Determination of some physical and mechanical properties of soybean and maize in relation to planter design

Babatunde Oluwamayokun Soyoye*, Olugboyega Cornelius Ademosun,
Leo Ayodeji S. Agbetoye

(*Agricultural and Environmental Engineering Department, Federal University of Technology, P. M. B. 704 Akure Ondo State Nigeria*)

Abstract: Maize and soybeans are agricultural materials that serve as food to both man and livestock and also serve as by-product used in manufacturing industries. The knowledge of some physical and mechanical properties of these seeds is an important tool for designing agricultural machines and equipment for planting, harvesting, processing, packaging and storage. Some of the properties determined include size, geometric mean diameter, surface area, bulk volume, bulk density, true density, porosity, sphericity, angle of repose, coefficient of friction, rupture force and rupture energy. The mean values measured and recorded for the length, width, thickness, geometric mean diameter, surface area, bulk volume, bulk density, true density, porosity and sphericity of maize were 1.043 cm, 0.883 cm, 0.405 cm, 0.716 cm, 1.621cm^2, 29.200 mL, 1.169 g mL^{-1}, 1.369 g mL^{-1}, 14.599% and 0.693 while 0.737 cm, 0.627 cm, 0.468 cm, 0.600 cm, 1.135 cm^2, 16.6 ml, 1.071 g mL^{-1}, 1.0865 g mL^{-1}, 1.397% and 0.814 respectively were for soybean. The mean angle of repose and coefficient of friction over stainless steel, galvanized steel, mild steel and plywood of 38.6° and 0.805, 36.7° and 0.746, 38.28° and 0.794 and 34.75° and 0.702 respectively were recorded for maize and 53.91° and 1.407, 51.67° and 1.293, 48.33° and 1.1425 and 47.67° and 1.110 respectively were recorded for soybean. The rupture forces on the major, intermediate and minor axis for maize were 175.296 N, 156.550 N and 328.488 N while 52.562 N, 40.504 N and 182.81 N were recorded for soybean. The properties determined relevant to the design of the components of a planter such as the hopper, the seed plate and the delivery tube. It also helps in the selection of materials to use and to know the amount of force a material can withstand before rupture occurs.

Keywords: maize, soybean, physical properties, mechanical properties, planting equipment

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1 Introduction

Planting is an art of placing seeds in the soil to have good germination in the field. Planting began with the use of hands and later the use of stones, hand tools and mechanized form of planting. Manual methods of planting resulted in low seed placement, low spacing efficiency, and health issues for the farmer considering the size of the farm land (Kumar et al., 2015; Soyoye et al., 2016). Seed planting machine is a device which helps in the sowing of seeds in a desired position, thereby assisting the farmers in saving time and money. The basic objective of sowing operation is to bear the seed, put the seed in rows at desired depth and seed to seed spacing, cover the seeds with soil and provide proper compaction over the seed (Odumal et al., 2014; Soyoye et al., 2016). However, in fabricating the form of this mechanized planting equipment, some properties of the seed which is to be planted must be determined in order to accurately specify the design considerations (Jouki and Khazaei, 2012). The physical properties of seed such as size, shape, axial dimensions, roundness and sphericity helps to determine the maximum size of the cup in the seed plate, the weight help in the material selection for the frame of the planter, the bulk density and moisture content helps to know the interaction between the seed and the material used for the hopper of the planter at maximum heat level (Jayan and Kumar, 2004). The mechanical properties

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*** Corresponding author: Babatunde Oluwamayokun Soyoye,** Engineer. Federal University of Technology Akure, Ondo State, Nigeria; Email: soyoye2002@yahoo.com. Tel: +234(0)8036577499.

such as the angle of repose helps to ensure free flow of seed in the hopper (Jayan and Kumar, 2004), the terminal velocity helps to determine the flow of the seed in air between the point of discharge and impact on the soil. The shear stress and impact stress help to determine the amount of pressure the seed plate should apply on the seed. These properties help in specifying the design considerations of planting equipment because it will be a waste of time, resources, effort and money if after fabricating, and the machine fails to deliver up to expectation.

1.1 Objectives of the project.

The objectives of this project are to:

i. Determine some physical and mechanical properties of maize and soybeans;

ii. Relate these properties to the design and fabrication of planting equipment.

1.2 Justification of the research

In order to reduce drudgery and to increase yield, the old method of planting must reduce to its barest minimum and the new methods which is the use of mechanically operated planter must be embraced. However, this new method cannot be designed and fabricated without first determining the properties of the seeds or grains that are to be planted. Therefore, it is important to carry out experiments on the physical and the mechanical properties of the required seeds before the design and fabrication of the planter.

2 Main body

2.1 Maize

Maize constitutes a stable food in many regions of the world. It is a basic stable for large population groups particularly in developing countries. Grain crops produced in Nigeria are maize, rice, cowpea, soybean, sorghum, millet and groundnut (Adekunle and Nabinta, 2000). The greater proportion of this grain is maize because of its ability to thrive under different ecological conditions. Adekunle and Nabinta (2000) also reported sustained increase in their output. Maize is the most important staple food in Nigeria (Nweke, 2006). Maize (*Zea mays L.*) is a member of the grass family (gramineae). It originated from South and Central America. It was introduced to West Africa by the Portuguese in the 10th century. Maize is one of the most important grains in Nigeria, not only on the basis of the number of farmers that engaged in its cultivation, but also in its economic value. Maize is a major important cereal being cultivated in the rainforest and the derived savannah zones of Nigeria. Maize has been in the diet of Nigerians for centuries. It started as a subsistence crop and has gradually become a more important crop. Maize has now risen to a commercial crop on which many agro-based industries depend for raw materials (Iken and Amusa, 2004). Maize is becoming the miracle seed for Nigeria’s agricultural and economic development. It has established itself as a very significant component of the farming system and determines the cropping pattern of the predominantly peasant farmers, especially in the Northern States (Ahmed, 1996). Maize has been of great importance in providing food for man, feed for livestock and raw materials for some agro-based industries.

2.2 Soybean

Soybean has been described in various ways. Some call it the “miracle bean” or the “golden bean” because it is a cheap, protein-rich grain. It contains 40 percent high quality protein, 20 percent edible vegetable oil, and a good balance of amino acids. It has therefore, tremendous potential to improve the nutritional status and welfare of resource-poor people particularly in a developing country like Nigeria. Soybean can also contribute to enhance sustainability of intensified cropping systems by improving soil fertility through nitrogen fixation, permitting a longer duration of ground cover in the cropping sequence, and providing useful crop residues for feeding livestock. However, soybean is a relatively new crop in Africa (Dugje et al., 2009). A commonly held view however is that soybean is of little or no importance in sub-Saharan Africa because it has not attained the status of one of the popular staple foods.

2.3 Grain properties

The knowledge of grain structure and composition is desirable for selecting the specific operation to be performed for processing into various products since cereal grains have a different structure in composition. Information on physical and aerodynamic properties of agricultural products is needed in design and adjustments of machines used during harvesting, separating, cleaning, handling and storing of agricultural materials and convert them into food, feed and fodder. The properties which are useful during design must be known and these properties must be determined under laboratory conditions (Mohammad, 2010). The mechanical properties such as hardness, compressive strength, impact and shear strength and the rheological properties affect the various operations of agricultural processing. Data on these properties are useful for application in designing equipment for milling, handling, storage, cracking, transportation, food processing etc. The development of satisfactory harvesting and processing method are greatly influenced by the mechanical properties of the product. Mechanical properties of the agricultural products are most conveniently measured with the force-deformation curve. For this curve, a number of mechanical properties can be determined such as maximum force and energy to rupture point, stiffness and deformation.

3 Materials and methods

3.1 Materials used

The following materials were used when conducting experiments in order to determine the physical and mechanical properties of soybean and maize. A pair of vernier caliper was used to measure the axial dimensions of the material including the length, breadth and thickness. The model used is the Gilson Vernier Caliper with calibration of 20 cm with error of 0.05 mm. Two measuring cylinders (Spyrex EX 20^{o}C with calibration of 250±2 mL and a measuring cylinder with 100 mL; 20^{o}C) were used to determine the bulk volume of the materials. The beaker (A BOMEX 600 mL beaker) served as a container to contain toluene (C_7H_8) when conducting the experiment. The weighing can was used to hold the materials in the oven when determinig the moisture content of the material. It was also used when weighing in bulk. The weighing balance was used to measure the weight of materials in gramms. The weighing balance used was Electronic Precision Balance with model JA303P, number 1505601, Max weighing 310 g and readability 0.001 g. The sliding box was the equipment used to determine the angle of repose and the coefficient of friction. It was made of ply-wood and a protractor was used for calculating the angle. The dimension is 0.3 m× 0.6 m. The Testometric (M500 – 100AT) Universal Testing Machine (UTM) was used for compression loading for which rupture force and rupture energy were obtained. The e physical and mechanical properties of soybeans and maize were determined. 100 samples of each kind of grain were used to determine the physical and the mechanical properties (Figures 1 and 2).

Figure 1 Maize grains

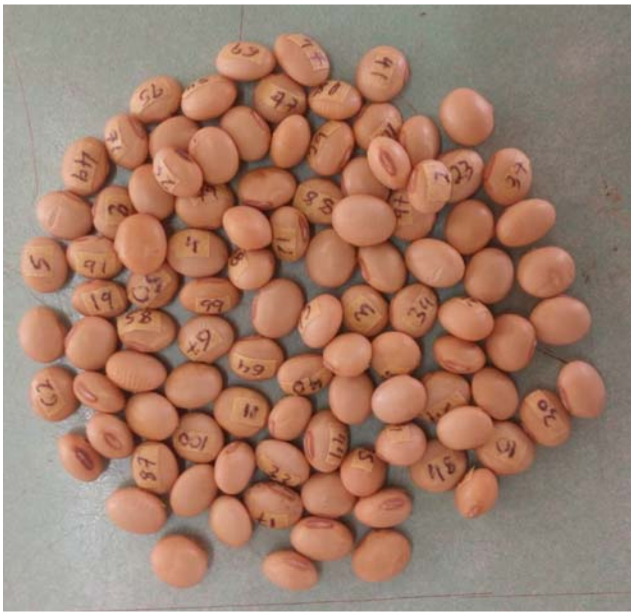

Figure 2 Soybean grains

3.2 Methods

The methods selected for this research work are those whose simplicity and practicability enjoy wide acceptability and above all exhibit high degrees of accuracy.

3.2.1 Size

A pair of digital vernier calipers was used to determine the dimensions such as length, width and thickness.

3.2.2 Geometric mean diameter

As described by Tarighi et al. (2011), the geometric mean diameter was determined using the Equation (1):

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

where, D_g is the geometric mean diameter, cm; L is the length, cm; W is the width, cm; T is the thickness, cm.

3.3.3 Surface area

The surface area was determined using the Equation (2):

$$S = \pi D_g^2 \quad (2)$$

where, S is the surface area, cm^2; D_g is geometric mean diameter, cm.

3.2.4 Roundness

The roundness of the materials was determined using Equation (3) (Jouki and Khazaei, 2012);

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

where, A_p is the largest projected area of the object in its natural rest position, cm^2; A_c is the area of the smallest circumscribing circle, cm^2.

3.2.5 Sphericity

It was determined using Equation (4) as described by Jouki and Khazaei. (2012)

$$\Phi = \frac{(LWT)^{1/3}}{L} \quad (4)$$

where, Φ is the sphericity; L is the length, cm; W is the width cm; T is the thickness, cm.

3.2.6 Bulk mass

The bulk mass was calculated using the weighing balance and the weighing can. The mass was measured in hundreds and the procedure was repeated 10 times so as to get the average.

3.2.7 Bulk volume

The bulk volume was determined using the displacement method. Toluene C_7H_8 was poured into the measuring cylinder to a certain level which was recorded. The bulk mass was then poured into the cylinder with toluene C_7H_8 in it. The volume of toluene in the cylinder rose. The new volume was recorded and subtracted from the initial volume. The volume obtained from the subtraction is the bulk volume for the bulk mass. The procedure was repeated 10 times.

3.2.8 Bulk density

The bulk density was determined mathematically by dividing the bulk mass by the bulk volume. The procedure was repeated 10 times.

$$Bulk\ density = \frac{Bulk\ mass}{Bulk\ volume} \quad (5)$$

3.2.9 True density

The true density was determined by finding the individual density of 10 random samples from the bulk of 100. The mass and the volume of the 10 samples were determined using the displacement method as done in the determination of the bulk density. The mass was divided by the volume to get the density for the 10 samples. The density was then divided by 10 so as to get the unity density. The procedure was repeated three times for the bulk 100 to get the average and the overall procedure was repeated 10 times.

3.2.10 Porosity

The porosity was determined using Equation (6) as described by Mohammad (2010).

$$Porosity = 100 \times \left(1 - \frac{bulk\ density}{true\ density}\right) \quad (6)$$

3.2.11 Angle of repose

The angle of repose was determined using the sliding box provided in the department. The dimension of the sliding box is 0.3×0.6 m. The seed were placed randomly in the box and allowed to lie in their natural resting position. The angle was increased gradually till when the seed slides or rolls away. The angle at which the seed slide is recorded. The procedure was repeated for 100 samples and across different surface which are; mild steel, stainless steel and galvanized steel, all which was used in the determination of the coefficient of friction.

3.2.12 Coefficient of friction

The coefficient of friction over four surfaces (plywood, mild steel, stainless steel and galvanized steel) was determined using Equation (7) described by Tavakoli et al. (2009).

$$\mu = \tan \alpha \quad (7)$$

where, μ is the coefficient of friction and α is the angle of tilt, °.

3.2.13 Compression test

The compression test was carried out at National

Centre for Agricultural Mechanization kilometer 20 Ilorin-Lokoja Highway, Idofian, P. M. B. 1525, Ilorin, Kwara State. The machine used was the Testometric M500 – 100AT Universal Testing Machine (UTM). The test was done on three axes which are the major axis, the minor axis and the intermediate axis. The dimension of each axis was determined before starting the test. The material was placed between a fixed jaw and a 5 kN load cell and the loading rate of 5 mm min^{-1} was applied. There is a screen that is used to visualize the whole process. After all the necessary procedures, compression began. Compression stopped automatically when rupture occurred, this is known either by the clicking sound made by the machine or by the deflection in the graph shown on the screen. The procedure was repeated 5 times for each axis (Figures 3 and 4).

Figure 3 Testometric (M500 – 100AT) UTM

Figure 4 UTM with seed placement

3.3 Rupture energy

It was determined using the Equation (8) proposed by Tavakoli et al. (2009)

$$E = \frac{F_r D_r}{2} \tag{8}$$

where, E is the rupture energy, J; F_r is the rupture force, N; D_r is the deflection at rupture point, mm.

4 Results and discussion

4.1 Physical properties of maize and soybean

The moisture content of the materials used for the experiments (maize and soybean) was measured and recorded on dry basis. The moisture content was found out to be 13.57% and 11.59% for soybean and maize respectively. Tables 1 and 2 showed the results of the experiment tests carried out. They showed the range, the mean and the standard deviation of each property.

Table 1 Values of the physical properties of maize

Property	Number of samples	Maximum	Minimum	Average	Standard Deviation
Length, cm	100	1.355	0.525	1.043	0.122
Width, cm	100	1.205	0.525	0.883	0.097
Thickness, cm	100	0.800	0.275	0.405	0.075
Geometric mean diameter, cm	100	0.913	0.502	0.716	0.061
Surface area, cm^2	100	2.619	0.793	1.621	0.275
Roundness	100	4.804	1.141	2.649	0.546
Sphericity	100	0.957	0.502	0.693	0.071
Bulk mass, g	10	37.152	31.787	34.122	2.119
Bulk volume, mL	10	32.000	28.000	29.200	1.687
Bulk density, g mL^{-1}	10	1.203	1.135	1.169	0.026
True density, g mL^{-1}	10	1.411	1.269	1.369	0.041
Porosity, %	10	19.543	9.003	14.599	2.989

Table 2 Values of the physical properties of soybeans

Property	Number of Samples	Maximum	Minimum	Average	Standard Deviation
Length, cm	100	0.900	0.640	0.737	0.046
Width, cm	100	0.755	0.250	0.627	0.056
Thickness, cm	100	0.570	0.390	0.468	0.039
Geometric mean diameter, cm	100	0.729	0.433	0.600	0.041
Surface area, cm^2	100	1.669	0.590	1.135	0.151
Roundness	100	1.825	1.391	1.579	0.089
Sphericity	100	0.869	0.619	0.814	0.031
Bulk mass, g	10	19.013	16.012	17.732	0.923
Bulk volume, mL	10	18.000	14.000	16.600	1.350
Bulk density, g mL^{-1}	10	1.144	1.006	1.071	0.050
True density, g mL^{-1}	10	1.162	1.019	1.087	0.053
Porosity, %	10	1.715	0.948	1.397	0.270

The sizes of the materials were determined based on the length, width and thickness. For maize, the length, width and thickness ranges from 0.525 to 1.355 cm, 0.525 to 1.205 cm, 0.275 and 0.800 cm respectively with the mean length, width and thickness determined to be 1.043, 0.883, 0.405 cm respectively and the standard deviation are 0.122, 0.097 and 0.075 cm respectively (Table 1). Alimardani and Seifi (2010) found similar result when they determined the moisture content effect on some physical and mechanical properties of corn (*Sc 704*).

Similarly, for soybeans, the length, width and thickness ranges from 0.640 to 0.900 cm, 0.250 to 0.755 cm and 0.390 to 0.570 cm respectively and the mean length, width and thickness were determined to be 0.737, 0.627 and 0.468 cm respectively with their respective standard deviation of 0.046, 0.056 and 0.039 cm (Table 2). These results are in line with what was reported by Esref and Halil (2007) for white speckled red kidney bean grains. The geometric mean diameter for maize ranges from 0.502 to 0.913 cm with the mean diameter determined to be 0.7716 cm (Table 1). Also, the geometric mean diameter for soybean ranges from 0.433 to 0.729 cm with the mean determined to be 0.600 cm (Table 2). The surface area for soybean ranges from 0.590 to 1.669 cm^2 with mean surface area determined to be 1.135 cm^2. Similarly, the surface area for maize ranges from 0.793 to 2.619 cm^2 with the mean surface area determined to be 1.621 cm^2. The roundness and sphericity for maize range from 1.141 to 4.804 and 0.502 to 0.957 respectively with the mean of 2.649 and 0.693 respectively. Similarly the roundness and the sphericity for soybeans range from 1.391 to 1.825 and 0.693 to 0.869 respectively with the mean of 1.579 and 0.814 respectively. The geometric mean diameter is a useful tool in the design of the metering cells. The metering cells for soybean planter base on the geometric mean diameter should be 0.60±0.05 cm while the metering cells for maize planter should be 0.80±0.05 cm. It can be seen from the data that due the high sphericity of soybean (0.814) it will tend to roll better that maize (0.693), this property helps in the design of hopper.

The bulk mass and bulk volume for soybean ranges from 16.102 to 19.013 g and 14.00 to 18.00 mL respectively with the mean value for the bulk mass and bulk density determined to be 17.732 g and 16.6 mL respectively. Also, the bulk mass and bulk volume for maize ranges from 31.787 to 37.153 g and 28.00 to 32.00 mL respectively with the mean value for the bulk mass and bulk density determined to be 34.122 g and 29.200 mL respectively. The bulk mass and volume help to determine when designing, the distance between the tip of the delivery tube and the soil. Because of the weight of the materials, the materials can be affected by wind hence the distance between the tip of the delivery tube and the soil should not be much.

The bulk density, true density and porosity for soybean ranges from 1.006 to 1.144 g mL^{-1}, 1.019 to 1.162 g mL^{-1} and 0.948% to 1.715% respectively with the mean values determined to be 1.071 g mL^{-1}, 1.087 g mL^{-1} and 1.397% respectively. Also, the bulk density, true density and porosity for maize ranges from 1.135 to 1.203 g mL^{-1}, 1.269 to 1.411 g mL^{-1} and 9.003% to 19.543% respectively with the mean values of 1.169 g mL^{-1}, 1.369 g mL^{-1} and 14.599% respectively. The bulk density and true densities of the materials (soybean and maize) are greater than 1 hence; the materials will sink in water. The porosity of the materials shows that for soybeans (1.397%), the rate of air flow will be very small hence making it difficult for it to dry easily unlike that of maize (14.599%).

The angle of repose over four surfaces for maize over four surfaces stainless steel, galvanized steel, mild steel and plywood was also determined and it ranges from 30° to 47°, 20° to 48°, 25° to 46° and 25° to 42° respectively with the mean angle repose over the four surfaces determined to be 38.6°, 36.7°, 38.28° and 34.75° respectively (Table 3). Similarly, the angle of repose for soybean was determined. The surfaces used were stainless steel, galvanized steel, mild steel and plywood. The angle of repose ranges from 40° to 65°, 43° to 63°, 30° to 59° and 40° to 57° respectively with the mean angle of repose over stainless steel, galvanized steel, mild steel and plywood determined to be 53.91°, 51.67°, 48.33° and 47.67° respectively (Table 4). The angle of repose helps when designing the hopper of the planter. The mean angle of repose for soybean is larger than that of maize and this is due to the fact that the sphericity of soybean is larger than that of maize.

Table 3 Angle of repose for maize

Surface	Number of Samples	Maximum, (°)	Minimum, (°)	Average, (°)	Standard Deviation
Stainless steel	100	47	30	38.600	4.048
Galvanized steel	100	48	20	36.700	5.270
Mild steel	100	46	25	38.280	3.704
Ply wood	100	42	25	34.750	5.087

Table 4 Angle of repose for soybean

Surface	Number of Samples	Maximum, (°)	Minimum, (°)	Average, (°)	Standard Deviation
Stainless steel	100	65	40	53.91	5.318
Galvanized steel	100	63	43	51.67	5.137
Mild steel	100	59	30	48.33	4.959
Ply wood	100	57	40	47.67	4.127

The coefficient of friction over four surfaces for maize over four surfaces stainless steel, galvanized steel, mild steel and plywood was also determined and it ranges from 0.577 to 1.072, 0.364 to 1.111, 0.466 to 1.036 and 0.466 to 0.900 respectively with the mean coefficient over the four surfaces determined to be 0.805, 0.746, 0.794 and 0.702 respectively (Table 5). Similarly, the coefficient of friction for soybean was determined. The surfaces used were stainless steel, galvanized steel, mild steel and plywood. The coefficient ranges from 0.840 to 2.145, 0.933 to 1.863, 0.5774 to 1.664 and 0.829 to 1.540 respectively with the mean coefficient over these surfaces to be 1.4069, 1.2934, 1.1425 and 1.1104 respectively (Table 6). The coefficient of friction helps when designing the hopper of the planter and also helps to determine the type of material to use when designing the seed plate. The coefficient of friction helps to know how a pack of grain or seed will flow in the hopper.

Table 5 Coefficient of friction for maize

Surface	Number of Samples	Maximum	Minimum	Average	Standard Deviation
Stainless steel	100	1.072	0.577	0.805	0.116
Galvanized steel	100	1.111	0.364	0.746	0.143
Mild steel	100	1.036	0.466	0.794	0.105
Ply wood	100	0.900	0.466	0.702	0.133

Table 6 Coefficient of friction for soybean

Surface	Number of Samples	Maximum	Minimum	Average	Standard Deviation
Stainless steel	100	2.145	0.839	1.4069	0.280
Galvanized steel	100	1.863	0.933	1.2934	0.253
Mild steel	100	1.664	0.577	1.1425	0.199
Ply wood	100	1.540	0.839	1.1104	0.161

4.2 Mechanical properties of maize and soybean

The compression test was carried out on maize and soybean three different axes which are the major, minor and intermediate axis. Five tests were carried out for each axis. The results of the tests are as shown in Tables 7 and 8. For maize, the mean rupture force for the major, minor and intermediate axis was determined to be 175.30, 328.45 and 156.550 N respectively. The mean deflection for the major, minor and the intermediate axis was determined to be 1.274, 0.344 and 0.343 mm respectively. The mean rupture energy for the major, minor and the intermediate was determined to be 0.078, 0.058 and 0.035 Nm respectively. Similarly, for soybean, the mean rupture force for the major and intermediate axis was determined to be 52.562 and 40.504 N respectively while the minor axis failed to rupture, instead, it compressed. The mean deflection for the major and the intermediate axis was determined to be 1.587 and 1.421 mm respectively. There was no deflection during the test for the minor axis this is because it failed to rupture at that axis. The mean rupture energy for the major and the intermediate was determined to be 0.042 and 0.034 Nm respectively. These confirm the report of Alimardani and Seifi (2010) that the rupture force and rupture energy for corn grain ranges from 298.11 to 198.44 N and 64.67 Nm to 130.8 Nm respectively for corn grain. Vursavus and Ozguven (2004), Altuntas and Yıldız (2005) and Olaniyan and Oje (2002) reported similar result for apricot pit, faba bean and shea nut, respectively.

The implication of these results in planter design is that the impact and rubbing forces resulting from the impact of the metering plate on the grains must not be greater than the peak force of the grains concerned. For soybean grains a plate impact force of 40±0.5 N is recommended. While an impact force of 156±0.5 N is recommended for maize grains. These forces can be achieved by introducing soft brush into the metering chamber to hold the grains in position to reduce the rubbing effect resulting from the plate to plate contact. This is of great importance because elimination of grain bruising is an essential ingredient to crop germination. In precision planting where the clearance should be kept constant, rubber material could be introduced in place of brush so as to maintain uniform clearance during planting operation.

Table 7 Results of compression tests on maize seeds

S/N		1	2	3	4	5	Min	Max	Mean	S. D
Height, mm	M_A	10.50	11.05	10.08	11.71	10.26	10.08	11.71	10.72	0.66
	M_a	6.67	5.36	5.32	5.03	4.45	4.45	6.67	5.37	0.82
	I_a	8.84	9.42	7.43	9.71	9.17	7.43	9.71	8.91	0.89
Force at Peak, N	M_A	145.89	166.09	157.96	187.46	219.08	145.89	219.08	175.30	28.79
	M_a	422.17	288.26	453.30	241.77	236.74	236.74	453.30	328.45	102.36
	I_a	190.28	166.29	68.84	178.65	178.69	68.84	190.28	156.55	49.76
Deflection at Peak, mm	M_A	1.155	1.317	1.125	1.716	1.059	1.059	1.716	1.274	0.265
	M_a	0.483	0.341	0.408	0.340	0.148	0.148	0.483	0.344	0.124
	I_a	0.260	0.475	0.148	0.365	0.465	0.148	0.475	0.343	0.139
Force at Break, N	M_A	145.89	166.09	157.20	186.34	219.08	145.89	219.08	174.92	28.79
	M_a	422.17	283.34	453.30	241.77	236.74	236.74	453.30	327.46	102.87
	I_a	190.28	166.29	68.39	174.90	178.69	68.39	190.28	155.71	49.57
Deflection at Break, mm	M_A	1.155	1.317	1.127	1.740	1.059	1.059	1.740	1.280	0.274
	M_a	0.483	0.343	0.408	0.340	0.148	0.148	0.483	0.344	0.124
	I_a	0.260	0.475	0.151	0.370	0.465	0.151	0.475	0.344	0.139

Table 8 Results of compression tests on soybean seeds

S/N		1	2	3	4	5	Min	Max	Mean	S. D
Height, mm	M_A	7.32	7.58	6.96	6.83	6.82	6.82	7.58	7.102	0.335
	M_a	4.69	4.43	3.98	4.20	4.07	3.98	4.69	4.274	0.288
	I_a	6.62	6.02	5.83	5.46	5.70	5.46	6.62	5.926	0.438
Force at Peak, N	M_A	39.320	62.490	44.160	58.760	58.080	39.320	62.490	52.562	10.166
	M_a	239.93	180.50	240.30	184.16	69.18	69.18	240.30	182.81	182.81
	I_a	19.730	46.670	33.650	64.620	37.850	19.730	64.620	40.504	16.622
Deflection at Peak, mm	M_A	1.047	2.285	1.357	1.814	1.432	1.047	2.285	1.587	0.476
	M_a	2.417	2.288	2.512	2.282	1.289	1.289	2.512	2.158	0.495
	I_a	0.727	1.659	1.286	1.963	1.470	0.727	1.963	1.421	0.462
Force at Break, N	M_A	31.630	36.060	23.190	47.030	37.620	23.190	47.030	35.106	8.710
	M_a	239.93	180.44	239.87	184.13	69.18	69.18	239.93	182.71	69.709
	I_a	18.990	46.280	31.090	61.550	36.950	18.990	61.550	38.972	16.036
Deflection at Break, mm	M_A	1.078	2.445	1.422	1.936	1.516	1.078	2.445	1.679	0.526
	M_a	2.417	2.293	2.517	2.287	1.289	1.289	2.517	2.161	0.496
	I_a	0.792	1.688	1.652	2.014	1.563	0.792	2.014	1.542	0.453

5 Conclusion

Some physical and mechanical properties of maize and soybeans in relation to planting equipment were determined. Based on the results, the following conclusions were made.

i. When designing the delivery tube of a planter, the average minimum diameter to use for maize and soybean should be 0.716 and 0.600 cm respectively. Also, the distance of the delivery tube to the soil should not be large because, the individual weight of the grains is quite small hence it could be affected by wind.

ii. When designing for the seed plate, the average surface area to use for maize and soybean should be 1.621 cm^2 and 1.135 cm^2 respectively.

iii. The average sphericity of soybean is 0.814 hence it will tend to roll faster than maize whose average sphericity is 0.693.

iv. The porosity of soybean is quite low hence when designing the furrow opener. It should not be allowed to cut too deep in to the furrow so as to allow adequate air flow in the soil.

v. The mean rupture forces for soybean for the major and intermediate axis were 52.562 N and 40.504 N respectively while the minor axis failed to rupture. Also, the mean rupture force for the major, minor and intermediate axis was determined to be 175.30, 328.45 and 156.55 N respectively for maize grains. This helps in designing the clearance between the seed plates in other to prevent crushing of the seed during operation.

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