Journal of Food Technology 3 (3): 314-318 2005

Determination of Selected Physical Properties and Their Relationship with Moisture Content for Sorghum Crop

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Abstract: Some selected physical properties of sorghum crop such as grain length, width, thickness, surface area, sphericity, roundness, angle of repose, thousand kernel weight (TKW), specific gravity, bulk density and porosity were determined. The relationships of these properties with moisture content were also presented. From the results, the kernel volume and other dimensions such as length, width and thickness increased with increase in grain moisture content. Comparative evaluation of the two varieties of sorghum (farafara and short kaura) on the above properties shows that only the difference in the means of a thousand kernel weight (TKW) and angle of repose (grain to glass) are the parameters which are statistically significant at 5 percent level of significance. The result also revealed that parameters such as length, width, thickness and volume of grain increased with increase in moisture content. Correlation coefficient between 86.6% - 97.9% were obtained with the relationship between moisture content and grain length, grain width, grain thickness and grain volume for both varieties.

Key words: Physical properties, moisture content sorghum crop

INTRODUCTION

Sorghum which is one of the most important cereal food which could be processed as flour and used for making pap and porridge.

The grain 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. In developed countries of the World, particularly United state, sorghum is grown mainly as feed crops for livestock's and poultry production. Also for the production of starches, crystalline sugar, paper adhesive etc.[1,2].

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[3]. 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.

It's quite interesting that several works have been done from literatures on the physical properties of sorghum by other researchers and scientists and their results were quite encouraging too, but the Post harvest machines designed with their data can to some extent not function effectively because of the peculiarity of some of the grains obtained and also the differences in agloclimatic zones which could either make the grains to be smaller or larger in sizes.

Objectives: The objectives of this study includes:

- Determination of selected physical properties of two varieties of sorghum and to compare the properties for the two varieties.
- To establish the relationship between the physical dimensions (length, width, thickness) of two varieties of sorghum and their relationship with moisture content.

MATERIALS AND METHOD

Two varieties of sorghum crop, namely farafara and short kaura varieties were used. After these varieties were acquired, they were thoroughly cleaned to free it from foreign material such as dirt, stones, dust and unremoved chaffs and then stored in a container at room temperature. The grains were classified into three size groups (small, Medium and large) for each variety. The size and principal axes of the grain (minor, intermediate and major)

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in each group were determined. The weight of the grains were also determined.

A good number of instruments were used in various measurement and determination of the dimensions and properties of the grains. Among these instruments were: venier caliper which was used for measuring axial dimensions (length, width, thickness) of grains. A meter balance with 0.01g calibration was used for all weight measurement of the grains. Glass and wood were the material used as medium for the determination of angle of repose. Overhead projector was used to project the grain kernel to enhance easy determination of sphericity and roundness.

Experimental Procedures: The following procedures were used in determining the physical properties of the two varieties of sorghum:

Moisture Content Determination: The moisture content on wet bases of the dried grain were determined by oven method according to ASAE[4] standard, this was done by putting 10-15 g of grains for each variety into two containers and then weighed using metler balance. It was then oven dried at a temperature of 130°C for 18 h. The average moisture content of the two samples was calculated to obtain the moisture content of the samples using the relationship below;

$$\text{Mc (w.b)\%} = \frac{W_w - W_d}{W_w} \times 100 \quad (1)$$

W_w = weight of wet samples, g
W_d = weight of dried sample, g

Size Determination: The grain sizes of the two varieties of sorghum such as length, width and thickness were determined using venier caliper. The venier caliper having a least count of 0.01cm was used. Readings were taken in three axes to obtain minor, intermediate and major diameters of the materials. An average of fifty kernels of each of the two varieties were used to determine the grain sizes.

Shape Determination: In determining the shape of the two varieties of sorghum grains, the grains were placed in a sequential order on the projector surface of an over head projector. The projector was focussed to obtain a sharp boundary of the grain on a graph paper. The out line on the graph paper was traced and the magnification factor (MF) was calculated as follow.

$$\text{MF} = \frac{\text{Screened length of a line on a graph paper}}{\text{Actual length of a line on a graph paper}} \quad (2)$$

Roundness Determination: The traced projection outline was used to estimate the roundness of the grain kernel. And this was done by drawing a circle to circumscribe the traced projection boundary on a graph paper and the area of the circle estimated by counting the number of boxes covered by the traced projection outline. The total number of the boxes was multiplied by the area of one box to get the total area of the projected boundary. And in the end the roundness was determined using the relationship as Mohsenin[5]:

$$\text{Roundness} = A_p/A_c \quad (3)$$

Where,
A_p = Largest projected area of the object in rest position
A_c = Area of smallest circumscribing circle.

Sphericity determination: Just like roundness, sphericity was determined by drawing an inscribing circle in the traced projection boundary after this another circle is drawn circumscribing the same traced projection boundary, then the sphericity of the material was determined by using the relationship as Waziri and Mittal[3]:

$$\text{Sphericity} = d_i/d_e \quad (4)$$

d_i = Diameter of largest inscribed circle
d_e = Diameter of smallest circumscribing sphere or usually the largest diameter of the object.

Volume Determination: The volume of the grains were determined by taking the dimensions of the various varieties of the grains in three axes of length, width and thickness, then the volume was estimated using the following relationship as Mohsenin[3]:

$$\frac{4\pi}{3}.\frac{L}{2}.\frac{w}{2}.\frac{h}{2} \quad (5)$$

Where,
V = volume of kernel, L = length of kernel
w = width of kernel, h = thickness of kernel

Porosity Determination: Porosity was determined using the densities (bulk and solid) parameters as Mohsenin[5]:

$$\text{Porosity} = [1 - \text{Bulk density/solid density}] \times 100 \quad (6)$$

Bulk Density Determination: Bulk density of the grain was determined by weighing the grains packed in a container of known volume. And the following expression was used in determining the bulk density of the two varieties of the crop as Waziri and Mittal[3]:

$$\text{Bulk density} = \frac{\text{Weight of material packed}}{\text{Known volume } (\pi r^2 h)} \quad (7)$$

Where,

r = radius of the container used, h = height of the container used, $\pi = 22/7$

Solid Density Determination: Solid density which is another way of describing density was determined by using the specific gravity bottle. This was carried out by first weighing the empty density bottle, this is then followed by filling the bottle one-third full and then weighed again. The bottle was then filled with water and the mixture of the grains was also weighed. The bottle was then filled with water only and weighed also. After this, the solid density of the material was determined using the following expression as Okeke and Anyakoha[6]:

$$\text{Solid density} = \text{Density of Water x Specific gravity of grain } (G_{sp}) \quad (8)$$

$$G_{sp} = \frac{M_2 - M_1}{(M_4 - M_1) - (M_3 - M_2)} \quad (9)$$

Where,

G_{sp} = specific gravity of the grains

M1 = weight of empty density bottle, M_2 = weight of empty density bottle about full of grain, M_3 = weight of density bottle and grain filled up with water, M_4 = weight of density bottle filled with water only.

Surface Area Determination: In determining surface area of the grains, ten kernels of each variety was selected at random, these kernels were singly and carefully wrapped with a foil paper, then the boundary of kernels as seen on the foil paper is placed and traced on a graph paper. The surface area of the kernels was then determined by counting the number of square boxes the traced boundary covered on the graph.

Angle of Repose Determination: In determining the angle of repose of the 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 with 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 procedure was also used with the grain piled on glass placed on the table. This experiment was repeated five times for the two varieties of the grain at different moisture content to ascertain the mean angle of repose of the material.

Weight Determination: In determining the weight of the grains, one thousand (1000) kernels of the two varieties of sorghum grain were weighed using the electronic weighing balance of 0.10g sensitivity and a parameter known as thousand kernel weight (TKW) was determined.

Statistical Analysis: Coefficient of variation (COV) was used to determine the variation of all the parameters within the given grain samples for both varieties of sorghum grains. Also, student's t-test was used to compare the significant difference in the means of each parameter between the two varieties of sorghum. Finally, linear regression analysis was used to establish the relationship between moisture content and the physical parameters such as length, width, thickness and volume of grain.

RESULTS AND DISCUSSIONS

The data obtained during the experiment are summarized in tables 1, 2 and 3. The results are also indicated graphically in Fig. 1 – 4.

Table 1 showed that there were variations in all the measured physical parameters, but the most significant variation was found with the grain volume with coefficient of variation 13.01%, while the least significant parameter was the specific gravity with 0.06% coefficient of variation for farafara sorghum variety.

Table 2 also showed that there were variations in all the physical parameters of short kaura variety of sorghum. It showed that grain thickness has the highest coefficient of variation of 14.77%, while the least varied

Table 1: Statistical Analysis of Measured Physical Properties Of Sorghum Grain (Farafara Variety)

Parameters	Mean values	S.D	CV%
Length, L (mm)	11.69	0.63	5.38
Width, W (mm)	8.89	0.54	6.45
Thickness, h (mm)	4.37	0.39	9.08
Volume, v (mm^3)	240.71	31.32	13.01
Sphericity, (cm)	0.67	0.05	7.46
Roundness, (cm)	0.78	0.05	5.99
Surface area, (cm^2)	5.94	0.28	4.91
TKW, (g)	270.93	1.01	0.37
Angle of repose (°)			
(grain to wood)	84.20	0.30	0.88
(grain to glass)	24.10	0.26	1.06
Specific gravity	1.18	0.00	0.06
Density, (kg/m^3)	1992.40	31.69	1.59
Bulk density, (kg/m^3)	699.68	1.92	0.28
Porosity, (%)	40.80	0.15	0.36

SD: Standard deviation

CV: Coefficient of variation

Table 2: Statistical Analysis Of Measured Physical Properties Of Sorghum grain (Short kaura variety)

Parameters	Mean values	S.D	CV%
Length, L (mm)	5.56	0.31	5.57
Width, W (mm)	1.18	0.36	0.78
Thickness, h (mm)	2.44	0.34	14.77
Volume, v (mm^3)	29.62	4.37	9.84
Sphericity, (cm)	0.64	0.04	7.10
Roundness, (cm)	0.64	0.06	9.02
Surface area, (cm^2)	0.74	0.08	10.81
TKW, (g)	31.51	0.74	2.31
Angle of repose (°)			
(grain to wood)	1.21	0	0.21
(grain to glass)	33.00	0.49	1.51
Specific gravity	34.90	0.54	1.54
Density, (kg/ m^3)	2051.80	0.65	0.17
Bulk density, (kg/ m^3)	783.80	0.79	0.10
Porosity, (%)	35.40	0.22	0.62

SD: Standard deviation CV: Coefficient of variation

Table 3: Comparison Of Selected Physical Properties For Two Varieties Of Sorghum (Farafara And Short Kaura)

Parameters	Average Values		Cal. 't'	Table 't'	Significance
	Farafara	S. Kaura			
Length, L (mm)	5.52	5.56	0.35	1.98	NS
Width, W (mm)	4.16	4.18	0.16	1.98	NS
Thickness, h (mm)	2.41	2.44	0.29	1.98	NS
Volume, v (mm^3)	29.01	29.62	1.45	1.98	NS
Sphericity, (cm)	0.62	0.64	0.10	2.10	NS
Roundness, (cm)	0.68	0.64	0.25	2.10	NS
Surface area, (cm^2)	0.77	0.74	0.22	2.10	NS
TKW, (g)	2.51	32.41	4.86	2.10	**
Angle of repose (°)					
(grain to wood)	33.90	33.00	1.98	2.31	NS
(grain to glass)	35.20	34.00	2.63	2.31	*
Specific gravity	1.21	1.21	0	2.31	NS
Density, (kg/ m^3)	2051.40	2051.88	0.15	2.31	NS
Bulk density (kg/m)	783.11	3.38	0.34	2.31	NS
Porosity (%)	35.10	35.40	1.76	2.31	NS

** = Highly significant at 5% level, * = Significant at 5% level
NS = Not significant at 5% level

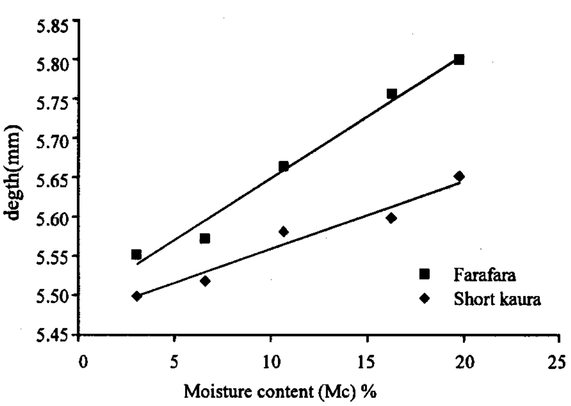

Fig. 1: Effect of moisture content jon grain length of two varieties of sorghum

parameter is the bulk density with coefficient of variation 0.10%.

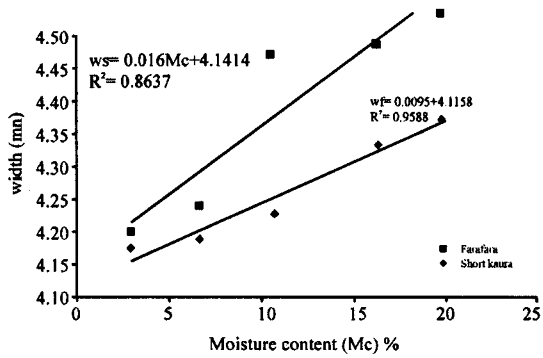

Fig. 2: Effect of moisture content on grain width for two varieties of sorghum

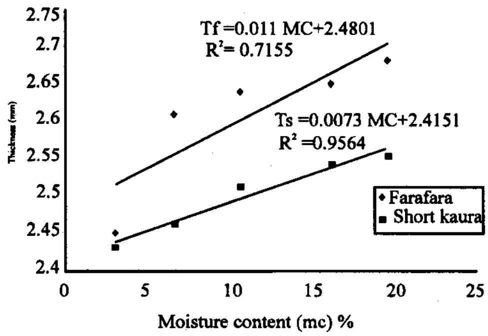

Fig. 3: Effect of moisture content on grain thickness of two varieties of sorghum

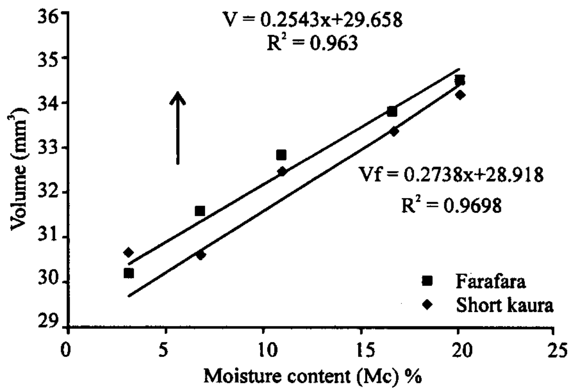

Fig. 4: Effect of moisture content on grain volumes of two varieties of sorghum

Table 3 shows the comparison between the difference in the means of the physical parameters of sorghum grains (farafara and short kaura) using the student t-test. From the table it was revealed that of all the measured properties, only parameters such as thousand kernel weight and angle of repose (grain to glass) were statistically significant at 5 percent level, since the calculated t-values (4.86 and 2.63) were higher than their table t-values of 2.10 and 2.31 respectively. But all other parameters were not statistically significant at 5 percent, since their calculated t-values were less than the table t-values.

Fig. 1-4 showed that length, width, thickness and volume of grain increased with increase in moisture content for the two varieties of sorghum (farafara and short Kaura varieties). And the values of these parameters obtained with short Kaura were higher than the values obtained with Farafara, variety for parameters such as length, width and volume (Fig. 1, 2 and 4), of kernel but lower with the grain thickness (Fig. 3). A much higher correlation coefficient above 86.6% was found with the relationship between moisture content and grain lengths (Fig. 1), width (Fig. 2), thickness (Fig. 3) and grain volume (Fig. 4) for both varieties of sorghum.

CONCLUSIONS

- From the result of the study, selected physical properties such as volume, length, width and thickness and others which includes, surface area, roundness, sphericity, porosity, angle of repose, density, specific gravity bulk density and thousand kernel weight (TKW) for the two varieties of sorghum (farafara and short kaura) were established.
- The relationship between the moisture content and physical dimensions length, width and thickness and volume of grain were established.
- In comparing the two varieties of sorghum only the difference in the means of thousand kernel weight (TKW) and angle of repose were found to be statistically significant at 5% level for the two varieties of sorghum.
- This study will serve as a useful information tool for designers of post-harvest systems.

REFERENCES

1. Dogett, H., 1970. Sorghum, Longman Green and Company Ltd. London.
2. Jackson, D.M., W.R. Grant and Shafer, 1981. United State Sorghum Industry. USA Department of Agricultural Economics, Statistics and Cooperative Services. Agricultural Economics Report No: 457.
3. Waziri, A.N. and J.P. Mittal, 1983. Design related physical properties of selected Agricultural Product. Journal of ASAE.
4. ASAE., 1983. Standard 37th.1990-S358.2, St Joseph MI; ASAE.
5. Mohsenin, N.N., 1970. Engineering Techniques for Evaluation of Texture of Solid Food Material–A Review. J. Text. Studies.
6. Okeke, P.N. and S.M. Anyakoha, 1987. Senior secondary physics. Revised Edn.