Journal of Agricultural Extension
Vol. 4, 2000

A COMPARATIVE EVALUATION OF HAMMER MILL AND GRATER FOR GARI PRODUCTION

O. K. Owolarafe*, J. A. Adesope*, L. A. Sanni*, K. A. Taiwo** and O. O. Ajibola*
*Department of Agricultural Engineering
Obafemi Awolowo University, Ile-Ife, Nigeria
**Technology Planning and Development Unit
Obafemi Awolowo University, Ile-Ife, Nigeria

Abstract

An investigation was carried out to determine the comparative performance of hammer mill and grater in gari production. The grater and hammer mill were used to pulverized cassava tubers and the dewatered mash of the samples. The throughput of 1002.7 and 1440 kg/h comminution and pulverization respectively) than the grater (with a throughput of 356.7 and 42.9kg/h respectively). The sieve analysis of the pulverized mash and gari shows that hammer mill communites finer than the grater. There is a difference in the swelling capacities of gari from both machines with that of the grater being greater than that of the hammer mill. The resulting gari products from both machines however meet the ASAE standards in terms of quality. With regards to energy use the hammer consumes more energy than the grater.

In general, the higher output of the hammer mill and the corresponding fitness of the products into the required range of standard accords it a higher potential in substituting other size reduction machines in large scale gari production.

1.0 Introduction

Cassava (Manihot spp) is one of the most important food crops with annual production figure 33 million tonnes in Nigeria (CBN, 1998). Its importance derives from utilisation for domestic export and industrial purposes. The crop is consumed in West Africa mostly in the form of a fermented, semi-dextrimised. creamy-white or yellow meal called gari. Gari is prepared (Fig. 1) by peeling cassava tubers. comminution of the tuber into mash and fermenting and dewatering the mash. The dewatered mash is partially gelatinised, dried to a moisture content of about 12% d.b. and pulverized (optional).

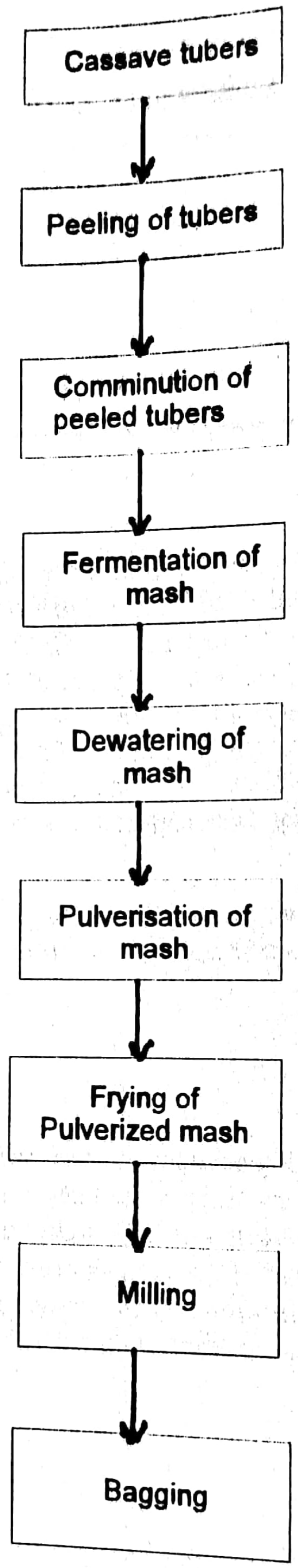

Fig. 1: Flow Process of Gari Production

The increasing demand for cassava products necessitated the mechanisation of the processing operations. This involves the incorporation of machines, labour saving devices and equipment in the various operational steps. Comminution is one of the operations that has been successfully mechanised. Comminution as a size reduction process involves the deformation of the tubers until they break or tear. It is usually achieved by application of forces which may be compressive attrition (shear) and/or chopping (Brennan et al, 1969; Headley & Pfost, 1968), Ige and Faborode (1982) reported that machines used as size reduction devices employ a combination of two or more of the three types of forces with one of the forces being predominant. They found that hammer mill utilises the impact principles as well as attrition forces while burr mill reduces size mainly by shearing.

The effectiveness and efficiency of a size reduction operation are measured by uniformity of the particle size, rise in temperature during the operation, power requirement and the trouble involved (Henderson & Perry, 1974). Thus, the effectiveness and efficiency of the operation are influenced by the type of feed material and the machine involved. Size reduction ratio is normally used in the prediction of performance of a particular machine (Brennan et al, 1969).

In an attempt to improve uniformity of product, Henderson (1961), in his studies on food grinding, suggested recycling of feed materials into the machine (closed circuit system). This was found to be capital intensive and hence the open circuit system (without recycling) was preferred (Henderson & Boloni, 1966).

The adequacy of cassava comminution largely affects some subsequent operations in gari production and hence the quality of the final product. Inappropriate and inefficient dewatering operation not only reduces the quality of product but makes the frying operation difficult.

The grater has been used successfully in grating cassava and found to be simple, in construction have a low initial cost, produces uniform guiding, generates low heat, and has low power requirement (IITA, 1990). However, it has high maintenance cost, low output and needs additional pressure from the operator. It was also reported that the hammer mill is simple in construction and in addition has low maintenance cost, has high output and requires no external pressure (IITA, 1990). The high initial cost and high power requirement place it at some disadvantage. Momodu (1996), in his study on the use of the hammer mill for wet milling of cassava, reported that the hammer mill has higher throughput capacity (when used for milling cassava tuber and pulverizing the dewatered mash). He also observed that the hammer mill products were finer, with the degree of fineness depending on the screen openings.

The result of a recent survey conducted on the adoption of agro-processing technologies (Abibola et al, 1998) revealed that the use of the hammer mill for the milling operation. Information gathered from the few users indicates that conventional grater is preferred to the hammer mill for the following reasons: high cost of the machine and fine particle size of the milled product which floats in cold or hot water. There is little or no information on the comparative performance of the hammer mill and the grater; hence, the study was undertaken to evaluate the performance of the hammer mill compared to that of the grater using product quality, throughput and energy requirement as indices.

2.0 Materials and Methods

2.1 Materials

The machines used include:

6. the hammer mill, fabricated in the Department of Agricultural Engineering with 4 rows of 1 beater per row driven by a 3.75kW electric motor through a double v-belt A type; a detachable screen (10mm aperture) located at loner 180^0 of grinding chamber, top offset feed, and gravity discharge;

7. the grater driven by a 7.5kW diesel engine through a flat belt, and with a top centre feed and gravity discharge;

8. an endecott Test sieve shaker Ser. No. 8747 (Johnson & Fifth Borw Ltd, England) and standard ASIM E11 sieve set (2.36 mm-0.3 mm);

9. a hydraulic press of 10 tonnes jack capacity;

10. a circular fryer; and

11. a manual sieve made of raffia material.

2.2 Method

Freshly harvested cassava tubers were obtained from the Obafemi Awolowo of University Teaching and Research Farm. The peeled cassava were divided into two sets of 50 kg each. One set was processed using the hammer mill and the other set using the grater. The moisture content of the peeled cassava was determined by oven drying method (with a measured weight dried at 105°C for 24 hours). The size reduction time was noted and the throughput of each of the machines was determined. The moisture content of the collected mash was also determined (using oven dry method). The mash from each sample was bagged and dewatered using the hydraulic press (with a 10 tonnes hydraulic jack). The moisture content of the pressed cake was also determined. The cake was divided into four parts and designated as: hammer mill tuber comminution and hammer mill cake pulverizing (HH); hammer mill tuber comminution and manual cake pulversing (HM); grater tuber comminution and hammer mill cake pulversing (GH); and grater tuber comminution and manual cake tuber comminution (GM). Throughput capacity was determined over time for processing the dewatered mash through the machines. The machines were allowed to run empty for about 20 seconds and attain a steady speed. Pulverized samples were fried into gari. The particle size analysis of samples of both the pulverized cake and the resulting gari from them was determined using ASAE standard (ASAE, 1982) to find the geometric mean diameter and geometric standard deviation. Swelling capacity of gari samples from the four groups were determined by placing a sample of 50 ml in a 400 ml beaker filled with water and noting the change in volume of gari in 5 minutes. Rittinger's law in Eqn (1) (Henderson & Perry, 1980) was used to compute energy use of the machines.

$$E = C\ (I/L_2 - I/L_1) \qquad (1)$$

where L_1 and L_2 are initial and final geometric mean diameter of the samples in mm respectively and C is a constant. Each of the experiments was replicated thrice.

3.0 Result and Discussion

The throughput capacities of the hammer mill and the grater for tuber comminution are 1002.7kg/h and 365.7 kg/h respectively (Table 1). Also the machines have throughput capacities of 1560kg/h and 42.86kg/h for the mash pulverization operation. These two results indicate that in terms of output, the hammer mill is better than the grater in gari processing. This is, therefore, in agreement with the result for performance of the hammer mill on other agricultural materials notably feed grains (IITA, 1990). The result for hammer mill also agrees with that of Momodu (1996). High output obtained may be attributed to the larger impact forces developed by the heater arms of the hammer mill rotating at a high speed.

Table 1

Effect of Processing Machine on Throughput Capacity and Energy Use

Parameter	Hammer Mill	Grater
Throughput capacity for grating tuber (kg/hr)	1002.7	365.7
Throughput capacity for pulverizing mash (kg/hr)	1560.0	42.9
Energy Use for grating (hp-hr)	0.28	0.67

The moisture content of the tuber was found to be 62.98% which is within the reported literature range of 60-70% (IITA, 1990). The average moisture content of the grated mash from hammer mill is 60.4% wet basis; this is a little lower than 61.7% wet basis for that of the grater. The moisture content of the dewatered mash (cake) for the hammer mill and grater are 46.6 and 47.8%, respectively, indicating an insignificant (probability $P < 0.5$) difference.

Table 2

Effect of Processing Method on the Pulverized Particle Size

Processing Method		Geometric mean diameter (mm)	Standard Deviation	Range (mm)
Tuber Comminution	Mash Pulverization			
Hammer mill	Hammer mill	0.8265	1.064	0.73
Hammer mill	Manual	1.023	1.057	0.55
Grater	Hammer mill	0.96	1.059	0.54
Grater	Manual	0.93	1.052	0.59

Table 2 shows the effect of processing method on the pulverized particle size. It can be observed that the hammer mill comminuted and pulverised sample has the smallest geometric mean diameter. This indicates that it produces finer particles when compared with the products of other methods. This result agrees with the findings of Momodu (1996) on the use of the hammer mill in comminuting cassava. Furthermore, the fact that the sample from the same method has the highest standard deviation and range indicates that the particles are evenly distributed. The geometric mean diameter of 0.96 and 0.93 for grater comminuted and hammer mill pulverized, and grater comminuted and manually pulverized respectively is an indication that no significant difference exists between the two processes.

The high geometric means diameter observed from manually pulverized product from hammer mill comminuted sample (HM) suggests that there is further breaking of the particles by the hammer mill during the pulverization process and hence smaller particles in the HH samples. Thus the particles are finer and uniform when passed through this process.

Table 3

Effect of Processing Method on Particle Size and Swelling Capacity of Gari

Processing Method		Geometric mean (mm)	Standard Deviation	Range	Swelling Capacity
Tuber Comminution	Mash Pulverization				
Hammer mill	Hammer mill	0.686	1.07	0.55	3.0
Hammer mill	Manual	0.859	1.06	0.46	3.4
Grater	Hammer mill	0.661	1.07	0.58	3.4
Grater	Manual	0.848	1.05	0.63	3.8

Table 3 shows the geometric mean diameter of gari from the different samples. It can be observed that gari from the hammer mill comminuted and pulverized (HH) and grater comminuted and hammer mill pulverized (GH) compared well in terms of fineness and even distribution (with values of 0.686 and 0.661 and 1.07 and 1.068 respectively).

The effect of the effective pulverization of the cake by the hammer mill is further manifested by the high geometric mean diameter observed for the samples of HM and GM. This result confirms the claim of the processors that the products from the hammer mill contain finer particles.

The energy use of the machines (hammer mill and grater) during the processing operations are 0.28 and 0.67 for the hammer mill (Table 1) and the grater respectively. This implies that the grater is able to convert the energy supplied for size reduction energy better than the hammer mill. About 5.6% of the energy supplied is used for size reduction while grater uses 11.2% of the same. This waste of energy by the hammer mill can be attributed to the fact that the hammer mill require high power to overcome the inertia of the beaters thereby making less energy available for size reduction process.

Table 3 shows the result of the swelling capacity of the gari from the four samples (i.e. HH, HM, GM and GH). The result indicates that the gari from the GM has the highest swelling capacity. This can be attributed to the fact that the coarse particles are largely distributed (Table 3) within the sample. Other samples of gari produced using hammer mill at certain stage of the process have low swelling capacities at each monitoring time when compared with that of grater comminution and manually pulverized. However, the samples meet the standard of reaching three times their initial volume within a minute as recommended by IITA (1990). Furthermore, there was floating of gari particles in all the samples when soaked in water. This suggests total milling of the fibrous materials in the sample during the processing operations. Processing method do not affect the colour of the gari products; all the samples were also white.

4.0 Conclusion

This paper presents results on a comparative evaluation of four different processing methods viz: hammer mill tuber comminution and hammer mill cake pulverizing (HH); hammer mill tuber comminution and manual cake pulverizing (HM); grater tuber comminution and hammer mill cake pulverizing (GH); and grater tuber comminution and manual cake tuber comminution (GM) for gari. Hammer mill incorporated methods yield finer particles when compared with other methods. The swelling capacity of gari from the grater comminution and manually pulverized is highest compared with the other three methods. With considerably higher throughput capacity and efficiency, the hammer mill is more suitable for large scale gari processing.

References

Ajibola, O. O; Faborode, M.O; Ajayi, O. A; Akanbi, C. T; Taiwo, K. A; Adeloye, K; Jeje, J. O; Owolarafe, O.K; Osunbitan, J. A; Sanni, L. A. and Sunmonu, O. A. (1998), Capacity and Appropriate Agro-procęssing Technology for Women in Osun and Ondo States, Survey Report on United Nation Development Project (Women in Development).

Brennan, J. G.; Butter, J. R.; Cowell, N. O; and Lily, A. E. (1969), Food Engineering Operations, Applied Science Publisher Ltd, London.

CBN (1998), Annual Report and Statement of Accounts, Central Bank of Nigeria.

Headley, V. E. and Pfost, H. G. (1968), A comminution equation relating energy to surface area by the Logarithmic probability method, Transaction of the ASAE, Pp 331-335 and 338.

Henderson, S. M. (1961), Feed Grinding Studies: basic Observations and Challenges in Grinding Procedures, Agricultural Engineering Year Book, Pp 350-352, 364.

Henderson, S. M. and Boloni, I. (1966), Closed circuit grinding of grains, Journal of Agricultural Engineering Research, Vol. 11 (4), Pp 248 - 254.

Henderson, S. M. and Perry, R. L. (1980), Agricultural Process Engineering, Second Edition, John Wiley and Sons Ltd, New York.

Ige, M. T. and Faborode, M. O. (1982), Design and performance evaluation of a low cost feed processing machine, Nigeria Journal of Engineering and Technology, Vol. 5, No. 1, Pp 21 - 30.

I.I.T.A. (1998), Cassava in Tropical Africa - A Reference Manual, Chayce Publication Service, UK.

Momodu, J. J. (1996), Studies on the Use of Hammer Mill for Size Reduction of Cassava in Gari Production, Unpublished M.Sc. Thesis Department of Agricultural Engineering, Obafemi Awolowo University, Ile-Ife.