KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

COLLEGE OF ENGINEERING

DEPARTMENT OF AGRICULTURAL ENGINEERING

PROJECT REPORT

ON

PERFORMANCE EVALUATION OF A CASSAVA PEELER

DISSERTATION SUBMITTED TO THE DEPARTMENT OF AGRICULTURAL ENGINEERING IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF A BSc. DEGREE IN AGRICULTURAL ENGINEERING

BY

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MAY, 2017

DECLARATION

I, Mensah Priscilla hereby declare that this submission is my own work towards the BSc Degree and that, no part to the best of my knowledge, contains material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledge has been made in the text.

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DEDICATION

I dedicate this project to God Almighty and my entire family.

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The study brought the researcher into contact with several people. Among them are lecturers, friends and well-wishers whose support, encouragement and advice helped in the completion of this work. It is in this connection that I wish to thank the Almighty God for his guidance and blessing. I am grateful to my supervisor, Prof. Ebenezer Mensah of the Agricultural and Biosystems Engineering Department and Dr. George Yaw Obeng of Technology Consultancy Centre (TCC), College of Engineering, Kwame Nkrumah University of Science and Technology, Kumasi whose guidance and support made it possible for the compilation of this thesis.

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ABSTRACT

Cassava is an important source of calories in sub-Saharan Africa. There are a lot of challenges associated with the peeling stage due to factors that include the irregularity in the shape, and sizes of the cassava tuber. Peeling by hand is tedious; the cost of labour is high, with losses of about 20 % on the average. A mechanical peeler has to be developed to ease the drudgery associated with manual peeling. It is essential to evaluate this mechanical peeler to assess its performance and suggest possible improvements. A cassava peeler has been produced by an association of farmers at *Fomena* in Adansi, Ghana. The parameters that were evaluated were the throughput capacity of peeler compared to the traditional way of peeling (peeling with knife), efficiency in terms of tuber losses of the peeler compared to traditional way of peeling and the safety level involved in using the knife to peel compared to the peeler. 5, 6 and 10 kg of cassava variety *Asiam* were used to evaluate the parameters. The throughput capacity ranged from 22.72 kg/h to 27.36 kg/h, the efficiency in terms of tuber losses for *Fomena* cassava peeler were 10.35% to 22.95%. Sixty-five percent (65%) of people were injured (cuts) when using the knife to peel and no injuries (cuts) have been recorded in using the *Fomena* cassava peeler.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to Study

Cassava (*Manihot esculenta* Crantz*)* is a long tuberous starchy root, high in carbohydrates. The root has a brown fibrous skin and snowy white interior flesh (Rodrigeuz, 2016). Cassava is mainly cultivated in the tropical parts of Africa, Asia, and Latin America. It is an important source of calories in sub-Saharan Africa (Haggblade *et al*, 2012).

Two hundred and fifty million metric tons of cassava is produced annually worldwide. It is estimated that African countries produce more than half of the total world production (Nisha, 2016). Nigeria, the largest producer of cassava in the world, has its annual production of fifty-two million metric tons (Nisha, 2016). The commercial potential of cassava is currently being underutilized in Ghana, the seventh producer of the crop in the world with fourteen million metric tons of fresh tubers being produced annually (Nisha, 2016). The root tuber is the main economically useful part of the cassava. In Ghana, the crop can be processed into *gari, fufu, konkonte* and it can also be eaten boiled. In Nigeria, it is also processed into *lafun, paki, pupuru*. The cassava peel is a good source of feed for animals especially livestock (sheep, goat, cattle) (Ilri, 2015).

Processing of cassava adds value to the cassava and extends its shelf life. The current cassava processing methods involve peeling, grating, dewatering and roasting. However, the present cassava processing methods are highly labour-intensive, time consuming and expensive. Manual processing for commercial purposes requires a minimum of four person-days to peel and wash, and twenty three person-days to prepare tons of flour. In contrast, the cost of processing cassava into flour could be approximately GH¢70.80/t (US$16/t) with mechanized processing (Kolawole *et al.,* 2010).

There have been many challenges faced in the processing of cassava. The absence of efficient equipment; appropriate processing technologies, machines and tools being some of these factors. Efficient equipment are not easily affordable and sometimes unavailable at the farm level. Presently, the equipment available is the grater, dryer, and dewatering machines. Some success was recorded with graters and some dewatering tools. The dewatering tools work in batches while factories need a continuously-working machine for better production. Almost all the processing of cassava requires the roots to be peeled at one stage or another, and no efficient peeler is on the market (Kolawole *et al*., 2010).

Peeling is the first operation performed after the cassava tubers have been harvested. There are challenges associated with the peeling method, due to factors that include the irregularity in the shape, and sizes of the cassava tuber. There are also differences in the properties of the cassava peel, which varies in thickness, texture and strength of adhesion to the root flesh. Attempts have been made by engineers, including the National Centre for Agricultural Mechanizations (NCAM), who developed the abrasive peeling machine (Agbetoye, 1999). Perhaps the most successful one is the motorized cassava peeler which was exhibited and demonstrated by the Federal University of Technology, Akure, (FUTA), Nigeria. The peeler was awarded a prize for outstanding innovative design. With the development of a functional peeling machine, the mechanization of cassava processing will be further enhanced. Other contributions have also been reported (Ogunlowo, 2003; Kolawole *et al*., 2010). As the years passed by, several developments were made to devise an effective mechanized peeler. Again, the Federal University of Technology, Akure, (FUTA), Nigeria together with the Bells University of Technology, Ota, Nigeria in 2012 compared and analyzed the performance of three cassava peelers which yielded good results (Olukunle and Jimoh, 2012). They realized the need for an effective cassava peeler. The effectiveness is low and not suitable for commercial purpose. More research efforts have been devoted to the development of peeling machines by many research institutes and individual researchers. Currently, some peeling machines have been developed and these include: continuous process cassava-peeling machine (Odigboh, 1976). This process has very high efficiency (95%) and non-waste of root flesh, although the machine is manually operated and there is a need for re-peeling of tubers. The model II cassava peeler prototype, which possesses bolls of metals as abrasive material have also been developed (Odigboh, 1983). The efficiency is comparatively low (64%) and there is a need for modification. Rotary cassava tuber peeling machine was designed and aimed at improving the effectiveness and peeling rate of cassava but it reported very high tuber losses (Ohwovoriole *et al*., 1988). Single and double gang models A and B cassava peeling machine, developed at FUTA also resulted in the production of commercial models (Agbetoye *et al*., 2006). This was effective but not suitable in peeling tubers with small sizes. FUTA cassava peeling machine (self-fed), model C, which is an improved design with capacity of 10 tons per day (Olukunle *et al*., 2006) have also been developed. The operation of this machine is tedious and splitting of useful flesh. NCAM improved cassava peeling tool was developed for peeling cassava tuber and recorded 35 kg/h throughput capacity, 99% and 0.4% capacity peeling efficiency and tuber losses respectively (Ariavie and Ohwovoriole, 2002). This system is manually operated. Several other cassava processing had been commercially mechanized successfully. However, cassava peeling remains a serious global challenge to processors of cassava, especially on large scale processing. Today, because of low efficiencies and losses, cassava peeling is still mainly carried out manually. This situation has made it necessary to provide a good, efficient and time conserving machine in the reduction of energy expended in carrying out manual peeling as well as the time taken in peeling."

In spite of these several improvements in the cassava peeling process, however, Ghana lacks the availability of mechanized peelers to boost and aid in the processing of the crop. This have led to the wastage of time and intensive labour to manually carry out peeling. In view of these developments, this project is aimed at evaluating a mechanized cassava peeler to improve productivity, reduce drudgery, labour and the time used in manually peeling cassava in Ghana.

1.2 Problem Statement

Peeling by hand is tedious, the cost of labour is high, with losses about 20 % on the average. In consequence, the output is low and limits the processing capacity.

The absence of an effective cassava peeler is one of the major problems in the cassava processing industry in Ghana. Tuber losses in this case are high and since majority of the cassava cannot be peeled in time for further processing, they become more susceptible to spoilage. Fresh cassava roots cannot be stored for long because they got rotten within 3-4 days after harvest. They are bulky with about 70% moisture content, and therefore transportation of the tubers to urban markets is difficult and expensive (Asare *et al., 2015*). Peels and other parts mixed with the peels, generated at the processing centres ranged from 25-32% of total cassava. It is said a total 3.6 million tonnes of cassava peel wastes during the peeling process were generated annually in Ghana. The peels represents about two third of cassava waste and it has been noted that about 200,000 tonnes of cassava could be saved through more efficient peeling which translates into potential saving of almost 37 million dollars. Currently, less than 10% of the peels generated at the processing level are utilized for animal feed (GNA, 2013).

To solve this situation of losses, drudgery, labour and prolonged processing, efficient means of mechanized peeling is required.

1.3. Justification

Peeling is the first operation performed after the cassava tubers have been harvested and cleaned from debris. There are a lot of challenges associated with the peeling stage due to factors that include the irregularity in the shape, and sizes of the cassava tuber (Agbetoye, 1999). Peeling by hand is tedious, the cost of labour is high, with losses of about 20 % on the average. A mechanical peeler has been developed to ease the drudgery associated with manual peeling. It is essential to evaluate this mechanical peeler to assess its efficacy, effectiveness and efficiency and suggest possible improvements.

1.4. Main Objective

The main objective of this study is to evaluate the *Fomena* cassava peeler.

1.5 Specific Objectives

The specific objectives of this project are to:

- Compare the throughput capacity of the *Fomena* cassava peeler to peeling with the knife.
- Compare the efficiency in terms of tuber losses of the *Fomena* cassava peeler to peeling with the knife.
- Compare the safety in terms of cuts of the *Fomena* cassava peeler to peeling with the knife.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1. Background of Study

2.1.1 Cassava Tuber

Cassava (*Manihot esculenta* Crantz*)* is a long starchy root, high in carbohydrates. Cassava root is a perennial plant that grows best under tropical, moist, fertile, and well-drained soils. Cassava roots develop radially around the base of the plant forming five to ten tubers per plant as shown in Figure.1. The mature tubers can be 5–10 cm in diameter and 15–30 cm long when harvested 9 – 12 months after planting. The tubers differ in weight, size and shape and are usually cylindrical and tapered. They may be white, brown or reddish in colour depending on the variety. It is mainly cultivated in the tropical parts of Africa, Asia, and Latin America. It is an important source of calories in sub-Saharan Africa (Haggblade *et al*, 2012).

Plate 2.1: Freshly harvested cassava plant with several tubers.

The tuber constitutes the main storage region and is surrounded by a thin cambium layer covered by the peel, which consists of a corky periderm on the outside and cortex on the inside (Adetan *et al*., 2003). The outer periderm may be thick and rough or thin and smooth with surfaces varying considerably in colour from pink to grey (Igbeka, 1984). The three regions of the cassava tuber as reported by Abdulkadir (2012) are as follows:

(i) The periderm: - This is the uttermost layer of the tuber, the peel (rind). It consists mainly of dead cells, which covers the surface of the tuber.

(ii) The cortex: - This lies below the periderm, usually about 1.5 – 2.5 mm thick and white in colour.

(iii) The central portion of the tuber: - This makes up the greater bulk of the cassava tuber and is composed essentially of stored starch and always white in colour.

2.1.2 Processing of Cassava

The traditional cassava processing methods used in Africa probably originated from tropical America, particularly north-eastern Brazil and may have been adapted from indigenous techniques for processing yams (Jones 1959). The processing methods include; peeling, boiling, steaming, slicing, grating, soaking or seeping, fermenting, pounding, roasting, pressing, drying, and milling.

According to Oriola and Raji (2013) processing of cassava into finished or semi-finished products often involves all or some of the following operations, depending on the desired end-product: peeling, washing, grating/chipping, dewatering, fermentation, pulverizing, sieving, pelletizing, and drying/frying (Kolawole *et al*., 2010; Jimoh *et al*., 2014). Products from cassava includes primary products such as *gari*, *fufu*, flour (for baking chips) and pellets (for producing starch, glucose, and starch) produced from the roots while the leaves and stems are used as animal feeds and concentrates. Some of the secondary products are ethanol, monosodium glutamate, glucose, starch, adhesives, noodles etc. Figure 2.1 portrays a schematic diagram depicting the processing of cassava storage root into different products.

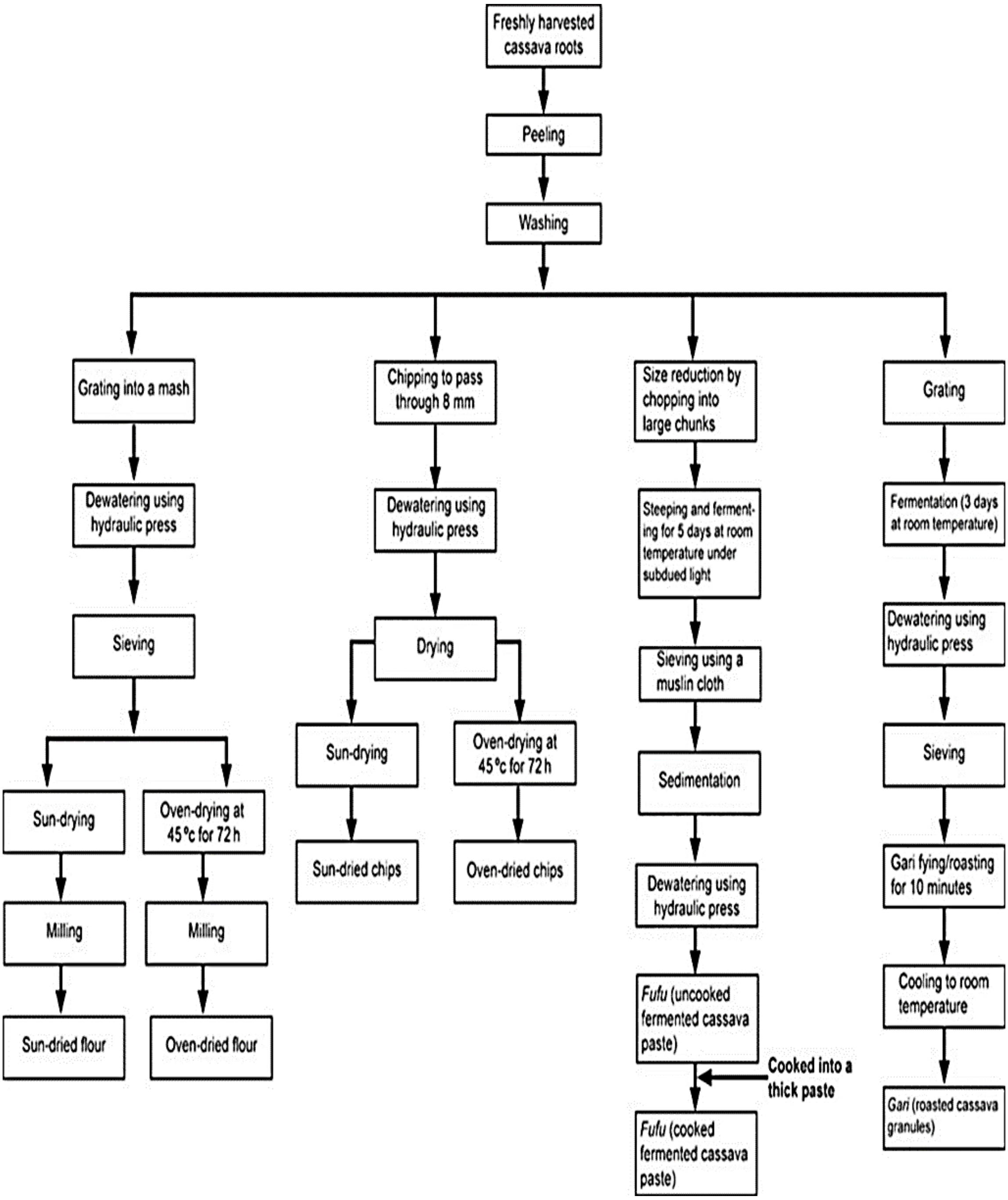

Figure 2.1: Schematic diagram of processing cassava storage root into different products

2.2 Peeling

Peeling is the first operation performed after the cassava tubers have been harvested and cleaned from debris. Cassava peeling has been practiced as far back as when cassava came into existence, but the instrument for peeling has evolved from stones and wooden flight into simple household knives.

Cassava must be peeled to remove the inedible outer parts of the root consisting of the corky periderm and the cortex (Adetan *et al*., 2003). These are known to contain most of the toxic cyanogenic glucosides, the ratio of glucosides compared to the starchy flesh varying between 5-10: 1. Hence, for a root composed of 15% peel with a total cyanide content of 950 mg/kg (fresh weight basis) and 35 mg/kg in the flesh, 83% of the total cyanide is removed by peeling (Bencini, 1991).

2.2.1 Concept of Peeling

A cross-sectional section of the tuber (Fig. 2.2) shows that it consists of a central core called the parenchyma or the pith. This is surrounded by the starchy flesh which forms the bulk of the tuber and the main storage region. Covering the cambium layer is the tuber peel which consists of a corky periderm on the outside and cortex on the inside. The cortical region is usually white in colour and varies in thickness between 1.2 and 4.15 mm (Adetan *et al.,* 2003). Unlike other root crops, the peel of fresh cassava roots is quite distinct from, and adheres relatively loosely to, the root flesh because of the thin cambium layer separating them. This peel breaks loose from the flesh when the tuber is subjected to sufficient compression.

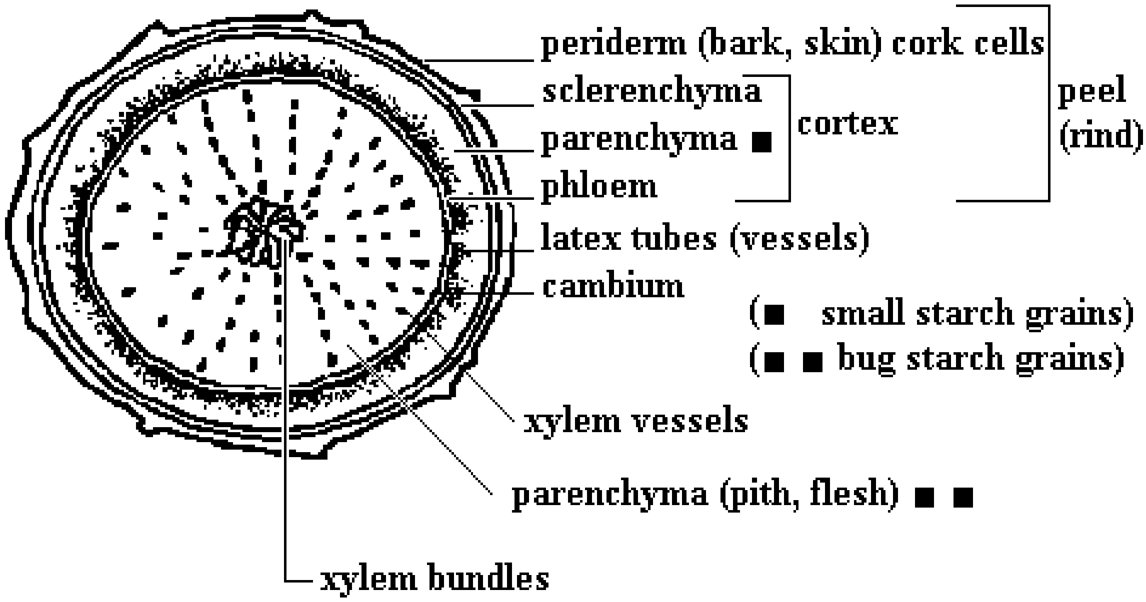

Figure 2.2: Cross sectional view of cassava tuber

2.3 Methods of Peeling

2.3.1 Method of Peeling

The methods of peeling includes;

- Manual peeling (traditional method)
- Chemical peeling
- Steam peeling
- Mechanical (machine) peeling

2.3.1.1 Manual Peeling

Peeling is usually done manually using a knife. In varieties which are easy to peel, the peel is slit along the length of one side of the root and the knife-blade and fingers are used to roll back the peels from the fleshy portion of the root. With varieties which are difficult to peel, the two layers of peels are whittled with a knife in a motion reminiscent of sharpening a pencil. This operation is less satisfactory as it usually results in the removal of some flesh along with the peels and some of the peels are left on the root.

The manual way of peeling of cassava tubers with knives are normally done by women and teenage girls (Ohwovoriele *et al*., 1988). The rate could be as high as 350 kg/day of 8 hour/person (Igbeka *et al.,* 1992). Manual processing for commercial purposes requires a minimum of four person-days to peel and wash, and twenty three person-days to prepare a tons of flour (Kolawole *et al.*, 2010). Hand peeling is time consuming and labour intensive which leads to low productivity. The losses involve in the method are high and this method is less efficient.

The National Centre for Agricultural Mechanizations (NCAM) has developed a manual tool (Plate 2.3) with output capacity of 35 – 40 kg/h, peeling efficiency of 99 % and tuber loss of less than 0.4 %. International Institute of Tropical Agriculture (IITA) has also produced a knife-like manual tool (Plate 2.4) with capacity of less than 30 kg/h with minimum tuber loss

Plate 2.2: Manual method of peeling cassava tubers with knives

Plate 2.3: NCAM cassava peeling tool **Plate 2.4:** IITA knife-like cassava peeling tool

2.3.1.2 Chemical Peeling

This process is normally carried out using a hot solution of sodium hydroxide (NaOH), a base and then dilute hydrochloric acid (HCL), an acid which neutralizes the effects of the base (Ebegbulem *et al.* 2013). This is to loosen the cassava peels. This method of peeling is well developed for peeling sweet potatoes in processing industries (Adetan *et al*., 2006).

Though the losses involved in this method is less but the major reason why this method will not be suitable for cassava peeling is that a higher temperature and more root immersion time will be required for cassava roots because they have peels that are tougher than those of potatoes(Jimoh and Olukunle, 2012). This will result in the formation of an objectionable heat ring (dark colour) on the surface of the useful root flesh and the gelatinization of starch in the cassava root (Igbeka, 1985). Such roots are obviously unsuitable for *gari* or industrial starch production.

2.3.1.3 Steam Peeling

In this method the cassava tubers are subjected to high steam pressure over a short period of time to avoid partial cooking (or eventual cooking). Timing the steam is a major problem with this method. Steaming beyond the time required will lead to cooking the tuber. Also, because of the shape of the cassava tuber, there will be unequal distribution of heat. By thermal softening the firmness, adhesiveness and springiness of the tuber is affected (Sajeev *et al*., 2009).

Despite the above demerits, the steaming method has a favourable peeling effect without causing any appreciable loss in the mass of the cassava tubers (Abdullahi *et al.,* 2010).

2.3.1.4 Mechanical (Machine) Peeling

As the name implies, the mechanical peeling methods involves the use of machines for peeling. This peeling method deals with the challenges associated with the manual, chemical and steaming methods stated above. It is therefore an improved method when compared to the other methods of peeling. However, this method of peeling has its own challenges. The irregularity in the shapes, sizes, thickness, texture and strength of adhesion to the root flesh (Physical and Mechanical Properties) underutilises the machines since roots of different shapes and sizes cannot be peeled together at the same time. Some of the physical and mechanical characteristics of the cassava root that poses as a challenge to the mechanical peeling process are given in Table2.1 below.

Table 2.1: Physical and mechanical properties of cassava root that poses a challenge to mechanical peeling process.

PHYSICAL PROPERTIES	MECHANICAL PROPERTIES
Roundness / shape of tuber	Poisson ratio
Tuber weight	Rolling resistance
Tuber diameter	Shear stress
Tuber length	Peeling stress
Peel thickness	Cutting force
Peel weight	Rupture force
Aspect ratio	Strength properties
Coefficient of friction tuber on hopper/chamber/peeling element	Penetration force
Aspect of repose	Breaking strength
Surface taper of angle of tuber	Breaking strength
Moisture content	Breaking deformation

The quest for developing effective and efficient peeling mechanisms started in the early 70s. The journey was pioneered by University of Nigeria, Nsukka, University of Ibadan and PRODA (Project Development Agency) Enugu, Nigeria. The journey further witnessed the contributions of The National Centre for Agricultural Mechanization (NCAM) and International Institute of Tropical Agriculture (IITA). These institutions invented knives suitable for the peeling of cassava root to replace the common/ household knives. The success chalked by these institutions served as a catalyst for the inventions of improved machines for the peeling of cassava to meet commercial purposes (Odigboh, 1976). Some of the machines invented for the peeling of cassava root include the following; the Double and single gang peelers, Double action /self-fed cassava peeling machine, Knife-edged automated cassava peeling machine type 2, An automated peeling cassava machine, Fixed outer peeling drum peeler machine, Abrasive rotary drum peeler, Factaroy (Company name) cassava peeling machine, etc.

In 2005, International Institute of Tropical Agriculture (IITA) and Federal University of Technology, Akura (FUTA) collaborated to develop the single and double gang hand-fed peeling machine which peels by using a rotary brush as reported by Agbetoye *et al*., (2006). Its efficiency was said to be less than 80 % and useful flesh waste of more than 8% with unsatisfactory output and unacceptable capacity of 10.4 kg/hr. Olukunle *et al*., (2010) emphasized that the peeling machine's output per day was dependent, among other things, on the variety and stage of maturity (age) of the roots. Plate 2.5 and Plate 2.6 shows the single gang cassava peeling machine and double gang cassava peeling machine respectively.

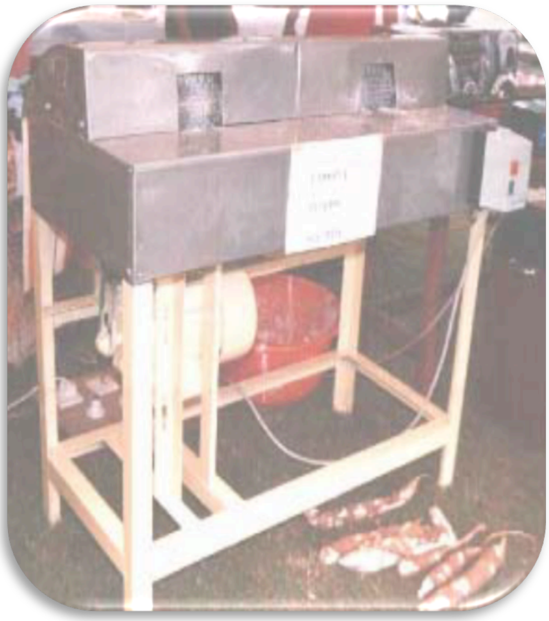

Plate 2.5: Single gang cassava peeling machine **Plate2.6:** Double gang cassava peeler

The double action/self-fed cassava peeling machine by Olukunle *et al*. (2010) (Plate 2.7) requires sizing the tubers to not less than 10cm before peeling. Machine capacity was reported to be 410 kg/h, peeling efficiency, 77 % and tuber loss, 8 %. Auger and brush speeds also have influence on the performance of the peeler but have been synchronized that a predetermined gear ratio between them is maintained by throttling the engine.

Plate 2.7: Double action self-fed cassava peeling machine

Olukunle and Jimoh (2012) evaluated the performance of three mechanised cassava peeling machines. The type 1 knife-edge automated cassava peeling machine with a special-made peeling tool (rotating cylindrical drum with auger-like peeling blades) is powered by a 1.0 hp electric motor. The machine and the peeling tool are shown in Plate 2.8 and Figure 2.3.

Plate 2.8: Knife-edged automated cassava peeling machine-type1.

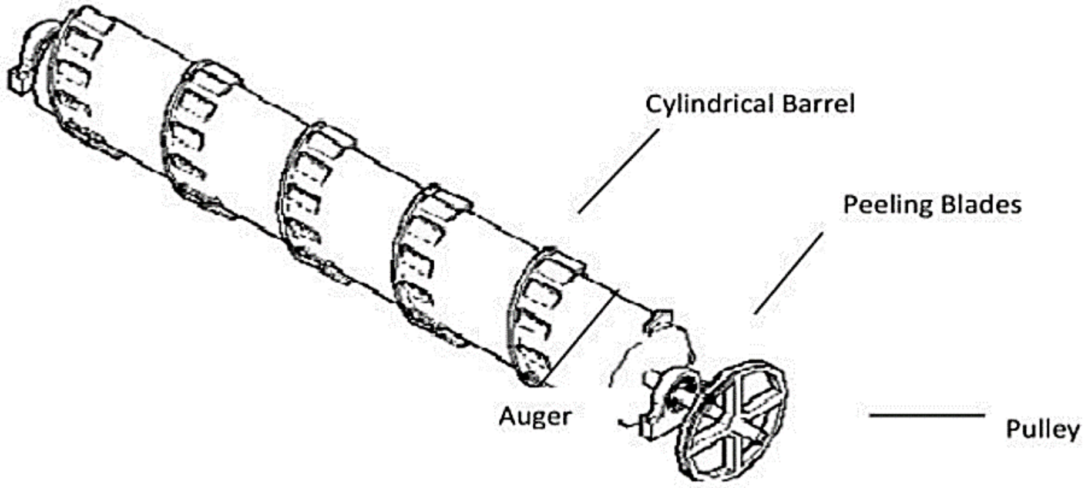

Figure 2.3: The peeling tool

The type 2 is a modified version of type 1 in terms of longer cutting blades, shorter peeling chamber and larger cylindrical barrel.

Plate 2.9: Knife-edged cassava peeling machine-type 2

The third type is the abrasive-tooled cassava peeling machine which has three rollers that make up its peeling assembly. The perforated surfaces of the rollers give the abrasive action and operate at about 7.0 rpm to achieve good level of peeling.

Plate 2.10: Abrasive-tooled cassava peeling machine

Olukunle and Jimoh (2012) reported that the peeling time decreased with the increase in speed for both types 1 and 2 peelers (24.03 – 3.57 s) but generally increased with increase in speed for the abrasive peeler (38.06 – 52.00 s) because of the low speed of the auger and the delivery mechanism. It was analysed that, the types 1 and 2, peeling efficiency and tuber losses are high while peel retention and peeling time are low. The abrasive type gave high peel retention, peeling time and tuber losses with low peeling efficiency for all sizes of tubers.

Olukunle and Akinnuli, (2013) reported a powerful automated cassava peeler which consists of the cutting, metering and the peeling unit in the peeling chamber (Plate 2.11 and Plate 2.12). The machine uses impact rotary motion on the tubers through shear/or abrasion effect required for the peeling process, with an output capacity of 500 – 583 kg/h. It was observed that its peeling efficiency decreased as its conveyer's speed increased. Also, it was observed that increased peel thickness (0.1 – 5 mm) decreased the peeling efficiency from 88.73 – 53.40 %. Meanwhile, as the moisture content of the tubers increased (45 – 70 %), the peeling efficiency also increased (31.11 – 48.40 %).

Plate 2.11: Side views of an automated cassava peeling machine

Plate 2.12: Front views of an automated cassava peeling machine

These peeling machines have not been able to produce the desired results as expected. There are still high root losses during peeling. So far, all the machines that have been invented have the problem of peeling off unacceptable percentage of useful flesh (IITA, 2006, Jimoh *et al*, . 2014). Peeling with some of these machines is time consuming and expensive because they are manually operated. Again, the absence of sufficient data on engineering properties of cassava root has also been a factor hindering the successful design of efficient cassava root peeling machine (Nwagugu & Okonkwo, 2009).

Although this method of peeling has registered a lot of successes in terms of the reduction of flesh losses during peeling and increased the quantity of roots peeled at a time, the above discussion has clearly revealed the demerits of the mechanical peeling process which even makes it seems like the mechanical method of peeling have failed to address the challenges associated with the other methods of peeling. It is in this vain that more research efforts have been devoted to the development of peeling machines by many research institutes and individual researchers including this work for an improved design to serve as a base for commercial production (Kawano, 2000; Hillocks, 2002).

CHAPTER THREE

3.0 MATERIALS AND METHODS

For the purpose of this study, a local variety of cassava, *Asiam* was used to evaluate the Fomena cassava peeler and the traditional method of peeling. This variety was selected because it is the main variety used by the women at the *Susanso gari* factory. The cassava was purchased from *Susanso* in Kumasi, Ashanti Region of Ghana. The work was carried out at the Food and Post-Harvest Laboratory of the Department of Agricultural Engineering and *Susanso*-Kumasi.

3.1 Material (Equipment / Tools) Used

- Electronic weighing balance
- Knife
- Bowls
- Cassava (*Asiam*)
- Digital Vernier calliper
- *Fomena* cassava peeler
- A pair of gloves

3.1.1 Description of Cassava (*Asiam*) Used for the Experiment

The root crop, cassava was used to conduct the experiment for both peeling with knife and the *Fomena* peeler. Table 1 below shows the average dimension and age of the variety used for the experiment.

Table 1: The average dimension and age of variety used for the experiment.

Variety	Average Length, (mm)	Average Mass , (kg)	Average age,(Months)
Asiam	290.2	1.325	14-16

3.1.3 Description of the *Fomena* Cassava Peeler

The *Fomena* cassava peeler (**Plate 3.1**) was produced by an association of farmers at *Fomena* in Adansi, Ghana. This mechanised cassava peeler is made of mild steel plate. The equipment has a vertical height of 619 mm. Four (4) stands; 610 mm long made of 5.08 mm angle iron which is supported at the top by a rectangular frame of angle iron of 240 mm × 300mm. A 1.7 mm rectangular mild steel cutting edge is bolted to the top part and held in position by a 35 mm galvanised pipe. Within the frame, is a mounted sloppy plate (peel tray) of 10 mm thickness which has been inclined at angle of 12.7°and held in place by a T-shape 35 mm galvanised pipe. This plate is used to collect peels of the cassava. The stands are also supported at the base by 50.8 mm angle irons.

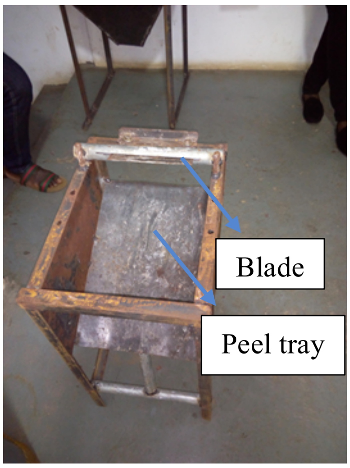

Plate 3.1: *Fomena* cassava peeler

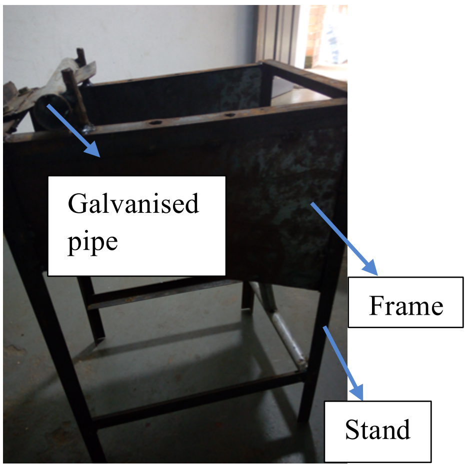

Plate 3.2: Side view of the *Fomena* Peeler

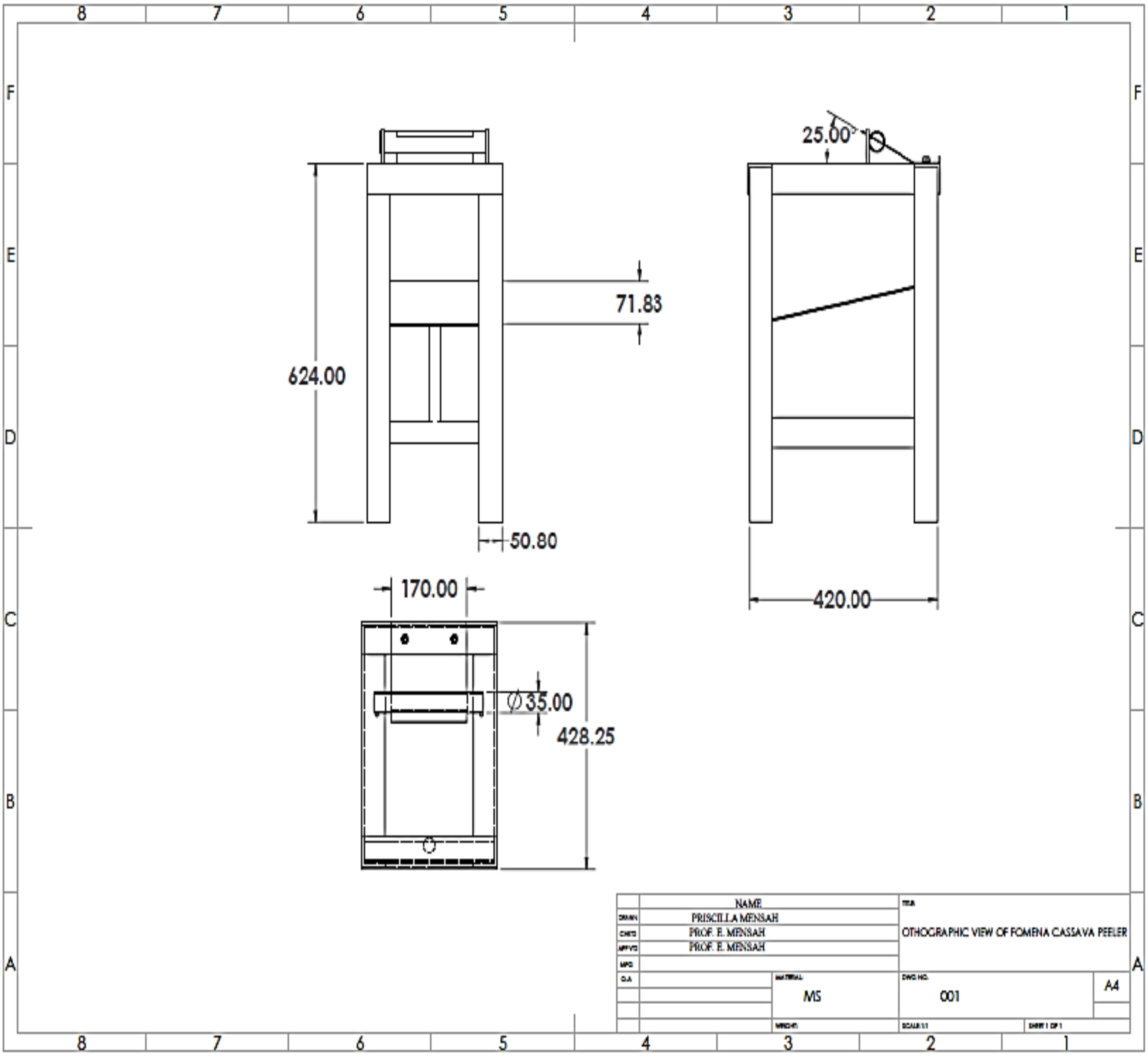

Figure 3.1: Orthographic view of *Fomena* cassava peeler

3.2.4 Method of Operating the Equipment (*Formena* Cassava Peeler).

- Harvested cassava roots were first cleaned of debris of soil.

- The outer layer of the cassava roots (cortex and the periderm) were removed carefully by abrasion and turning on the surface of the cutting edge.

- The ends of the cassava were trimmed with the aid of a knife manually

3.2 Experimental Procedure for Testing of the *Fomena* Cassava Peeler.

3.2.1 Physical Properties of the Cassava Root

A. Moisture Content Determination

The moisture content was determined based on wet basis (W_{wb}) since it's mostly used for agricultural produce.

PROCEDURE

Different masses were obtained from five (5) different roots which ranged from 24.07-47.07 kg were used. The cassava flesh was then further sliced into small sizes and put in metallic containers to facilitate oven drying at 105ºC for 24 hours. It was then weighed after drying. The moisture was then determined on wet basis. The formula was used to determine the moisture content

$$\text{Moisture content of cassava flesh } (W_{wb}) = \frac{Mass\ of\ water\ of\ the\ cassava\ flesh}{Total\ mass\ of\ cassava\ flesh} \times 100$$

B. Peel Thickness Determination

The diameters of five (5) cassava roots at its proximal end, middle section and its distal end were determined using a Vernier calliper for both before peeling and after peeling. It was then recorded as D_A (before peeling) and D_B (after peeling) respectively. The difference between each diameter section thus before and after peeling for each section were recorded as $\boldsymbol{D_1}$ $\boldsymbol{D_2}$ and $\boldsymbol{D_3}$. The averages for the differences of each section was computed and denoted by $\boldsymbol{P_P}$, $\boldsymbol{P_M}$ and $\boldsymbol{P_D}$ for the proximal, mid and distal sections respectively. The averages denotes the peel thickness for each section (*Oriola* and *Raji*, 2013).

Proximal Thickness, $\boldsymbol{P_P}$ (mm) = Diameter before Peeling (D_A) – Diameter after Peeling (D_B)

Mid-Section Thickness, $\boldsymbol{P_M}$ (mm) =Diameter before Peeling (D_A) – Diameter after Peeling (D_B)

Distal Thickness, $\boldsymbol{P_D}$ (mm) = Diameter before Peeling (D_A) – Diameter after Peeling (D_B)

Plate 3.3: Determination of diameter before peeling

Plate 3.5: Determination of diameter after peeling

3.3 Traditional Peeling (Longitudinal Peeling)

For the Traditional peeling, different masses 5 kg, 6 kg, and 10 kg samples of cassava were weighed. These different masses were chosen to examine whether the quantity to be peeled affects the efficiency in terms of time spent during peeling and also whether there is biasness during peeling depending on the quantity. Adult women who were already peeling at the premises were randomly selected and consent sought to partake in the experiment. These women were Dzifa Sedezor, Patricia Awulaweh and Jennifer Adoboe. The samples were then peeled using the kitchen knife to remove the outer layer of the cassava thus the cortex and the periderm. Time taken in peeling was monitored and recorded.

PROCEDURE FOR PEELING

- The cassava root was cleaned of debris.

- The cleaned roots were then weighed (5 kg, 6 kg, 10 kg) before peeling by using an electronic weighing balance.
- For each mass, five replications were undertaken.
- A stop watch was used to time the peeling duration.
- The mass of peeled cassava was then taken and the mass of the peels was determined (initial cassava mass – peeled cassava mass)

Plate 3.7: Initial weighing of the cassava

Plate 3.8: Traditional peeling

Plate 3.9: Traditional peeling **Plate 3.10:** Peeled cassava after traditional peeling

3.2.3 Peeling with the *Fomena* Cassava Peeler

5 kg, 6 kg and 10 kg samples were weighed. The ends of each samples were taken off and weighed again. The samples were then peeled using the *Fomena* cassava peeler. Time taken for efficient peeling was monitored and recorded. The peeled cassava samples were weighed and recorded. The whole procedure was repeated five times for each sample (5 kg, 6 kg and 10 kg).

PROCEDURE

- The cassava roots were cleaned of debris.
- The cleaned roots was then weighed (5 kg, 6 kg, 10 kg) using an electronic weighing balance before peeling.
- The ends of the cassava roots for each sample were taken off and weighed again.
- For each mass, five replications was undertaken by using the *Fomena* cassava peeler to peel.
- Cassava roots were peeled at the cutting blade one by one manually and the results were evaluated.
- A stop watch was used to time the peeling duration for each replication.
- The mass of peeled cassava was then taken and also the mass of the peels was also taken.

Plate 3.11: Peeling with the Fomena cassava peeler

Plate 3.12: Peeling with the Fomena cassava peeler

Plate 3.13: Initial weighing of the cassava

Plate 3.14: Peeled tubers by the peeler

3.3 Performance Evaluation of the Machine

The machine operational variables such as, throughput capacity the effect of the body mass of individuals on the throughput capacity, tuber losses and the safety involved in peeling were determined using the following expressions:

3.3. 1. Determination of throughput capacity

Throughput capacity, Tc (kg/h) = $\frac{WT}{T}$................ Equation (1) (Oriola and Raji, 2013).

Where,

W_T = Mass of sample before peeling (kg)

T = Time taken for peeling (s)

3.3.2 Effect of the Body Mass on the Throughput Capacity by volunteers used for the Experiment.

The body mass of the volunteers were taken by the use of a questionnaire. This data was taken to determine whether the body mass has effects on the throughput capacity.

3.3.3 Determination of Efficiency in Terms of Losses of Cassava Flesh

The Cassava flesh that got stacked in the peel during the course of peeling was removed manually and weighed with the electronic weighing balance and recorded as tuber losses. The tuber losses percentage was determined using the formula below

Tuber Losses, % = $\frac{ML1}{Mp+ML1} \times 100$……………….. Equation (2)

Where

M_P = Mass of tuber flesh peeled with Machine (kg)

M_{L1} = Mass of tuber losses (kg)

Tuber Losses, % = $\frac{ML2}{MM+ML2} \times 100$……………….. Equation (3)

Where

M_M = Mass of peeled cassava manually (kg)

M_{L2} = Mass of tuber losses (kg) [The Cassava flesh that got stacked in the peel during the course of peeling was removed manually and weighed and was then recorded as tuber losses].

3.3.4 Safety Level in the Using the Knife in Peeling

3.3.4.1 Method of Data Collection

The principal method of data collection for this parameter was through interviews, questionnaire administration and observations. Forty (40) people were interviewed at *Susanso gari* factory on injury (cuts) when peeling 300 kg of cassava. At *Susanso gari* factory, individuals are assigned 300 kg of cassava to peel per day.

3.3.5 Data Analysis

The field data as well as the data generated using the questionnaire were analysed using descriptive statistics that is tables and graphs.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1. Physical Properties of the Cassava (*Asiam*)

A. Moisture Content

Moisture content in the tuber determines the peel adhesion to the flesh. The higher the moisture content the lesser the peel adhesion to the tuber flesh and hence the easier for the peels to be removed (Olukunle and Akinnuli, 2013).

Table 4.1: Moisture content of cassava variety (*Asiam*) on wet and dry basis.

Sample	Initial mass, kg	Mass after oven drying, kg	Moisture Content (Wet Basis, %)
1	34.05	10.42	69.40
2	47.04	14.98	68.15
3	39.25	15.05	61.66
4	24.27	8.59	64.61

5	41.63	16.4	60.61
Mean			**64.88**

Table 1 indicates that moisture content of the cassava variety (*Asiam)* ranged from 69.40-60.61% with an average of 64.88 % on wet basis.

The results obtained above shows the cassava (*Asiam*) contained a lot of water, hence the peel adhesion to the tuber was less. This made the peeling less tedious.

B. Peel Thickness

Peel thickness helps to determine the pressure required to penetrate the peels without damage to the tubers. As the peel thickness increases the damaged caused to the tuber during the peeling process decreases (Ilori o. and Adetan D.A, 2013).

Table 4. 2: Cassava peel thickness at proximal, mid-section and distal end.

	Diameter before peeling, mm			Diameter After Peeling, mm			Peel Thickness, mm		
Sample	Proximal End	Middle Section	Distal End	Proximal End	Middle Section	Distal End	Proximal Peel Thickness	Middle Peel Thickness	Distal Peel Thickness
1	63.94	59.29	24.42	60.43	56.79	17.16	3.51	2.5	7.26
2	39.95	59.38	49.01	33.02	55.73	36.02	6.93	3.65	12.99
3	53.62	54.4	47.49	45.27	48.27	43.17	8.35	6.13	4.32
4	42.45	39.35	27.47	35.05	35.74	24.49	7.4	3.61	2.98

5	61.37	49.14	36.03	59.24	46.17	31.31	2.13	2.97	4.72
Mean							**5.66**	**3.77**	**6.45**

The average peel thickness were 5.66 mm, 3.77 mm and 6.45 mm at the Proximal, mid – section and distal respectively as indicated in the Table 4.2. This indicates that the peel thickness of the cassava, *Asiam* is less and hence less pressure to be applied during the peeling process.

4.2. Performance Evaluation of the *Fomena* Cassava

4.2.1 Throughput Capacity

The results presented in Figure 4.1 indicate that the throughput capacity is lower with the *Fomena* peeler as compared to using the knife. It depicts that more time was spent using the peeler than the knife. This may be so because the women have more experience peeling with the knives than the *Fomena* peeler. Also the women stood while using the *Fomena* peeler and have to bend to take the cassava before peeling. Due to this more time was spent to peel the cassava while when peeling with the knife they were comfortably seated. It was also observed that increase of the quantity of cassava had no effect on the time spent peeling.

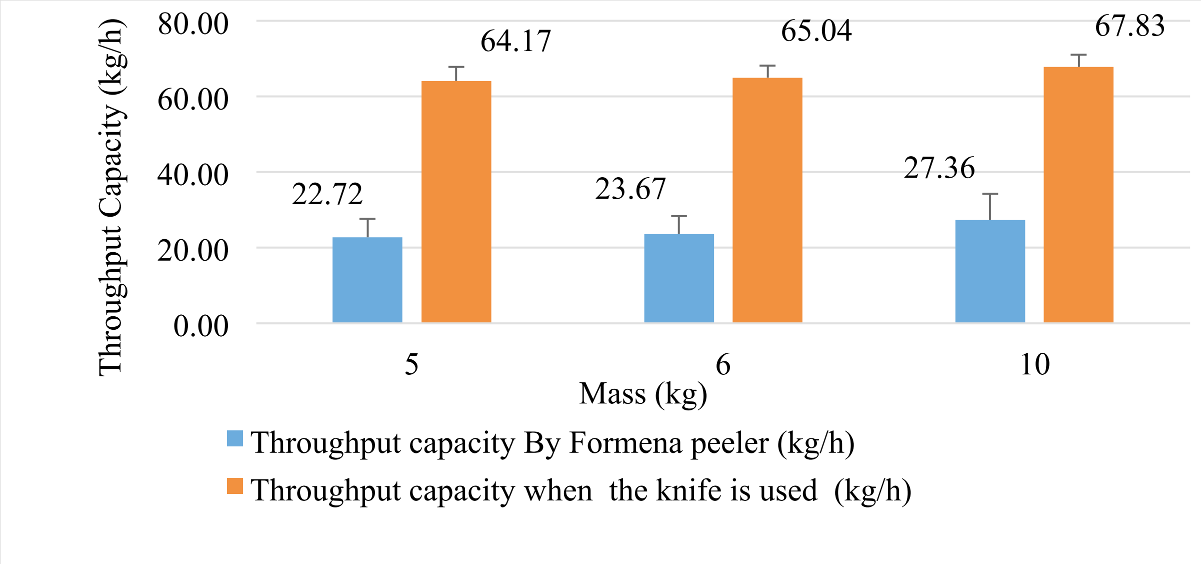

Figure 4.1: Bar chart graph of the throughput capacity against mass

4.2.2 Effect of the Body Mass on the Throughput Capacity.

Table 4.3 shows the volunteer who carried out experiment and their body masses. Volunteer A had the highest body mass followed by Volunteer B and then Volunteer C. From Figure 4.2 Volunteer A had the highest throughput capacity for both using the knife and the *Fomena* cassava peeler, followed by Volunteer B and then volunteer C. Thus the body mass had effect on the time spent in peeling. The higher the body mass the lower the throughput capacity.

Table 4.3 Body masses of Individuals used for the experiment.

Individual	Volunteer A	Volunteer B	Volunteer C
Body Mass (kg)	55	65	100

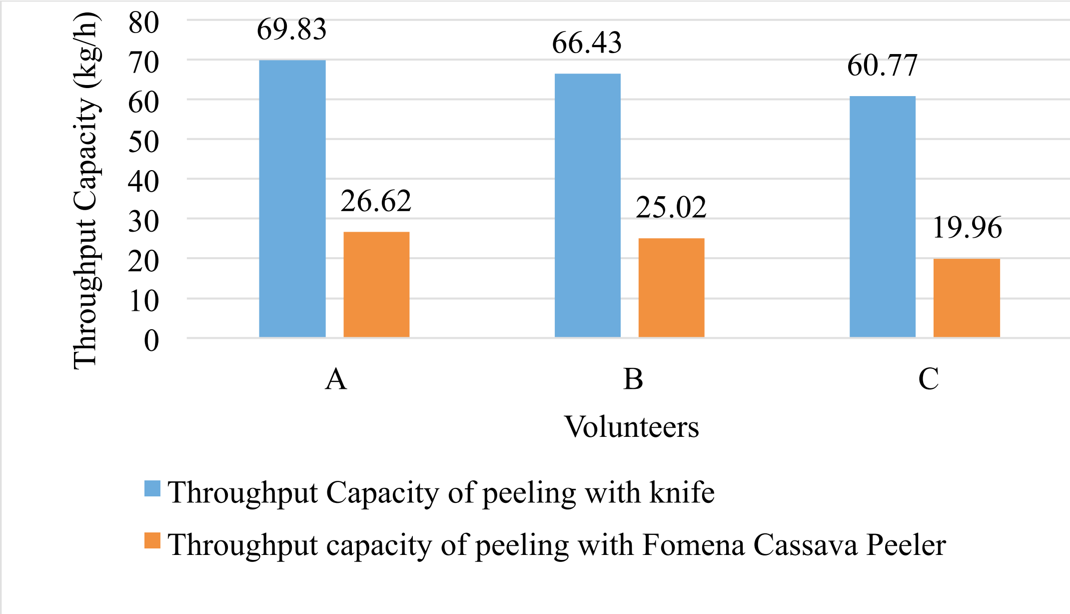

Figure 4.2: Bar chart graph of the throughput capacity against body masses of individual

4.2.3 Efficient in Term Percentage Tuber Losses

The results presented in the figure 4.3 indicate that the percentage tuber losses is higher when using *Fomena* peeler than peeling with the knife. It depicts that more tuber losses occurred when using the *Fomena* peeler to peel than the knife. This may be so because the women were not used to *Fomena* peeler .they put a lot of force on the cassava at blade so as to take the peels off. Also, during the peeling process, the cassava has to be turned. Failure to turn the cassava during peeling ate into the flesh.

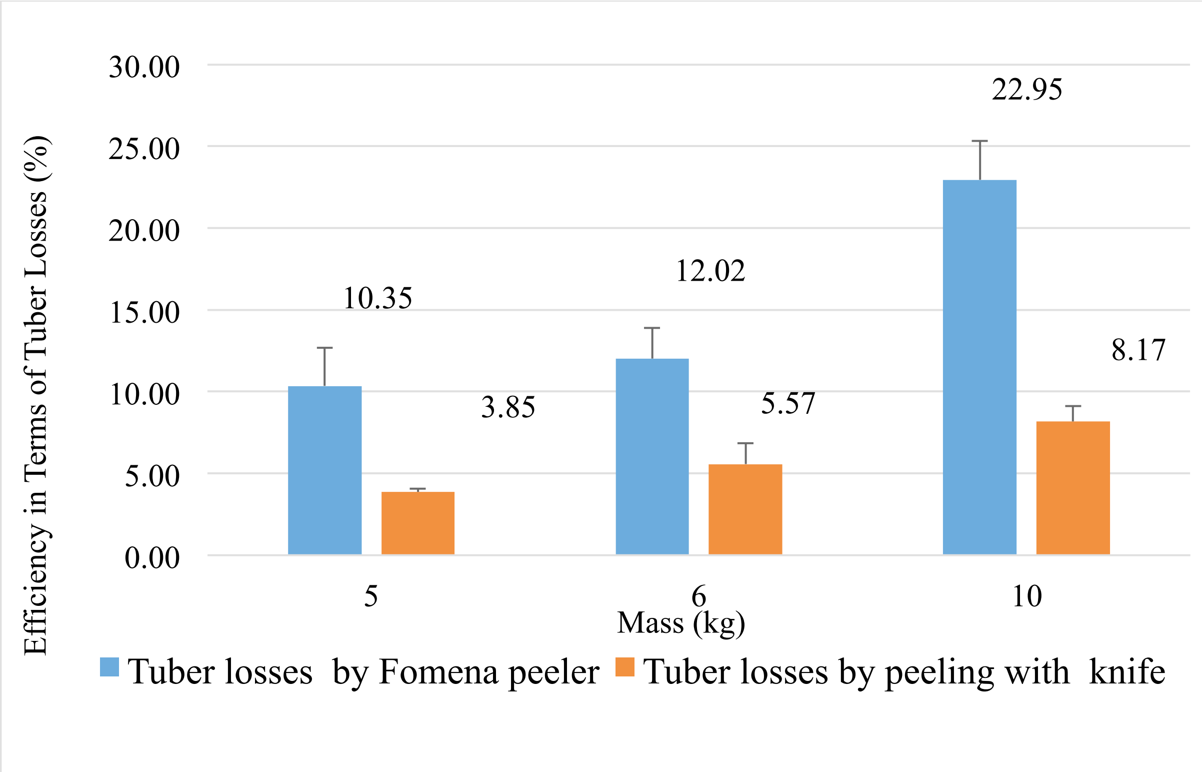

Figure 3.3: Efficiency in terms of tuber losses against mass

4.2.4 Safety Involved In Peeling with Knife

As shown in Figure 4.4, 68% of the people have more than ten (10) years working experience in processing cassava into *gari* and 32% have below ten (10) years working experience. Because of their experience, their zeal to work is high and also very fast when it comes to work.

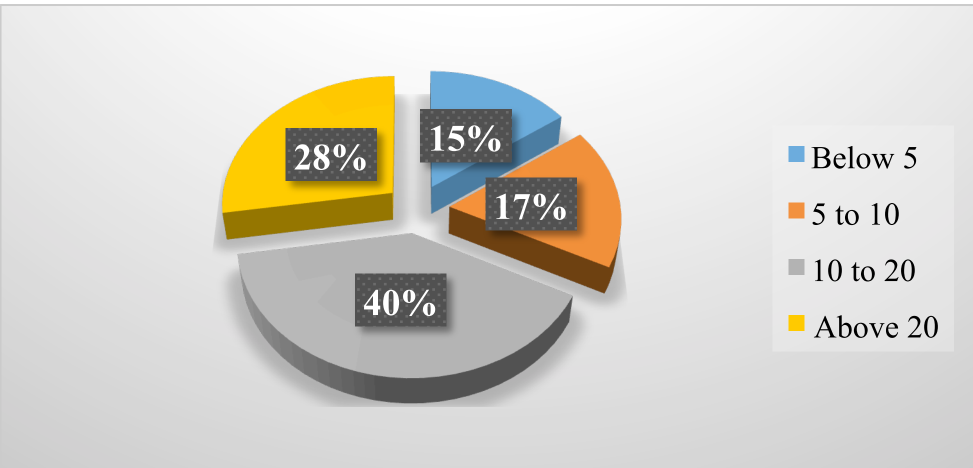

Figure 4.4: Working experience of people interviewed

Figure 4.5 indicated that sixty- five percent (65%) of the people got cut when peeling 300 kg of cassava and thirty- five percent (35%) had no cut during peeling. This indicates that using the knife in peeling is highly dangerous for the majority of them. Therefore, the need to enhance the peeling technology is very paramount.

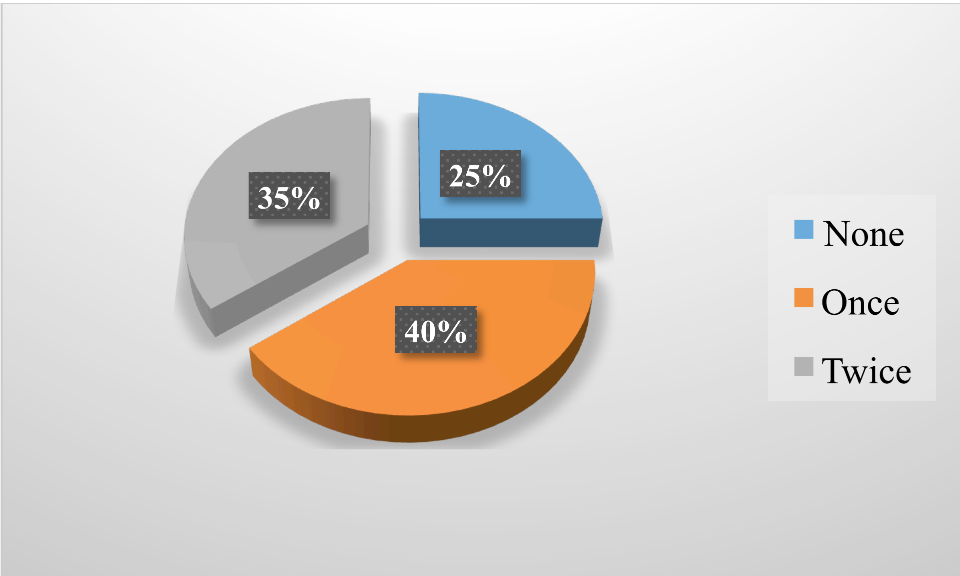

Figure 4.5: Number of cuts when peeling 300 kg (6 bags) of cassava

Comparatively, several tests had been run with the *Fomena* cassava peeler and no bruises has been recorded and this is because of the position of the blade and hence safer than using the knife in peeling.

4.2.5 Comparison of the *Fomena* Cassava Peeler to Existing Cassava Peelers

The results revealed that within the mass (5 kg, 6 kg and 10 kg) range tested, the throughput capacity ranged from 22.72 to 27.36 kg/h, peel removal efficiency was 100% because all the peels are removed during the peeling process since it is operated manually and the percentage tuber losses from 10.35 to 22.95 % of the *Fomena* cassava peeler.

The results show that the throughput capacity is lower than 165 and 55 kg/h given by Odigiboh (1976) and ohwovoriole *et al* (1988) respectively from their machines which are also operated manually. The throughput capacity obtained shows the equipment will not help in large scales and industrial processing of the roots. This is so because of low self-fed.

Percentage tuber losses (tuber losses) ranged from 10.35 to 22.95 % which is lower than that of the knife-edge operated peeler type II with which ranged percentage tuber losses from 25-42 % (Jimoh and Olukunle, 2012) but it's also higher than the rotary batched cassava peeler Ohwovoriole *et al.,* (1988) developed with a percentage tuber losses of 2.5 %.

The peeling removal efficiency of the *Fomena* peeler is better as compared to most fabricated cassava peeler. Since it can take off all the peels. But it takes much time for all peels to be removed and also eats into flesh.

The *Fomena* cassava peeler has a peel collector or plate that is able to collect the peels. This prevents spillage of the peels and can be used for whatsoever it can be used for.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

The following conclusions are being drawn from the study:

1. The *Fomena* peeler had a throughput capacity ranging from 22.72 kg/h to 27.36 kg/h and that of using the knife in peeling was from 64.1 kg/h to 67.83 kg/h.
2. The efficiency in terms of tuber losses for *Fomena* cassava peeler ranged from 10.35% to 22.95% and that of the knife in peeling ranged from 3.85% to 8.17%.
3. Sixty-five percent (65%) of people were injured (cuts) when using the knife to peel and no injuries (cuts) have been recorded in using the *Fomena* cassava peeler

Further studies are recommended in the following areas:

1. Supports must be provided for the *Fomena* cassava peeler to increase its stability on the ground.
2. The *Fomena* cassava peeler should have a blade cover to help prevent cuts when not in use.
3. There should be an attachment at the side of the *Fomena* cassava peeler to ease the stress of bending.

REFERENCES

Abdulkadir, B. H. (2012). Design and fabrication of a cassava peeling machine. International Organization on Scientific Research (IOSR).*Journal of Engineering (IOSRJEN), 2(6); 01-08.*

Abdullahi, M. E. D. F. Aloko, & V. J. Mustapha (2010). Optimization of some operating parameters for steam peeling of cassava tubers. *International Journal of Chemical Technology Research, 2(3);*

Adetan, D.A., L. O. Adekoya, & O. B. Aluko (2003).Characterization of some properties of cassava root tubers. *Journal of Food Engineering, 59, 349-353.*

Adetan, D.A., L. O. Adekoya, & O. B. Aluko (2006).Theory of mechanical method of peeling cassava tubers with knives. *International Agrophysics, 20(4), 269 – 276.*

Agbetoye, L. A. S, O. C. Ademosun, A. S. Ogunlowo, O. J. Olukunle, O. P. Fapetu, & A. Adesina (2006). Developing indigenous machinery for cassava processing and fruit juice production in Nigeria. In proceedings of the first *International Conference on Advances in Engineering and Technology, Entebbe, Uganda.16th -19th July, 2006, 375-384, Elsevier Publication Limited.*

Ariavie, G.O. & E. N. Ohwovoriole (2002). Improved Ohwovoriole's rotary cassava tuber peeling machine. *Nigerian Journal of Engineering Research and Development, 1(2), 61-63*

Asare, P.A., Galyuon, I.K.A., Sarfo, J.K. and Tetteh, J.P. (2015). Morphological and molecular based diversity studies of some cassava (Manihot esculenta Crantz) germplasm in Ghana. *African Journal of Biotechnology*, *10*(63), pp.13900-13908.

Bencini, M.C. (1991). Post-harvest and processing technologies of African staple foods: a technical compendium. Agriculture Services bulletin No. 89, FAO, Rome

Ebegbulem Judith, Ngoddy O. Patrick and Akindele F. Alonge (2013). Cassava peeling using a combination of chemical and mechanical methods. CSBE 13-102.

GNA, (2013). Cassava processors advised to improve handle practices.

Haggblade, S., Andersson Djurfeldt, A., Banda Nyirenda, D., Bergman Lodin, J., Brimer, L., Chiona, M., et al. (2012). Cassava commercialization in Southeastern Africa. *J. Agribus. Dev. Emerg. Econ.* 2, 4–40. doi: 10.1108/20440831211219219

Hillocks, R. J. (2002).Cassava in Africa; In Cassava: Biology, Production and Utilization. Eds. Hillocks, R.J., Thresh, J .M. and Bellolli, A.C. CAB International, Wallingford, 41-54.

Igbeka, J.C. (1984). Some mechanical and rheological properties of yam and cassava. *African Journal of Science and Technology, 3(2); 45-60.*

Iiri (2015). From food waste to animal feed, cassava peels potentially

IITA (International Institute of Tropical Agriculture) (2006).IITA Annual report, 8.

Jimoh, M.O. & O. J. Olukunle (2012).An Automated Cassava Peeling System for the Enhancement of Food Security in Nigeria. *Journal of Nigerian Institute of Food Science and Technology (NIFST), 30(2); 73 – 79.*

Jimoh, M. O., O. J. Olukunle, S. I., Manuwa, & O. T. Amumeji (2014).Theoretical analysis of tuber movement during mechanical peeling of cassava. International Organization on Scientific Research (IOSR). *Journal of Mechanical and Civil Engineering (IOSR-JMCE) 11, 6(I); 27-36.*

Jones, W.O. 1959. Manioc in Africa Stanford University Press. 315 pp

Kawano, K. (2000). Cassava as a source of animal feed and income generation in upland farming communities of Asia. *Science Report of the Faculty of Agriculture, Kobe University, Japan, 24(1); 123-124.*

Kolawole, O.P., Agbetoye, L.A.S. & Ogunlowo, A.S. (2010) .Sustaining world food security with improved cassava processing technologies: *The Nigerian Experience on Sustainability, 2; 3681- 3694.*

Nisha (2015).Top ten producing countries in the world.

Nwagugu, N. I., & Okonkwo, W.I. (2009). Experimental determination of comprehensive strength of sweet cassava (*Manihot Esculenta Cranz*). *International Conference of West African Society of Agricultural Engineers and Nigerian Institution of Agricultural Engineers, 9 – 197.*

Odigboh, E.U, (1976). A cassava peeling machine: development, design and construction, *Journal of Agricultural Engineering Research, 21; 361-369.*

Odigboh, E.U. (1983a). Cassava production, processing and utilization, In: Chan Jnr, H. T. (ed.), Handbook of Tropical Foods, New York: Mercel Decker Pub. Inc., 145-200.

Ohwovoriole, E.N., Oboli, S. & Mgbeke, A.C. (1988). Studies and preliminary design for a cassava tuber peeling machine. *Transactions of the American Society of Agricultural Engineers (ASAE), 31(2) 380-385.*

Olukunle, O. J., Ogunlowo, A.S. & Sanni, L. (2010).The search for effective cassava peeler. *The West Indian Journal, 32 (1 &2), 42-47.*

Olukunle, O. J. & Jimoh, M.O. (2012).Comparative analysis and performance evaluation of three cassava peeling machines. *International Research Journal of Engineering Science, Technology and Innovation (IRJESTI), 1(4), 94-102.*

Olukunle, O. J. & Akinnuli, B.O. (2013). Theory of an automated cassava peeling system. *International Journal of Engineering and Technology (IJEIT), 2, 2277-3754*

Oriola, K. O. & A. O. Raji, A.O. (2013). Trends at mechanizing cassava postharvest processing operations. *International Journal of Engineering and Technology (IJET), 3(9): 879-887.*

Rodriguez Hector (2017) Introduction to cassava (yucca)

Sajeev, M.S., Sreekumar, J. Unnikrishnan, J. Moorthy, M.S.N. & Shanavas, S. (2009). Kinetics of thermal softening of cassava tubers and rheological modeling of the starch, *Journal of Food Science and Technology, 47 (5):507-518.*

APPENDICES

APPENDIX I

1.0 Throughput Capacity

1.1 Peeling with *Fomena* peeler data obtained from 5 kg of cassava

Experiment	Initial Mass, kg	Time spent, mins	Time spent, h	Throughput capacity, kg/h
1	5	19.51	0.33	15.38
2	5	12.14	0.20	24.71
3	5	10.3	0.17	29.13
4	5	13.05	0.22	22.99
5	5	14.02	0.23	21.4
Mean				**22.72**

1.2 Peeling with knife data obtained from 5 kg of cassava

Experiment	**Initial Mass, kg**	**Time spent, mins**	**Time, h**	**Throughput capacity, kg/h**
1	5	4.05	0.07	74.07
2	5	4.31	0.07	69.17
3	5	4.58	0.08	65.5
4	5	5.25	0.09	57.14
5	5	5.5	0.09	54.55
Mean				**64.17**

1.3 Peeling with *Fomena* peeler data obtained from 6 kg of cassava

Experiment	**Initial Mass, kg**	**Time spent, mins**	**Time, h**	**Throughput capacity, kg/h**
1	6	20.51	0.34	17.55
2	6	17.51	0.29	20.57
3	6	12.53	0.21	28.73
4	6	15.06	0.25	23.9
5	6	13.05	0.22	27.59
Mean				**23.67**

1.4 Peeling with knife data obtained from 6 kg of cassava

Experiment	**Initial Mass, kg**	**Time spent, mins**	**Time spent, h**	**Throughput capacity, kg/h**
1	6	6.23	0.10	57.78
2	6	5.05	0.08	71.29
3	6	5.4	0.09	66.67
4	6	5.01	0.10	71.86
5	6	6.25	0.10	57.6
Mean				**65.04**

1.5 Peeling with *Fomena* peeler data obtained from 10 kg of cassava

Experiment	**Initial Mass, kg**	**Time spent, mins**	**Time spent, h**	**Throughput capacity, kg/h**
1	10	37.37	0.62	16.06
2	10	22.35	0.37	26.85

3	10	21.18	0.35	28.33
4	10	17.19	0.29	34.9
5	10	19.56	0.33	30.67
Mean				**27.36**

1.6 Peeling with knife data obtained from 10 kg of cassava

Experiment	**Initial Mass, kg**	**Time spent, mins**	**Time spent, h**	**Throughput capacity, kg/h**
1	10	8.08	0.13	74.26
2	10	8.15	0.14	73.62
3	10	8.45	0.14	71.01
4	10	10.45	0.17	57.42
5	10	9.55	0.16	62.83
Mean				**74.26**

APPENDIX II

2.0 PERCENTAGE TUBER LOSSES

2.1 Peeling with *Fomena* peeler data obtained from 5 kg of cassava

Experiment	**Initial Mass, kg**	**Mass of Tuber Losses, kg**	**Mass of peeled cassava, kg**	**Tuber Losses, %**
1	5	0.393	3.65	9.72
2	5	0.329	3.75	8.07
3	5	0.409	3.715	9.92
4	5	0.374	3.45	9.78
5	5	0.534	3.21	14.35
Mean				10.35

2.2 Peeling with knife data obtained from 5 kg of cassava

Experiment	**Initial Mass, kg**	**Mass of Tuber Losses, kg**	**Mass of peeled cassava, kg**	**Tuber Losses, %**
1	5	0.124	3.9	3.08
2	5	0.155	3.62	4.11
3	5	0.143	3.73	3.69
4	5	0.156	3.615	4.13
5	5	0.159	3.585	4.25
Mean				**3.85**

2.3 Peeling with *Fomena* peeler data results obtained from 6 kg of cassava

Experiment	**Initial Mass, kg**	**Mass of Tuber Losses, kg**	**Mass of peeled cassava, kg**	**Tuber Losses, %**
1	6	0.542	4.41	10.95
2	6	0.75	4.38	14.62
3	6	0.501	4.66	9.71
4	6	0.604	4.495	11.85
5	6	0.643	4.309	12.98
Mean				**12.02**

2.4 Peeling with knife data obtained from 6 kg of cassava

Experiment	**Initial Mass, kg**	**Mass of Tuber Losses, kg**	**Mass of peeled tuber, kg**	**Tuber Losses, %**
1	6	0.156	4.28	3.52
2	6	0.093	4.505	2.02
3	6	0.445	4.26	9.46
4	6	0.299	4.49	6.24
5	6	0.305	4.305	6.61
Mean				**5.57**

2.5 Peeling with *Fomena* peeler data obtained from 10 kg of cassava

Experiment	**Initial Mass, kg**	**Mass of Tuber Losses, kg**	**Mass of peeled cassava, kg**	**Tuber Losses, %**
1	10	2.059	6.75	23.37
2	10	1.934	6.308	23.47
3	10	1.804	6.395	22.00
4	10	1.634	6.66	19.70
5	10	2.29	6.455	26.19
Mean				**22.95**

2.6 Peeling with knife data obtained from 10 kg of cassava

Experiment	**Initial Mass, kg**	**Mass of Tuber losses, kg**	**Mass of peeled tuber, kg**	**Tuber Losses, %**
1	10	0.577	7.435	7.2
2	10	0.769	7.18	9.67
3	10	0.599	7.316	7.57
4	10	0.85	6.965	10.88
5	10	0.415	7.065	5.55
Mean				**8.17**

APPENDIX III

3.0 **Safety Involved in Peeling**

3.1 Working Experience (Years)

Working Experience (Years)	Number of People
Below 5	6
6 to 10	7
11 to 20	16
Above 20	11
Total	**40**

3.2 Number of Cuts When Peeling 300 kg of Cassava

Number of Cuts per 300 kg of cassava (6 bags)	Number of People
None	10
Once	16
Twice	14

APPENDIX IV

4.0 Mass Reduction When the Ends of the Cassava is Taken Off

Experiment	Initial Mass, kg	Mass After Taken the Ends Off, kg
1	5	4.84
2	5	4.885
3	5	4.855
4	5	4.91
5	5	4.884
6	6	5.85
7	6	5.9
8	6	5.88
9	6	5.865
10	6	5.78
11	10	9.86
12	10	9.618
13	10	9.775
14	10	9.81
15	10	9.675

APPENDIX V

5.0 A Questionnaire on Number of Bruises Encountered During The Peeling Processes When Peeling A Pole (300 Kg Or 6 Bags) Of Cassava.

Name:

Sex A) male ☐ B) female ☐

Age:

Body Mass:

1) Working Experience (Years): A) Below 5 ☐ B) 6-10 ☐
C) 11-20 ☐ D) Above 20 ☐

2) How days are used to peel 300 kg (6 bags) of cassava

A) One (1) ☐ B) Two (2) ☐ C) Three (3) ☐ D) Four (4) ☐

3) Number of bruises during peeling 300 kg (6 Bags)

A) None ☐ B) Once ☐ C) Twice ☐ D) Thrice (3) ☐