Physical properties of some maize varieties

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***Abstract*— Some physical properties of maize varieties were determined. The aim of this study was to provide information on the physical properties of the maize varieties commonly grown in Nigeria which has been fortified with protein. Properties determined include tri-axial dimensions (length, width and thickness) sphericity, bulk density, true density, porosity, a thousand seed grain and coefficient of static friction. The data obtained were subjected to ANOVA and LSD tests. The mean values of the moisture content of maize used for the experimentation were 11.35%, 11.34% and 11.26% for ART/98/SW06-OB-W, ART/98/SW1 and Suwan-1-SR-Y respectively. Suwan-1-SR-Y variety has the largest grain sizes out of the three varieties considered for this research. The maximum value, 0.58 of coefficient of friction was obtained for Suwan-1-SR-Y on both smooth glass and plywood. The ANOVA result showed that length, thickness and effective diameter, bulk density, true density, porosity and repose were highly significant (*p* < 0.05) among the three varieties. LSD result also revealed that there were significant differences among the three varieties in their length, effective diameter and thickness except for ART/98/SW06-OB-W and ART/98/SW1.**

Keywords*— *Maize, varieties, physical properties

I. INTRODUCTION

Maize (*Zea mays L.*) or "corn" as it is known in some part of the world is a cereal crop from the grass family. The total area under maize cultivation in the world is 139 million hectares with a production of 598 million MT (mMT). USA is the world's largest producer and exporter of maize with an out put of 240 mMT from an area of 29 million hectares and among all cereals, maize occupies the fifth largest in area, fourth largest in output and third largest in yield. (1). Maize is most productive in the middle and Northern belts of Nigeria, where sunshine is adequate and rainfall is moderate (2) and of the most important cereals in Nigeria maize remains the most popularly grown and consumed in all-ecological zones of the country (3). The yellow dent maize components are starch, corn oil, protein, fiber and moisture content in the following proportion 61%, 3.8%, 8%, 11.2% and 16% respectively (4). Agricultural produce are subjected to various physical treatments involving mechanical, thermal, electrical, optical and sonic techniques and devices from the field to the consumer; therefore, it is essential to understand the physical laws governing the response of the crop so that machine, processes and handling operation can be designed for maximum efficiency and highest quality of the end product (5). Several works has been done on physical properties of maize. (6) determined sweet corn seed properties as a function of moisture content. (7) reported similar results on popcorn kernels. (8) worked on sweet corn kernel properties. Dent corn was worked on by (9). Data concerning the physical and mechanical properties of agricultural food materials are of importance to plant breeders, engineers, machine manufactures, food scientists, processors and consumers. Those properties are useful in postharvest unit operations for the design of cleaning, grading, sorting, transportation, handling, aeration, sizing, storing, size reduction, packaging and other processing equipment (10). The aim of this study was to provide information on the physical properties of the maize varieties commonly grown in Nigeria which has been fortified with protein.

II. MATERIALS AND METHODS

A. *Varieties of Maize*

Three varieties of maize- ART/98/SW06-OB-W, ART/98/SW1-*Oloyin* and Suwan-1-SR-Y were obtained from the Institute of Agricultural Research and Training, Moor Plantation, Ibadan in Nigeria. The varieties were fortified with protein.

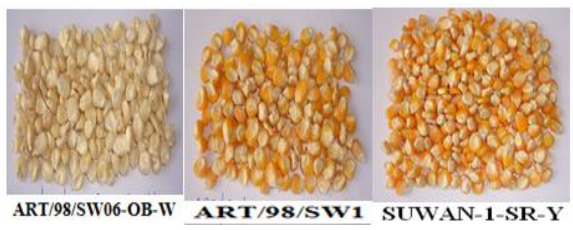

Plate 1: Maize grains for the experiment

B. *Moisture content*

The moisture content of the maize sample was first determined using microprocessor grain moisture meter.

C. *Size and Sphericity*

100 seeds were randomly selected for size determinations. A digital raider micrometer screw gauge (0.01 mm) was used to determine the tri-axial dimensions; length, width and thickness of the grain.

However, the values obtained were used to calculate the geometric mean diameter, sphericity according to (11); (12) from equations 1 and 2 and surface area (13); (5).

$$D_g = (abc)^{1/3} \quad (1)$$

$$\varphi = \frac{(abc)^{1/3}}{a} \quad (2)$$

Where, *a* is the length, the dimension along the longest axis in mm, *b* is the width, the dimension along the longest perpendicular to *a* in mm and *c* is the thickness, the dimension along the longest axis perpendicular to both *a* and *c.*

D. Bulk Density, True Density and Porosity

A known self-weight container measuring 200 ml by volume was filled with the grains to the brim. The net weight of the grains was determined. The weight of the grain was used to calculate the bulk density. Bulk density was calculated using the relationship between mass and volume given by (14), equation 3.

$$\rho_b = \frac{weight\ of\ sample\ (g)}{Volume\ occupied\ by\ sample\ (cm^3)} \quad (3)$$

True density was determined by water displacement method (15), equation 4. This was replicated ten times. Maize absorbs water, thus grains were carefully wrap in a thin, light, sensitive flexible nylon paper and carefully immersed to disallow air spaces (16).

$$\rho_t = \frac{weight\ of\ sample\ (g)}{Volume\ of\ water\ displaced\ (cm^3)} \quad (4)$$

Porosity was also calculated from the relationship between true and bulk densities from the equation 5, according to (17).

$$\epsilon = \frac{(\rho_t - \rho_b)}{\rho_t} \text{ X } 100 \quad (5)$$

E. A thousand Seed Grains

A thousand (1000) seed grains were randomly selected from the sample and weighed using a digital weighing balance having sensitivity of 0.01 g

F. Coefficient of Static Friction

Coefficient of static friction of the seed on different surfaces- smooth glass (SG), rough glass (RG), galvanize steel (GS), stainless steel (SS) and plywood (PW) were determined using an inclined plane apparatus (tilting table). The coefficient of friction (tan *μ*) was calculated from the angle obtained (18); and (19). The dynamic angle of repose was also determined by (20) method.

G. Data Analysis

The descriptive statistics of the mean and standard deviations of the parameters were estimated with Analysis of variance (ANOVA) and Least Significant Difference (LSD) using Statistical Packages for Social Sciences (SPSS 16).

III. Results and Discussion

The descriptive statistics results for some physical properties of maze varieties were presented in Table 1. The mean values of the moisture content of maize used for the experimentation were 11.35%, 11.34% and 11.26% for ART/98/SW06-OB-W, ART/98/SW1 and Suwan-1-SR-Y respectively.

A. Dimensional Properties

The maximum value obtained for dimensional properties including length, width, thickness and effective diameter were 12.65 mm (Suwan-1-SR-Y), 11.05 mm (Suwan-1-SR-Y), 7.19 mm (ART/98/SW06-OB-W) and 9.23 mm (Suwan-1-SR-Y) respectively (Table 1). However, the minimum values obtained for the length, width, thickness and effective diameter were 11.11 mm (ART/98/SW1), 9.54 mm (ART/98/SW06-OB-W), 6.89 mm (Suwan-1-SR-Y) and 8.01 mm (ART/98/SW1) respectively. This implies that Suwan-1-SR-Y variety has the largest grain sizes out of the three varieties considered for this research. 21Pabis (1967) defined the use of an effective diameter. The ANOVA results presented in Tables 2 showed that length, thickness and effective diameter were highly significant ($p < 0.05$). The LSD (Table 3) result also revealed that there were significant differences among the three varieties in their length, effective diameter and thickness (except for ART/98/SW06-OB-W and ART/98/SW1). There were no significant differences among the varieties in their width. The one thousand (1000) seeds mass (Table 1) increased across the varieties. The values obtained are 0.1814 kg, 0.1901 kg and 0.3089 kg for ART/98/SW06-OB-W, ART/98/SW1 and Suwan-1-SR-Y respectively. (22) and (23) reported a similar trend for faba bean and barbunia bean respectively. The ANOVA and LSD results, Table 2 and 3 show significant differences among the varieties ($p < 0.05$).

B. Bulk Density, True Density and Porosity

The values obtained for bulk density and true density were shown in Table 1. The mean values for the bulk density were 752.3 kg/mm^3, 764.3 kg/mm^3 and 749.7 kg/mm^3 for ART/98/SW06-OB-W, ART/98/SW1 and Suwan-1-SR-Y respectively. Whereas 1220.6 kg/mm^3, 1227.3 kg/mm^3 and 1274 kg/mm^3 are the true density for ART/98/SW06-OB-W, ART/98/SW1 and Suwan-1-SR-Y respectively. At 5.15 % moisture content dry basis for maize, (23) obtained 679.11 kg/m^3 and 990 kg/m^3 for bulk and true densities respectively (24) reported a bulk density of 789 kg/m^3 and true density of 1395 kg/m3 for wheat and (25) reported 598 kg/m^3 and 1136 kg/m3 for bulk and true densities respectively for rice.

Table 1: Descriptive statistics of the physical properties for maize varieties

Properties	Variety	N	Mean	Minimum	Maximum
Length (mm)	ART/98/SW06-OB-W	100	9.55 (1.23)	5.57	11.92
	ART/98/SW1	100	8.57 (1.57)	2.60	11.11
	Suwan-1-SR-Y	100	9.99 (1.18)	7.11	12.65
Width (mm)	ART/98/SW06-OB-W	100	7.87 (0.76)	6.31	9.54
	ART/98/SW1	100	7.91 (1.44)	2.14	10.82
	Suwan-1-SR-Y	100	7.97 (1.09)	5.04	11.05
Thickness (mm)	ART/98/SW06-OB-W	100	4.34 (0.96)	2.94	7.19
	ART/98/SW1	100	4.26 (0.89)	2.14	6.98
	Suwan-1-SR-Y	100	4.60 (0.85)	3.20	6.89
Effective Diameter (mm)	ART/98/SW06-OB-W	100	6.84 (0.50)	5.72	8.20
	ART/98/SW1	100	6.56 (0.85)	2.62	8.01
	Suwan-1-SR-Y	100	7.13 (0.56)	5.91	9.23
Sphericity	ART/98/SW06-OB-W	100	0.73 (0.11)	0.56	1.20
	ART/98/SW1	100	0.78 (0.13)	0.58	1.39
	Suwan-1-SR-Y	100	0.72 (0.07)	0.61	0.90
Surface Area (mm^2)	ART/98/SW06-OB-W	100	147.06 (21.49)	102.80	211.00
	ART/98/SW1	100	137.30 (29.66)	21.50	201.40
	Suwan-1-SR-Y	100	160.69 (25.89)	109.70	267.50
Moisture Content (%)	ART/98/SW06-OB-W	10	11.35 (0.34)	11.10	12.20
	ART/98/SW1	10	11.34 (0.67)	10.30	12.50
	Suwan-1-SR-Y	10	11.26 (0.61)	10.80	12.90
Mass of 1000 grains (kg)	ART/98/SW06-OB-W	10	0.1814 (0.00)	0.18	0.18
	ART/98/SW1	10	0.1901 (0.00)	0.19	0.19
	Suwan-1-SR-Y	10	0.3089 (0.01)	0.30	0.32
Bulk Density (kg/mm^3)	ART/98/SW06-OB-W	10	752.30 (3.60)	746.80	757.60
	ART/98/SW1	10	764.30 (9.60)	755.35	777.70
	Suwan-1-SR-Y	10	749.70 (6.18)	739.25	757.20
True Density (kg/mm^3)	ART/98/SW06-OB-W	10	1220.6 (37.96)	1176.50	1250.00
	ART/98/SW1	10	1227.3 (19.57)	1212.10	1250.00
	Suwan-1-SR-Y	10	1274.0 (20.66)	1250.00	1290.00
Porosity	ART/98/SW06-OB-W	10	38.31 (1.96)	36.03	40.26
	ART/98/SW1	10	37.71 (1.28)	35.84	39.51
	Suwan-1-SR-Y	10	41.14 (0.92)	39.76	42.69
Repose	ART/98/SW06-OB-W	10	43.76 (1.67)	41.55	46.66
	ART/98/SW1	10	43.07 (1.06)	41.33	44.66
	Suwan-1-SR-Y	10	42.04 (1.65)	38.66	43.81

Std. Deviation in parentheses

The ANOVA result, Table 2 show significant differences in the bulk and true densities among the varieties (p < 0.05). The LSD result, Table 3 for bulk density showed show that there are high significant differences between ART/98/SW06-OB-W and ART/98/SW1; and ART/98/SW1 and Suwan-1-SR-Y, however there no significant difference between ART/98/SW06-OB-W and Suwan-1-SR-Y. Also, True density was significant between ART/98/SW06-OB-W and Suwan-1-SR-Y; and ART/98/SW1 and Suwan-1-SR-Y. The porosity varied among the varieties (Table 1). The mean values were 38.31, 37.71 and 41.14 for ART/98/SW06-OB-W, ART/98/SW1 and Suwan-1-SR-Y respectively. The ANOVA Table 2 shows that porosity was highly significant (p<0.05) among the varieties. Similarly, the LSD results showed significant differences between ART/98/SW06-OB-W and Suwan-1-SR-Y; ART/98/SW1 and Suwan-1-SR-Y but, no significant different between ART/98/SW06-OB-W and ART/98/SW1.

C. Repose

Results of average value for repose were 43.76, 43.07 and 42.04 for ART/98/SW06-OB-W, ART/98/SW1 and Suwan-1-SR-Y respectively. Repose was significant (p<0.05) for the varieties and the LSD results showed significant differences between ART/98/SW06-OB-W and Suwan-1-SR-Y; but, no significant different between ART/98/SW06-OB-W and ART/98/SW1; ART/98/SW1 and Suwan-1-SR-Y.

D. Coefficient of Friction

The result of the descriptive statistics for coefficient of friction was presented in Table 4. Also, Table 5 and 6 presented the ANOVA and LSD respectively. The mean value 0.33 was obtained for ART/98/SW06-OB-W on smooth glass, galvanize steel and plywood. The maximum value, 0.58 of coefficient of friction was obtained for Suwan-1-SR-Y on both smooth glass and plywood.

Table 2: ANOVA result for the physical properties and the effect of varieties

Properties		Sum of Squares	Df	Mean Square	F	Sig.
Length	Between Groups	106.00	2	53.00	29.60	0.000
	Within Groups	531.91	297	1.79		
	Total	637.91	299			
Width	Between Groups	0.51	2	0.26	0.20	0.818
	Within Groups	378.19	297	1.27		
	Total	378.70	299			
Thickness	Between Groups	6.55	2	3.28	4.04	0.019
	Within Groups	241.04	297	0.81		
	Total	247.59	299			
Effective Diameter	Between Groups	16.24	2	8.12	19.06	0.000
	Within Groups	126.56	297	0.43		
	Total	142.81	299			
Sphericity	Between Groups	0.25	2	0.13	11.72	0.000
	Within Groups	3.18	297	0.01		
	Total	3.43	299			
Surface Area	Between Groups	27612.80	2	13806.40	20.59	0.000
	Within Groups	199109.87	297	670.40		
	Total	226722.67	299			
Moisture Content	Between Groups	0.05	2	0.02	0.08	0.924
	Within Groups	8.33	27	0.31		
	Total	8.38	29			
Mass of 1000 grains	Between Groups	0.10	2	0.05	1946.00	0.000
	Within Groups	0.00	27	0.00		
	Total	0.10	29			
Bulk Density	Between Groups	1213.38	2	606.69	12.71	0.000
	Within Groups	1289.06	27	47.74		
	Total	2502.44	29			
True Density	Between Groups	16935.14	2	8467.57	11.29	0.000
	Within Groups	20252.78	27	750.10		
	Total	37187.93	29			
Porosity	Between Groups	67.18	2	33.59	15.96	0.000
	Within Groups	56.82	27	2.10		
	Total	124.00	29			
Repose	Between Groups	15.09	2	7.55	3.41	0.048
	Within Groups	59.82	27	2.22		
	Total	74.92	29			

There were significant differences in coefficient of friction on all the surfaces. The LSD results also showed that there were significant differences between coefficients of friction for ART/98/SW06-OB-W and Suwan-1-SR-Y, or between ART/98/SW1 and Suwan-1-SR-Y on all the surfaces. However, no significant different was observed between the coefficient of friction for ART/98/SW06-OB-W and ART/98/SW1 on smooth glass, galvanize steel, stainless steel and plywood. Previous studies showed a similar trend (17).

IV. Conclusions

The physical properties observed revealed that Suwan-1-SR-Y has the largest grain sizes out of the three varieties considered for this research. The mean values for the bulk density are 752.3 kg/mm^3, 764.3 kg/mm^3 and 749.7 kg/mm^3 for ART/98/SW06-OB-W, ART/98/SW1 and Suwan-1-SR-Y respectively, whereas 1220.6 kg/mm^3, 1227.3 kg/mm^3 and 1274 kg/mm^3 are the true density for ART/98/SW06-OB-W, ART/98/SW1 and Suwan-1-SR-Y respectively. Porosity varied among the varieties. Average values for repose were 43.76, 43.07 and 42.04 for ART/98/SW06-OB-W, ART/98/SW1 and Suwan-1-SR-Y respectively. The maximum value, 0.58 of coefficient of friction was obtained for Suwan-1-SR-Y on both smooth glass and plywood.

Table 3: Properties and the effect of varieties

Properties	(I) VarietyD	(J) VarietyD	Mean Difference (I-J)	Sig.	Remark
Length	ART/98/SW06-OB-W	ART/98/SW1	0.9828*	0.000	S
	ART/98/SW06-OB-W	Suwan-1-SR-Y	-0.4390*	0.021	S
	ART/98/SW1	Suwan-1-SR-Y	-1.4218*	0.000	S
Width	ART/98/SW06-OB-W	ART/98/SW1	-0.0412	0.796	NS
	ART/98/SW06-OB-W	Suwan-1-SR-Y	-0.1007	0.529	NS
	ART/98/SW1	Suwan-1-SR-Y	-0.0595	0.710	NS
Thickness	ART/98/SW06-OB-W	ART/98/SW1	0.0851	0.505	NS
	ART/98/SW06-OB-W	Suwan-1-SR-Y	-0.2622*	0.040	S
	ART/98/SW1	Suwan-1-SR-Y	-0.3473*	0.007	S
Effective Diameter	ART/98/SW06-OB-W	ART/98/SW1	0.2780*	0.003	S
	ART/98/SW06-OB-W	Suwan-1-SR-Y	-0.2920*	0.002	S
	ART/98/SW1	Suwan-1-SR-Y	-0.5699*	0.000	S
Spericity	ART/98/SW06-OB-W	ART/98/SW1	-0.0568*	0.000	S
	ART/98/SW06-OB-W	Suwan-1-SR-Y	0.0082	0.575	NS
	ART/98/SW1	Suwan-1-SR-Y	0.0650*	0.000	S
Surface Area	ART/98/SW06-OB-W	ART/98/SW1	9.7650*	0.008	S
	ART/98/SW06-OB-W	Suwan-1-SR-Y	-13.6290*	0.000	S
	ART/98/SW1	Suwan-1-SR-Y	-23.3940*	0.000	S
Moisture Content	ART/98/SW06-OB-W	ART/98/SW1	0.0100	0.968	NS
	ART/98/SW06-OB-W	Suwan-1-SR-Y	0.0900	0.720	NS
	ART/98/SW1	Suwan-1-SR-Y	0.0800	0.750	NS
Mass of 1000 grains	ART/98/SW06-OB-W	ART/98/SW1	-0.0087*	0.001	S
	ART/98/SW06-OB-W	Suwan-1-SR-Y	-0.1275*	0.000	S
	ART/98/SW1	Suwan-1-SR-Y	-0.1188*	0.000	S
Bulk Density	ART/98/SW06-OB-W	ART/98/SW1	-12.0050*	0.001	S
	ART/98/SW06-OB-W	Suwan-1-SR-Y	2.5950	0.408	NS
	ART/98/SW1	Suwan-1-SR-Y	14.6000*	0.000	S
True Density	ART/98/SW06-OB-W	ART/98/SW1	-6.6600	0.591	NS
	ART/98/SW06-OB-W	Suwan-1-SR-Y	-53.4000*	0.000	S
	ART/98/SW1	Suwan-1-SR-Y	-46.7400*	0.001	S
Porosity	ART/98/SW06-OB-W	ART/98/SW1	0.6040	0.360	NS
	ART/98/SW06-OB-W	Suwan-1-SR-Y	-2.8290*	0.000	S
	ART/98/SW1	Suwan-1-SR-Y	-3.4330*	0.000	S
Repose	ART/98/SW06-OB-W	ART/98/SW1	0.6990	0.303	NS
	ART/98/SW06-OB-W	Suwan-1-SR-Y	1.7270*	0.015	S
	ART/98/SW1	Suwan-1-SR-Y	1.0280	0.134	NS

Table 4: Descriptive statistics of the coefficients of friction for maize varieties

Surfaces	Variety	N	Mean	Minimum	Maximum
Smooth Glass	ART/98/SW06-OB-W	10	0.33 (0.04)	0.26	0.40
	ART/98/SW1	10	0.31(0.03)	0.27	0.34
	Suwan-1-SR-Y	10	0.46(0.06)	0.38	0.58
Rough Glass	ART/98/SW06-OB-W	10	0.24(0.03)	0.21	0.29
	ART/98/SW1	10	0.27(0.02)	0.23	0.31
	Suwan-1-SR-Y	10	0.33(0.03)	0.31	0.38
Galvanize Steel	ART/98/SW06-OB-W	10	0.33(0.03)	0.29	0.38
	ART/98/SW1	10	0.34(0.02)	0.31	0.36
	Suwan-1-SR-Y	10	0.51(0.03)	0.47	0.55
Stainless Steel	ART/98/SW06-OB-W	10	0.29(0.03)	0.25	0.34
	ART/98/SW1	10	0.27(0.02)	0.23	0.31
	Suwan-1-SR-Y	10	0.43(0.03)	0.38	0.47
Plywood	ART/98/SW06-OB-W	10	0.33(0.04)	0.29	0.40
	ART/98/SW1	10	0.33(0.04)	0.29	0.40
	Suwan-1-SR-Y	10	0.52(0.03)	0.49	0.58

Table 5: ANOVA result for coefficient of friction and the effect of varieties

Surfaces		Sum of Squares	df	Mean Square	F	Sig.
Smooth Glass	Between Groups	0.14	2	0.069	37.76	0.000
	Within Groups	0.05	27	0.002		
	Total	0.19	29			
Rough Glass	Between Groups	0.04	2	0.020	28.93	0.000
	Within Groups	0.02	27	0.001		
	Total	0.06	29			
Galvanize Steel	Between Groups	0.20	2	0.101	157.60	0.000
	Within Groups	0.02	27	0.001		
	Total	0.22	29			
Stainless Steel	Between Groups	0.14	2	0.071	102.84	0.000
	Within Groups	0.02	27	0.001		
	Total	0.16	29			
Plywood	Between Groups	0.23	2	0.116	86.04	0.000
	Within Groups	0.04	27	0.001		
	Total	0.27	29			

Table 6: Coefficient of friction and the effect of varieties

Surfaces	(I) Variety	(J) Variety	Mean Difference (I-J)	Sig.	Remark
Smooth Glass	ART/98/SW06-OB-W	ART/98/SW1	0.0207	0.290	NS
	ART/98/SW06-OB-W	Suwan-1-SR-Y	-0.1328*	0.000	S
	ART/98/SW1	Suwan-1-SR-Y	-0.1534*	0.000	S
Rough Glass	ART/98/SW06-OB-W	ART/98/SW1	-0.0353*	0.006	S
	ART/98/SW06-OB-W	Suwan-1-SR-Y	-0.0887*	0.000	S
	ART/98/SW1	Suwan-1-SR-Y	-0.0534*	0.000	S
Galvanize Steel	ART/98/SW06-OB-W	ART/98/SW1	-0.0174	0.138	NS
	ART/98/SW06-OB-W	Suwan-1-SR-Y	-0.1825*	0.000	S
	ART/98/SW1	Suwan-1-SR-Y	-0.1651*	0.000	S
Stainless Steel	ART/98/SW06-OB-W	ART/98/SW1	0.0189	0.120	NS
	ART/98/SW06-OB-W	Suwan-1-SR-Y	-0.1358*	0.000	S
	ART/98/SW1	Suwan-1-SR-Y	-0.1547*	0.000	S
Plywood	ART/98/SW06-OB-W	ART/98/SW1	0.0057	0.732	NS
	ART/98/SW06-OB-W	Suwan-1-SR-Y	-0.1833*	0.000	S
	ART/98/SW1	Suwan-1-SR-Y	-0.1890*	0.000	S

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