Effect of variable chipping clearance and operational speed on the cassava chip geometry

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Abstract

Most cassava chipping machines adopt the fixed chipping clearance at different speeds accounting for inconsistencies in chip geometries. These irregularities influence drying time and may cause fermentation, culminating in poor quality and safety of dried chips. The need to develop a variable chipping machine capable of producing varied chip sizes for different uses necessitated this research. The main objective of this study was to develop and test the impact of a cassava chipping machine with a variable clearance and varying cutting speed on chip geometry. Drum operation speeds of 460 rpm, 730 rpm, and 800 rpm, and chipping clearances of 6 mm, 18 mm, and 28 mm were considered in this study. The study considered two twelve-month maturing varieties of cassava. These varieties were the *Ampong* (an improved variety) and *Ankrah* (a local variety). Processing time was varied between freshly harvested (FH) and 48 h after harvest (48AH). The initial moisture contents of the *Ampong* variety were 68.1% and 65.4% wet basis for the FH and 48AH samples, respectively. The *Ankrah* variety recorded 66.0% and 61.0% wet basis for FH and 48AH samples, respectively. Results from the performance evaluation test indicated that operational speed and chipping clearance had a significant effect ($P<0.05$) on the chips' length, width, and thickness. *Ankrah* variety recorded the shortest mean chip length at 6mm clearance and 730 rpm for the FH samples. On the other hand, *Ampong* samples at 730 rpm and 18 mm machine clearance recorded the shortest mean chip length for the 48AH samples.

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Introduction

Cassava (*Manihot esculenta Crantz*) is a major root crop and serves as an important staple food for more than half a billion people in the developing world (Falade and Akingbala, 2010; Ayetigbo *et al*., 2018). Cassava is drought resistant, a cheap food source, as well as a reliable source of carbohydrates during times of food shortages or famine. Cassava is the sixth major staple crop in the world after corn, wheat, rice, sweet potato, and potato (Gro Intelligence, 2015; Egbeocha *et al.,* 2016).

Cassava and its by-products serve as an essential food source for several rural households in Ghana. When processed into fufu, kokonte, gari, tapioca, flour, and starch for onward consumption, it seems to be a 'food of choice' even amid alternative food options in urban areas (Oyedeji *et al.,* 2011). Cassava is utilised as a raw material in producing processed food, animal feed, and industrial products. The wide selection and use of cassava products can function as the basis for rural industrial development and increase income for producers, processors, and investors.

The high perishability of cassava due to high moisture content is a major concern in cassava utilization (Igbeka *et al.,* 1992). Deterioration caused by physical changes, biochemical changes, and microbial infestation occurs within 40-48 hours after harvest (Saravanan *et al.,* 2016). This phenomenon is understood as a 'post-harvest physiological deterioration' (PPD). The rapid deterioration of cassava storage root dramatically reduces its time for fresh consumption and affects transport (Westby, 2002; Iyer *et al.,* 2010). Due to the rapidly deteriorating nature of cassava roots, they are left in the soil even when matured until they may be utilised as a part of long-established local practice. To attenuate PPD in cassava roots due to poor post-harvest storage methods, it is imperative to process the roots into dry, shelf-stable edible forms (Falade and Akingbala, 2010) and other industrial products (Igbeka *et al.,* 1992).

To minimise post-harvest losses (Saravanan *et al.,* 2016) and reduce transportation costs (Falade and Akingbala, 2010; Okechukwu *et al.,* 2012), size reduction of roots must be critically evaluated. Fresh chips could also be dried naturally in the sun or artificially using different dryers such as mechanical dryers (hot-air or oven drying). The rate of drying and quality of the chips produced are dependent on the chip size, the initial moisture content of the product, and the loading density (Pornpraipech *et al.,* 2017). Post-harvest processing of cassava increases its value by improving palatability and facilitating the marketing of more acceptable hygienic quality products (Falade and Akingbala, 2010). In addition, the drying of cassava, a significant processing activity, increases shelf-life. Cassava is chipped into smaller sizes to achieve a faster drying rate. Drying, which is a major processing activity, increases shelf-life and allows further processing into flour at a quicker rate where roots are chipped into smaller sizes.

Fresh chips could be dried naturally in the sun or artificially using artificial hot air or oven drying. Quality and the drying time of cassava chips in the sun drying process are influenced by the 'chips' geometry and the weather conditions. The drying rate depends on the chip size, loading density, and initial moisture (Pornpraipech *et al.,* 2017). The foremost widespread orthodox method of cassava chipping is using knives, which is tedious and ineffective and fails to realise uniform chips and ultimately inhibits uniform drying (Ariavie and Ohwovoriole, 2002). Many researchers have developed and evaluated cassava chipping machines to address the issue relating to cassava chip geometry and to increase drying rate by producing chips with larger surface areas (Adejumo *et al.,* 2011; Awulu *et al.,* 2015). Many devices, including those designed by Awulu *et al.* (2015) and Bolaji *et al.* (2008), have been developed. A single cutting blade and a sieve are used in these machines. As a result, the machine desired output will be fixed or constant chipped sizes of the tuber. Therefore, if varied desired sizes are required, two or more machines will be required, which may be cost-effective. In the case of Awulu *et al.* (2015), however, only operating speeds were considered by using varying pulley diameters without reference to chipping clearance. A cassava chipper with variable chipping clearance was designed, and the machine's capacity and chipping efficiency were evaluated (Ahorsu *et al.,* 2021). As a result, the goal of this study was to determine the effect of the cassava chipper with variable chipping clearance and varying operational cutting speeds on chip geometry.

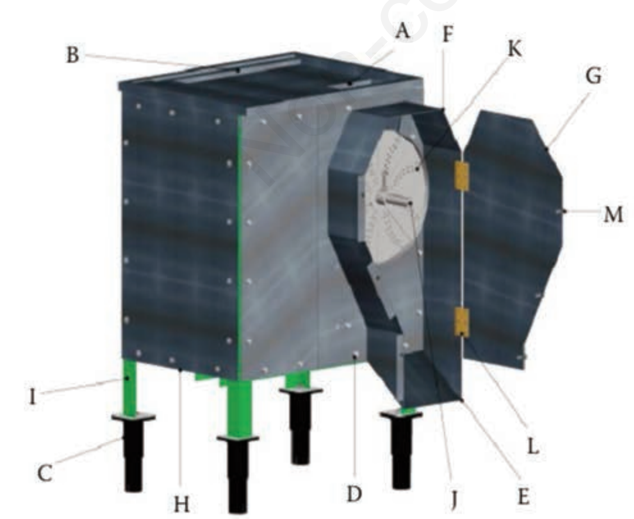
Materials and methods

Machine description and construction details

Figure 1 depicts the isometric view of the developed variable clearance cassava chipper and the major components. The major components of the variable clearance cassava chipper (VCCC) consist of the loading platform that holds peeled roots before being fed to the inclined hopper for chipping. The chipping disc that does the chipping, adjustable variable clearance drive shaft is used to vary the clearance between the chipping disc and the fixed plate for varied sizes of chipped roots. Concerning ergonomic considerations, the machine has four adjustable stands, which can be altered for 'operator's comfort, a delivery chute, and other parts shown in Figure 1. In addition, the entire unit has a frame that serves as a structure covered with side plates.

Principle of operation of the HTU-MVCCC

This consists of a loading platform to hold whole cassava produce ready for chipping. A 3-phase electric motor of voltage 415 V, with a power of 2.2 kW and a speed of 1944 rpm, is used to power the chipping machine. The power from the motor is transmitted through a belt and three pulleys of different diameters, and the main driving shaft. Peeled cassava roots are fed by gravity through an inclined hopper or duct to a rotating chipping disc, where they are chipped with the operator's help. The rotation of the chipping drum performs an impact action on the roots, and the sharp expanded groove cutting edges press against the roots with an impact-shear force to the required chip geometry. The chips are discharged via the delivery chute. The chipping disc is adjusted to align with any of the three predetermined variable clearance slots machined on the main drive shaft to obtain varying chip geometry. This creates a gap between the face of the inclined hopper and the sharp expanded groove cutting edges on the chipping disc that cor-



PART LIST

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	1
I	Frame	1
J	Variable clearance drive shaft	1
K	Chipping disc drum	1
L	Hinges	2
M	Self-locking device	3

Figure 1. Isometric view of the variable clearance.

responds to giving variable chipping clearances, *i.e.*, 6 mm, 18 mm, and 28 mm. The size and shape of the cassava chips are influenced by the gap between the expanded cutting edges on the chipping disc.

Cassava variety used

Twelve months old *'Ampong'* (an improved variety) and *'Ankrah'* (a local variety) were selected for this study and were obtained from Caltech Cassava Processing Company farms in '*Hodzo'* Ho in the Volta Region of Ghana. These cassava varieties were selected because they are varieties used by Caltech cassava processing company to produce starch. The *Ankrah* and *Ampong* varieties also have good texture and quality for cassava chips production. The *Ampong* variety was released in 2010 and had a mean root yield of 40-50 T/ha (Acheampong *et al.,* 2021); the total mean value of dry matter is 36%, resistant to African cassava mosaic disease (CMD) and adaptable to wider ecological environments. It is mainly used in flour and fufu production (Acheampong *et al.,* 2021). During the outbreak of CMD in the 1930s, several crosses were made between local varieties, East Africa and Caribbean varieties, resulting in the release of four outstanding cassava varieties, namely *Queen*, *Gari*, *Williams*, and *Ankrah*, in 1935, with the latter being highly resistant to CMD well after the 1950s (FAO, 2005).

Instruments and tools for measuring

A digital weighing balance, Yaohua brand, model YH-T7E, with a maximum load of 6 kg and an accuracy of 0.001 kg, was used to determine the mass of the cassava root and chips. The measuring tape was used to determine the respective dimensions of the sampled cassava roots. A pair of vernier callipers, which have a measuring range of 150 mm and an accuracy of 0.05 mm, were used to determine the diameter of the cassava roots and chip geometry. The operating speeds of the chipping drum were determined using a Lutron brand digital tachometer, Model DT-2236B, with a photo-contact type.

The sample size of cassava tuber used

The investigation employed a sample size of 25 kg of '*Ampong*' and '*Ankrah*,' respectively, based on the weight of the sample.

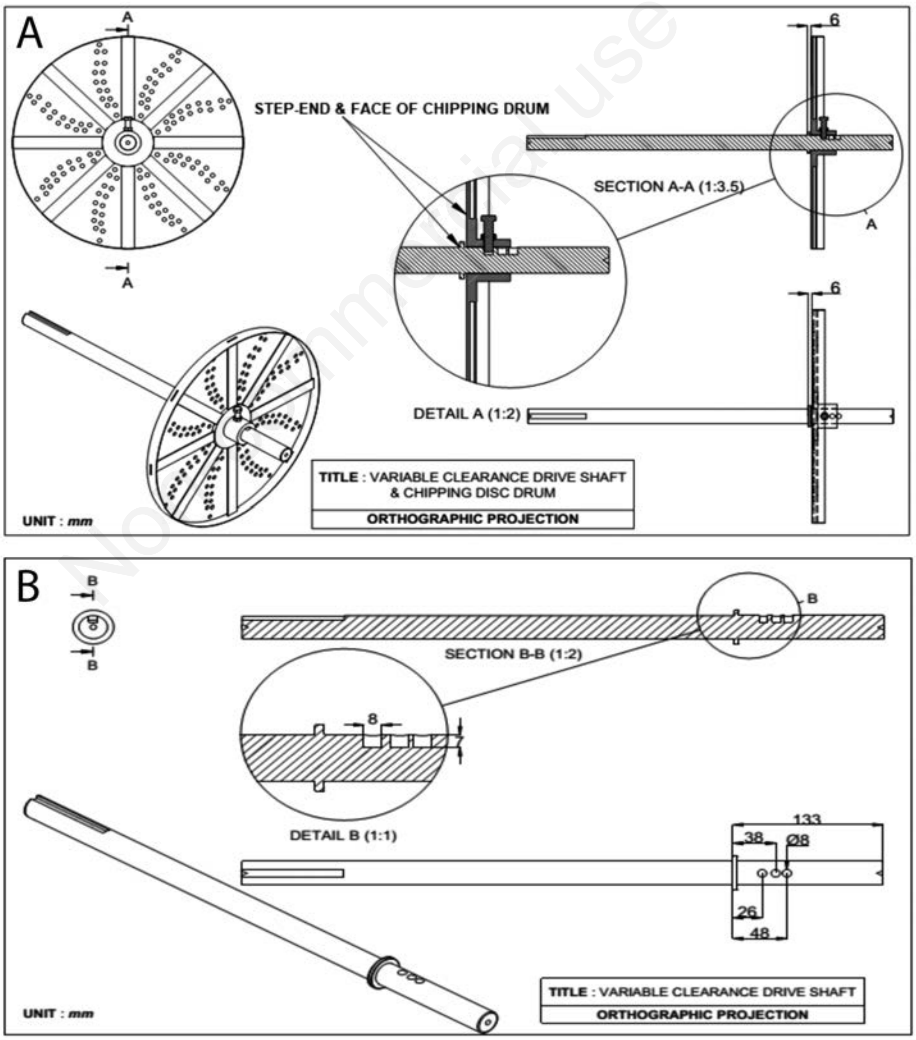


Figure 2. A) Orthographic projection views of the variable clearance drive shaft and chipping disc drum; B) orthographic projection views of the variable clearance drive shaft.

Moisture content determination of cassava roots

The initial moisture contents for the two cassava root varieties '*Ampong*' and '*Ankrah*', with two processing periods, thus (freshly harvested FH and 48 hr after harvest 48AH) were determined using the hot-air electric oven method on a wet basis similar to that carried out by Taiwo *et al.* (2014). The initial moisture contents of the *Ampong* variety were 68.08% and 65.44 % wet basis (wb) for the FH and 48AH samples, respectively. *The Ankrah* variety recorded 66.0% and 61.0 % wb for FH and 48AH samples, respectively.

Chipping clearance

The chipping clearances (6 mm, 18 mm, and 28 mm) were chosen based on the clearance of an existing cassava chipper used by CalTech Cassava Processing Company in Ho, Ghana's Volta Region, which has a clearance of 30 mm. This equipment, used by the CalTech cassava processing company, generated larger cassava chips that took longer to dry. To see how chip geometry was influenced, the researchers tested three chipping clearances: 6 mm, 18 mm, and 28 mm (small, medium, and large clearances). Shifting the chipping drum against the step machined on the main drive shaft to align with the three predetermined variable clearance slots machined on the main shaft (26 mm, 38 mm, and 48 mm) and positioning it with a lock bolt and nut as shown in Figure 2A and B yielded chipping clearances of 6 mm, 18 mm, and 28 mm. A chipping clearance of 6 mm is achieved between the fixed plate and the face of the chipping drum when the chipping drum is positioned between the step-end machined on the main drive shaft to align with the first slot 26 mm away from the face of the fixed plate and locked with a bolt and nut as shown in Figure 2A and B. The chipping drum is then positioned in the second slot, 38 mm away from the fixed plate's face, and secured with a bolt and nut to achieve an 18 mm chipping clearance between the fixed plate and the chipping drum's face. Subsequently, the drum is moved into the third slot, 48 mm away from the face of the fixed plate and locked with a bolt and nut to have a 28-mm chipping clearance.

Physical properties (chip geometry)

Physical properties such as size and shape are significant. Smaller cassava chips are best since they dry faster and are healthier than larger chips (Bolaji *et al.,* 2008). Because of the shorter drying time, smaller chips stay cleaner and are less prone to pest and insect infestation. Cassava chip size and shape are described by three axial dimensions: length, breadth, and thickness. Oladipo *et al.* (2021) estimated chipped cassava's length, width, and thickness using ten (10) samples each. However, for this study, thirty (30) fresh cassava chip sample pieces were chosen at random for each combination of factors, and their dimensions were measured with a pair of vernier callipers.

Experimental design

Treatments

A 3×3×2×2 factorial experiment in a completely randomised design was used with 3 replications:

- Factor (1) - Chipping clearance (6 mm, 18 mm, and 28 mm);
- Factor (2) - Operating speed at 800 rpm, 730 rpm, and 460 rpm;
- Factor (3) - *Ampong* and *Ankrah cassava* varieties;
- Factor (4) - 2 Processing times: freshly harvested (FH) and 48 hours after harvest (48AH).

Test procedure

The cassava roots were manually peeled with broad-bladed stainless-steel kitchen knives and placed in a plastic bowl. Peeled roots were thoroughly washed with clean water to remove all foreign materials. The study used a 5 kg raw weight of cassava root for each treatment combination. The HTU-MVCCC was operated at three speeds of 800 rpm, 730 rpm, and 430 rpm, with three chipping clearances of 6 mm, 18 mm, and 28 mm, respectively.

Data analysis

The analysis was carried out using SPSS Version 24 and Microsoft Office Excel 2016. The outcomes of the cassava chipping trials and measurement records were statistically evaluated using a three-replicated factorial completely randomised design (FCRD). The Kruskal-Wallis test was used to investigate the influence of operation speed, chipping clearance, and their interacting effect on chip geometry. In order to calculate pairwise comparisons between group levels of chipping clearance and operating speed, a pairwise

Table 1. Chip geometry, chipping clearances, and operational speeds for *Ankrah* FH using Kruskal-Wallis and pairwise Wilcoxon rank sum tests.

Kruskal-Wallis test	Chi-Square value	DF	P-values	Pairwise Wilcoxon rank sum test	P-values
The length by chipping clearance	8.88	2	0.01**	6 mm by 18 mm 6 mm by 28 mm 18 mm by 28 mm	0.02** 0.77 0.03**
The length by operational speed	26	2	0.00**	460 rpm by 730 rpm 460 rpm by 800 rpm 730 rpm by 800 rpm	0.00** 0.20 0.00**
Width by chip clearance	3.01	2	0.22	-	-
Width by operational speed	84.19	2	0.00**	460 rpm by 730 rpm 460 rpm by 800 rpm 730 rpm by 800 rpm	0.00** 0.9 0.00**
Thickness by chip clearance	10.34	2	0.01**	6 mm by 18 mm 6 mm by 28 mm 18 mm by 28 mm	0.1 0.1 0.01**
Thickness by operational speed	47.29	2	0.00**	460 rpm by 730 rpm 460 rpm by 800 rpm 730 rpm by 800 rpm	0.00** 0.06 0.00**

**Figures with asterisks are significant ($P<0.05$).

Wilcoxon rank-sum test was used. The independent variables were subjected to an ANOVA with a P-value of less than 0.05.

Results and discussion

Analysis of variances

From Table 1 chip width for clearance, there were statistical differences for chip length and thickness at a P-value of 0.01. Also, in the context of the pairwise comparison test, there were statistical differences for the length (6 mm by 18 mm; 18 mm by 28 mm) and thickness (18 mm by 28 mm) as well as operational speeds for length, width, and thickness (460 by 730 rpm; 730 by 800 rpm). Bolaji *et al.* (2008) reported that an increase in cutting speed had a corresponding increase in average chip length.

Table 2 indicates that there were statistically significant differences in chip thickness for chipping clearances of P-value=0.01. In the context of pairwise comparison, there was also a statistically significant difference in chip thickness across chipping clearances. Also, there was a statistically significant difference in chip thickness with operational speeds (P-value=0.00). In the pairwise comparison test, there is a significant difference in chip lengths across operational speeds; specifically, 460 rpm and 730 rpm (P-value=0.02) and 460 rpm and 800 rpm (P-value=0.00) and among others were obtained. The effect of operational speed on thickness was evident in the machine's test run, except for the speed at 460 by 800 rpm.

From Table 3, there was a significant difference in the chip length clearance. These differences were seen for the 6 mm by 18 mm and the 6 mm by 28 mm. The effect of operational speeds on-chip length was statistically insignificant for *Ampong* FH. However, the effect of operational speeds on the width and thickness was statistically significant. These significant differences were evident for the 460 by 730 rpm and 460 by 800 rpm. The insignificant difference in the operational speed for both width and thickness at 730 by 800 rpm may be due to the close range between the speeds.

Results from Table 4 indicated that there were statistically significant differences in chip lengths and thickness for chipping clearances and operational speeds, respectively, for the length and width. These differences were observable at 6 mm by 18 mm and 6 mm by 28 mm, among others. The effect of the chipping clearance on the length found for *Ampong* FH (Table 3), and *Ampong* 48AH (Table 4) were both statistically significant at 6 mm by 18 mm and 6 mm by 28 mm. On the other hand, it was indicated in Table 4 that there were insignificant differences in chip thickness for chipping clearances. In pairwise comparison, there was also an insignificant difference in chip thickness across chipping clearances. Also, there was a statistically significant difference in chip thickness operational speeds (P-value=0.00). In pairwise compari-

Table 2. Chip geometry, chipping clearances, and operational speeds for *Ankrah* 48AH using Kruskal-Wallis and pairwise Wilcoxon rank sum tests.

Kruskal-Wallis test	Chi-Square value	DF	P-values	Pairwise Wilcoxon rank sum test	P-values
The length by chip clearance	5.16	2	0.01		
The length by operational speed	26.92	2	0.00**	460 rpm by 730 rpm	0.02**
				460 rpm by 800 rpm	0.00**
				730 rpm by 800 rpm	0.24
Width by chip clearance	2.61	2	0.27		
Width by operational speed	3.31	2	0.19		
Thickness by chip clearance	1.7	2	0.4		
Thickness by operational speed	14.63	2	0.00**	460 rpm by 730 rpm	0.00**
				460 rpm by 800 rpm	0.16
				730 rpm by 800 rpm	0.02**

**Figures with asterisks are significant (P<0.05).

Table 3. Chip geometry, chipping clearances, and operational speeds for fresh *Ampong* using Kruskal-Wallis and pairwise Wilcoxon rank sum tests.

Kruskal-Wallis test	Chi-Square value	DF	P-values	Pairwise Wilcoxon rank sum test	P-values
The length by chip clearance	11.12	2	0.00**	6 mm by 18 mm	0.00**
				6 mm by 28 mm	0.01**
				18 mm by 28 mm	0.82
The length by operational speed	2.01	2	0.4		
Width by chip clearance	1.19	2	0.5		
Width by operational speed	10.87	2	0.00**	460 rpm by 730 rpm	0.03**
				460 rpm by 800 rpm	0.00**
				730 rpm by 800 rpm	0.6
Thickness by chip clearance	3.14	2	0.2		
Thickness by operational speed	21.04	2	0.00**	460 rpm by 730rpm	0.00**
				460 rpm by 800 rpm	0.00**
				730 rpm by 800 rpm	0.1

**Figures with asterisks are significant (P<0.05).

son, there was also a statistically significant difference in chip lengths across the operational speeds, specifically at 460 rpm and 730 rpm (P-value=0.00) and 460 rpm and 800 rpm (P-value=0.00).

Chip mean length

Figures 3 and 4 show the chip mean lengths for the two varieties when FH and 48AH.

Concerning the freshly harvested samples (Figure 3), a maximum mean chip length of 74.87 mm was recorded in the *Ampong* variety at 730 rpm with a clearance of 28 mm. The *Ampong* variety recorded the second-highest chip mean length of 68.69 mm at 800 rpm and 18 mm clearance. The highest chip means length for the *Ankrah* variety was documented at 800 rpm and 28 mm clearance. Overall, for freshly harvested samples, the least chip mean length of 31.32 mm has registered at 730 rpm and 6 mm clearance. The results indicate that chip clearance and speed influence the cassava chip geometry length. The storage period of cassava before processing also influences the chip geometry length. An increase in operational speed resulted in an increase in chip length, most especially from 460 rpm to 730 rpm. Research conducted by Bolaji *et al.* (2008) reported that an increase in cutting speed had a corresponding increase in average chip length, which validates the results of this study.

At 48 hours after harvesting cassava, the mean chipped length of the *Ampong* variety registered the highest value of 55.22 mm at 460 rpm and 18 mm clearance (Figure 4). Ampong very closely followed this at 460 rpm and 6 mm clearance. Generally, the Ampong variety recorded higher chip lengths for all operational speeds than the *Ankrah* variety. The highest chip length for *Ankrah* was recorded at 460 rpm and 28 mm clearance. Operating the chipping machine at 730 rpm and 18mm clearance produced the least chip length of 32.18 mm. The lowest speed of 460 rpm produced the largest mean chip length geometry (49.98 mm) compared to that at 730 rpm (41.52 mm) and 800 (39.41mm) in the two varieties. *Ampong* processed 48 hours after the harvest had a mean chip length of 32.18 mm at a speed of 730 rpm and a clearance of 18 mm (Figure 4). From Figures 3 and 4, it can be seen that when operated at 730 rpm and 28 mm clearance, *Ampong* FH had almost twice longer the chip length (74.87 mm) than *Ampong* 48AH (39.18 mm); this may be attributed to higher MC in *Ampong* FH producing fluidised chips.

Table 4. Chip geometry, chipping clearances, and operational speeds for fresh *Ampong* 48AH after using Kruskal-Wallis and pairwise Wilcoxon rank sum tests.

Kruskal-Wallis test	Chi-Square value	DF	P-values	Pairwise Wilcoxon rank sum test	P-values
The length by chip clearance	18.25	2	0.00**	6 mm by 18 mm 6 mm by 28 mm 18 mm by 28 mm	0.00** 0.00** 0.13
The length by operational speed	10.87	2	0.00**	460 rpm by 730 rpm 460 rpm by 800 rpm 730 rpm by 800 rpm	0.00** 0.00** 0.93
Width by chip clearance	5.46	2	0.07		
Width by operational speed	12.48	2	0.00**	460 rpm by 730 rpm 460 rpm by 800 rpm 730 rpm by 800 rpm	0.00** 0.05 0.2
Thickness by chip clearance	13.69	2	0.00**	6 mm by 18 mm 6 mm by 28 mm	0.02** 0.00**
Thickness by operational speed	3.31	2	0.19	18 mm by 28 mm	0.17

**Figures with asterisks are significant (P<0.05).

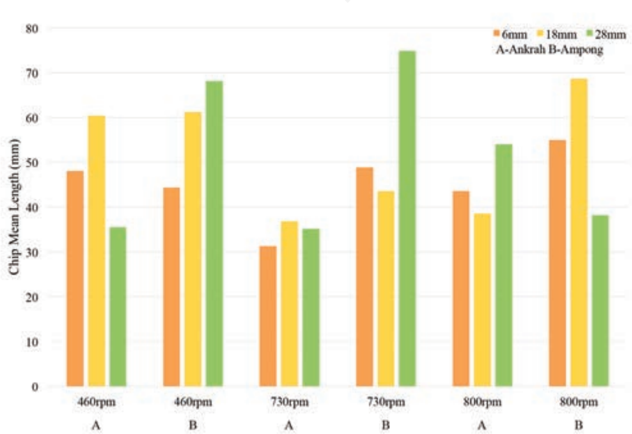


Figure 3. Chip mean length (mm), operating speed (rpm), and chipping clearance (mm) of *Ankrah* FH and *Ampong* FH.

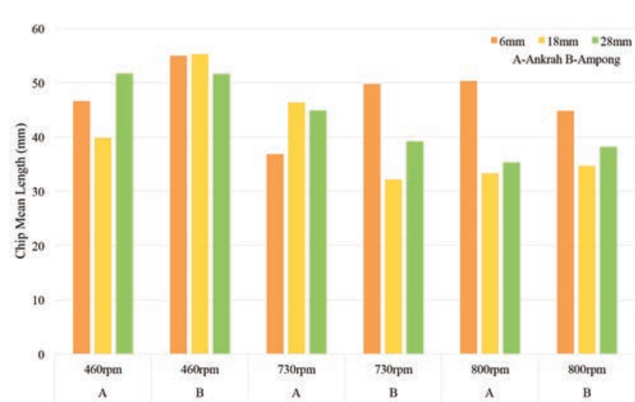


Figure 4. Chip mean length (mm), operating speed (rpm), and chipping clearance (mm) of *Ankrah* 48AH and *Ampong* 48AH.

Chip mean width

From Figures 5 and 6, the mean chip widths of *Ankrah* FH and *Ampong* FH were the highest at 460 rpm and chipping clearance of 28 mm. A chip mean width of 5.47 mm was obtained at 6 mm clearance and an operating speed of 800 rpm for the *Ankrah* FH variety. The minimum mean chip width (4.16 mm) was observed for *Ankrah* FH at a speed of 800 rpm and a clearance of 18 mm.

During experimentation at 48AH, the highest and least mean the Ankrah variety recorded widths at 730 rpm and 28 mm clearance, and 730 rpm and 18 mm clearance, respectively. The *Ampong* variety recorded its highest width of 5.08 mm when chipped at 460 rpm with 6 mm clearance. There were variations in the mean chip width for all the cassava varieties at the respective operating speeds and clearances. The shape of chips, which depends on the chip geometry (length, width, and thickness), affects the drying rate (Elohor *et al.,* 2008). A wider chip width or smaller chip thickness increases the drying rate. This is due to the greater surface area of the chip exposed to the drying air (Usman and Idakkwo, 2011).

Chip mean thickness

When tests were carried out on freshly harvested samples, *Ampong* recorded the highest chip thickness of 2.70 mm at 730 rpm with 18 mm clearance. This was followed by the *Ankrah* variety with 2.48 mm thickness at 800 rpm and 6 mm clearance. *Finally, the Ampong* variety had the smallest chip mean thickness of 1.49 mm at a chipping clearance of 6 mm and an operational speed of 800 rpm.

The Ampong variety recorded the highest thickness of 2.70 mm during tests at 48AH under the operational speed of 730 rpm and 18 mm clearance. Following closely was the *Ankrah* variety with 2.22 mm chip mean thickness under the operational speed of 800 rpm and 18 mm clearance. The thickness of the chip affects the rate at which moisture is removed from the product. A smaller chip thickness accelerates the desorption of moisture faster than a bigger chip thickness, improving the quality of chips. Usman and Idakkwo (2011) found out that dried cassava chip thickness of 3-7 mm does not support the growth of mould, and from the study, the maximum chip thickness of 2.7 mm was observed, which will promote better quality chips.

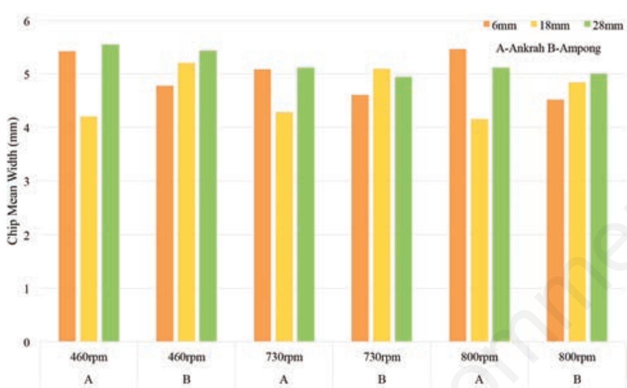


Figure 5. Mean width (mm), operating speed (rpm), and chipping clearance (mm) of *Ankrah* FH and *Ampong* FH.

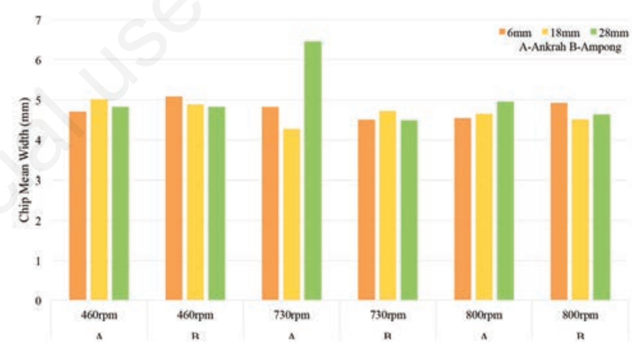


Figure 6. Mean width (mm), operating speed (rpm), and chipping clearance (mm) of *Ankrah* 48AH and *Ampong* 48AH.

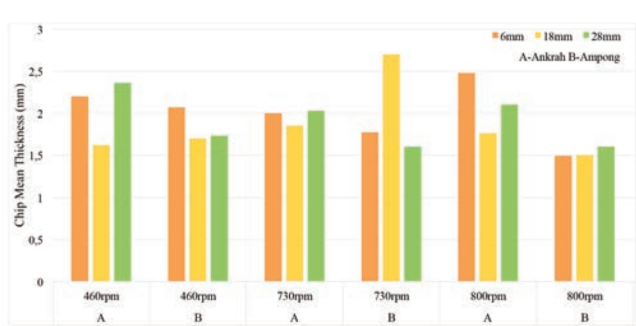


Figure 7. Mean thickness (mm), operating speed (rpm), and chipping clearance (mm) of *Ankrah* FH and *Ampong* FH.

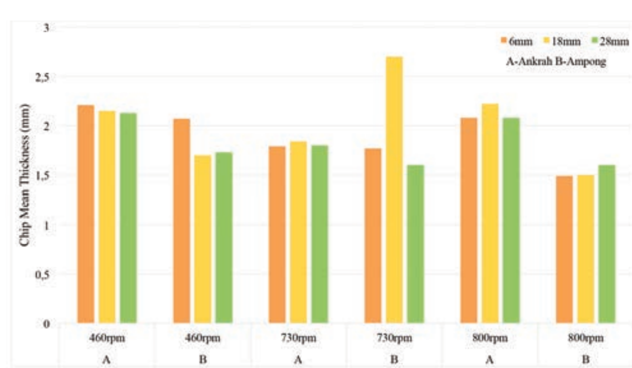


Figure 8. Mean thickness (mm), operating speed (rpm), and chipping clearance (mm) of *Ankrah* 48AH and *Ampong* 48AH.

Observations from Figures 3 to 8 indicate that an increase in the operational speed and chipping clearance do not necessarily decrease chips' length, width, and thickness. This could be a result of variable chipping clearances and operational speeds. Findings from this study is in accordance with Bolaji *et al.*, (2008), who observed a significant effect of higher cutting speed on-chip length. Research carried out by Ajibola *et al.* (1991), Adejumo *et al.* (2011), and Awulu *et al.* (2015) reported that low operational speeds produced the smallest chip sizes, which buttresses observations from Bolaji *et al.* (2008), and the findings obtained in this study. The study also revealed variations in the chip geometry concerning operating speeds and chipping clearances for the cassava varieties.

Conclusions and recommendations

The effect of chipping clearance (6 mm, 18 mm, and 28 mm) and operational speeds (460 rpm, 730 rpm, and 800 rpm) on cassava chip geometry were assayed in this study. The analysis of variance revealed significant differences among some pairs of the chipping clearances and the operational speeds on the cassava chip geometry. For *Ankrah* FH, significant differences were observed in the chip mean length (6 mm by 18 mm; 18 mm by 28 mm) and operational speed (460 rpm by 730 rpm; 730 rpm by 800 rpm). Also, *Ankrah* 48AH did not record any significant difference in the mean chip length for clearance. However, some pairs of length by operational speed registered significant differences for the speeds of 460 rpm by 730 rpm and 460 rpm by 800 rpm.

Among the freshly harvested chips, *Ampong* chips produced at 730 rpm and 28 mm clearance gave the highest output length of 74.87 mm. *Ampong* (48AH) chips produced at 460 rpm and 18 mm clearance gave the highest length output of 55.22 mm. *Ankrah* FH chips produced at 460 rpm, and 28 mm clearance gave the largest width of 5.55 mm among all the freshly harvested samples. Again, *Ankrah* samples chipped at 730 rpm, and 28 mm clearance gave the largest width of 6.46 mm for chips processed 48h after harvesting. *Ankrah* variety recorded the shortest mean chip length (31.32 mm) at 6 mm clearance and 730 rpm for the FH samples. On the other hand, *Ampong* samples at 730 rpm and 18 mm machine clearance recorded the shortest mean chip length (32.18 mm) for the 48AH samples.

Comparing the two treatments (FH and 48AH), the *Ampong* variety produced the highest chip thickness of 2.7 mm at 730 rpm and 18 mm clearance. The study recorded the least thickness among *Ampong* (1.49 mm for both FH and 48AH) at 800 rpm and 6 mm clearance. It may be assumed that samples with the least thickness would generate the highest drying rate due to the short distance from which moisture in the sample must travel during evaporation to get to the external environment. Hence, chipping *Ampong* at high speeds and low clearance has the potential to churn out samples that would dry faster within a relatively short time.

The machine was suitable for chipping cassava into various uniform sizes and shapes and is recommended for uptake and upscale by small and medium-scale cassava processing enterprises. The study revealed the effects of interactions between chipping clearance and operational speed on the chipping geometry for cassava samples. Unmistakably, the choice regarding the shape of chips produced depends on the cassava chipper's operational speed and chipping clearance. It is recommended that: i) further studies should be conducted on the root orientation, age, feed rate, and cassava root in interaction with the chipping disc to evaluate its uniformity of the chips; ii) the chipping machine should be evaluated against other roots and tubers of economic importance, such as yam, cocoyam, and potatoes.

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