Some Physical Properties of Samaru Sorghum 17 Grains

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ABSTRACT

Some physical properties of Samaru Sorghum 17(SAMSORG 17) were determined within the moisture range of 8.89 -16.5% wb being the moisture range for threshing and storage of sorghum. The diameter, one thousand weight and sphericity of the grain and and the sorghum grain mass, projected area, volume, particle density, and bulk density were the physical parameters measured. Results of the investigations showed that the average diameter of sorghum grain calculated by arithmetic mean, geometric mean and equivalent diameter methods were 3.32 mm and 3.31 mm, 3.31 mm and 4.20 mm, 4.16 mm and 4.18 mm at 8.89 % wb and 16.50 % wb respectively. The mean mass, projected area, volume, particle density and bulk density for sorghum grain were 0.044 g, 4.66 mm^2, 0.091 cm^3, 1.02 g/cm^3 and 568.5 g/cm^3 at 8.89 % wb respectively. The sphericity of sorghum grain was normally distributed about 0.92. The sorghum grain particle density decreased with increasing moisture content within the moisture range considered.

Keywords: Mass, particle density, projected area, diameter, sphericity, volume, bulk density

1. INTRODUCTION

Sorghum (*Sorghum bicolor*) is one of the crops grown in Africa, primarily as food crop with less than 5 % of the annual production commercially processed by the industry (Rohrbach and Kiriwaggulu, 2001). It is a security crop widely grown in the arid and semi-arid ecologies with annual production put at 18 million tonnes in the Sub-Saharan Africa and 7.5 million tonnes from Nigeria (FAO, 2003).

Sorghum has a great potential both on the domestic and international markets due to its increasing demand for the production of food and feed products, alcoholic and non alcoholic beverages (Rohrbach, 2004). Sorghum also has a great potential as source of starch used as raw material in different industries. However, it has been reported that the major constraints in producing excellent food products from sorghum is the lack of consistent supply of good quality grain for processing as sorghum grain in existing markets are variable in kernel size, colour and cleanliness (Rooney, 2003).This requires more efficient methods of threshing and cleaning sorghum from other impurities.

The performance of threshing machines depends on machine variables such as frequency of sieve oscillations, amplitude of oscillation, sieve slope, length of sieve, width of sieve, sieve hole diameter, threshing speed, velocity of air, air stream pressure and air density, angle of air stream and terminal velocity of particles(both for grains and other materials.) and crop parameters such as crop variety, maturity stage, grain moisture content, straw moisture content, bulk density of grain, bulk density of straw, stalk length and grain diameter. (Simonyan, 2005). Materials obtained after threshing are heterogeneous mixture of grain and various component fractions (Hurburgh Jr, 1995) with different ranges of physical and aerodynamic properties (Farran and Macmillan, 1979). Physical properties have great influence on the behaviour of crops when subjected to forces. Physical properties of agricultural materials are needed to adequately design appropriate equipment and systems for planting, harvesting and post harvest operations such as cleaning, conveying and storage (Asoegwu et al., 2006). The physical properties of sorghum such as weight, diameter, surface area, bulk density are required and necessary in the design and optimal performance of the grain threshing unit. The shape and size of agricultural materials had been found useful in understanding the problem of separating grains from undesirable materials. The size of grains represented by their equivalent diameter and sphericity is necessary to describe their shape (Asoegwu et al., 2006). The surface area is useful to calculate the rate of heat transfer and in the design of appropriate heating equipment. Material size is required for grading and packing (Singh et al., 2004) and in sieve separation and grinding operations (Wilhelm et al., 2004).

Mohsenin (1980) published that shape and size are considered when dealing with problems of stress distribution in the material under load, designing of sizing and grading machines. Density is needed in mathematical conversion of seed mass to volume and also in heat transfer operations. The bulk density gives the degree of kernel filling during growth and serves as the quality indicator for breakage susceptibility, hardness tests and baking quality (Chang, 1988) and it also determines the dielectric properties(Nelson and You,1989) and useful in dielectric mixture equations (Nelson,1980).

The milling quality of sorghum is determined by the kernel shape, density, hardness and structure (Rooney, 2003). Samaru Sorghum 17 (SAMSORG 17) was selected as test crop for this study due to its economic importance and growing market demand in malting and baby food industries as well as other agro-based industries (RUSEP, 2001). It is a late maturing variety suitable for the guinea savanna vegetation zone of Nigeria.

Mohsenin (1980) and Vaughan et al., (1980) documented that crop separation from unwanted materials is based on differences in physical properties between the crop and materials. The process of cleaning sorghum requires that differences in the physical properties of sorghum grain be known. This study was undertaken to determine some physical properties of Samaru Sorghum 17(SAMSORG 17) grain which influence separation and cleaning.

2. MATERIALS AND METHODS

2.1 Test Material

The Samaru Sorghum 17 (SAMSORG 17) grains were used throughout the experiment to eliminate varietal differences. The seed was obtained from the Seed Multiplication Unit of the Plant Science Department, Institute for Agricultural Research, Ahmadu Bello University, Zaria.

Selected physical properties of sorghum grain, such as grain diameter, mass, projected area, volume, particle density, sphericty and bulk density were determined. The sorghum grain was obtained after mechanical threshing. The frequency distribution of the sorghum grain sample was determined and used to calculate the skewness and kurtosis.

2.2 Moisture Content

Moisture content of sorghum grain was determined using the procedure detailed by Henderson et al., (1997). The grain samples were dried at 130^0 C for 18 hours (ASAE, 2003). The weight loss of the samples was recorded and the moisture determined in percentage. This was replicated three times. The moisture content was calculated as:

$$MC_{wb} = \frac{W_i - W_d}{W_i}.100 \qquad 2.1$$

Where

MC_{wb} = Moisture content, wet basis, %.
W_i = Initial weight of sample, kg.
W_d = Dried weight of sample, kg

2.3 Size and Shape

Micrometer screw gauge (Sheffied S 139 Br) with least resolution count 0.01mm was used to determine the diameter of the sorghum grains. Three groups of 50 sorghum grains samples were drawn randomly from each moisture content level. From each group, 20 grains were picked randomly and were thoroughly mixed together from which 30 sorghum grains were randomly selected.

The diameter of each individual sorghum grain was measured triaxially along the principal axis, major (L_1), intermediate (L_2) and minor (L_3). Its equivalent diameter D_e was calculated using the using equation 2.2 given by Ciro, 1997(reported by Aseogwu,et al., 2006).

$$D_e = \frac{(F_1 + F_2 + F_3)}{3} \qquad 2.2$$

Where

F_1 = Arithmetic mean diameter $=(L_1 + L_2 + L_3)/3$, mm.
F_2 = Geometric mean diameter $=(L_1 L_2 L_3)^{1/3}$, mm.

$$F_3 = \text{Square mean diameter} = \left[\frac{(L_1L_2 + L_2L_3 + L_3L_1)}{3}\right]^{1/2}, \text{ mm.}$$

Sphericity is a criterion for describing the shape of the grain. The sphericity of grain samples, S, was determined using the relationship given by Mohsenin (1980) using equation from 2.3.

$$S = \frac{(L_1L_2L_3)^{\frac{1}{3}}}{L_1} \qquad 2.3$$

2.4 Projected Area

The projected area of the sorghum grain was obtained by tracing method in the natural rest position as described by Oje and Ugbor (1991). The projected area was determined by tracing out the boundary on a linear graph paper and counting the number of square boxes the traced boundary covered.

2.5 Mass

The mass of sorghum grain was determined using an electronic mettler balance (Sarturlus 2355, max160g, d= 0.001g).The mass of one thousand sorghum grains of thousand grains of sorghum randomly selected was obtained using electronic mettler weighing balance with d= 0.001g. The effect of moisture content on the one thousand weights was also determined. Thirty replications were taken.

2.6 Volume

The volume of sorghum grain was determined by water displacement method as described by Oje (1993). The samples were put in a polyethylene bag attached to a thread and immersed in water inside a measuring cylinder (100ml). The volume of the empty polyethylene bag was obtained with the aid of a sinker. Five grams of sorghum grains was placed in the polyethylene bag and immersed in the water. The volume of water displaced was measured. The volume of the sorghum grain is the difference in water level minus the volume of the polyethylene. The average volume was obtained by dividing the volume obtained by the number of grains making up the known mass. The representative value of the volume of sorghum grain was taken as the average of thirty replications.

2.7 Bulk Density

The bulk density, β, of sorghum grain was determined by using a container of known volume. A rectangular container dimensioned 210 mm by 145 mm by 72 mm was used. The container was filled to the brim with grain samples. The grain was densely packed by gently tapping the container 10 times in the same manner for all measurements to allow the grains to settle in the container (Waziri and Mittal, 1983) so as to obtain uniform density. The grains which filled the container respectively, was weighed using electronic mettler balance (Sarturious 2355, maximum 160g, d = 0.001d). The volume of the container was estimated by filling the container with water. The water was then poured out into a measuring cylinder (100ml) and the volume was recorded.

The bulk density of grain was calculated as the ratio of the bulk weight and the volume of the container.

$$\beta = \frac{m}{v} \qquad 2.4$$

Where m is the mass of sorghum grain and straw in kg respectively and v is the volumeof the container in m^3.

2.8 Particle Density

The particle density of sorghum grain was determined by dividing the sorghum grain mass measured by the electronic weighing balance by the sorghum grain volume determined by water displacement method. The sorghum grain was conditioned to obtain different moisture contents in the range 8.89 and 16.50 % wb. This was obtained by rewetting the sorghum grain sample to a higher moisture content using the method given by Aviara et al., 2004. This method involved soaking a 1kg of sorghum grain in clean water for given number of hours depending on the final moisture content desired. At the end of soaking, the sorghum grain were spread out in thin layer to dry in natural air in the room to enable stable and uniform moisture content to be obtained. The moisture levels used for the experiment were 8.89, 10.87, 12.33, 14.56, and 16.50 % wb respectively to investigate the effect of moisture on sorghum grain particle density.

3. RESULTS AND DISCUSSION

3.1 Size and Shape

Table 1 presents the mean values and standard errors of the axial dimensions of the sorghum grain at different moisture contents. The table also contains the arithmetic mean, geometric mean and the equivalent diameters of the sorghum grain. The average values obtained for the arithmetic mean, geometric mean and equivalent diameters were 3.32 mm, 3.31 mm and 3.31 mm, respectively at moisture content of 8.89 % wb. At moisture content of 16.50 %wb, the values were 4.20 mm, 4.16 mm and 4.18 mm respectively. The average diameter of the sorghum grains calculated by the arithmetic mean, geometric mean and equivalent diameter methods in the moisture range of 8.89 – 16.50 % wb are similar (Table 1).The result obtained from this study are in agreement with those of Picket and West (1988) who obtained arithmetic mean and geometric mean diameters of 3.73 and 3.66 mm respectively, while Gorial and O'Callaghan (1990) obtained equivalent and geometric diameters of 3.5 and 3.61 mm respectively for sorghum, though the variety and moisture content was not specified. However, the values obtained are higher than the 2.72 mm obtained by Waziri and Mittal (1983) for LS187 variety of sorghum.

The arithmetic mean and geometric mean can therefore be used to determine the average diameter of sorghum grain. This is useful in determining the diameter of sieve hole.

Table 1. Dimensions of sorghum grains

MC %wb	Major axis, L_1, mm	Medium axis, L_2, mm	Minor axis, L_3, mm	Arithmetic Mean, mm $\frac{(L_1 + L_2 + L_3)}{3}$	Geometric mean, mm $(L_1 L_2 L_3)^{1/3}$	Equivalent diameter, D_e mm
8.89	3.70(0.29)*	3.18(0.30)	3.08(0.22)	3.32	3.31	3.31
10.87	3.81(0.22)	3.29(0.18)	3.09(0.24)	3.40	3.38	3.41
12.33	4.04(0.04)	3.50(0.03)	3.61(0.05)	3.72	3.71	3.71
14.56	4.45(0.07)	4.39(0.12)	3.40(0.38)	4.08	4.05	4.06
16.50	4.62(0.06)	4.53(0.01)	3.44(0.07)	4.20	4.16	4.18

* Standard error (SE)

3.2 Mass

Table 2 presents the summary of the results of mean mass of sorghum grain, the skewness and kurtosis measured at average moisture of 8.89 %. The frequency distribution of mass is shown in figure 1.

The frequency distribution of the mass of sorghum grain was positively skewed and platykurtic with 67 % of it ranging between 0.042 g and 0.044 g. The minimum and maximum mass of sorghum grain obtained were 0.037 g and 0.054 g respectively.

Table 2. Mean physical properties of sorghum grain and their skewness and kurtosis

	Mass, g	Projected area, cm^2	Volume, cm^3	Particle density, g/cm^3
No of samples	30	30	30	30
Values	$0.044^{*} \pm 0.007^{**}$	4.66 ± 0.85	0.091 ± 0.04	1.02 ± 0.2
Skewness, Γ^1	0.88	1.23	-0.50	1.22
Kurtosis, Γ^2	-1.00	5.26	1.41	7.31

*Mean values of 30 replicates
**Standard error

Γ^1 = skewness which characterizes the degree of symmetry of a distribution around its means. Positive skewness indicates a distribution with an asymmetric tail extending towards more values. Negative skewness indicates a distribution with an asymmetric tail extending towards more negative values. Zero values indicate symmetrical distribution.

Γ^2 = kurtosis which characterise the relative peakness or flatness of a distribution compared to the normal distribution. Positive kurtosis indicates leptokurtic distribution. Negative kurtosis indicates platykurtic distribution. Zero values indicate normal or mesokurtic distribution.

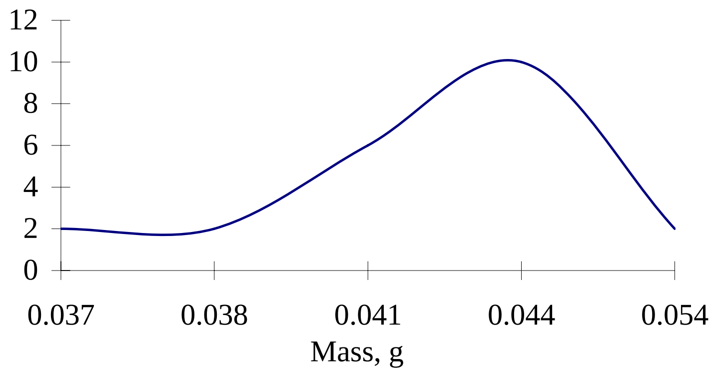

Figure 1. Mass of sorghum grain

The mean mass obtained for sorghum grain (SAMSORG 17) of 0.044 ±0.007g was higher than the 0.030 g obtained by Gorial and O'Callaghan (1990) for sorghum whose variety and moisture content were not specified and 0.0351g obtained for LS 187 variety of sorghum by Waziri and Mittal(1983). Kashayap and Pandya (1965) reported that the lighter a particle, the more time it takes to pass through the air stream and it is carried away further.

The one thousand grain mass is a useful index in measuring the relative amount of dockage or foreign material in a given lot of material, and the amount of shriveled or immature kernels (Luh, 1980). The variation of the one thousand sorghum grain masses with moisture content is plotted in Figure 2. The thousand grain mass gives an increasing relationship with increasing moisture content within the moisture content range of 8.89 – 16.50 % wb. When the moisture content is 8.89 %wb, the mass is 34.91g, which increased to 61.12g at 16.50 % wb.

An increase in one thousand grain mass with moisture content has been observed for white lupin (Ogut, 1998), makahna (Jha, 1999) and QP-38 pigeon pea variety (Baryeh and Mangope, 2002). The addition of moisture increases the weight and volume of the sorghum grain. The value obtained for SAMSORG 17 of 34.91-61.12 g within moisture range of 8.89-16.50% was higher than the one obtained by Waziri and Mittal, (1983) for LS187 variety of sorghum, which was 30.51 ±1.18 g, though they did not specify the moisture content when the value was taken.

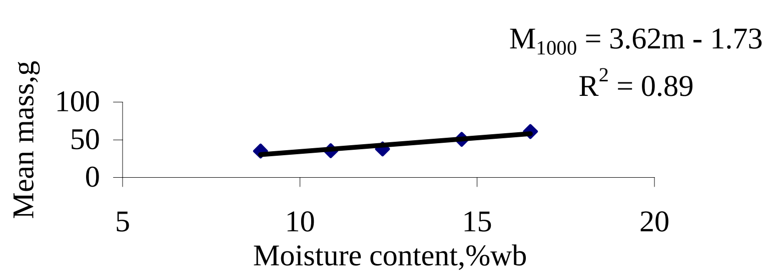

Figure 2. Effect of moisture content on the one thousand sorghum grain mass

3.3 Projected Area

The frequency distribution of projected area of sorghum grain is given in figure 3 and the mean projected area, skewness and kurtosis are given in Table 2. The projected area of sorghum grain has a kurtosis which was leptokurtic and positively skewed with 93 % ranged between 4.4 mm^2 and 5.5 $mm^{2.}$ The highest projected area obtained for sorghum grain was 5.90 mm^2 while the lowest was 3.90 mm^2.

Projected area has been shown to influence separation efficiency (Jodlowski, 1976, Stankovick and Woolever, 1978, Shukla et al., 1991). Kashayap and Pandya (1965) published that the greater the projected area of a particle, the further it is carried away in unit time in a given air stream since the drag force on a particle is directly proportional to its projected area.

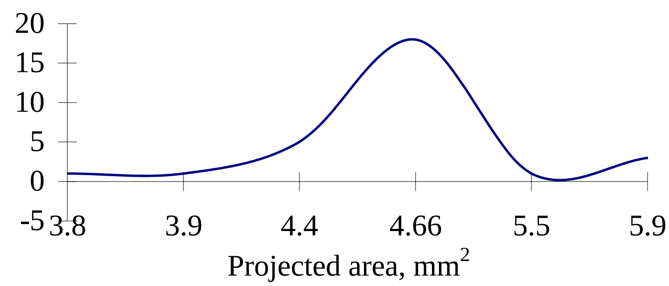

Figure 3. Projected area of sorghum grain

3.4 Volume

Figure 4 shows the frequency distribution of volume of sorghum grain while the mean volume, skewness and kurtosis are presented in Table 2. The maximum volume obtained for sorghum grain was 0.13 cm^3 while the minimum was 0.04 cm^3. The frequency distribution of the volume of sorghum grain was platykurtic with 83 % within the range of 0.06 cm^3 and 0.11 cm^3.

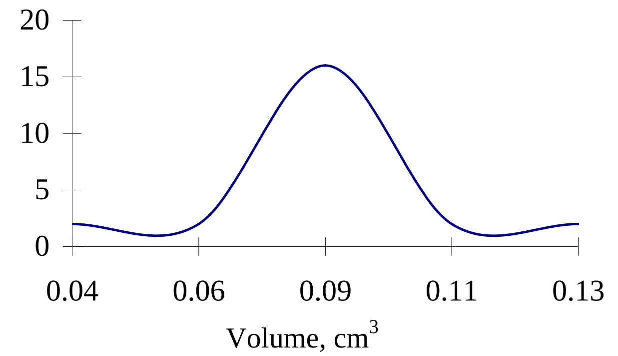

Figure 4. Volume of sorghum grain

The volume obtained for sorghum grain (SAMSORG 17) 0.091 ± 0.04 cm^3 was higher than the one obtained by Picket and West (1988) for sorghum of 0.021-0.023 cm^3.

3.5 Particle Density

The sorghum grain particle density frequency distribution is given in figure 5 while the mean volume, skewness and kurtosis are presented in Table 2. The minimum density of 0.70 g/cm^3, and maximum density of 1.35 g/cm^3 were obtained for sorghum grain. The frequency distribution for grain was leptokurtic.

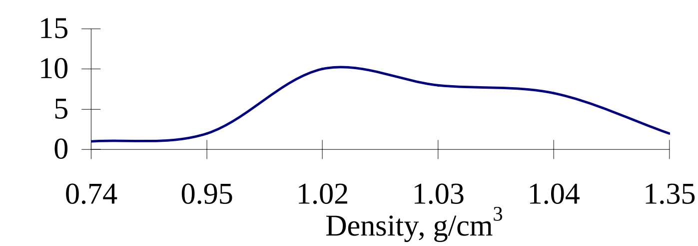

Figure 5. Density of sorghum grain

The variation of the particle density of sorghum grain with moisture content within the range of 8.89 to 16.50% wb is presented in Figure 6. The particle density was linearly regressed against the moisture content with coefficient of determination being 0.86.

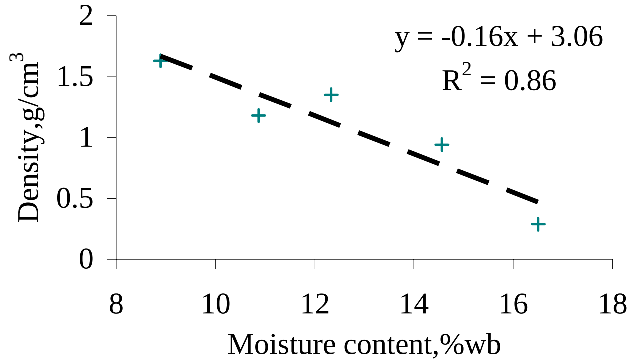

Figure 6. Effect of moisture content on the particle density of sorghum grain

The sorghum grain density decreased with increasing moisture content within the moisture range considered. When the moisture content was 8.89 %wb, the sorghum grain density was 1.63 g/cm^3, which decreased to 0.29 g/cm^3 at 16.50 %wb. This trend agrees with the results obtained by Nura and Pedersen (1987) that the density of cereals decreases with an increase in grain moisture for moisture range of 10-25%. The reason given by them for this behaviour is that at moisture content above 25 %, the starch molecules becomes saturated and at a moisture content below 10 %, the starch molecules were dry and the inter-molecular spaces were contracted and grain approached the true density of bone dry material. This shows that the increase in mass resulting from moisture gain of the sorghum grain is lower than the accompanying volumetric expansion. Similar trends have been reported for other biological materials (Balasubramanian, 2001; Nelson, 1980; Shephard and Bhardwaj, 1986).

3.6 Sphericity of Sorghum Grain

The sphericity of sorghum grain was calculated individually using equation 2.3. The frequency distribution of sphericity of sorghum grain was normally distributed as shown in Figure 7. The mean value was 0.92 $\pm$0.02. The highest sphericity obtained for SAMSORG 17 was 0.94 while the lowest sphericity obtained was 0.90. The sphericity of 0.90 – 0.94 obtained for SAMSORG 17 was higher than 0.80 obtained by Gorial and O’Callaghan (1990) for sorghum, though the variety on which their result was based is not known. Wolfe and Tatepo(1972) reported that the sphericity of materials is always below unity and that the more regular an object is , the lower the sphericity. Oje (1993) published that high sphericity would make material rather slide than roll.

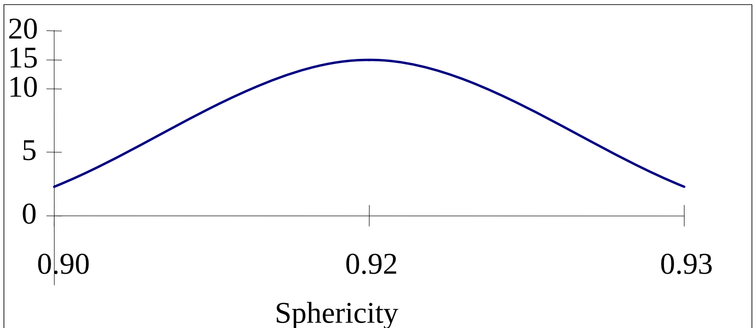

Figure 7: Sphericity of sorghum grain

3.7 Bulk Density

A summary of the individual bulk density of sorghum grain is presented in Table 3 while the frequency distribution is given in figure 8. The frequency distribution of bulk density was skewed to the left. Sixty two percent (62%) of the sorghum grain bulk density ranged between 568.51 g/cm^3 and 575.92 g/cm^3. The maximum bulk density obtained was 585.11 g/cm^3 and minimum obtained was 532.68 g/cm^3 for sorghum grain.

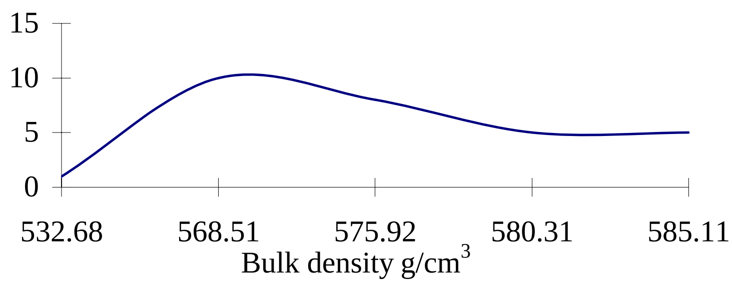

Figure 8. Bulk density of grain

Table 3: Bulk densities of sorghum samples

	Grain g/cm^3
No of Observation	30
Mean	568.51 ± 20.94
Minimum	532.68
Maximum	585.11
Kurtosis	9.7118
Skewness	-2.4567

The bulk density for SAMSORG 17 grain is within the range obtained by Picket and West (1988) for sorghum grain between 512.46 g/cm^3 and 832.96 g/cm^3.

4. CONCLUSIONS

From the investigation of some physical properties of Samaru Sorghum (SAMSORG 17), the following conclusions could be drawn:

1. The average diameter of the sorghum grain calculated by the arithmetic mean, geometric mean and equivalent diameter within the moisture range of 8.89-16.50 % wb were similar. At 8.89 % wb moisture content, the values were 3.32 mm, 3.31 mm and 3.31 mm respectively while at 16.5% wb the values obtained were 4.20, 4.16 and 4.18mm respectively.

2. The mean mass, projected area and volume of sorghum grain obtained were 0.044g, 4.66 mm^2 and 0.091 cm^3 respectively.

3. The mean particle and bulk density of sorghum grain obtained were 1.02 g/cm^3 and 568.5 g/cm^3 respectively. The particle density of SAMSORG 17 grain decreased with increasing moisture within the moisture range of 8.89-16.50%wb.

4. The sphericity of SAMSORG 17 grain was normally distributed about 0.92.

5. ACKNOWLEDGEMENTS

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