SOME ENGINEERING PROPERTIES TOMATEOS

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ABSTRACT

Some physical and mechanical properties of two tomatoes cultivar, local Dwarf and Roma VF were determined with a view to obtaining information needed as parameter in computer simulation of deformation of this vegetable under compressive loading using Discrete Element method. The properties were determined using standard methods. The major and minor diameters have normal distribution, the sphericity is found to be above 80% implying the fruit can be modeled as a sphere. The bulk densities for the two cultivars ranged between 500 – 630 kg/m^3. The rupture force of less than 50N for the two cultivars is a confirmation of the soft and delicate nature of the fruit. These properties are useful in the modeling of the behavior as the necessary threshold values have been obtained.

Keywords: DEM, Physical properties, Mechanical properties, Tomatoes.

INTRODUCTION

Tomatoes are an important aspect of diet and are widely consumed in almost every part of Nigeria. It is either eaten raw, cooked or used commonly in making paste; pickles and sauce. It is also used as a spice and flavour ingredient in food industries. Tomatoes are often selected on the basis of appearance and tend to follow a cyclic path-growth, decay, death and disintegration like other biomaterials; this eventually leads to losses [1]. Tomatoes, due to their high moisture content, soft tissue and high rate of physiological activities such as respiration and transpiration, made them susceptible to high degree of deterioration and handling damage after harvest. Preserving these crops in their fresh state for months has been a problem that is yet to be solved [1]. The methods employed in their processing are still traditional. It becomes imperative to characterize the products with a view to understand their microscopic and macroscopic behavior that may affect the design of specific machine to handle their processing [2].

Discrete element methods (DEM) is a numerical methods that make use of contact mechanics between particle in assembly (particle-to-particle, particle-to-wall) to model overall system behavior as a result of this interaction. DEM offers the opportunity for better understanding of rupture and large deformation leading to improvements in equipment design and operation that can lead to optimize design and operating conditions. To model using DEM, physical and rheological properties must be obtained [2]. Physical and rheological properties are important in many problems associated with the design of machines and the analysis of the behaviour of the product during agricultural processing handling [2].

Due to large scale indigenous production, high rate of consumption, high commercial exploitation of tomatoes there is a need for a comprehensive study of their engineering properties to develop appropriate technologies for their handling. The objective of this study therefore was to determine some engineering properties of tomatoes which are important in parametric study for computer simulation of failure using DEM and the design of specific machinery for handling

MATERIALS AND METHODS.

Physical Properties

Two cultivars of tomatoes (Roma VF and Local Dwarf) which have not have contact with each other were randomly selected at commercial farm of Federal College of Agriculture Ibadan. Two hundred pieces of each cultivar were randomly selected and their physical properties were determined

In order to obtain the moisture content of the two tomatoes cultivar, samples of known masses were kept in an electric oven at 103^{0}C $\pm$5. Weight loss on drying to a final constant weight was recorded as moisture content and was replicated five (5) times. The moisture content was calculated on wet basis using equation (1);

$$M.C = \frac{M_{initial} - M_{dried}}{M_{initial}} \times 100 \qquad (1)$$

Where, M.C is Moisture Content (w.b), $M_{initial}$ is initial mass (g), M_{dried} is final mass (g) of the two variety of tomatoes.

Mass of individual tomatoes of the two varieties was determined using an electronic weighing balance with a sensitivity of 0.001g. The mass individual of the tomatoes were taken with the stock. Volumes of the tomatoes were measured by water displacement method [2]. For this purpose, individual tomatoes were submerged into a known volume of water and the volume of water displaced was recorded.

Three mutually perpendicular axes; "a" major, (the longest intercept), "b" intermediate (the longest intercept normal to a), and "c" minor, (the longest intercept normal to a, b) of the tomatoes were measured using digital Vernier caliper (Carrera Precision model CP8812-T 12-Inch Titanium Digital LCD Calliper Micrometer, United States) having an accuracy of 0.01mm. The mean, ranges and standard deviation were then reported for the two tomatoes. The Sphericity (SPH) and Geometric mean diameter (GMD) were then calculated using the method describe by [2], [2] and [2]. The sphericity index was introduced as the multiplier of the geometric mean diameter to take care of the deviation from the true shape of tomatoes as that assume by the theoretical shape [2].

The bulk density(BD) was determined using the mass/volume relationship [2] by filling an empty plastic container of predetermined volume and mass with tomatoes poured from a constant height and weighed. Then the bulk density was computed using Equation (4). This process was replicated ten (10) times.

True density (TD) is defined as the ratio of the given mass to volume. The volume and density were determined by water displacement method using *eureka* can as described by [1]. To accomplish this, a graduated measuring cylinder was filled with water to certain level. Tomatoes of known mass were submerged in the cylinder resulting in rise in the level of water. The true density was calculated for each of the ten (10) replications. Porosity (PR) was calculated as the ratio of the differences in the tomatoes density (true density and bulk density) to the true density using Equation (2) value and expressed in percentage [3];

$$PR = \frac{(TD - BD)}{TD} \times 100 \quad (2)$$

Biaxial Compressive Test

To determine the mechanical properties of the two tomatoes varieties in quasi-static compression test, a Universal Testing Machine ( ) was used. Twenty (20) tomatoes were randomly picked from each varieties and each loaded between two parallel plates of the machine and compressed at a loading rate of 4mm/min until rupture occur. The compression was applied to the middle of the flower stalk as longitudinal orientation and perpendicular axis to the flower stalk as transverse orientation. The average values of all the 20 tests were reported in terms of the average rupture force, energy used to rupture, force at yield and Energy at yield. The force-deformation curve up to the point of rupture was plotted by utilization of the computing software installed on the universal testing machine used.

RESULTS AND DISCUSSION

Physical Properties

The summary of the result for all the parameters measured were collated, analyzed and presented in Table1. Descriptive statistics were used to determine mean value, range of values (maximum and minimum) and Standard Deviation (STDEV.). The skewness and kurtosis analysis for the frequency distribution curve for the 200 readings taken for each dimension shown in Figure 1 and Figure 2 are presented in Table 1.

Average moisture content of 93.11% and 92.93% were reported for Roma VF and Local Dwarf respectively and this serves as the moisture level at harvest and the basis at which all measured parameters were obtained. This value is fall in range with the one obtained by [4]. The values obtained from each replication were calculated using equation (1). Moisture content determination is important as it is a vital parameter which is an influential factor on all crops processing procedures and other physical properties it can fluctuate greatly as it is influenced by relative humidity. The average individual mass and volume of the 200 observed were reported for Roma V and Local Dwarf 17.94g, 13.03g, 19.87cm^3 and 8.23cm^3.

The value obtained for major, intermediate and minor diameter ranges from 30.99mm – 11.15mm, 31.30 – 15.54mm and 79.45 – 25.96mm with mean of 23.60mm, 24.32mm and 50.67mm respectively for Roma VF While Local Dwarf had its major, intermediate and minor diameter ranges from 44.95mm – 19.94mm, 37.93mm – 17.93mm and 38.59mm – 15.78mm with the mean of 30.46mm, 26.41mm and 25.67mm respectively. Fig. 1 and Fig. 2 shows the frequency distribution of the axial dimension of the two tomatoes observed. The axial dimension (major -, intermediate -, minor - diameter) of Roma VF is skewed (Table 1) to the left this means that the asymmetric tail is extending out to the left of the distribution while the kurtosis of this distribution is platykurtic that is, it is too flat when compare to the normal distribution curve. However, the axial dimension (major -, intermediate -, minor - diameter) of Local Dwarf is skewed to the right and only the major and minor diameter is leptokurtic, which is its central peak is higher and its tails are longer and fatter. The kurtosis of the distribution for intermediate diameter is platykurtic.

The average sphericity value obtained were 61.85%, 90.63% and 8.08mm, 6.47mm as the mean and the standard deviation for Roma VF and Local Dwarf respectively. The sphericity of Local Dwarf is very close to sphere while that of Roma VF is less than 90% due to large variation in the axial dimension. In discrete element method, particles are modeled as sphere of constant diameter. The higher the sphericity, the closer the shape to been spherical the more the accuracy of the prediction by DEM.

The geometric mean diameter for the two tomatoes were computed from the axial dimension and the average value obtained were 30.64mm for Roma VF and 27.47mm for Local Dwarf respectively. It was observed that an increase in tomatoes size leads to an increase in the geometric mean diameter of that tomatoes which then result in the tomatoes with the least or smallest minor diameter or thickness having the least geometric mean diameter. This is similar in trend as those observed for bell and chilli pepper [5]. The geometric mean of axial dimension is useful in defining the characteristics dimension for irregular solid.

The value obtained for bulk density ranges from 0.58g/cm^3 – 0.62g/cm^3 and 0.50g/cm^3 – 0.63g/cm^3 for Roma VF and Local Dwarf respectively. Bulk density is an indicator of quality and predicate of breakage susceptibility and hardness study. The computation of true density ranged from 0.81g/cm^3 – 1.07g/cm^3 with average mean of 0.98g/cm^3 for Roma VF and 0.84g/cm^3 – 1.33g/cm^3 with average mean value of 0.96g/cm^3 for Local Dwarf. This property is useful in computing product yield and mathematical conversion of mass to volume.

Porosity shows the relationship between bulk and true density and the extent of pore spaces. The average value obtained were 37.73% and 37.97% for Roma VF and Local Dwarf tomatoes respectively. This attribute determine the ease of passage of gases such as air, liquid circulation through a mass of particles in aeration, drying, heating, cooling and distillation operation.

Biaxial Compression Test.

Results of biaxial compression test of the two tomatoes cultivar between two parallel plates at a constant loading rate of 4mm/min are as presented in Table 2. The average values of rupture force, energy used for rupture, force at yield, energy at rupture and young modulus of elasticity on transverse loading position are 39.95N, 28.35J, 9.93N, 24.55J and 2003KPa for Roma VF and 44.14N,29.29J, 10.97N, 19.24J and 1581KPa for Local Dwarf respectively. However, the average values of rupture force, energy used for rupture, forces at yield, energy at rupture and young modulus of elasticity on longitudinal loading position are 39.6N, 42.66J, 12.01N, 43.3J and 8757.3KPa for Roma VF and 21.31N, 17.58J, 5.61N, 5.65J and 10154.9KPa respectively. The result obtained is similar in the same trends with those reported for cherry tomatoes [6] and for granular Agricultural material [].

Conclusions

Some physical and mechanical properties necessary in modeling of handling and processing of tomatoes have been determined for two cultivars. These properties have shown that the fruit is almost spherical and can be modeled as spheres and the fruits are dense enough to fall under gravity but may not sink in water. The mechanical properties obtained have given an understanding of the threshold values required during loading while modeling. The ability to model with the properties is a source of databank for non-destructive studies of tomatoes handling.

Acknowledgement .

The authors appreciate the effort of Miss Nora. A. Onyensom, Federal College of Agriculture Ibadan, for data collection

Table 1: Physical Properties of Two Varieties of Tomateos (Roma VF and Local Dwarf)

Variety / Statistical Value		a (mm)	b (mm)	c (mm)	M (g)	V (cm^3)	BD (g/ cm^3)	TD (g/ cm^3)	GMD (mm)	SPH (%)	PR (%)	MC (%)
ROMA VF	No. of Observation	200	200	200	200	200	10	10	200	200	10	5
	Mean	23.60	24.32	50.67	17.94	19.87	0.61	0.98	30.64	61.85	37.73	93.11
	Maximum	30.99	31.30	79.45	50.38	41.00	0.62	1.07	40.35	90.10	43.91	94.11
	Minimum	14.15	15.44	25.96	4.23	8.00	0.58	0.81	19.47	46.37	29.14	90.81
	STDEV	3.08	3.33	10.77	7.00	6.82	0.01	0.08	4.23	8.08	4.41	1.34
	Skewness	-0.224	-0.250	-0.263	=	=	=	=	=	=	=	=
	Kurtosis	-0.086	-0.318	-0.501	=	=	=	=	=	=	=	=
DWARF	No. of Observation	200	200	200	200	200	10	10	200	200	10	5
	Mean	30.46	26.71	25.67	13.03	8.23	0.61	0.96	27.47	90.63	37.97	92.93
	Maximum	44.95	37.93	38.59	27.40	25.00	0.63	1.33	36.01	99.97	49.74	94.32
	Minimum	19.94	17.93	15.78	3.61	3.00	0.50	0.84	18.35	71.78	23.76	91.68
	STDEV	4.12	3.84	3.84	4.26	3.47	0.04	0.15	3.19	6.47	6.86	1.15
	Skewness	0.196	0.194	0.228	=	=	=	=	=	=	=	=
	Kurtosis	0.521	-0.267	0.668	=	=	=	=	=	=	=	=

a, b, c – Diameter; M – Mass; V – Volume; BD – Bulk Density; TD – True Density; GMD – Geometric Mean Diameter; SPH – Sphericity; Pr – Porosity; MC – Moisture Content..

Table 2: Mechanical Properties of two Tomatoes variety at 93.11% and 92.93% mc wb

Variety	Loading Position	Rupture Force (N)	Energy used for Rupture (J)	Force at yield (N)	Energy at yield (N)	Young's modulus (KPa)
ROMA V	Transverse	39.95(13.05)*	283.5(134.2)	9.93(3.74)	24.55(21.7)	2003(641.1)
	Longitudinal	39.6 (14.9)	426.6(342.1)	12.01(5.29)	43.3(6.69)	8757.3(2702.2)
DWARF	Transverse	44.14(23.13)	292.9(158.0)	10.97(4.38)	19.24(11.56)	1581(434.5)
	Longitudinal	21.31(13.18)	175.81(100.1)	5.61(3.15)	5.65(4.47)	10154.9(4498.8)

*Figures in the parenthesis are standard deviation

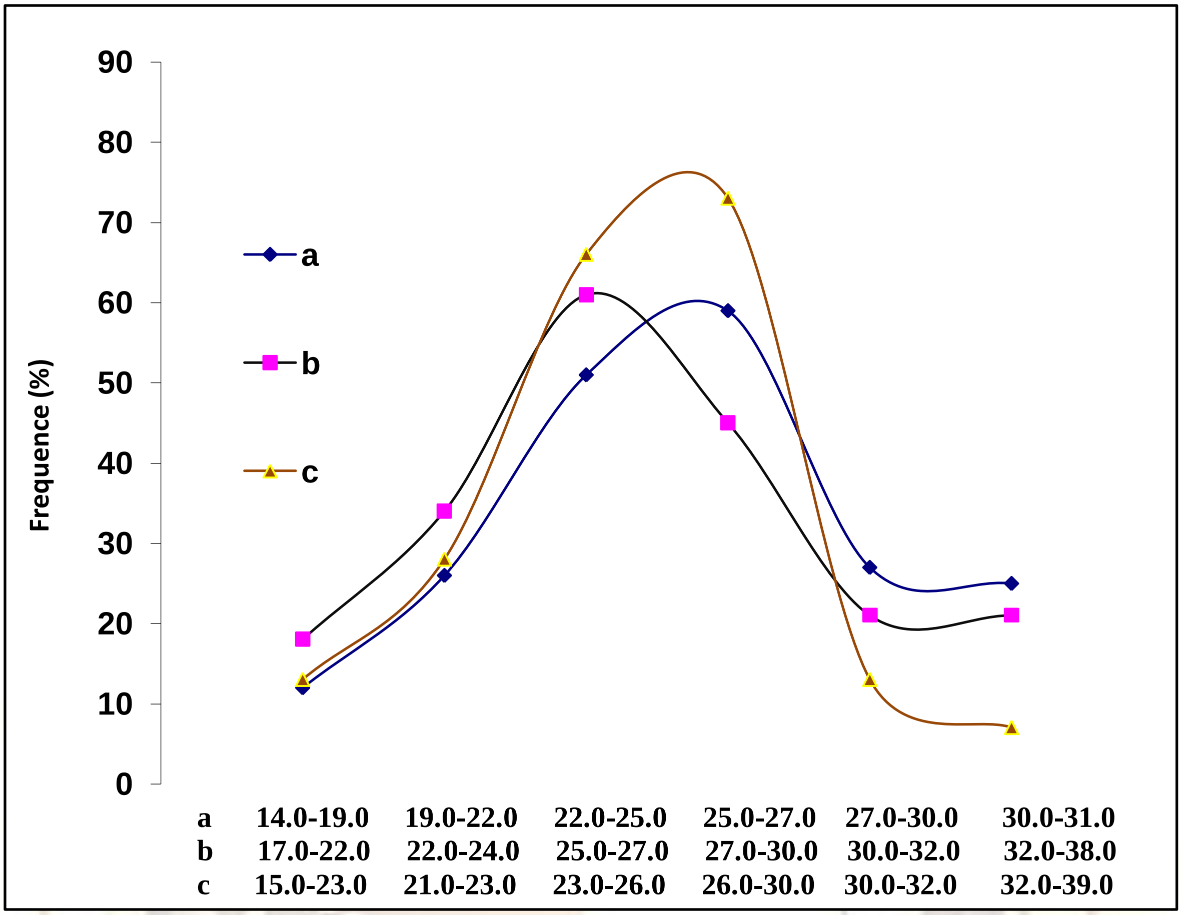

Fig.1: Frequency distribution for the axial dimensions of the Roma VF: a, major diameter, b, intermediate diameter, c, minor diameter.

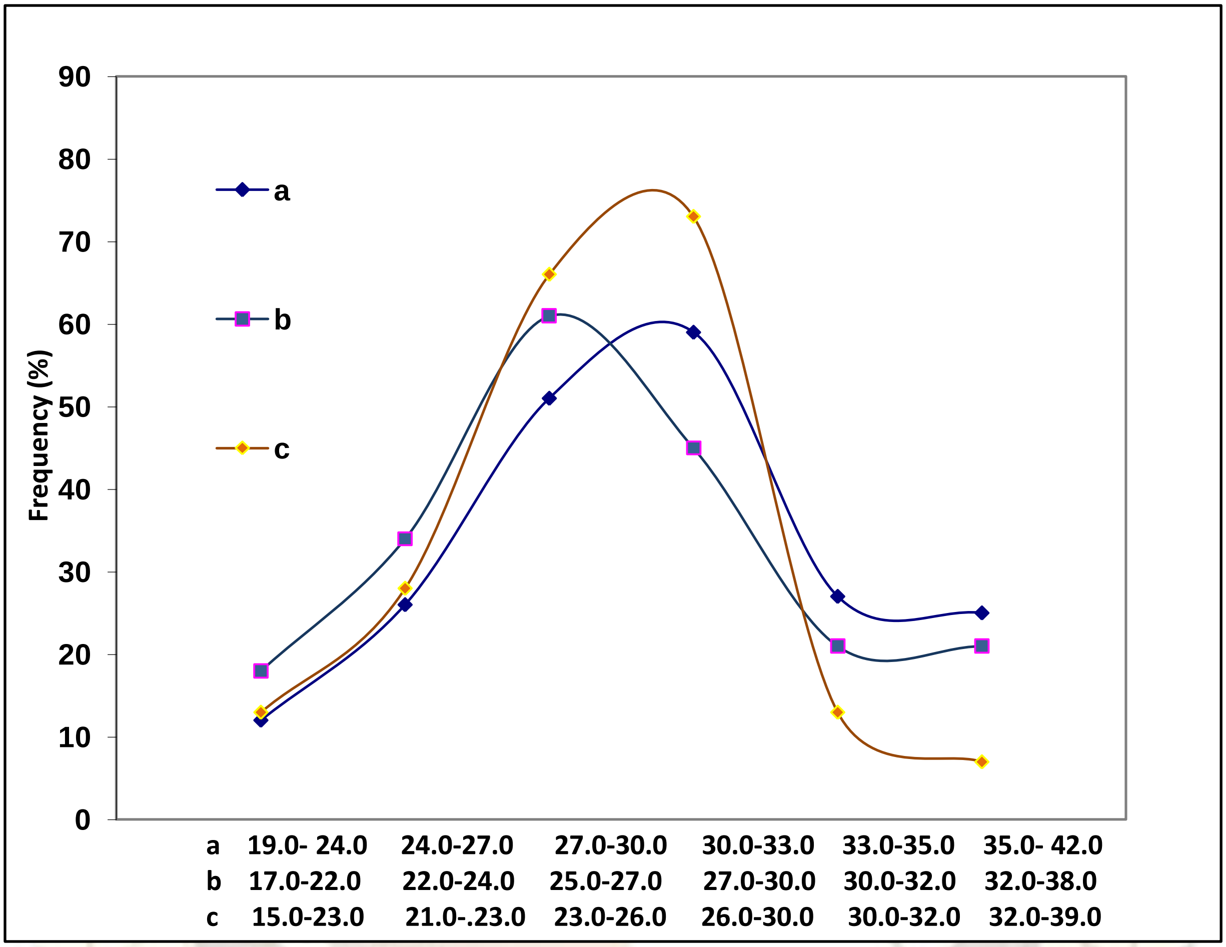

Fig.2: Frequency distribution for the axial dimensions of the Local Dwarf: a, major diameter, b, intermediate diameter, c, minor diameter.

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