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Effect of Operating Speed and Chipping Disc Blade Number on the Performance of a Motorised Cassava Chipping Machine

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Abstract
Cassava (Manihot esculenta) remains one of the most important and widely grown food crops in tropical region which has persistently contributed food security and economy. Cassava roots deteriorate rapidly within 40-48 hours after harvest, due to physiological factors and microbial infection. Fresh roots storage is a huge challenge, there is thus a pressing need to process tubers into some stable form as soon as they are harvested. Cassava roots can be processed into chips to hasten drying into a staple form while vital qualities of the roots are preserved. This creates a huge export demand for cassava chips making it an agricultural foreign exchange earner.

A rotary disc (knife and groove) type chipping machine was also developed at the National Centre for Agricultural Mechanization, Ilorin, Kwara State, Nigeria (NCAM). This study sought to test the effect of the number of knives on the rotary chipping disc on the performance of the chipping machine. This is intended to improve chip efficiencies for boosting capabilities to preserve cassava root and also make Nigeria better active in the international chip export market.

Results of this study showed that the chipping disc with two blades at the medium test operating speed of 596 rpm had the best chipping capacity of 375kg/hr., while the two blade disc operating at the least test speed of 422 rpm gave the best chipping efficiency of 88%. The two blade disc operating at the mid test speed of 596 rpm also recorded the best quality performance. On the other hand, the three blade disc at the medium test operating speed had the highest mechanical loss.

***Keywords**: Cassava, Chipping disc blade, chipping machine.*

INTRODUCTION

For a long time cassava (Manihot esculenta) has positioned its self as one of the most important and widely grown food crops in tropical region which has persistently contributed food security and economy (Saranraj et al. 2019). According to FAOSTAT (2019), Nigeria has remained the highest producer of cassava in the world with about 59 million tonnes turnover in 2017. Cassava is widely grown in Nigeria for cash, food, and raw materials for the production of starch, ethanol, animal feed, pharmaceuticals and confectioneries.

Cassava roots deteriorate rapidly within 40-48 hours after harvest, due to physiological factors and microbial infection (Ashaye et. al.2005). Fresh roots storage is a huge challenge, there is thus a pressing need to process tubers into some stable form as soon as they are harvested. Processing is also necessary to eliminate or reduce the poisonous cyanide contained in cassava roots (Igbeka et. al.1992). A vital step in processing cassava is the reduction of fresh roots into smaller sizes by slicing or chipping. In the traditional method of cassava chipping, knives and machetes are used to reduce peeled cassava to small sizes. According to Ariavie and Ohwovoriole (2002), the manual method is tedious, slow, and dangerous, as body injuries are easily sustained. Also, high labor inputs and high processing losses are incurred in large scale processing.

Cassava roots are processed into chips to hasten drying into a staple form while vital qualities of the roots are preserved. The dry chips can also be further grounded to flour to improve shelf life. Cassava chips have become useful raw materials for the manufacture of animal feed and ethanol (Hahn and keyer 1985). There is thus a huge export demand for cassava chips making it an agricultural foreign exchange earner.

Towards complementing supply for the growing market demand for cassava chips by removing drudgery in the chipping process, several efforts have being made in developing cassava chipping machines which include; (adejumo et. al. 2011, Mogaji and Adejuyigbe 2013, Ipilakyaa et.al.2017). Bolaji et.al (2007) went further to investigate the effect of operating speed on chipping capacity, chipping efficiency and chip geometry. Adejumo et.al (2011) also compared the chipping efficiency and capacity of a knife and groove chipping disc respectively. Little or no effort has been reported on comparing the effect of blade number on chipping parameters.

A rotary disc (knife and groove) type chipping machine was also developed at the National Centre for Agricultural Mechanization, Ilorin, Kwara State, Nigeria (NCAM). The knife chipping disc has been found to be very efficient as corroborated by Adejumo et.al. 2011. In a bid to improve the efficiency of this rotary disc chipping machine, rotary disc with different number of knifes were developed. This study therefore sought to test the effect of the number of knives on the rotary chipping disc on the performance of the chipping machine. This is intended to improve chip efficiencies for boosting abilities to preserve cassava root and also make Nigeria better active in the international chip export market.

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MATERIALS AND METHODS

Machine Description and Operation

The cassava chipping machine used for this test consists basically of the frame, hopper, chipping unit, delivery chute and drive unit. The chipping unit is designed to carry either a knife or groove type circular disc. This is driven by a prime mover (6.5hp petrol) engine via belt and pulley drive connected to a shaft. Pictorial views of the cassava chipping machine is shown in plate 1.

Loaded cassava roots falls by gravity down the sharply inclined trapezoidal hopper straight into the chipping unit. In the chipping unit the fed roots are dropped against the sharp edges of the knives of the rotating disc. At impact, the roots are sliced into slim chips by shear force. These chips then discharged via the delivery chute at the bottom of the chipping unit.

The two, three and four blade knife chipping discs were respectively used for this study. They were separately mounted on the chipping machine for the tests carried out.

Plate 1. Cassava chipping machine mounted with a four blade chipping disc.

Plate 2. Three and two blade chipping discs.

Experimental Procedure

Freshly harvested cassava was de-stalked, peeled and washed in clean water. These roots were divided into twenty seven (27) equal portions of 5kg each. Three chipping discs of two, three and four blades were mounted on the chipping machine for test one after the other. For each chipping disc, test was carried out at three different operating speeds of 422rev/min, 596rev/min and 725rev/min. At each of these speed of operation, the prepared 5kg of cassava was feed into the machine, the test was done in three replicates respectively at each speed. The chipping machine was tested with each of the three chipping disc having different numbers of blade. Observed parameter in each operation were recorded for analysis. The chips collected from the chute were also manually separated and categorized as good quality chips and bad quality chips and their weight noted.

Performance parameters were thereafter calculated as follows for each of the tested chipping discs and the results compared.

a. Chipping efficiency(η_c) = $\frac{W_{wc}}{W_i} \times 100\%$

b. Machine chipping capacity(C_c) = $\frac{W_{tc}}{t} kg/hr$

c. Chipping mechanical loss(C_{ml}) = $\frac{W_i - W_{tc}}{W_i} \times 100\%$

d. Quality performance efficiency(Q_p) = $\frac{G_{qc}}{G_{qc} + B_{qc}} \times 100\%$

Where; W_{wc} = weight of well chipped cassava

W_i = input weight of cassava

W_{tc} = total weight of cassava chipped

G_{qc} = weight of good quality chip

B_{qc} = weight of bad quality chip

t = chipping time

Estimation of Physical Characteristics of Cassava Chips: The size characteristics of the chips were measured using a digital vernier caliper. 10 pieces of cassava chips were randomly selected and the length, breadth and thickness were measured using the caliper. The means of the sizes were then determined and later compared.

Plate 3. Chipped cassava from chipping machine

Plate 4. Cassava chipping machine in operation.

RESULTS AND DISCUSSION

Performance parameters; Chipping efficiency (η_c), Machine chipping capacity (C_c), Chipping mechanical loss (C_{ml}), and Quality performance efficiency (Q_p) of the chipping machine obtained for the tested two, three and four blade chipping discs are shown in Tables 1-3.

Table 1. Performance parameter of chipping machine tested with two blade chipping disc

Two blade chipping disc										Average chip size		
Speed (rpm)	W_i (kg)	W_{tc} (kg)	W_{wc} (kg)	B_{qc} (kg)	t (s)	η_c (%)	C_c (Kg/hr.)	C_{ml} (%)	Q_p (%)	H (mm)	W (mm)	T (mm)
422	5.00	4.80	4.35	0.45	55	87.00	313.73	4.00	90.63	44.40	21.83	8.33
	5.00	4.80	4.39	0.41	59	87.80	292.68	4.00	91.46	52.00	33.67	12.33
	5.00	4.82	4.43	0.39	58	88.60	299.38	3.60	91.91	64.50	31.67	10.93
596	5.00	4.90	4.50	0.40	46	90.00	382.81	2.00	91.84	52.15	31.37	9.79
	5.00	5.00	4.32	0.68	52	86.40	347.22	0.00	86.40	50.93	26.30	5.93
	5.00	4.90	4.30	0.60	50	86.00	352.52	2.00	87.76	47.48	30.86	7.79
725	5.00	4.80	4.38	0.42	56	87.60	307.69	4.00	91.25	46.13	20.94	6.29
	5.00	4.80	4.19	0.61	66	83.80	262.30	4.00	87.29	45.46	25.00	9.39
	5.00	4.40	3.80	0.60	60	76.00	263.47	12.00	86.36	34.03	22.55	3.37

Table 2. Performance parameter of chipping machine tested with three blade chipping disc

Three blade chipping disc										Average chip size		
Speed (rpm)	W_i (kg)	W_{tc} (kg)	W_{wc} (kg)	B_{qc} (kg)	t (s)	η_c (%)	C_c (kg/hr)	C_{ml} (%)	Q_p (%)	H (mm)	W (mm)	T (mm)
422	5.00	4.90	4.30	0.60	234	86.00	75.38	2.00	87.76	43.60	30.03	2.74
	5.00	4.80	4.25	0.55	270	85.00	64.00	4.00	88.54	47.26	26.13	3.78
	5.00	4.80	3.35	1.45	295	67.00	58.54	4.00	69.79	40.59	28.63	4.26
596	5.00	4.40	4.20	0.20	264	84.0	60.27	12.00	95.45	42.02	30.82	9.20
	5.00	4.60	4.35	0.25	246	87.00	67.65	8.00	94.56	41.89	24.70	5.99
	5.00	4.85	4.35	0.50	244	87.00	71.32	3.00	89.69	39.33	26.71	5.76
725	5.00	4.40	4.00	0.40	125	80.00	125.71	12.00	90.90	21.65	21.65	5.42
	5.00	4.70	4.45	0.25	280	89.00	60.26	6.00	94.68	19.42	19.42	7.85

	5.00	4.70	4.30	0.30	234	86.00	72.31	6.00	91.49	23.73	23.73	11.09

Table 3. Performance parameter of chipping machine tested with four blade chipping disc

Four blade chipping disc										Average chip size		
Speed (rpm)	W_i (kg)	W_{tc} (kg)	W_{wc} (kg)	B_{qc} (kg)	t (s)	η_c (%)	C_c (kg/hr)	C_{ml} (%)	Q_p (%)	H (mm)	W (mm)	T (mm)
422	5.00	4.60	3.10	1.50	267	62.00	6170	8.00	67.39	21.14	21.90	10.85
	5.00	4.70	3.50	1.20	264	70.00	64.12	6.00	74.47	33.60	20.02	13.30
	5.00	4.75	3.50	1.25	255	70.00	67.09	5.00	73.68	25.63	20.05	11.50
596	5.00	4.90	3.75	1.15	230	75.00	76.68	2.00	76.53	55.67	28.20	12.20
	5.00	4.80	3.50	1.30	228	70.00	75.83	4.00	72.92	44.50	21.67	14.57
	5.00	4.90	3.70	1.20	210	74.00	84.05	2.00	75.51	45.80	25.77	10.07
725	5.00	4.60	3.40	1.20	196	68.00	84.56	8.00	73.91	40.20	28.87	18.80
	5.00	4.65	3.30	1.35	166	66.00	10087	7.00	70.97	41.97	27.60	11.37
	5.00	4.65	3.45	1.20	186	69.00	89.94	7.00	74.19	35.73	25.83	15.53

These represents results for three different operational speed used for this study. Statistical analysis of these results revealed that difference in the number of chipping disc blade together with operating speed had a highly significant (0.00) effect on chipping efficiency, capacity and quality performance efficiency of the chipping machine at 5% level of significance (prob≤0.05). While chipping mechanical loss had of low significant effect (0.04) at 5% level of significance.

Further investigation into the best combination of operating speed and number of disc blade for the best performance values was done using post hoc (Duncan) and the results whose graphical representations are presented in figures 1-4. These revealed that there are no significant different between operational speed and blade number combinations S3B3, S1B3, S1B2, S2B2, S2B3 and S3B2 in terms of performance parameter (machine chipping capacity) but S3B1 and S1B1 deferred significantly. On the other hand, S2B1 was significantly different to all other combination. Comparatively, S2B1 can be seen to give the best machine chipping capacity performance value. (Where: S1=speed @ 422 rpm, S2=speed @ 596 rpm, S3=speed @ 725 rpm, B1=two blades, B2=three blades, B3=four blades).

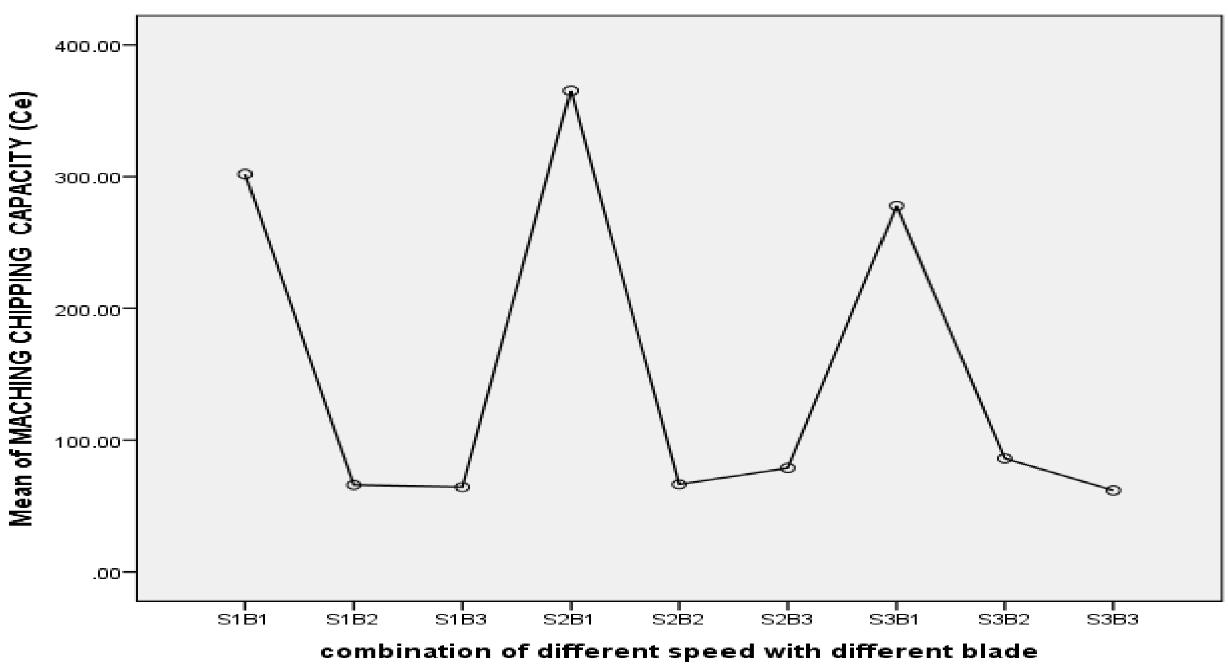

Fig 1. Chipping capacity against speed, blade no combination

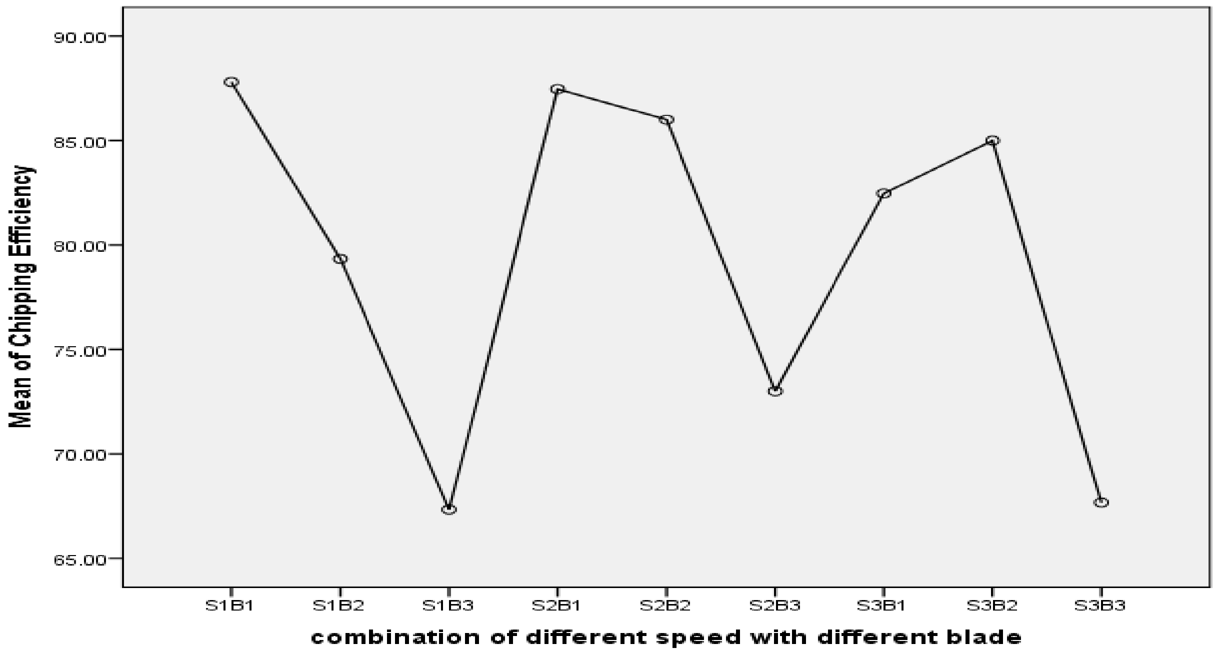

Fig 2. Chipping efficiency against speed, blade no combination

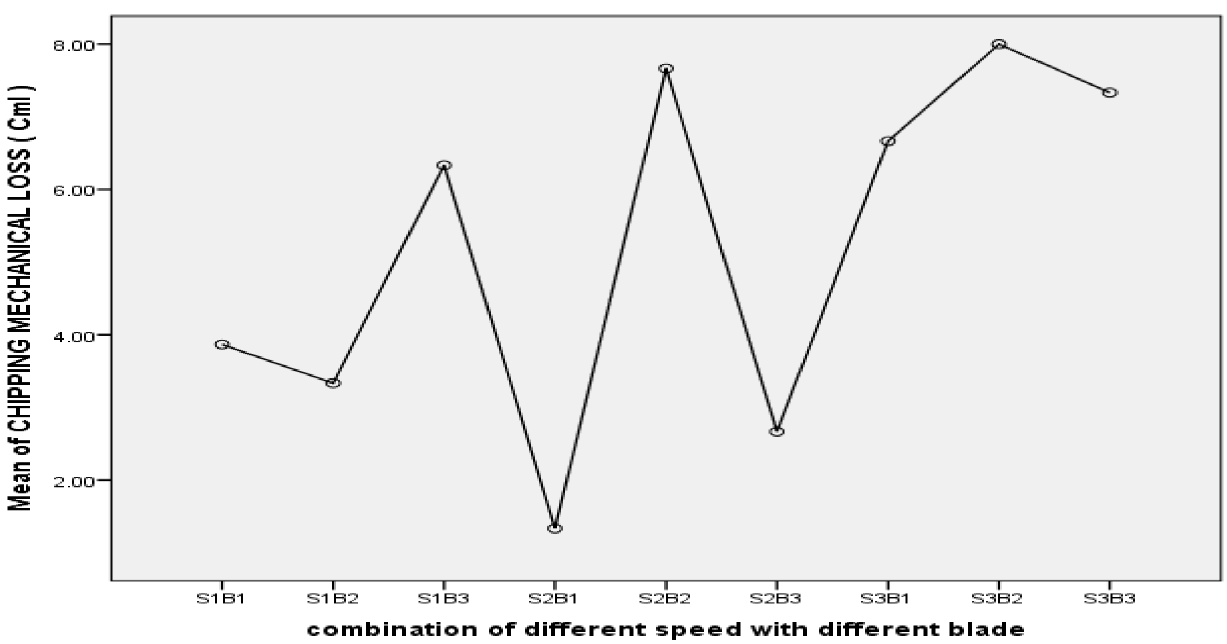

Fig 3. Chipping mechanical loss against speed, blade no combination

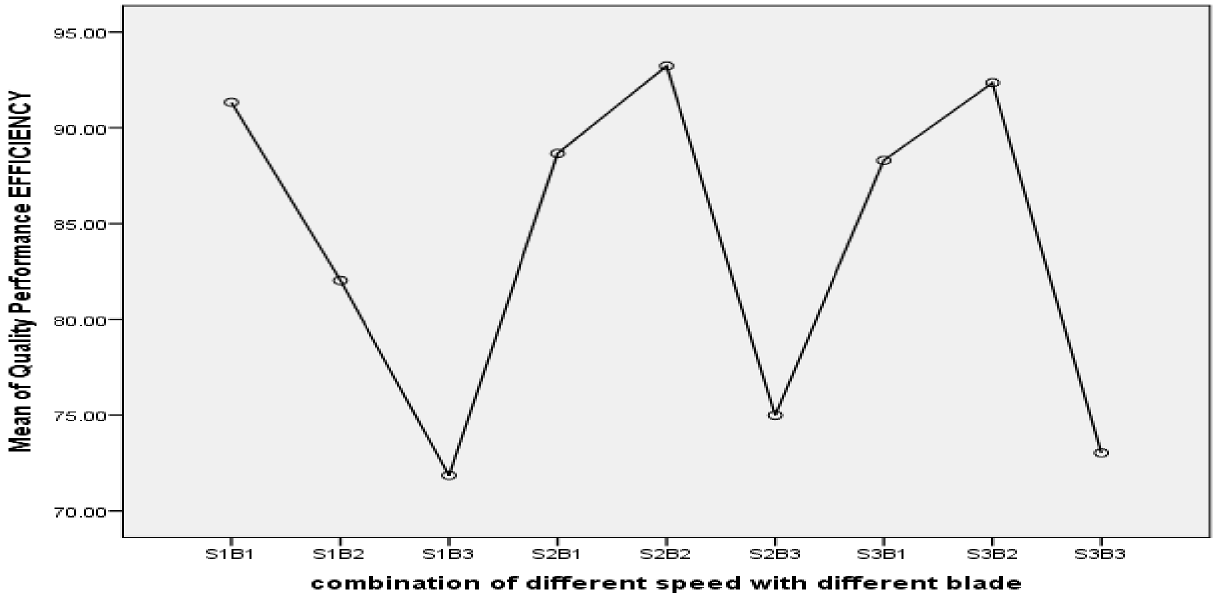

Fig 4. Chipping mechanical loss against speed, blade no combination

It was also observed that chipping efficiencies from combinations S1B3, S3B3 and S2B3 were not significantly different from each other, but they were not at per with S1B2. However, S3B1, S3B2, S2B2, S2B1 and S1B1 combinations were also not significantly different amongst each other. Consequently, any of S3B1, S3B2, S2B2, S2B1 and S1B1 will give the best chipping efficiency.

Results of the analysis in terms of chipping mechanical loss revealed that mechanical loss there are no significant difference in its values obtained for combinations S2B3, S1B2 and S1B1. However these values were significantly different from those attained by S2B1, S1B3, S3B1 S3B3, S2B2 and S3B2. Overall, it was observed that S2B1 gave the best chipping mechanical loss compared to other combinations.

Furthermore, for quality performance efficiency as response, analysis of data obtained showed that there are no significant difference in the level of quality performance efficiency with combinations S1B3, S3B3 and S2B3. However, these figures were significantly different from those of S1B2. Similarly, levels of quality performance efficiencies from combinations S3B1 and S2B1 were not significantly different from each other but different from those of S1B1, S3B2 and S2B2. Comparatively the combination S2B2 was observed to have given the best value.

CONCLUSION

The chipping disc with two blades at the medium test operating speed of 596 rpm had the best chipping capacity of 375kg/hr., while the two blade disc operating at the least test speed of 422 rpm gave the best chipping efficiency of 88%. The two blade disc operating at the mid test speed of 596 rpm also recorded the best quality performance. On the other hand, the three blade disc at the medium test operating speed had the highest mechanical loss.

It can thus be inferred that the two blade chipping disc exhibited the best chipping parameters at moderate operating speeds with minimal chipping mechanical losses.

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