ideal for storage		
Less than 5%	5	22
5 - 6%	11	48
Above 6 - 8%	2	9
Above 8 - 10%	1	4
No idea	4	17
Total	**23**	**100**
Method of determining moisture content		
By experience	11	48
By sound	9	39
Use of moisture metre (aqua boy device)	3	13
Total	**23**	**100**

Among the PCs, 47% of them indicated to store their purchased cocoa beans with other items whilst 53% said they do not store with any other items (Table 4.7). Among those PCs who store their purchased cocoa beans with other items, 40% of them reported to store with food items, 26% of them said they store with agrochemicals, 23% indicated to store with clothes and 11% of them said they store with building materials (Table 4.7).

The materials PCs have used for roofing of the storage facility, 58.67% reported to use iron sheets, 25.33% of them indicated to have used bamboos and 16% said they have used thatches. With regards to materials used to build the storage facility, 40% of the PCs said they have used blocks, 34.67% of them have used wood and 25.33% said they have used mud (*Ata Kwame).*The nature of floor of the storage facility, 36% of the PCs indicated to have bear floor, 20% of them have concrete floor, 18.67% said to have cemented floor, 12% said to have tiled floor and 13.33% have wooden floor (Table 4.7).

Table 4.7: Conditions of storage facilities of Purchasing Clerks

Items	Frequency	Percentage
Storage with other items		
Yes	35	47
No	40	53
Total	**75**	**100**
Others items cocoa beans are stored with		
Food items	14	40
Agrochemicals	9	26
Building materials	4	11

Clothes	8	23
Total	**35**	**100**

Roofing materials for the storage facility		
Bamboo	19	25
Iron sheet	44	59
Thatch	12	16
Total	**75**	**100**

Materials used for shed/storage facility		
Wood	26	35
Mud (*Ata Kwame*)	19	25
Blocks	30	40
Total	**75**	**100**

State of floor of shed / storage facility		
Concrete floor	15	20
Cement floor	14	19
Tile floor	9	12
Bare Floor	27	36
Wooden floor	10	13
Total	**75**	**100**

4.2 Laboratory Studies

4.2.1 Effect of Different Storage Periods on Some Physical Properties of Dry Cocoa Beans of Amelonado and Mixed Hybrid Varieties

4.2.1.1 Effect of different storage periods, variety and their interaction on number of slaty beans produced by Amelonado and Mixed Hybrid cocoa varieties

Table 4.8 gives the effect of variety, storage period and their interactions on slaty beans in the stored cocoa beans.

Cocoa variety did vary significantly ($p<0.01$) in slaty beans in the stored cocoa beans. Mixed hybrid varieties had greater slaty beans of 0.54% which was different from the Amelonado variety with 0.20%.

Number of slaty beans was not affected by storage period (*p>0.01*). Similar trend was observed for the interactive effect of variety and storage Period.

Table 4.8: Effect of variety, storage period and their interaction on number of slaty beans in the dried stored cocoa beans

	Slaty beans (%)					
	Storage Period (SP) (days)					
Variety (V)	**Initial**	**30**	**60**	**90**	**120**	**Mean**
Mixed hybrid	0.70 [a]	0.70 [a]	0.57 [a]	0.43 [a]	0.30 [a]	**0.54 [a]**
Amelonado	0.20 [a]	0.20 [a]	0.20 [a]	0.20 [a]	0.20 [a]	**0.20 [b]**
Mean	**0.45 [a]**	**0.45 [a]**	**0.38 [a]**	**0.32 [a]**	**0.25 [a]**	
HSD (0.01)	V = 0.17	SP = 0.35	V×SP= 0.58			
CV (%)	4.37					

Means of variety, storage Period and their interactions with same alphabet indicates no significant difference at p=0.01

4.2.1.2 Effect of different storage periods, variety and their interaction on number of mouldy beans produced by Amelonado and Mixed Hybrid cocoa varieties Neither variety, storage period nor their interaction did influence (*p>0.01*) mouldy beans (Table 4.9).

Table 4.9: Effect of variety, storage period and their interaction on mouldy beans in the dried stored cocoa beans

	Mouldy beans (%)					
	Storage Period (SP) (days)					
Variety (V)	**Initial**	**30**	**60**	**90**	**120**	**Mean**
Mixed hybrid	0.23 [a]	0.23 [a]	0.47 [a]	0.56 [a]	0.43 [a]	**0.39 [a]**
Amelonado	0.00 [a]	0.00 [a]	0.10 [a]	0.10 [a]	0.33 [a]	**0.11 [a]**
Mean	**0.12 [a]**	**0.12 [a]**	**0.28 [a]**	**0.33 [a]**	**0.38 [a]**	

HSD (0.01)	V = 0.30	SP = 0.61	V×SP= 1.01
CV (%)	1.14		

Means of variety, storage period and their interactions with same alphabet indicates no significant difference at p=0.01

4.2.1.3 Effect of different storage periods, variety and their interaction on number of purple beans produced by Amelonado and Mixed Hybrid cocoa varieties Neither variety, storage period nor their interaction did influence (*p>0.01*) purple beans (Table 4.10).

Table 4.10: Effect of variety, storage Period and their interaction on purple beans in the dried stored cocoa beans

	Purple beans (%)					
	Storage Period (SP) (days)					
Variety (V)	**Initial**	**30**	**60**	**90**	**120**	**Mean**
Mixed hybrid	21.58 [a]	20.77 [a]	20.67 [a]	21.00 [a]	20.90 [a]	**20.98 [a]**
Amelonado	21.01 [a]	20.67 [a]	20.33 [a]	20.23 [a]	20.23 [a]	**20.50 [a]**
Mean	**21.30 [a]**	**20.72 [a]**	**20.50 [a]**	**20.62 [a]**	**20.57 [a]**	
HSD (0.01)	V = 0.75	SP = 1.55	V×SP= 2.54			
CV (%)	3.42					

Means of variety, storage period and their interactions with same alphabet indicates no significant difference at p=0.01

4.2.1.4 Effect of different storage periods, variety and their interaction on number of all other defects beans produced by Amelonado and Mixed Hybrid cocoa

varieties

All other defects were not different (*p>0.01*) among variety, storage period and their interaction (Table 4.11).

Table 4.11: Effect of variety, storage Period and their interaction on all other defects beans in the dried stored cocoa beans

	All other defects beans (%)					
	Storage Period (SP) (days)					
Variety (V)	**Initial**	**30**	**60**	**90**	**120**	**Mean**
Mixed hybrid	0.80 [a]	0.57 [a]	0.43 [a]	0.33 [a]	0.23 [a]	**0.47 [a]**
Amelonado	0.43 [a]	0.30 [a]	0.10 [a]	0.20 [a]	0.23 [a]	**0.25 [a]**
Mean	**0.62 [a]**	**0.43 [a]**	**0.27 [a]**	**0.27 [a]**	**0.23 [a]**	
HSD (0.01)	V = 0.24	SP = 0.50	V×SP= 0.81			
CV (%)	6.25					

Means of variety, storage period and their interactions with same alphabet indicates no significant difference at p=0.01

4.2.1.5 Effect of different storage periods, variety and their interaction on the purity of cocoa beans of Amelonado and Mixed Hybrid cocoa varieties

Results of purity test in the stored cocoa beans are presented by Table 4.12. Purity test did vary significantly between the cocoa varieties. Amelonado variety had 99.45% which was higher than that of mixed hybrid varieties (98.65%) which might be due to the varietal difference.

Storage period did not affect purity test in the stored cocoa beans significantly (*p>0.01*). The combined effect of variety and storage period had significant (*p<0.01*) impact on the purity test in the stored cocoa beans (Table 4.12). The only significant difference existed between Amelonado variety stored at 60 days and mixed varieties at initial storage period with 99.60% and 98.53% respectively. Amelonado variety throughout the storage period had purity in the range of 99.27% to 99.60% whereas Mixed hybrid variety had purity in the range of 98.53% to 99.37%.

Table 4.12: Effect of variety, storage period and their interaction on purity test in the dried stored cocoa beans

	Purity test (%)					
	Storage Period (SP) (days)					
Variety (V)	**Initial**	**30**	**60**	**90**	**120**	**Mean**
Mixed hybrid	98.53 [b]	99.37 [ab]	98.53 [ab]	98.67 [ab]	99.03 [ab]	**98.65 [b]**
Amelonado	99.37 [ab]	99.50 [ab]	99.60 [a]	99.50 [ab]	99.27 [ab]	**99.45 [a]**
Mean	**98.95 [a]**	**99.43 [a]**	**99.07 [a]**	**99.08 [a]**	**99.15 [a]**	
HSD (0.01)	V = 0.32	SP = 0.65	V×SP= 1.07			
CV (%)	0.30					

Means of variety, storage period and their interactions with same alphabet indicates no significant difference at p=0.01

4.2.2 Effect of Different Storage Periods on Some Chemical Properties of Dry Cocoa Beans of Amelonado and Mixed Hybrid Varieties

4.2.2.1 Effect of different storage periods, variety and their interaction on moisture content of stored dry cocoa beans

Effect of variety, storage period and their interaction is given by Table 4.13. Moisture content did not differ significantly (*$p>0.01$*) between the cocoa varieties.

Storage period had significant (*$p<0.01$*) effect on the moisture content in the stored cocoa beans. Storage at 60, 90 and 120 days had 6.75, 6.37 and 6.15% respectively which were similar in moisture content but only storage at 60 and 90 days were different from the moisture content at 30 days and the initial stage. In other words, the moisture content recorded at initial, 30 and 120 days were similar (5.48, 5.53 and 6.15% respectively).

The combined effect of variety and storage period had significant (*p<0.01*) influence on the moisture content. Amelonado variety stored on 30, 60, 90 and 120 days together with mixed hybrid varieties stored at 60 and 90 days had similar moisture content in the range of 5.89% to 6.93%. Similarly, Amelonado variety stored at 30, 60, 90 and 120 days had similar moisture content with mixed hybrid varieties stored at 90 and 120 days in the range of 5.67% to 6.63%. Moreover, Amelonado variety at initial, 30 and 60 days with mixed hybrid varieties at initial, 30 and 120 days had similar moisture content in the range of 6.17% to 5.20%.

Table 4.13: Effect of variety, storage period and their interaction on moisture content in the dried stored cocoa beans

	Moisture content (%)					
	Storage Period (SP) (days)					
Variety (V)	**Initial**	**30**	**60**	**90**	**120**	**Mean**
Mixed hybrid	5.27 [c]	5.20 [c]	6.93 [a]	6.57 [ab]	5.67 [bc]	**5.93 [a]**
Amelonado	5.70 [bc]	5.89 [abc]	6.57 [bc]	6.17 [abc]	6.63 [ab]	**6.19 [a]**
Mean	**5.48** [b]	**5.53** [b]	**6.75** [a]	**6.37** [a]	**6.15** [ab]	
HSD (0.01)	V = 0.36	SP = 0.74	V×SP= 1.22			
CV(%)	5.61					

Means of variety, storage period and their interactions with same alphabet indicates no significant difference at p=0.01

4.2.2.2 Effect of different storage periods, variety and their interaction on pH of

stored dry cocoa beans

Influence of variety, storage period and their interaction is present in Table 4.14. The Amelonado variety had pH of 5.43 and this was similar to that of mixed hybrid varieties which had 5.39.

Table 4.14: Effect of variety, storage period and their interaction on pH in the dried stored cocoa beans

	pH					
	Storage Period (SP) (days)					
Variety (V)	**Initial**	**30**	**60**	**90**	**120**	**Mean**
Mixed hybrid	5.13 [a]	5.20 [a]	5.67 [a]	5.50 [a]	5.43 [a]	**5.39 [a]**
Amelonado	5.43 [a]	5.43 [a]	5.50 [a]	5.40 [a]	5.40 [a]	**5.43 [a]**
Mean	**5.28 [a]**	**5.32 [a]**	**5.58 [a]**	**5.45 [a]**	**5.42 [a]**	
HSD (0.01)	V = 0.16	SP = 0.34	V×SP= 0.56			
CV(%)	2.87					

Means of variety, storage period and their interactions with same alphabet indicates no significant difference at p=0.01

Neither effect of storage period nor combination of variety and storage period did influence pH in the stored cocoa beans (Table 4.14).

4.2.2.3 Effect of different storage periods, variety and their interaction on fat content of stored dry cocoa beans

Fat content in the cocoa beans did vary significantly ($p<0.01$) between the Amelonado variety (38.34%) and mixed hybrid varieties (34.10%) (Table 4.15).

Fat content in the stored cocoa beans differed significantly ($p<0.01$). Fat content at the initial, 30 and 90 days which were 41.02%, 38.33% and 35.92% respectively and their contents were similar. Only the fat content at the initial stage was statistically different from the fat contents at 60 and 120 days (32.17 and 33.67% respectively (Table 4.15).

Interactive effect of variety and storage period had significant (*p<0.01*) influence on the fat content in the stored cocoa beans (Table 4.15). Amelonado variety at initial, 30, 60, 90 and 120 days had statistically similar fat content with mixed hybrid varieties at initial, 30 and 90 days in the range of 34.00% - 42.67%. Fat content of Amelonado variety at 30 days was statistically different from that of mixed hybrid varieties at 60 and 120 days which had 29.50% and 31.00% respectively. Again, Amelonado variety at initial stage, 60, 90 and 120 days had similar fat content with mixed hybrid varieties at initial, 30, 90 and 120 days in the range of 31.00% to 41.67%. Moreover, Amelonado variety stored at 60, 90 and 120 days had fat content of 34.83% to 37.00% which were similar to fat content of mixed hybrid varieties stored at 30, 60, 90 and 120 days which had 29.50% to 34.83% (Table 4.15).

Table 4.15: Effect of variety, storage period and their interaction on fat content in the dried stored cocoa beans

	Fat content (%)					
			Storage Period (SP) (days)			
Variety (V)	**Initial**	**30**	**60**	**90**	**120**	**Mean**
Mixed hybrid	41.17 [ab]	34.00 abc	29.50 [c]	34.83 abc	31.00 [bc]	**34.10 [b]**
Amelonado	40.87 [ab]	42.67 [a]	34.83 abc	37.00 abc	36.33 abc	**38.34 [a]**
Mean	**41.02 [a]**	**38.33 [ab]**	**32.17 [b]**	**35.92 [ab]**	**33.67 [b]**	
HSD (0.01)	V = 3.02	SP = 6.26	V×SP= 10.28			
CV(%)	7.92					

Means of variety, storage period and their interactions with same alphabet indicates no significant difference at p=0.01

4.2.2.4 Effect of different storage periods, variety and their interaction on free fatty acid content of stored dry cocoa beans

Effect of variety, storage period and their interaction on free fatty acid content is presented in Table 4.16. Free fatty acid in Amelonado variety was 1.69% which was statistically lower (*p<0.01*) and different from that of the mixed hybrid varieties (1.98).

Storage period had significant (*p<0.01*) effect on free fatty acid content in the stored cocoa beans. Free fatty acid recorded at the initial stage, 30, 60 and 120 days were similar (2.12%, 1.98%, 1.57% and 2.09% respectively. Only the fat content recorded at 60 days was similar to that of 90 days (1.43%).

Table 4.16: Effect of variety, storage period and their interaction on free fatty acid content in the dried stored cocoa beans

	Free fatty acid content (%)					
	Storage Period (SP) (days)					
Variety (V)	**Initial**	**30**	**60**	**90**	**120**	**Mean**
Mixed hybrid	2.16^{ab}	2.20^{ab}	1.79^{ab}	1.36^{b}	2.40^{a}	**1.98**^{a}
Amelonado	2.06^{ab}	1.77^{ab}	1.36^{b}	1.49^{b}	1.77^{ab}	**1.69**^{b}
Mean	**2.12**^{a}	**1.98**^{a}	**1.57**^{ab}	**1.43**^{b}	**2.09**^{a}	
HSD (0.01)	V = 0.27	SP = 0.55	V×SP= 0.91			
CV(%)	13.78					

Means of variety, storage period and their interactions with same alphabet indicates no significant difference at p=0.01

Effect of variety and storage period combined was significant (*$p<0.01$*) on free fatty acid content in the stored cocoa beans (Table 4.16). Free fatty acid content of mixed hybrid varieties at the initial, 30, 60 and 120 days ranged from 2.17% to 2.40% which were similar those recorded in Amelonado variety at initial, 30 and 120 days with 1.77% to 2.09%. Only the free fatty acid of mixed hybrid varieties (2.40%) was different from that of Amelonado variety at 90 days (1.36%) and mixed hybrid varieties at 60 and 90 days (1.36% and 1.49% respectively).

CHAPTER FIVE

5.0 DISCUSSION

5.1 Cocoa storage practices of farmers and Purchasing Clerks

Storage quality is influenced by the level of moisture content in the dried cocoa beans, almost all the farmers used experience to determine the moisture content notably hand feeling, visual assessment/ colour and sound (Figure 4.1). With regard to duration of storage, 82% of the farmers stored their beans less than 7 days in the main season whereas the rest store for at least 7 days to maximum of 21 days. In the minor season, 62% of the farmers store their cocoa beans for less than 7 days and the rest stored for either 7 – 14 days or 14 – 21 days (Table 4.2). Key reasons why majority of the farmers stored their dried cocoa beans for short duration could be due to competition among the LBCs to purchase cocoa beans from farmers and cocoa production is the major source of income for their livelihood hence the need to exchange promptly their cocoa for money (Vigneri and Santos, 2007).

Forty percent (40%) of farmers used jute sack to store cocoa beans since jute sack is the recommended storage material which is perforated, ensures proper circulation of ventilation to avoid heat buildup and moisture condensation on the dry beans whereas others farmers used baskets, fertilizer bags, hermetic bags, polythene bags and rubber bowls as a substitute for the jute sacks when procurement for jute sacks is delayed (Figure 4.2).

The most common material PCs use to store their purchased beans is jute sack whereas few of the PCs store in hermetic bag (Table 4.5). Storage management plays a vital role in maintaining the quality of cocoa beans in storage (Jonfia-Essien, 2004). The use of jute sack by majority of PCs supports the assertion that storage material for cocoa need to be perforated to facilitate ventilation of the product (Boxall *et al.,* 2002).

Procedures PCs used to determine to dryness of the cocoa beans they purchase from farmers were experience by hand feeling, visual assessment /colour, Moisture Meter (Aqua Boy Device) and sound (Figure 4.3).

Twenty-eight per cent (28%) of the PCs stored cocoa beans purchased from farmers for less than 14 days and 29% of the PCs, 23% of the PCs and 20% of the PCs stored for 14 – 21, 21 – 28 and more than 28 days respectively in the main season (Table 4.4). In the minor season, 12%, 25%, 35% and 28% of the PCs stored dried cocoa beans for less than 14 days, 14 – 21 days, 21-28 and beyond 28% days respectively (Table 4.4). The more number of days PCs used to store cocoa in the main crop confirm that reports of Vigneri and Santos (2008) that PCs serve as the aggregation point for LBCs in the cocoa value chain in Ghana. However in the minor crop season, the variation in storage periods between main and minor crop season could be due to anticipation of cocoa price increase prior to the re-opening of main crop to be declared by COCOBOD and low volumes of cocoa during the minor crop season which may take LBCs longer period to assemble appreciable quantities for evacuation (Asante, 2014).

Majority being 85% of the PCs re-dry their purchased beans with few been 15% do not re-dry further (Table 4.5). Those that re-dry use do it on cemented floor, raised raffia mat platform, tarpaulin and black polythene sheet (Table 4.5). The minority (16%) of PCs do grading of their purchased beans during storage whilst 84% of them do the contrary (Table 4.5). The standards PCs use to do grading include uniform state of dryness, use uniform size, use uniform colour and use uniform quality (Table 4.5).

Moisture content during storage influences the quality of the stored beans (Wood and Lass, 2001). Minority of the PCs determine moisture content in their stored cocoa beans whilst the majority not to determine moisture content (Table 4.6). Knowledge of PCs on recommended moisture content in the dried cocoa beans for storage, 47.83% of the PCs know 5 – 6 %, 22% of the PCs know less than 5%, 9% of the PCs know above 6% to 8% moisture content, 4% of them know moisture content above 8% – 10% (Table 4.6). This indicates that minority of PCs (9%) have good idea of the ideal moisture content in the range of 6 – 8% (Wood and Lass, 2001).

Storability of dry cocoa beans depends on appropriate moisture content of 6-8% and the storage environment with humidity of 65-70%. Moisture content below 5% beans becomes brittle, however above 8% moisture with humidity above 70%, microbial infection takes place rendering the beans mouldy (Lopex and Dimicks, 1995; Thompson *et al* 2001).

Proper drying of the beans ensures removal of moisture from 50% to 7-8% which has positive effect on major biochemical process such as flavor development, reduction in bitterness and astringency and development of chocolate brown colour of fermented cocoa beans (Afoakwa, 2000; Fowler, 2009).

Among the procedures PCs use in determining moisture content during storage were by experience (48%), by sound (39%) and aqua boy device (13%) (Table 4.6).

Among the PCs, minority been 47% stored their purchased cocoa beans with other items whilst 53% do not store with any other items (Table 4.7). Those who store with other items, 40% store with food items, 26% store with agrochemicals, 23% store with clothes and 11% store with building materials (Table 4.7). 47% of the Pcs indicated that they cannot afford separate shed (storage facility) for storage of only cocoa beans.

Storage of dry cocoa with other items (food, clothing and building materials) provide alternate host and food for insect, pest, microbes and rodents which eventually contaminate the cocoa beans by feeding on the beans if pests primary food is exhausted.

The other items such as agrochemical may contaminate the cocoa beans in storage with its odour thereby producing off flavor to the beans. For this reason cocoa should not be stored with other items. (Cocoa Industry Regulations on Care and Storage of Cocoa beans 1968)

The materials PCs used for roofing of the storage facility include iron sheets (59%), bamboos (25%) and thatches (16%). With regards to materials used to build the storage facility notably blocks (40%), wood (35%) and mud (*Ata Kwame)* (25%). The nature of floor of the storage facility, 36% have bare floor, 20% have concrete floor, 19% have cemented floor, 12% have tiled floor and 13% have wooden floor (Table 4.7). As reported by ICCO (2009) that once the drying and sorting out process has been completed, the cocoa beans must be put into appropriate bags and stored. Proper bagging and storage of the processed beans is just as important as proper fermentation and drying (ICCO, 2009). Incorrect or careless bagging and storage can lead to rejection of the beans, meaning that time and efforts as well as money have been wasted. The bagged cocoa beans must be placed in storage sheds that are water-proof, well ventelated, free from damp and insect pests and away from smoke and other smells that would contaminate the cocoa (ICCO, 2009). The bags must be kept above ground level and away from walls. The storage areas must be kept locked and clean at all times.

5.2 Effect of cocoa variety on some physical and chemical attributes of stored dry cocoa beans

Physical quality of dried cocoa beans is determined by cut test. The cut test is the simplest and still the most widely used method to assess the quality of a random sample of beans from a batch by visual evaluation of the cut beans (Lopez and Dimick, 1995). It is used for the evaluation of sanitary quality of beans (Guehi *et al.*, 2007) and also assesses the degree of fermentation (Fowler, 2009). In this study, slaty beans differed significantly ($p<0.01$) between the mixed hybrid variety and Amelonado variety. This difference could be caused by the mixture of different hybrid varieties which may require different periods of fermentation. As reported by Asare (2012) slaty beans indicate that the beans have not been properly fermented and that slaty beans do not produce the characteristic chocolate aromas and brown colour of the beans. Again, according to Wood and Lass (2001) types of cocoa influence fermentation which vary for instead Criollo cocoa is fermented for a relatively short period of 2 – 3 days while Forastero cocoa is fermented for 3 – 7 days, occasionally longer. Mouldy, purple and all other defects beans did not vary significantly between the mixed hybrid variety and Amelonado variety.

However, percentage purity which is the overall assessment of the effect of all the defects on the quality of the cocoa under consideration indicated an overall good performance of the Amelonado variety over the mixed hybrid variety. As the Amelonado variety had 99.45% which was higher than that of mixed hybrid variety which had 98.65% (Table 4.12). All the varieties produced beans which belong to grade I of cocoa beans, according to Boateng (2012) grade I has cocoa which is thoroughly dry, free from foreign matter, smoky beans and any evidence of adulteration, and which contains not more than 3% by count of mouldy beans, not more than 3% by count of slaty beans, and not more than 3% by count of all other defects. Amelonado cocoa variety is characteristically stronger in chocolate flavor with great market value accounting for 90-95% of world cocoa production (Lopex and Dimick 1995; Thompson *et al*,.2001).

The moisture content and pH did not vary between the Amelonado and mixed hybrid varieties evaluated in this study. pH for Amelonado and mixed hybrid varieties were 5.43 and 5.39 respectively (Table 4.13). Fat and free fatty acid contents in Amelonado and mixed varieties vary significantly ($p<0.01$). The Amelonado and mixed hybrid varieties had 38.34% and 34.10% of fat respectively (Table 4.15). The fat contents obtained, favourably fell below the expected levels of 45-55% of bean weight (Jonfia-Essien and Navarro, 2010). This could be caused by the stage of growth of the cocoa trees from why the pods used for the study were obtained from which was relatively less than 10 years.

Amelonado variety had 1.69% FFA which was lower than that of mixed hybrid variety (1.98%) (Table 4.16). The FFA of Amelonado variety was lower than the internationally accepted level of 1.75% (Jonfia-Essien and Navarro, 2010). The variation in this study may be due to varietal difference between the Amelonado and mixed hybrid variety.

5.3 Effect of storage period on some physical and chemical attributes of stored dry cocoa beans

In this study, slaty, mouldy, purple and all other defects beans together with the purity of the beans did not differ significantly (*p>0.01*) among the storage periods. No variation observed in the physical quality could be attributed to the qualities assessed in this study which are influenced by the stage of pod maturity, degree of fermentation and extend of drying (Guehi *et al.,* 2007). This contrasts the report of Wood and Lass (2001) that stored cocoa beans quality decline with Period.

The moisture composition in the stored beans varied significantly (*p<0.01*) with Period. Storage at 60, 90 and 120 days had 6.75, 6.37 and 6.15% respectively which were similar in moisture content but only storage at 60 and 90 days were different from the moisture content at 30 days and the initial stage. In other words, the moisture content recorded at initial, 30 and 120 days were similar (5.48, 5.53 and 6.15% respectively). This may be caused by the relative humidity and temperature in the room where the experimental was conducted and this supports the assertion of Villers *et al*. (2007) that cocoa beans are considered hygroscopic thus, moisture exchange between atmosphere and the beans. The pH of the stored cocoa beans did not vary significantly (*p>0.01*) with period.

Fat content at the initial stage, 30 and 90 days were similar but only that of the initial stage was statistically different from the fat contents at 60 and 120 days (32.17% and 33.67% respectively (Table 4.15). Storage Period had significant (*p<0.01*) effect on FFA content in the stored cocoa beans. FFA content recorded at the initial stage, 30, 60 and 120 days were similar (2.12%, 1.98%, 1.57% and 2.09% respectively but only the fat content recorded at 60 days was similar to that of 90 days (1.43%). Increase in FFA and fat during storage could be attributed to the activities of the enzyme lipase, which is naturally present in cocoa beans according to Minifie (1989) and this enzyme becomes active due to the changes in moisture content of the beans and high temperatures of storage environment (See Appendix 4). The increase in the amount of FFA is reported to have a direct impact on the fat content and causes a negative change in cocoa flavour

(BCCCA, 1996).

5.4 Interactive effect of cocoa variety and storage period on some physical and chemical attributes of stored by cocoa beans

Slaty, mouldy, purple and all other defects beans did not vary among the combinations of cocoa variety and storage. However, the combined effect of variety and storage period had significant ($p<0.01$) impact on the purity test in the stored cocoa beans (Table 4.12). The only significant difference existed between Amelonado variety stored at 60 days and mixed varieties at 30 days of storage with 99.60% and 98.53% respectively. This indicates that Amelonado variety stored better than the mixed hybrid variety which may be due the differences in the composition of hybrid varieties bulked as one variety. All the combinations had purity of cocoa beans that fell within the grade I category of cocoa beans according to the standards of Quality Control Company of Ghana COCOBOD (Boateng, 2012).

The interactive effect of variety and storage period had significant ($p<0.01$) influence on the moisture and fat and FFA contents. Amelonado variety fairly maintained moisture, fat and FFA contents throughout the storage periods compared to mixed hybrid variety.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

- All the farmers and 74% of PCs use experience to determine level of dryness and moisture content of dry cocoa beans.
- Within four months of storage, the storage period did not affect physical qualities of stored cocoa beans.
- Storage period significantly affected moisture, free fatty acid and fat contents in the cocoa beans stored for four months.
- Cocoa variety significantly affected the purity, fat and free fatty acid contents of stored cocoa beans
- Amelonado variety had better physical quality in terms of purity and chemical qualities (fat and free fatty acid contents) than mixed hybrid variety which could be due to mixture of hybrid varieties.

6.2 Recommendations

The following recommendations are made based on the findings of the study:

- COCOBOD in collaboration with LBCs should train and supply PCs with aqua boy device to use to measure the state of dryness and moisture content of dry cocoa beans.
- Hybrid cocoa varieties should be fermented separately than mixing.

- It is also recommended that Amelonado variety should be stored for longer periods than the mixed hybrid varieties.
- Further research can be conducted to find out the effect of storage periods on Amelonado variety stored in different storage materials such hermetic bags and fertilizer bags/ synthetic fiber.
- Further study should be done on microbial infection at different storage periods on the quality of dry cocoa beans.
- Additional research should be conducted to determine the major source of losses and percentage losses farmers and PCs incur during storage of dried cocoa beans.
- This research can be replicated with other cocoa varieties in Ghana.

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APPENDICES

APPENDIX 1: SAMPLE QUESTIONNAIRE FOR PCS

KWAME NKRUMAH UNIVERSITY OF SCIENCE & TECHNOLOGY

COLEGE OF AGRICULTURE AND NATURAL RESOURCES

DEPARTMENT OF HORTICULTURE

INFORMED CONSENT FOR PCs

Dear Sir/Madam,

The researcher is a student at the Department of Horticulture, Kwame Nkrumah University of Science and Technology, Kumasi. I am conducting a study to "effect of storage periods on quality of Amelonado and Mixed Hybrid Variety of dry cocoa bean. A case study in Asankrangwa of Wassa Amenfi West District". I wish that you take full participation in the survey. However, participation in this study is completely voluntary and you reserve the right to decide not to respond to certain questions or withdraw at any Period in the course of the survey without any penalty. This interview is anonymous and your responses are completely confidential. Notice that whatever information you disclose will only be used for academic purposes and will be treated as strictly confidential as possible and that will be reported in a way that no one will know your specific responses.

Tick **(√)**, mark **(×) or** write where appropriate. If you have any question and queries concerning this research, please do not hesitate to contact the researcher at +322 (0) 244956272.

PART ONE: BACKGROUND INFORMATION

1. Gender: i. Male ( ) ii. Female ( )

2. Age: i. 20-29 years ( ) ii. 30-39years ( ) iii. 40-49years ( ) iv. 50-59years ( ) v. Above 59 years ( )

3. Educational Qualification i. No formal education ii. Primary ( ) iii. MSLC / JSS /JHS ( ) iv. Secondary ( ) v. Tertiary ( )

4. Number of years in the cocoa business (buying) i. 1-10 years ( ) ii. 11-20 years ( ) iii. 21-30years ( ) iv. 31- 40 years ( )

PART TWO: STORAGE PRACTICES

5. How do you ascertain the dryness of cocoa beans you buy from farmers?

   i. By experience /hand feel ( ) ii. Visual assessment / colour ( ) iii. By sound ( ) iv. Use of aqua boy device ( )

6. How long do you store the main season dried cocoa beans you buy from farmers?

   i. Less than 7 days ( ) ii. Between 7 – 14 days ( ) iii. Between 14 – 21 days ( ) iv. More than 21 days ( )

7. How long do you store your light crop dried cocoa beans you buy from farmers?

   i. Less than 14 days ( ) ii. Between 14 – 21 days ( ) iii. Between 21 – 28 days ( ) iv. More than 30 days ( )

8. In what material do you store your beans before you send to depot?

   i. Jute sack ( ) ii. Hermetic bag ( ) iii. Fertilizer bag ( ) iv. Polythene bag ( ) v. In basket ( ) vi. On tarpaulin ( ) vii. Others (specify)..

9. Where do you place your purchased beans? i. On cemented floor ( )

   ii. On grate ( ) iii. On bear floor ( ) iv. On tarpaulin ( )

v. Others (specify)…………………………………………………………

10. How frequent do you re-dry your purchased beans during storage?

i. Once a while ( ) ii. Do not re-dry ( ) iii. Frequently ( )

iv. Whenever necessary ( ) v. Others (specify)…………………………11. Where do you do your re-drying? i. Cemented floor ( ) ii. Raise mat platform ( ) iii. Plastic polythene sheet ( ) iv. Tarpaulin ( )

v. Others (specify)..

12. Do you do grading of your cocoa beans during storage? i. Yes ( ) ii. No ( )

13. If yes, how do you do the grading during storage? i. Uniform size ( ) ii. Uniform colour ( ) iii. Uniform state of dryness ( ) iv. Uniform quality ( )

v. Others (specify)..

14. Do you check moisture level of cocoa beans during storage? i. Yes ( ) ii. No ( )

15. If yes to q16, what is the recommended moisture content for storage of cocoa?

i. Less than 5% ( ) ii. 5 - 6% ( ) iii. Above 6 - 8% ( ) iv. Above 8 - 10% ( ) v. No idea ( ) vi. Others (specify)............................... 16. If yes q16, how do you assess the moisture content? i. Use of aqua boy device ( ) ii. By experience ( ) iii. By sound ( ) iv. Others (specify).......................

17. Do you store your cocoa beans with other items in same room? i. Yes ( ) ii. No ( )

18. If yes to q20, what other items do you store your cocoa with? i. Food items ( ) ii. Agrochemicals ( ) iii. Building materials ( ) iv. Clothes ( )

v. Other (specify)..

19. Roofing of the shed is made of what material? i. Bamboo ( ) ii. Iron sheet ( )

iii. Thatch ( ) iv. Other (specify)..

20. The shed/storage room is made of what material? i. Wood (   )   ii. Mud (*Ata Kwame*)   iii. Blocks (   )   iv. Other (specify)..............................

21. What is the state of floor of your shed / storage room? i. Concrete floor ( ) ii. Cement floor (   )   iii. Tile floor (   )   iv. Bear Floor (   )
   v. Wooden floor (   )   vi. Others (specify)................................

APPENDIX 2: SAMPLE QUESTIONNAIRE FOR FARMERS

KWAME NKRUMAH UNIVERSITY OF SCIENCE & TECHNOLOGY

COLEGE OF AGRICULTURE AND NATURAL RESOURCES

DEPARTMENT OF HORTICULTURE

QUESTIONAIRE FOR FARMERS

INFORMED CONSENT FOR FARMER

Dear Sir/Madam,

The researcher is a student at the Department of Horticulture, Kwame Nkrumah University of Science and Technology, Kumasi. I am conducting a study to "effect of storage periods on quality of Amelonado and Mixed Hybrid Variety of dry cocoa bean.

A case study in Asankrangwa of Wassa Amenfi West District". I wish that you take full participation in the survey. However, participation in this study is completely voluntary and you reserve the right to decide not to respond to certain questions or withdraw at any Period in the course of the survey without any penalty. This interview is anonymous and your responses are completely confidential. Notice that whatever information you disclose will only be used for academic purposes and will be treated as strictly confidential as possible and that will be reported in a way that no one will know your specific responses.

Tick **(√)**, mark **(×) or** write where appropriate. If you have any question and queries concerning this research, please do not hesitate to contact the researcher at +322 (0) 244956272.

PART ONE: BACKGROUND INFORMATION

1. Gender: i. Male ( ) ii. Female ( )

2. Age: i. 20-29 years (   ) ii. 30-39years (   ) iii. 40-49years (   ) iv. 50-59years (   )

v. Above 59 years ( )

3. Educational Qualification i. Non formal education ii. Primary (   ) iii. MSLC / JSS /JHS ( ) iv. Secondary (   ) v. Tertiary ( )

4. Number of years in the cocoa farming i. 1-10 years (   ) ii. 11-20 years (   ) iii. 21-30years (   ) iv. 31- 40 years ( )

PART TWO: STORAGE PRACTICES

5. How do you ascertain the dryness of your cocoa beans before you sell to LBCs?

   i. By experience /hand feel (   ) ii. Visual assessment / colour (   ) iii. By sound (   ) iv. Use of aqua boy device ( )

6. How long do you store the main season dried cocoa beans before you sale?

   i. Less than 7 days (   ) ii. Between 7 – 14 days (   ) iii. Between 14 – 21 days ( ) iv. More than 21 days (   )

7. How long do you store your light crop dried cocoa beans before you sale?

   i. Less than 14 days (   ) ii. Between 14 – 21 days (   ) iii. Between 21 – 28 days (   ) iv. More than 30 days (   )

8. In what material do you store your beans before you sale? i. Jute sack (   ) ii. Hermetic bag ( ) iii. Fertilizer bag (   ) iv. Polythene bag (   )

   v. In basket (   ) vi. Jute sack (   ) vii. In rubber bowl ( ) vi1. Others (specify) ....

9. Do you separate defects beans from the normal beans? i. Yes ( ) ii. No ( )

10. If yes to q9, what do you do with the defects beans? i. Discard ( ) ii. Add to the normal beans (   ) iii. Sell separately (*Abinkyi*) (   )

iv. Others (specify)..

11. If no to q9, why? ....

12. Have any LBC reject your cocoa beans before? i. Yes ( ) ii. No ( ) 13. If yes to q12, what was the reason(s) for the rejection? i. Not well dried ( ) ii. Mouldy beans ( ) iii. Small beans size ( ) iv. Abinkyi ( ) **APPENDIX 3: ANALYSIS OF VARIANCE (ANOVA) OF VARIABLES**

V = VARIETY

SP = STORAGE PERIOD (DAYS)

V*ST = INTERACTION OF VARIETY AND STORAGE PERIOD

Analysis of Variance Table for Slaty

Source	DF	SS	MS	F	P
Rep	2	0.04200	0.02100		
V	1	0.86700	0.86700	33.11	0.0000
SP	4	0.18133	0.04533	1.73	0.1870
V*SP	4	0.18133	0.04533	1.73	0.1870
Error	18	0.47133	0.02619		
Total	29	1.74300			

Grand Mean 0.3700 CV 4.37

Analysis of Variance Table for Mould

Source	DF	SS	MS	F	P
Rep	2	0.13267	0.06633		
V	1	0.58800	0.58800	7.42	0.0139
SP	4	0.36800	0.09200	1.16	0.3610
V*SP	4	0.11867	0.02967	0.37	0.8240
Error	18	1.42733	0.07930		
Total	29	2.63467			

Grand Mean 0.2467 CV 1.14

Analysis of Variance Table for Purple

Source	DF	SS	MS	F	P
Rep	2	1.0758	0.53792		
V	1	1.7910	1.79096	3.56	0.0753
SP	4	2.4908	0.62270	1.24	0.3296
V*SP	4	0.4379	0.10946	0.22	0.9250
Error	18	9.0440	0.50245		
Total	29	14.8395			

Grand Mean 20.740 CV 3.42

Analysis of Variance Table for All Other Defects

Source	DF	SS	MS	F	P
Rep	2	0.47267	0.23633		
V	1	0.36300	0.36300	7.05	0.0161
SP	4	0.62800	0.15700	3.05	0.0441
V*SP	4	0.13867	0.03467	0.67	0.6193
Error	18	0.92733	0.05152		
Total	29	2.52967			

Grand Mean 0.3633 CV 6.25

Analysis of Variance Table for Purity Per cent

Source	DF	SS	MS	F	P
Rep	2	0.56600	0.28300		
V	1	4.72033	4.72033	52.64	0.0000
SP	4	0.14333	0.03583	0.40	0.8063
V*SP	4	0.65133	0.16283	1.82	0.1697
Error	18	1.61400	0.08967		
Total	29	7.69500			

Grand Mean 99.050 CV 0.30

Analysis of Variance Table for Moisture

Source	DF	SS	MS	F	P
Rep	2	0.1387	0.06933		
V	1	0.5070	0.50700	4.40	.0504
SP	4	7.1287	1.78217	15.46	0.0000
V*SP	4	2.2847	0.57117	4.96	0.0072
Error	18	2.0747	0.11526		
Total	29	12.1337			

Grand Mean 6.0567 CV 5.61

Analysis of Variance Table for pH

Source	DF	SS	MS	Rep	F	P
2	0.07800	0.03900				
V	1	0.01633	0.01633		0.68	0.4219
SP	4	0.33867	0.08467		3.50	0.0278
V*SP	4	0.25867	0.06467		2.67	0.0655
Error	18	0.43533	0.02419			
Total	29	1.12700				

Grand Mean 5.4100 CV 2.87

Analysis of Variance Table for fat

Source	DF	SS	MS	Rep	F	P
2	81.944	40.972				
V	1	134.832	134.832		16.37	0.0008
SP	4	303.091	75.773		9.20	0.0003
V*SP	4	70.345	17.586		2.13	0.1183
Error	18	148.296	8.239			
Total	29	738.508				

Grand Mean 36.220 CV 7.92

Analysis of Variance Table for FFA

Source	DF	SS	MS	Rep	F	P
2	0.49166	0.24583				
V	1	0.64240	0.64240		10.03	0.0053
SP	4	2.40735	0.60184		9.40	0.0003
V*SP	4	0.56561	0.14140		2.21	0.1091
Error	18	1.15301	0.06406			
Total	29	5.26003				

Grand Mean 1.8370 CV 13.78

APPENDIX 4: RELATIVE HUMIDITY AND TEMPERATURE AT ROOM THE EXPERIMENT WAS CONDUCTED