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Development of HTU-model variable chipping clearance cassava chipper

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Abstract: The objective of this research was to design, construct and evaluate a variable chipping clearance cassava chipper for processors which will produce uniform and varying cassava chip geometry for multipurpose usage. It consists of a drive shaft with varying chipping clearances (6, 18, and 28 mm) to produce varied chip geometry. The average throughput capacity of the chipper was found to be 475.5 kg·h^{-1} at a speed range of 460–800 rpm with a chipping clearance of 6–28 mm. The average chipping efficiency ranges from a minimum–maximum of 76.6–99.4% for the selected operational speeds and chipping clearances. The chipping capacity and the output to input ratio is dependent on the operational speeds and chipping clearances of the machine.

Keywords: cassava roots; efficiency; moisture content; operational speed; throughput capacity

The cassava (*Manihot esculenta* Crantz) is one of the starchiest root tuber crops grown globally. Currently, cassava plantations are experiencing a transition from a mere subsistent crop found on the field of peasants to a commercially grown crop due to its versatile usage. The crop is a crucial element in the diet of over one billion people worldwide. This incomparable expansion of the crop is ascribed to its discovery as an economical source of edible carbohydrates that can be processed into different varieties. Andoh (2010) posits that the cassava crop accounts for 22% of Ghana's Agricultural Gross Domestic Product (AGDP). The cassava is a vital industrial raw material used for production of starch, bioethanol, flour and chips (Rañola et al. 2009). Statistics divulge that 35%–40% of the cassava root cultivated in Ghana are lost after harvesting due to post-harvest physiological deterioration (PPD) (FAO 2011). This PPD is initiated in the roots immediately after they are cut from the parent stock, the entire root begins to oxidise and blackens within two to three days after harvest, rendering it unpalatable and useless (Adjekum 2006). The high moisture content (65%) of the roots also poses a great challenge, as it makes the roots highly perishable (Igbeka et al. 1992). To minimise the deterioration in cassava roots, Igbeka et al. (1992) assert that it is imperative to process the roots as soon as they are harvested. The best form of preservation and reduction of post-harvest losses is, therefore, the immediate processing into various shelf-stable products such as gari, chips, pellets and flour. Prompt processing is crucial to avert the poisonous cyanide stored in the raw cassava roots making it tasteless. The manual method of processing cassava roots into chips is very laborious and ineffective, compounded with uneven chip sizes due to the inability to regulate chip sizes which affects drying. Not only is the rate of drying affected, but also the quality of the dried

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chips produced is not commensurate with the standards required by customers due to ineffective and efficient drying emanating from uneven symmetrical sizes. To obtain symmetry, the even and fast drying of the chips requires a well-designed chipper. Okechukwu et al. (2012) reported that the appropriate processing of the cassava root changes its form into a safer and reliable market value, extends the shelf-life thereby reducing post-harvest losses. Adejuyigbe and Bolaji (2005) assert that for agricultural mechanisation in tropical and the sub-tropical regions to be sustainable, it must be centred on the local design and construction of relevant agro-processing machinery to warrant their appropriateness. Several attempts have been made at solving these problems which have resulted in the development of various types of cassava chipping machines (Bamgboye and Adebayo 2009). The existing mechanically operated cassava chipping machines usually have a fixed chipping clearance with variable speed levels for their operations. The general consideration for designing a variable chipping clearance cassava chipper (VC^4) is another innovation aimed at creating and obtaining variable chip geometry sizes to meet customer's preferences; hence, the main objective of this research was to design, construct, and evaluate a variable chipping clearance cassava chipper.

MATERIAL AND METHODS

Design consideration and material selection. The method used for the design was based on the existing theories with modifications on the main drive shaft to obtain a variable clearance for variability in the chip geometry. The chipper is suitable for medium scale processors, manufactured from locally available materials, and is not for its ease of operation and maintenance, as well as its variable chip size changeover. The materials chosen for the construction, as listed in Table 1, were based on their mechanical properties, corrosion resistance, ease of working, and availability.

Instruments and equipment used. A digital weighing balance (Model YH-T7E) having a measuring range of 6 000 g (a scale of 0.001 g), was used to determine the mass of the cassava roots and chips. The respective dimensions of the sampled cassava roots were measured using a steel measuring tape (5 000 mm). A digital tachometer (Model DT-2236B) photo-contact was used to determine the operating speeds of the chipping drum. The chipping time was obtained with the use of a digital stop clock. A stainless-steel knife was used for the residual peeling, while plastic buckets and bowls were used to wash the peeled roots and collect the chipped roots. The following equipment was also used for the construction: an electric welding machine, an electric grinder, etc.

Design analysis. The power required to chip the cassava is based on Equation (1) (Bolaji et al. 2008).

$$Power = R_t V_D = R_t\left(\omega_s R_D\right) \tag{1}$$

Also, $power = R_t \dfrac{2\pi N_S}{60} \times \left(\dfrac{R_D}{1000}\right)$

where: R_t – required force (N); V_D – velocity of the chipping drum ($m \cdot s^{-1}$); ω_s – speed of the shaft ($rad \cdot s^{-1}$); R_D – radius of the chipping drum (mm); N_S – rotational speed of shaft ($rev \cdot m^{-1}$)

The required force (R_t) to chip the cassava is subject to the shear and frictional forces on the disc (Bolaji et al. 2008) as given in Equation (2). Figure 1 shows the forces acting on the cassava root during chipping.

$$R_t = F_S + F_F = F_S + \mu F_N \tag{2}$$

For μ = 0.3 and $F_S = F_N$:

$$R_t = F_S\left(1+0.3\right) = \tau_C \times A_{DS}\left(1+0.3\right) \tag{3}$$

where: R_t – force required (N); F_S – shear force (N); F_F – frictional force (N); μ – coefficient of friction; A_{DS} – exposed area of the disc to the cassava; τ_c – shear stress of the cassava (0.140–0.048 $N \cdot mm^{-2}$) (Nwagugu and Okonkwo 2009).

Table 1. Material and components used

Material	Component used for
Stainless steel	platform, chipping disc drum, inclined hopper, fixed side plates, and shaft
Thermosetting plastic	machine stand
Mild steel	structural frame

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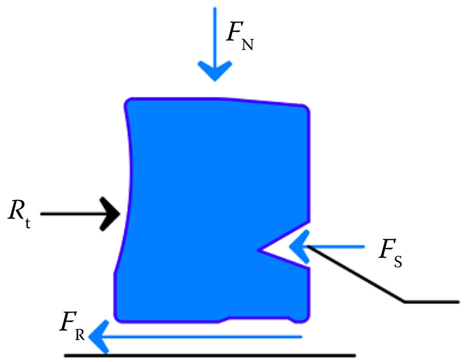

Figure 1. Forces acting on the cassava during chipping

The shaft diameter was determined using the method described by the American Society of Mechanical Engineers (ASME 1985) as seen in Equation (4).

$$d^3 = [16/(\pi S_s)] \times \left[(K_b M_b)^2 + (K_t M_t)^2\right]^{1/2} \tag{4}$$

where: d – diameter of the shaft; K_b – combined shock and fatigue factor applied to the bending moment; K_t – combined shock and fatigue factor applied to the torsional moments; M_b – bending moment; M_t – torsion moment; S_s – allowable stress.

For a shaft with a keyway, the allowable stress (S_s) of 45 MN·m^{-2} was used. The average power required to overcome the inertia, volume, mass of the chipping disc, and the power required to drive the machine were computed based on Equations (5–8), respectively (Khurmi and Gupta 2008).

$$\textit{Average power}\ (P_{av}) = \frac{KE_2}{4s} \tag{5}$$

$$\textit{Volume of the chipping disc}\ (V_{cd}) = \pi r^2 h \tag{6}$$

$$\textit{Mass of the chipping disc}\ (M_{cd}) = \rho V_{cd} \tag{7}$$

$$\textit{Power required to drive the machine}\ (P) = \frac{2\pi n T}{60} \tag{8}$$

The density of the stainless and mild steel materials used were in the values of 7 930 kg·m^{-3} to 7 860 kg·m^{-3}, respectively.

The method described by Hannah and Stephen (1970) was used in this study to determine the power transmitted by the belt [Equation (9)]:

$$P = (T_1 - T_2)\,V \tag{9}$$

However,

$$V = \frac{\pi DN}{60} \tag{10}$$

where: P – power (W); V – velocity (m·s^{-1}); T_1 and T_2 – tensions on the tight and slack sides, respectively (N).

Figure 2 shows the forces acting on the main drive shaft.

$$KE_1 + \textit{work done}_{1-2} = KE_2 \tag{11}$$

where: $KE_1 = 0$.

$$KE_2 = \textit{translational KE} + \textit{rotary KE} \tag{12}$$

where: *translational KE* = 0.

$$KE_2 = \textit{rotary KE} = \sum_{i=1}^{n} \frac{I_{xi}}{2}(\omega_2^{\,2}) = \frac{\omega_2^{\,2}}{2}\sum_{i=1}^{n} I_{xi} \tag{13}$$

$$KE_2 = \frac{\omega_2^{\,2}}{2}\left[\frac{1}{2}\left(m_P\left(r_{1P}^2 - r_{2P}^2\right)\right) + \frac{1}{2}\left(m_s r_s^2\right) + \frac{1}{2}\left(m_A\left(r_{1A}^2 - r_{2A}^2\right)\right) + \frac{1}{2}\left(m_D\left(r_{1D}^2 - r_{2D}^2\right)\right)\right] \tag{14}$$

$$\textit{Work done}_{1-2} = \textit{work by couple} = \sum M\omega dt = \sum M d\theta \tag{15}$$

$$\textit{Work done}_{1-2} = (T_1 - T_2)\ r\ (\theta_2 - \theta_1) \tag{16}$$

$$\textit{Work done}_{1-2} = KE_2 \tag{17}$$

$$\textit{Average power} = \frac{\textit{work done}_{1-2}}{\textit{time}} \tag{18}$$

Hence, the average power and tension required on the shaft is given in Equations (19) and (20), respectively.

$$\textit{Average power} = \frac{KE_2}{4s} \tag{19}$$

$$\textit{Tension} = \frac{T_1}{T_2} = e^{\mu\theta\cos\beta} \tag{20}$$

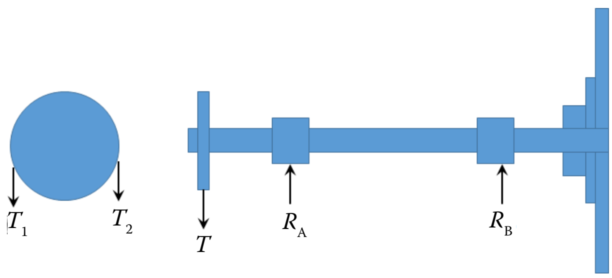

Figure 2. Forces acting on the shaft

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where: T_1 – tension on the tight side; T_2 – tension on the slack side; s – time (s); β – groove semi-angle; θ – angle of wrap; KE – kinetic energy (J); e – angle of the contact on the smaller pulley; μ – coefficient of friction.

The coefficient of resistance (μ) for a rubber belt on cast iron or steel working on a dry surface is given as μ = 0.3 (Ogunwede 2003).

A 12.7 mm in width V – belt SPA was selected based on the pulley diameter (90 mm). The nominal power (P_N) per belt was calculated based on Equation (21).

$$Z = \frac{P C_2}{P_N C_1 C_3} \tag{21}$$

where: Z – number of belts; C_1 – angle of the wrap factor; C_2 – load factor; P – power; C_3 – factor related to the length of the belt; P_N – nominal power transmitted per belt.

C_1: 0.98 was obtained from $\frac{D_S - D_M}{a}$ and the 1.2 angle of the wrap (160°).

C_2 was obtained from a table based on a 10- to 16-h operational duration under average loading of 0.96.

C_3 is for belt length of 1 357 mm ≈ 1 400 mm.

Equation (22) was used to establish the link between the basic life rating, the basic dynamic rating, and the bearing load.

$$C = P\left[\frac{L}{L_{10}}\right]^{1/K} \quad \text{or} \quad \frac{C}{P} = \left[\frac{L}{L_{10}}\right]^{1/K} \Rightarrow$$
$$\left[\frac{C}{P}\right]^{K} = \frac{L}{L_{10}} \quad \text{or} \quad L_{10} = \left[\frac{C}{P}\right]^{K} / L \tag{22}$$

where: L – $60_n/10^6$ million revolutions, therefore, L_{10} – $(10^6/60_n) \times [C/P]^K$; L_{10} – life of the bearing for 90% survival at one million revolutions; K – $^{10}\!/_3$ for the roller bearing; L – required life of the bearing per million revolutions (min·rev^{-1}); n – rotational speed (rev·min^{-1}); C – basic dynamic load rating (N); K – exponent for the life equation with: K = 3 for the ball bearing; P – radial load + axial load.

The value of P which is the radial and axial loads on the bearing were computed by using Equation (23).

$$P = \left(XF_r + YF_a\right) \tag{23}$$

where: X – radial load factor on the bearing; Y – axial load factor on the bearing; F_r – actual radial bearing load (N); F_a – actual axial bearing load (N).

The volume of the hopper was estimated based on Equation (24):

$$Volume\ (\mathrm{m}^3) = L\,B\,H \tag{24}$$

where: L – length (m); B – breath (m); H – height (m).

The mass of the hopper was estimated based on Equation (25):

$$Mass\ (\mathrm{kg}) = \rho V \tag{25}$$

where: ρ – density of the material (stainless steel, 7 930 kg·m^3); V – volume of the hopper (m^3).

The capacity of the machine (kg·h^{-1}) and the chipping efficiency (%) were found using Equations (26) and (27), respectively (Adejumo et al. 2011).

$$Machine\ capacity\ \left(C_m\right)(\mathrm{kg{\cdot}h^{-1}}) = \frac{W_{tc}}{T_c} \tag{26}$$

$$Chipping\ efficiency\ (\eta_c)\,(\%) = \frac{W_{wc}}{W_i} \times 100 \tag{27}$$

where: C_m – machine capacity (kg·h^{-1}); W_{tc} – mass of the total chipped cassava (kg); T_c – chipping time (h); η_c – chipping efficiency (%); W_{wc} – mass of the chipped cassava (g); W_i – initial mass of non-chipped cassava (g).

Three chipping clearances of 6, 18 and 28 mm were achieved by adjusting the chipping disc drum to align with the three predetermined variable clearance slots machined on the main driving shaft (23, 13, 14 mm, respectively) and positioned with a lock bolt and nut as shown in Figure 3.

The major components and specifications of the chipper are shown in Table 2. The cassava chipper consists of a loading platform that holds the peeled roots before they are fed into the inclined hopper for chipping. The chipping unit is made up of a chipping disc and a variable clearance drive shaft to vary the clearance between the chipping disc and the fixed plate for different sizes of chipped roots. The machine has four adjustable stands which can be altered to give comfort to the operator in terms of the operator's elbow rest height. Also, a delivery chute which allows chipped roots to exist. The entire unit has a structural frame covered with side plates.

Figures 4 and 5 show the isometric and exploded views of the HTU-model VC[4], respectively.

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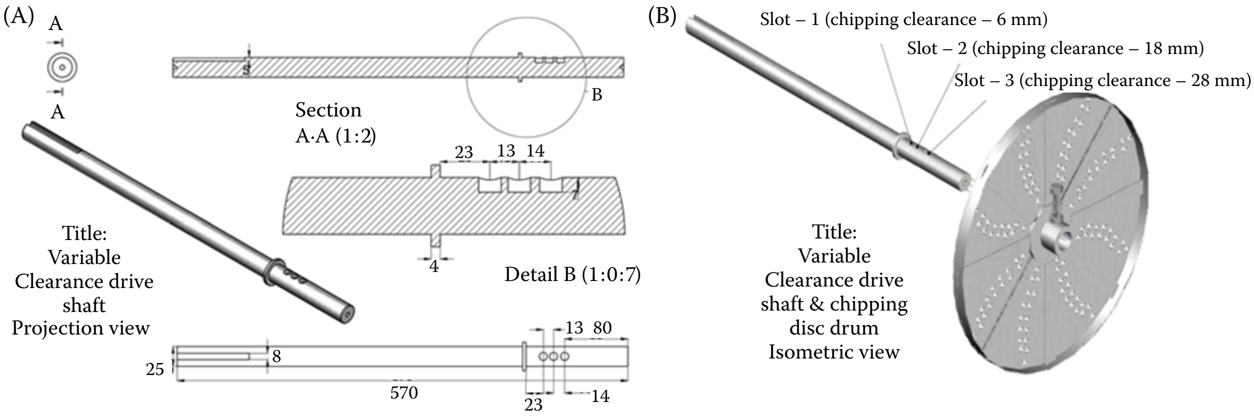

Figure 3. Detailed projection (A) and isometric (B) views of the main drive shaft depicting the three chipping clearances

The principle of operation of the HTU-model variable chipping clearance cassava chipper. Freshly peeled cassava roots are placed on the loading platform prior to being chipped. The chipper is propelled by a three-horsepower electric motor via a belt drive. The cassava roots are conveyed through an inclined hopper to a rotating chipping disc through the use of gravity into the chipping unit. The rotation of the chipping drum performs an impact action on the roots, and the sharp expanded grooved cutting edges press against the roots with an impact-shear force to the required chip geometry. The chips are pressed through an opening on the chipping disc and are discharged via the delivery chute. For a varying chip geometry, the chipping disc is adjusted to align with any of the three

Table 2. Design specification of the chipper

Parameters	Values	SI Unit
Chipping clearance	6, 18, 28	mm
Diameter of the chipping disc	360	mm
Overall length	698	mm
Overall width	555	mm
Overall height	1 102	mm
Overall weight	105	kg
Ground glearance	380	mm
Required force	464.1	N
Shear force	65.8	N
Frictional force	19.74	N
Maximum power transmitted by V-belt	2.168	$Nm·s^{-1}$
Volume of inclined hopper	1 072	mm^3
Volume of loading platform	2100	cm^3
Mass of platform	111.02	kg
Design capacity of platform	117.72	kg
Volume of chipping disc	6.272	cm^3
Mass of chipping disc	49.74	kg
Torque	15.5	kN
Power required	4.08	kW
Minimum shaft diameter based on torsion	26.74	mm
Minimum shaft diameter based on rigidity	21.5	mm
Selected shaft diameter	30	mm
Key dimensions (length, width, height)	40, 7, 7	mm
Superimposed alternating stress	81.3	$kN·m^{-2}$
Equivalent dynamic radial load on bearings	47	N

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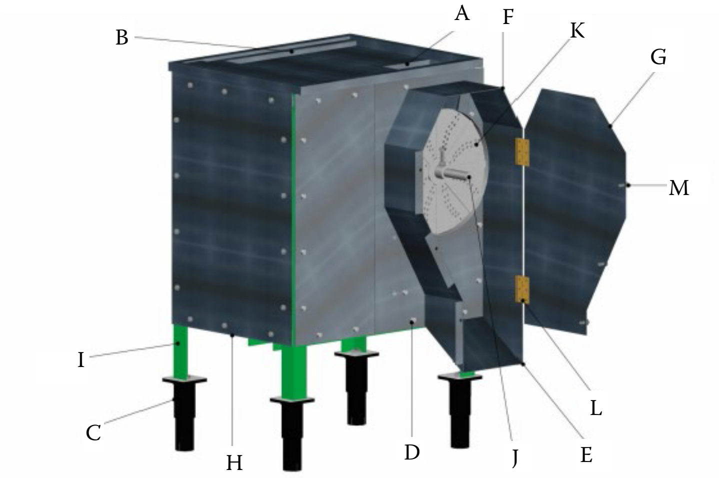
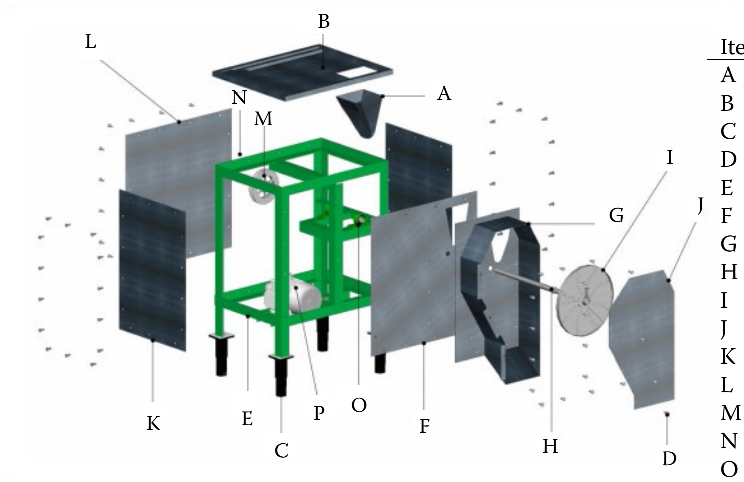


Item	Description	Quantity
A	Inclined hopper	1
B	Loading platform	1
C	Adjustable stand	4
D	M9 bolt	64
E	Delivery chute	1
F	Chipping disc drum housing	1
G	Chipping disc drum Housing cover	1
H	Side fixed plate	2
I	Frame	1
J	Variable clearance drive shaft	1
K	Chipping disc drum	1
L	Hinges	2
M	Self-locking device	3

Figure 4. Isometric view of the variable clearance of casava chipper

predetermined variable clearance slots machined on the main drive shaft. This creates a gap between the face of the inclined hopper and the sharp expanded groove cutting edges on the chipping disc that corresponds to the variable chipping clearances, i.e. 6, 18 and 28 mm. The size and shape of the cassava chips are equivalent to the gap between the expanded cutting edges on the chipping disc with the corresponding operational speeds (800, 730 and 460 rpm) for the chipping drum.

Sample preparation. Two varieties of cassava cultivars were obtained from the Caltech cassava processing company, (Hodzo, Volta region, Ghana). Twelve (12) months old Ampong, an improved variety, and Ankrah a local variety at different processing periods (freshly harvested and 48 h after harvest) were used. The initial moisture contents (MC) were found to be 68.08% and 65.44%; 66% and 61.0%, wet basis respectively for the Ampong and Ankrah cultivars (both the freshly harvested and 48 h after harvest). At each chipping clearance and operational speed, peeled cassava roots with a total weight of 5 kg were used to determine the throughput capacity and efficiency of the chipper. The experiments were conducted in duplicates and, in each case, the mean values were used. MS Excel 2016 was used to plot the graphs for the interpretations.



Item	Description	Quantity
A	Inclined hopper	1
B	Loading platform	1
C	Adjustable stand	4
D	M9 bolt	64
E	Frame	1
F	Front fixed plate	1
G	Disc housing	1
H	Variable clearance drive shaft	2
I	Chipping disc drum	1
J	Housing covering plate	1
K	Side fixed plate	1
L	Rear fixed plate	2
M	Drive pulley	1
N	Key	1
O	Self aligned breaking	1 pair
P	Induction electric motor	1

Figure 5. Exploded view of the variable clearance of cassava chipper

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RESULTS AND DISCUSSION

The machine was tested for its throughput capacity and chipping efficiency using chipping clearances of 6, 18, and 28 mm and operational speeds of 460, 730, and 800 rpm. The results of the test carried out are shown in Figures 6–13.

The tests carried out on the chipper revealed that an increase in the chipping clearance (28 mm) with a decreased operational speed (460 rpm) resulted in a decrease in the chipping time and a corresponding increase in the chipping capacity for both the freshly harvested and 48 h after harvest Ankrah variety (Figures 6 and 7). The throughput capacity for the freshly harvested Ankrah variety declined with an increase in the operational speeds for all the chipping clearances except for the 6 mm chipping clearance (Figure 6), which increased at a speed of 730 rpm and further deceased with an increased speed. The maximum and minimum capacities for the fresh harvested Ankrah were 327 kg·h^{-1} and 154 kg·h^{-1} respectively, with an operational speed of 460 rpm at chipping clearances of 28 mm and 6 mm (Figure 6). For the Ankrah variety 48 h after harvest, a maximum throughput capacity of 643 kg·h^{-1} was obtained at a 28 mm chipping clearance and an operational speed of 460 rpm. At an operational speed of 730 rpm for the Ankrah variety 48 h after harvest, the throughput capacity for all the clearances dipped and then increased with an increase in the operational speed at 800 rpm (Figure 7).

For the freshly harvested Ampong, an increase in the operational speed saw a corresponding increase in the throughput capacity for all the chipping clearances (Figure 8). However, this trend was not same for the Ampong variety processed 48 h after harvest. The throughput capacity was greater at 730 rpm for the 28 mm chipping clearance, but dipped as the speed increased (Figure 9). The greatest throughput capacity for the freshly harvested Ampong was 581 kg·h^{-1} at a speed and clearance of 800 rpm and 6 mm, respectively. However, the Ampong variety 48 h after harvest showed the greatest throughput capacity of 600 kg·h^{-1} at a speed of 730 rpm and clearance of 28 mm. An increased in speed saw a corresponding decrease in the capacity, except for the 6 mm clearance (Figure 9).

In Figure 10, the maximum chipping efficiency for the freshly harvested Ankrah variety was recorded as 99.4% at a speed of 800 rpm and a clearance of 6 mm. For the 18 mm clearance, an increase in the speed saw a corresponding decrease in the efficiency. However, *vice versa* were seen for the 6 and 28 mm chipping clearances.

The chipping efficiencies for the Ankrah variety 48 h after harvest (Figure 11) were uniform for the selected speeds and chipping clearances of 6 and 8 mm. However, the efficiency decreased with the speed and chipping clearance of 730 rpm and 28 mm, respectively. The highest efficiency (97.2%) was recorded for the clearances of 6 and 18 mm. At a speed of 730 rpm and a clearance of 28 mm, the efficiency (76.6%) dipped.

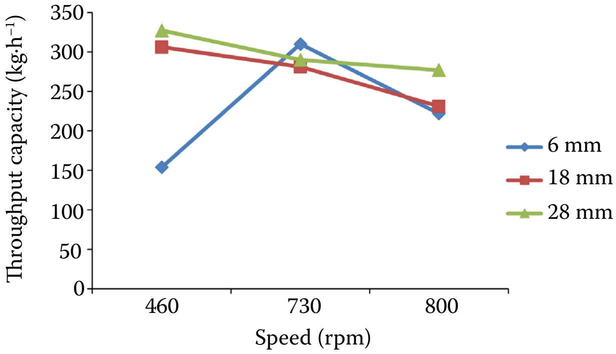

Figure 6. Throughput capacity for the freshly harvested Ankrah

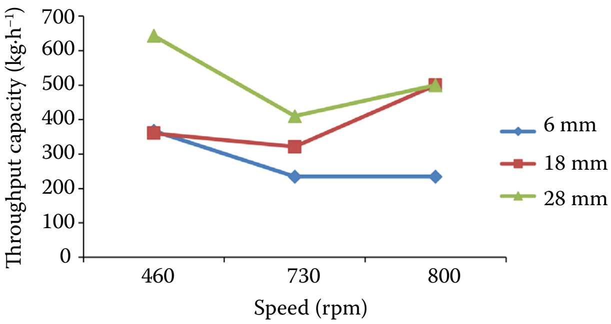

Figure 7. Throughput capacity for the Ankrah variety 48 h after harvest

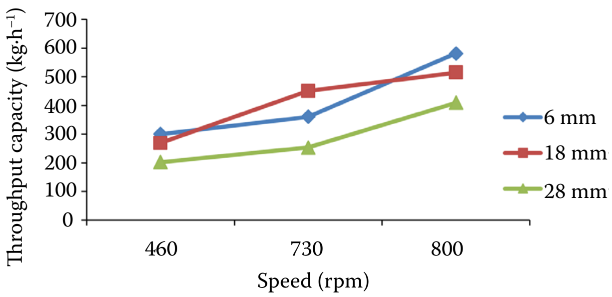

Figure 8. Throughput capacity for the freshly harvested Ampong

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The chipping efficiency for the freshly harvested Ampong shown in Figure 12 reveals that an increase in speed had a corresponding increase in the efficiency for all the chipping clearances. The maximum efficiency (98.6%) was recorded for a speed of 800 rpm and a clearance of 18 mm, and the lowest was obtained for a speed 460 rpm and a chipping clearance of 6 mm.

Figure 13 shows the chipping efficiency, clearances and the corresponding speeds for the Ampong variety 48 h after harvest. The lowest chipping efficiency (96.9%) was recorded in the Ampong variety 48 h after harvest at a speed and clearance of 800 rpm and 18 mm, respectively. With decreasing efficiencies for 18 mm clearance for all the speeds, 6 and 28 mm clearances recorded an increase in the efficiencies for increasing speeds.

Bolaji et al. (2008) also found an increase in the chipping capacity with a corresponding increase in the operational speed. An increase in the operational speed resulted in a decrease in the time to chipping the specific quantity of the produce. The increase in the throughput capacity is inversely proportional to the time decrease for processing a batch of the produce. Other works, such as Adejumo et al. (2011) and Awulu et al. (2015) also found a decrease in the operational speed with a corresponding increase in the throughput capacity. The average throughput capacity of the chipper was found to be 475.5 kg·h^{-1} at a speed range of 460–800 rpm with chipping clearances of 6–28 mm. Oladeji (2014) obtained a chipping capacity of 346 kg·h^{-1} and an efficiency of 87.09% for a test run for a chipper. However, Bolaji et al. (2008), found the capacity and efficiency to be 240 kg·h^{-1} and 92.6%, respectively, at a speed of 400 rpm. Also, Adejumo et al. (2011), found the capacity and efficiency for a chipper to be 451.35 (± 49.59) kg·h^{-1} and 74.91 (± 18.86)%, respectively, for a speed range of 300–400 rpm. These variations in throughput capacities and efficiencies could be due to the varietal differences of the samples used, the design parameters of the chipper, the period of processing the produce after harvest, and as well as inefficiency on the side of the operator. However, the results obtained were in variance to other researchers in literature, as the obtained test run for the chipping capacity and efficiency were high. The overall average chipping capacity for the developed HTU-model chipper was relatively greater than the other works found in the literature. The average throughput capacity was found to be 475.5 kg·h^{-1} at a speed range of 460–800 rpm and a 6–28 mm chipping clearance.

The average minimum–maximum chipping efficiencies were in a range of 76.6–99.4% at an operational speed ranging from 430–800 rpm and a chipping clearance of 6–28 mm. The efficiency of the developed chipper was not uniform as shown in Figures 10–13; however, this agrees with other researchers such as Bolaji et al. (2008) and

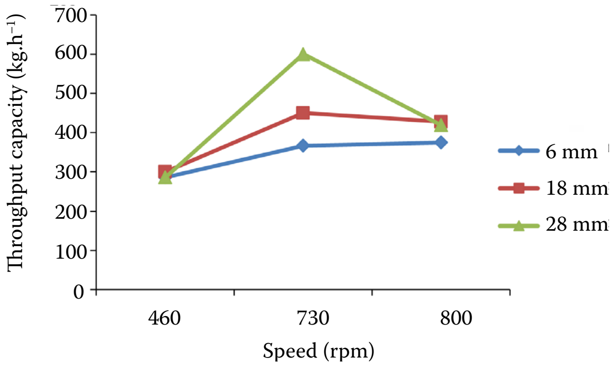

Figure 9. Throughput capacity for the Ampong variety 48 h after harvest

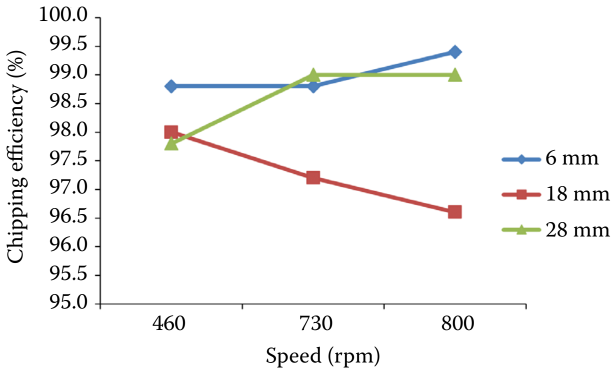

Figure 10. Chipping efficiency for the freshly harvested Ankrah

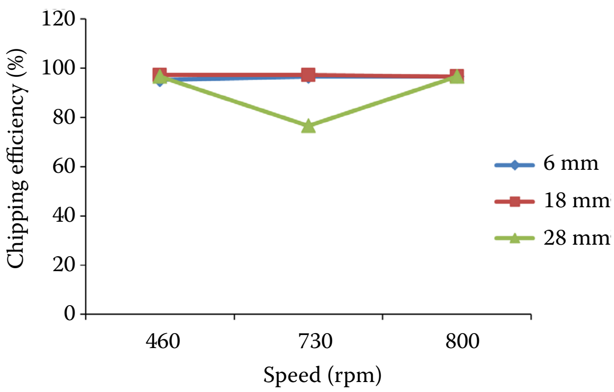

Figure 11. Chipping efficiency for the Ankrah variety 48 h after harvest

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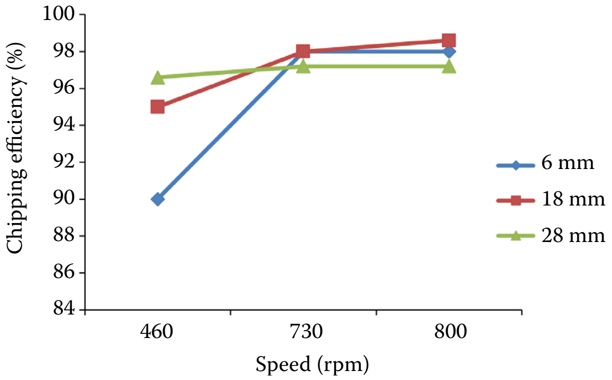

Figure 12. Chipping efficiency for the freshly harvested Ampong

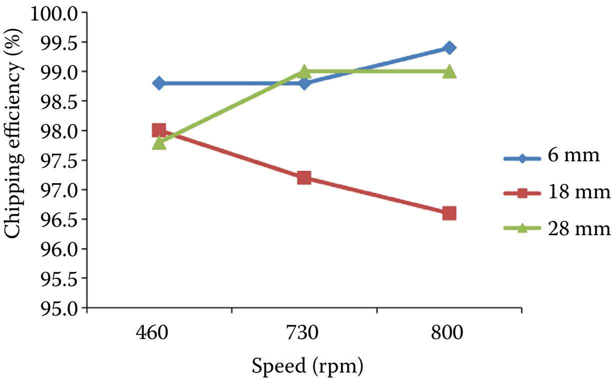

Figure 13. Chipping efficiency for the Ampong variety 48 h after harvest

Oladeji (2014) who obtained chipping efficiencies of 92.6% and 91.83%, respectively. These variations in the obtained chipping efficiencies in the test run of the machine may be due to the varietal differences of the produce, moisture reduction after 48 h after harvest before chipping, producing a resistance force thereby affecting the rate of the chipping time and other factors, such as the feeding orientation (crosswise, lengthwise, vertical, etc.) of the produce for chipping.

The results found confirm that the throughput capacity and the efficiency of the chipper is dependent on the operational speeds and the chipping clearances of the machine.

CONCLUSION

An HTU-model variable chipping clearance cassava chipper was designed, and its performance was evaluated. The test results showed that an increase in the chipping clearance and a decrease in the operational speed resulted in a decrease in the chipping time with a corresponding increase in the chipping capacity. The reverse statement of the results affirms that a decrease in the chipping clearance and an increase in the operational speed resulted in a decrease in the chipping time and an increase in the chipping capacity. The minimum–maximum average throughput capacity of the chipper was found to be 475.5 $kg\cdot h^{-1}$ at a speed of 460–800 rpm and 6–28 mm chipping clearance. The minimum–maximum chipping efficiency was in a range of 76.6–99.4% at an operational speed of 800 rpm and at a chipping clearance of 18–28 mm.

Therefore, the choice of chipping capacity and the chipping efficiency is dependent on the operational speed and chipping clearance of the machine. A future study is recommended to investigate the root orientation, age, size, shape, feed rate, and density of the cassava root in interaction with the chipping disc and clearances to evaluate the uniformity of the chips.

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