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EFFECT OF GRAIN MOISTURE CONTENT ON THE PHYSICAL PROPERTIES OF SOME SELECTED SORGHUM VARIETIES

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Abstract: Determination of physical characteristics of grain of biomaterials is important in the design of harvesting, handling, and processing equipment. This helps in understanding the problem of separating grains from undesirable materials during threshing and winnowing, as well as in designing post-harvest handling equipments. Physical properties of sorghum grains from ten varieties (7 released and 3 breeding lines) were investigated under three different grain moisture content of 10%, 20% and 30% dry basis (d.b.). Results from the experiment revealed wide variation among the sorghum varieties on the physical properties measured. Arithmetic Mean Diameter ranged from 4.233 mm to 4.872 mm, while the Geometric Mean Diameter of the varieties ranged from 4.215 mm to 4.864 mm. Sphericity for the different sorghum varieties fall within the range of 0.86 to 0.96. It was also observed that the surface areas of the sorghum varieties are between 52.2 mm^2 to 70.00 mm^2. The results further showed that Aspect ratio ranged from 0.84 to 0.94 and the Angle of repose for the sorghum varieties were from 31.51^0 to 34.25^0. Result from the study revealed that, increase in moisture content led to increase in the surface area, arithmetic mean diameter, geometric mean diameter, sphericity and angle of repose. Variety and changes in moisture content significantly affected the physical properties determined.

Keywords: moisture content, sorghum, physical properties, varieties

SIGNIFICANCE: The findings of the research study presented in this paper could be used in the design of processing machines for wide varieties of sorghum crop that are under cultivation.

Introduction

Sorghum is one of the world's most important cereals which could be processed into flour and used for making diverse food products such as pap and porridge as well as livestock feed. The grains of some varieties are now being used in the industries for the production of biscuits, confectionaries, beverages, pharmaceutical syrups and also for making of beer in beer 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 different kernel size, colour and cleanliness (Rooney, 2003). 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). 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).
Works done by different researchers have given encouraging results on the physical properties of sorghum did not include the post-harvest machines designed with their data to function effectively. This is because of the peculiarity of some of the grains obtained and the differences in agro climatic zones, which could either, make the grains to be smaller or larger.

Agricultural materials poses special problem in determining their physical properties because of their diversity in shape, size, moisture content and maturity level. Recent scientific development have improved the handling and processing of bio-materials through mechanical and thermal devices, but little is known about the basic physical characteristics of these materials. Such basic information which is not only important to engineers but also to food scientist and processors, plant and animal breeders and other scientists in handling, processing and design of post-harvest machines. Therefore, this study was targeted towards determination of selected physical properties of ten sorghum varieties compare these properties and investigate the relationship between the physical dimensions of the ten varieties as well as their relationship with moisture content.

MATERIALS AND METHODS

Material

Samples of ten sorghum varieties were obtained from ICRISAT Station in Nigeria from 2016 rainy season production, which included 7 popular varieties in Nigeria (CSR 01, CSR 02, Samsorg 17, Samsorg 44, Samsorg 45, Samsorg 46, and ICSV 400) and 3 breeding lines (ICSR93034, IESV911040L and S-35). The seeds were cleaned to remove broken grains and other un-wanted materials and then labeled accordingly before conducting the experiment. Moisture content was determined on dry basis using the International Seed Testing Association procedure and using the ASAE 1999 standards**.** The materials used during the experiment included; venire caliper, ruler, graduated measuring cylinder, electronic sensitive scale, and drying oven.

Methods

Determination of Moisture Content

Moisture contents of 10%, 20% and 30% was used for the experiment, 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

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clean water for a period of time in order to condition the seed final moisture content desired. At the end of soaking, the sorghum grains were spread to dry in natural air in the room to enable stable and uniform moisture content to be obtained.

The moisture content of the grains was determined by oven method according to ASAE 1999 standard, this was done by putting 100 g of grains for each variety into three containers and then weighed using the sensitive scale. It was then oven dried at a temperature of 130˚C for 18 h. The average moisture content of three samples was calculated to obtain the moisture content for each of the samples using equation 1;

$$\text{Mc (w.b) \%} = \frac{W^{щ} - W^{d}}{W^{щ}} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

$W^{щ}$= weight of wet samples, g
W^{d} = weight of dried sample, g

Determination of the Physical Dimensions of the Sorghum Grains
One hundred seed were randomly taken and each seed was measured for its length (major diameter), width (intermediate diameter) and thickness (minor diameter), using a Godmarch venire caliper with 0.01 mm accuracy. Each seed was placed between the outside jaws of the caliper to measure the length along the major, intermediate and minor axis of the seed.

Determination of Arithmetic mean diameter
Arithmetic mean diameter of the sorghum varieties was determined using equation 2 as given by Sirisomboon *et al.* (2007).

$$D_a = \frac{a+b+c}{3}\,mm \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Where,
a is the major diameter
b is intermediate diameter and
c is minor diameter of the seed.

Determination of Geometric mean diameter
The geometric mean diameter was also determined from the physical dimensions of the grains (Prandhan *et al.,* 2009) as presented in equation 3:

$$D_g = (abc)^{⅓}\ \text{mm} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Where
a is the major diameter
b is an intermediate diameter
c is a minor diameter of the seed.

Determination of Sphericity

Sphericity of the seeds was determined from equation 4 as used by Sirisomboon et al., 2007.

Sphericity (S) = $\frac{a.b.c^{1/3}}{a}$ ………………………………………………………..………………. (4)

Where,
a is the major diameter
b is intermediate diameter and
c is minor diameter of the seed.

Determination of Surface area

The surface area of the sorghum grains was determined using equation 5 as given by Jain and Bal, 1997; Bart –Plange and Baryeh, 2003:

Surface area **=** $\frac{\pi d a^2}{(2a-d)} mm^2$ ……………………………………………………………….…. (5)

Where,
a is the major diameter,
b is intermediate diameter
c is minor diameter of the seed and
d = $(bc)^{0.5}$

Determination of Aspect Ratio

The relationship given by Altuntas *et al.* and 2005 and Sharma *et al.,* 2011 as given in equation 6 was used in computing the aspect ratio (Ra) of the ten sorghum varieties at different moisture contents.

Ra= $\frac{b}{a}$ ……………………………………………………………………..……………. (6)

Where,
a is the major diameter,
b is intermediate diameter of the seed.

Determination of Angle of Repose:

In determining the angle of repose of grains, they were piled on plywood, placed on a table in a conical form and then the plywood was tilted until the grains begin to slide (flow) freely, the angle which the plywood makes with the table as at the time of free flow was taken as the angle of repose of the grain. This experiment was repeated five times for each of the ten varieties of the grain at different moisture content to ascertain the mean angle of repose of the material.

Statistical Analysis: Data computed from the experiments was subjected to Analysis of Variance (ANOVA) using Genstat statistical software 17th Edition. Also, means with significant differences were separated with LSD using Duncan multiple range test.

Results and Discussions

Effect of Varieties and Moisture Content on the Arithmetic Mean Diameter of Selected Sorghum Varieties

Results presented in Table 1 showed highly significant difference (P<.001) among the ten sorghum varieties with respect to their Arithmetic Mean Diameter (AmD) which ranged from 4.233 mm to 4.872 mm with average mean AmD value of ±4.536 mm. The result further revealed that moisture content had highly significant effect on the Arithmetic Mean Diameter of the selected sorghum varieties with grain moisture content of 10%, 20% and 30% (d.b) having Arithmetic Mean Diameter of 4.301 mm, 4.515 mm and 4.793 mm respectively. This result implies that there is an inverse relationship between sorghum grain moisture content and its Arithmetic Mean Diameter. The results agreed with the report of Ndirika and Mohammed (2005) that parameters such as sorghum grain length, width, thickness and volume increased with increase in moisture content.

Effect of Varieties and Moisture Content on the Geometric Mean Diameter of Selected Sorghum Varieties

The effect of different sorghum varieties was highly significant (P<.001) on the Geometric Mean Diameter (GmD) Table 1. The result showed that Samsorg 45 had the highest GmD of 4.864 mm while ICSV 400 had the least GmD of 4.215 mm. However, CSR 01, CSR 02, Samsorg 17 and Samsorg 46 had GmD of 4.639 mm, 4.784 mm, 4.725 mm and 4.626 mm respectively and are statistically at par. Sorghum grain moisture content was also found to be highly significant with respect to the grain GmD, moisture content at 10 %, 20% and 30% had GmD of 4.290 mm, 4.501 mm and 4.784 mm respectively, indicating that increase in grain moisture content leads to increase in GmD. This report is in line with the findings of Sobukola *et al.* (2013) which concluded that Axial dimensions (length, width and thickness), geometric mean diameter, mass of 1000 seeds, surface area, volume and sphericity of high quality maize seeds (SWAM 1) increased linearly with increase in moisture levels.

Effect of Varieties and Moisture Content on the Sphericity of Selected Sorghum Varieties

Table 1 showed highly significant difference (P<.001) among the sorghum varieties Sphericity with S-35 accounting for the least Sphericity of 0.86 while Samsorg 17 recorded a significantly higher mean Sphericity of 0.96. The results further revealed that CSR 01, CSR 02, ICSV 400, Samsorg 44, Samsorg 45, Samsorg 46, IESV911040L and ICSR93034 had Sphericity of 0.93, 0.93, 0.91, 0.93, 0.93, 0.94, 0.93 and 0.90 respectively, and are statistically at par. Simonyan *et al.* (2007) reported that the sphericity of SAMSORG 17 grain was between (0.90 – 0.94) and normally distributed about 0.92. Similarly, moisture content significantly affects the sphericity of sorghum varieties used in this experiment increasing from 9.2 to 9.4 as moisture content increase from 10 % to 30% (d.b).

Effect of Varieties and Moisture Content on the Surface Area of Selected Sorghum Varieties

The effect of variety and moisture content was highly significant on the surface area of the sorghum varieties as presented in Table 1. Results revealed a significantly higher mean surface area of 70.00 mm^2 was obtained for Samsorg 45 while ICSV 400 accounted for least surface area of 52.2 mm^2. Furthermore, the surface area for Samsorg 44, IESV 911040L, S-35 and ICSR93034 were found to be 57.55 mm^2, 54.56 mm^2, 54.17 mm^2 and 56.02 mm^2 respectively and are statistically at par. Similarly, CSR 01, CSR 02, Samsorg 17, Samsorg 45 and Samsorg 46 had surface area of 63.97 mm^2, 67.79 mm^2, 67.76 mm^2, 70.00 mm^2 and 63.71mm^2 respectively and have no statistical difference. Moisture content significantly affected the surface area of sorghum varieties. Results showed that increasing moisture content from 10 % to 30% (d.b) lead to increase in surface area from 54.25 mm^2 to 68.52 mm^2. Similar result was reported by Sobukola *et al.* (2013) that the surface area of maize increased linearly with increase in moisture content.

Effect of Varieties and Moisture Content on the Aspect Ration of Selected Sorghum Varieties

The experimental results (Table 1) revealed highly significant (P<.001) difference among the sorghum varieties. Aspect ratio of 0.94, 0.93, 0.89, 0.92, 0.92, 0.90, 0.90 and 0.90 was recorded for CSR 01, CSR 02, ICSV 400, Samsorg 17, Samsorg 44, Samsorg 45, Samsorg 46 and IESV 911040L respectively and are statistically at par. Similarly, S-35 and ICSR 93034 has aspect ratio of 0.85 and 0.84 respectively.

Effect of Varieties and Moisture Content on the Angle of Repose of Selected Sorghum Varieties

The investigated effect of sorghum variety on angle of repose (Table 1) showed no significant difference among the sorghum varieties used. However, the effect of moisture content was highly significant (P<.001) on angle of repose revealing significant increase on angle of repose as grain moisture increased. Similarly, the combine effect of moisture content and variety was significant (Figure 1). The result showed significantly higher mean angle of repose 36^o recorded for the interaction between sorghum variety (ICSR93034) and grain moisture content of 30%. These results are in line with the findings of Saiedirad *et al.* (2008) and Abdul-Rasaq *et al.* (2011) which states that Angle of repose increased as moisture content increases.

Conclusion

The study concludes that wide variation exist among the sorghum varieties with respect to the physical properties determined. The linear dimensions of arithmetic mean diameter, geometric diameter, surface area, sphericity, aspect ratio and angle of repose, increased with increased grain moisture content irrespective of variety. The result from this study will help provide designer of post-harvest equipment with an in-depth understanding of the variation that exist among sorghum varieties under cultivation, effect of moisture content and relationship between moisture content and sorghum varieties on the physical properties of sorghum crop.

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Table 1: Mean: Mean of the Physical Properties of the Selected Sorghum Varieties

Treatments	**Arithmetic Mean Diameter**	**Geometric Mean Diameter**	**Sphericity**	**Surface Area**	**Aspect Ratio**	**Angle of Repose**
Variety (V)						
CSR01	4.651^{b}	4.639^{b}	0.93^{bc}	63.97^{c}	0.94^{b}	32.06^{ab}
CSR02	4.795^{bc}	4.784^{bc}	0.93^{bc}	67.79^{cd}	0.93^{b}	32.98^{ab}
ICSV 400	4.233^{a}	4.215^{a}	0.91^{ab}	52.20^{a}	0.89^{b}	32.01^{ab}
Samsorg 17	4.731^{bc}	4.725^{bc}	0.96^{c}	67.76^{cd}	0.92^{b}	31.51^{a}
Samsorg 44	4.401^{a}	4.393^{a}	0.93^{bc}	57.55^{b}	0.92^{b}	34.25^{b}
Samsorg 45	4.872^{c}	4.864^{c}	0.93^{bc}	70.00^{d}	0.90^{b}	32.71^{ab}
Samsorg 46	4.634^{b}	4.626^{b}	0.94^{bc}	63.71^{c}	0.90^{b}	33.02^{ab}
IESV911040L	4.289^{a}	4.282^{a}	0.93^{bc}	54.56^{ab}	0.90^{b}	31.95^{ab}
S-35	4.354^{a}	4.336^{a}	0.89^{a}	54.17^{ab}	0.85^{a}	31.62^{a}
ICSR93034	4.4^{a}	4.387^{a}	0.90^{ab}	56.02^{ab}	0.84^{a}	31.94^{ab}
P of F	**<.001**	**<.001**	**0.006**	**<.001**	**<.001**	**0.301**
SED	0.0824	0.0829	0.015	2.271	0.021	1.073
LSD	0.1648	0.1659	0.030	4.545	0.042	2.147
Moisture (M)						
10 (%)	4.301^{a}	4.290^{a}	0.92^{a}	54.25^{a}	0.90^{a}	32.70^{b}
20 (%)	4.515^{b}	4.501^{b}	0.92^{a}	59.55^{b}	0.89^{a}	30.55^{a}
30 (%)	4.793^{c}	4.784^{c}	0.94^{b}	68.52^{c}	0.91^{a}	33.96^{c}
P of F	**<.001**	**<.001**	**0.030**	**<.001**	**0.401**	**<.001**
SED	0.0451	0.0454	0.008	1.244	0.011	0.588
LSD	0.0903	0.0908	0.017	2.490	0.023	1.176
Mean	**4.536**	**4.525**	**0.92**	**60.77**	**0.90**	**32.40**
CV	3.9	3.9	3.5	7.9	4.9	7.0
Interaction						
V x M	NS	NS	NS	NS	NS	*

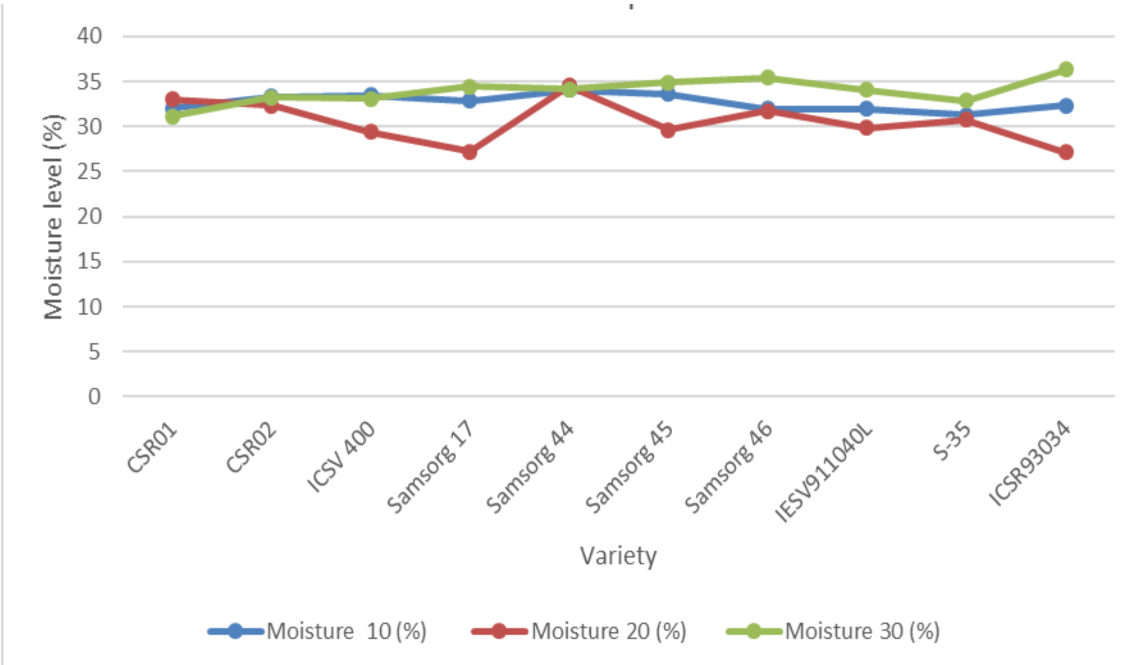

Figure 1: Effect of variety and grain moisture content on angle of repose