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Research Paper

Investigation of effect of maize varieties on selected physical properties

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Abstract. The engineering properties of some selected variety of maize (SM39, SM40 and Oba Super 6) which is needed in the design and development of a functional handling and processing equipment for the crop was studied. The seeds were bought from the Agricultural settlements in Ogbomoso South-Western Nigeria. The selected properties are size, shape, weight, true density, and bulk density, angle of repose, coefficient of friction, and moisture content. The results of the experiments showed that the mean length was between 8.7 and 9.78 mm; width, 7.69 and 8.26 mm; thickness, 4.11 and 4.60 mm; geometric mean diameter, 7.17 and 7.78 mm; equivalent diameter, 6.62 and 6.62 mm; unit weight, 0.22 and 0.24 g; true density, 954.25 and 1245 kg/m3; bulk density, 734.45 and 752.23 kg/m3, and angle of repose of the three varieties are between 29.20 and 36.60. While the average values of static coefficient of friction measured was between 0.39 and 0.49. The results from this experiment showed that the effect of varieties is significant on the engineering properties of maize. The results obtained from these studies will be useful for the design and manufacturing of operating system for handling and processing of different varieties of maize.

Keyword: Engineering properties, design, processing equipment, manufacturing, varities.

INTRODUCTION

Maize (*Zea mays L*), also known as corn, is one of the most extensively cultivated cereal crops in the world. More is produced, by weight, than any other grain, and almost every country cultivates it both for consumption by man and animal and commercial purposes. The crop plays many roles in the human diet and the production of animal feeds (Olaniyan and Lukas, 2004; Enujeke, 2013). It is processed to make an assortment of products which includes corn oil, maize flour, and biofuels. The exact domestication point for maize is unknown, but it is estimated that the crop is at least 9,000 years old (Brigit, 2018). It has been reported that maize is cultivated on about 139 million hectares with a total yearly production of 598 million (mMT) worldwide (Atere *et al*., 2016). Wudiri (1991) reported that maize is the most popular crop grown and consumed in all areas of Nigeria. There are many varieties of maize, the yellow one was shown to contain starch (61%), oil (3.8%), protein (11.2%) and moisture (16%) (Davis, 2001). The variations in the physical properties of crops have necessitated its measurement for a proper design. Production of maize crops from cultivations to processing involves using machines to easy the job for mechanization. To design an efficient machine for mechanization of this crop, the engineering properties of the crop is required. The data on the physical and engineering properties of crops is important knowledge for engineers, machine manufacturers, food scientists and even the consumer's decision. Jadhave *et al.* (2020) reported measurement of engineering properties of paddy and wheat seeds in orther to use the data for design a pneumatics metering device for the crop. Many work have been reported on physical properties of maize: Coskun *et al.* (2006), Inderpal *et al.* (2017) and Karababa (2006) determined physical properties of sweet corn and popcorn as a function of moisture content and Atere (2016) also reported the effect of physical properties on some varieties of maize. To have a comprehencive data for the developement of the handling machine for the crop, the effect of varieties on physical properties of another three varities found in Nigeria were determined in this research.

MATERIALS AND METHODS

The three varieties used for this experiment were bought from the agricultural settlement in Ogbomoso, Oyo State, Nigeria. The three varieties were *SM39, SM40 and Oba Super 6*.

Moisture content determination

The moisture content of the seed was determined by using the oven drying method as adopted by Ogunsina *et al*. (2009) and Ozguven *et al.* (2005) as reported by Idowu and Owolarafe (2015). A weighed sample of the seed was kept in an oven at a temperature of 105°C for 6 h. The sample was weighed again at the end of the period to determine its final weight. This experiment was replicated five times and the average weight was recorded. The moisture content was calculated using Equation 1.

$$Moisture\ Content(db) \quad = \quad \frac{(W_i - W_f)}{W_i} \quad \times \quad 100\% \qquad (1)$$

Where: W_i is initial weight; and W_f is final weight

Linear dimension

50 seeds were selected at random and their linear dimensions determined. For each seed, three linear dimensions were measured, that is, length (L), width (W) and thickness (T), using a venier caliper (with the accuracy of 0.01 mm). Hence, measurements of all size indices were replicated 50 times.

Sphericity

The shape of the seed was expressed in terms of its sphericity index *(ϕ)*. The sphericity was determined using Equation 2 which was reported by Sessiz *et al.* (2007) and Ozguven *et al.* (2005) and adapted by Idowu and Owolarafe (2015):

$$\phi \quad = \quad \frac{(LWT)^{1/3}}{L} \quad \times \quad 100\% \qquad (2)$$

Geometry mean diameter (G_g)

Geometry mean diameter (G_g) was obtained for 50 seeds selected at random using Equation 3 which has been used by Sessiz *et al.* (2007) and Ozguven *et al.* (2005) and was adapted by Idowu and Owolarafe (2015):

$$G_g \quad = \quad (LWT)^{1/3} \qquad (3)$$

Determination of 1000 seed mass

The mass of 1000 seeds was determined by using an electronic balance to an accuracy of 0.001 g. The measurement was replicated 5 times for 1000 seeds selected at random (Mohsenin, 1978). This method was adoapted by Idowu and Owolarafe (2015).

Determination of true and bulk densities

The true density of the seed was determined by the water displacement technique (Owolarafe *et al.*, 2007; Idowu and Owolarafe, 2015). Twenty randomly selected maize seeds from the three varities were weighed and lowered into a graduated measuring cylinder containing 30 ml of water. It was ensured that the seeds were submerged during immersion in water. The net volumetric water displacement was recorded. The true density, ρ_t was then calculated using Equation 4:

$$\rho_t \quad = \quad m/v \qquad (4)$$

Where: *m* is the mass of the seed in kg; and v is the volume of the seed in m^3

For bulk density measurement, an empty cylindrical container of 1000 ml volume was filled with the seeds at a height of about 15 cm, striking the top of the level and then weighing the content, the bulk weight was then recorded. This was done in 10 replications. Using the equation above, the bulk density (ρ_b) was then calculated for each of the replications.

Measurement of the mechanical properties

The mechanical properties determined in this study included the angle of repose and the coefficient of friction.

Determination of angle of repose

The dynamic angle of repose or the emptying angle was determined using the method of Amin *et al.* (2004) and

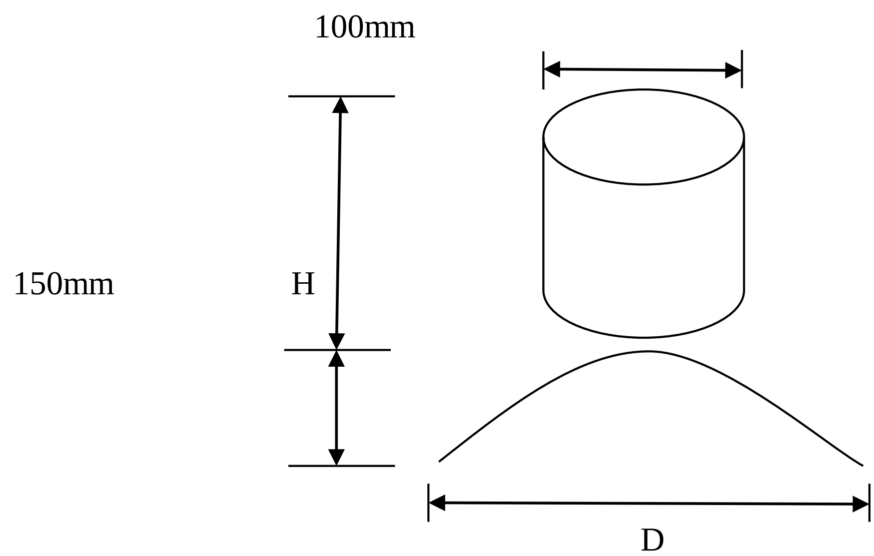

Figure 1. Determination of angle of repose.

Sessiz *et al.* (2007) as adopted by Idowu and Owolarafe 2015. A regular cylinder of 100 mm diameter and 150 mm height was used in determining the angle of repose. A cylinder was placed on the surface, filled with the *maize* seeds, and raised slowly until it forms a cone of seeds (Figure 1). This was replicated five times. The angle of repose was then calculated using Equation 5:

$$\phi = \tan^{-1}\left(\frac{2H}{D}\right) \quad (5)$$

Where: H- is Height; D- is Diameter

Determination of coefficient of friction

The coefficient of friction was determined on four different surfaces namely, stainless steel and galvanized steel and glass.

These are the common materials used for handling and processing of grains and construction of storage and drying bins (Baryeh, 2002).

The experimental equipment consists of a frictionless pulley fitted on a frame, topless and bottomless plywood box of dimensions 250 × 250 × 90 mm, loading pan, and test surfaces. The box was connected using string, parallel to the surface of the material and passed over a frictionless pulley with a pan hanging from it. The box was placed on the test surface and filled with a known quantity of the Maize variety seeds and the box was raised gradually until the box and its containers started to move on the surface. The static coefficient of friction was then determined using the following formula reported by Amin *et al.* (2004) and Sessiz *et al.* (2007), as adapted by Idowu and Owolarafe (2015).

$$U_s = F_s / W \quad (6)$$

Where: U_s is the static coefficient of friction; F_s is the applied force; W is weight

RESULTS AND DISCUSSION

The results of the experiment on the physical properties of the selected varieties of maize are as presented in Table 1.

Size and shape

The results of the measurement of the effect of variety on the size of three maize variety selected are as presented in Table 1. The average values of the three principal dimensions namely, length, width and thickness were 9.78, 8.259 and 4.60 mm for SM39; 8.73, 8.03 and 4.51 mm for SM40 and 9.29, 7.67, 4.11 mm for Oba super, respectively. This result of the maize length was in agreement with the results published by Anoop *et al.* (2017) and Atere *et al.* (2016) who reported between 8.18 and 10.90 mm for three varieties of maize (PMH-1, PMH-10 and PIONEER-3396) and between 9.99 and 8.57 mm for another three varieties (ART98SW06-OB-W, ART98SW1 and Suwan-1-SR-Y), respectively. Although Sangamithra *et al*. (2016) reported a slightly higher length (10.59 mm) for the variety of maize they used. Figure 2 shows the size relationship for the three varieties and compared it to three additional varieties found in the

Table 1. Physical properties of selected maize varieties.

	Properties	Variety	Number	Mean	Minimum	Maximum	Standard deviation
1	Length	SM39	50	9.78	8.76	11.27	1.02
		SM40	50	8.73	7.10	10.17	0.87
		Oba super	50	9.29	8.21	10.28	0.64
2	Breadth	SM39	50	8.26	7.74	9.23	0.52
		SM40	50	8.03	7.24	9.35	0.62
		Oba super	50	7.69	6.92	8.50	0.48
3	Thickness	SM39	50	4.60	3.88	5.62	0.59
		SM40	50	4.51	3.62	5.18	0.46
		Oba super	50	4.11	3.63	5.18	0.46
4	Unit weight	SM39	500	0.24	0.2	0.3	0.05
		SM40	50	0.24	0.2	0.3	0.05
		Oba super	50	0.22	0.2	0.3	0.04
5	Equivalent diameter	SM39	50	7.17	6.61	7.72	0.38
		SM40	50	6.80	6.46	7.18	0.42
		Oba super	50	6.62	6.25	7.00	0.26
6	Sphericity	SM39	50	0.74	0.64	0.83	0.05
		SM40	50	0..78	0.67	0.85	0.05
		Oba super	50	0.72	0.66	0.82	0.03
7	Angle of repose	SM39	5	36.41	32.91	40.48	3.81
		SM 40	5	29.19	28.77	29.75	0.50
		Oba super	5	31.16	29.25	32.91	1.83
8	Coefficient of friction	**SM39**					
		Galvanized steel	5	0.49	0.43	0.51	0.03
		Stainless steel	5	0.50	0.43	0.53	0.05
		Glass	5	0.39	0.36	0.42	0.02
		SM40					
		Galvanized steel	5	0.47	0.46	0.52	0.02
		Stainless steel	5	0.42	0.38	0.46	0.01
		Glass	5	0.40	0.38	0.42	0.05
		Oba super					
		Galvanized steel	5	0.44	0.42	0.43	0.03
		Stainless steel	5	0.43	0.42	0.46	0.04
		Glass	5	0.35	0.34	0.36	0.02

literature.

Implication of the result

The size is used in the design of grading, cleaning, handling and processing equipment. In the selection of a functional screen for grading and cleaning equipment the sizes (length, breadth and thickness) are important information needed for the proper design. In the design of an air screen, grain cleaner, the shape of grain determined the shape of the screen opening and vibration amplitude of screens.

Equivalent diameters

The results of the equivalent diameter showed that the diameter of the varieties are: SM39 (7.17 mm), SM40 (6.80 mm), and Oba super (6.62 mm) was in the range reported by Atere *et al*. 2016 and Sangamithra *et al*. (2016) for the varieties studied. The result of the

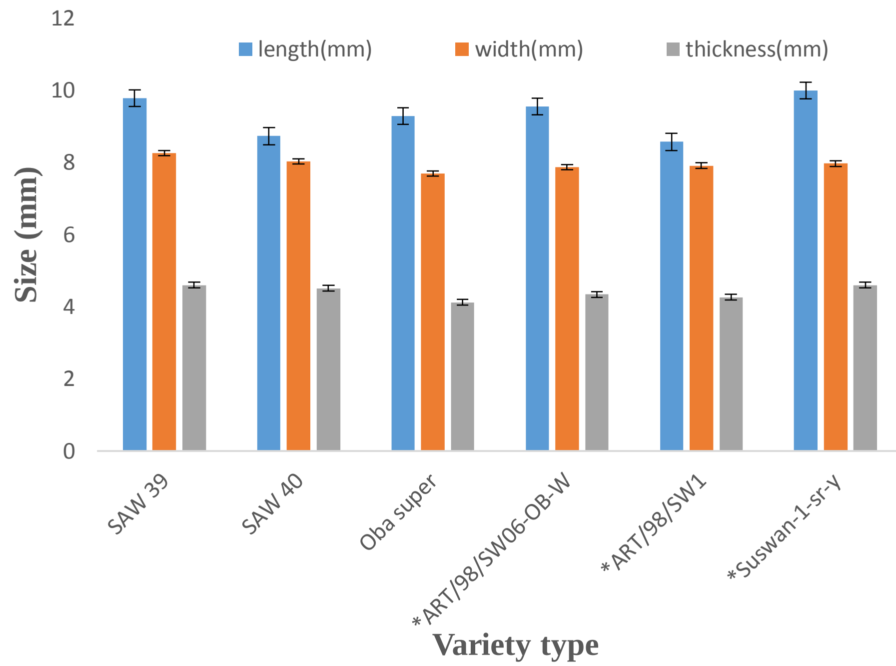

Figure 2. Effect of maize varieties on its size. Note: * Atere *et al.* (2016).

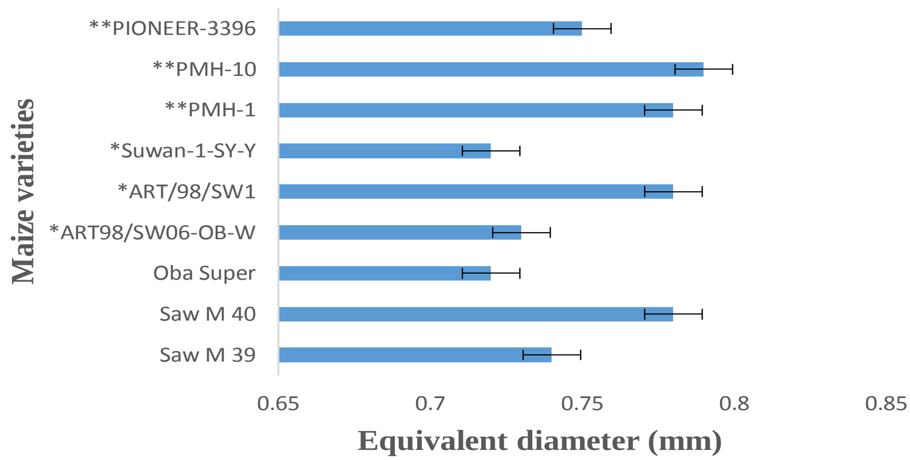

Figure 3. Effect of varieties on equivalent diameter of maize. *Atere *et al*. (2017), **Iderpal *et al*. (2017)

experiment was compared with the one found in literature (Figure 3).

Implication of the result

The different measurements of the diameters is part of the essential information needed for determination of the terminal velocity of the grain. This terminal velocity determine the effectiveness of winnowing in selecting the velocity of the air blast for separation of chaff, dirt and other unwanted materials from clean grain in air screen grain cleaners. Frontal area and related diameters are essential for the determination of terminal velocity, Reynolds number and drag coefficient.

Effect of maize varieties on sphericity

The sphericity of the three varieties of maize investigated was found to be between 0.6 and 0.7. This results was in agreement with the report presented by Sangamithra *et al*. (2016) who reported a variation between 0.5 and 0.7 for maize when its moisture was varied and Atere *et al*. 2016 who reported between 0.7 and 0.78 for the three varieties of maize they studied. The results of the three

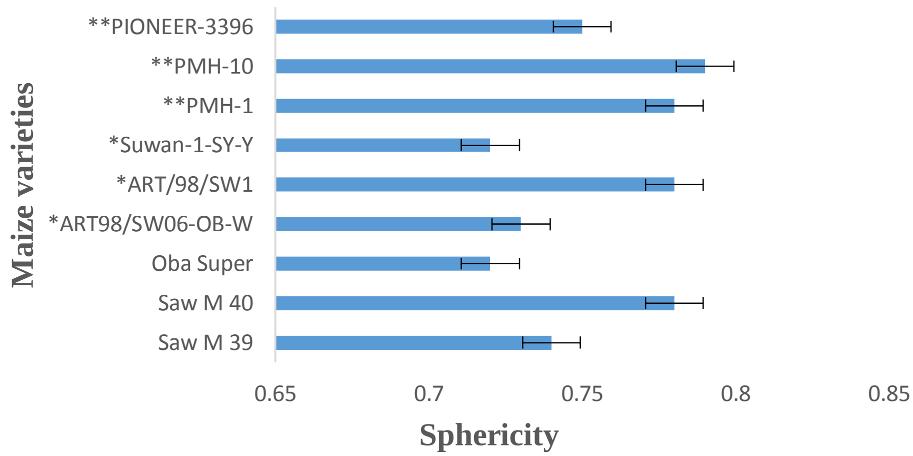

Figure 4. Effect of maize variety on sphericity. *Atere *et al.* (2017), **Iderpa *et al.* (2017).

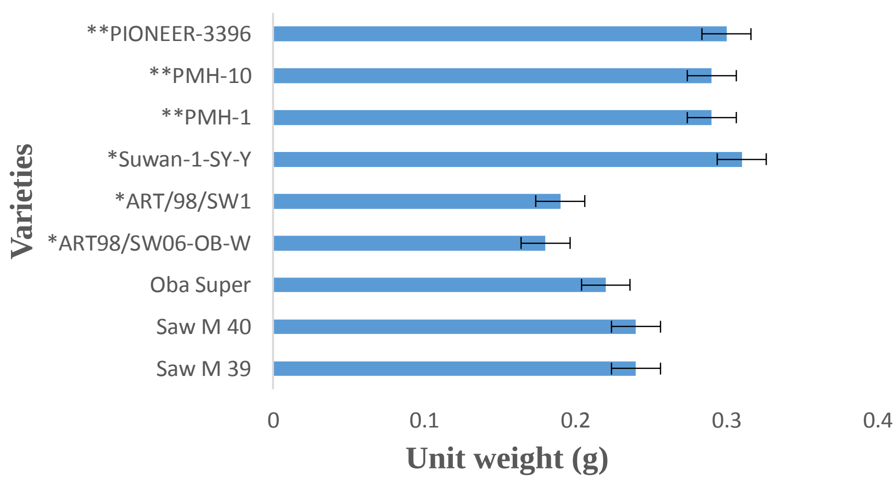

Figure 5. Effect of maize variewties on unit weight. Note: *Atere *et al.* (2017), **Iderpa *et al.* (2017).

varieties were compared with the results of other varieties in the literature (Figure 4).

Implication of the result

The shape of crop is important parameter which affects conveying characterizes of solid materials by air or water. The shape is also considered in calculating various cooling and heating loads of materials.

Unit weight

The unit weight of the three varieties are SM39 (0.24 g), SM40 (0.24 g) and Oba Super (0.22 g). This weight was found to be higher than the weight reported for ART/98/SW06-OB-W (0.18 g), ART/98/SW1 (0.19 g) but lesser than Suwan-1-SR-Y (0.31 g) reported for maize varieties investigated by Atere *et al.* (2016). Figure 5 compared the unit weight of the three varieties studied in this project and some selected maize varieties found in the literature.

Implication of the result

The weight of grain is important parameter in the design of types and size of handling, processing, storage ban and equipment.

Effect of varieties on bulky density of maize

The average values for the bulk density of the three varieties are, SM39 (733.56 kg/m^3), SM40 (745.64 kg/m^3)

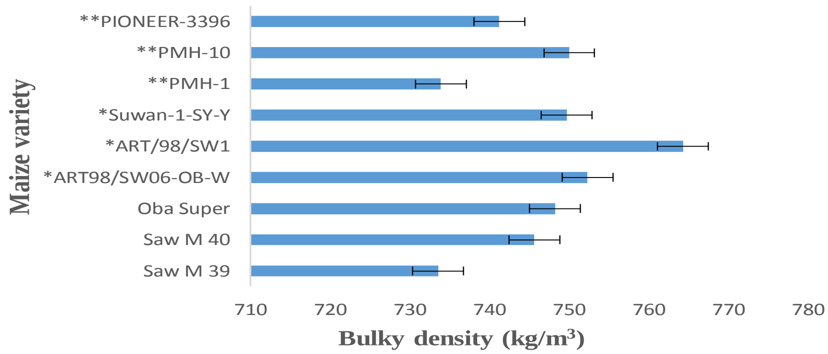

Figure 6. Effect of varieties on bulk density of maize. *Atere *et al*. (2017), **Iderpa *et al*. (2017).

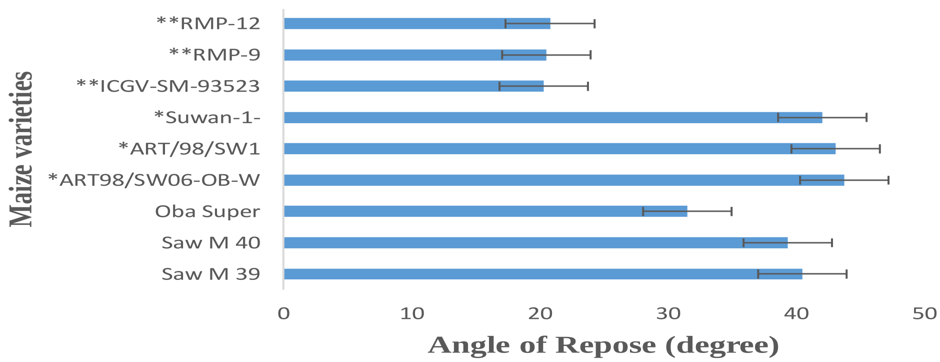

Figure 7. Effect of varieties on angle of repose. *Atere *et al.* (2017), **Maduako and Hamman (2004).

and Oba Super (748.23 kg/m^3). The bulk density was found to be within the range reported in the literature (Figure 6).

Implication of the result

The measurement of densities is essential for determination of the terminal velocity of the grain. Density and specific gravity are needed for calculating the thermal diffusivity in heat transfer operations to determine Renoids number in pneumatic and hydraulic handling of the crops. Also, the bulk density is very important in the design of seed hopper.

Effect of varieties on mechanical properties

The effect of varieties on the selected mechanical properties was discussed below.

Effect of maize variety on the angle of repose

Table 1 shows the result of the experiment on the effect of varieties on angle of repose on selected varieties of maize. The results showed that the angle of repose range between 32.91 and 40.48° for SM39, 28.77 and 29.75° for SM40 and 29.25 and 32.91° for Oba Super. The result of this experiment is in the range presented by Atere *et al.* (2016) for ART/98/SW06-OBW, ART/98/SWI and SUWAN-1-SR-Y who reported the variation of the angle of repose within the varieties to range between 38.66 and 43.76°. Maduako and Hamman 2004 reported angle of repose for three varieties of maize, ICGV-SM-93523, RMP-9 and RMP-12 to be between 33.7 and 36.0° while Sangamithra *et al.* (2016) reported 31.4° for angle of repose at different level of moisture for the variety of maize they examined (Figure 7).

Implication of the result

The angle of repose is used in the design of handling and processing equipment. In a functional design of hopper and other equipment where free or gravity flow is required, the angle of inclination of the plane to the horizontal must be at least about 10° above the angle of repose of the material (Maduako and Faborode, 1990). In the design of sheller hopper, grading and other handling

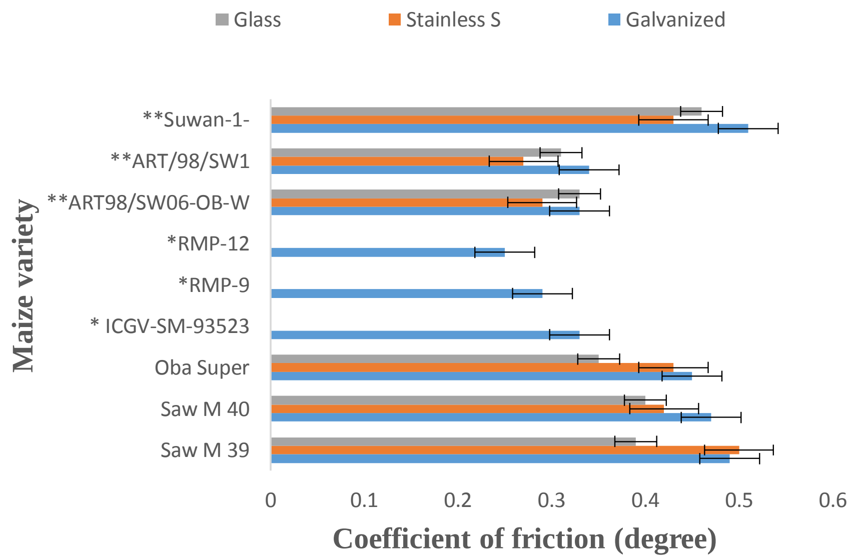

Figure 8. Effect maize varieties on coefficient of friction on some selected surfaces. *Atere *et al*. (2017), **Maduako and Hamman (2004).

equipment, it is recommended that the angle of inclination should be more than 45°. It also determines the maximum angle of a pile of grain in the horizontal plane, and is important in the filling of a flat storage facility when the grain is not piled at a uniform bed depth rather is peaked (Mohsenin, 1986).

Effect of maize varieties on the coefficient of friction

The coefficient of friction of maize for the three varieties ranges from 0.39 in SM39 to 0.35 in Oba Super on glass, from 0.41 in SM40 to 0.43 in Oba super on stain-less steel and from 0.44 in Oba super to 0.45 in SM39 on galvanize steel. The result of the experiment shows that the coefficient of friction was greater on galvanize steel and lowest on the glass. The results were in the range reported in the literature (Figure 8).

Implication of the result

The coefficient of friction is very necessary engineering information in sizing motor requirements for grain transportation and handling. The coefficient of friction is used in determining the angle at which chutes must be positioned to achieve a consistent flow of material through it (Olajide and Igbeka, 2003).

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