EFFECTS OF OPERATING SPEED AND SCREEN DIAMETERS ON THE EFFICIENCY OF A HAMMER MILL.

[1]Opadotun, O.O, [1]Oladipo, N.O, [1]Okoro, O.N And [2]Oriola, K.O.

[1] National Centre for Agricultural Mechanization (NCAM), Ilorin, Kwara State.

[2]Ladoke Akintola University of Technology, Ogbomoso, Oyo State.

e-mail: hopeopa@yahoo.com; +2348038302301.

Abstract

A hammer mill was developed for pulverizing dried yam. The machine was evaluated using screens of different sizes (1.5mm and 5.0mm) and different operating speeds (650 rpm and 1300rpm) to ascertain effects of these parameters on the machine output efficiency, capacity and fineness of the end-products. Four replicate samples were prepared namely: A – [5.0mm ø screen, 650rpm speed], B – [1.5mm ø screen, 650rpm speed], C – [1.5mm ø screen, 1300rpm speed] and D – [5.0mm ø screen, 1300rpm speed] respectively. The end-products were subjected to sieve analysis; the following inferences were drawn: (i) D is most time efficient with operational time of 8.10sec for 10Kg of dried yam, followed by C (8.60sec), A (9.15sec) and B (9.40sec) respectively for same mass of test material; this shows that higher operational speed and screen size enhanced the milling time.(ii) The output efficiency (%) are in the order: C (81.50%), B (79.40%), D (77.10%) and A (73.39%) respectively; best output efficiency was achieved at higher speed cum small screen hole diameter.(iii) Also that the operational speed and screen hole diameter affects the machine output capacity, as shown:D (74.07 Kg/hr), C (69.77 Kg/hr), A (65.57 Kg/hr), and B (63.83Kg/hr) in decreasing order respectively and fineness modulus: A (0.88), D (0.84), B (0.75) and C (0.62) in increasing order respectively. Therefore, a suitable operational speed and screen size was ascertained and recommended for the optimum efficiency of the hammer mill.

Key words*: Hammer mills, Screen, Pulverizing, Efficiency and Sieve analysis.*

1.0. INTRODUCTION

Nigeria is the world's largest yam producer, contributing approximately two thirds of the global production with about 2,837,000 hectares land area under yam cultivation (FAO, 2013). Yam is an important staple food crop in Nigeria, produced both for household consumption and as a cash crop.It is an important source of carbohydrate for many people of the sub-Sahara region, especially in the yam zone of West Africa (Akissoe et al., 2003). Yam contributes more than 200 dietary calories per capita daily for more than 150 million people in West Africa and serves as an important source of income to the people (Babaleye, 2003). It is not rich in vitamin A and C, as sweet potatoes, but tends to be higher in protein and minerals like phosphorous and potassium than any other root crops (Degras, 1993).

According to AMCOST (2006), pre- and postharvest food crop loss among African countries is estimated at about 40%, which is higher than the global average. Onebunne (2006), reported that due to its perishable nature, lack of good processing equipment and methods and poor storage facilities, high percentage of yam (about 30%) produced is wasted annually in Nigeria. Various efforts have been made to add value to this pernicious crop in order to retain, sustain and maintain its quality and quantity. Part of this effort is the storage of yam in pit, building structures, platform and barn (Igbeka, 1985). Yam can be stored in these various structures for 4 to 6 months in fresh weight (Hounhouingan, 2006).

Fresh yam can be dried as lump or sliced; this extends the shelf life to between 11-14 months under proper storage. This makes yam less susceptible to pest and rodent attacks; makes it readily available in the market during off- season and helps to reduce post- harvest losses (Hounhouingan, 2006). Dried yam can further be processed into flour which stores longer under proper storage and is used in making special local delicacy called “Amala” (an elastic food paste) enjoyed in the Western part of Nigeria and some parts of West Africa.

The process line for yam after harvest is highlighted below,

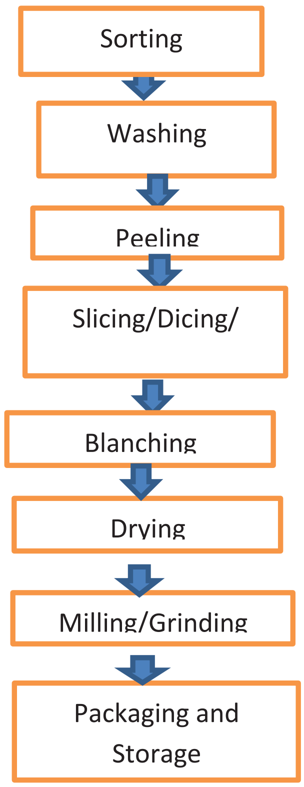


Figure 1: Block diagram for processing yam to flour.

Processing of dried yam into flour is a series of size reduction processes. The general term, size reduction, includes the mechanical processes of cutting, shearing, crushing, grinding, and milling feed grains. These processes expose more surface area for digestion without causing any noticeable change in the chemical properties of the material. At the same time, size reduction facilitates uniform mixing. And although uniformity in size and shape of the reduced particles is usually desired, it is seldom attained (Rudnitski et al, 2012).

Traditionally, size reduction is done using mortar and pestle; the end product gotten is sifted with sieve and the process repeated over again till the chaff residue is minimal. After the introduction of the burr mill, the manually pulverized dried yam is milled into fine powder with the help of the burr mill.

Presently, the manual pulverization with the mortar and pestle is no more practiced, with the invention of hammer mill, which is used in pulverizing dried yam mechanically before the process is completed with the use of burr mill. In other words, a typical dried yam milling shop is equipped with a hammer mill and a burr mill with a diesel engine in between them for power supply to each of the machine one after the other (*personal findings*). These mechanical means of pulverizing dried yam saves times and energy and better end product is gotten than the old traditional means.

Various hammer mills have been developed for different purposes ranging from post harvest processing to stone grinding for civil construction works. Various hammer mills have been developed for different purposes ranging from post harvest processing to stone grinding for civil construction works. Nasir (2005) developed a multi-purpose hammer miller for cereals and dried cassava tubers and evaluated the performance based on operational time using cereals and dried cassava flakes. Ngabea et al (2015) fabricated a magnetic sieve crusher to remove metal objects from the test materials. Xuan et al (2012) developed a hammer mill with separate sieving device and evaluated the machine based on the sieve performance.

Efforts to improve milling process would be further boosted through this research by establishing a suitable operational speed and screen size for optimum output result of end-product. The hammer mill used for this research was designed and fabricated for pulverizing dried yam.

2.0. MATERIALS AND METHODS

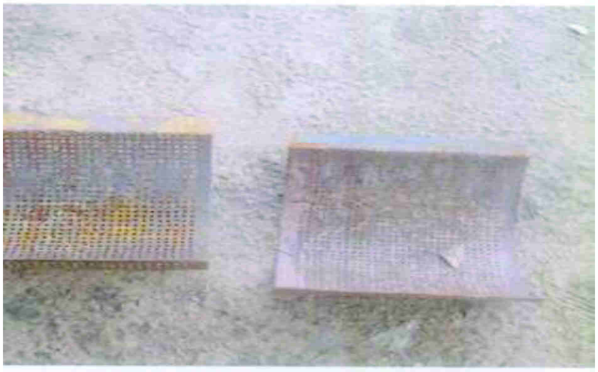
2.1. MACHINE DESCRIPTION

The hammer mill used for this research was designed and fabricated for pulverizing dried yam with a modification in the mechanism by incorporating sets of rollers with the hammers and an interchangeable screen.

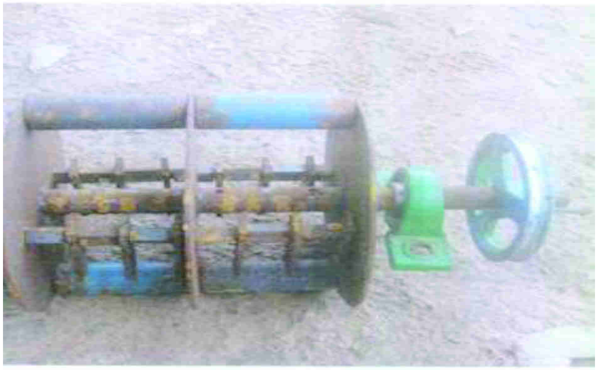
The hopper is made up of 2.5mm mild steel plate. It has a composite shape and a cover for safety of the operator and to prevent the dried yam from falling during operation. A mild steel solid shaft of 35mm diameter supported by pillow bearings was used. A V-belt (type B) was used on a single groove cast iron pulley to transmit the power from the electric prime mover.

The sieves were made of 5.0mm thick mild steel with two screen sizes (1.5 and 5.0 mm) constructed for the testing. Angle iron bars of 50 x 50mm were used for the frame supports to give the need rigidity to shock and vibration.

:The machine after Finishing



5:The screens used on the machine



The mechanisms of the machine

Figure 2: Pictorial views showing the machine, sieves and the mechanism arranged from top to down respectively.

2.2. Materials

Dried yam lumps (White yam "D. rotundata") were sourced from Ijeru market, in Ogbomoso South Local Government Area of Oyo state for the performance evaluation. It was subjected to further drying; a moisture content of 8.68% dry base was achieved. A weighing scale of accuracy ±0.01kg was used for weighing each portion of the test material, a tachometer to determine the operating speed of the machine when loaded, collecting bowls for collecting the crushed sample, a stopwatch to record the time of operation at each instance and polythene bags for storing the end product for safe keep.

2.3. Methodology

Two screens of diameters 1.5 mm and 5.0mm Screens of size 1.5 and 5.0 mm were made to have large difference in screen size. A Chinese Steelman 5.0 hp prime mover with 1430 rpm with adjustable speed regulator was used to vary the operating speed. From literatures, Nasir, 2005 and Ngabea et al, 2015 affirmed the average speed for operating hammer mill as 700 and 850 rpm respectively. Therefore, a speed slightly below (i.e. 650 rpm) was chosen as the base operating speed; the speed was doubled (1300 rpm) to examine its effects on the output efficiency of the machine.

10 Kg of the dried yam lump was weighed out in four portions on the weighing scale at a moisture content of 8.68% dry basis.

The two speeds (650 and 1300 rpm) were run on the machine with the screen interchanged one after the other and the operating time recorded. The crushed dried yam at each instance was tagged as follow: A – (5.0 mm screen diameter with 650 rpm speed), B – (1.5 mm screen diameter with 650 rpm speed), C – (1.5 mm screen diameter with 1300 rpm speed) and D – (5.0 mm screen diameter with 1300 rpm speed).

The end-products gotten were taken for particle size analysis to determine the degree of fineness and uniformity index of the four replicates. The procedure as explained by California Test 202 (2011) was followed: 200g of the grinded replicates were weighed out and shaken through 5 set of Tyler sieves for 5 minutes by means of tapping sieve shaker. The mesh numbers of the 5 sieves are 40, 60, 80, 100 and 150 microns from top to base respectively. The sieves are designated 1 – 5 starting from the smallest to the biggest (i.e. from 150 to 40), while the pan is designated as 0. The following were thereafter determined,
(i) The percentage of material retained on each sieve by:

$$\% \, retained \, in \, sieve = \frac{W_{sieve}}{W_{total}} \times 100 \quad (1)$$

Where, W_{sieve} is the weight of aggregate in the sieve, W_{total} is the total weight of the aggregate.

(ii) $\% \, cumulative \, retained = R_{S1} + R_{S2} + \cdots + R_{S5}$ (2)

Where, R_s- % retained on each sieve from largest to smallest.

(iii) The percentage of material passing each sieve:

$$\%\,cumulative\ passing = 100 - \ \%\,cumulative\ retained \quad (3)$$

(iv) The machine output efficiency was determined by:

$$machine\ efficiency = \frac{mass\ output}{mass\ input} \times 100 \quad (4)$$

(v) $$material\ loss = \frac{(M_b - M_a)}{M_b} \quad (5)$$

Where, M_a- Mass after grinding, M_b- Mass before grinding.

(vi) $$machine\ capacity = \frac{mass\ of\ input\ material}{milling\ time} \times 60 minutes \quad (6)$$

(vii) $$\Sigma FM = \frac{\Sigma\ \%\,retained}{100} \quad (7)$$

Where, ΣFM- Fineness modulus.

3.0. RESULTS AND DISCUSSION

1. The effect of operating speed and screen size on particle size:

High operating speed with small screen size gave the best result in terms of fineness (Figure 3). The percentage of material retained is lowest for sample C followed by B, D and A respectively. This conforms to the findings of Anderson, 2003 and Yancey, et al, 2014 which affirmed that the optimal grinder configuration for maximal process throughput and efficiency of hammer mill is strongly dependent on tip speed of the rotor, screen diameter, feedstock type and properties, such as moisture content. Hence, in selecting the proper grinder process parameters, speed and screen size are important factors.

2. The effect of operating speed and screen size on operation time:

The time for milling same quantity of dried yam increased in the order: D, C, A and B respectively (table 1); showing that at larger screen size and higher speed, the operation is more time efficient. This is in line with El Shal et al (2010) which reported that aside moisture content, factors like screen size, speed rating, etc. also affect the residence time of feed in hammer mill operation.

3. The effect of operating speed and screen size on machine throughput:

The machine throughput (table 1) is highest for D, followed by C, A, and B respectively in decreasing order. This connotes that the higher the operating speed and screen size, the higher the output capacity because of lower residency time in the machine (Yancey, et al, 2014).

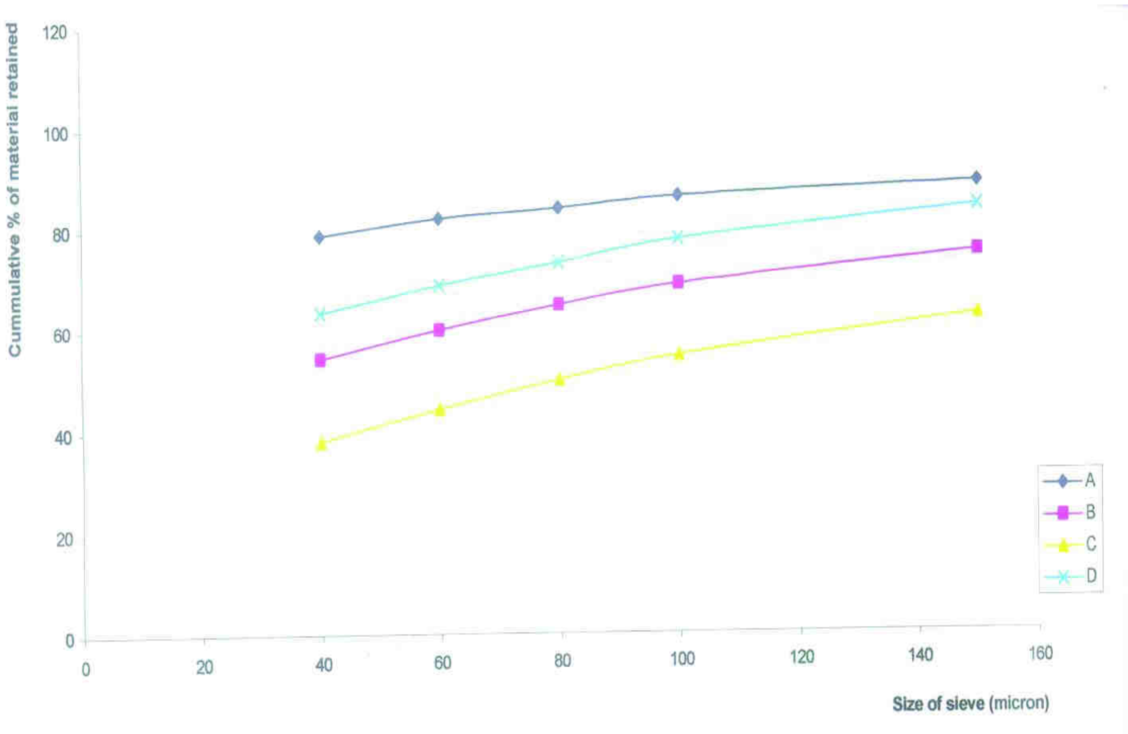
4. The effect of operating speed and screen size on machine efficiency:

Based on the ratio of residue retained on the sieve during sieve analysis to fine particles, the machine was most efficient at instance C followed by B, D and A in the decreasing order (table 1). This conforms to Yancey, et al, (2014), which reported that the smaller the size of the screen the finer the grains generated from the grinding machine.

Table1: Parameters from machine testing.

Sample	Mass of material input (Kg)	Milling Time (Min.)	Machine Capacity(Kg/hr)	Material Output(Kg)	Material Loss(Kg)	Machine Efficiency (%)
A	10.0	9.15	65.57	7.34	2.66	73.40
B	10.0	9.40	63.83	7.94	2.06	79.40
C	10.0	8.60	69.77	8.15	1.85	81.50
D	10.0	8.10	74.07	7.71	2.29	77.10
Average	**10.0**	**8.81**	**68.31**	**7.79**	**2.21**	**77.85**

Figure 3: Graph of the sieve analysis of the samples of crushed dried yam showing the fineness in increasing order from top to down.



4.0. CONCLUSIONS

Hammer mill, as a processing equipment, is more efficient if operated at the appropriate optimal conditions. The machine throughput, efficiency, fineness of end-product and timeliness of operation are essential to the overall performance of the machine. This research has been able to establish that higher operational speed (1300 rpm) and smaller screen size (1.5mm) is best among other operational instances used giving a throughput of 69.77 Kg/hr, working efficiency of 81.50% in terms of fineness of end-product and operational time of 8 minutes 60 seconds for 10 Kg of dried yam lump at 8.68% moisture content.

REFERENCES

Akissoe, N., C. Mestres, J. Hounhouigan, and M. Nago (2003). Biochemical origin of browning during the processing of fresh yam (*Dioscorea*spp.) into dried product. *J. Agric. FoodChem.,* 53 (7): 2552-2557.

AMCOST (2006), Technologies to reduce post-harvest food loss The African Ministerial Council on Science and Technology (AMCOST) of the African Union (AU), Pretoria, South Africa.

Anderson, S (2003). Hammer mill design tip for feed materials: Producing a finer grind with a large-rotor, high-speed hammer mill.CSC Publishing,Waterloo, Iowa.319/232-8444.

Babaleye, T. (2003). Raising the status of the yam, a major food crop in West Africa.ANB-BIA SUPPLEMENT ISSUE/EDITION.No. 463. Pp. 1-3.

California Department of Transportation, Division of Engineering Services. (**2011**). California Test 202**:** Method of Test for Determining Sieve Analysis of Fine and Coarse Aggregates.pp.1-21.

Degras, L. (1993). The Yam: A Tropical Root Crop. 3rd Edition, London, Sterling Publisher.

El Shal, M.S, Tawfik, M.A, El Shal, A.M and Metwally, K. A. (2010). Study The Effect of Some Operational Factors on Hammer Mill.Misr. J. Ag. Eng., 27(1): 54 – 74.

FAO. (2013). *FAOSTAT database*. [Online]. Available at: http: //bit.ly/NmQzZf. [Accessed: 10. April 2014].

Hounhouingan, J.D. (2006). "Make millions from yam production". Available through: http://www.selfemployment@yahoo.com. Accessed: 22nd April, 2007.

Igbeka, J.C. (1985). "Storage Practices For Yam in Nigeria" Agricultural Mechanization in Asia, Africa and Latin America, Vol.16 No.1 pp.55-58.

Nasir, A. (2005). Development and Testing of a Hammer Mill. AU J.T. 8(3): 124-130.

Ngabea, S.A, Okonkwo W.I and Liberty, J.T. (2015). Design, Fabrication and Performance Evaluation of a Magnetic Sieve Grinding Machine.Global Journal of Engineering Science and Researches (GJESR).Vol. 2 (8): 65-72.

Onebunne, A. (2006). "Yam production and Export". Available through: www.cigar.org/ research / yam. Accessed: 22nd April, 2007.

Rudnitski, S, Birenbaum, R and Heslop, L. (**2012).** Handling Agricultural Materials: Size Reduction and Mixing. Available through: www.archive.org/details/handlingagri00bire. Retrieved 5th Sept; 2016.

Xuan, C, Cao, L, Wu, P, Ma, Y and Han, D. (2012). Development on a Hammer Mill with Separate Sieving Device.TELKOMNIKA Indonesian Journal of Electrical Engineering.Vol.10, No.6, pp. 1151~1156.

Yancey, N, Wright, C.T and Westover, T.L. (2014). Optimizing hammer mill performance through screen selection and hammer design, Biofuels, 4:1, 85-94. Article available on: http://dx.doi.org/10.4155/bfs.12.77.