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Comparison of Some Engineering Properties of Common Cereal Grains In Nigeria

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ABSTRACT: *Most cereal crops grown in Nigeria are subjected to local processing and post harvest handling activities which is considered very tasking, laborious and generally leads to a low output. The study of the engineering properties of these crops will give the engineers. The objective of this study was to determine some engineering properties (including angle of repose, bulk density, porosity, particle density and the coefficient of friction) of rice, wheat, maize and millet grown in Nigeria as this will help to develop appropriate technologies for the post harvest handling of cereals. The Engineering properties were determined in compliance with ASAE Standard S352.1 (1984) and the coefficient of friction was obtained using a tilting table and three different structural surfaces (glass, plywood and stainless steel). Results obtained showed a bulk density ranging from 563-795.3 kg/m^3 for rice and wheat respectively, the true density ranges from 970.1-1390.5 kg/m^3 for maize and wheat respectively. Significant difference was observed for the porosity of the grains which ranges from 30.37 to 50.22 % for maize and rice respectively. Coefficient of friction of the grains on glass, stainless steel and plywood ranges from 0.37 to 0.47 with the least values on glass and highest values on plywood, this implies that an angle above 48^0 is suitable for hopper construction to enable the grains slide and roll down easily.*

KEYWORDS: *Bulk Density, True Density, Porosity, Angle of Repose and Coefficient of Friction*

I. INTRODUCTION

Cereals belongs to the grass family *Poaceae* (formerly *Gramineae*), they are cultivated for their seed, which is used as food. The name is derived from *Ceres*, the Roman goddess of grains and agriculture. The most extensively cultivated cereals in Nigeria are wheat, rice, corn or maize, different kinds of millet, and the grain sorghums known as durra or guinea corn. These have all been cultivated since ancient times. Blandino *et al*., (2003) reported that cereal grains are considered to be one of the most important sources of dietary proteins, carbohydrates, vitamins, minerals and fibre for people all over the world. Although, when in comparism with milk and milk products, cereals are deficient in nutritional and sensorial properties like essential amino-acids, lower protein content, low starch availability and the coarse nature of the grains. However, most cereal crops grown in Nigeria are subjected to local processing and post harvest handling activities like cleaning, sorting, grading, drying, size reduction etc, this is considered very tasking, laborious and generally leads to a low output. The study of the engineering properties of these crops will give the engineers guidelines for the designing of various agricultural machine that will be suitable for the processing of the grains. Most important among them is the physical and mechanical properties which are important in design, improvement and optimization of separation and cleaning machines.The objective of this study was to determine some physical properties of rice, wheat, maize and millet grown in Nigeria, properties determined include angle of repose, bulk density, porosity, particle density and the coefficient of friction as this will help to develop appropriate technologies for the post harvest handling of cereal grains grown in Nigeria.

II. MATERIALS AND METHOD

Sampling: cereal grains (wheat, millet, rice and maize) were from Bodija market, Ibadan, Oyo State, Nigeria. The seeds were sorted and cleaned manually to remove all foreign matter such as dirt, pieces of stone and metals present in the grains. The moisture content of the seeds was obtained according to ASAE Standard S352.1 (1984). The moisture content of the grains in percent dry basis was calculated using Equation 1.

$$Ms = \frac{100\ (W_i - W_f)}{W_f} \qquad (1)$$

Where: *Ms* is the Moisture Content of cereals (% dry basis), *Wi* is the Initial Mass of the seeds before oven drying (g) and *Wf* is the final mass of the seeds after oven drying (g).

Determination of Angle of Repose: The angle of repose was evaluated by using a specially constructed topless and bottomless box made of plywood of 140 x 160 x 35 mm with a removable front panel (Dutta *et al.*, 1988; Olaoye, 2000, Tabatabaeefar, 2003; Ghasemi *et al*., 2008). The box was filled with grains and placed on the floor, the front panel was quickly removed allowing the grains to slide down and assume natural slope. The angle of repose was calculated from the measurements of the height (*h*) of the free surface of the seeds and the lenght (*l*) of the heap formed outside the box using the relationship described by Bamgboye and Adejumo, (2009):

$$\theta = tan^{-1}(\frac{h}{l}) \qquad (2)$$

Where: θ is the Angle of Repose (degrees), *h* is the height of the free surface of the grains and *l* is the Length of the heap formed outside the box.

Determination of Static Coefficient of Friction: the static coefficient of friction of the grains against three different structural materials namely; stainless steel, plywood and glass were determined using a tilting table shown in figure 1. The grains were placed parallel to the direction of motion and the table is raised gently by a screw device, the angle at which the seeds begin to slide (the angle of inclination) was read from a graduated scale on the tilting table, this was repeated three times for each structural material. Thus, the coefficient of friction was calculated as the tangent of this angle as shown in Equation 5 (Olaoye, 2000; Adejumo, 2003; and Pliestic *et al.*, 2006).

$$\mu = \tan\theta \qquad (3)$$

Where: μ is the Static Coefficient of Friction (dec), θ is the angle of Inclination (degrees).

Figure 1: Tilting Table

Determination of Bulk Density, True Density and Porosity: the average bulk density of the grains were determined using the standard test weight procedure reported by Singh and Goswami (1996) and Gupta and Das (1998) by filling a container of 500 ml with the seeds from a height of 150 mm at a constant rate and then weighing the content.

The average true density was determined using the toluene and displacement method. The volume of toluene (C_7H_8) displaced was found by immersing a weighed quantity of the seeds in the toluene (Sacilik *et al.*, 2003; Garnayak *et al.*, 2008). The porosity was calculated from the following equation (Mohsenin, 1970; Tarighi *et al.*, 2011; Naderiboldhaji *et al*., 2008):

$$£ = \left(1 - \frac{Pb}{Pt}\right) x\ 100 \qquad (4)$$

III. RESULTS AND DISCUSSIONS

Moisture Content: The amount of water available in the cereal grains used for the research work obtained in compliance with ASAE S352.1 in dry basis was computed using equation 1 is 5.14, 5.3, 5.56 and 5.79 % dry basis for maize, rice, millet and wheat respectively

Bulk Density: The bulk density is important in separating and grading of grains, the values obtained from one grain to the other, rice showed the least average bulk density of 563 kg/m^3 while the highest bulk density was observed in wheat 795.3 kg/m^3. Table 1 shows the average bulk densities of the four grains examined (rice, millet, maize and wheat). A similar trend was reported for maize at 5.15 % moisture content dry basis by

Tarighi *et al*. (2011) who obtained 679.11 kg/m^3. Moreover, Gursoy and Guzel (2010) and Sadeghi *et al.* (2008) reported a bulk density of 789 kg/m^3 for wheat and 598 kg/m^3 for rice respectively.

True Density: The true and bulk density plays a significant role in drying, design of silos and storage bins, separation of undesirable materials, seed purity determination and grading (Mohsenin, 1970). Maize showed the least true density and wheat showed the highest true density, similar trends were reported by Sadeghi *et al.* (2008) for rice (1136 kg/m^3), Gursoy and Guzel (2010) for wheat (1395 kg/m^3) and Tarighi *et al.* (2011) for maize (990 kg/m^3).

Porosity: The percent voids of cereals, it is often needed in air flow and heat flow studies, maize showed the least porosity and rice showed the highest as presented in table 1. Similar trends by reported by Gursoy and Guzel (2010) for wheat (43.44^0), Sadeghi *et al.* (2008) for rice (47.41^0) and Tarighi *et al.* (2011) for maize (31.41^0)

Angle of Repose: This is useful in the design of agricultural machine hopper and other conveying equipment. The angle of repose obtained for rice, wheat, maize and millet is presented in figure 2.

Coefficient of Friction: The coefficient of friction of seeds is required in design of silos and hopper for processing systems and values were obtained for three different materials of construction namely; plywood, glass and stainless steel. The values obtained are presented in figure 3, and it was observed that for all the grains used that glass showed the lowest friction, medium values were obtained on stainless steel and the highest coefficient of friction values were obtained on plywood for the four grains. This however implies that glass is suitable for construction hopper for the grains but stainless steel is preferable because of its malleability. However, the values obtained for the four grains on the three structural faces ranges from 0.37 to 0.47 thus implying that if a machine is to be constructed for processing the four grains (rice, millet, wheat and maize), the hopper can be made slide at an angle above 48^0 as this will enable the grains to slide and roll down easily.

Table 1: Summary of Bulk Density, True Density and Porosity

GRAIN (m c % dry basis)	**Bulk Density** (Kg/m^3)	**True Density** (Kg/m^3)	**Porosity** (%)
Rice *(5.3 % d. b.)*	563	1130.9	50.22
Millet *(5.56 % d. b.)*	766.2	1266.3	39.49
Wheat *(5.79 % d. b.)*	795.3	1390.5	42.8
Maize *(5.14% d. b.)*	675.5	970.1	30.37

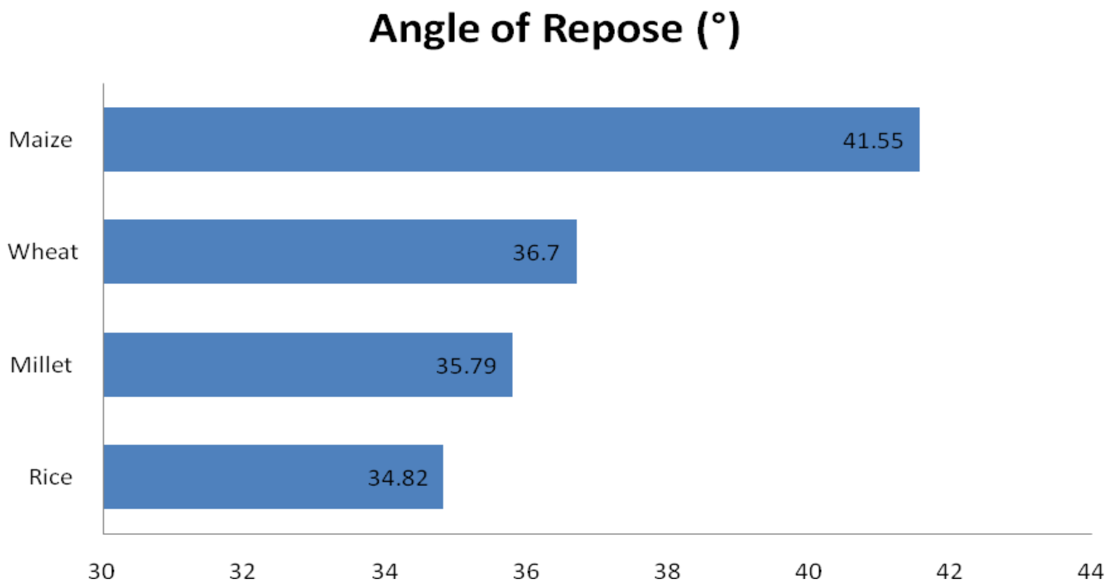

Figure 2: Angle of Repose of Rice, Wheat, Maize and Millet

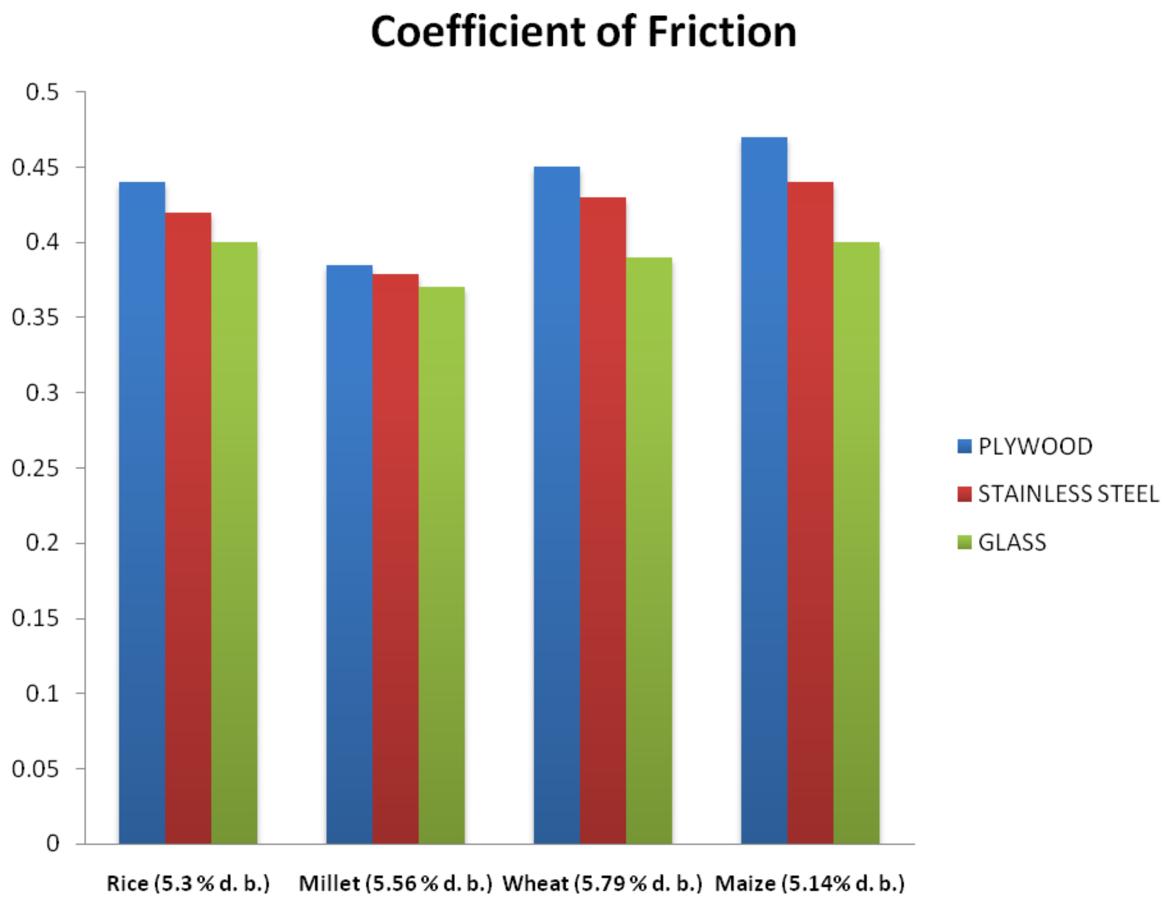

Figure 3: Coefficient of Friction of Plywood, Glass and Stainless

IV. CONCLUSION

Some engineering properties of cereal grains common in Nigeria were determined. The grains are rice, millet, maize and wheat, the engineering properties determined include bulk density, porosity, true density, angle of repose and the coefficient of friction however, the following conclusions were drawn from the research:

[1] rice showed the least average bulk density of 563 kg/m^3 while the highest bulk density was observed in wheat 795.3 kg/m^3.
[2] the least true density was noticed in maize while wheat showed the highest true density
[3] a significant difference was also noticed in the porosity as maize, millet, wheat and rice showed a respective ascending order of porosity
[4] the coefficient of friction were obtained on glass, plywood and stainless steel. Glass showed the least values while plywood showed the friction
[5] Coefficient of friction for the four grains on the three structural faces ranges from 0.37 to 0.47 thus, an angle above 48^0 is suitable for hopper construction to enable the grains slide and roll down easily.

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