Quality Assurance along the Primary Processing Chain of Cocoa Beans from Harvesting to Export in Ghana

By

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Abstract

Cocoa beans are an important cash crop in many tropical countries. Ghana is the second largest producer of cocoa beans in the world, and in 2005, about 60 % of the country's foreign income came from export of cocoa beans. Export prices of cocoa beans are dependent upon quality. High quality cocoa beans give the farmers premium prices on the world market and it is important to obtain high quality of the final cocoa product. Indications of good quality is whole, well ripe, well fermented and well dried beans.

This study is based on observations, made at the Cocoa Research Institute of Ghana (CRIG). Primary processing of cocoa beans were observed at a small farm in the plantations, and pod opening, fermenting and drying were observed at the research institute. Maintenance of different plantations and quality control processes before shipping were also observed. Scientific articles and books were examined in databases and at the CRIG library.

Maintenance of the plantations at the small farm was generally observed to follow the recommendations in the scientific literature. However, many pods were diseased, which probably is caused by inefficient removing of dead and diseased branches. Some trees could be top pruned with advantages. Maintenance of CRIG's plantations was at high standard even though some trees were damaged. Weeding was needed in both plantations, but on account of the timing where the processes were observed, this issue is not a problem.

Harvesting in both plantations was performed with professionalism and knowledge of literary pieces of advice. Diseased pods at the small farm were some times left in the plantations. These pods should be buried or destroyed.

During pod opening at the small farm, many beans with germinated pulp, unripe beans and placenta were fermented with the beans. These defects should have been removed since they increase the risk of developing ochratoxin A. Bad pods were left on the ground. They should be destroyed. Breaking of pods with a machete did not damage the cocoa beans. The pod breaking is a time consuming job, and a manual pod break machine is suggested at CRIG. Present working posture is possibly harmful to the human body in the long run. This concern has not been investigated.

Fermentation processes at the small farm resulted in well fermented cocoa beans. Dividing the fermenting heap into smaller heaps will ease the hard work of turning the beans, without deteriorating the quality of the cocoa beans. Tray fermentation at CRIG is an effective and fast method. No improvements are suggested.

Drying processes were observed in dry and sunny weather, giving no troubles of producing high-quality cocoa beans. The drying mat at the small farm is consistent with literary advice and it has a good location in front of the house. Drying methods at CRIG were suitable for the period of

observations. However, a low cost solar dryer is an opportunity during wet periods in the main season.

Quality control is carried out on every sack of cocoa beans more than one time. Tracking is possible through a metal sign and a inscription on every sack. However, sometimes only 0.00016 % of the cocoa beans in one batch are used to grade the beans. Storing and shipping of cocoa sacks ensures that the sacks will not get contaminated before they reach the manufacturing companies all over the world.

Resume

Kakao er en stor indtægtskilde i mange tropiske lande. Ghana er den anden største producent af kakaobønner i verden, og landet fik i 2005 cirka 60 % af dets udenlandske indkomst fra eksport af kakao. Det er meget vigtigt at kvaliteten af de eksporterede kakaobønner er god. Kakaobønner af høj kvalitet giver kakaobønderne præmiepriser på verdensmarkedet, og de hjælper til at opnå en god kvalitet af det færdige kakaoprodukt. For at opnå god kvalitet af kakaobønner, skal bønnerne være hele, modne, tilpas fermenterede og tilpas tørrede.

Denne rapport er lavet på baggrund af observationer på Cocoa Research Institute of Ghana (CRIG). Primære processer af kakaobønner er blevet observeret på en lille kakaofarm i plantagerne, og åbning af frugten, fermentering og tørring er observeret på CRIG. Vedligeholdelse af forskellige plantager og kvalitetskontrol inden eksport er også observeret. Videnskabelige artikler fra online databaser og bøger fra CRIGs bibliotek er studeret. Vedligeholdelse af plantagerne på den lille farm fulgte generelt set hvad videnskabelig litteratur anbefaler. Dog var der mange sygdomsramte kakaofrugter, hvilket formodentlig skyldes at mange syge og døde grene ikke var fjernet.

Nogle af træerne kunne med fordel beskæres til en lavere højde.

Vedligeholdelse af CRIG's plantager var af høj standard selvom at nogle af træernevar beskadiget. Der trængte til at blive fjernet ukrudt i begge plantager, men dette er ikke set som et problem idet observationerne blev foretaget kort efter den store høstsæson.

Høst af kakaofrugterne var professionelt udført på både den lille farm og i CRIG's plantage. En del sygdomsramte kakaofrugter på den lille farm, var efterladt på jorden. Disse skulle være enten begravet eller til intetgjort.

Under åbning af kakaofrugterne på den lille farm, blev både fordærvede bønner, umodne bønner og placentæn fermenteret sammen med de gode kakaobønner. Disse deffekter skulle have været fjernet, idet de øger ricikoen for udvikling af giftstoffet ochratoxin A. Dårlige kakaofrugter blev efterladt på den omkringliggende jord. Disse skulle være tilintetgjort. Det beskadigede ikke bønnerne at frugten blev åbnet med en machete. Det er et tidskrævende arbejde at åbne kakaofrugterne, og en manuelt styret maskine er foreslået til CRIG. Nuværende arbejdsstilling under abning af kakaofrugterne er muligvis skadelig for kroppen i det lange løb. Denne tese har endnu ikke været undersøgt.

Fermenteringsprocesserne på den lille farm resulterede i vel-fermenterede kakaobønner. Det vil lette det hårde arbejde det er, at vende de fermenterende kakaobønner, hvis bunken blev delt op i mindre bunker på 50 – 150 kg. Dette vil heller ikke ødelægge kvaliteten af kakaobønnerne. Tray-fermentering på CRIG er en effektv og hurtig metode. Der er ikke foreslået nogen forbedringer.

Tørring af kakaobønner blev observeret i tørt og solrigt vejr, der gjorde det nemt at opnå høj kvalitet. Tørringsmåtten på den lille farm er i overensstemmelse med hvad der anbefales i litteraturen, og den havde en god placering lige foran huset. Tørringsmetoderne på CRIG var velegnede til den periode, observeringerne blev udført. En soltørrer, er en mulighed for våde perioder i den store høstsæson.

Kvalitetskontrol er mere end en gang udført på hver enkelt sæk med kakaobønner. Sporbarhed er muligt via et metalskilt og et print på hver sæk. Dog kan det ske at kun 0,00016 % af alle kakaobønnerne i et batch, bestemmer hvilken grad af kvalitet, batchet skal have. Opbevaring og skibsfragt af kakaosækkene sikrer til fulde at sækkene ikke er blevet dårlige inden de når frem til kakaoforhandlerne verden over.

Preface

This paper is the result of a two month study at the Cocoa Research Institute of Ghana (CRIG), New Tafo, in fulfillment of the requirements for 15 ECTS point at the University of Copenhagen, Faculty of Life Science, on the third year of the bachelor education in Food Science. The study was performed in the period 1th February – 19th April 2010.

The study concentrates on quality assurance along the primary processing of cocoa beans from harvesting to export. It is addressed to students of Food Science and others with interest in primary processing of cocoa.

I would like to thank my supervisor, Asst. Professor Dennis Sandris Nielsen, Department of Food Science, Food Microbiology, for guidance through the study and for help with preparations for the stay in Ghana. The same thanks go to Dr. Jemmy Takrama who also helped me in other ways in Ghana and offering me the use his office. I will also thank Miss Winifred Kumi, my project supervisor in Ghana. The Cocoa Research Institute of Ghana and Toms Group A/S (A XOCO) made this project possible, and I am very thankful for their acceptance of me.

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1. Introduction

Cocoa is an important cash crop in many tropical countries. Only within 10° north and 10° south of the equator, is the climate suitable for producing cocoa (Hartemink, 2005). The original home of cocoa trees is Central and South America, but in the year 1634, cocoa pods were shipped from what today is Venezuela, and cultivated in different West African countries (Acquaah 1999). Cocoa trees have been grown in Ghana on a commercial scale for 130 years. It started in 1879, when a Ghanaian blacksmith returned from the Spanish island, Fernando Po, with only one cocoa pod. He wanted to become a cocoa farmer himself. The seeds were planted, and one tree grew. About seven years later, more cocoa pods were sent to Ghana from Sao Thome (Anon, 1964). During most of the 19th century, Ecuador was the biggest cocoa producing country, but in 1910, Ghana and Brazil surpassed that position (Acquaah 1999).

Today, more than two thirds of the world's cocoa beans are produced in West Africa, and Ghana specifically, earned in 2005 about 60 % of its foreign income from export of coca beans (ICCO, 2009; Hartemink, 2005). In the year 2008/2009, Ghana produced 662,000 tones of cocoa beans, equal to 19 % of World cocoa bean production. This makes Ghana the second largest cocoa bean producer in the world. Ghana's neighboring country, Côte d'Ivoire, the largest world producer, produced 1,222,000 tons of cocoa beans in 2008/2009 (ICCO, 2009).

Primary processing of cocoa beans, from the farmers' point of view, is time-consuming, hard work. Primary processing of cocoa includes farm establishment, maintenance of the plantation, harvesting, gathering the pods at a central location in the farm, pod opening, removing of the beans, fermenting the beans and drying the beans. All of these steps are critical, in order to obtain high quality cocoa beans (Are & Gwynne-Jones, 1974).

One of the advantages of the primary processing of cocoa beans is that it is relatively inexpensive, and this gives good opportunities for small farm holders in Ghana to use cocoa beans as a cash crop (Are & Gwynne-Jones, 1974). Added to this, small farm holders in Ghana are aware of what characterizes good quality beans, and they know strategies for obtaining the good quality. Hence, the cocoa farmers in Ghana produce very high quality of cocoa beans which have given them premium prices on the world market (Aneani and Takrama, 2004).

In 1937, the preparatory work began on what today is the Cocoa Research Institute of Ghana. The assignment was to establish a station, at which investigations in cocoa diseases should be made. The institute, that is internationally acclaimed, has today seven different departments: Entomology, Plant Physiology and Biochemistry, Plant Pathology, Plant Breeding, Soil Science, Agronomy and Plantations Management.

1.1 Purpose of study

Ghana produces high quality of cocoa beans, and the primary processing methods are simple, efficient, inexpensive and time tested (Takrama & Adomako, 1996). However, further researches are needed to promote development and to sustain knowledge about the primary processing of cocoa beans.

Critical points along the primary processing chain include diseases among cocoa trees, which cause heavy losses of cocoa pods every year (Hanada *et al.*, 2009). Harvesting the cocoa pods may injure the cocoa trees and spread fungi diseases (Vos *et al.*, 2003; Mossu, 1992), and opening the pods is a slow and labour-intensive process (Are & Gwynne-Jones, 1974). Fermentation of cocoa beans is very inhomogeneous and difficult to control (Mossu, 1992; Amoa-Awua, 2007), and microbial understanding of some of the fermenting processes is still inadequate (Nielsen *et al*., 2007). Well-fermented cocoa beans of high quality can easily be spoiled, and it can be difficult to sun dry cocoa beans on mats in the wet season (Amoa-Awua, 2007).

This work aims to identify any critical points along the primary processing chain of cocoa beans that may impact negatively on quality. Observations of present methods of processing cocoa beans, and published scientific literature will be compared to determine if changes should be implemented.

1.2 Aims of study

The aims of this study are to answer following questions:

1. What are the present methods of the primary processes of cocoa beans in Ghana?
2. Do the methods meet what literature and scientific studies recommend?
3. For each processing step; which changes should be made and what is the appropriate alternative?

2 Literature review

This chapter describes studies that have been made on the primary processing chain of cocoa trees and cocoa beans.

2.1 Maintenance of the plantation

To ensure high yield and good quality of cocoa beans, it is important that the cocoa plantations are well-maintained. Maintaining includes replanting, weeding, shade management, fertilizer application and control of pests and diseases (Are & Gwynne-Jones, 1974).

A major problem in the cocoa plantation is diseases among the cocoa trees. Most important, world-wide, are the Black pod disease, Witches' broom and Monoliasis, also known as Frosty pod (Aima & Phillips-mora, 2005; Hanada *et al.*, 2009; Ndoumbe-Nkeng *et al.* 2004; Soberanis *et al*., 1999). Black pod disease and swollen shoot virus disease are the most common in West Africa. Black pod disease is caused by the fungus *Phytophthora* species, and costs on average 30 % losses of cocoa bean harvest every year (Hanada *et al.*, 2009). A two year experiment of removing the diseased pods in two small farm holders plot in Cameroon showed that by removing diseased pods, the Black pod rates were reduced by respectively 22 % and 31 % during the first year. In the second year, they were reduced by 9 % and 11 %, compared to a plot in which no preventive control measures were taken (Ndoumbe-Nkeng *et al.*, 2004). A similar experiment was made in 1999 in Peru. By weekly removal of diseased pods, it was possible to reduce the incidence of diseases significantly. Monoliasis decreased by 26 – 41 %, Witches' broom decreased by 14 – 57 % and Black pod decreased by 35 – 66 % (Soberanis *et al*., 1999).

The effects of shade management of the cocoa trees have been investigated. A review of investigations of shading trees in cocoa plantations concluded that there is a variety of benefits by shading trees in cocoa plantations. The benefits include reduction of air and soil temperature extremes, reduction of wind speeds, buffering of humidity and soil moisture availability, reduction of soil erosion, reduction of transmitted light and thereby avoiding of excessive vegetative growth. Shade also reduced nutritional imbalances and dieback (Beer *et al.*, 1998). Shade trees are of economic value for timber. This has tended to destroy cocoa farms in the past, for this reason, the practice of retaining valuable trees on cocoa fields is discouraged in Ghana (Oberi *et al.*, 2007).

All branches which are hanging, diseased or dead should be cut off. Coupons and branches that grow within 60 cm of the ground or towards the centre of the canopy should also be cut off. This ensures better ventilation and exposure to the sun. After the initial pruning, every tree should be cut to a height of four meter, since this facilitates harvesting and the removal of mummified pods (David, 2005).

One cocoa tree can produce cocoa pods for more than 30 years. Yields rise gradually as the tree grow, and then decreases again in old trees (Kazianga & Masters, 2006).

2.2 Harvesting

First step in the processing of cocoa beans is harvesting of the pods. Ripe pods are easy to identify by having another color than the immature pods. For instance, Amelonado turns from green to yellow when ripe. The ripening process is slow, and a mature pod will remain suitable for harvesting for two or three weeks. It is important that only well ripe pods are taken. Unripe pods will not undergo fermentation, and over ripe pods often become dry (Barclays Bank 1970).

It is important that the harvesting tools are sharp, so the cushions of the trees are not damaged. If so, they are a potential point of entry for fungi. When cutting, the pod stem should be cut as close to the tree as possible, and the thickened joining portion should be left attached to the cushion. It will fall of later and leave a well healed scar that is impermeable to fungi (Barclays Bank, 1970). While harvesting, the farmer may spread fungal diseases from contamination by the hook, knife or shoes (Vos *et al.*, 2003). Unharvested pods turn black and the beans begin to rot or germinate. This may cause spread of diseases among cocoa trees (Amoa-Awua *et al.*, 2007)

Pods that are reachable should not be picked by hand, as this may damage the flower cushions. Cocoa trees should not be climbed or shaken as this may result in the flowers falling off, and thereby reduce yield. If the cocoa tree is cut anywhere else other than the cushion, the wound is a potential point for fungi injections (Are & Gwynne-Jones, 1947; Mossu, 1992). Cocoa trees are very slow in repairing themselves (Beer *et al*, 1998). Due to all of the above statements, harvesting should be done gently and carefully and not in a rush (Barclays Bank, 1970).

In Ghana, the main season for cocoa harvest is from September to January (Anon, 1964), and the minor season is from May to August (Barclays Bank 1970). Continuous harvesting may result in a loss of soil nutrients, but regular complete harvesting has also resulted in reduced levels of diseases (Vos *et al.*, 2003).

2.3 Pod opening

Opening of cocoa pods is preferably done with a wooden mallet or by striking two pods together. Opening the pod with a knife or machete might damage the beans (Barclays Bank, 1970; Mossu, 1992). Pods should not be opened more than six days after harvesting (Are & Gwynne-Jones, 1974; Mossu, 1992).

The first pod opening machines were introduced and tested in Nigeria and Cameroon in the 1960's. The machine tested in Cameroon was able to open 2.000 pods per hour with two men operating it, but was never widely used (Are & Gwynne-Jones, 1974). Other machines have been developed in France, Spain and Brazil, but they lack the same skills: to be cheap, economic to run, and easy to operate (Mossu, 1992).

2.4 Sweating

The sweating (pulp juice) is an acidic juice with ~12 % sugar (Adomako, 1997). It is used for by-products such as gin, brandy, vinegar, vine, jam and pectin. Collecting the sweating is feasible when large amounts of cocoa beans are going to be fermented. The wet beans are loaded into a custom-made poly tank and a piece of plywood is placed on the top of the beans and loaded with stones. This will press down the beans, and the sweating run off faster. Collection of sweating normally takes 6 – 12 hours depending on how much beans there are in the poly tank. It is not advisable to ferment the beans in the tank, but collecting the sweating will not spoil the beans. The by-products from sweating are an extra income from something that normally goes waste (Adomako & Takrama, 1996; Cudjoe[1] *et al.*, 2009).

2.5 Fermentation

There are several ways to ferment the cocoa beans. The most common are box - , heap - , tray - , and basket fermentation. Heap fermentation is carried out on a bed of banana leaves on the ground, and the heap of cocoa beans is covered with banana leaves and sticks. It is a cheap method that produces well fermented beans, when it is done properly (Are & Gwynne-Jones, 1974). Among small holders in Ghana, heap fermentation is a popular method. It does not require permanent equipment, and therefore, it suits well to family holders with small production (Doyle *et al.*, 2001).

Box fermentation is a system of three wooden boxes, each having a capacity of 1,000 kg cocoa beans (figure 1). Box number one is placed two box-sizes above the ground, box number two in the middle, and box three is on ground level The beans start in box number one and ferment for two days under a cover of banana leaves. To mix the beans, upper half of the first box is poured into the bottom of box number two, followed by the lower half. The beans will ferment for another two days under banana leaves. To make sure that no beans are left in the middle of the boxes during the whole process, the beans are split vertically and then poured into box number three. After two days more under banana leaves, the cocoa beans are properly fermented (Asare, 2010; Are & Gwynne-Jones, 1974).

With smaller amount of beans, the basket method is preferable. The baskets are of different sizes, but generally hold 30 – 40 kg beans, sometimes up to 90 kg. They are made of weaved plant materials and therefore, they are not airtight. Before the fermentation begins, the insides of the basket are covered with banana leaves, but the bottom remains uncovered to let the sweating drain away. The beans are turned on the second and the fourth day, and after six days, the beans are properly fermented (Asare, 2010; Mossu, 1992).

A fourth method to ferment cocoa beans is the tray fermentation. One tray measures 120 x 90 x 10 cm and holds about 90 kg wet beans. The trays are stacked in piles, 3 - 12 trays high (figure 2). Less than three trays will not produce enough heat. Higher piles do not affect the fermenting process, but it will be too hard work to handle the trays at this height. The bottom tray is placed on a wooden platform to avoid the ground absorbing the produced heat, to allow the sweating to drain away, and to promote air circulation. Tray fermenting takes four to five days without turning the beans (Asare, 2010).

Figure 1. Boxes for fermenting cocoa beans. Picture by: LSM

Figure 2.Four trays with fermenting cocoa beans. Picture by: Amoa-Awua *et al.*. Printed with permission.

The microbiology of cocoa fermentations has been an issue for many researches during the last 100 years (Ardhana & Fleet, 2003). Yet, many microorganisms are still to be identified (Ardhana & Fleet 2003; Jespersen *et al.*, 2004). Surveys investigating general microbiology and environmental bacteria on cocoa farms are tools to understand the whole consortium of microorganisms involved with cocoa fermentation. If that is to be identified, well considered conditions and methods in processing cocoa beans can be performed, and the quality of final cocoa beans will be raised. Figure 3 shows the classification of microorganisms. Lactic acid bacteria (LAB) and acetic acid bacteria (AAB) are found on the left green under 'Gram positives' and 'Proteobacteria' respectively. Spore forming *Bacillus* species are also Gram positive bacteria (Todar, 2009; Nielsen *et al.* 2007).

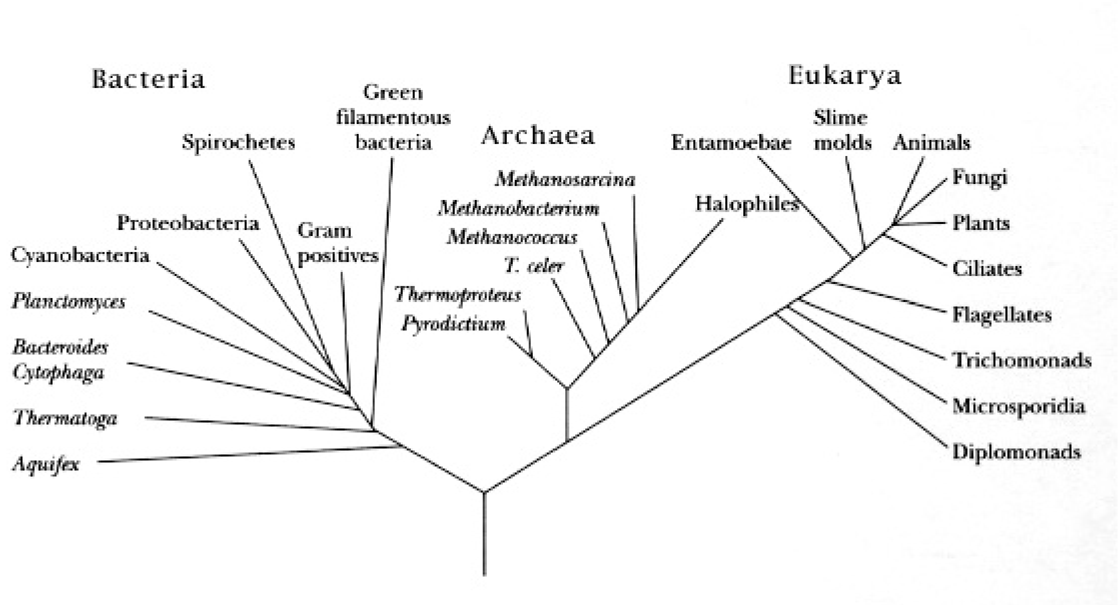

Figure 3. Classification of organisms with emphasis on microorganisms. Source: Todar, 2009

The cocoa fermentation is a spontaneous process. The pulp is sterile, but as soon as the beans are removed from the pod, the pulp gets inoculated with yeasts and bacteria from the surroundings (Jespersen *et al.*, 2004; Nielsen *et al.*, 2006; Takrama & Adomako 1996). As fermentation of the pulp starts, ethanol and acetic acid are produced and penetrate the beans (Doyle *et al.*, 2001).

Yeasts and LAB dominate the first 24 – 36 hours (Nielsen *et al.*, 2006). Yeasts mainly convert sugars in the pulp into alcohol and CO_2. Enzyme activities and maceration of the pulp makes the acidy juices run off as sweating, which result in a rise of pH (Takrama & Adomako, 1996). The yeast cell counts decrease after 24 – 36 hours while LAB remain high throughout the fermentation (Nielsen *et al.*, 2007) Both homo- and hetero fermentative LAB species are observed, metabolizing glucose to respectively lactic acid and lactic acid, alcohol, acetic acid, and carbon dioxide (Takrama & Adomako, 1996).

Turning the heap, makes conditions more aerobic, and increases the population of AAB. These bacteria species oxidize ethanol to acetic acid, which is an exothermic process that rises the temperature to nearly 50°C (Camu *et al.*, 2008; Takrama & Adomako, 1996).

Spore forming *Bacillus* species are dominant at the end of the fermenting period and while drying (Nielsen *et al.*, 2006; Ardhana, 2003). These bacteria form some undesirable short fatty acids, giving an off-flavor to the final chocolate (Doyle *et al.*, 2001)

An overview of the biochemistry of cocoa fermentation is seen in table 1:

Table 1. Biochemistry of cocoa fermentation

	Reactant	**Product**	**Microorganism, involved in reaction**
Anaerobic fermentation	Sugar	Ethanol + CO_2	Yeast
	Glucose	Ethanol	Lactic acid bacteria
		Lactic acid	
		Acetic acid	
		CO_2	
Aerobic fermentation	Ethanol	Acetic Acid	Acetic acid bacteria
	Citric Acid	Acetic acid	Acetic acid bacteria
	Malic Acid		
	Lactic Acid		

Modified after J.F. Takrama, 2010

Many factors influence the quality of the final beans in the fermenting step. These include:

- Degree of ripeness of the pods. Unripe pods do not contain enough sugar to ferment properly.
- Type of cocoa. Some types, for example Criollo, need shorter fermentation period than other sorts like Trinitarios and Forasteros.
- Climate and season. Dry weather shrinks the pulp, which restrains the fermentation. Too much pulp is also a disadvantage, as it reduces gaseous exchange and may result in high acid levels. Cold weather, which especially occurs in areas more than 800 meters above sea level, will also inhibit the cocoa bean fermentation.

- Quantity of cocoa beans in one batch.
- Duration of fermentation. Under fermented beans have not developed the brown chocolate color, and they have at bitter and astringent taste. Over fermented beans will rot (Mossu, 1992).

2.5 Drying

Proper drying is very important to avoid moulds and off-flavors in cocoa beans. During this process, the oxidative stage of fermentation of the beans continues and reduces the constringency and bitterness in the cocoa product. The drying process also develops the characteristic brown color of chocolate (Takrama & Adomako, 1996; Fagunwa *et al.*, 2009).
After fermentation, the water content is about 60 %, and it must be reduced to less than 7.5 % during drying to avoid spontaneous mould and bacterial growth under storage and transport (Takrama & Adomako, 1996). Drying takes 7 – 21 days, depending on the weather (Takrama & Adomako, 1996; Are & Gwynne-Jones, 1974; Barclays Bank, 1970)

Drying temperatures should neither get too high nor too low. At low temperatures, the drying is too slow which allows moulds to grow. Drying too rapidly will inhibit the activation of enzymes that are necessary to ensure good chocolate flavor (Are & Gwynne-Jones, 1974).

Rate of drying depends on:

1. Heat transfer into the bean
2. Water transfer from within the bean to the air.
3. Humidity of the air
4. Surface area of the bean, exposed to the air (Bharath & Bowen-O'Connor, 2007; Sukha, 2009).

The first few days, where the moisture levels are still high, are the most important. The layer of the cocoa beans should have a maximum depth of about 5 cm and the beans should be mixed at least every hour during the drying. The beans are properly dried if they make a cracking sound when they are rubbed together in ones palms (Amoa-Awua, 2007).

2.5.1 Sun drying

The natural way to dry the cocoa beans is in the sun on drying mats, which is a simple and cheap method. The mats are usually placed on a raised platform to protect the cocoa beans against animals

and foreign matters. At night and whenever the rain comes, the mats should be rolled up (Are & Gwynne-Jones, 1974: Mossu, 1992).
Sun drying can be carried out in a drying 'autobus', which is a shelter and ramps at different heights allowing trays to slide from the sun under the roof (figure 4). Sliding roofs and immobile drying platforms are also developed (Mossu, 1992).

Figure 4. Drying autobus at CRIG. Picture by: LSM.

2.5.2 Artificial drying

Artificial drying is necessary in weather conditions that are cold and rainy or at plantations that are so big that sun drying would take too much space (Mossu, 1992).

Ovens are simple dryers that use heat to dry the cocoa beans. They can be heated either by the base of the oven, or by hot air from an external fire. The beans are spread in trays, allowing the air to permeate through a ladder system (Mossu, 1992). Using this method, it is very important that the cocoa beans are not contaminated with smoke from the fire, since dry beans easily absorb flavors and aromas from the environment (Barclays Bank, 1970). To avoid this, it must be ensured that the smoke ducts are impermeable. This method is also used in family plantations (Mossu, 1992).

Mechanical dryers are occasionally used in larger plantations, where big volumes of cocoa beans are to be dried. The cocoa beans are placed on rotating platforms that circulate in a tunnel through which hot air is blown. This method takes 10 – 20 hours, depending on the initial moisture-content of the cocoa bean (Mossu, 1992).

In the past, the beans were dried on rocks or floors or on the ground, which allowed animals to contaminate the beans with droppings (Are & Gwynne-Jones, 1974). Beans should not be dried by smoking, near roads with cars, or near anything that has a strong smell (Cudjoe[2] *et al.*, 2008).

Regarding to human health, the main safety risk related to the production of cocoa, is a toxin named ochratoxin A (OTA). OTA is one of the toxins that collectively are called mycotoxins, all harmful to human health and produced by mould species. Samples of cocoa producing areas all over the world have been found to contain OTA (Amoa-Awua *et al.*, 2007; Takrama, 2007).
The hurdle connected to OTA is that it is colorless and stable during cooking and fermentation. It may even be present in foods where no visible mould growth is seen. OTA occurs naturally in plant materials and it can be found in every stage of the production chain from harvest to export of cocoa beans (Amoa-Awua *et al.*, 2007; Takrama, 2007).
Organisms that are able to produce OTA are also present all over the farm environment, which gives a high risk of contaminating the cocoa beans as soon as the pod is broken. OTA might develop in contaminated cocoa beans while drying. (Amoa-Awua *et al.*, 2007; Takrama, 2007).

To minimize the risk of OTA contamination, following guidelines should be followed:

- Harvest every 2 to 4 week and avoid pods from touching the soil and damaging.
- Open the pods less than one week after harvest.
- Avoid unripe, overripe and mummified pods.
- Avoid damage of the beans during pod opening and complete the pod opening in maximum two days.
- Discharge diseased pods and burn pod husk
- Remove pod husk and placenta and remove mouldy, diseased and damaged beans before fermentation.
- Cover fermenting heaps properly and ferment for maximum 7 days.
- Dry on raised platforms, keep drying layer thin and turn regularly.
- Use clean sacks to store cocoa beans
- Avoid re-wetting.
- Store cocoa in clean, dry and odour-free conditions.

2.6 Quality control

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

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

International standards are made to measure quality of cocoa beans. This is performed via a cut test where the cocoa beans are cut lengthwise and visually divided after quality. Purple beans, slaty beans and beans with all other defectiveness are grouped. Defectiveness among cocoa beans includes flat, moldy and geminated beans (Asare, 2010, Are & Gwynne-ones, 1974; Lockhart, 2010). Table 2 shows the causes of defected beans.

Table 2. Causes of defective beans.

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

Modified after Are & Gwynne-Jones, 1974; Asare, 2010.

The colors of a well fermented brown cocoa bean, slaty bean and purple bean are shown in figure 5.

A

B C

Figure 5. A: Well fermented brown bean. B: Slaty bean. C: Purple bean. Pictures byLSM.

Grades have following limits:

Table 3. Grading of cocoa beans

Defect	Grade 1	Grade 2
Mouldy beans	3 %	4 %
Slaty beans	3 %	8 %
All other defective beans	3 %	6 %
Purple beans	20 %	45

Modified after Lockhart, 2010

Samples that exceed the limits in grade 2 are rejected and sold to the cosmetic industry (Amoa-Awua, 2007; Lockhart, 2010).
It is a part of the chocolate manufacturing requirements that cocoa beans are of reasonable same size. This will ensure even roasting of all beans and prevent small beans in being burned. A Bean Count test tells the size of beans. There are seven categories of bean size: Super main crop, Main crop, Super light, Light crop, Small beans and remnant category (Lockhart, 2010).

During storage of cocoa beans, it is important that the cocoa sacks are clean, strong and tight. The sacks should not be stored directly on the ground, but on a wooden platform that prevents the base of the cocoa sack in getting misty. It also prevents rats and other animals from having access to the cocoa beans (Cudjoe[2] *et al.*, 2008).

3 Results

To observe the progress of the primary processes of cocoa beans, a two-month attachment at the Cocoa Research Institute of Ghana (CRIG) was conducted. The primary processes of one batch of cocoa beans were followed at a small farm holder. The farmer, Mr. Johnson Akpalu, has a farm near the CRIG station. His wife and eight children (7 – 24 years old) take part in the production of cocoa beans when they are not in school or doing other things. The processing was observed at the end of the main season (February 2010). In the main season when cocoa harvests are heavy, small farm holders help each other processing the cocoa beans.

The processes at CRIG, which deals with much bigger amounts of cocoa beans, were also observed. The institute has three employed workers to process the beans after the pods are opened. That work includes fermentation, drying and packing. Pod breaking is handled by the staff of the plantation management division at CRIG.

3.1 Maintenance of the plantation

The cocoa trees were approximately 4 – 6 meters tall at the small farmer's farm. A number of trees had dead and diseased branches. Some branches grew low or towards the tree trunk. No damaged trees were observed. Generally seen, the plantation floor was covered with dry, dead leaves, but high grass was also seen. The cocoa trees were shaded by big shade trees.

Every plantation at CRIG is a part of an experiment, which means that some plantations are maintained differently. In plantations where maintenance is not a part of the experiment, trees are sprayed with pesticides and fungicides four times in a year. The plantations are weeded 3 – 6 times per year, depending on the age of the trees in the plantation. The trees are not top pruned since only budded plants, grown at the CRIG nursery, are used. These trees are cultivated to grow short. The observed trees in CRIG's plantations were at a height of 3 – 5 meters. General pruning is performed two times in a year. The experiment in the particular observed plantation focused on shade management, meaning that some trees were shaded more than other trees. High grass covered the ground where weeding had not yet been finished. Many trees had wounds and scars from a machete or a hook.

3.2 Harvesting

At the small farm, reachable ripe pods were cut off by machetes. Those at the top of the trees were cut off by a sharp cutting hook, attached to a long pole. When the pods were cut, they were collected from the ground into baskets. The baskets, bearing about 20 kg, were transported on the head of the farmer back to the farm-house. Black pods were also harvested, and some of them were brought to the farm-house. The rest was left on the ground.

Cocoa pods were harvested on Mondays to Thursdays in CRIG's plantations. The number of harvested pods was counted. Black pods were harvested and buried in the edge of the plantations. These pods were also counted. Reachable pods were cut off by machetes and unreachable pods were harvested with cutting hooks, attached to a long pole. Good pods were carried in baskets to a vehicle that brought the pods to CRIG fermentary. No pods were left on the ground.

Figure 6. Vehicle that brings harvested pods to CRIG fermentary.
Picture by J.F.Takrama. Printed with permission.

3.3 Pod opening

At the small farm, the pods were placed in a pile on the ground. The farmer and his family participated in the job. They sat on a piece of wood or a plastic container and cut the pods with a sharp machete. First along the pod, then across and this allowed them to break up the rest of the pod. The placenta was not removed, and several beans in mouldy pulps were accepted as good beans. Shells and bad pods were thrown on the surrounding area. They would later be burned and used for making soap.

At CRIG, the fermentation officer decided how many people he needed to open the pods that had been harvested during that particular week, so that all the pods could be opened the same day. Bad pods were sorted out and left in another pile. Those beans were not fermented, but dried and sold to companies in Holland for cosmetic manufacture. The pods that were too bad for cosmetics use were collected with the shells and made into potassium fertilizer, soap or animal feed. The placenta was removed at the pod opening step.

As soon as the pod opening had finished at CRIG, the good cocoa beans were put in poly tanks to drain the sweating (figure 7). Poly tanks are plastic containers, common used in Ghana for water reservoirs of house holders. The poly tanks, used for draining the sweating, have a capacity of 500 – 2,000 liters. They were placed upside down and the bottom was cut off. The lid was removed and a piece of plywood was put between the open end and the beans. In the plywood, there were a lot of small holes that allowed only the sweating to sieve into the plastic containers underneath.

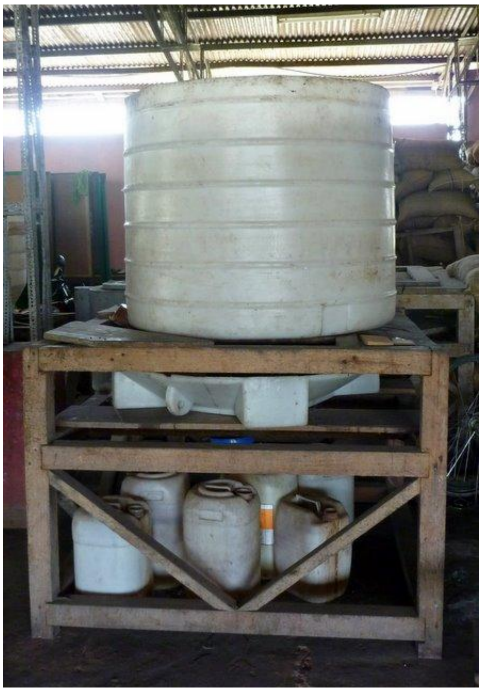

Figure 7. Poly tank construction for draining the swearing. Picture by: LSM

3.4 Fermentation

Heap fermentation was practiced at the small farm. Banana or plantain leaves were neatly laid on the ground, covering an area big enough to avoid the beans touching the ground. Fermentation was carried out on sloping area for easy drain of sweating. Once the beans were piled up in a heap on the leaves, they were pressed together. The beans were covered tightly with banana/plantain leaves, and other plant material was added to prevent the top leafs in blowing off (figure 8). Observations of heap turning were not conducted, but according to the farmer, turning was performed after two days. The placenta was not removed at the time of turning. The fermentation was brought to an end after four days.

Figure 8. Fermenting heap at small farm. Picture by: LSM

Figure 9. Fermenting heap after 4 days. Picture by: LSM

The fermentation at CRIG is done by box-, basket- and tray methods. Heap fermentation is only practiced whenever there is an experiment going on. In this study, tray fermentation was observed. The lower tray was placed on a wooden platform, about 30 cm high. The cocoa beans were poured into the first tray and distributed evenly before the next tray was positioned on top. Same procedure was repeated till the stack was three trays high. The trays were filled so the surface of the cocoa beans was higher than tray level. The top tray was covered with banana leaves and held in place by sticks. Four days later, the fermentation was brought to an end. Plantain leaves are not used at CRIG. Plantain is an important food resource, and cutting off too many leaves from the trees, may reduce plantain yield.

3.5 Drying

Drying was practiced on bamboo mats on a raised platform at the small farm. As the beans were spread, the placenta and the bad beans were sorted out. During drying, bad and under fermented beans were continually sorted out. The mats were rolled up at night to cover the cocoa beans from dew. The observations were made in dry and sunny weather, and the beans were dried for four days.

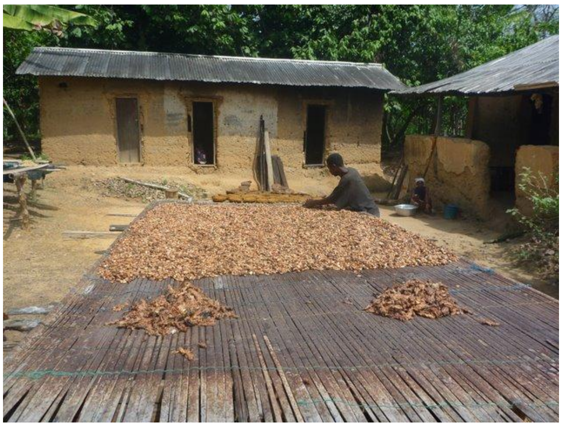

Figure 10. Drying mat at the small farm. Placenta and bad beans are seen in the front. Picture by: LSM

All the beans were dried in the same area at CRIG, on different mats of bamboo. Some of the mats were mobile, which means they could slide from side to side on a track. At night, those mats were stored under a roof which means that they did not have to be rolled up. CRIG also had stationary drying mats, which were rolled up in the night. The mats were 8 – 18 square meter, and a wooden rake was used to turn the beans. Any bad bean was removed. When the beans were dry, they were packed in sacks and sold to the local buying depot.

3.6 Quality control

A cut test was observed at CRIG. A sample of about 200 beans was collected from one sack, holding 62.5 kg. The beans were mixed and divided into four piles. Two piles opposite each other were chosen and mixed in an opaque bag. This ensured randomly picking of every bean that was used for the cut test. After cutting the beans lengthwise, the beans were placed on a white board, divided into 100 squares. One bean was laid on each square. Slaty beans, purple beans and defected beans were grouped and counted.

Quality control, performed by Quality Control Division, was observed at Tema Port. The sacks of cocoa beans were transported on truck beds from the different regions of Ghana (Figure 11). The cocoa, produced in different areas in Ghana, was divided into six regions, each having a warehouse to store the sacks before shipping. On arrival, every sack was stabbed with a sampling horn, and a handful of cocoa beans were squeezed to hear if they made a cracking sound (figure 12).

Figure 11: Truck with cocoa sacks. Picture by: LSM

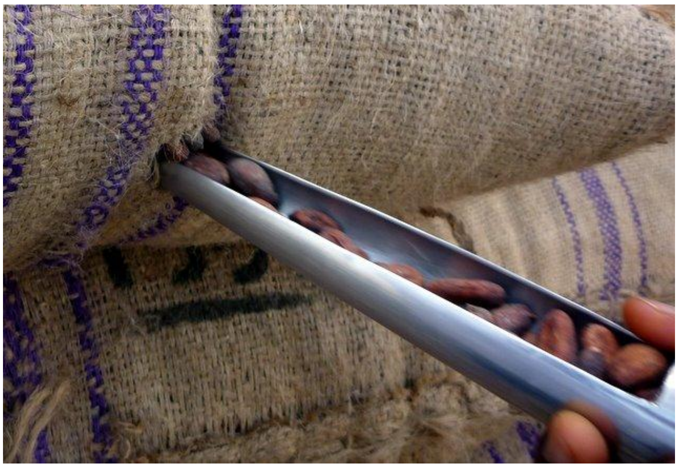

Figure 12. Sampling horn to collect beans. Picture by: LSM

A cut test was made on each batch of cocoa beans. One batch of 500 sacks was tested by one cut test. Samples from each bag were mixed and separated randomly till 100 – 200 beans remained. A batch of more than 500 sacks would be tested with three cut tests. Moisture was measured with a Moisture Meter. Size of the beans was determined by Bean Counts, where 100 grams of cocoa beans were weighed and counted. This was repeated three times, and the average result determined to which category the beans belonged.

Graded beans were stored in environment-controlled warehouses. Before the sacks were stored, the warehouses were sprayed with insect killing chemicals. Temperature was kept around 25 degrees and a poisonous deter gas was discharged to kill pests three times a week. This gas had been pretested to ensure that the cocoa beans do not absorb poison traces. Completed stacks of cocoa beans were covered with thick tarpaulins, and removed to promote air circulating, if the sacks were to remain in the warehouse for a long time.

Cocoa beans were shipped in containers that had been sprayed with pesticides and closed for 24 hours. The insides of the container were then covered with corrugated paper to absorb any substances that might be in the container. Immediately before the cocoa sacks entered the containers, they were sprayed one more time. The door was sealed as soon as the container was full.

4 Discussion

The observed primary processes of cocoa beans at CRIG and at the small farm will be compared with scientific literature in this chapter. Improvements will be sought and suggestions of changes will be stated. Obstacles in making changes will also be discussed.

4.1 Maintenance of the plantation and harvesting

According to Hanada *et al.*, (2009), black pod disease accounts for on average 30 % losses of cocoa harvest every year. To ensure good and stable income to the cocoa farmers, high yield and high quality of the beans is necessary. Some studies (Hanada *et al.*, 2009; Ndoumbe-Nkeng *et al.*, 2004) found a decrease in incidences of diseases among cocoa pods by removing the diseased pods in the cocoa plantations. During observations at the small farm, black pods were harvested, but not all of them were removed. However, removing the pods means bringing them to the farm together with the healthy pods and leaving them on the ground for maybe two or three days. After the pod opening, diseased pods remain on the ground till they are burned and used for soap making. This may be done one or two weeks after the pod opening, since the pod husk must dry before burning. There is no isolated storage area for the diseased pods on the farm. To decrease incidences of diseases, all bad pods should be destroyed (Are & Gwynne-Jones, 1974; Takrama, 2007). It is the author of this paper's opinion that diseased pods at the small farm should be either burned the same day they are harvested, or kept isolated until burning together with the husks from healthy pods.

Another way to decrease spreading of diseases is to be gentle to the trees during harvest (Are & Gwynne-Jones, 1974; Barclays Bank, 1970). As for the small farm holder, work with the machetes and the hook was performed gently and professionally. However, the pods in the top of the trees are very difficult to harvest and control, and cutting the cushion as close to the tree as possible, is almost impractical. The observed cocoa trees at the small farm were approximately 4 – 6 meters high. By cultivating or pruning the trees to a smaller size, harvesting would be easier and more controlled. It would also diminish the risk of leaving unseen pods on the ground. David (2005) recommends top pruning of every cocoa tree that is more than five years old. The observed farmer prunes the trees 2 – 3 times every year, but only hanging, diseased and low growing branches are cut off. During the period where observations were made, many poor and horizontally growing branches were found, indicating that pruning is performed either inefficiently or too seldom.
The trees in CRIG's plantations were well-pruned and in good condition, probably as a result of different factors. Removing of black pods has shown significant improvements in decreasing

diseases (Soberanis *et al*., 1999), and destroying of the black pods is recommended (Are & Gwynne-Jones, 1974; Takrama, 2007).

During observations of the workers in CRIG's plantation, tree trunks were sometimes used to fasten the hook to the stick. The hook is sharp on both sides, so naturally, it damages the trees. After a closer look at the tree trunks, several wounds and scars were found (figure 13). However, it seems that the workers are aware of the damaging effect, since when demonstrating how to fasten the hook, a machete was used instead of the tree trunk (figure 14).

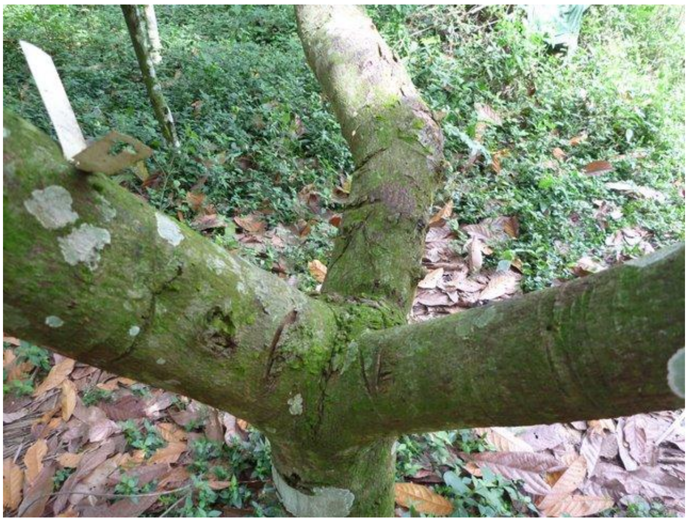

Figure 13. Damaged cocoa tree in the cocoa plantation at CRIG . Picture by: LSM

Figure 14. Correct way of fastening the hook to the long pole. Picture by: LSM

Some cocoa trees in CRIG's plantations are more than twenty years old. According to Kazianga & Masters (2006), yield decreases in old trees. However, this is only a question about yield, and not about the quality of the beans, according to Baker *et al.* (1994). They found in a survey of Ghanaian cocoa and influences on cocoa flavor, that age of the trees has no effect on taste.

4.2 Pod opening

Pod opening seems to be a greater hazard to human health than to the quality of cocoa beans both at CRIG and at the small farm. The position of the way the workers sit while opening the pods seems to be ergonomically incorrect, which might influence states of health later on. No surveys stating the health of cocoa farmers and cocoa workers has been found, so to state that the work is harmful to human health would be incorrect. Possible solutions to this problem will be discussed later on in this chapter.

Another risk to human health is when the machete is applied in pod opening with relatively hard blow close to the body. This method seems to be preferred even though it is opposed by several authors (Barclays Bank 1970; Mossu, 1992), as it may damage the beans. Despite this, the method seemed to be effective and controlled at both CRIG and at the small farm, and only experienced workers are allowed to use the machete. Inexperienced workers at CRIG are required to use a wooden mallet (Asare, 2010).

Speaking of the small farm holder, there is no benefit in suggesting sophisticated tools or machines that might diminish incidences of harming the beans with a machete. This is said with particular reference to a survey made by Aneani & Takrama in the year 2003. They examined 240 cocoa farmers, aiming to ascertain the farmer's insight in strategies and practices that affect the quality of cocoa beans. Furthermore, the survey determined the farmer's awareness of those practices. The cocoa farmers were aware of what characterize good quality of cocoa beans, and they know the strategies are to achieve this quality. However, the methods were not practiced by all of the farmers. Regarding the pod opening, 64.6 % preferred to cut through the pod and 0.4 % broke the pods with a wooden club (Aneani & Takrama 2006). Easy and cheap methods seem to be preferred rather than safety, costive and sometimes also methods that ensure good quality of the final beans.

History of Ghana tells that cocoa beans have been produced in more than one hundred and thirty years in the country. Traditions have then taken form, and breaking those habits might be a process that will take several years. A barrier can be found in the farmer's feelings about the work he is doing. If the present farmer has learned the methods from his parents and grandparents, he may see it as an honor to do it exactly the same way as they did it.
To attain a better quality of the beans, the new strategies must essentially also be more effective, faster or easier to practice.

A possible solution that has already been invented is a pod break machine, but as described in chapter 2.3, developed machines never really have had success. The deficiency of the machine described by Are & Gwynne-Jones (1974), were that shells from the cocoa pods sometimes ended up with the beans. However, this has no influence on the fermentation of the beans (Are & Gwynne-Jones, 1974). More important is that the machine was not able to sort out the bad beans from the good ones, which must be done after the pods are opened. Pods that look diseased may contain good beans and vice versa. A pod break machine would also take a lot of space, require petrol and maintenance and it would be too expensive to buy.

The CRIG station had a peaceful and calm atmosphere, which probably would be disturbed by the noise of a machine. To avoid a smoky and noisy station, a manual operated machine could be a solution. This machine should only break the pods, not separate the beans. The following work would be to separate the beans from the placenta and the shells, which at the same time give the possibility to separate bad beans from the good ones. Such a machine could consist of a rectangular hopper with the long sides of caterpillar tracks (Figure 15). They are connected to a crank handle that forces the pods to pass down through the hopper. The pods will thereby be squeezed and broken. All materials that touch the pods are made of wood, which is not damaging for the beans. Wood is also a local material that is cheap and easy to obtain.

Figure 15. Sketch of pod break machine. Design & picture by: LSM.

At CRIG, cocoa pods that are harvested on Mondays, are left on the ground for four days before they are opened. This seems to be acceptable since leaving the ripe, harvested pods on the grounds a few days before opening the pods, increase the chocolate flavor (Baker *et al.*, 1994) and there is no risk of contaminating healthy pods if they are mixed up and left with diseased ones (Asare, 2010).

Many diseased pods were opened and accepted for fermentation by the small farm holder, and according to Are & Gwynne-Jones (1974) is it generally safe to use beans from pods that show the first signs of black pod disease. However, more recently Takrama (2007) described the risks of

OTA contamination during the primary processing chain of cocoa beans, and the report was strongly opposed to diseased and mouldy beans being fermented together.

4.3 Fermentation

The placenta was fermented with the beans at the small farm. This issue has been investigated at CRIG, where cut test data was measured on beans, fermented with the placenta. The results showed that cocoa fermented with placenta yielded the same quality as those fermented without (Takrama *et al.*, 2006). Speaking of OTA, the risk of contamination is bigger if the placenta is not removed (Takrama, 2007). Removing the placenta during pod breaking would also reduce the weight to carry and the fermenting heaps would not be unnecessarily large. Consequently, the placenta should have been removed.

The fermenting heap at the small farm holder was estimated 600 kg and fermented for four days with turning on the second day. In a survey of fermenting Ghanaian cocoa beans, larger heaps at more than 150 kg including the placenta, required up to six days fermenting with one time turning. Small heaps (50 – 150 kg) required only 4 days without turning (Takrama *et al.*, 2006). Camu *et al.* (2008) studied the effect on flavor of turning small heaps (150 kg). They found that turning the heaps accelerates fermentation speed and promotes AAB growth, but it does not necessary favor the flavor of the beans. For these reasons the small farm holder should have fermented the cocoa beans for six days instead of four days, and it would be efficient with turning the heap on the third day. If he wished to complete the process as quickly as possible, he should split the heap into smaller heaps (50 - 150 kg) and fermented them for four days. This solution would also ease the work of turning the 600 kg heap of fermenting cocoa beans.

It is difficult to determine exactly which procedure the fermentation should follow, as two batches seldom are identical. The factors involved in fermentation are mentioned in chapter 2.5. After studying the diversity of yeasts involved in cocoa bean fermentation, Jespersen *et al.* (2004) concluded that the fermentation is a very inhomogeneous process with high variation in both yeast counts and species composition. Also the bacteria in the cocoa fermentation process vary in microbial count. Reasons for variations include pod ripeness, post harvest storage, pod diseases, fermentation method, size of the batch, season and weather, turning the heap, and fermentation time (Camu *et al.*, 2008; Nielsen *et al.*, 2007).

Much care of air-tightening and covering the heap properly was taken at the small farm. These steps ensure good isolation for the heat produced and protected the cocoa beans against insects (Nielsen *et al*., 2007). Some unripe beans were fermented at the small farm and removed before drying. The placenta and pieces of pod husk has no influence on the fermentation (Takrama *et al.*, 2006; Are & Gwynne-Jones, 1974), and according to sensory quality, it would be highly unexpected that unripe cocoa beans should affect the fermentation. Much more important, the risk of developing OTA in the fermenting heap is higher when unripe beans are not removed (Takrama, 2007). Therefore, unripe beans should have been removed.

The fermenting heap at the small farm was placed on a small hill to promote the sweating draining off. The majority of literature about heap fermentation advise the heaps to be lifted by sticks (Mussu, 1992; Are & Gwynne-Jones, 1974; Barclays Bank, 1970), while others suggest to make a small drain around the heap (Anon, 1964). Cudjoe[1] *et al.*, (2009) state that fermenting on a flat land will not allow the sweating to drain away. It was clear that the sweating had run off downhill at the small farm and therefore, this method seems to be safe.

The tray fermentation at CRIG was completed after four days, which also is recommended by Are & Gwynne-Jones, (1974). In each tray, the surface of the fermenting beans was higher than tray level. This was performed to prevent air pockets when sweating run off. Air pockets will cool down the heat and promote moulds growth (Asare, 2010). Due to this, fermenting processes were regarded as being well-planned and well-organized.

4.4 Drying

At CRIG, the drying area was surrounded by a fence, and every drying mat was raised above the ground. Three employed workers were watching the drying area constantly while the beans were in the sun. It is very important that the drying area is observed, especially to ensure quick coverage of the beans whenever the rain falls. The beans were turned every hour when the workers were not busy. In that case, there might be up to two hours interval between turnings. Turning the beans ensures a uniform drying, it breaks possible agglomerates and it prevents mould growth (Amoa-Awua *et al.*, 2007).

The layer of the drying cocoa beans should not be more than 5 cm thick (Amoa-Awua *et al.*, 2007). The observed drying layers were only one bean thick, which is normal in the minor season. In the

main season, layers are maximum 5 cm thick and only exceeded when the weather is dry and sunny. Cloudy weather allows only one or two beans in a layer at CRIG.
Drying ovens are not used at CRIG, but a mechanical dryer was used until it broke down last year (Asare, 2010).

To summarize, the drying methods at CRIG seems to be well planned and safe. Directions to keep drying layers thin are followed, the drying area is constantly observed and the beans are turned often. The fact that turnings sometimes are not done every hour is considered acceptable in the light of the awareness of the drying cocoa beans.

Figure 16. Typical amount of cocoa beans on a drying mat in the main season.
Picture by: J.F. Takrama. Printed with permission.

Artificial dryers can help to avoid moldy beans in wet seasons (Mossu, 1992). The mechanical dryer at CRIG is too costly to repair and to run, but an oven with a heating base could be a solution. Smoke from a fire is a bad solution since it will affect the quality of the beans (Cudjoe[2] *et al.*, 2008), and even the best quality of fermented cocoa beans can easily be spoiled by wrong treatment afterwards (Mossu, 1992; Amoa-Awua *et al.*, 2007).

With the up-coming technology and global warming, much focus has been on alternative energy such as wind- and solar energy. Ghana has an annual duration of sunshine of 1800 – 3000 hours, which gives the country a daily average solar radiation of 4 – 6 kWh / m^2 (AREED, 2010). An intermittent solar dryer with thermal energy storage was built from readily available and local materials in Nigeria. The energy was based on a combination of convective heating and direct radiation, and the results showed that the solar dryer is able to dry cocoa beans with a moisture level from 53,4 % to 3.6 % within 72 hours. The quality of the beans was good, and comparable to that of traditionally sun dried cocoa beans (Fagunwa *et al.*, 2009).

In another experiment with solar dryers, a solar tunnel dryer was built in Malaysia for drying longan fruits from moisture content of 84 % before drying to 12 % after drying. Longan fruit are, like cocoa beans, sun dried on mats or more often, mechanically dried with hot air. The experiment resulted in good quality and considerable reduction in drying time, compared to natural sun drying (Janjai *et al.*, 2009).

Both studies are made recently and show positive results, but already 12 years ago, Bonaparte *et al*., (1998) stated that low cost solar drying has the potential of enhancing drying rate in cocoa beans, after surveying quality characteristics of solar-dried cocoa beans. They also found that the solar dryer did not cause problems associated with drying at high temperatures (Bonaparte *et al.*, 1998). It is likely that there will be much more focus on solar energy in the future, and it might be worth investigating the possibilities for a solar dryer at an institute as CRIG.

As for the small farm, an artificial dryer is not a possibility, so only present methods will be discussed. The farmer made sure to remove the bad beans and the placenta when spreading out the fermented beans on the drying mat. The mats were placed right in front of the house, raised about one meter from the ground. Placing the mats in this position is perfect. Whenever a member of the family enters or leave the house, it may compel them naturally to remove one or two bad beans. It is also easy to keep an eye on the mat, and the height ensures that animals are not getting in touch with the beans. Most important, in this position, it will not take long to cover and protect the beans against water, if the rain comes suddenly.

Efforts in drying beans are not heavy, but it requires one’s attention constantly during the time the beans are in the sun. This may first of all get tiresome, but also nearly impossible when there is a farm and a life to take care of. If there is no threat of rain, it should be safe to leave the drying beans for a longer period, but never more than one hour. The farmer turns the beans 6 times per day during drying, giving an interval on about every second hour. This is not quite efficient according Amoa-Awua *et al.* (2007), who recommend the turning to be performed every hour. The mats were rolled up every night. A survey in perceptions of cocoa farmers in Ghana (2006) showed that more than 4 out of 5 were frequently stirring and pressing the drying cocoa beans, but only 8.8 % prevented wetting of beans by rain or dew (Aneani & Takrama, 2006). Compared to this survey, the observed farmer was more alert on producing good quality of cocoa beans than his colleagues.

The beans were dried for four days at the small farm. This period is too short, according to several authors (Takrama & Adomako, 1996; Are & Gwynne-Jones, 1974; Barclays Bank, 1970), who state that drying takes 7 – 21 days. To avoid spontaneous mould and bacterial growth under storage and transport, water content must be reduced to less than 7.5 % during drying (Takrama & Adomako, 1996). Because the farmer is not able to measure water content, he uses as a rule of thumb that the cocoa beans are well dried when they make a cracking sound in the drying mat when stirring. As for the beans observed, they did make a sound on the drying mat, but it is debatable whether it was sufficiently cracking.

In wet and cloudy seasons, lighting a fire at the small farms might be tempting. The observed farmer is aware that smoke will damage the beans and he has never used fire to speed up the drying process. He let the beans dry for a longer period. However, the quality of the beans might be reduced in rainy seasons.

Little research has been done on mycotoxin evaluation, and mycotoxigenic fungi in cocoa beans (Sánchez-Hervás *et al*., 2008). Amezqueta *et al.*, (2008) aimed to identify fungal populations in unroasted cocoa beans, in order to evaluate the OTA production of 16 *Aspergillus* species. 20 batches of cocoa beans with different origin and OTA level were examined but they did not find any correspondence between the amounts of OTA and the presence of OTA producing fungi. More recently, Sánchez-Hervás *et al.*, (2008) examined the incidence of fungal species that are potential producers of mycotoxins to a greater extent. More than 350 *Aspergillus* strains were identified, and their potential ability to produce mycotoxins was studied. Results showed that almost half of the isolated black aspergillus strains were able to produce OTA, and about half of the isolated *Aspergillus* species were able to produce other toxins (aflatoxins and cyclopiazonic acid) in amounts, making them moderate to highly toxic. That means that there is a possible risk factor posed by mycotoxins contamination cocoa beans (Sánchez-Hervás *et al.*, 2008). However, it is worth focusing on OTA since this toxin is stable during most food processing stages, and thereby probably ends up in the final cocoa product (Amoa-Awua, 2007; Sánchez-Hervás *et al.*, 2008). Accumulation of aflatoxin is inhibited by caffeine, which naturally occurs in cacao beans (Amoa-Awua, 2007). Levels of mycotoxins and pesticide residues in cocoa beans are controlled in Ghana before export, and refused shipping when levels are too high (Lochart, 2010).

4.6 Quality control

Unfortunately cut test data and general quality control at Quality Control Division, Tema Port, could not be obtained from the observed batches of cocoa beans. This is due to the fact that quality control is made after collecting several sacks of cocoa beans all over the country. However, traceability of every sack is possible. This is ensured with the inscription on the sack, with information of the cocoa beans origin. The first quality control test of the cocoa beans, produced at CRIG and the small farm, is made in Koforidua, which is the capital of Eastern Region. A metal sign is fixed firmly to the sack, telling who did the quality control. This step has not been observed. Tracking the exact two sacks of cocoa beans where observations have been made is therefore possible, but a complex work, that demand more than this survey is required.

However, no modifications have been made on the processes of the observed batches of cocoa beans. Therefore, it is presumed that the observed cut test respond the quality of the observed batches of cocoa beans. Bad quality of cocoa beans from Ghana is hardly ever seen.

One cut test (100 beans) grades up to 500 sacks of cocoa beans. One cocoa bean weigh on average 0.5 gram and one sack weigh 62.5 kg (Asare, 2010). This gives every sack of coca beans the amount of 125,000 beans. 500 sacks will contain 62,500,000 beans. 100 cocoa beans will therefore correspond to 0.00016 % of one batch. It is doubtful whether this gives the correct picture of the quality. Conversely, every single sack is stabbed and tested visually and by hand. Cross checking is achieved via several tests through the transport- and storing chain. Therefore, routines of controlling the quality of cocoa beans are considered as being comprehensive.

The treatment of cocoa bean sacks at Quality Control Company Ltd. ensures that no contamination happens in the warehouses and under shipment. The sacks of cocoa beans are seldom stored for more than 5 months in the warehouses. As long as the warehouses are in good condition, the quality of the stored cocoa beans will remain high for years (Lochart, 2010).

6 Conclusion

Present methods for primary processes of cocoa beans are well-concerned and successful. The small farm holder generally follows literary advice and is aware of what influence the quality. However, several defects as placenta, mouldy beans, diseased beans and unripe beans, should have been removed during pod opening to minimize the risk of Ochratoxin A contamination. Methods at CRIG are verified and followed in each step of the primary processing chain of cocoa beans. Opening the cocoa pods with a machete result in good, whole beans. The quality of Ghanaian cocoa beans is high and analyzed with great care.

The work of processing cocoa beans is labor-intensive and demanding. No surveys have examined the statement of cocoa farmer's and worker's health. Instant improvement along the primary processing of cocoa beans are possible through careful treatment of cocoa trees and smaller fermenting heaps at the small farm. A manual pod break machine is a possible aid at CRIG. The machine should the speed up the pod breaking process and prevent workers in harming their health. A low cost solar drier is also suggested as possible aid at CRIG. A solar drier has resulted in high quality in other countries with weather conditions that are similar to Ghana.

Quality control is considered as being comprehensive. Storing and shipment of cocoa sacks is handled with great care that ensures that no contaminating or spoiling happens to the final cocoa beans.

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