Effects of Moisture Content and Operating Speed on the Milling Efficiency of a Burr Mill

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***Abstract*—This paper examines the effects of moisture content and operating speed on the milling efficiency of a burr mill in size reduction of cowpea. Dry and wet experiments were carried out. The operating speeds for the experiments were 500, 550 and 600 rpm. The weight of sample was measured using an electronic weighing machine; a moisturemeter for the moisture content and a stop-watch for the milling time. The results showed that milling efficiency increased with a decrease in moisture content in the two experiments. The milling efficiency increased with increase in operating speed in the dry experiment with optimum performance at 10 % moisture content; operating speed of 600 rpm and 83 % milling efficiency. But it decreased with increase in operating speed at optimum performance at 22 % moisture content, 550 rpm operating speed and 71 % milling efficiency in the wet experiment. It is concluded that a linear relationship exists between the moisture content, operating speed and the milling efficiency. The results are therefore recommended for the use of farmers and cowpea processors.**

Keywords—Moisture content, operating speed, milling efficiency, size reduction, cowpea

1. INTRODUCTION

Cowpea (*Vigna Unguiculata*), an annual legume that is commonly referred to as Southern Pea, black eye pea, Crowder Pea, Lubia, niebe, coupe of frijole originated in Africa, Latin America, South east Asia and in the Southern United States (Davis et al., 2009; Ojomo et al., 2010). Its important use as a grain crop, animal fodder, or as a vegetable has made its development and processing germane concerns to the professionals in charge. As earlier mentioned, cowpea can be used at all stages of growth. The tender green leaves are the important food source in Africa and are also prepared as a port herb; immature snapped pods are used in the same way as for snap beans, often mixed with other foods. Green cowpea seeds are boiled as a fresh vegetable or may be combined or frozen and the dry mature seeds are also suitable for boiling and canning (Davis et al, 2009; Ojomo, et al., 2010). Due to this economic importance of cowpea, agronomists have been working tremendously for improvement in its growth and yields but lots have to be done to its processing and value additions.

Cowpea products are widely consumed but are facing increasing competition from soybean especially in weaning mixes. However, there are several dishes using cowpea flour produced in the household and these provide a varied nutritious diet and have added desirable attributes which include easy cooking, availability, and favorable taste (Nyankori et al., 2002).

Many food processes frequently require the reduction in the size of solid materials for different purposes. Size reduction may aid other processes such as expression and extraction or may shorten heat treatment, as in blanching and cooking. Communition is the generic term used for size reduction and includes different operations such as crushing, grinding and milling, mincing and dicing. Most of these terms are related to a particular application. The reduction mechanism deforms the pieces of food until it breaks or tears. Breaking of hard material along cracks or defects in their structure is achieved by applying diverse forces. The types of forces commonly used in food processes are compressive, impact, attrition or shear and cutting (Brennau et al., 1981; Bankole et al., 2013).

Processing is a form of value addition. Its objective is to minimize the qualitative and quantitative deterioration of the materials after harvest (Sule and Odugbose, 2014). Food processing and preservation is a branch of manufacturing that transforms raw animal, vegetable, or marine materials into consumable safe food products (Taylor et al., 2008). According to Ogwuagwu (2007), the evolution of modern and appropriate agricultural machines for food crop processing in the country has been hampered as a result of non-availability of appropriate engineering materials and processing facilities used in the production of farm processing machine which helps in the transformation of agro-based produce from one form into another.

Particle size reduction, milling or communition is a necessity for agro- materials to make them smaller before further processing or utilization. There are different size reduction forces at work in various size reduction machines (Sule and Odugbose, 2014). This improves the eating quality or suitability of foods for further processing and to increase the range of available products. A material's physical and mechanical properties often determine the ease or difficulty in reducing the material to an appropriate particle size. The following material characteristics are some of the most common that can present milling challenges fibrous, non- friable, heat-sensitive, wet, fatty or sticky and dense or hard materials.

Milling as a unit operation is usually designed to break a solid material into smaller pieces (Mc Gee 2004; Bankole et al., 2013). It is also used to create a free-flowing material. Milling usually involves constraints with regard to particle size. Particles size is controlled by using different screens and clearances. The type of mill used also has a major impact on quality yield of the output. Milling is divided into wet and dry milling. Wet milling is used on produce to produce fiber starch and protein extracts. Kethireddipalli et al. (2002) reported that freshly wet milled paste produces dishes of superior quality. Overall wet milling produced a superior taste and end product.

Milling involves the application of external force; the amount of particles reduction caused by the external forces depends on the amount of energy applied to the particle, the rate at which it is applied (Wennerstrum et al., 2002; Bankole et al., 2013). Traditional milling and other processing practices are time and labour intensive, cumbersome and expose the product to losses and adulteration. It was observed in a research by Nyankori et al., 2002 on cowpea market in Ghana that the majority of the processors are small scale operators of whom over ninety percent produce less than five tons a day and only four percent produce more than five tons a day and a low percentage of processors (4%) mill cowpea exclusively but 72% does not mill cowpea and other grains

Traditionally, cowpea is processed by wet milling. An alternative processing technique is dry milling. The cowpea can be milled into flour and then hydrated to the desired consistency and used for *akara* production. Dry milling has its limitations, however, and research indicates that the dry milled cowpea makes poor quality *akara*, which is dense and hard in texture. The poor quality of *akara* is attributed to the fine particle size of the flour. Fine milling breaks down the cell wall materials, thus destroying the fiber structure (Kethireddipalli et al., 2002; Sighn, 2003).

A burr mill or burr grinder is a device to grind hard, small food products between two revolving abrasive surfaces separated by a distance usually set by the user (Fellows, 2003).

Grain fed between the plates are crushed and sheared, the fineness of grinding is controlled by the size and quantity of burrs on the plate and the clearance between the two plates (Kaul and Egbo, 1985; Sule and Odugbose, 2014). The burr mill can also be referred to as attrition mill and could be powered manually, mechanically or electrically.

For variation in value additions to tropical crops of which cowpea belongs, the milling efficiency of the applicable machine and the quality of the milled products depend on the crop and machine parameters like moisture content, operating speeds, feed rate, crop size, and shape, etc. Therefore, this study was carried out to determine the effects of moisture content and machine operating speed on the milling efficiency of a burr mill.

2. MATERIALS AND METHODS

2.1 Evaluation Procedure

Wet Experiment

In the wet experiment, cowpea of variable moisture contents (22 %, 25 %, 30 % and 35 %), 1 kg of each sample of the different moisture content was weighed before milling at variable operating speeds varying of 500, 550 and 600 rpm. Each of these samples was milled at various operating speed to determine the effect of operating speed and moisture content on the milling efficiency of the machine. The output was weighed by the use of an electronic weighing machine and the time used for each milling was recorded using a stop-watch. The milling efficiency was determined using equation 1

Dry Experiment

In the dry experiment, the cowpea was subjected to different moisture contents varying from 10 %, 12 %, 14 % and 16 %. 1kg of each sample was milled at operating speed of 500, 550 and 600 rpm to determine the effect of operating speed and moisture content on the milling efficiency of the machine. The output was weighed using the electronic weighing machine and the time taken to mill was recorded using a stop watch. The milling efficiency was determined using same equation 1.

$$\textbf{Milling Efficiency}, \boldsymbol{E} = \frac{Out\ put}{Input} \times 100 \qquad 1$$

3. RESULTS

The results of this study are respectively presented in the figures below

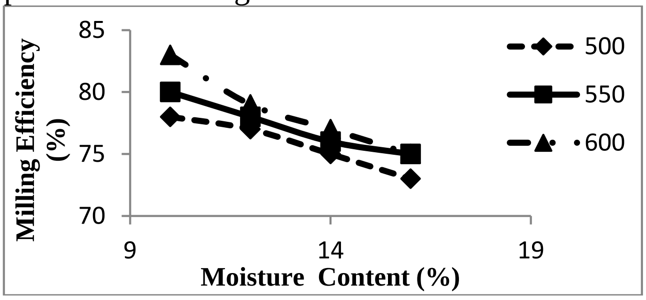

Fig. 1: Effect of Moisture Content on Milling Efficiency of Dry Cowpea at 500, 550 and 600rpm

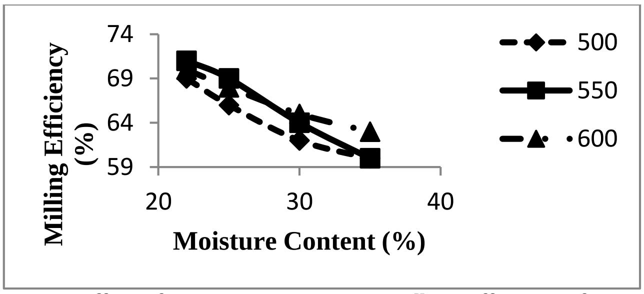

Fig. 2: Effect of Moisture Content on Milling Efficiency of Wet Cowpea at 500, 550 and 600rpm

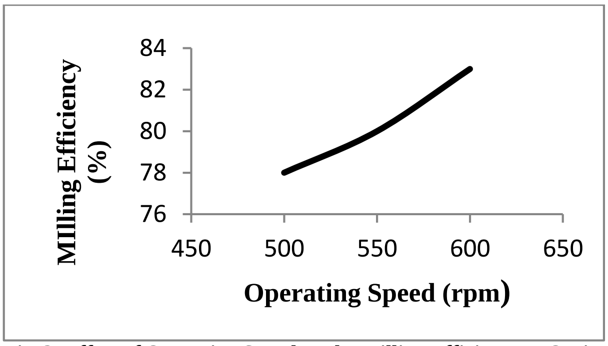

Fig. 3: Effect of Operating Speed on the Milling Efficiency at Optimum Moisture Content of 10% for Dry Cowpea Experiment

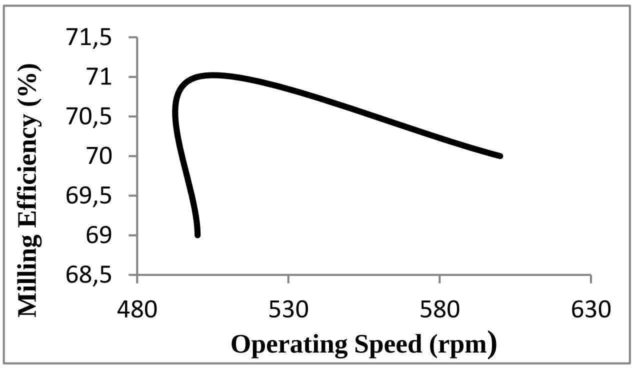

Fig. 4: Effect of Operating Speed on the Milling Efficiency at Optimum Moisture Content of 22% for Wet Cowpea Experiment

4. DISCUSSIONS

4.1 Effects of Moisture Content on Milling Efficiency

The relationship between moisture content and milling efficiency for both dry and wet experiments are represented in Fig. 1 & Fig. 2. It was observed that the milling efficiency decreased with increase in moisture content at all operating speeds (500, 550 and 600) for milling both dry and wet cowpea. But the highest milling efficiency was recorded at 600 rpm for dry and wet milling at the optimum moisture content of 10% for dry experiment and 22% for the wet experiment. A linear relationship as observed exists between moisture content and the milling efficiency of dry and wet experiments. This is in conformity with Feyisetan (2009) who reported that efficiency of fabricated burr mill depended on the moisture content of the food materials.

4.2 Effects of Operating Speed on Milling Efficiency

Fig. 3 shows that milling efficiency increased with increase in operating speed at optimum moisture content 10% for the dry experiment. It was also observed as presented in Fig. 4 that the milling efficiency decreased with increase in operating speed at the optimum moisture content 22% in wet experiment. This is in conformity with Lux and Clermont (2004) that the best grinding efficiency was obtained from the lowest speed in secondary grinding.

CONCLUSIONS

From the experiment, it is concluded that the moisture content and operating speed of the machine affect the milling efficiency of a burr mill in the size reduction operation for cowpea.

It is also concluded that milling efficiency decreases with increase moisture content at all the operating speeds for both dry and wet milling of cowpea at the optimum moisture content of 10% for dry cowpea and 22% for the wet experiment.

There is a linear relationship between the operating speed and the milling efficiency of both dry and wet maize as well as milling efficiency and the operating speed.

The results are therefore recommended for the use of farmers and cowpea processors.

REFERENCES

[1] A.O. Ojomo, M.O Ale, and O. G. Olajide. Development and Performance Evaluation of a Cowpea Harvester. ARPN Journal of Applied Sciences. Vol.5, no. 10, 2010, pp. 5-12.

[2] A. Singh. Enhancing the Physical and Functional Properties of Cowpea Paste used in Akara Production through Modification of Milling and Paste Preparation Methods. M.Sc. Thesis. The University of Georgia. 2003.

[3] D.W. Davis, E.A. Oelke, E.S. Oplinger, J. D. Doll, C.V Hanson and D.H. Putnam. Cowpea; Alternative field Crop Manual; 2009 http:www.hort.purdue.edu/newcrop/afcm/cowpea.html.

[4] H. Mc Gee. On Food and Cooking. The Science and Love of the Kitchen. Complementary Revised and Updated Edition. New York Scribner xi, 2004, pp 884.

[5] J. C. O. Nyankori, V. Wabukawo, E. Sakyi-Dawson, and S. Sefa-Dedeh. Product Life Cycle Model of Cowpea Based Products. Department of Agricultural and Applied Economics, Clemson University, Clemson. 2002.

[6] J. G. Brennau, J. R. Butters. N. D. Cowell and A.V.E. Lilly. Food Engineering Operations 2nd edition reprinted. Applied Science Publishers.1981.

[7]J. Lux and B. Clermont. The Influence of Mill Speed and Pulp Density on The Grinding Efficiency for Secondary Stage Grinding. International Platinum Conference 'Platinum Adding Value', the South African Institute of Mining and Metallurgy, 2004. Method (wet and dry) on the Functional Properties of Cowpea (vigna Unguiculata) Pastes and End

[8] O.O. Feyisetan. Construction and Evaluation Burr Mill Machine, unpublished HND Thesis Submitted Agricultural Agriculture
Moore Plantation Ibadan. 2009.

[9] O.S. Sule, and D.B. Odugbose. Assessment of Dry and Wet Milling using Fabricated Burr Mill. Food Science and Quality Management. Vol.31, 2014, pp. 1-11. www.iiste.org

[10] P.J. Fellows. Food Processing Technology: Principles and Practice 2nd Edition 2000, Wood-Head Publishing Ltd and CRC Press LLC. 2003, pp. 98-117

[11] P. Kethireddipalli, Y.C. Hung, K.H Mc Watters and R.D. Phillips. Effect of Milling
Product Quality. Journal of Food Science Vol.67, no. 1, 2002, pp. 48-52.

[12] R.N. Kaul and C.O. Egbo. Introduction to Agricultural Mechanization. Macmillan,
London, England, UK. 1985, pp. 128-41.

[13] S. Wennerstrum, T. Kendrick, J. Tomaka, and J. Cain. Powder and Bulk Engineering; Size Reduction Solutions for Hard-To-Reduce Materials (the Fitzpatrick co). 2002.

[14] Taylor-Davis, Stephanie, and Stone, Martha B. (2008) "Food Processing and Preservation." Microsoft® Encarta® 2009 [DVD]. Redmond WA Microsoft Corporation, 2008.

[15] V. O Ogwuagwu. Simulation Study of the Fracture Characteristics of Locally Fabricated Aluminium Bar used as Connecting Rod in Vibratory Sieves, Leonardo Journal of Sciences. Vol.10, 2007, pp. 93-100.

[16] Y. O. Bankole O. A. Taninola, B. S. Adesina and D. O. Samuel. Quality of Pepper Paste Using Different Milling Methods. Journal of Interdisciplinary Studies. Vol. 2, Issue 10, 2013, pp 187- 193.