NIGERIAN AGRICULTURAL JOURNAL
ISSN: 0300-368X
Volume 52 Number 2, August 2021 Pg. 160-163
Available online at: http://www.ajol.info/index.php/naj
https://www.naj.asn.org

EFFECT OF CUTTING VELOCITY AND SLOT SIZE ON THE EFFICIENCY OF A COCOYAM CHIPPER

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Abstract
The developed cocoyam chipper was evaluated. Two varieties of cocoyam tubers (NXs 001 and NXs 002) were used. The machine cutting velocities used were 3. 60, 3.93, 4.25, 4.58 and 4.91m/s, and the chipping slot sizes used were 0.0014, 0.0016 and 0.0018 m^2. Statistical analysis was used to evaluate the effect of cutting velocity and the chipping slot size on the efficiency of the cocoyam chipper. The analysis results showed that the cutting velocity within the range of 3.6 to 4.91m/s had a significant effect at 0.05 level, on the efficiency of the cocoyam chipper. Also, the chipping slot size within the range of 0.0014 to 0.0018m^2 had a highly significant effect at 0.01 level. The data obtained also showed that the highest efficiency of 85.18% was obtained at machine cutting velocity of 4.91m/s and chipping slot size of 0.0018m^2. These ranges of chipping slot sizes and cutting velocities are therefore recommended to obtain the maximum chipping efficiency of cocoyam chipper.

Keywords: Efficiency, velocity, slot size, cocoyam, chipper

Introduction

Cocoyam corms when harvested are prone to deterioration mainly due to leaf blight disease. Traditional methods of cocoyam storage have prevailed till date (Eze *et al*., 2015), and these include; heaping the corms under shade or covering them with leaves, storing inside a pit and covering them with leaves and soil. Alternatively, only corms that are needed for consumption or to be taken to the market are harvested, while the rest are left un-harvested in the farm till when they are needed or next planting season. These traditional methods are inefficient. The recommended storage conditions for the two species of cocoyam (*tannia*) and (*taro*) as presented by Opara (1999) can only be practiced with regulated temperature and relative humidity storage where there is adequate power supply. In spite of the importance of cocoyam as a staple food in many countries, cocoyam has received very little research attention to enhance its production and utilization potentials. The processing of cocoyam in Nigeria is hampered by unavailability of machines and equipment to carry out various processing tasks. The shortage of processing and preservative machines and equipment for cocoyam may be because data on the engineering properties of cocoyam required for the design of these machines are insufficient and not available in some cases. The major limiting factor in the utilization of cocoyam is the presence of oxalates which causes irritation when foods prepared from them are eaten (Sefa-Dedeh and Agyir- Sackey, 2004). Cocoyam processing help to reduce the oxalate content and produce good quality flour (Onayemi and Nwigwe, 1987). The cocoyam corms must be dried to ensure safe storage over a much longer period without the risk of losses from rotting (Kay, 1987). Chipping or slicing the corm into smaller units before drying has the added advantage of reducing the drying time of the processed cocoyam. The manual chipping of cocoyam is very tedious, time-consuming and the operators feel typically uncomfortable due to the itching nature of the tubers. It is necessary to mechanize the chipping process of cocoyam in order to overcome the difficulties of handling large scale processing with the traditional method. The various factors affecting the performance of chipping machine as presented by Adejumo *et al.* (2011), Bolaji *et al*. (2008), Ogundipe *et al*. (2011), and others include machine factors such as: cutting velocity, feed rate, chipping slot size, weight of chipping disc, chipping force, radius of chipping plate, feeding chute clearance and also crop factors such as: crop moisture content, bulk density, length and weight of tubers. The study by Adejumo *et al*. (2011) reported that age, size and shape, orientation, feed rate and pressure of the tuber in contact with the chipping disc are factors affecting the chipping efficiency and the uniformity of the chips. Also, Bolaji *et al*. (2008) studied the effect of machine speed on chipping capacity, efficiency and chips geometry. The results showed that the higher the speed, the lower the chipping efficiency and the longer the chips. The existing chipping machines developed by Bolaji *et al*. (2008), Raji and Igbeka (1994), Adejumo *et al*. (2011), Ogundipe *et al*. (2011) and others were all designed specifically for cassava roots. Ikejiofor *et al.* (2016) developed a chipping machine that was specifically designed for cocoyam, which encourages mechanized chipping or slicing of the corm into smaller units in order to reduce the drying time. This study aims to evaluate the effect of cutting velocity and slot size on the efficiency of the developed cocoyam chipper.

Materials and Methods

Performance evaluation of the developed cocoyam chipper was carried out using two varieties of cocoyam tubers (NXs 001 and NXs 002) at five varying cutting velocities (3.60, 3.93, 4.25, 4.58 and 4.91m/s), and three chipping slot sizes (0.0014, 0.0016 and 0.0018m^2). Fresh cocoyam tubers 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 throughput capacity, chipping efficiency, and cutting velocity using equations 1, 2 and 3. The throughput capacity was measured by weighing the quantity of cocoyam tubers chipped by the machine per unit time, expressed in kg/s. An electronic balance of sensitivity 0.01g, whose values ranged between 0.01 to 5000g was used for weighing. Time was measured using a stop watch. Moisture contents of the sliced cocoyam corms were determined by oven drying the cocoyam samples at a temperature of 75°C for 24 hours, using hot air oven with temperature range of 0 – 90°C. The throughput capacity was evaluated by determining the total quantity of tubers chipped by the machine per unit time expressed in kg/hr. This is expressed by Ogundipe *et al*. (2011) in equation 1:

$$\text{Machine capacity (kg/hr)} = \frac{W_2 + W_3}{t} \quad .....(1)$$

Where, t = time (hr), W_2 = output weight for normal chips (kg), W_3= output weight of crushed tubers (kg).

The chipping efficiency was evaluated by determining the quantity of normal chips produced compared with the total quantity of cocoyam tuber fed into the machine usually expressed in percentage. This is expressed by Ogundipe *et al*. (2011) in equation 2:

$$\text{Chipping efficiency (\%)} = \frac{W_2}{W_1} \times 100 \quad ......(2)$$

Where, W_1= input weight (kg), W_2= output weight for normal chip (kg).

The cutting velocity was evaluated by determining the speed at which the cutting blades rotate and cut the cocoyam tuber and it is expressed in equation 3:

$$\text{Cutting velocity } (V_c) = \frac{\pi DN}{60} \quad ....(3)$$

Where, V_c = cutting velocity (m/s), D = diameter of machine pulley (m), N = speed of rotation of machine pulley (rpm).

The performance evaluation results obtained from the cocoyam chipper were subjected to further statistical analysis using a 3x5 factorial experiment in RCBD as expressed by Obi (2002), to determine the effect of the crop and machine variables on the performance parameters.

Results and Discussion

Chipping efficiency

The highest efficiency of 85.18% was obtained at machine cutting velocity of 4.91m/s and chipping slot size of 0.0018m^2 as indicated in Table 1. This occurred when it took 4.77kg out of 5.6kg of the peeled and washed cocoyam tubers fed into the machine to be chipped within 102.79 seconds. The lowest efficiency of 30.05 % was also obtained at machine cutting velocity of 3.6m/s and chipping slot size of 0.0014m^2. This occurred when it took 1.803kg out of 6.0kg of the peeled tubers to be chipped within 284.51 seconds. It was observed that increase in chipping slot size results in an increase in chipping efficiency.

Table 1: Data obtained for the machine chipping efficiency

Chipping Slot Area (m^2)	Cutting Velocity (m/s)					
	3.60	**3.93**	**4.25**	**4.58**	**4.91**	**Total**
0.0018	61.07	66.79	72.41	78.84	85.18	364.29
0.0016	42.09	45.84	47.95	51.52	54.24	241.64
0.0014	30.05	30.19	31.62	33.65	35.24	160.75
Total	133.21	142.82	151.98	164.01	174.66	766.68

The curve of variation of the machine chipping efficiency with the cutting velocity at varying slot size is shown in Figure 1. The highest machine efficiency value of 85.15% obtained also agrees with the highest machine efficiencies values of 86.7 and 87.09% obtained by Awulu *et al*. (2015) and Oladeji (2014) from their cassava chipping machine.

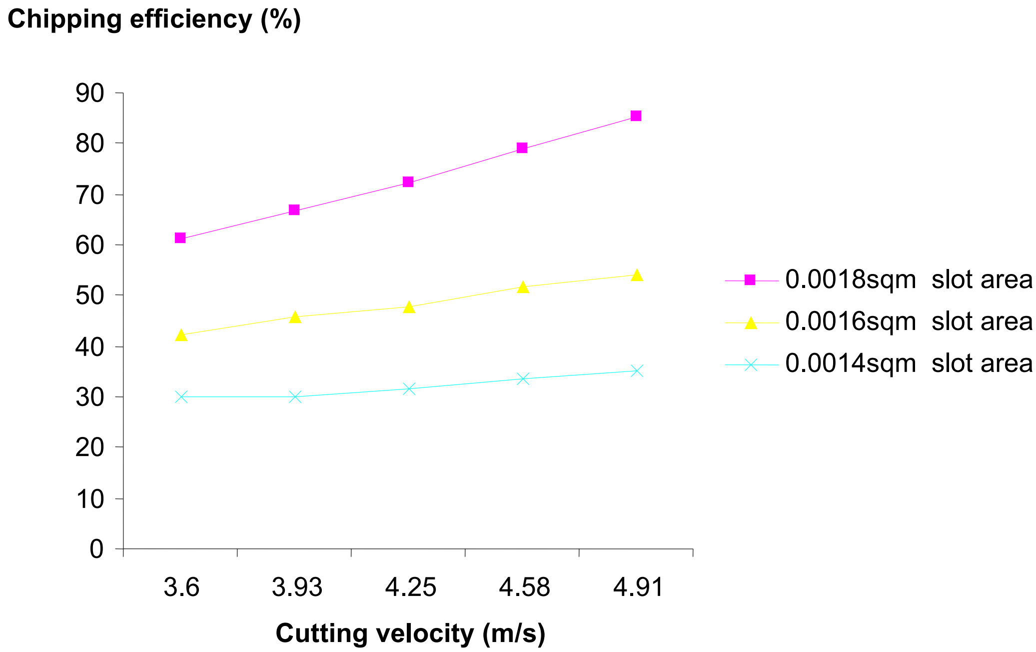

Figure 1: Curve of variation of machine chipping efficiency with cutting velocity at varying slot sizes

Total chip loss

The lowest total chip loss of 0.168kg was obtained at the machine cutting velocity of 4.91m/s and chipping slot size of 0.0018m^2. It was observed that the total chip loss reduced with increase in machine cutting velocity and chipping slot size. The curve of variation of total chip loss with the cutting velocity at varying chipping slot sizes iss shown in Figure 2.

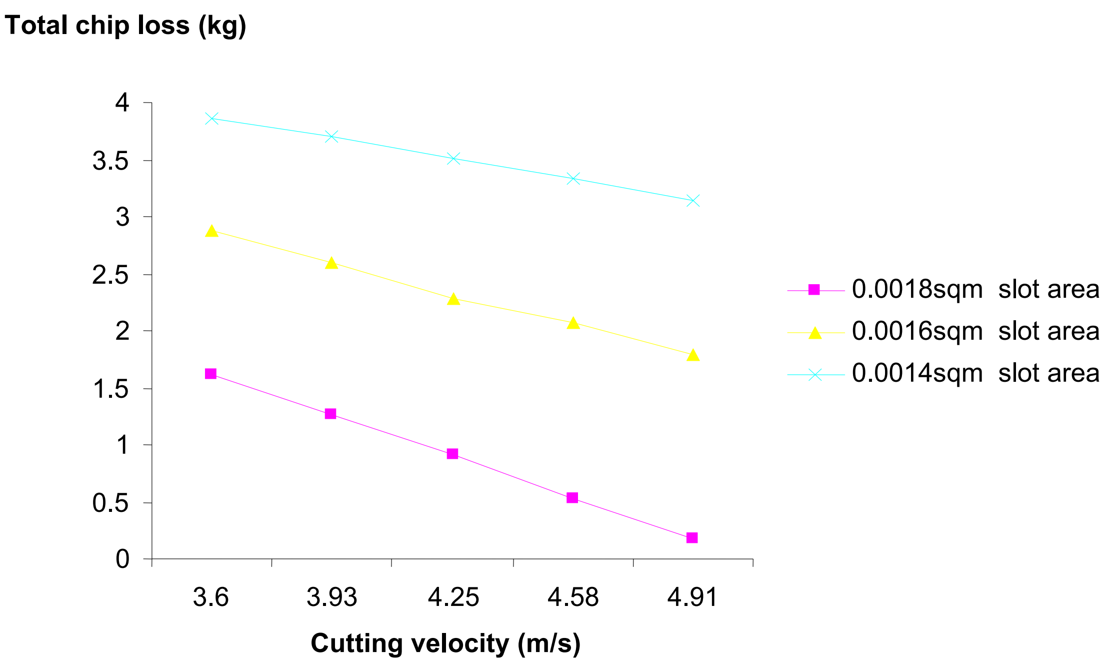

Figure 2: Curve of variation of total chip loss with cutting velocity at varying slot sizes

The results of the analysis as indicated in Table 2 showed that the chipping slot size within the range of 0.0014 to 0.0018m^2 had highly significant effect at 0.01 level on the efficiency of the cocoyam chipper. Also, the cutting velocity within the range of 3.6 to 4.91m/s had significant effect at 0.05 level on the efficiency of the cocoyam chipper. The result of the analysis obtained agrees with the result obtained by Awulu *et al*. (2015), using Duncan's New Multiple Range Test to determine the significant effect of speed of operation at P≤ 0.05. The result indicates that speed has significant effect on the efficiency of the chipper at that level of significance. This means that increase in cutting velocity of the cocoyam chipper from 3.6-4.91m/s increases the efficiency of the cocoyam chipper but beyond that limit, the efficiency will start to drop. The result of the analysis also indicated that as the chipping slot size increases within the stipulated range, the efficiency of the cocoyam chipping machine also increases.

Table 2: Analysis of variance of machine chipping efficiency

Source of variation	d.f	S.S	M.S	F-Cal	F- Tabulated	
					5%	1%
Chipping slot size	2	4200.983	2100.492	149.672**	4.46	8.65
Cutting velocity	4	362.045	90.511	6.449*	3.84	7.09
Error	8	112.268	14.034			
Total	14	4672.296				

***** = Highly significant (P = 0.0), * = Significant (P = 0.05)***

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