# Performance Evaluation of the Automated System for Cleaning, Peeling and Washing Cassava Tubers

S. Ogunlowo[1], S. A. Olaleye[2], and M. S Fasunla[3]

***Abstract*—**An automated system for cleaning, peeling and washing cassava tubers was developed in the Department of Agricultural and Environmental Engineering, Federal University of Technology Akure, Nigeria (FUTA). Some of the major machine features and its use for cleaning, peeling and washing cassava tubers were discussed. The peeling section has a rotary drum inscribed with cutting blades of 10 mm in height, 2700 mm long with an auger of 2 mm thick flights and 2700 mm in length. With this components it was possible to remove the tuber peels achieving 100 % flesh recovery at a maximum of two peeling throughput. The washing system of the machine utilizes gravitational and pressurized washing techniques with the possibility of recirculation of the filtered water. The washing system assisted the machine to have <1% peel retention. .The complete system was evaluated using newly harvested tubers of length, L_T and diameter, Ø_T grouped into small; large and big sizes as: 100<L_T<250, 31.35<Ø_T<45.55; 150<L_T<280, 40.75<Ø_T<70.29 and 175<L_T<310, 68.27<Ø_T<91.67 respectively. The capacity of the conveying and peeling systems at an average feed rate of 2 tons/hr are 314 kg/hr and 3.96 tons/hr respectively. The washing system has water utilization capacity of 1.2 litres/kg/day. The operational parameters used for the evaluation of the peeling system were, rotational speed of the peeling drum using values ranging from 40 rpm to 60 rpm at 5 rpm increment, tuber loadings ranging from 1 to 5 tubers, peeling evaluations were done for tubers kept for one to three days. The peeling results obtained ranged from 69 % - 83 %; 55 % - 75 % and 86 % - 95 % for the average peeling efficiencies at first peeling, second peeling and overall peeling throughput respectively for all the operational parameters. The average result of the peeling and washing efficiencies indicated that the automated system was effective for peeling cassava tubers.

***Keywords*—**Peeling, Cassava, Peeling Machine, Washing, Performance Evaluation.

## I. INTRODUCTION

Various common post-harvest handling and processing of cassava tubers includes; storage, peeling, grating, frying, drying, etc. Before cassava can be processed into any meaningful product, it requires cleaning and peeling. Peeling of cassava has been seen as the first operation after washing. In most cases, the corky periderm and the cortex of the tuber (known as the peel), as shown on Figure 1, is removed for further processing. Cassava tuber is generally fattest at the proximal end and tapers gently towards the distal end. The Peels can represent 10% to 20% of the fresh root weight, of which the periderm accounts for 0.5% to 2.0%. The process of removing the corky periderm and the cortex of the cassava tuber is called peeling. The three common methods adopted for peeling cassava tubers are manual method, chemical method and mechanical method. Olukunle and Akinnuli (2012) conducted a research on the performance evaluation of a single action cassava peeling machine. The work recorded that the machine peeling efficiency 70%.

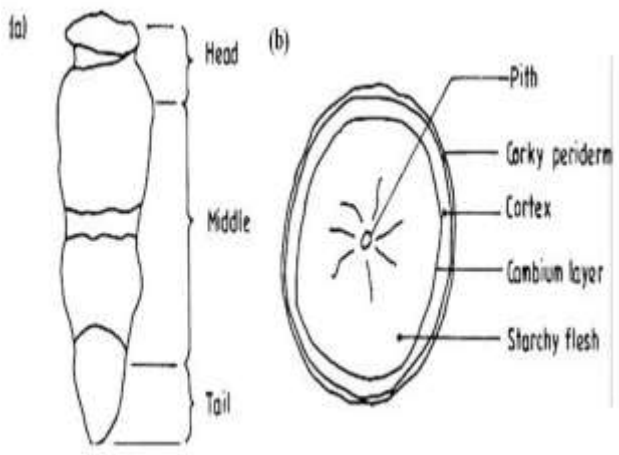


Fig. 1: Morphology of the cassava tuber: (a) general morphology and (b) transverse section (Adetan *et al*., 2003)

### *A. Objectives*

The aim of the work presented in this paper is to develop and evaluate the cleaning, peeling and washing mechanisms of an automated system for cassava tubers. The specific objectives of this project are to:

I. Develop an automated cleaning, peeling and washing system using peeling drum method for cassava tubers; and

II. Evaluate the performance of the machine.

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## II. Literature Review

It is important to note that before cassava root can be processed into useful products, the toxic peels must be removed by peeling. The manual method is the most common way of peeling tubers ranging from home consumption purpose to small scale food processing purpose. With the amount of energy involved in manual method of peeling and the time consumed in the process, manual method is not suitable for medium to large scale tuber processing. Chemical and mechanical methods are the two available methods that can be utilized for the peeling of tubers for medium to large scale processing. Oluwole and Adio (2012) reported that the manual method of peeling cassava involves the use of knife to manually remove the peel.

The chemical method involves the use of hot solution of sodium hydroxide to loosen and soften the skin of the roots. The prolong immersion of the tuber to soften the peel has been reported to account for the gelatinisation of starch in the cassava root and the formation of an objectionable heat ring (dark colour) on the surface of the useful root flesh which is not suitable for gari processing and industrial starch processing (Igbeka, 1985). The mechanical method of peeling cassava root tubers has been adjudged the best compared to both manual and chemical methods because of it's resultant energy conservation, time saving, high product capacity, and human drudgery reduction leading to stable food security. The morphological nature of cassava root posed great challenges to the mechanization of its peeling processes. Several efforts have been made to develop effective cassava peeling machines especially in Nigeria. Several Researchers, notably Olukunle *et al.*, 2006, Adetan *et al* (2003); Olukunle (2005), Olukunle *et al* (2010), Oluwole *et al* (2012), Odighoh (1979) and Sherrif *et al* (1995) had made remarkable research attempts on identifying suitable methods that could be used to design appropriate mechanical systems for cassava handling and processing. Olukunle and Akinnuli (2012) reported that 91.87% cassava peeling efficiency can be achieved with mechanical peeling machine. Oluwole *et al* (2012) employed the abrasive method of peeling cassava tubers with the use of stationary outer abrasive drum and rotating inner abrasive drum. The average peeling efficiency recorded by the machine was 70.45 % with an average flesh loss of 5.09 % and 2 % estimated broken cassava tubers

## III. Materials and Method

The cassava tubers used for this project were locally sourced from the surrounding farms in Akure, Ondo State, Nigeria. The complete system was evaluated using newly harvested tubers of length, $L_T$ and diameter, $\emptyset_T$ and Mass ($C_w$) (g) grouped into small; large and big sizes as: $100<L_T<250$, $S_d$ = 8 $31.35<\emptyset_T<45.55$; $S_d$= 1.3 $150<C_w<600$. $S_d$ = 20, $150<L_T<280$, $S_d$ = 10, $40.75<\emptyset_T<70.29$, $S_d$ = 1.5, $170<C_w<700$ $S_d$=22 and $175<L_T<310$, $S_d$= 13, $68.27<\emptyset_T<91.67$, $S_d$= 1.8, $350<C_w<1250$ $S_d$= 23 respectively. Dimensions in, mm.

### A. Machine Description

The automated machine system comprises of the following, the cleaning unit, the peeling unit and the washing unit. Figure 2 shows the schematic view of the peeling machine. The figure shows the major components of the machine. The fabricated and assembled peeling machine is shown on Plate 1 with the complete automated system combining the cleaning, peeling and washing units, shown in Plate 2. The peeling drum comprises of the drum, inscribed auger and the cut out cutting blades. The cut out in the cutting blades created the opened paths through which peels escaped the drum. The dimension of the peeling drum was determined as 2740 mm in total length and ϕ300 mm in diameter. The electric motor, the pulleys and the belts supplied rotational power was transmitted through the pulleys and belt to the peeling drum for operation.

The mechanism adopted as shown in Figure 3 utilizes the shearing method of peeling. The peeling operation was carried out by the peeling drum. The cassava tubers fed into the peeling machine enters through the hopper into the peeling drum. Inside the peeling drum, the cassava experiences a shearing force exerted by the cutting blades through the rotational motion of the drum. The power transmission devices transmit motion to the peeling drum. The rotational motion of the peeling drum drives both the inscribed auger and the cutting blades. The cassava tubers in the peeling drum.


Plate 1: The peeling Unit of the Cleaning, Peeling and Washing Machine for Cassava Tubers


Plate 2: The complete machine assembly showing the direction of cassava flow

gained rotational momentum, through the rotation of the drum, which displace the tubers tangentially and drives them through an intermittent revolution. The rotation of the auger picks the tubers and conveys them linearly through a tangentory motion into the discharge outlet.

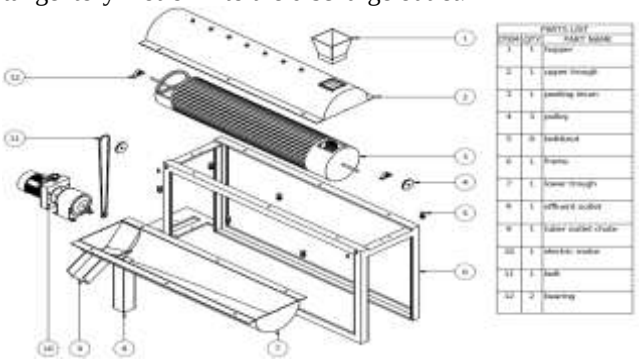


Fig. 2: The schematic exploded view of the peeling machine

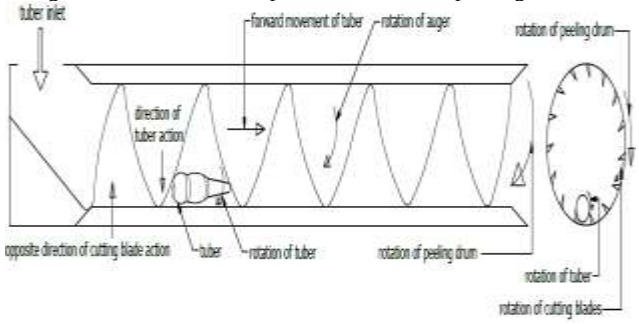



Fig. 3. Schematic diagram of the machine's operational mechanism

The forward tangential movement of the cassava is opposed by the opposite rotational motion of the cutting blades which in turns exert a penetrating force into the peels of the tubers. These actions enabled the cutting blades to cut through the tubers resulting into the unwrapping of the cassava peels. The designed internal arrangement of the drum makes it easy for all the exposed body of the cassava to experience peeling. This is, due to the techniques adopted attaching the auger to the cutting blades. When the drum moves at the designed optimum speed, the cassava tuber jumps up tangentially and land on the cutting blade. This action enables the unpeeled potions of the tubers to experience peeling within the resident time in the drum.

As the auger conveys the tuber through the drum, the peels of the tuber are removed. The jumping tangential movement of the tuber is one of the uniqueness of this machine as it allows optimum adequate engagement of the cutting blades with the tubes within the resident time in the peeling drum thus, increasing the peeling efficiency . This continues until the tuber travels to the end of the peeling drum and exits the drum through the discharge opening into the lower trough which in turn exits the machine through the tuber outlet chute. The tuber peels are unwrapped to tiny chips form, by the cutting blades, which enabled them to pass easily through the cutout open paths of the drum into the lower trough thereby increasing the efficiency of peel removal from the drum. The angle of inclination of the machine with the help of the washing processes enabled the peels to flow down the lower trough and exit the machine through the effluence outlet. These processes the machine to have >99 % peel removal efficiency, that is, < 1 % peel retention.

**Machine Evaluation**: Five rotational speeds- 40 rpm, 45 rpm, 50 rpm, 55 rpm and 60 rpm were selected for the evaluation of the peeling machine. The average feed rate of the machine is 2 tons/hr. The peeled mass ratio and the unpeeled mass ratio were determined in order to evaluate the peeling efficiency of the machine. The peeling machine was operated at these speeds with respect to the tuber loading and days of peeling. The results obtained were evaluated as appropriate. One tuber loading, two tubers loading, three tubers loading, four tubers loading and five tubers loading- were selected for loading into the machine. The tubers were divided into three for three days peeling experimentation.. A survey conducted during this study revealed that cassava tubers are best peeled at the day of harvest or the second day after harvest. It was also learned that cassava tubers can still be extended to the third day after harvest, depending on the period of harvest.

The overall efficiency of the machine was determined by considering the first and second peeling efficiencies. Data generated for the peeling efficiencies for the firs, second and the third daynwere subjected to appropriate statistical analysis using Microsoft Excel software packages to determine the parameters most important to effective cassava peeling.

## IV. Results and Discussions

### First Peeling, Second Peeling and Overall Peeling Efficiencies of the Machine

The results of the average peeling efficiencies for first peeling, second peeling and overall peeling for all the rotational speeds and tuber loadings for the three peeling days are as shown in Figures 4 to 8.. It was observed that the efficiencies decreased as the peeling days increased. The highest average peeling efficiency recorded across the days for first peeling; second peeling and overall peeling were 79 %; 65 % and 90 % respectively. This indicated that when the machine was operated for the first day, an average of 79 % peels was removed by the machine at first peeling while an average of 64 % peels was removed at the second peeling. The cumulative percentage peels removed by the action of first and second peelings resulted into the overall peeling efficiency of 90 % for the first day.

### Effects of Tuber Loading on the Overall Peeling Efficiency of the Peeling Machine

The overall peeling efficiency of the machine was determined at various tuber loadings with respect to the rotational speeds and days of peeling. Figure 4 to Figure 8 presented the graphical results of the effects of tuber loading on the overall peeling efficiency for all the various rotational speeds and peeling days. The highest overall efficiency recorded by the machine, as presented on Figure 6, was 95 % which was obtained when the machine was operated at 50 rpm with single loading of the tubers. Similarly, the lowest overall peeling efficiency, 82 %, was recorded at 40 rpm for five loading of cassava tubers. It can be concluded that on day 1,

the best operational parameters that will result into the highest overall peeling efficiency of the machine is 50 rpm at single loading of cassava tubers.

On day 2 and day 3, the overall peeling efficiency of the machine, as shown on Figure 6 and Figure 8, decreases as the tuber loading increases across the five rotational speeds. At day 2, the highest overall efficiency of peeling, 93 %, was recorded at 60 rpm for single loading of cassava tubers while the lowest overall peeling efficiency, 81 %, was recorded at 40 rpm for five loading of cassava tubers. On day 3, the highest overall efficiency of peeling, 89 %, was recorded at 60 rpm for single loading of cassava tubers while the lowest overall peeling efficiency, 78 %, was recorded at 40 rpm for five loading of cassava tubers. The efficiency of peeling increases as the rotational speed increases from 40 rpm to 60 rpm at each tuber loading on day 3.

**Effects of Rotational Speeds on the Overall Peeling Efficiency of the Peeling Machine**

The effects of rotational speeds, 40 rpm to 60 rpm, on the performance of the machine at various tubers loading for the three selected days were evaluated as shown Figures 9. Considering Figure 9, it can be concluded that the rotational speed of the peeling drum that will result in the highest average overall peeling efficiency for all the tuber loadings are 50 rpm for day 1; 50 rpm and 60 rpm for day 2 and 60 rpm for day 3. Samples of peeled and washed cassava tubers after second peeling at 50 rpm and 60 rpm with respect to the evaluation parameters are shown on Plates A and B.

## V. Conclusions

A cassava peeling machine was designed and fabricated in the Department of Agricultural and Environmental Engineering, Federal University of Technology Akure. A horizontal rotational peeling drum that has enabled the cassava peeler to properly engage the cassava tubers during peeling and recorded very high peeling efficiency. Cassava tubers of categories A (small size); B (medium size) and C (large size) of length, $L_T$, and diameter, $\emptyset_T$, with the value ranges of $100<L_T<250$, $31.35<\emptyset_T<45.55$; $150<L_T<280$, $40.75<\emptyset_T<70.29$ and $175<L_T<310$, $68.27<\emptyset_T<91.67$ respectively were used for the design and testing of the machine. The testing of the machine recorded a peeling efficiency of 94% which is a remarkable improvement over the previous peelers review.

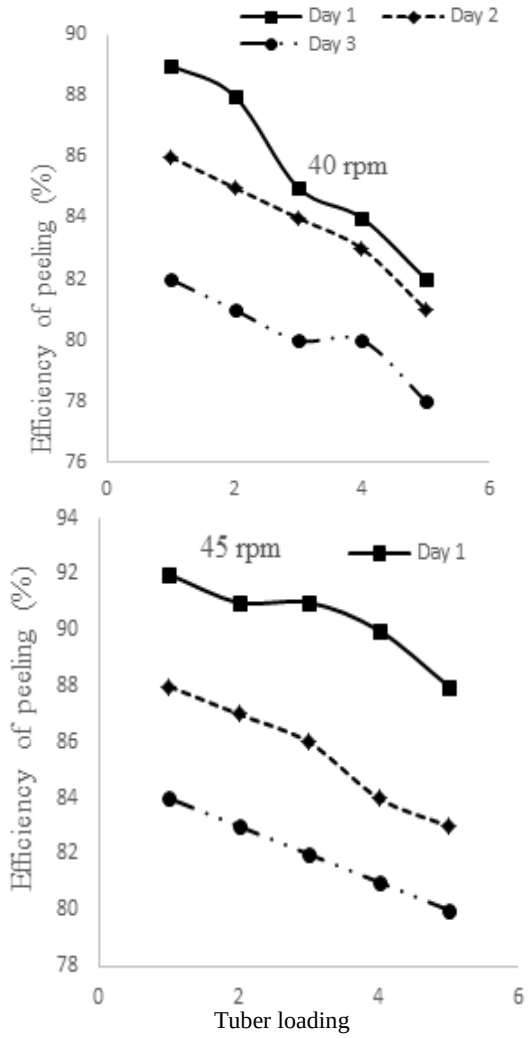



Fig. 5: Effect of Tuber Loading on Peeling Efficiencies at 45 rpm From Day 1-3

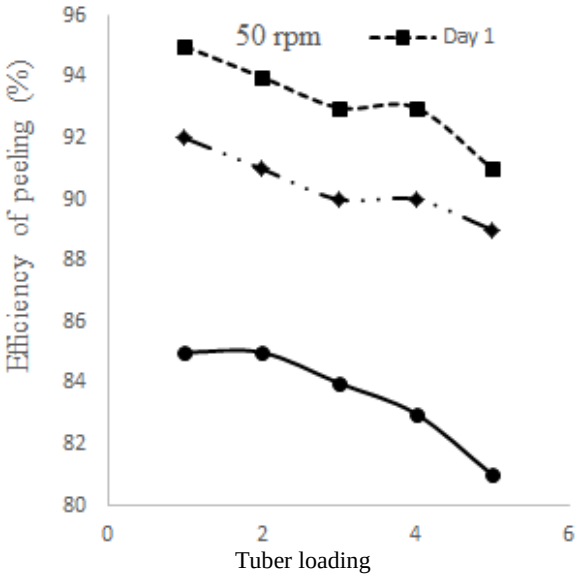



Fig. 6: Effect of Tuber Loading on Peeling Efficiencies at 50 rpm From Day 1-3

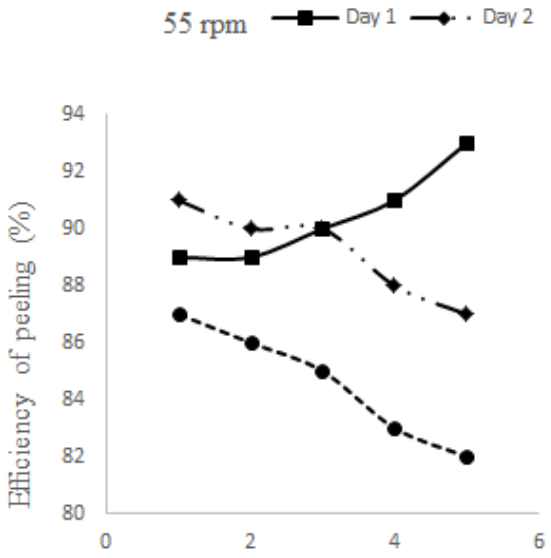



Fig. 7: Effect of tuber loading on peeling efficiencies at 55 rpm from day 1-3

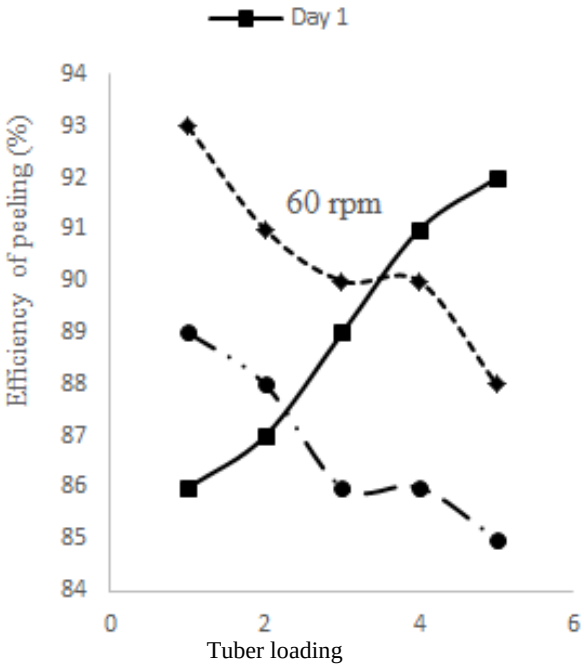
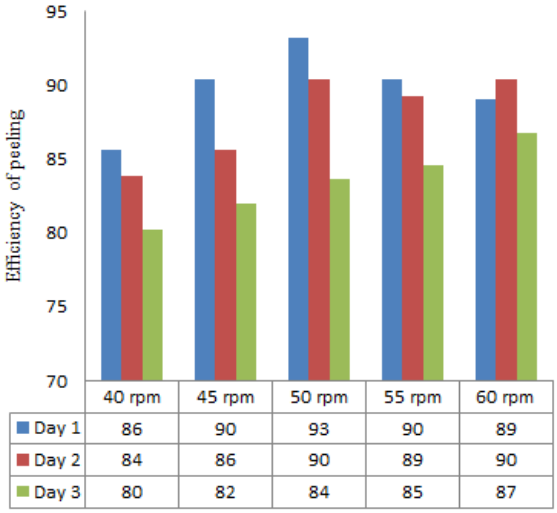



Fig. 8: Effect of Tuber Loading on Peeling Effieciecies at 60 rpm Day 1-3




| | 40 rpm | 45 rpm | 50 rpm | 55 rpm | 60 rpm |
|---|---|---|---|---|---|
| Day 1 | 86 | 90 | 93 | 90 | 89 |
| Day 2 | 84 | 86 | 90 | 89 | 90 |
| Day 3 | 80 | 82 | 84 | 85 | 87 |

Fig. 9: Average peeling efficiency across all tubers loading at various rotational speeds from day 1-3

Plate 4

Plate 5

Plate 4 shows sample of peeled and washed tubers a cassava t 50 rpm while Plate 5 shows sample of peeled and washed cassava tubers at 60 rp**m respectively**

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