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Influence of Physical Properties of Cassava Tubers on the Performance of an Automated Cassava Peeler

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Abstract: *Cassava peelers have not been fully developed due to irregularity in shape, size and weight of cassava tubers. The key objective of the study was to determine the impact of physical properties of cassava tubers on the performance of a cassava peeler. Eight tillage treatments were used, namely: ploughing + harrowing; ploughing + harrowing + ridging; manual ridging; flat manual clearing; ploughing + harrowing + manual digging to a depth of 30 cm + 10 cm saw-dust placed at the base; ploughing + harrowing + ridging +10 cm saw-dust placed at the base; manual ridging + 10 cm saw-dust placed at the base and manual digging to a depth of 30 cm + 10 cm saw-dust placed at the base. One improved cassava variety, one nutrient dosage and two soil conditions were used. Statistical Package for Social Science window 21 versions was used to analyze the data. Peeling efficiency, percentage broken tubers, percentage flesh loss, machine throughput capacity, mass of unpeeled patches and material recovery ranged from 28.05-92.88 %, 15.00-46.69 %, 8.78-42.88 %, 0.48-0.58 tons/h, 0.46-1.82 % and 69.56-92.55 % respectively. The physical properties of cassava tubers had influence on the performance evaluation parameters of an automated cassava peeler.*

Keywords: *influence, physical properties, cassava tubers, performance, cassava peeler.*

1. INTRODUCTION

Cassava is second to sweet potato as the utmost vital starchy root crop of the humid world. In major areas of the humid, cassava is cultivated on small plots. Nevertheless, in some countries, like Nigeria, Brazil and Mexico, huge farmsteads have been ongoing and attention in automation is increasing seasons [21]. The root is drought resistant and capable of growing in different types of soil and seasons [38]. It has been identified for drought resistant and producing adequately on peripheral soils, a low-priced origin of calories consumes in human food and a basis of carbohydrate in formulation of animal feed [24]. It produces healthy in zones with yearly rainfall of 500-5000 mm and complete sun; however, it is vulnerable to cold climate and ice [6]. Cassava has high yield in poor soils and ability to stay in the soil for periods after maturity with limited labour requirements. The root system can penetrate below two meters of soil enabling cassava plants to obtain water if it is available deeply [15].

Africa produces over 88 million tonnes of the crop or around 55 % of the total world produce. Nigeria is the leading producer of cassava worldwide with approximately 49 million tonnes per annum (17, 39). Cassava rank the 6th main essential crop worldwide after rice, wheat, maize, potato and sweet potato with yearly production of about 185 million tonnes [14]. The production of cassava and its demand will go beyond twice by 2020 [27] as the movement in cassava production reveals a stable growing over time and it was reported that enhanced cassava varieties were cultivated on around 22% out of 9 million hectares of land that were established in 20 countries worldwide. In 1999, Nigeria accounted 33 million tons while 10 years later it generated around 45 million tons, which is approximately 19% of world total production recently. As from 2000 till date, the mean produce per hectare was approximately 10.6 tons [16].

It has been reported that Nigeria is the highest producer of the crop in Africa, therefore, there is an urgent need to give a due consideration to cassava processing most especially the cassava peeling operation which has been the main problem in the automation of cassava peeling operations. Various researchers had reported that wholly the unit processes tangled in cassava processing operations e.g., milling, grating, pressing, sieving, drying, frying and extrusion had been fully automated, but peeling operation is yet to be automated which has a major setback to food industries and the world at large. This has affected the medium-large scale uses of the tuber [2]. [32] stated that soil features would also affect shape and size of tuber, conclusively peeling still pose a major problem. [33] stated that the main problem of cassava processing is peeling, and this operation is still usually carried out manually, despite the production of some mechanical peelers, based on the cost and most times the inefficiency of such machines compared to the traditional knife peeling method. Ideally and especially in the food industry, the peel needs to be completely removed without removing the useful tuber flesh, but this has not been the case most times [3].

Many researchers such as [41, 7, 36] agreed that knowledge of the engineering properties of agricultural products are important in the design and analysis of machines for agricultural materials. A conscious and desperate search for effective cassava peeling machine began in the Department of Agricultural Engineering, Federal University of Technology, Akure, Nigeria in July 2004 [29]. This research led to the production of commercial models of the single and double gang hand-fed cassava peeling machine. The actual process of the machine was however dependent on tuber trimming and cuttings to eliminate bends. [32] reported that peeling efficiency in an automated peeling arrangement is usually affected by crop, machine and operational parameters.

There are also changes in the properties of the cassava peel which differs in thickness, texture and strength of adhesion to the root flesh. Thus, it is challenging to design a cassava peeling machine that is able of proficiently peeling tubers due to the alterations in properties of tubers from various sources. The major objective sort to be tested in this study was to determine the relative effect of some engineering properties mainly physical properties on the performance of a cassava peeler.

2. Materials and Methods

2.1 Site Description and Experimental Design

Field experiment was conducted between May 2014 and July 2015 in Teaching and Research Farm of the Federal University of Technology Akure (7^{o}15^{1}N, 5^{o}15^{1}E). Weather conditions during the growing period were recorded using digital thermometer, rainguage, hygrometer and barometer. Eight tillage treatments were used, namely: ploughing + harrowing; ploughing + harrowing + ridging; manual ridging; flat manual clearing; ploughing + harrowing + manual digging to a depth of 30 cm + 10 cm saw-dust placed at the base; ploughing + harrowing + ridging +10 cm saw-dust placed at the base; manual ridging + 10 cm saw-dust placed at the base and manual digging to a depth of 30 cm + 10 cm saw-dust placed at the base. One improved cassava variety, one nutrient dosage and two soil conditions were used. The total area of experiment is 10 x 22 meters (220 m^2) and a line spacing of 1 meter between the plots and cassava stand was observed. The cassava stem of 15-20 cm long at planting depth of 5-10 cm was planted on the 27th May 2014 and it was harvested in July 2015 in which some physical properties of sixteen cassava stands were determined. Table 1 shows the experimental design of the treatments.

2.2 Determination of Physical Properties of Cassava Tubers

The physical properties of cassava tubers were determined using standard methods and equations as presented in Table 2.

2.3 Machine Description and Operation

The cassava peeling machine was designed and fabricated by [33] of the Department of Agricultural Engineering, Federal University of Technology, Akure, Nigeria. The main feature of the machine includes peeling chamber cover, peeling tool, gear motor, V-belt and pulley, frame, guard, pillow bearing, inlet, outlet and inlet cover. The gear motor of 5 Hp provides electrical energy and this is converted to mechanical energy by transmission system, delivered to the peeling tool where peeling operation is being carrying out. The machine is design in such a way that the operator is secured and safe from moving cutting tool and transmission system. The movement of cassava on the cutting tool is linear under the influence of gravitational force and static frictional force that brings about compression pressure and gravitational impact between the tuber and the rotating cutting tool. The peel is collected and discharged through flat plate mounted under peeling chamber while tuber flesh is collected at the exit point for further processing. It is automated cassava peeler because it was capable to eradicate manual involvement throughout peeling procedure since metering device was boosted to bring a known number of cassava tubers into the peeling compartment per unit time. The machine makes use of impact rotary motion on the tubers through shear/or abrasion outcome essential for the peeling procedure, with an output capacity of 500 – 583 kg/h [31]. Figure 1 shows the exploded view of an automated cassava peeling machine used for the performance evaluation of the cassava tubers under different tillage practices. Figure 2 shows the isometric drawing of an automated cassava peeler.

2.4 Machine Performance Evaluation Parameters

The mass of each of unpeeled fresh tubers was recorded along with the bulk mass of all the cassavas obtained from a single plant using an electronic weighing balance, the length was taken using tape rule and the diameter was also taken using Vernier calliper. These values were recorded [34]. The fresh tubers were loaded into the peeling drum by batch process. The tubers peeled by abrasion using the cassava peeler machine. The mass of tubers after mechanical peeling, mass of peels removed by the machine, mass of peels removed with knife after mechanical peeling, mass of tuber after hand trimmed (completely peeled tuber), mass of flesh removed by the machine, mass of unpeeled patches after mechanical peeling, total mass of flesh and the time taken for the mechanical peeling process were noted and recorded. The machine performance evaluation parameters were determined using equations 1 to 6 as recommended by [34, 18].

$$P.E = \frac{M_P}{M_T} \times 100 \quad (1)$$

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$$BT = \frac{SBT}{TNS} \times 100 \tag{2}$$

$$FL = \frac{M_f}{M_{Tf}} \times 100 \tag{3}$$

$$C = \frac{MUFL}{T} \tag{4}$$

$$UP = \frac{M_U}{M_T} \times 100 \tag{5}$$

$$M_R = \frac{M_3}{M_{Tf}} \times 100 \tag{6}$$

where P. E. is peeling efficiency; M_P is mass of peels by the machine; M_T is total mass of peels; BT is the percentage of broken tubers; SBT is the sample of broken tubers; TNS is the total number of samples; FL is the percentage of flesh loss; M_f is mass of flesh removed by the machine; M_{Tf} is total mass of tuber flesh; C is the capacity; MUFL is the mass of unpeeled fessh tubers; T is the time taken to peel; UP is the percentage of unpeeled patches; M_R is the percentage of material recovery; M_U = mass of unpeeled patches; M_T = total mass of peels M_3= mass of tubers after hand trimming (manual peeling) and M_{Tf} is total mass of tuber flesh.

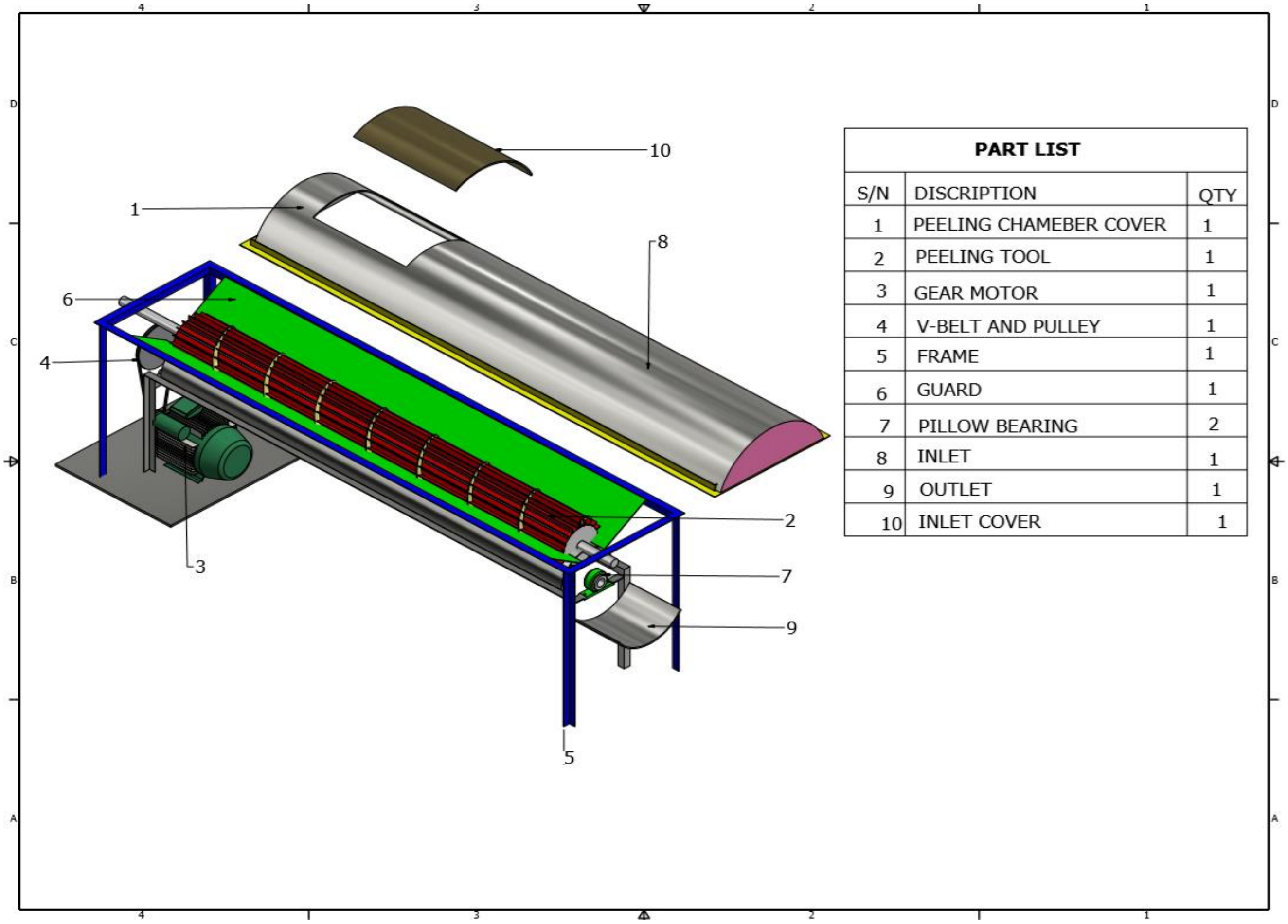

Figure 1: Exploded View of Automated Cassava Peeler

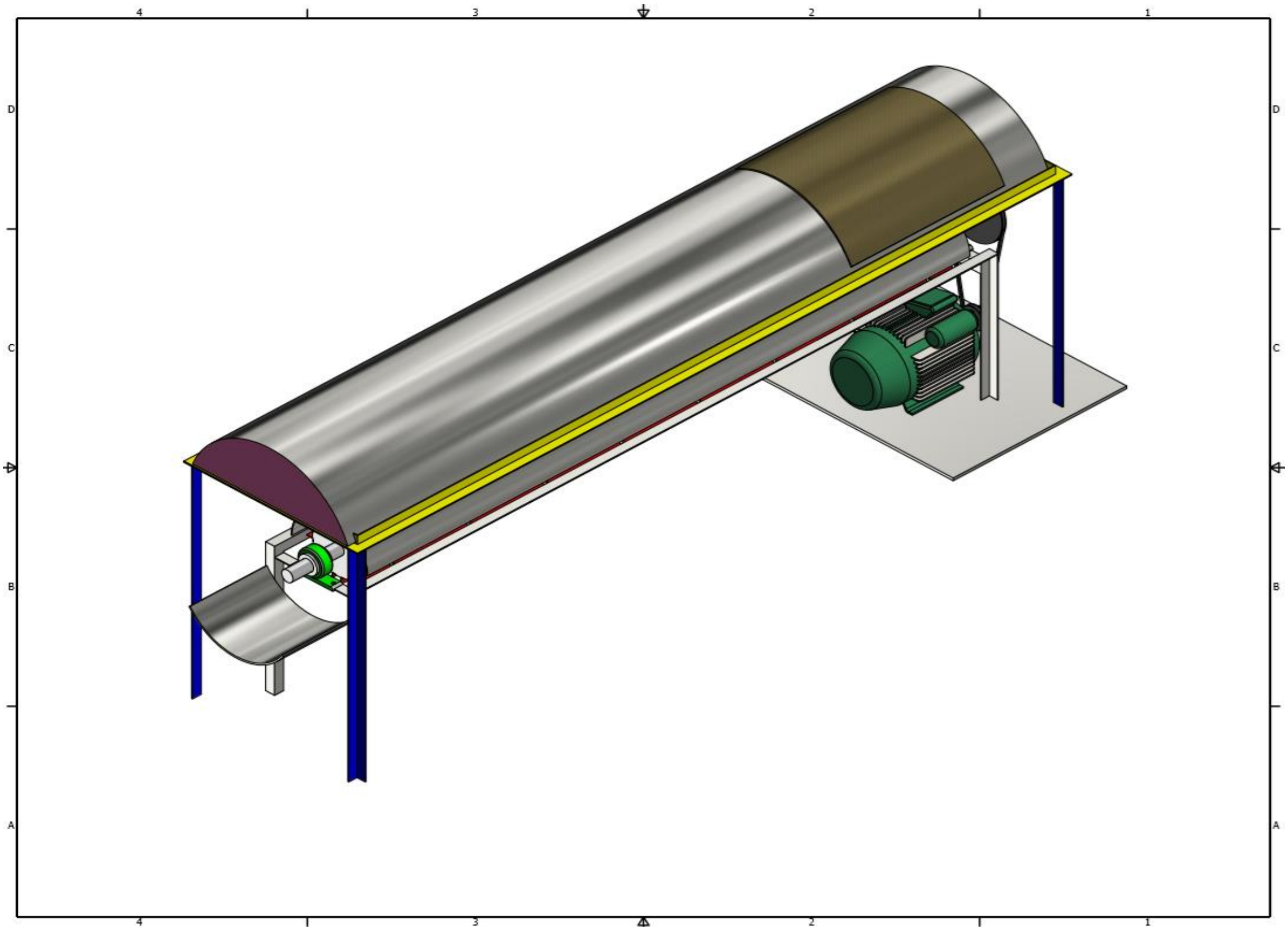
Figure 2: Isometric Drawing of an Automated cassava Peeler

2.4 Statistical Analysis

Statistical Package for Social Science (SPSS) window 21 versions was used to analyze the data generated from this study using Correlate Bivariate to compare the relationship between the physical properties of cassava tubers and cassava peeling machine performance evaluation parameters.

Table 1: Experimental design and treatments of tillage practices with TME 419 and 933.75 kg/ha of NPK 15:15:15 fertilizer

Treatments	Description	Codes
T1	Ploughing + Harrowing + TME 419 + Rainfed soil + 933.75 kg/ha of NPK 15:15:15 fertilizer	AV1RfdF3
T2	Ploughing + Harrowing + ridging + TME 419 + Rainfed soil + 933.75 kg/ha of NPK 15:15:15 fertilizer	BV1RfdF3
T3	Manual Ridging + TME 419 + Rainfed soil + 933.75 kg/ha of NPK 15:15:15 fertilizer	CV1RfdF3
T4	Zero or No-till + TME 419 + Rainfed soil + 933.75 kg/ha of NPK 15:15:15 fertilizer	DV1RfdF3
T5	Ploughing + Harrowing + Manual digging to a depth of 30 cm + 10 cm Sawdust placed at the base + TME 419 + Rainfed soil + 933.75 kg/ha of NPK 15:15:15 fertilizer	EV1RfdF3
T6	Ploughing + Harrowing + ridging +10 cm Sawdust placed at the base + TME 419 + Rainfed soil + 933.75 kg/ha of NPK 15:15:15 fertilizer	FV1RfdF3
T7	Manual Ridging + 10 cm Sawdust placed at the base + TME 419 + Rainfed soil+ 933.75 kg/ha of NPK 15:15:15 fertilizer	GV1RfdF3
T8	Manual Digging to a depth of 30 cm + 10 cm Sawdust placed at the base + TME 419 + Rainfed soil + 933.75 kg/ha of NPK 15:15:15 fertilizer	HV1RfdF3
T9	Ploughing + Harrowing + TME 419 + Irrigated soil + 933.75 kg/ha of NPK 15:15:15 fertilizer	AV1IrdF3
T10	Ploughing + Harrowing + ridging + TME 419 + Irrigated soil + 933.75 kg/ha of NPK 15:15:15 fertilizer	BV1IrF3

T11	Manual Ridging + TME 419 + Irrigated soil + 933.75 kg/ha of NPK 15:15:15 fertilizer	CV1IrF3
T12	Zero or No-till + TME 419 + Irrigated soil + 933.75 kg/ha of NPK 15:15:15 fertilizer	DV1IrF3
T13	Ploughing + Harrowing + Manual digging to a depth of 30 cm + 10 cm Sawdust placed at the base + TME 419 + Irrigated soil + 933.75 kg/ha of NPK 15:15:15 fertilizer	EV1IrF3
T14	Ploughing + Harrowing + ridging +10 cm Sawdust placed at the base + TME 419 + Irrigated soil + 933.75 kg/ha of NPK 15:15:15 fertilizer	FV1IrF3
T15	Manual Ridging + 10 cm Sawdust placed at the base + TME 419 + R Irrigated soil + 933.75 kg/ha of NPK 15:15:15 fertilizer	GV1IrF3
T16	Manual Digging to a depth of 30 cm + 10 cm Sawdust placed at the base + TME 419 + Irrigated soil + 933.75 kg/ha of NPK 15:15:15 fertilizer	HV1IrF3

where T is treatment, A is ploughing + harrowing, B is ploughing + harrowing + ridging, C is manual ridging, D is flat manual clearing, E is ploughing + harrowing + manual digging to a depth of 30 cm + 10 cm saw-dust placed at the base, F is ploughing + harrowing + ridging +10 cm saw-dust placed at the base, G is manual ridging + 10 cm saw-dust placed at the base, H is manual digging to a depth of 30 cm + 10 cm saw-dust placed at the base, TME is Tropical Manihot Esculenta, Rfd is Rainfed soil, F3 is 933.75 kg/ha of NPK 15:15:15 fertilizer and Ir is Irrigated soil.

Table 2: Determination of Physical Properties of Cassava Tubers

Property	Method or equation for determining of physical properties	References
Length	Measuring tape	[30]
Width	Digital vernier caliper	[30]
Thickness	Measuring three different segments of cassava tubers using digital vernier caliper	[30]
Size	$D_g = (abc)^{1/3}$	[7, 30]
Aspect ratio	$R_a = \frac{b}{a}$ 100%	[12]
Surface area	$S_a = \pi D_g{}^2$	[30, 41]
Sphericity	$S_p = \frac{(abc)^{1/3}}{a}$ 100%	[30, 41]
Roundness	$R_o = \frac{A_P}{A_C}$	[30, 41]
Angle of repose	The apparatus consisting of plywood box with a fixed stand attached with a protractor and an adjustable plate at the surface	[37]
Coefficient of friction	$\mu = \tan \alpha$	[30, 41]
Mass	A digital weighing balance 10 kg was used in weighing each of the cassava tubers	[30, 41]
Volume	By putting a known mass of a (unit) sample into cylindrical container of water, change in level of the liquid in the cylinder gives the unit volume	[36]
True density	$\rho_t = \frac{W_t}{V_t}$	[40, 5]
Bulk density	$\rho_b = \frac{W_s}{V_s}$	[7, 41]
Bulk mass	By weighing together all the cassava in a bucket	[30]
Bulk volume	The whole sample in a stand was put into the cylindrical container of water, and the change in level of the liquid in the cylinder	[36]
Porosity	$\varepsilon = (1 - \frac{\rho_b}{\rho_t})$ x 100	[7]

D_g is equivalent diameter; a is length; b is width and c is thickness, R_a is aspect ratio; S_a is surface area; S_p is sphericity; R_o is roundness; A_p is largest projected area of object in natural resting position; A_c is area of smallest circumscribing circle; μ is coefficient of static friction and α is angle of repose; ρ_t is true density; W_t is true weight; V_t is true volume; ρ_b is bulk

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density in kg/m^3; W_s is weight of sample in kg; V_s is volume occupied by sample in m^3; ε is porosity, ρ_t is true density and ρ_b is bulk density.

3. RESULTS AND DISCUSSION

3.1 Effect of Different Tillage Practices on Physical Properties of Cassava Tubers

The effect of different tillage practices on physical properties of cassava tubers are presented in Figures 2, 3, 4, 5, 6, 7, 8 and 9 respectively. The results revealed that different tillage practices had significant effect on the physical properties of cassava tubers such as the length (L), width (W), thickness (T), size (DG), sphericity, (SP), aspect ratio (AR), porosity (P), roundness (R), surface area (SA), true density (TD), bulk density (BD), bulk mass (BM), static friction coefficient (CF) and angle of repose (AP). This implies that the various tillage practices used in cultivating cassava by farmers will in turn have significant effect on the physical properties of cassava tubers. Different tillage practices used in growing cassava results in variation in engineering properties especially the physical properties of cassava tubers. However, it has been reported by different researchers that variation in engineering properties of cassava tubers has been the major challenge and bottle neck in development of an effective and efficient cassava handling and processing equipment and machines toward the full automation of cassava processing. Different tillage practices adopted which resulted in disparities the physical properties of cassava tubers might be caused by ecological features such as relative humidity, temperature, rainfall, soil type, soil moisture, soil acidity, soil fertility, and vegetation of the farm. The tillage practice adopted also constitutes a major effect on the physical characteristics of a typical cassava tubers. Tillage holds all processes of seedbed arrangements that enhance soil and ecological environments for crop growth from seedling to maturity stage. Tillage provides a seedbed of good tilth, add humus and fertility to the soil by covering vegetation and manure, destroy the weeds and prevent their growth, leave the soil in such a condition that air will circulate freely and retain moisture from rain, destroy insects and their eggs, larvae and their breeding places, leave the surface in a condition to prevent erosion by wind. Tillage prepared a good seedbed in which if the crop is placed can get suitable condition for development and growth. [32] reported that environmental factors which vary from one planting place to another include soil type, soil moisture, temperature, relative humidity, rainfall, soil acidity, vegetation and soil fertility of the farm could influence the tuber properties that intrude on their peeling. The results corroborate result found by other scientists [25, 35].

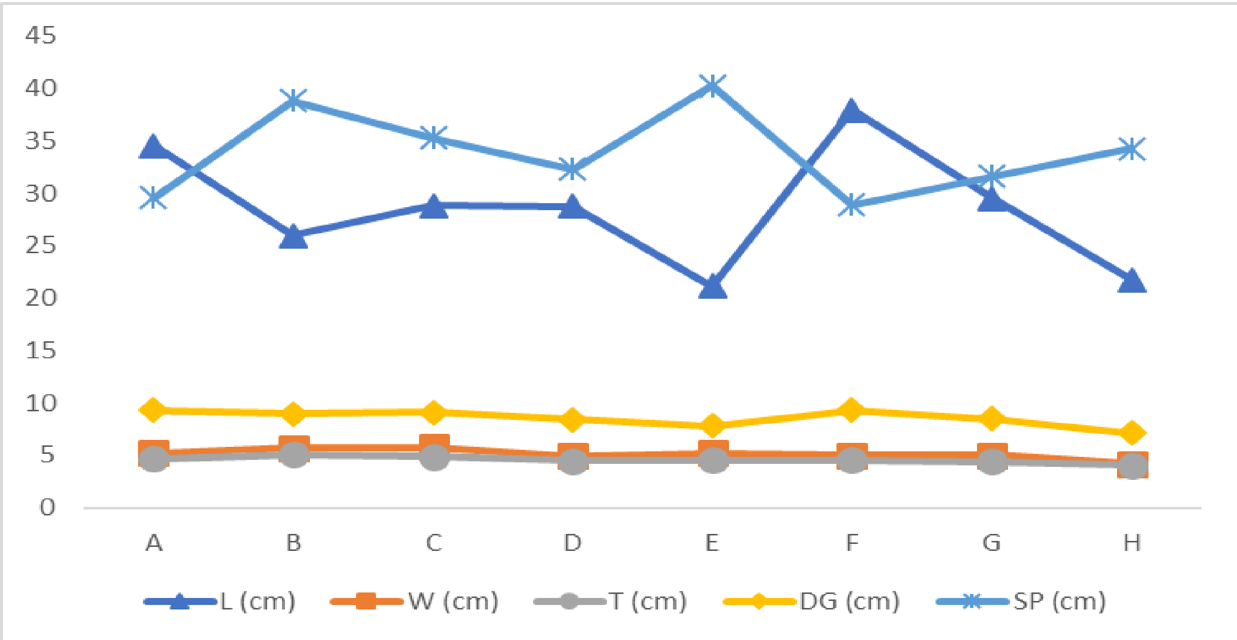

Figure 3: Effect of Tillage Practices on Length (L), Width (W), Thickness (T), Size (DG) and Sphericity (SP) of TME 419 Cassava Tubers for a Rain Fed Soil + 933.75 Kg/Ha Fertilizer for 2014/2015 Planting Season.

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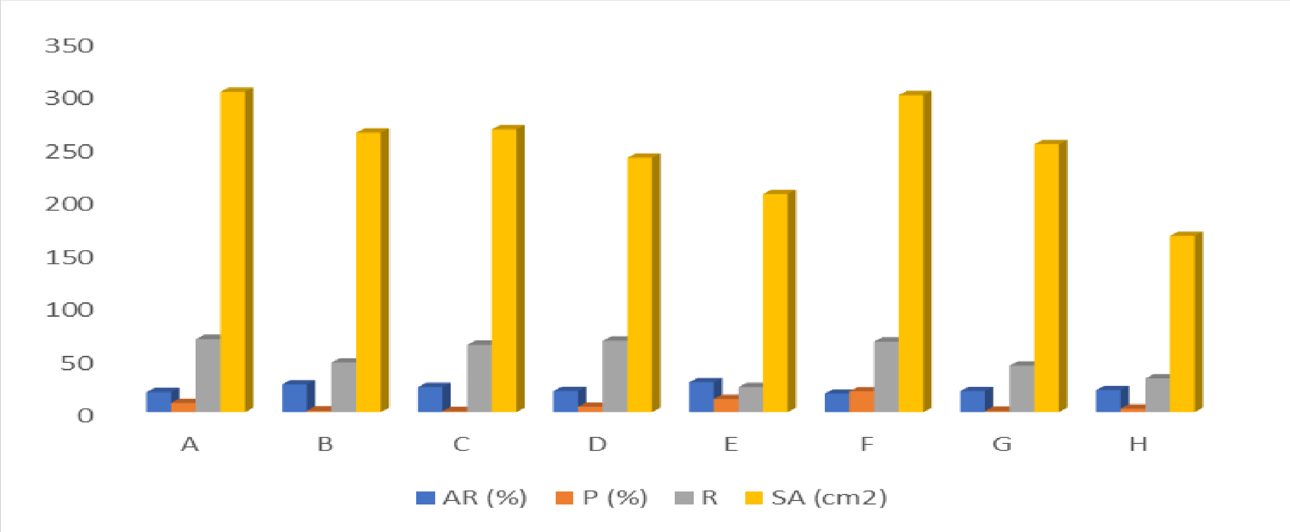

Figure 4: Effect of Tillage Practices on Aspect Ratio (AR), Porosity (P) and Surface Area (SA) of TME 419 Cassava Tubers for a Rain Fed Soil + 933.75 Kg/Ha Fertilizer for 2014/2015 Planting Season.

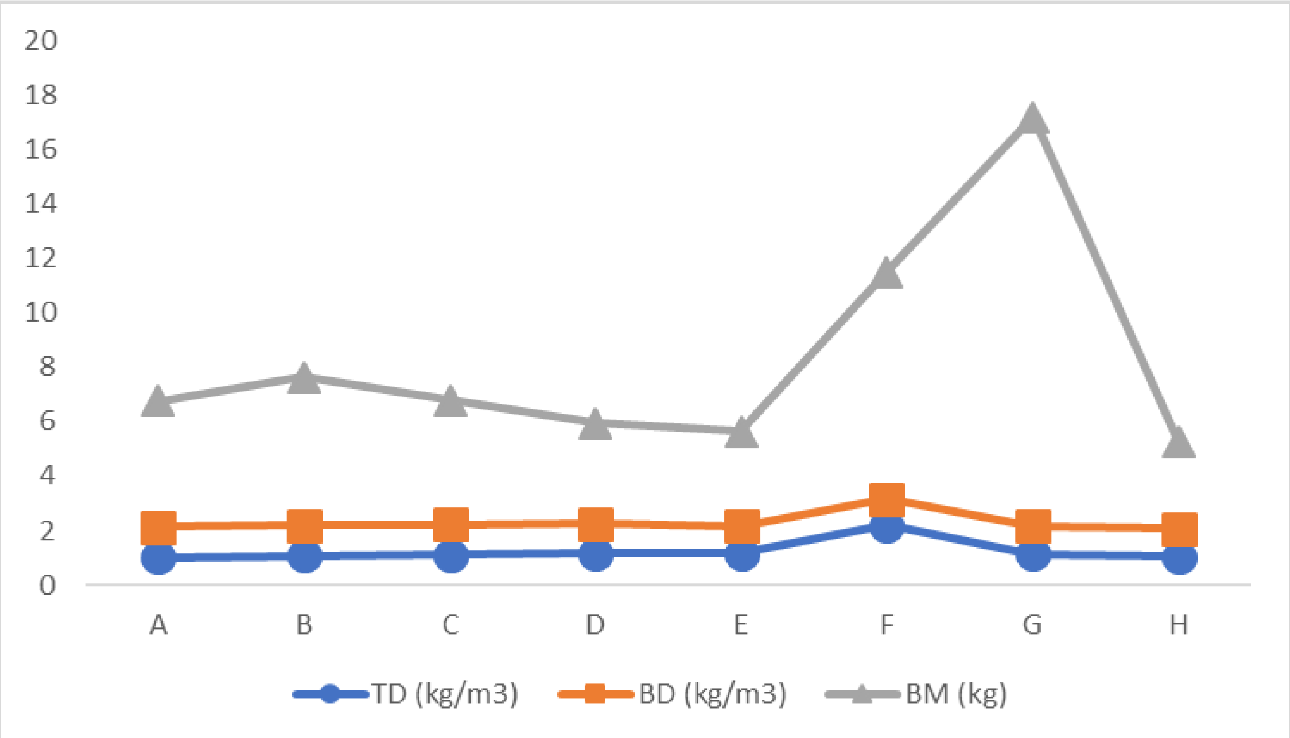

Figure 5: Effect of Tillage Practices on True Density (TD), Bulk Density (BD) and bulk mass (BM) of TME 419 Cassava Tubers for a Rain Fed Soil + 933.75 Kg/Ha Fertilizer for 2014/2015 Planting Season.

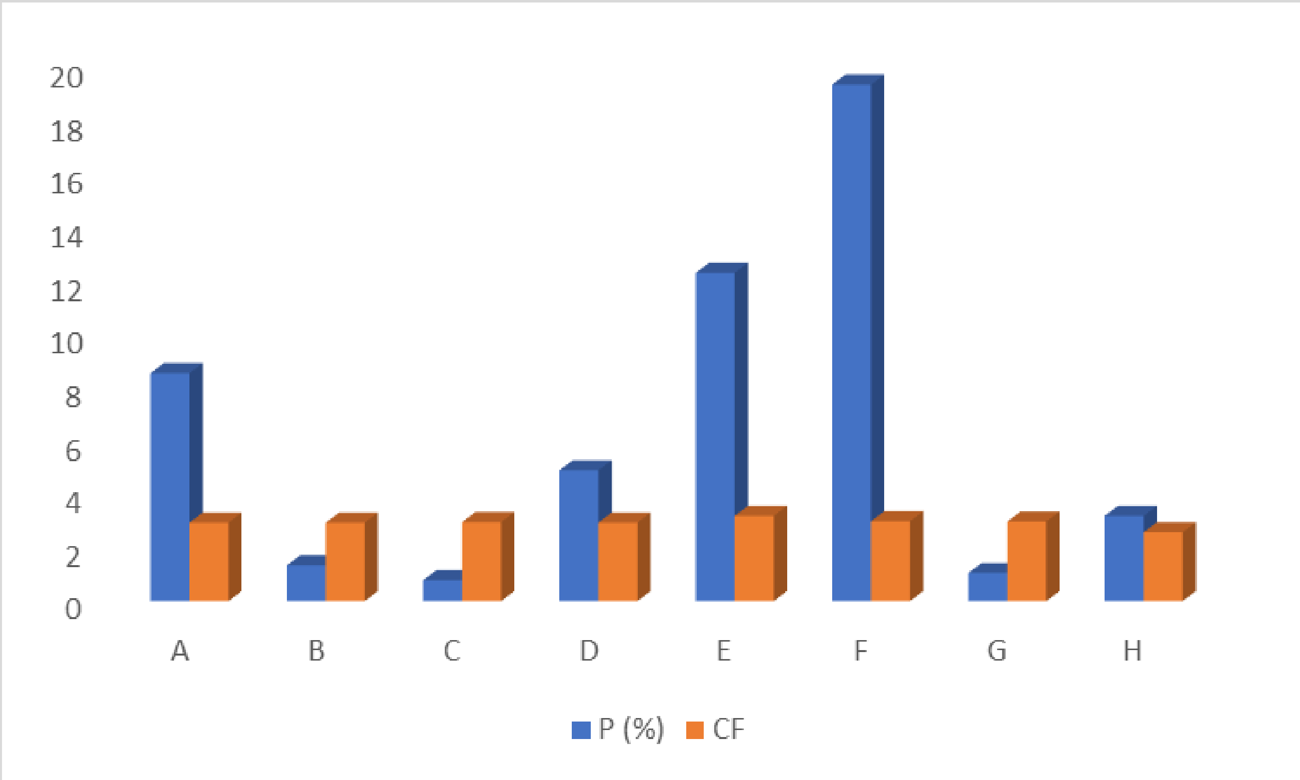

Figure 6: Effect of Tillage Practices on Porosity (P) and Coefficient of Static Friction (CF) of TME 419 Cassava Tubers for a Rain Fed Soil + 933.75 Kg/Ha Fertilizer for 2014/2015 Planting Season.

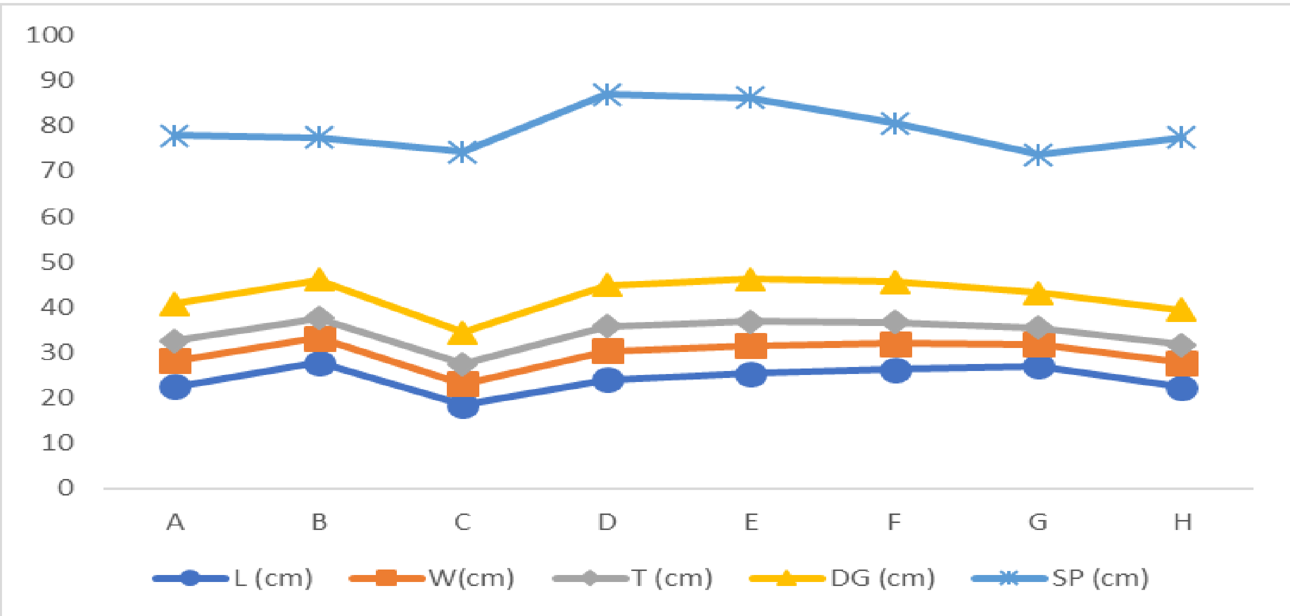

Figure 7: Effect of Tillage Practices on Length (L), Width (W), Thickness (T), Size (DG) and Sphericity (SP) of TME 419 Cassava Tubers for an Irrigated Soil + 933.75 Kg/Ha Fertilizer for 2014/2015 Planting Season.

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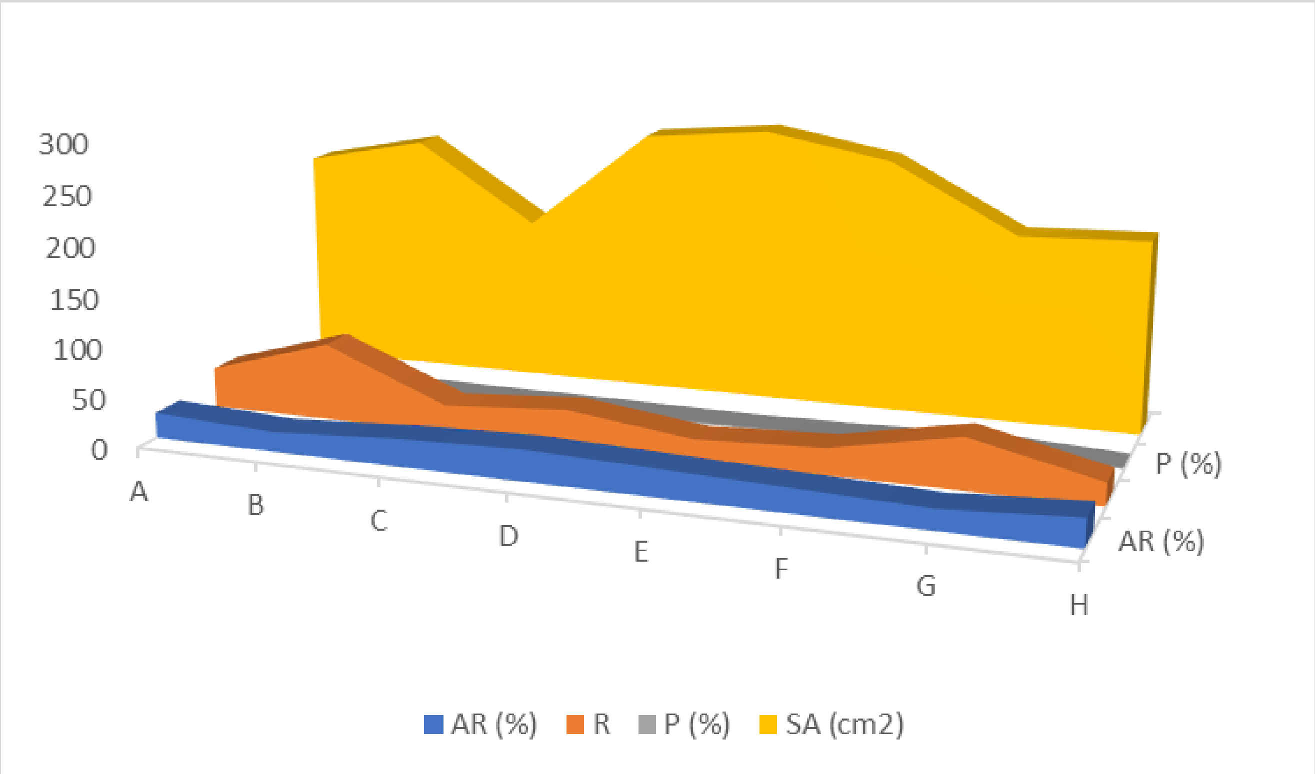

Figure 8: Effect of Tillage Practices on Aspect Ratio (AR), Porosity (P) and Surface Area (SA) of TME 419 Cassava Tubers for an Irrigated Soil + 933.75 Kg/Ha Fertilizer for 2014/2015 Planting Season.

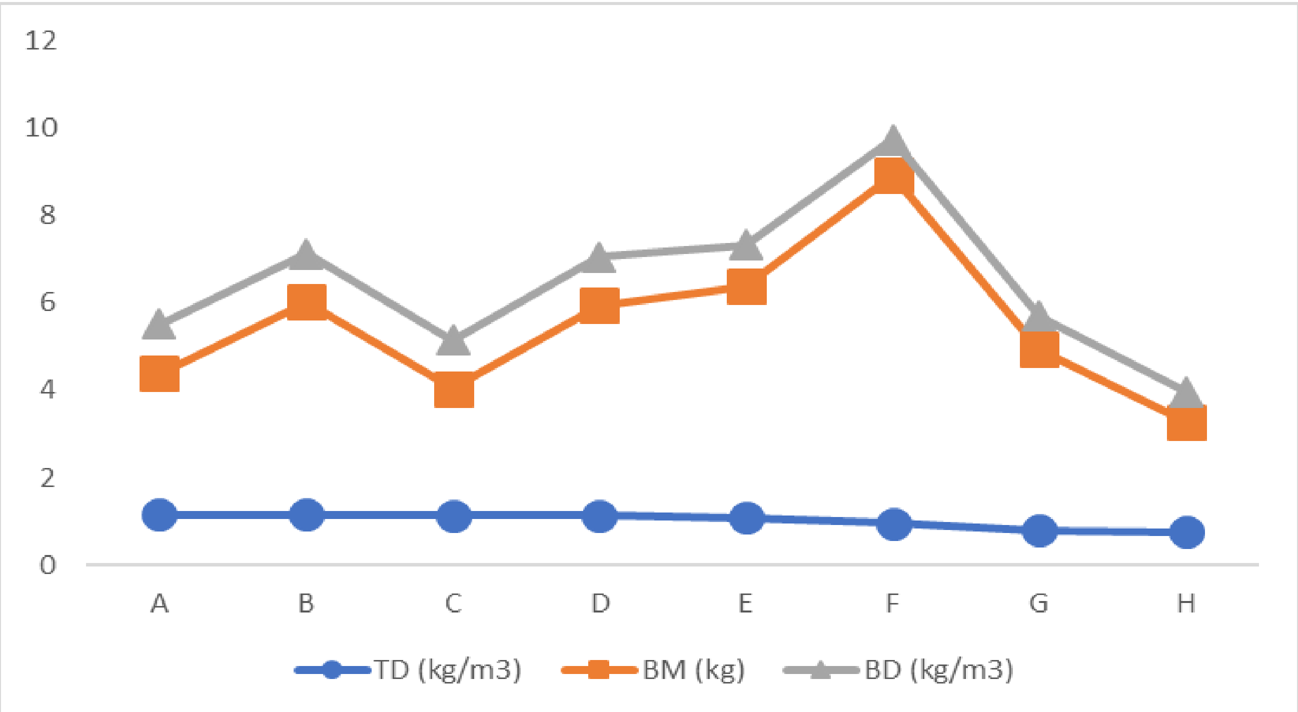

Figure 9: Effect of Tillage Practices on True Density (TD), Bulk Density (BD) and Bulk Mass (BM) of TME 419 Cassava Tubers for an Irrigated + 933.75 Kg/Ha Fertilizer for 2014/2015 Planting Season.

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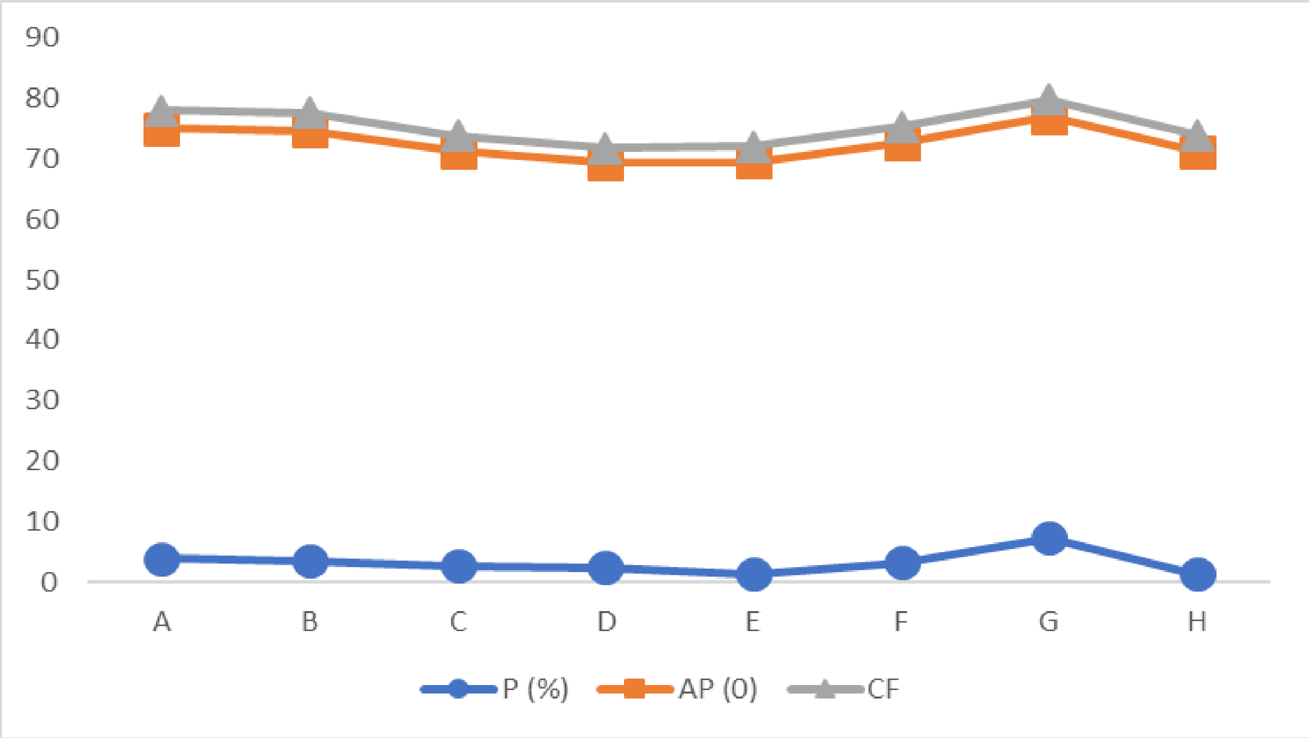

Figure 10: Effect of Tillage Practices on Porosity (P), Angle of Repose (AP) and Coefficient of Static Friction (CF) of TME 419 Cassava Tubers for a Irrigated Soil + 933.75 Kg/Ha Fertilizer for 2014/2015 Planting Season.

3.2 Effect of Different Treatments on the Performance Evaluation of the Cassava Peeling Machine

The effect of different treatments on the performance evaluation of the cassava peeling machine are presented in Figures 9 and 10 respectively. The results revealed that there were variations in the machine performance evaluation parameters due to different tillage practices used in cultivating cassava tubers. The peeling efficiency, percentage of broken tubers, percentage of flesh loss from tuber, machine capacity, mass of unpeeled patches and material recovery ranged from 28.05-92.88 %, 15.00-46.69 %, 8.78-42.88 %, 0.48-0.58 tons/h, 0.46-1.82 % and 69.56-92.55 % respectively. The maximum peeling efficiency, percentage of broken tubers, percentage of flesh loss from tuber, machine capacity, mass of unpeeled patches and material recovery were recorded in T7 (Manual Ridging + 10 cm Saw-dust placed at the base + TME 419 + Rainfed soil+ 933.75 kg/ha of NPK 15:15:15 fertilizer), T16 (Manual Digging to a depth of 30 cm + 10 cm Sawdust placed at the base + TME 419 + Irrigated soil + 933.75 kg/ha of NPK 15:15:15 fertilizer), T11 (Manual Ridging + TME 419 + Irrigated soil + 933.75 kg/ha of NPK 15:15:15 fertilizer), T2 (Ploughing + Harrowing + ridging + TME 419 + Rainfed soil + 933.75 kg/ha of NPK 15:15:15 fertilizer), T3 (Manual Ridging + TME 419 + Rainfed soil + 933.75 kg/ha of NPK 15:15:15 fertilizer) and T7 (Manual Ridging + 10 cm Saw-dust placed at the base + TME 419 + Rainfed soil+ 933.75 kg/ha of NPK 15:15:15 fertilizer) while the minimum were recorded in T6 (Ploughing + Harrowing + ridging +10 cm Sawdust placed at the base + TME 419 + Rainfed soil + 933.75 kg/ha of NPK 15:15:15 fertilizer), T9 (Ploughing + Harrowing + TME 419 + Irrigated soil + 933.75 kg/ha of NPK 15:15:15 fertilizer), T1 (Ploughing + Harrowing + TME 419 + Rainfed soil + 933.75 kg/ha of NPK 15:15:15 fertilizer), T14 (Ploughing + Harrowing + ridging +10 cm Sawdust placed at the base + TME 419 + Irrigated soil + 933.75 kg/ha of NPK 15:15:15 fertilizer), T7 (Manual Ridging + 10 cm Saw-dust placed at the base + TME 419 + Rainfed soil+ 933.75 kg/ha of NPK 15:15:15 fertilizer) and T11 (Manual Ridging + TME 419 + Irrigated soil + 933.75 kg/ha of NPK 15:15:15 fertilizer) respectively. Variation in physical properties which resulted in disparities among the machine performance evaluation parameters might be caused by ecological features such as relative humidity, temperature, rainfall, soil type, soil moisture, soil acidity, soil fertility, and vegetation of the farm. The tillage practice adopted also constitutes a major effect on the physical characteristics of a typical cassava tubers. Tillage holds all processes of seedbed arrangements that enhance soil and ecological environments for crop growth from seedling to maturity stage. Tillage provides a seedbed of good tilth, add humus and fertility to the soil by covering vegetation and manure, destroy the weeds and prevent their growth, leave the soil in such a condition that air will circulate freely and retain moisture from rain, destroy insects and their eggs, larvae and their breeding places, leave the surface in a condition to prevent erosion by wind.

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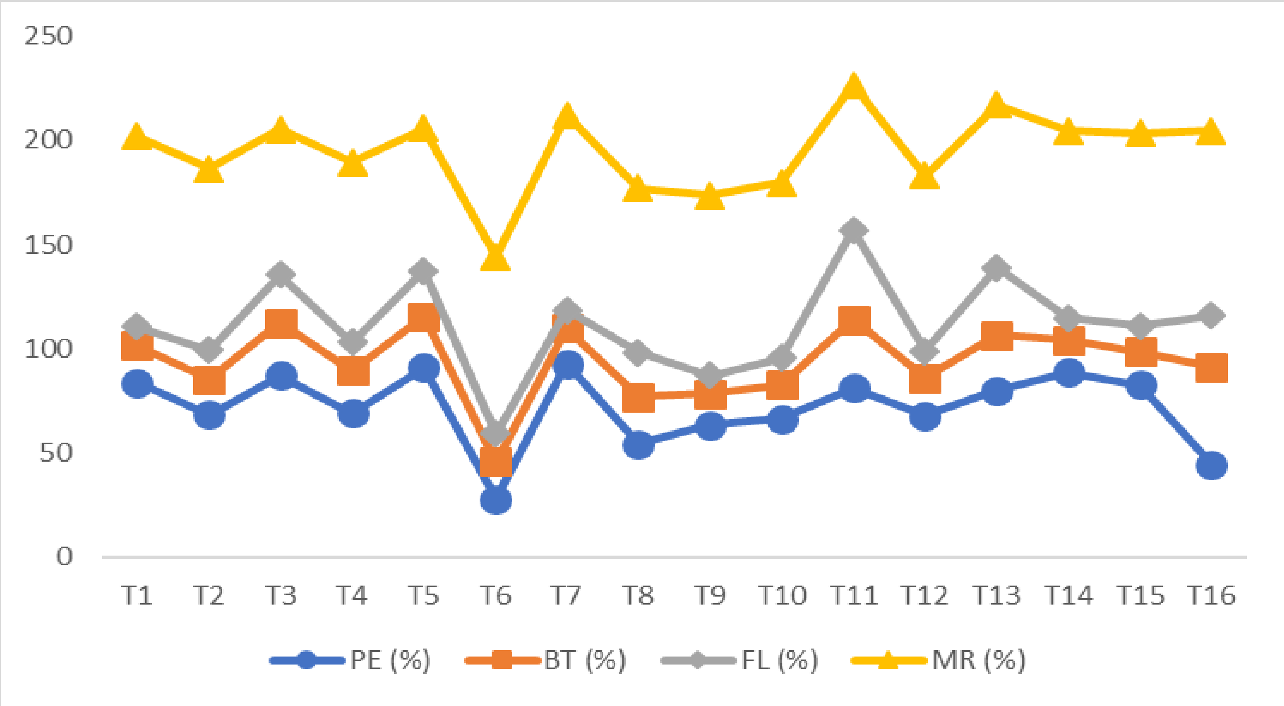

Figure 11: Effect of Different Treatments on the Performance Evaluation of the Cassava Peeling Machine

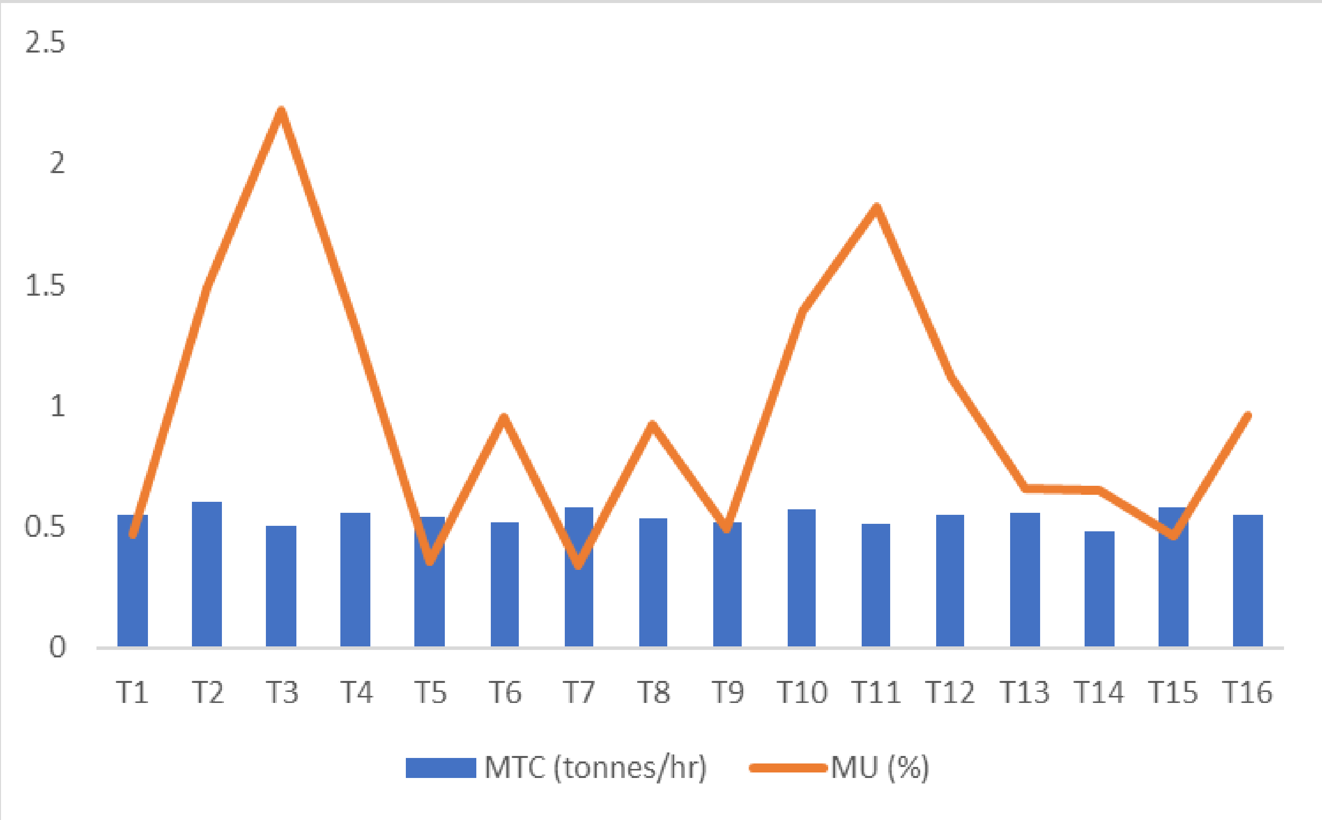

Figure 12: Effect of Different Treatments on the Performance Evaluation of the Cassava Peeler.

3.3 Influence of Size of Cassava Tubers on Cassava Peeler Performance Evaluation Parameters

The results in Table 3 revealed that as the size increases the machine throughput capacity, mass of unpeeled patches and material recovery increase whereas peeling efficiency, percentage of broken tubers and percentage flesh loss from the tuber decrease the size of cassava tuber increases. Size having a drastic effect on cassava peeler performance evaluation parameters might be variation in soil characteristics and tillage practices which might have caused irregularity in the size of cassava tubers. Tillage prepared a good seedbed in which if the crop is placed can get suitable condition for development and growth.

[32] reported that environmental factors which vary from one planting place to another include soil type, soil moisture, temperature, relative humidity, rainfall, soil acidity, vegetation and soil fertility of the farm could influence the tuber properties that intrude on their peeling. The results corroborate result found by other scientists [25, 35].

3.4 Effect of Sphericity of Cassava Tubers on Cassava Peeler Performance Evaluation Parameters

Sphericity is defined as ratio of surface of a sphere having the same volume as the particle to the surface of that particle [41]. Table 3 shows that as the sphericity increases the percentage of broken tubers, machine throughput capacity, mass of unpeeled patches and material recovery increase whereas peeling efficiency and percentage flesh loss from the tuber decrease as the as the sphericity of cassava tuber increases. Variation in sphericity which had influence on cassava peeler performance evaluation parameters might be caused by the soil characteristics and tillage practice adopted for planting. Climatic factors which vary from one planting place to another, such factors include; relative humidity, temperature, rainfall, soil type, soil moisture, soil acidity, vegetation and soil fertility of the farm [32] can also affect the tuber engineering properties that intrude on their peeling. Generally, tillage practice impacts rising drive of moisture to the soil surface, vapour transfer from surface to troposphere, heat transfer to the soil, delivers a perfect prospect to break up nutrients designed in the deep zones of soil, pathogen cycles and disrupts pests. Earlier study by [4, 22] also supports the results of this study.

3.5 Effect of Roundness of Cassava Tubers on Peeler Performance Evaluation Parameters

Roundness could be defined as the ratio within the inscribed and the circumscribed circles, i.e. the highest and lowest sizes for circles that are mere enough suitable inside and to encompass the outline [31, 30]. Table 3 reveals that as the roundness of cassava tubers increases peeling efficiency and percentage flesh loss from the tuber increase whereas the percentage of broken tubers, machine throughput capacity, mass of unpeeled patches and material recovery decrease as the as the roundness of cassava tuber increases. Difference in roundness of the cassava that impose on the cassava peeler performance evaluation parameters might likely due to variation in soil characteristics, environmental conditions and tillage practice adopted. Tillage practice advances the physical state of the soil by manipulating and pulverizing. It also contributes to pest control by destroying some perennial weeds, unruly the life cycle of more or essential organisms. However, it is believed that conventional tillage generates more bacterial activity. Climatic conditions which vary from one place to another may influence cassava tubers engineering properties which might intrude the efficiency of a typical cassava peeler. These results agree with findings of [32, 25, 35], who discovered anomaly of the tubers among various varieties of the crop.

3.6 Effect of Bulk Mass of Cassava Tubers on Peeler Performance Evaluation Parameters

The results presented in Table 3 revealed that as the bulk mass of cassava tubers increases peeling efficiency, machine throughput capacity, mass of unpeeled patches and material recovery increase whereas the percentage of broken tubers and percentage flesh loss from the tuber decrease as the bulk mass of cassava tuber increases. Discrepancy in bulk mass of cassava tubers which has a drastic effect on cassava peeler performance evaluation parameters is greatly influenced by the climatic conditions of that location, the tillage practice adopted for planting as well as the variety of the cassava stem. Tillage method used by farmers have influence on the yield of the crop as well as proper management of the land. Proper land management method aids in increasing soil nutrient by retaining the crop scum to enhance the sustainability of organic material which will result in high crop yield and abundance of food production. There is therefore the necessity for a proper and effective tillage practice methods for surplus production and greater yield of crop. Tillage practice has influence on cassava yield Unsuitable tillage practices may decrease crop development and produce. Whereas, selection of a proper tillage practice for crop production is very significant for best growth and yield. The term tillage used broadly, embraces all operations of seedbed preparations that optimize soil and environmental conditions for proper growth and development of the crop from seedling to maturity stage [26]. [9] found a positive influence of rainfall on cassava production of the Guinea Savanna portion of Nigeria. In disparity to the results by [20, 9]. [13] also discovered a positive influence of rising temperature on cassava produces in Nigeria, but a negative outcome of rising rainfall. Planting on time in rainy season will usually produce the maximum produces since plants have enough soil water during the major important part of their development cycle. However, study had found out that yields may vary conferring to variety utilized, soil type, plant age at maturity, dispersal throughout any year and rainfall intensity [39]. These results are similar with the results of other researchers [10, 11, 8].

3.7 Effect of Aspect Ratio of Cassava Tubers on Peeler Performance Evaluation Parameters

Aspect ratio of an image describes the proportional relationship within its width and height [12]. Table 3 revealed that as the aspect ratio increases the percentage of broken tubers, machine throughput capacity, mass of unpeeled patches and material recovery increases whereas peeling efficiency and percentage flesh loss from the tuber decreases as the as the aspect ratio of cassava tuber increases. Disparity in aspect ratio of cassava tubers which impinge on the performance evaluation parameters of the cassava peeler might have been caused by physico-chemical properties of the soil, climatic factors and tillage practice. Tillage is a progression of physical handling of the soil to attain suitability of tilt, non-natural porosity, airing, weed control, evenness, friability and optimal wetness gratified to enable sowing and covering of seed [26]. Tillage practice release the soil and integrate materials at the surface (fertilizers, amendments, weeds, etc.), followed by two secondary passes to form an acceptable seedbed. These results agree with the ones reported by [27, 19]. [23] reported that tillage practices had influence on physicochemical characteristics of soil.

3.8 Effect of Surface Area of Cassava Tubers on Peeler Performance Evaluation Parameters

The surface area of a material is a measure of the total that the surface of the material occupies. Smooth surfaces, such as a sphere, are assigned surface area [41, 30]. Table 3 revealed that as the surface area increases the machine throughput capacity, mass of unpeeled patches and material recovery increase whereas peeling efficiency, percentage of broken tubers and percentage flesh loss from the tuber decrease as the as the surface area of the cassava tuber increases. Dissimilarity in the surface area of the cassava tubers which intrude on the performance evaluation parameters of cassava peeler could be because of tillage practice adopted, soil factors and environmental factors. Generally, tillage practice prepared a fine seedbed for ideal germination and better start of the seedlings. Earlier study by [27, 35] is like the findings in this research, who observed wide variations in the thickness of the peel across different varieties of the crop.

3.9 Effect of Unit Mass of Cassava Tubers on Peeler Performance Evaluation Parameters

Table 3 revealed that as the mass of cassava tubers increases machine throughput capacity, mass of unpeeled patches and material recovery increase whereas the peeling efficiency, the percentage of broken tubers and percentage flesh loss from the tuber decrease as the mass of cassava tuber increase. Effect of unit mass of cassava tubers on peeler performance evaluation parameters. Variation in unit mass constitute a major hindrance in cassava peeler performance evaluation parameters. Basically, disparity in unit mass could be because of variety, soil factors, climatic conditions and tillage practice adopted. Tillage is the rudimentary operation in agriculture. It is usually carried out to produce a suitable environment for seed planting and proper growth of plant. These operations include ploughing, harrowing and mechanical destructions of weeds and soil crust, etc. Throughout history substantial advance has been made in the enhancement of tillage tools. The advancement of a country matches the growths of the tillage tools cast-off in the tilling of its soil [28]. Cassava can endure phases of drought but very subtle to soil moisture shortage throughout the first three months after planting. Moisture stress at any time in that early period diminishes meaningfully the development of roots and shoots, thus damages successive growth of storage roots. In most parts of the world, cassava is almost exclusively a rain-fed crop. In locations with just one rainy season yearly, farmers generally plant early once the rains start. Late planting can result to severe yield falls. In locations with two moderately brief rainy seasons yearly, cassava could be planted in the early or mid-part of either rainy period and reaped after 10 to 14 months, usually in the dry season [39]. Planting as soon as rainy season commence will usually produce the maximum yields since the plants have enough soil water during the utmost serious portion of their development cycle. Moreover, study revealed that yields may differ conferring to the variety, soil type, plant's age at maturity, and rainfall intensity and distribution throughout any year. Planting methods must be patterned to soil moisture environments with rain-fed production. If the soil is not properly drained and wet because of heavy rains, it is advisable to plant stakes on top of ridges or mounds to have the roots overhead standing water [39]. Researchers have shown that cassava variety produced tubers with varying quality of roots at differing maturity duration and storage in the ground. These improved varieties always gave high yields Farmers preferred improved varieties due to their higher yields, earlier maturity, high suppression of weeds, and greater resistance to diverse diseases and pests [5].

3.10 Effect of Porosity of Cassava Tubers on Peeler Performance Evaluation Parameters

Porosity of the solid mass governs the resistance to flow in the dryer and dictates the thickness of the layers which can be dried safely, and the type of blower needed [25]. Table 6 revealed that as the porosity of the cassava tubers increases machine throughput capacity, mass of unpeeled patches and material recovery increase whereas the peeling efficiency, percentage of broken tubers and percentage flesh loss from the tuber decrease as the porosity of the cassava tuber increases. Discrepancy in porosity of the cassava tubers might be due to tillage practice adopted and environmental factors. Tillage practice advances the physical condition by manipulating and pulverizing the soil, which provides appropriate setting for growth and development, free oxygen and accessibility of soil moistness and vital nutrients to plants. These results are in line with that of the findings of [4], who found out varied disparities in the thickness of the peel across diverse varieties of the crop.

Table 3: Effect of Physical Properties of Cassava Tubers on Performance of Cassava Peeler

	PE	BT	FL	MTC	MU	MR
Size	-0.48	-0.42	-0.63*	0.35	0.61*	0.63*
Sphericity	-0.39	0.21	-0.33	0.09	0.21	0.33
Roundness	0.39	-0.19	0.26	-0.09	-0.22	-0.26
Bulk mass	0.07	-0.16	-0.29	0.86**	0.47	0.29
Length	0.02	-0.39	-0.15	0.13	0.20	0.15
Width	-0.65**	-0.28	-0.74**	0.30	0.62*	0.74**

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Thickness	-0.58*	-0.26	-0.68**	0.41	0.68**	0.68**
Aspect ratio	-0.38	0.18	-0.34	0.07	0.18	0.34
Surface area	-0.44	-0.36	-0.61*	0.41	0.62*	0.61*
Mass	-0.50	-0.26	-0.62*	0.58*	0.69**	0.62*
Volume	-0.37	-0.24	-0.48	0.62*	0.66**	0.48
True density	-0.40	-0.30	-0.51	0.00	0.12	0.51
Bulk density	-0.30	0.05	-0.34	-.020	0.18	0.34
Bulk volume	0.12	-0.12	-0.21	0.84**	0.41	0.21
Angle of repose	0.19	-0.24	-0.13	0.29	0.41	0.13
Coefficient of friction	0.23	-0.24	-0.08	0.28	0.45	0.08
Porosity	-0.32	-0.44	-0.36	0.14	0.15	0.36

where PE is the peeling efficiency, BT is the percentage of broken tubers, FL is the percentage of flesh loss from tuber, MTC is the machine throughput capacity, MU is the mass of unpeeled patches and MR is the material recovery.

4. CONCLUSION

The study found out that the physical properties of cassava tubers had influence on the performance of an automated cassava peeler. Manual ridging gave the highest peeling efficiency of 92.88 %. Thus, it is necessary to carefully choose suitable and appropriate tillage practice that will enhance uniform physical properties of cassava tubers that can enhance the optimum and greater performance of an automated cassava peeler. The information provided in this research will be useful in designing more appropriate and efficient cassava peelers which will enhance automation and mechanization of processing cassava tubers preferably to useful cassava products. From the data collected, it was not possible to determine the effect of the peeling tools on the quality of the products. Further studies are therefore necessary to determine the effects of peeling tools on the quality of the products.

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