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Full Length Research Paper

Comparative analysis and performance evaluation of three cassava peeling machines

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Cassava is posed with inherent characteristics, morphological distributed in numerous cultivars, being these have contributed to the global un-acceptable peeling technique of the tuber. In recent development, machine designers and engineers intensified efforts toward finding lasting solution to the cassava peeling problem. Three cassava peelers newly developed in the Department of Agricultural Engineering, Federal University of Technology, Akure, Nigeria namely 'knife-edged automated peeler type1', 'knife-edged automated peeler type2' and abrasive-tooled automated peeler' were considered for comparative analysis using regression model. The machines were evaluated at three different speeds; (300, 500 and 700rpm with 1.0 HP electric motor. Cassava tubers were graded into small, medium and large sizes with chosen weight 150, 550 and 1150g respectively. The following variables were evaluated: tuber losses, peeling efficiency, peel retention and peeling time. 'Knife-edged peeler type1' had optimum efficiency, with tuber losses, peel retention and peeling time were 91.87%, 24.17%, 16.00% and 24.03 seconds, respectively. 'Knife-edged peeler type2' had optimum efficiency, with tuber losses, peel retention and peeling time were 82.50%, 25.42%, 28.26% and 19.60 seconds, respectively. 'Abrasive-tooled peeler' had optimum efficiency, with tuber losses, peel retention and peeling time were 71.11%, 18.11%, 38.78% and 50.00 seconds, respectively. The result indicates that up to 91.87% peeling efficiency is achieved in less than 25 seconds using mechanical peeling method.

Keywords: *Manihot esculenta*, automated peelers, optimum performance, time conservation.

INTRODUCTION

Cassava (*Manihot* esculenta Crantz) is one of the most important food energy productions and staple crops in Tropical Africa. Nigeria, Brazil, Thailand and Indonesia are the principal producing countries and this is because of its suitability for present farming and food systems (Olakulehin and Ajijola, 2005). Africa accounts for more than half about 88 million tons of cassava or about 55% of the world production, Nigeria being a major producer amongst others (IITA, 1984). This output is projected to be more than double by 2020 (Scott et al., 2000) as the trends in cassava production indicate a steady growth over time. Cassava is the sixth major staple crop in the world after rice, wheat, maize, potato, and sweet potato with an annual production of 185 million (FAO, 2000). Scott et al., (2000) further revealed that improved cassava varieties were grown on about 22% of the 9 million hectares that were planted in 20 countries.

Cassava peeling is still majorly carried out manually. 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. The Federal University of Technology, Akure, Nigeria (FUTA) has played significant role in consistent development of mechanical peeling system. Since early 70s, when the search for affective peeling mechanisms really started and the knives of the National Centre for Agricultural Mechanization (NCAM) were invented to substitute for primitive knives. 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

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flesh, although the machine is manually operated and there is need for re-peeling of tubers. The model II cassava peeler prototype, which possesses bolls of metals as abrasive material reported (Odigboh, 1983). The efficiency is low (64%) and there is need for modification. Rotary cassava tuber peeling machine (Ohwovoriole et al., 1988), designed and aimed in to improvement the effectiveness and peeling rate of cassava but with very high tuber losses. Single and double gang models A and B cassava peeling machine, developed at FUTA, which resulted in the production of commercial models (Agbetoye et al., 2006). This is 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). The operation of this machine is tedious and splitting of useful flesh. NCAM improved cassava peeling, tool developed for peeling cassava tuber with 35 kg/h, 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 remain a serious global challenge to lovers and processors of cassava, especially in large scale production. Today, because of low efficiency and losses, cassava peeling is still majorly carried out manually. This situation has made it essential to provide a good, efficient and time conserving machine in the reduction of energy expended as well as the time taken in peeling. In view of this development, this research work is focused on comparative analysis and performance evaluation of three recent cassava peeling machines aimed at peeling cassava at different sizes.

MATERIALS AND METHODS

Research materials

The cassava tuber *(Manihot utilissima)* used for the experiment was acquired from a local farmer around FUTA community. The tubers planted two years before harvest; these were newly harvested and adopted for the peeling experiment almost immediately after the purchase. Remaining tubers were placed in shades to prevent the tubers' dehydration. The research work was carried out in January when the moisture in the soil and that of the tuber is low. 100 samples of similar weight in each size ranges were selected for each peeling process and for each of the machines. 10 samples of similar weight in each size ranges were also selected as control experiment.

Measuring tools and instruments

A variety of tools and instruments were used to carry out different measurements on the root tubers. A tap rule was used to measure the length of roots while the diameter of the roots was measured using a pair of vernier caliper. The weight of root before peeling, after peeling and weight of peel were measured with an electronic weighing balance. Time of operation was measured by stop watch while the residual peel was removed by kitchen knife.

Description of the machines

Three different machines were used: (1) knife-edged automated cassava peeling machine - type1; (2) Abrasive-tooled cassava peeling machine; and (3) Knife-edged automated cassava peeling machine-type2. These machines were designed and fabricated at the Department of Agricultural Engineering, Federal University of Technology, Akure, Nigeria. The peeling processes were carried out simultaneously using the same materials.

Knife-edged automated cassava peeling machine-type1

This machine has its peeling chamber and peeling tool mounted upon a supporting frame. The peeling tool is a rotating cylindrical drum or barrel upon which peeling blades are permanently welded in an auger-like manner. Also a stripe of metal is attached between the columns of blade so as to enhance conveyance of the tuber in the machine while in operation. The barrel is driven by a solid shaft which is powered by a 1.0 HP electric motor. A belt and pulley mechanism was used to transfer the motion from the electric motor to the shaft. The hopper is designed such that cassava tubers put into it will automatically lie horizontally on the peeling blades. The peeling blades on the hollow cylinder roll against the tuber and against an adjustable sharpened blade welded to the body with a very little clearance that will not allow cassava tuber to go through but will be large enough to allow the tuber peel to fall off and find its way to the exit point. A guard is placed to prevent direct contact between the operator and the fast rotating cutting blades. The picture of the machine and peeling tool configuration is shown in Figures 1 and 2.

Abrasive-tooled cassava peeling machine

This peeling machine consists of three peeling rollers which make up a peeling assembly as shown in Figure 3. This effects abrasion when they get in contact with the

Figure1. Knife-edged automated cassava peeling machine-type1.

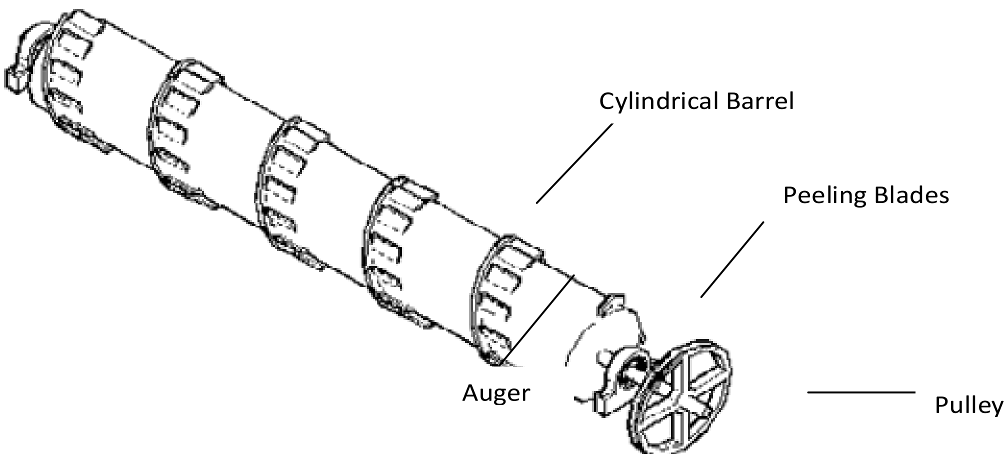


Figure 2. The peeling tool

Figure 3. Abrasive-tooled cassava peeling machine.

tuber surface. The peeling tools were made up of stainless steel which was perforated at intervals and cylindrical rollers which were made from galvanized steel. The tool was fixed to the roller by riveting. The three rollers were connected to one another with the aid of chains and sprockets and they receive motion through

Figure 4. knife-edged cassava peeling machine-type2.

Table1. Cassava tuber clustering in weight (g).

Variable	Size Small(A)	Range (g) Medium(B)	Large(C)
Weight	1-300	300-700	700-2000
Mean	150	550	1150
SD	19.85	30.24	87.66

belt and pulley. The tool assembly is powered by 1.0 HP electric motor. An auger is incorporated above the peeling tools which convey the tubers from the inlet point to the outlet. A gear reduction motor reduces speed and drives the auger at a speed of 7.0 rpm. This is done to achieve a good level of peeling by allowing longer peeling of tuber in the chamber. The machine as afore said generates motion from the electric motor and as the tools are set in motion, the cassava tubers are introduced and moved by the auger along abrasive surface to exit point, hence tubers peel is being cut by the abrasive edges of the punched plates.

Knife-edged automated cassava peeling machine-type2

The mechanism is identical to that of type1 machine, but the differences include the following:

i. The cutting blades have a much longer length and are continuous, i.e., the blades run from one end of the cylinder to the other except for the auger cut;
ii. The peeling chamber is shorter;
iii. The cylindrical barrel is larger thereby, giving the tool a larger surface area for contact.

The machine receives power from a 1.0 HP electric motor, while belts and pulley are used to reduce speed of the machine.

The machine, when powered, drives the peeling tool and as the tool rotate, cassava tubers are peeled against the body of the peeling chamber. The auger incorporated drives the tuber along the peeling chamber against the blades and this is done until it reaches the outlet. Belt and pulley are used to transmit motion as shown in Figure 4.

Determination of tuber sizes

Cassava tubers used in this experiment were categorised into three different classes, namely small, medium and large while the clustering criteria include the combined features of length of tuber, weight and diameter. In the course of the experimentation, it was observed that an accurate diameter classification cannot be achieved for the ranges of small, medium and large tubers. Therefore, weight of tubers was chosen as the constant variable for the tuber classification. The mean value and standard deviation (SD) of 100 selected samples of each size ranges were determined as shown in Table 1.

Performance evaluation of the machines

During the peeling operation, some part of the epicarp may remain on the tuber unpeeled and this may be due to irregular shapes of the tuber or due to short peeling time. The machine operational variables such as peeling efficiency, tuber losses, peel retention and peeling time were determined and considered as dependent variables while crop and machine variables such as tuber size, weight and machine speed were treated as independent variables.

Experimentation

The machines were tested and evaluated on speed 300, 500 and 700 rpm respectively. Tubers with irregular shapes were considered for second pass for effective peeling. The control experiment using manual knife peeling method was carried out to determine the percentage by weight of peel for the respective sizes. The descriptive statistical analysis was used to describe the general characteristic of the observed data before the commencement of modelling. Regression models of the general form:

$Y = \beta_0 + \Sigma\ \beta n\ X_n$ ………………………………………….(1)

The expression is used to explain the influence of tuber size, tuber weight and machine speed on peeling efficiency, tuber losses, peel retention, and peeling time. Y explained variable and represents any of the evaluation variables. B_0 is the model constant, β_n is the coefficient of variables and X_n is the explanatory variables (n=1-4). The variables considered during experiment were the follow:

M = weight of tuber before peeling
M_k = weight of tuber flesh peeled manually
M_{p1} = weight of peeled tuber after first pass
M_{p2} = weight of peeled tuber after second pass
M_{pf} = weight of tuber flesh peeled with Machine
M_{k2} = weight of peel during mechanical peeling
T_P = time taken for the tuber in peeling chamber
Weight of peel during manual peeling = $M - M_k$ .... (2)

Determination of peel retention

Peel retention (PR) = $(M - M_k) - M_{k2}$ .... (3)

Determination of tuber losses

Tuber loss (TL)=$M - \{[M_{pf} + (M - M_k)]\}$ ....(4)

Determination of peeling efficiency

Peeling efficiency (PE) = $\{[(1 - PR)\ (1 - TL)]\}$ .... (5)

RESULTS AND DISCUSSION

Effect of speed on the performance of the machine

Effect of speed on tuber losses

As the speed of the machine increases for a particular size range of cassava tuber, the tuber loss increases. The clustering A (Table 1), as the speed increases from 300 – 700 rpm; the tuber losses increased from 12.28 - 24.17% for knife-edge automated peeler type1; of 17.14 - 25.42% for knife-edge automated peeler type2; and 0% for abrasive-peeler, as shown in Figure 5A. The clustering B, as the speed increases from 300 – 700 rpm; tuber losses increased from 1.20 - 6.14% for knife-edge automated peeler type1; of 1.00 - 1.98% for knife edge-peeler type2; and 0% for abrasive-peeler, as shown in Figure 5B. At clustering C, as the speed increases from 300 - 700 rpm; tuber losses increased from 2.17 – 8.19% for peeler-type1; of 4.94 - 10.63% for peeler-type2; and of 3.87 - 18.11% for abrasive-peeler, as shown in Figure 5C. The reason for general increase in tuber losses as speed of the machine increases is as a result of increased number of impact between tuber and cutting tools coupled with surface curvature and irregular shape of the tubers.

Effect of speed on peel retention

As the speed of the machine increases for a particular size range of cassava tuber, peel retention increases. At clustering A (Table 1), as the speed increases from 300 - 700 rpm; peel retention was at 0% for knife-edge automated peeler type1; of 4.44 - 9.38% for knife-edge type2; and of 30.77 - 38.78% for abrasive-peeler, as shown in Figure 6A. At clustering B, as the speed increases from 300 - 700rpm; peel retention increased from 10.42 - 13.79% for peeler type1; of 16.67 - 28.26% for peeler type2; and of 30.19 - 34.78% for abrasive-peeler, as shown in Figure 6B. At clustering C, peel retention increased from 6.09 - 8.54% for peeler type1; of 13.24 - 16.23% for peeler type2; and of 26.03 - 30.70% for abrasive-peeler, as shown in Figure 6C. The reason for general increase in peel retention is that increase in speed brings about displacement of tuber from cutting tools during its movement to the exit thereby reduces the number of contact during operation.

Effect of speed on peeling efficiency

As the speed of the machine increases for a particular clustering range of cassava tuber, peeling efficiency reduces. At clustering A, as the speed increases from 300 - 700 rpm; peeling efficiency reduced from 87.72 - 75.83% for knife-edge automated peeler type1; of 79.17 -

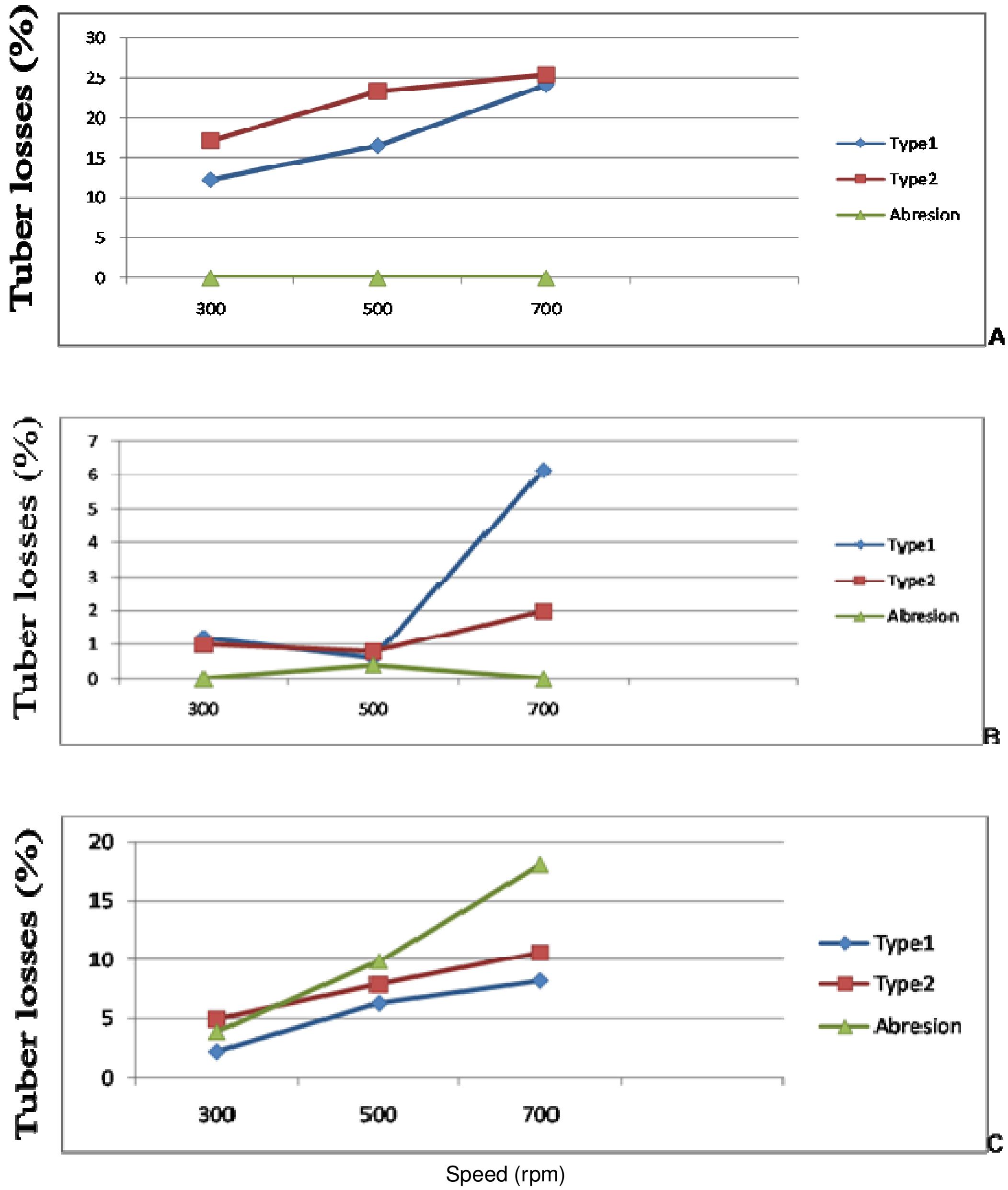
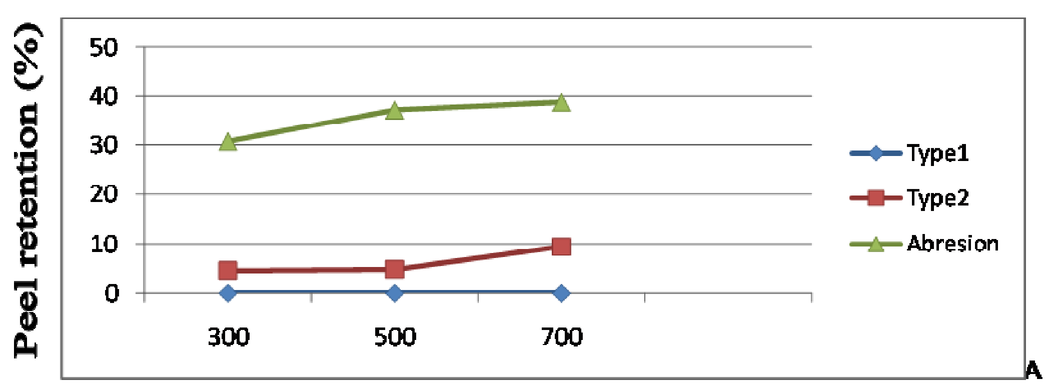


Figure 5. Effect of machine speed (rpm) on tuber losses (%) at different clustering of tubers (A = small; mean = 150g, SD = 19.85. B = medium; mean = 550g, SD = 30.24. C = large; mean = 1150g, SD = 87.66) for three different machines.



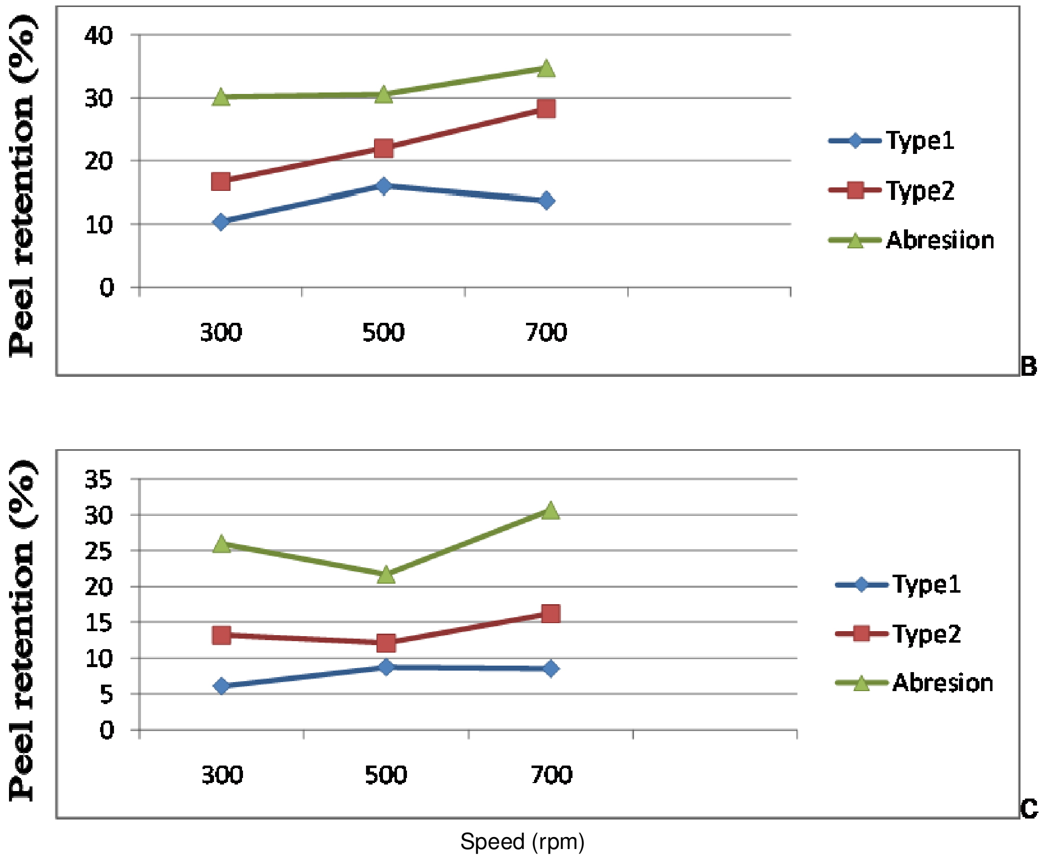


Figure 6. Effect of machine speed (rpm) on peel retention (%) at different clustering of tubers (A = small; mean = 150g, SD = 19.85. B = medium; mean = 550g, SD = 30.24. C = large; mean = 1150g, SD = 87.66) from three different machines.

67.58% for knife-edge automated peeler type2; and of 69.23 - 61.22% for abrasive-peeler, as shown in Figure 7A. At clustering B, the peeling efficiency reduced from 88.51 - 80.91% for peeler type1; of 82.50 - 70.89% for peeler type2; and of 69.81 - 65.22% for abrasive-peeler, as shown in Figure 7B. At clustering C, the reduction was of 91.87 - 83.98% for peeler type1; of 82.47 - 73.05% for peeler type2; and of 71.11 - 56.75% for abrasive-peeler, as shown in Figure 7C. The reason for this general reduction in peeling efficiency is because at high speed, the peeling tools engaged in cutting of the tuber flesh than the peel due to spontaneous reaction of the blades on the tubers.

Effect of speed on peeling time

Generally, peeling time reduced as machine speed increases from 300 - 700 rpm in both knife-edged peeler type1 and type2 as shown in Figures 8A-C, because the auger and cutting tools are incorporated together and this brings about quick delivery at the exit point. At clustering A, as the speed increases from 300 - 700 rpm; peeling time reduced from 8.01 - 5.01s for peeler type1; of 6.02 - 3.57s for peeler type2; and of 46.01 - 45.03s for abrasive-peeler, as shown in Figure 8A. At clustering B, peeling time was reduced of 12.01 - 9.56s for peeler type1; of 9.24 - 6.41s for peeler type2; and increased from 41.07 - 43.12s for abrasive-peeler, as shown in Figure 8B. At clustering C, the peeling time was reduced of 24.03 - 12.96s for peeler type1; of 19.60 - 15.09s for peeler type2; and increased from 38.06 - 52.00s for abrasive-peeler, as shown in Figure 8C. Increased in the peeling time reported in abrasive-peeler is because the speed of the auger, delivery mechanism is low.

CONCLUSION

1. The result of descriptive statistical analysis as shown in Figures 5 - 8 revealed that in knife-edge peeler type1 and 2; peeling efficiency is very high, peel retention is low, peeling time is low and tuber losses is relatively high. In abrasive-tooled peeler; peeling efficiency is low, peel retention is high, peeling time is very high and tuber losses particularly for large sizes is also high. The performances of knife-edge peeler type1 and 2 are far better than that of abrasive-tooled peeler.

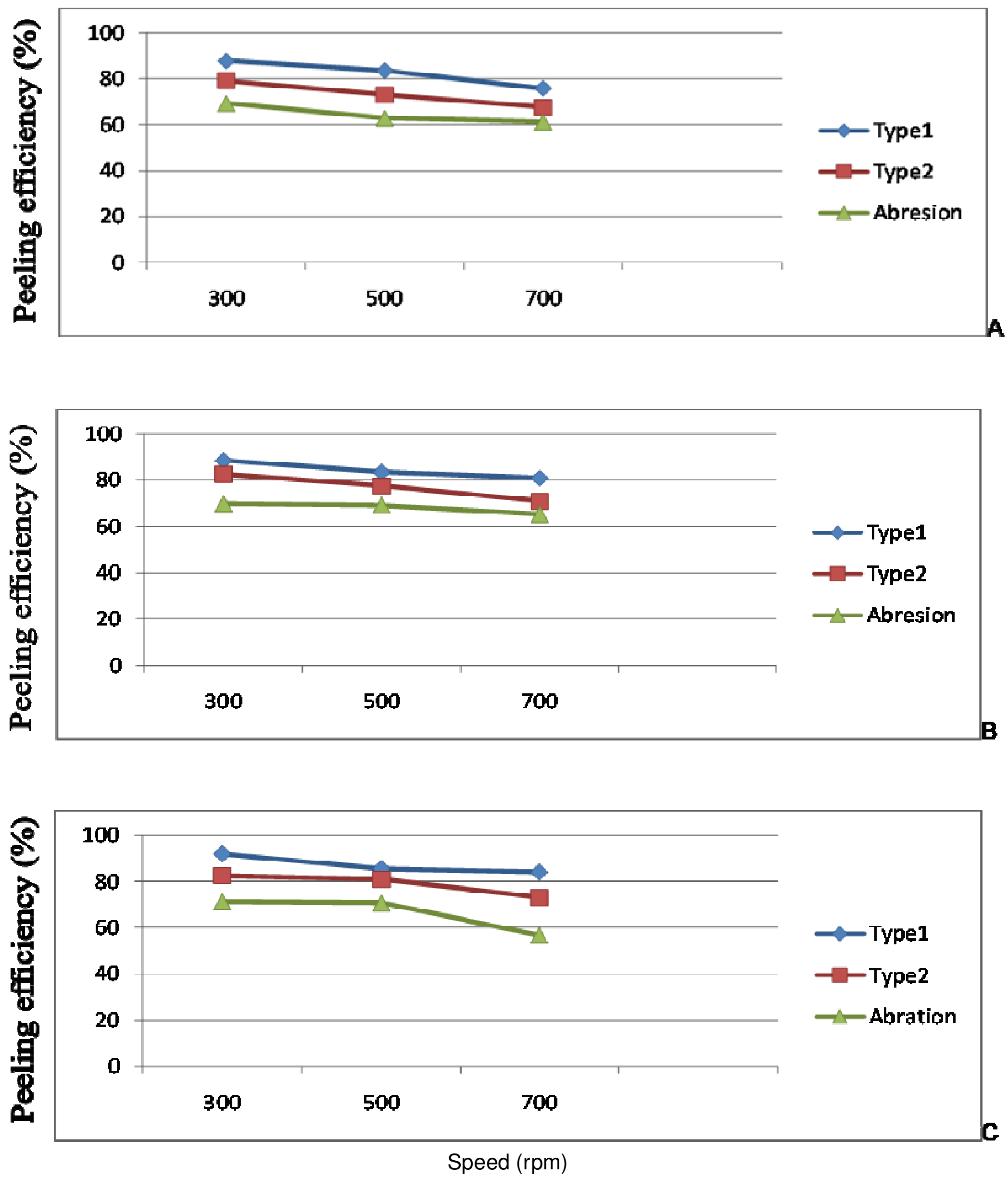
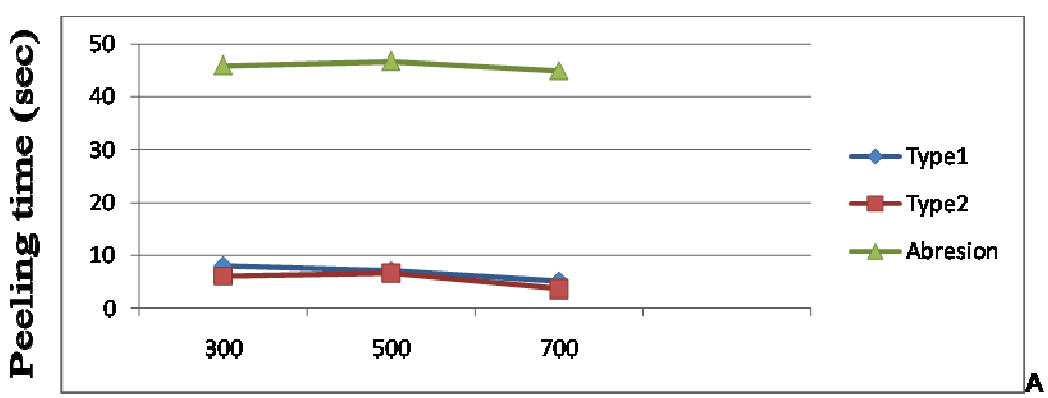


Figure 7. Effect of machine speed (rpm) on peeling efficiency (%) at different clustering of tubers (A = small; mean = 150g, SD = 19.85. B = medium; mean = 550g, SD = 30.24. C = large; mean = 1150g, SD = 87.66) from three different machines.



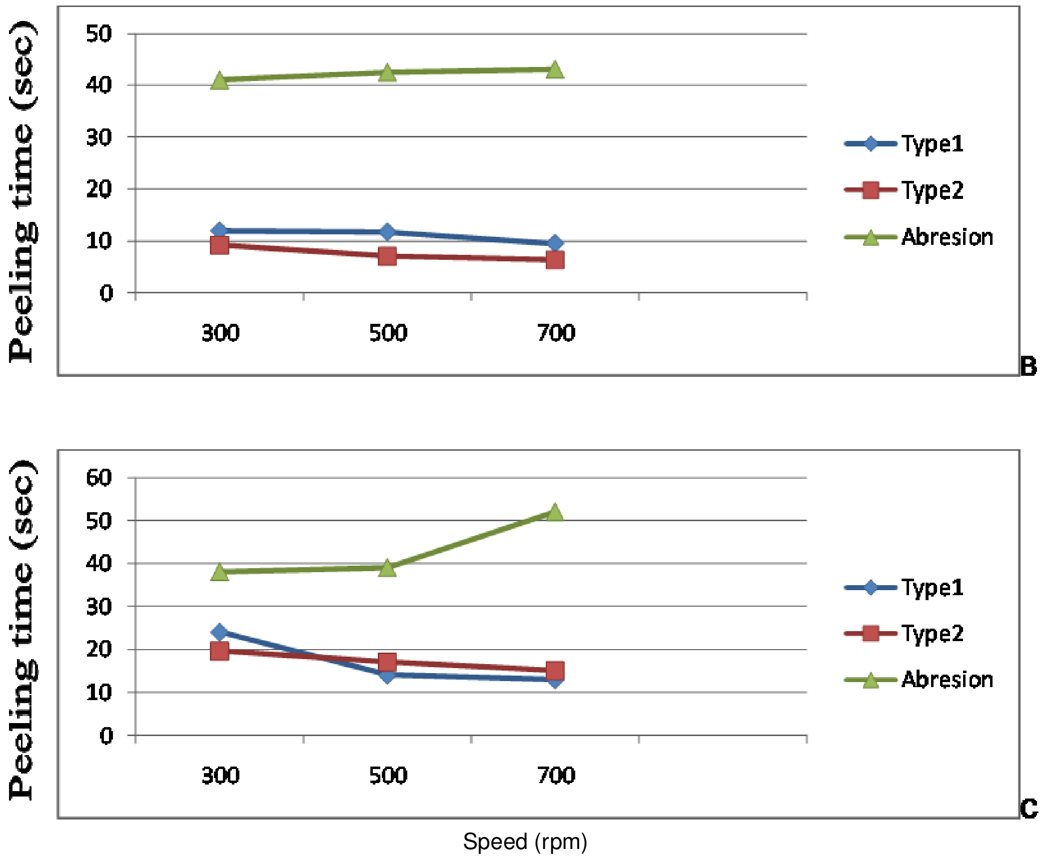


Figure 8. Effect of machine speed (rpm) on peeling time (sec) at different clustering of tubers (A = small; mean = 150g, SD = 19.85. B = medium; mean = 550g, SD = 30.24. C=large; mean = 1150g, SD = 87.66) from three different machines.

2. General performance of these machines on small sizes is low because of breaking characteristic of the tubers; when subjected to bending load during displacement, and during escape through the clearance between cutting tools and peeling chamber.
3. Since this peeling process lasted for period of 5 days, low level of moisture content constitutes high strength of cohesion between the peel and the tuber flesh and therefore affected the result.
4. The problem posed by tuber size and shape could be reduced in further research work by trimming and cutting at the point of curvature.

REFERENCES

Agbetoye LAS, Ademosun OC, Ogunlowo AS, Olukunle OJ, Fapetu OP, Adesina A (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 GO, Ohwovoriole EN (2002). Improved Ohwovoriole's rotary cassava tuber peeling machine. Nigerian J. Engr. Res. Dev. 1(2):61-63.

FAO (2000). FAOSTAT website.

IITA (International Institute of Tropical Agriculture) (1984). Annual report 1984, Ibadan, Nigeria.

Odigboh EU (1976). A cassava peeling machine: development, design and construction. J. Agric. Engr. Res., 21: 361-369.

Odigboh EU (1983). Cassava production, processing and utilization. In Chan. Jnr., H.T., Edition. Handbook of tropical foods, Marcel Decker Pup. Inc., 270, Madison Avenue, New York, 145-200.

Ohwovoriole EN, Obi S, Mgbeke ACC (1988). Studies and preliminary design for a cassava tuber peeling machine. Transactions of the ASAE 31(2) 380-385. View Record in Scopus, Cited by in Scopus (8).

Olakulehin JO, Ajijola FS (2005). Cassava production: Nigerians best kept secret Lagos farmers 1, 1-4.

Olukunle OJ, Ademosun OC, Ogunlowo AS, Agbetoye LAS, Adesina A (2006). Development of a double action cassava peeling machine. Proceeding of the International Conference on Prosperity and Poverty in a Globalized World: Challenges for Agricultural Research. Deutscher Tropentag 2006, Bonn,Germany. http:/www.tropentag.de/abstract/full/312.pdf

Scott J, Rosengrant MW, Ringley C (2000). Roots and tubers for the twenty-first century: Trends, Projections, and Policy options. Discussion paper 31. IFPRI 2020 vision for Food, Agriculture, and Environmental Initiative in collaboration with Centro International de la Papa, Washington, DC, USA.