UNIZIK JOURNAL OF AGRICULTURAL AND BIOSYSTEMS ENGINEERING

Journal homepage: https://journals.unizik.edu.ng/ujabe/

UJABE

April (2026), 1(2): 98-105

ISSN: 3141-2912

PERFORMANCE EVALUATION OF A MOTORIZED COCOYAM CHIPPING MACHINE

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Received: 24th March 2026; **Accepted:** 29th March 2026; **Available Online:** 30th April 2026

ABSTRACT

The performance of a motorized cocoyam chipping machine developed at the National Root Crops Research Institute, Umudike was evaluated. The machine comprises of the following major parts namely, the main frame, housing, chipping plate and the power transmission unit. Two varieties of cocoyam tubers from *Colocasia esculenta* species, NCe 001 (*coco India*) with average geometric mean diameter (3.20 cm), sphericity (0.81), weight (98.05 g), moisture content (48.97 %) and NCe 002 (*ede ofe* green) with the average geometric mean diameter (3.42 cm), sphericity (0.76), weight (87.14 g), moisture content (52.06 %) were used for the evaluation. The machine was evaluated using 5 kg of cocoyam tubers for capacity and efficiency at five varying speeds of 300, 325, 350, 375 and 400 rpm. The results obtained showed that the capacity of the machine increases with the speed, while the efficiency increases with speed up to 375 rpm, but beyond that level, it drops. The highest capacity of 195.04 kg/hr was obtained at speed of 400 rpm, but 92 % efficiency was obtained at 375 rpm. Evaluation of the effect of feed rates and chute clearance on the capacity of the chipper was also carried out using Analysis of Variance (ANOVA) in 3 x 5 factorial with three levels of feeding chute clearance (0.07, 0.09 and 0.12 m) and five levels of feed rate (2.5, 2.8, 3.0, 3.2 and 3.5 kg/min) in a Randomized Complete Block Design (RCBD). The results of the statistical analysis showed that both the feed rate from 2.5 to 3.5 kg/min and the chute clearance from 0.07 to 0.12 m had a highly significant effect at 1% level on the capacity of the chipper

Keywords: Evaluation, Capacity, Efficiency, Chipper, Cocoyam

1.0 INTRODUCTION

Cocoyam (*Colocasia esculenta and Xanthosoma sagittifolium*) is a stem tuber that is widely cultivated in both the tropical and subtropical regions of the world (Ikejiofor *et al*. 2016a). The different varieties of cocoyam, according to Nwakor (2014) are "NCe 001(*coco India*), NCe 002(*ede ofe* green), NCe 003 (*ede ofe* purple), NCe 004 (*ede ofe* giant), NCe 005 (*ede ukpang*), and NCe 006 (ede *Ghana*) from Colocasia species and NXs 001 (*ede ocha*), NXs 002 (*ede uhie*), and NXs 003 (ede *okorokoro*) from Xanthosoma species. According to Ikejiofor (2021) "some varieties of cocoyam, such as NXs 001 and NXs 002, can be used in the production of cocoyam crisps, which are a very good snack". The cocoyam varieties NCe 001 and NCe 002 are very good in the production of cocoyam soup thickener. They can also be processed into various food products used for industrial and culinary purposes. Cocoyam starch is also an important product with physical and functional properties for industrial applications (Adeyanju *et al*., 2019). Determination of some physical properties of cocoyam tubers such as moisture content, size of tuber, weight, shape, tuber diameter etc are necessary in the design of cocoyam processing machines as stated by (Balami *et al*., 2012). Ikejiofor and Ndirika, (2015) reported on the determination of physical properties of two cocoyam varieties NXs 001 and NXs 002. In Nigeria, processing of cocoyam is affected by unavailability of machines and equipment for the various processing operations (Ikejiofor, 2021). Processing of cocoyam reduces the oxalate content and

also helps to obtain good quality flour. Oxalate in cocoyam is a limiting factor in its utilization (Adeyanju *et al.*, 2019). Chipping of the cocoyam corm enhances the drying process, and the manual chipping is very tedious and time-consuming (Ikejiofor, 2021). Mechanizing the chipping process of cocoyam is very crucial in order to maintain large scale processing. As reported by Ikejiofor (2021), most of the existing crop chipping machines designed and developed by Bolaji *et al*. (2008), Adejumo *et al.* (2011), and others were specifically for cassava roots. Ipilakyaa *et al.*, (2017) reported on the development of a motorized chipping machine for tubers and the machine was tested for its efficiency using yams and cassava, and the chipping efficiency of 78.19% was obtained. Bolaji *et al*. (2008) studied the effect of machine speed on chipping capacity, efficiency and chips geometry. The results showed that increase in speed result in increase in chipping capacity. It was discovered that the higher the speed, the lower the chipping efficiency and the longer the chips. Ikejiofor (2021) reported on the effect of cutting velocity and slot size on the efficiency of a cocoyam chipper. Also, Ikejiofor, *et al.* (2016b) reported on the development of a chipping machine specifically for cocoyam. Hence, there is need for performance evaluation of the machine to determine the performance parameters such as capacity and efficiency. This paper aims to report on the evaluation of the cocoyam chipper's performance.

2.0 MATERIALS AND METHODS

2.1 Description of the Machine

The machine comprises of the following parts: the main frame, chipping plate, housing and power units. The main frame is the machine part that carries the total weight of the machine. It is constructed with a 50mm thick angle iron. The machine frame is 430mm long, 430mm wide and 720mm high. The machine has the chipping plate that does the cutting of the tuber into chips. The chipping plate was formed from a circular plate having a diameter of 300mm. The surface of the plate was serrated by punching outward to obtain the required chipping cutting edges. The housing unit of the machine holds the cocoyam tubers and it has an adjustable chute that is inclined at 36^{o} to the frame so as to enable the loaded tubers slide down by gravity. The machine is powered by three phase 2h.p electric motor via belt and pulley drive. A petrol engine of the same power rating can be used where there is no electric power supply. The pictorial views of the cocoyam chipper are shown in Figure 1a and b.



Figure 1(a): Front view of the machine



Figure 1(b): Back view of the machine

2.2 Working Principles of the Machine

The machine is simple to operate and therefore requires only one operator. Before the machine is operated, all parts must be properly fixed and bolted together. The machine is put into operation by starting the electric motor, which provides the required power to drive the pulley of the chipping machine, causing the chipping plate to rotate. Peeled and washed cocoyam tubers fed into the machine through the chute against the chipping slots (cutting edges) of the rotating chipping plate resulted in the formation of cocoyam chips. The chips produced fall by gravity through the outlet located at the bottom part of the housing unit.

2.3 Samples Preparation

The two cocoyam varieties NCe 001 (*Coco India*) and NCe 002 (*Ede ofe* green) used for the evaluation were obtained from National Root Crops Research Institute (NRCRI) experimental farm. The average size, shape, weight and moisture content of the samples were determined. The harvested cocoyam tubers obtained were weighed, peeled and washed manually before introducing them into the machine.

2.4 Instrumentations and Measurements

The shape of the tubers was obtained by measuring the axial dimensions of each cocoyam tuber with vernier caliper to an accuracy of 0.01cm. The Figure 2 below shows the geometry of the cocoyam tuber, indicating the axial dimensions a, b and c.

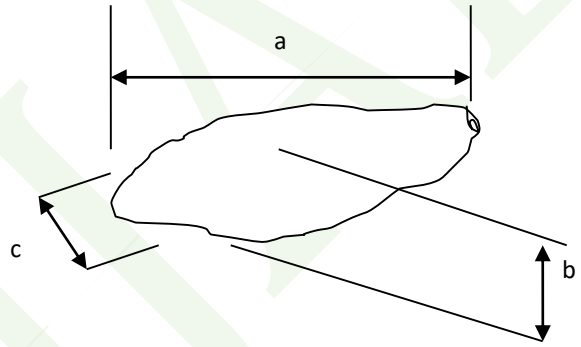


Figure 2: Geometry of Cocoyam Tuber

The values obtained were used to calculate geometric mean diameter (Gmd) and sphericity as stated by Balami *et al*., (2014) using Equations 1 and 2:

$$\text{Gmd (cm)} = (abc)^{1/3} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$\text{Sphericity (cm)} = \frac{(abc)^{1/3}}{a} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

The cocoyam chipper was powered by a 2 h.p / 3 phase electric motor with speed of 1415 rpm. Five different pulley sizes of 34, 32, 30, 28 and 26 cm in diameter were used for the machine to obtain the varying speeds of 300, 325, 350, 375 and 400 rpm respectively using the expression given by (Ogundipe *et al*., 2011) as equation 3:

$$N_1D_1 = N_2D_2 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Where,

N_1= speed of driving pulley (rpm), D_1= diameter of driving (mm), N_2= speed of driven pulley (rpm), D_2= diameter of driven pulley (mm). An electronic balance with the sensitivity of 0.01 g, whose values ranged from 0.01 g to 5000 g was used for weighing. Time was determined using a stop watch. The machine was designed to easily adjust the feeding chute clearance. Meter rule was used to measure the chute clearance. The average moisture contents of the cocoyam tubers used were determined by drying the cocoyam samples using hot air oven at a temperature of 75^{o}C for 24 hours as Ikejiofor and Ndirika (2021). The percentage of the moisture content (wet basis) were calculated as Equation 4:

$$\text{Mct (wb) \%} = \frac{W_f - W_d}{W_f} \text{X100} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Where,

Mct (wb) % = Moisture content wet basis, W_f = weight of the fresh sample (g), W_d = weight of the dried sample (g).

2.5 Experimental Procedures

Performance evaluation of the cocoyam chipper was carried out. For the preliminary evaluation of the machine, the treatments used in the experiment include five varying machine speeds (275, 300, 325, 350 and 375 rpm) with the input cocoyam tuber weight of 5kg and feeding chute clearance of 0.12 m. The fresh cocoyam tubers from two varieties used were weighed, peeled and washed manually in clean water and then introduced into the machine. The weights of the normal and crushed chips produced were determined. The machine was evaluated for output capacity and chipping efficiency using equations 5 and 6 respectively as expressed by Ikejiofor (2021).

$$\text{Machine capacity (kg/hr)} = \frac{W_1}{t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

Where, t = time (hr), W_1 = Input weight (kg)

$$\text{Chipping efficiency (\%)} = \frac{W_2}{W_1} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

Where, W_1 = Input weight (kg), W_2 = Output weight of normal chips (kg)

The treatments used in the further evaluation of the machine include three levels of feeding chute clearance (0.07, 0.09 and 0.12 m) and five levels of feed rate (2.5, 2.8, 3.0, 3.2 and 3.5 kg/min) The data obtained were subjected to statistical analysis using the ANOVA in 3 x 5 factorial to determine the effect on machine capacity.

3.0 RESULTS AND DISCUSSION

The average size, shape, weight and moisture content of the two cocoyam varieties used were determined. The cocoyam variety NCe 001 (*coco India*) has average Gmd (3.20cm), sphericity (0.81), weight (98.05 g) and moisture content (48.97 %), and the variety NCe 002 (*Ede ofe* green) has average Gmd (3.42cm), sphericity (0.76), weight (87.14 g) and moisture content (52.06 %). The data obtained from the preliminary evaluation of the cocoyam chipper is presented in Table 1.

Table1: Preliminary Evaluation Results of the Cocoyam Chipper

Speed (rpm)	Input weight (kg)	Chipping time (sec.)	Weight of normal chips (kg)	Weight of crushed chips (kg)	Machine capacity (kg/hr)	Efficiency (%)
300	5.0	125.91	3.62	1.06	142.96	72.4
325	5.0	115.43	4.02	0.73	155.94	80.4
350	5.0	105.60	4.33	0.53	170.46	86.6
375	5.0	98.40	4.60	0.32	182.92	92.0
400	5.0	92.29	4.26	0.46	195.04	85.2

3.1 Machine Capacity

The highest machine capacity of 195.04 kg/hr was obtained at 400 rpm. This occurred when it took the machine 92.29 seconds to chip 5 kg of peeled and washed cocoyam tubers fed into the machine as shown in Table 1. The lowest machine capacity of 142.96 kg/hr was obtained at the machine speed of 300 rpm. This also occurred when it took the machine 125.91 seconds to chip 5 kg of the tubers. The results obtained indicated that machine capacity increases with the speed. The highest machine capacity of 195.04 kg/hr is in agreement with the highest machine capacity of 209kg/hr obtained by Awulu *et al*. (2015). The chipping time also reduces with increase in the machine speed. The relationship of machine capacity with the speed is shown in Figure 3

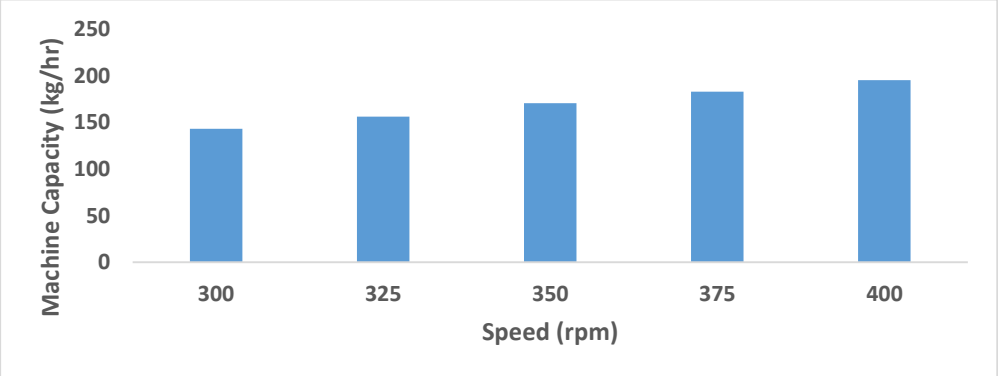


Figure 3: Machine Capacity Versus Speed

3.2 Chipping Efficiency

The highest efficiency of 92 % was obtained at machine speed of 375rpm. This occurred when the machine produced 4.6 kg of normal chips out of 5 kg of the peeled and washed cocoyam tubers fed into the machine. The lowest efficiency of 72.4 % was also obtained at machine speed of 300rpm. This occurred when the machine produced 3.62 kg of normal chips out of 5 kg of the peeled tubers. It was observed that increase in machine speed results in an increase in chipping efficiency. However, beyond the machine speed of 375rpm, the chipping efficiency begins to fall. This is as a result of more chips being crushed at very high speed. The relationship of machine chipping efficiency with the speed is shown in Figure 4.

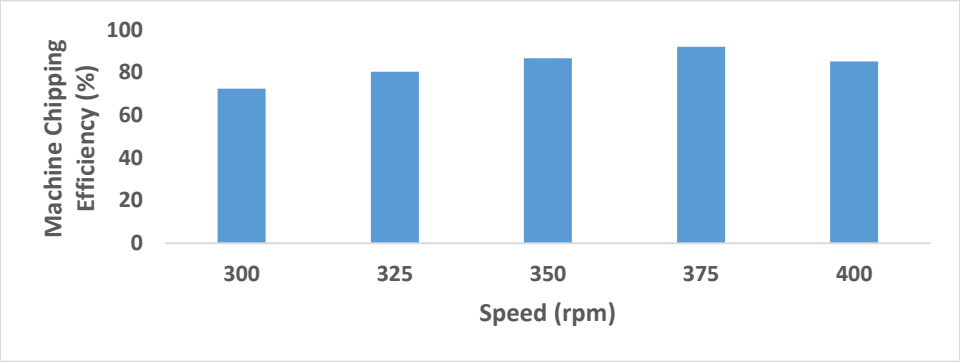


Figure 4: Machine Chipping Efficiency Versus Speed

3.3 Effect of Feed Rates and Chute Clearance On Machine Capacity

Further evaluation of the machine performance was also carried out using three levels of feeding chute clearance (0.07, 0.09 and 0.12 m) and five levels of feed rate (2.5, 2.8, 3.0, 3.2 and 3.5 kg/min to determine the effect on the machine capacity. The results obtained showed that the highest machine capacity of 195.04 kg/hr was achieved at the feed rate of 3.5 kg/min and feeding chute clearance of 0.12 m as shown in Table 2. Also, the lowest machine capacity of 75.8 kg/hr was achieved at the feed rate of 2.5 kg/min and feeding chute clearance of 0.07 m. It was also observed that the machine capacity increases with increase in feed rate and chute clearance. The feeding chute clearance of 0.12 m gave the optimum capacity. The result obtained agrees with the report from Ahorsu *et al*., (2021), that an increase in feed rate and chute clearance increases the capacity and quality of the chip geometry.

Table 2: Effects of Feed Rates and Chute Clearance On the Machine Capacity

Feeding chute clearance (m)	**Feed rate (kg/min)**				
	2.5	**2.8**	**3.0**	**3.2**	**3.5**
0.07	75.8	81.96	88.30	94.88	102.48
0.09	106.24	114.82	124.56	133.89	142.30
0.12	142.96	155.94	170.46	182.92	195.04
Total	**325.00**	**352.72**	**383.32**	**411.69**	**439.80**

3.4 Statistical Analysis Results

The data obtained from the statistical analysis as presented in Table 3 indicated that both the feed rate from 2.5 to 3.5 kg/min and the chute clearance from 0.07 to 0.12 m had highly significant effect at 1% level on the capacity of the machine. The result of the analysis obtained agrees with the report of the analysis from Ahorsu *et al*., (2022) on cassava chipping machine, that there was significant effect of the feed rate on the machine capacity. This showed that the machine capacity increases with the feed rate. The result also showed that as the chute clearance increases, the machine capacity increases.

Table 3: Analysis of Variance Table for The Effect of Feed Rates and Chute Clearance

Source of Variation	Degrees of freedom (Df)	Sum of square (Ss)	Mean square (Ms)	F-calculated	F-tabular	
					5%	1%
Chute clearance	2	16385.859	8192.929	303.071**	4.46	8.65
Feed rate	4	2776.369	694.092	25.676**	3.84	7.01
Error	8	216.260	27.033			
Total	**14**	**19378.489**				

** = Highly significant (P = 0.01)

4.0 CONCLUSION AND RECOMMENDATIONS

The evaluation of the cocoyam chipper's performance showed that the machine performed satisfactorily with highest capacity and efficiency of 195.04 kg/hr and 92 % respectively. It was observed that the machine capacity increases with speed of the machine, also very high speed beyond 375 rpm reduces the machine efficiency. The statistical analysis result showed that the feed rate from 2.5 to 3.5 kg/min and chute clearance from 0.07 to 0.12 m had highly significant effect at 1% level on the capacity of the cocoyam chipper. The highest machine capacity was obtained at the highest values of feed rate and chute clearance. This means that the cocoyam chipper capacity increases with increase in feed rate and the machine chute clearance. The feeding chute clearance of 0.12 m and feed rate of 3.5 kg/min gave the optimum capacity, while the machine speed of 375 rpm gave highest efficiency. Therefore, for optimum performance of the cocoyam chipper, these values should be recommended for enhanced production of cocoyam chips that can be dried and processed into flour for industrial applications and other food forms.

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To cite this article:
Ikejiofor, M.C. and Ndirika, V.I.O, 2026. Performance Evaluation of a Motorized Cocoyam Chipping Machine 1(2): 98-105. https://journals.unizik.edu.ng/ujabe/