# DECLARATION

I Owusu Daniel, declare that I personally undertook this project and it has not been produced anywhere for award of a degree except other people's works cited which have been dully acknowledged.

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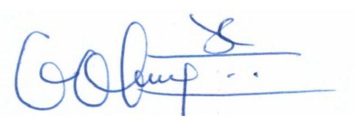

MAY 19, 2017

DR. GEORGE YAW OBENG ..................................... ....................................

Co-Supervisor Signature Date

PROF. ATO BART-PLANGE …………………………… ………………………

Head of Department Signature Date

## DEDICATION

This work is dedicated to Mr. and Mrs. Owusu, all my siblings, Ms. Jacquelyne Ansah Eshun and the entire members of Harvest Chapel International Ministries.

## ACKNOWLEDGEMENT

First and foremost I wish to acknowledge the Almighty God who has granted me unlimited grace and favour and through his unfailing love which has brought me out of nothing to this far. I give all praise to him.

To my supervisors Prof. Ebenezer Mensah and Dr. George Yaw Obeng, I am grateful for your consistent supervision and guidance without which the completion of this thesis would not have been possible.

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May the blessings of God extend to Technology Consultancy Center (TCC), KNUST, and MIT C-Lab, International Development and Innovative Network (IDIN) for funding the project. To the director, Dr. Michael Adjarloo, Mr. Johnson Opoku Asante, Mr. Derick Yeboah and all the staff of TCC, God richly bless you.

Finally, I wish to express my deepest appreciation to my entire family for their prayers, financial support and generally being there at all times. I say a big thank you to you all.

## ABSTRACT

The cocoa pod splitter is a simple machine fabricated from mild steel. It has a simple design and it is a user-friendly machine for splitting cocoa pods of all sizes. The pod splitter is operated manually by pressing an upper blade on the cocoa pod to break it inside a chamber. The pod splitter breaks one pod at time and requires one farmer to operate. Due to its design and ergonomics, it takes a farmer one working day to be familiar with its usage. The cocoa pod splitter was field-tested on a cocoa farm in Atobiase town in Ashanti region of Ghana. The purpose was to evaluate its performance and compare with the traditional method of using cutlass. The parameters measured for testing the performance of the cocoa pod splitter include the number of pods splitting per operation (splitting rate), percentage beans damaged and the maximum force required to break one pod. The average number of beans in a pod was also measured. The sizes of the cocoa pods were also measured and classified according to variety. The machine has a working space of 940 cm×700cm. From the results the splitting rate was 259 pods per hour. The percentage beans damaged per hour of operation was 0.97% and the maximum force required to break one pod was 10.42 kN.The average weight of wet beans in a pod was 228.3 grams. The cocoa pod splitter has the potential to replace the cutlass in the splitting of cocoa pods in Ghana. .

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# CHAPTER ONE

# INTRODUCTION

## 1.1 Background to study

Cocoa (*Theobroma cacao)* is one the important cash crops grown in the world today. Due to its high export earnings, cocoa production has been a supporting factor for the economy of producing countries. It is also a key import commodity for consuming countries due to its economic value and its various uses (organiza, 2008).

Cocoa was increasingly cultivated by the Maya-speaking peoples of tropical Central America. The Maya Indians discovered that when the beans of the cocoa tree were roasted, a divine aroma was emanated. They believed the tree was a gift from their deity, “Quetzalcoatl”. Drinks from the roasted beans were made and used during rituals and ceremonies. They called it “xocolatl”, from which we obtained chocolate.

From the Amazon Basin where the Mayas presumably had grown their cocoa tree, cocoa production has spread throughout the world.  Cocoa trees now are mostly grown in tropical areas within 15 to 20 degrees latitude from the equator. “The ideal climate for growing cocoa is hot, rainy, and tropical, with lush vegetation to provide shade for the cocoa trees” (organiza, 2010). Major producing countries in each region of the world are; Africa: Cote D’Ivoire, Ghana, Nigeria, and Cameroon. Indonesia, Malaysia, and Papua New Guinea are leading producers in the Asian/ Oceania continent. Brazil, Ecuador, and Colombia dominate the America’s in cocoa production.

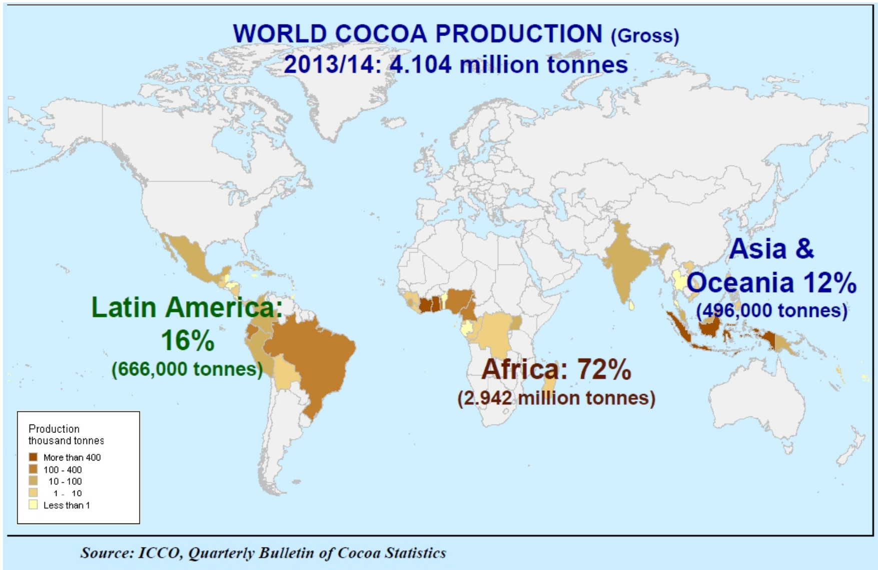


Fig. 1.1 showing world cocoa production

The cocoa fruit has useful applications in many industries. The beans extracted from the cocoa pod is used to produce soft drinks and alcoholic beverages.  Cocoa liquor after processing is mixed with other ingredients to produce chocolate. More than a millennium after the discovery of cocoa, Chocolate is now a lucrative business. The United States of America alone, the world's biggest consumer, consumes about 1 to 1.4 million tonnes of chocolate every year (Vos, 2003).Chocolate also forms part of the largest share of the global trade, which is estimated to be about $80 million. It is used as a product on its own or combined with other ingredients to form confectionery products. Cocoa powder can be used as an ingredient in almost any foodstuff. For example, it is used in chocolate flavored drinks, chocolate flavored desserts such as ice creams, chocolate spreads and sauces, and cakes and biscuits. The husks of cocoa pods and the pulp, or sweatings, surrounding the beans and the cocoa bean shells can be used as animal feeds. Shells from cocoa beans can be used as an organic mulch and soil conditioner for the garden.

Cosmetic products such as moisturizing creams and soaps can be made from cocoa butter which is a product of processed cocoa beans (Adumako, 1995).

Cote D’Ivoire is the leading producer of cocoa in West Africa, with Ghana as the second leading country. Other nations like Nigeria and Cameroon are also actively involved in cocoa production in West Africa. According to the International Cocoa Organisation, 2.942 million tonnes of cocoa beans produced by Africa in the period of 2013/2014 contributed to 72% of the world’s total production.

Ghana is one of the largest suppliers of cocoa on the world market and its cocoa sector employs millions of people. Globally, Ghana’s cocoa bean production is ranked second in the world after her western neighbour Côte d'Ivoire (FAOSTAT, 2005). Cocoa beans from Ghana have been tagged as the best premium quality in the world (Ntiamoah & Afrane, 2008). Over 80% of all cocoa is produced by smallholder farmers (Vos, 2003). Cocoa provides employment in many rural communities and pays for school fees for farmers’ children. Smallholder cocoa in Ghana is mostly grown under shade trees and either mixed cropped or grown in a semi-natural agro-forestry setting. (Vos, 2003). Small holder farmers are not the only beneficial of revenue generated by cocoa. The economic value of cocoa to Ghana cannot be dispensed. It’s a great contributor to the GDP of the country. Its production affects lives and contributes directly or indirectly to the standard of living in the nation. The state is dependent on earnings from cocoa since it’s a major export commodity (ICCO, 2006). Cocoa beans from Ghana are exported to Countries like Germany, United States of America, France, United Kingdom, China etc., with annual cocoa beans export estimate of about 48,500 tonnes per year (COCOBOD, 2012).

In Ghana, cocoa is produced in the country's forested areas such places like; Ashanti Region, Brong-Ahafo(Clarke, 2016) Region, Central Region, Eastern Region, Western Region, and Volta Region, where rainfall is between 1,000-1,500 millimeters per year. In the year 2013, about 90% of total production was grown by smallholder farmers. This explains most cocoa beans in Ghana are produced by smallholder farmers.

## 1.2 Problem statement

Demand for more cocoa production by consuming countries has been increasing annually. This calls for faster and convenient ways of boosting production in Ghana. One stage of cocoa production is the splitting of the ripe pods to expose the beans. Farmers in Ghana carefully break the pods with either blunt cutlass, a wooden pub or by hitting two pods together. (Mossu, 1992)

The contents of the cocoa pod, namely the fresh beans with mucilaginous pulp cover are then scooped out, piled and prepared for fermentation. This activity is usually carried out at the same spot year after year (Otumfo, 2014). Farmers are at risk of splitting or hitting their hands with cutlass if they should miss their target and angle of hit. Therefore splitting of the cocoa pods to expose the cocoa beans has been a major challenge. It is labour intensive and time-consuming.

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Moreover, the traditional method of splitting cocoa pods with a cutlass tends to damage the beans inside the pods and may lead to poor quality of cocoa beans and also makes some of the beans unsuitable for fermentation causing losses (Bamgboye, 2003). Poor quality cocoa beans may decrease the grade and market price of the beans resulting in a decline in export. Less export of cocoa beans will mean decreased foreign exchange for the country.

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## 1.3 Justification

Performing an evaluation of the cocoa pod splitter is vital to test the machine to meet the full specification of the market. It is also essential to perform this evaluation to opt out the strength and weakness of the machine. It will help users especially farmers to know the efficiency of the machine (total number of pods splitting per hour). This will enable famers to effectively calculate volumes of beans they can heap per day and estimate the returns on their cocoa beans.

Fig. 1.2 Picture showing how farmers split cocoa pods in Ghana

**1.4 Objectives of study**

The main objective of this study was to evaluate the performance of the cocoa pod splitter.The specific objectives were to:

1. Determine average weight of beans in a pod and number of pods splitting in an hour in comparison with manual splitting using cutlass.
2. Identify the forces applied to break the pod
3. Identify effective working position when a farmer uses the machine(ergonomics)

- Determine the percentage mechanical bean damage when using the pod splitter and its comparison when using cutlass for splitting cocoa pods.

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# CHAPTER TWO

## LITERATURE REVIEW

This chapter recounts literature on studies done by other researchers, publications, and journals relevant to the current study. Many designs or concept of the pod splitter have been developed, fabricated and tested. This chapter will also focus on the following enlisted agenda;

- Identifying other designs and existing prototypes
- Motives and criteria designers used in selecting their designs,
- Analysing choice of materials for their models.
- Analysing the potentials of their models
- How to fuse their research and study into making this model more efficient.
- Relating their theories to effectively evaluating the current model of the pod splitter

Research has been carried out to study what work has been done so far in this area of mechanization of cocoa pod breaking (Adewumi & Ayodele, 1997).This research was mainly conducted over the last decade in Ghana, Nigeria and Cote d'Ivoire of the West African sub-region.

Information gathered from the Internet and other sources have it that there has been a cocoa breaking machine designed, fabricated and tested which was simple, hand-operated and low-cost impact type cocoa pod-splitting machine for the peasant farmers in the rural area where there is no electrical source of power. It has been claimed that the splitting of pods is a size reduction process, which aims at extracting the beans from the pod (Adewumi & Fatusin, 2006.).

The splitting of pods is a size reduction process, which aims at extracting the beans from the pod. The forces involved in splitting the cocoa pods could be compressive, impact or shearing forces depending on the type of machine and process (Audu et al., 2004).

## 2.1 Traditional methods of splitting cocoa pods

Harvesting is the start of the post- harvest process that determines the quality of the cocoa beans to be sold to the cocoa and chocolate industry.The main season in Ghana for cocoa harvest is from September to January and the minor season is from May to August (Mikkelsen, 2010). Harvesting of cocoa pods can be done by hand or using an assisted tool. Pods from lower trees can be done by plucking the pods from the tress by hand. However, knives are attached to long bamboos to pluck ripe pods located high beyond the reach of the farmer. Cocoa pods are usually harvested every two to four weeks over a period of several months, as ripening does not occur at the same time. Cocoa pods are gathered after removing them from the trees. They are opened immediately or allowed to stay for few days before opening. Pod storage technique has been reported to have the potential to increase the flavour quality of the beans during subsequent fermentation and processing (Adewumi & Fatusin, 2006).

## 2.2 Pod breaking

The harvested cocoa pods are split or broken to extract the beans. It is normally done using either a club, mallet or a cutlass to break the pod after which the beans are scooped out. In Ghana, the most popular methods of breaking cocoa pods is the use of cutlass. The technique is to strike the longer dimension once with the cutlass. A second blow is given on the opposite side and the two halves of the husk is parted by twisting the cutlass. The beans together with the placenta are the scooped out with the cutlass. The practice of cutting the cocoa pods using the cutlass or machete needs considerable skill as the beans can be easily damaged during the process and subsequent penetration by mould and stored pests, making them defective (Afoakwah, 2014).

Fig. 2.1 splitting of the pods using cutlass


Fig. 2.2 Opening pods with wooden club

**2.3 Cocoa pod splitters in Nigeria**

Nigeria, our neighbouring country and an active producer of cocoa beans in West Africa had their first cocoa pod splitter constructed at the Cocoa Research Institute of Nigeria (CRIN), (Jabagun, 1965). A similar machine built by Messers Christy and Norris Limited of England was tested at Cadbury Brothers Cocoa Plantation at Ikiliwindi, Cameroon (Are & Gwynee-Jone, 1974). Two people are required to operate the machine; one feeds the cocoa pods into the machine while the other collects the beans. It breaks the pod by means of a revolving ribbed wooden cone mounted vertically inside a ribbed cylindrical metal drum. The pods are fed into the hopper to move to the shelling section by gravity. The beans pass through the meshes into a collecting wooden box, while the shell fragments drop out at the open end of the rotary sieve.

The major components of the machine included a frame, rail, hammer, pulley, bearings and rope. The machine required rope tension, tensile stress and cross-sectional area of 128.7 N, 728 kN/m2, 1.77 x 10-4 m2 respectively. Impact energy of 30.9 J is required to break one pod while 78.6 J is required for five pods at a time. Hammer speed was determined to be 3.13 m/s. The total load on the pulley shaft was 143.52 N. The machine required a shaft diameter of 14.6 mm and a shaft of 15 mm was used. The machine had a power requirement of 201.6 W.

In the same study by Adewumi and Fatusin, reported the existence of an earlier machine, the Zinke machine which used several rotary jaws or toothed rollers (Faborode & Oladosun, 1991). This machine had the problem by crushing the husks further into tiny portions. This mixed with the wet beans, and posed problems during separation (Faborode & Oladosun, 1991).The machine was tested to break cocoa pods and extract the wet beans. It consists of a hopper, meter plate, hammer and reciprocating sieve. The hammer broke the pods while the vibrating sieve separated the husk. The beans were finally collected through a discharge chute.

Fig. 2.3 Picture showing manually operated cocoa depodding machine designed by Adewumi & Fatusin.

**2.4 Cocoa Pod Splitting Machines in Ghana**

A design of another cocoa splitting machine has been developed in Ghana. The design showed that the machine had the potential to split open five cocoa pods at a time. The knives which do the splitting were actuated by simple hydraulic mechanisms devoid any major stresses, forces or moments acting on them. These mechanisms were powered by simple low - powered lobe positive displacement or hydrostatic hydraulic pumps of power rating of 87.5 kW (65.625 Horsepower). The machine also operates on a simple two-stroke internal combustion (IC) Engines. The total cost of the machine was $1186 approximately GH₵ 5182.82.The target of the machine was for groups of cocoa farmers who could easily bear the low cost of maintenance (Adzimah & Esiam, 2010).

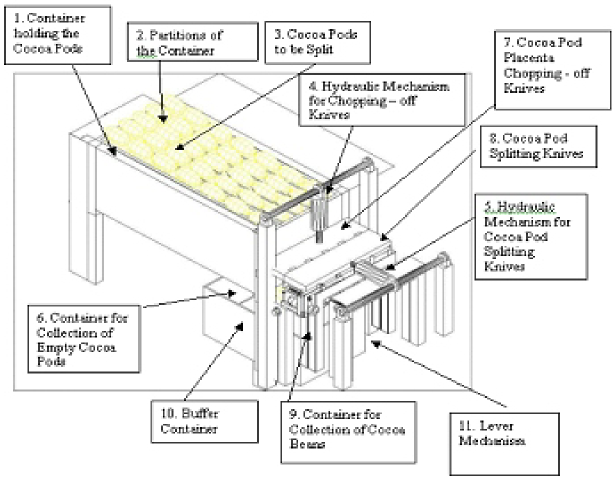



Fig. 2.4 Picture showing the Cocoa Pod splitting machine designed, developed and fabricated by S.K Adzimah and E.K. Esiam

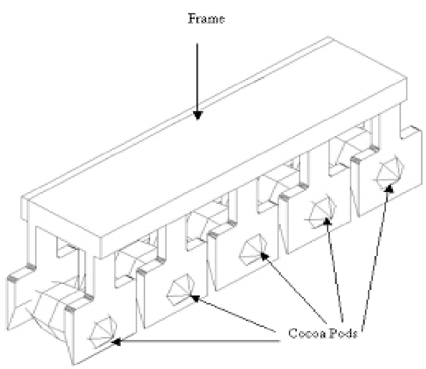


Fig. 2.5 Picture showing the assembly of the Cocoa Pod slashing ("chopping-off") knives ready to "chop-off" the ends of the Cocoa Pods

### 2.5 The Pinhalense cocoa pod crusher

The Pinhalense cocoa pod breaker was manufactured in Brazil. Currently, it is available and used on Lembrance Farm in Bahia State of Brazil. The machine is claimed to have the ability to break different sizes of pods with no manual labour. The machine consists of the breaker which includes an agitator that starts the process of separating the beans from the husk, a conveyor belt, cocoa bean pulp agitator and a pulper. The conveyor belts moves beans and husk to the cocoa bean pulper whiles the cocoa bean pulper agitates the material and further separates beans from husk. This makes the beans drop through the grated pulper floor.

The Pinhalense machine works automatically from the cocoa pod receival through the splitting process, fermentation, drying and dry bean bagging. The dimensions of the machine are 5.35m ×1.55m×2.45m. The machine uses standard electric motors and switching equipment. It is also large scale and requires factory installation and trained engineering support (Clarke, 2016).

The machine was tested in Australia and the following reveals the throughput of the machine (Clarke, 2016).

#### 2.5.1 Through put (pods per hour) of the Pinhalense machine.

- 1.2 tonne of wet bean per hour according to Pinhalense website
- 1.2 tonne of wet bean = 12 tonne of dry bean
- 1 tonne of dry bean = 10 tonne of wet bean = 25,000 pods
- 1.2 tonne of wet bean = 3,000 pods/hour

  1 tonne= 10,000 kg

#### 2.5.2 Observations from the test

1. The machine was a pod breaker rather than a splitter as it breaks the pod husk into many small pieces

2. It was claimed that the percentage of splitting husk is not more than 15% but careful examination of photos what appears to have be a higher percentage and this would interfere with the quality of fermentation and resultant chocolate (Clarke, 2016).

### 2.5.3 Advantages of The Pinhalense Cocoa Pod splitting machine

According to the Pinhalense website the following are the advantages of the Pinhalense pod splitter.

- Able to break different sizes of pods
- Stainless steel contact parts
- Works in continuous flow
- No damage to the pods

Fig 2.6 Picture showing the Pinhalense cocoa pod splitting machine

## 2.6 Binder/Marmara xp1 prototype

The Binder/Marmara XP1 prototype was delivered to Daintree Estates cocoa pod receiving and processing facility in Mossman, Far North Queensland in November 2015. Test conducted in Australia revealed the throughput of the machine to be 1,000 pods/hour. The pricing of the machine was estimated to be approximately thirty thousand US dollars ($30,000) (Clarke, 2016).

## 2.7 QDAF pod splitter

QDAF pod splitter was developed as part of the RIRDC funded Northern Australia Cocoa Development Alliance (NACDA). QDAF prototype equipment includes a pot splitter, bean separator and conveyors. Equipment was developed, tested, patented but not commercialised (Diczbalis et al 2010).

Prior to the development of the QDAF prototype equipment between 2001 and 2009 a number of inventions for pod splitting and bean extracting had been developed overseas but none had been widely adopted. Excessive breakage of the pods husk leading to wet bean contamination has been a major problem with most designs (Diczbalis et al 2010). The QDAF pod splitter splits pods longitudinally into two halves. Pods need to be delivered to the machine individually in an endwise orientation. The machine has a continuous operation without complex mechanical manipulation of pods for splitting or splitting (Diczbalis et al 2010). Demonstrated capacity of the QDAF pod splitter is in the range of 2,400 to 4,000 pods / hour (20,000 to 30,000 pods/day). A wide range of pod sizes can be handled by the machine ranging in length from 100 to 275 mm with corresponding diameters of 50 to 100 mm without the need for adjustment. For optimum performance it is proposed that pods be graded into two sizes prior to splitting with the machine adjusted for each grade (Diczbalis et Al., 2010)

Figure 2.7  Picture showing the QDAF Pod Splitter Assembled and Ready for Testing Daintree Estates in July 2016

**2.8 COBRE cocoa pod splitter-Malaysia**

The COBRE machine was designed as a mechanical device to facilitate cocoa processing in Malaysia. COBRE is a machine for breaking cocoa pods to expose the cocoa beans and separating the beans from the split-open pods. It resolves the problems and drawbacks associated with manual pod breaking where the number of labours needed is reduced and the production efficiency and reliability is increased. The simple operation procedure does not require highly skilled workers and is safer to use. It is also capable of completing the process without causing any damage to the cocoa beans.

Fig. 2.8 The COBRE Cocoa pod splitter

# CHAPTER 3

## MATERIALS AND METHODS

### 3.1 Experimental site

The study was conducted in the cocoa farms of Atobiase town. It is a small town and also a suburb of Sawua found in the Ashanti Region of Ghana. The coordinates for the project site are 6°36'37.66"N and 1°31'44.76"W.

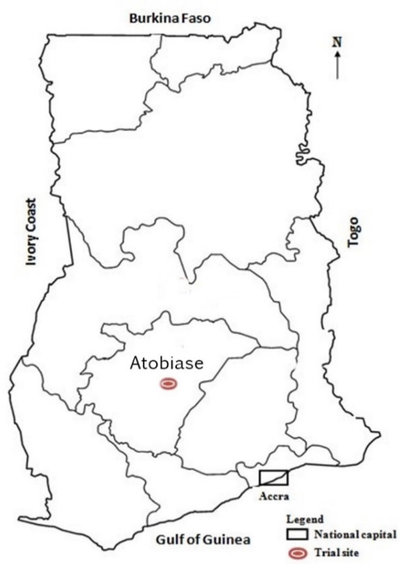



Figure 3.1 Map showing Atobiase town in Ashanti Region, Ghana

### 3.2. Cocoa Samples for the experiment

There were four varieties of cocoa, namely; criollo, forestero, trinitario and nacional. In this study, criollo, forestero and trinitario were used. Each variety had different physical and mechanical proper ties.


Figure 3.2 Picture showing varieties of cocoa used for the experiment

### 3.3 Materials

- Cocoa pod splitter
- Cutlass
- Plastic sampling bags (White)
- Cocoa pods
- Weighing scale
- Tape measure
- Stopwatch
- Vernier caliper
- Rubber sheets
- Permanent marker

Fig. 3.3.1 Cutlass

Fig. 3.3.2 Cocoa


Fig. 3.3.3 Avery Tensile testing machine

Fig. 3.3.4 Camry weighing scale

### 3.4 Description of the cocoa pod splitter prototype

The cocoa pod splitter has two main parts. The upper section and the lower section. The entire body of the pod splitter is fabricated from mild steel.

- Upper section: This part consists of an upper frame, a welded handle, axial blade and a central upper blade fixed internally to the upper frame.
- Lower section: This section consists of the pod chamber, lower blade, fixed internal supports and legs (support). They are welded together to form one unit. *The lock prevents the upper section from exceeding the maximum angle of 80 degrees (See picture of cocoa pod splitter in figure3.4).

#### 3.4.1 Upper section

1. Upper frame: This section has an area of 30cm×13cm and forms 80% of the upper section. It prevents the cocoa pods from slipping outside the machine. It also holds the upper blade and the handle.
2. Handle: The metallic pipe handle enables the farmer to exert force to cut the pod.it is 55cm in length with reference from the axial blade and has a diameter of 2.5cm.
3. Axial blade: The blade is 9.0cm×8.0cm in dimension. Its purpose is to cut the axial section of the cocoa pod. The axial part of the cocoa pod is cut to ease the removal of beans.
4. Central upper blade: Having a total length of 23.5cm, it lies centrally under the upper frame. It cuts the upper longitudinal section of the cocoa pod.

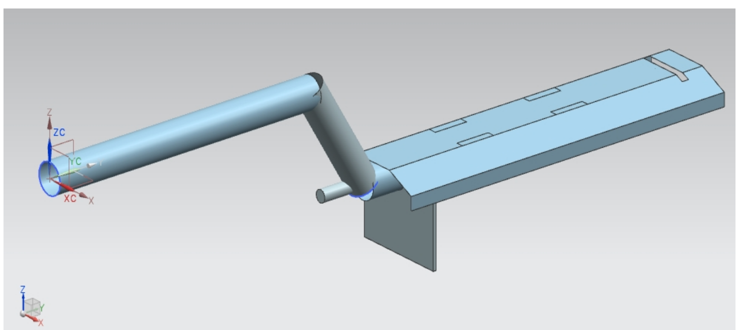
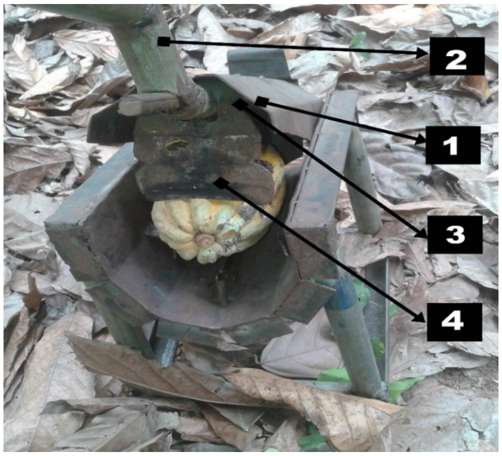


Fig. 3.4.1 3D CAD of the upper section of the cocoa pod splitter




**LEGEND**

1. Upper frame
2. Handle
3. Axial blades
4. Central upper blades

Fig. 3.4.2 The cocoa pod splitter prototype showing upper section

**3.4.2 Lower section**

1. Pod chamber: Allows room to contain all varieties of cocoa pods. Splitting is done in this section. It is semicircular and has a diameter of 17cm. 6 rectangular mild steel plate was welded to form the frontal view of this chamber. It contains the lower blade and the fixed internal supports.
2. Lower blade: it lies centrally in the pod chamber. With a length of 22.5cm and height of 2.5cm, it cuts the cocoa pod from the lower longitudinal end.
3. Fixed internal supports: To cancel all kinematic movements of the pod and to establish a stable cut to avoid bean damage, these supports disallows vertical movement of the cocoa pod inside the pod chamber.
4. Stand: It is welded together by four mild steel bars. It supports the machine.

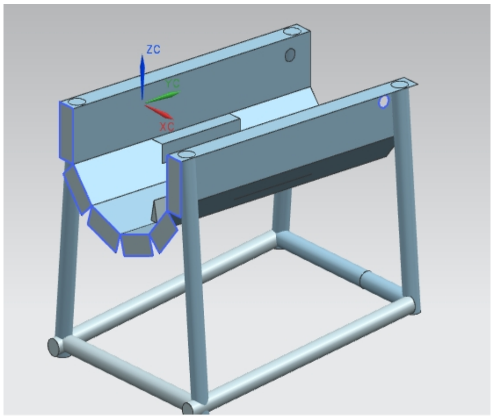
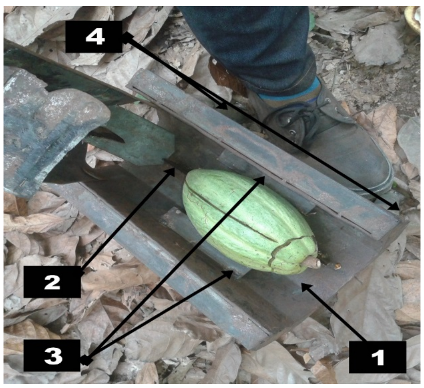



Fig. 3.4.3 3D CAD of the lower section of the pod splitter

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1. Pod Chamber
2. Lower blade
3. Fixed Internal supports
4. Legs (supports)

Fig. 3.4.4 Pictorial view showing lower section of the pod splitter

## 3.5 METHODOLOGY

### 3.5.1 Number of pods split in One hour

The Apparatus used for the experiment was stopwatch, cocoa pod splitter prototype and a machete. The aim of the experiment was to determine the splitting rate of pods. And also compare the splitting rate of the cocoa pod splitter and the machete. Hundred freshly harvested cocoa pods were gathered for both the pod splitter and the cutlass. The stopwatch was used to record the time. Rubber sheets were used to collect cocoa beans from the pod after splitting. Two farmers were required to for this experiment. One farmer operated the pod breaker whiles the other used the cutlass. The results were recorded within one hour period in sections of 5 minutes.

Precautions taken

- Each farmer was briefed about how the cocoa pod was operated before the experiment
- The farmer who used the pod splitter tested the pod splitter with a few samples of pods before the experiment commenced.
- The two farmers performed the operation under sitting conditions.

### 3.5.2 Determination of percentage beans damaged

The total number of pods split by the cocoa pod within the allocated hour was counted. The total number of beans in a pod was counted and recorded and the average was taken. All damaged beans by the splitting action of the pod splitter and the cutlass were also recorded.

A= No. of damaged beans

B= Total number of beans

The percentage of beans damaged can be calculated as;

$$Percentage\ beans\ damaged = \frac{A}{B} \times 100$$

### 3.5.3 Determination of force (F) required to split one pod

Cocoa pods are manually split by pressing on an upper handle in the cocoa pod splitter prototype. Force is needed to foster this action. The force needed to split a pod was determined experimentally using the Avery tensile testing machine. The experiment was conducted at the K.N.U.S.T Mechanical Laboratory and the apparatus used were Avery tensile test machine, 4 cocoa pods from three varieties, constant price computing scale and a cutlass. Fresh cocoa samples from the three varieties were prepared for the experiment and the masses of the pods were measured using the weighing balance and recorded. Each pod was placed on the table of the machine and the machine was engaged. A cutlass was placed at the upper section of the pod in contact with the upper arm of the machine. The knife was placed longitudinally with respect to the axis of the pod. The machine was stopped at the point when the pod was 40% splitting. The force was recorded and the average was taken.

The calibration factor of the Avery tensile testing machine, $Y = (11.216x+9.4882)$ kN

The variable $X$ = force derived from the machine (tonnes)

Therefore the value read from the machine was substituted in equation to derive the force in kN .

### 3.5. 4 Average weight of cocoa beans in a pod.

Thirty cocoa pod samples were selected, ten samples from each variety. The samples were then split using the cocoa pod splitter. The pods were placed in three separate plastic sheets which were labelled according to variety. The three plastic sheets with samples were weighed and recorded.

These were the precautions taken when performing the experiment.

- The dimensions (sizes) of the pods were determined and recorded
- Plastic sheets were clearly labelled with black permanent marker

Fig. 3.5 Farmer splitting cocoa pods with cutlass

**3.5.5 Time spent for loading, breaking and unloading of pods**

**Pod splitter**: During the splitting of the pods, the total times of loading of pods into the machine, the time required to break one pod and the time required to offload beans from the pod into the rubber sampling bags or pan were recorded using the stopwatch. For accuracy purposes, video recording of the entire experiment was done.

**Manual Splitting**: The method above was repeated for manual splitting. This process involved recording the time for the farmer to obtain a pod from the heap to his left hand ready for splitting, time for making a complete split to expose the beans and the time to remove the beans from the pod into rubber sampling bags or pan.

**3.6 Ergonomics**

A comparative study was done between siting positions and standing positions when a farmer used the cocoa pod splitter. At standing position, the number of pods split was recorded whiles same procedure was repeated for sitting position. These two positions were used for both the cocoa pod splitter and the cutlass. The height of the chair was 24cm above the ground level and the height of the pod splitter was 30cm.

### 3.7 Determination of the size of cocoa pods

The shape of the cocoa pod is ellipsoidal as shown in figure 3.9. Hence major diameter, minor diameter intermediate diameter and thickness of the pods were measured using the Vernier calliper. This was recorded using minimum and maximum values and the average taken.

A =Major diameter

B= Intermediate diameter

C=Minor diameter

T= Thickness

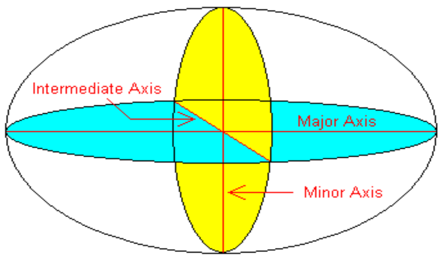


Fig. 3.6 Major, minor and intermediate diameter.

### 3.8 Data analysis

The data collected were analyzed using Microsoft Excel 2010. The data was used to plot graphs of

Values recorded from field tests carried out on the cocoa pod splitter and the cutlass.

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# CHAPTER FOUR

## RESULTS AND DISCUSSION

This chapter presents results from the field experiments conducted on the project site. The data are illustrated with tables and graphs.

### 4.1 Time spent on harvesting the pods.

For a total period of 2 hours, the farmer was able to collect 415 pods. Gathering of the pods exhausted most of the time. 212 cocoa pods were gathered. From this result, it can be estimated that one farmer can harvest and heap about 1,484 pods within eight hours with one hour of rest period.

### 4.2 Average weight of wet beans

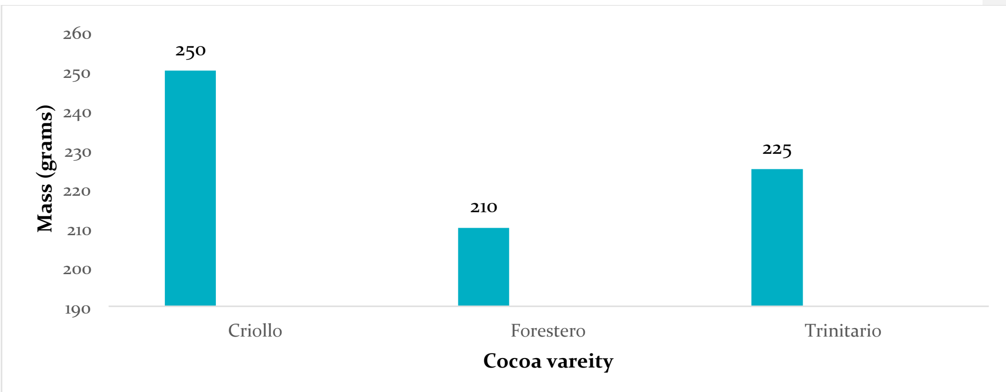


Figure 4.1 Variety of cocoa pods and their weights in grams beans

According to results shown in Figure 4.1, criollo had the largest average weight of 250 grams. Criollo pods are relatively larger and contains more wet beans (Adzimah & Esiam, 2010). Trinitario showed a significant average mass of 225 grams wet beans in a pod. Forestero had the least wet beans weight of 210 grams. The forestero variety had the least pod size and contained less number of beans. Therefore to project in greater net profit, a farmer must estimate planting greater percentage of criollo for high returns for sold dry beans.

### 4.3 Number of pods split in one hour

As shown in figure 4.2, the pod splitter prototype split 5 pods in the first minute whiles the cutlass did 10 pods. This result can be attributed to the fact that the farmer was new to the operation of the cocoa pod splitter prototype. Farmers in Ghana have been acclimatised to the use of cutlass for a long time (Akowuah, 2014). The pod splitter increased from 5 to 24 pods( 79.17% rise) in the next 4 minutes whiles the cutlass increased from 10 to 23 (56.52% rise). The maximum number of pods which was split within the hour period was 37 for pod splitter and 33 for cutlass within the 10th minute. The lowest was recorded from the 10th minute to the 15th where the pod splitter decreased from 33 to 19 pods (42.42 % decrease) whiles the cutlass decreased from 37 to 26 pods (29.73% decrease). The pod splitter had a uniform increase from the 20th minute to the 35th minute, rising from 19 to 26 pods whiles the cutlass had a shallow increase from the 25th minute to the 35th minute. The cutlass increased from 16 to 25 pods, a 64% rise. The 40th to the 50th minute saw a decrease in result for both the pod splitter and the cutlass, 23 to 13 pods (43.47% fall) and 21 to 19 (9.52% fall) respectively. Final recordings showed that the pod splitter broke 13 pods and cutlass did 19 pods in the final 5 minutes.

The least recorded number of split pods for the pod splitter was 5 and also the least recorded number of split pods for the cutlass was 10. From figure 4.2, the pod splitter showed the best consistent results as compared to the cutlass. Inconsistencies in the result of Figure 4.2 can be explained by lack of experience with respect to the usage of the pod splitter and fatigue.

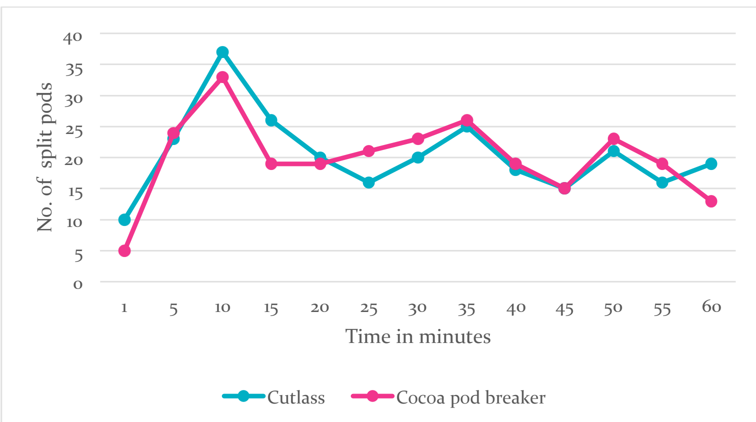


Figure 4.2 Comparing the No. of pods split in an hour

### 4.4 Percentage beans damaged

Results from table4.1 showed the pod splitter had a percentage bean damage of 0.97%. For less than 1% proves good fermentation for the stored beans and expected increase the quality of the stored beans (Adewumi & Fatusin, 2006). The tables also shows the result of percentage dean damaged for the cutlass which was 0.67%.

Table 4.1 Percentage bean damaged

| METHOD | No. of damaged beans (A) | Total No. of beans(B) | Percentage bean damaged $= \frac{A}{B} \times 100$ |
|---|---|---|---|
| Cocoa pod splitter | 11,655 | 113 | 0.97 |
| Cutlass | 11,970 | 76 | 0.63 |

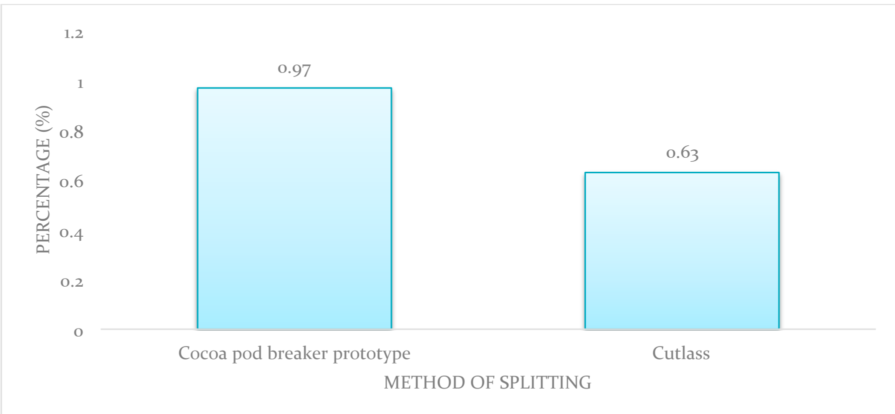


Figure 4.3 Results showing percentage beans damaged

### 4.5 Forces required to split one pod

Results from Table revealed that force of 10.217 kN was required to split one pod. After using the calibration factor of the machine, 0.065 tonnes was converted to 10.217 kN.

Table 4.2 Compressive force required to split one pod

| TYPE OF SPLITTING | TONNES (X) | FORCE (kN) |
|---|---|---|
| 1.Splitting | 0.065 | 10.217 |

### 4.6 Average time for loading, splitting and unloading of pods

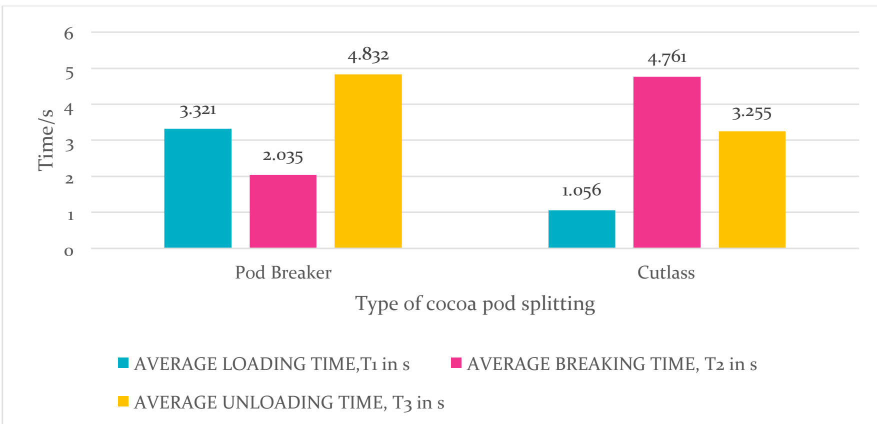


Figure 4.4 Graph of average loading, splitting and unloading

It is evident in figure 4.4 that the pod splitter used 3.32 seconds for loading pods into its chamber whiles the cutlass used 1.06 seconds (Figure 4.4).Therefore the cutlass was 31.93% faster in terms of loading pods be split. The probable explanation could be the easy access of the cutlass to heaped pods and faster hand picking of pods into the palm of the farmer. Moreover, time of loading for pod breaker was greater due to the time spent when pods had to be gently positioned in the chamber of the pod splitter. The time of positioning cocoa pods of all sizes in the chamber to line up with all the blades of the pod splitter also could have contributed to the increased time (Figure 4.4).

Results from figure indicates a decrease in time for splitting the pods using the cocoa pod splitter prototype compared with the cutlass. The pod splitter used an average of 2.04 seconds to split a pod whiles cutlass did 4.76 seconds. The pod splitter was 42.86 % faster than the cutlass in the breaking process. It could be explained that the pod splitter strikes the pod once to obtain a split whiles more time has to be spent when splitting a pod using the cutlass. Pods are struck not less than twice to split (Afoakwa, 2014).

The same figure shows total time for scooping beans out of the split pod (unloading time). The pod splitter used 4.83 seconds whiles the cutlass did 3.26 seconds. The delay in time for the pod breaker could be attributed to the time spent to remove the split pod from the chamber and an additional time spent on scooping beans out to the pods by hand. The farmer using the cutlass scooped out the beans from the pod quickly after splitting using the same cutlass.

In total the pod splitter used an average time of 10.19 seconds to split one pod whiles cutlass used 9.07 seconds. Assume a farmer spends eight hours for cutting with a period of one hour as a rest period , it could be estimated that when he uses the pod breaker, he could achieve 2,473 split pods within that period. An average of 45 wet beans are in a pod. Therefore an estimated total number beans within the 8 hour period is 111,285. Results from 4.2 shows that a pod contains 45 beans weighing 228.3 g. therefore Within the 8 hour period, 111,285 wets beans will yield 25,406.37 kg (2.54 tonnes).

### 4.7 Pod sizes

Results from figure 4.5 showed that the criollo pods had the largest mean diameter size of 190mm. Trinitario variety had 175mm whiles least recorded pod size was the forester variety. It had a mean major diameter of 132.5 mm. The same figure showed that criollo had the largest recorded pod thickness of 16mm. Triniatrio and forester had a common average thickness of 7mm. The thickness of the pods affected the results of time spent on splitting a pod. The greater the thickness, the greater the force to cut through.

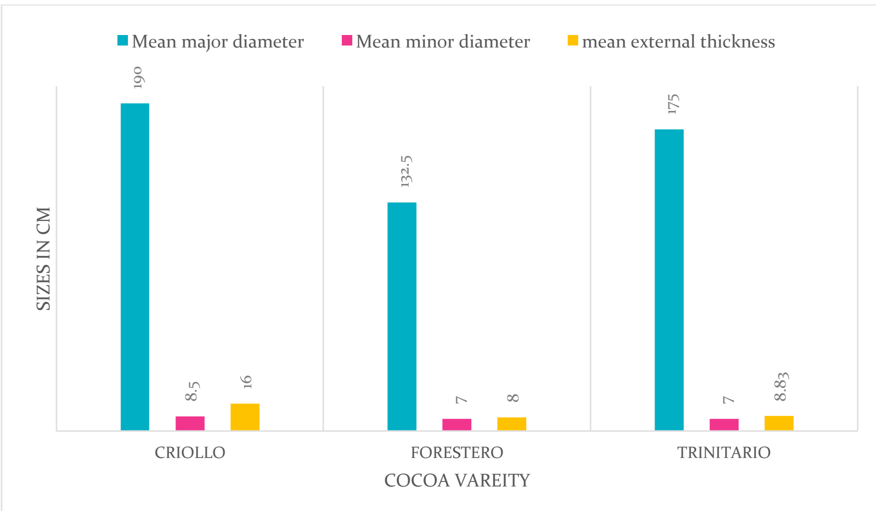


Figure 4.5 Graph showing pod sizes and thickness

CHAPTER 5

## CONCLUSION AND RECOMMENDATIONS

### 5.1 Conclusion

The evaluation of the cocoa pod splitter and the cutlass as methods for splitting cocoa pods resulted in the following conclusions:

1. Splitting rate (throughput) of the cocoa pod splitter was 259 pods/hr whereas the cutlass was 266 pods/hr.
2. The average time to crack one pod with the pod splitter was 10.19s whereas average total time for splitting one pod using the cutlass was 9.07 seconds.
3. Average weight of beans in a pod was 228.3 grams an average pod contains 45 beans.
4. The estimated force required to break a cocoa pod was 10.217 kN.
5. Percentage beans damaged by the pod splitter was 0.97% whereas the percentage beans damage by cutlass was 0.63%.

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**Comment [5]:** Include the average number of beans in a cocoa pod.

### 5.2 Recommendations

- It is recommended that two farmers operate the cocoa pod splitter. One farmer loads pods into the splitting chamber whiles the other holds the handle to break the pod.
- For the handle of the cocoa pod splitter, it is recommended that the length should be increased from 25cm to 35cm to increase the torque action of the handle.

- For the upper section of the pod splitter, it is recommended that the mass block on the upper section be increased to ease splitting action and increase splitting rate.
- It is also recommended that there should be multiple blades in the lower section of the pod splitter to enhance rigid position of the pod and also a reduction in the length of the axial blade and a new fixed axial blade.

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# APPENDICES

Table 4.3 Average weight of the beans in a pod

| Variety | Weight (g) |
|---|---|
| Criollo | 250 |
| Forestero | 210 |
| Trinitario | 225 |

Table 4.4 Comparing time of splitting pods in an hour period (Cutlass and Pod splitter)

| Time (Minutes) | No. of pods split using Manual (Cutlass) | No. of pods split using Pod splitter |
|---|---|---|
| **1** | 10 | 5 |
| **5** | 23 | 24 |
| **10** | 37 | 33 |
| **15** | 26 | 19 |
| **20** | 20 | 19 |
| **25** | 16 | 21 |
| **30** | 20 | 23 |

| | | |
|---|---|---|
| **35** | 25 | 26 |
| **40** | 18 | 19 |
| **45** | 15 | 15 |
| **50** | 21 | 23 |
| **55** | 16 | 19 |
| **60** | 19 | 13 |
| **Total** | 266 | 259 |

Table 4.5 Variation of loading of pods, splitting and unloading time of beans

| **METHOD OF SPLITTING** | **AVERAGE LOADING TIME,$T_1$ (s)** | **AVERAGE SPLITTING TIME, $T_2$ (s)** | **AVERAGE UNLOADING TIME, $T_3$ (s)** |
|---|---|---|---|
| Pod Splitter | 3.321 | 2.035 | 4.832 |
| Cutlass | 1.056 | 4.761 | 3.255 |

Table 4.6 Pod sizes

| **Size** | **Criollo** | | | | **Forestero** | | **Trinitario** | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameters | Mean Value | Min Value | Max Value | Mean value | Min Value | Max Value | Mean Value | Min Value | Max Value |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| (A),mm | 190.00 | 180.00 | 210.00 | 132.50 | 120.00 | 150.00 | 175.00 | 160.00 | 18.50 |
| (B),mm | 8.50 | 7.00 | 10.00 | 7.00 | 6.00 | 8.00 | 7.00 | 8.00 | 6.00 |
| (C), mm | 8.50 | 7.00 | 10.00 | 7.00 | 6.00 | 8.00 | 7.00 | 8.00 | 6.00 |
| (t), mm | 11.75 | 8.00 | 15.00 | 16.00 | 5.00 | 8.00 | 8.83 | 5.00 | 12.00 |

Plate 3.1 Pod samples split using the cocoa pod splitter

Plate 3.2 Pod samples split using cutlass

Plate 3.3 Axis of split after using the pod splitter

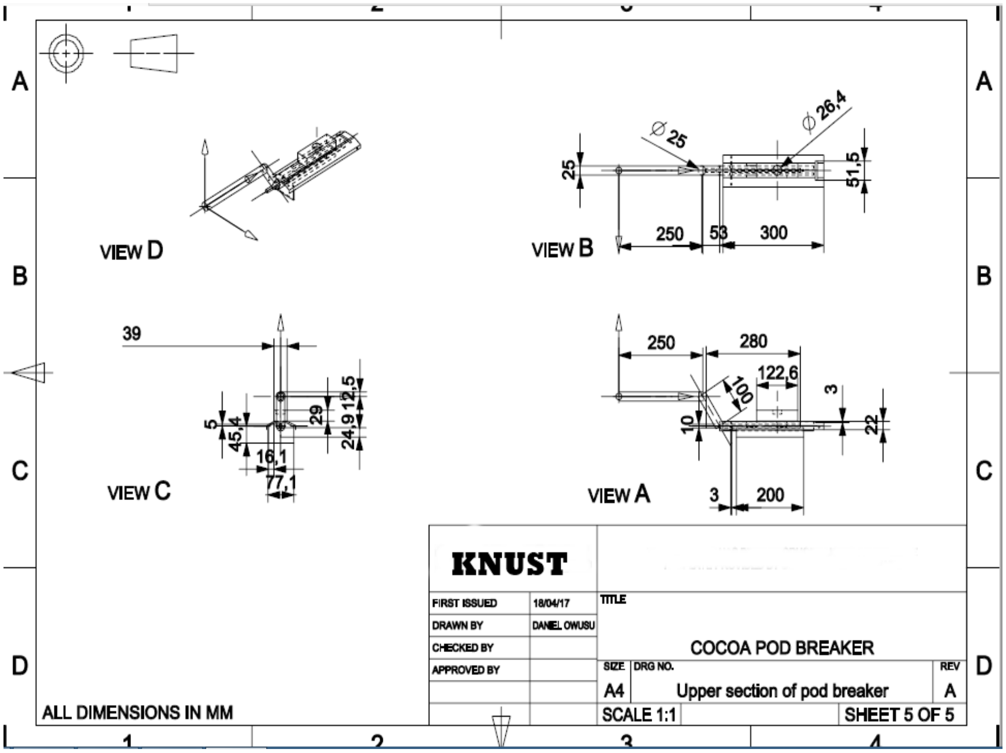


Plate 3.4 Upper section of the cocoa pod splitter (Engineering drawing)

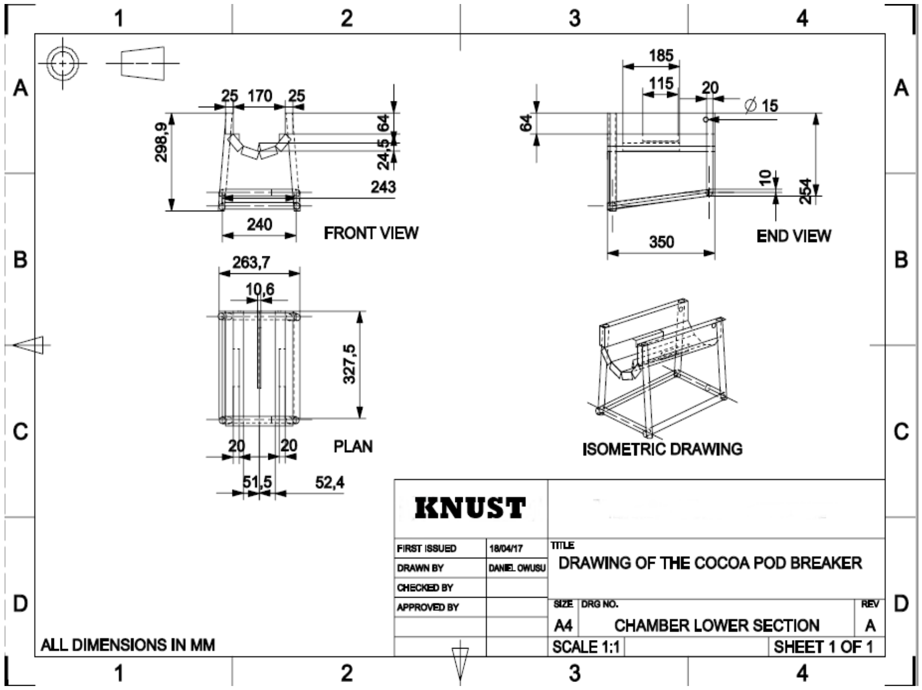


Plate 3.5 Engineering drawing of lower section of the cocoa pod splitter