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Determination of Engineering Properties of Some Fresh Tomato Cultivars Grown In Nigeria

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In this paper, some engineering properties of three varieties of tomato cultivars (chico, roma and cherry) were determined from compression test. The fruits were at two stages (turning and fully ripe) of maturity and grouped into two (small and big) sizes. A standard compression testing machine, the Testometric Universal Testing Machine (UTM) was used to apply loads on the samples. The properties determined were, force (load), energy absorbed, stress, Young modulus and deformation. The effects of variety, maturity stages and sizes of the fruits on these properties were investigated by subjecting the data to statistical analyses. The results show that the main effects variety, stage of maturity and sizes of the fruits were highly significant at 5 % level of probability. The turning stage of maturity seems to have the greater capacity for taking elastic or recoverable deformation than the fully ripe samples. The results also show that the cherry variety is the weakest among the three varieties studied. The data obtained can be of great assistance in reducing mechanical damage to this produce especially during handling.

Introduction

Fresh fruits of tomato (*Lycopersicon esculentum*) are highly susceptible to mechanical injury during handling. The mechanical damage suffered by these produce is normally influenced by their engineering properties. There has been widespread interest in engineering properties of foodstuff, fresh or processed. The information is required by food researchers for various purposes such as quality assessment and evaluation, process design, operation and control of food plant, handling and transportation and design of packaging methods and materials, mass and energy balances among others.

In the last forty years, several studies were carried out to assess product physical and mechanical properties, hence susceptibility to mechanical damage, that is, bruising, cracking, cuts etc (O'Brien *et al*., 1965; Singh and Singh, 1992; Jan *et al*., 1997; Batu, 1998; Dewulf *et al*., 1999; Nwanekezi and Ukagu, 1999; Ozoemena and Ozumba, 2003; Berardinella *et al*., 2005). Most of these work on engineering properties of food whether fresh or processed were carried out in the temperate and developed countries of the world. But in the developing countries, very little information (if any) especially on the indigenous produce are available. In particular, there is very scanty information on the physical and mechanical properties of tomato fruits especially varieties cultivated in Nigeria.

The distribution of fresh tomato fruits in Nigeria is usually characterized by long chain of handling process due to the distance between the producing areas and the consuming centres. Fresh tomatoes, just like any other horticultural produce, are highly susceptible to mechanical damage caused by external load which in turn leads to changes in structure and tissue (Roudot *et al*., 1991). Evidence of severe problems of mechanical damage is on the increase and this is affecting the trade in fruits and vegetables both locally and internationally. Damage during transport is a major cause of quality deterioration in fresh fruits and vegetables (Jones *et al*., 1991). Damage to fresh tomatoes during transportation is quite significant. For instance, in transit, storage and market places, large percentages (30- 50%) of the produce are lost as a result of various factors. Mechanical injuries such as cuts, bruises, ruptures, abrasions, crushing and cracking account for over 50% of these losses (Okhuoya, 1995).

Damage caused by vibration during transportation had been assessed on different species of fruits and vegetables such as Cling peaches (Obrien *et al*., 1965), tomatoes (Singh and Singh 1992), peaches (Ogut *et al*., 1999) and pears (Berardinelli *et al*., 2005).

The aim of this study is to determine some engineering properties of some varieties of tomato fruits grown in Nigeria with the view to generating data that will be used to design systems that will curtail mechanical damage and hence losses in these materials especially during handling.

Materials and Methods

Fresh tomato fruits of three varieties, *chico*, *roma* and *cherry* were obtained from farms in Ilorin, Kwara State of Nigeria. The fruits were obtained at two stages of maturity (ripening), turning (1-50% pink) and ripe (80 - 100% red skin) but firm. These were sorted into two size groups of reasonable uniformity, termed small (10-55 g) and big (60 g and above) sizes. The moisture content of the samples was determined using the air oven method. The minor, intermediate and major diameters of each of the samples were measured using the vernier calipers (Mohsenin, 1986) before subjecting them to compression test.

A standard compression testing machine, the Testometric Universal Testing Machine (UTM) was used to apply loads on the samples. The machine which has a capacity for exerting 50 kN of force was installed in the laboratory of the National Centre for Agricultural Mechanization (NCAM) in Ilorin. The average temperature of the laboratory during test was 26° C.

Five samples from each size groups at each stage of maturity from each of the varieties were subjected to compression test using a crosshead speed of 2.5 mm per minute. The parameters measured were the force- deformation curve, load applied, stress, energy absorbed, elasticity modulus and deformation. The results of these parameters including the force-deformation curves were obtained as a print out from the readout unit of the UTM machine at end of each compression test. Also from the force-deformation curve and using known formulae, the above properties were determined thus:

The toughness value (energy absorbed), *T* is defined as the total energy absorbed up to rupture point and is given by the area under the force-deformation curve Olorunda and Tung (1985)

$$T = \frac{1}{2} FD \qquad (1)$$

The fruit bioyield values were taken as the peak force (*F*) just prior to sudden decrease in force sustained by the fruit due to tissue rupture. Deformation (*D*) is defined as the distance of the crosshead traveled from the first contact with the fruit surface to the point of rupture.

The rupture stress was determined from

$$\sigma = \frac{F}{A} \qquad (2)$$

where, σ = rupture stress [N/m^2], *F* = peak force [N], *A* = contact area between the compression tool and the convex bodies [m^2].

$$A = \pi a^2 \qquad (3)$$

where, *a* = radius of circle of contact given by

$$a^2 = \frac{D}{\frac{1}{R} + \frac{2}{d}} \qquad ASAE\,(1998) \qquad (4)$$

Where, *D* = elastic deformation [m], *d* = diameter of spherical indenter (compression tool) [m], *R* = average of radii of convex bodies [m].

The modulus of elasticity (*E*) is given by the relationship:

$$E = \frac{0.531(1-\mu^2)F}{D^{3/2}}\left[\frac{1}{R_1} + \frac{1}{R_1'} + \frac{4}{d}\right]^{\frac{1}{2}} \qquad ASAE\,(1998) \qquad (5)$$

where, *E* = modulus of elasticity [N/m^2], *F* = bioyield force (half peak force [N], *D* = deformation (half of the value at peak) [m], *d* = diameter of spherical tool [m], R_1, R_1' = radii of curvature of the contact surfaces and determined from the dimensions of the fruits (ASAE, 1998)

The data obtained were subjected to statistical analyses. As stated earlier, three -factor experimental design and analysis were used in this experiment. The factors were variety, stage of maturity and size of fruits, i.e. variety, 3 levels; maturity, 2 levels and size 2 levels and there were five replications giving a total of 3x2x2x5 treatments. The Analysis of Variance (ANOVA) and Duncan Multiple Range Test (DMRT) were used to ascertain the differences among the means, using a statistical package, MINITAB, release 14, (2003).

Results and Discussion

The results of the study are presented as follows. Although the properties of the fresh tomato fruits were measured at different stages of loading namely, yield, peak and rupture points, the results of the average values at rupture point are used in the subsequent discussion since it is when the produce ruptures under excessive loads that deterioration is enhanced because the produce is then predisposed to attack from other deteriorating agents.

Load Applied

Figure 1 shows the values of the average load required to rupture the samples at different maturity stages. The effects of the three factors of variety, maturity and size of the fruits can be seen from the results. Samples at the turning stage of maturity seem to withstand more loads than those at fully ripe stage. Since load applied to the produce is a measure of the capability of the produce to resist mechanical damage, it follows that fruits at turning maturity stage are less prone to mechanical damage than others. The results seem to confirm some observations made in other studies that transporters of fresh tomatoes usually prefer handling tomatoes that are at green/turning stages of maturity for long distance haulage because they are usually less susceptible to mechanical injuries (Erinle and Karikari, 1988; Olorunda and Tung, 1985).

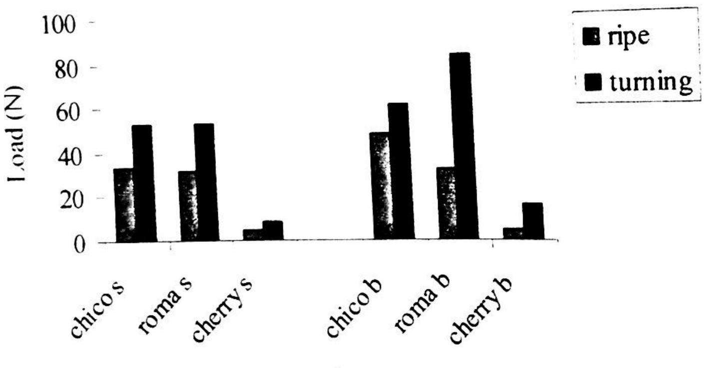

Fig 1 Average load sustained by fresh tomato fruit at rupture point

The results also indicate that the *chico* and *roma* varieties have the ability to withstand more load than the *cherry* variety. These results agree with the findings of earlier studies by Singh and Singh (1992). The findings revealed that the pear shape varieties which are called *roma* variety in this study are firmer than the round shape varieties called *cherry* in this study. The effects of the sizes can also be seen from the results. Generally, the bigger samples seem to withstand more loads than the smaller ones irrespective of the variety and stage of maturity. Table 1 shows the effects of these three factors and their interactions on these engineering properties. The main effects of variety, stage of maturity and sizes are highly significant at 5% level of probability, but interactive effects are not.

Energy Absorbed

The results of the energy absorbed by the samples tested at rupture point are shown in Fig. 2. It is clear from the results that an average of 0.0476 Joules is required to rupture a small sample (< 55g) of fully ripe *cherry* variety, whereas for the same size range of *chico* and *roma* varieties, the average values are 0.1295 and 0.3980 Joules respectively. The same trend of results can be observed for the other size (56 g and above) and maturity stage.

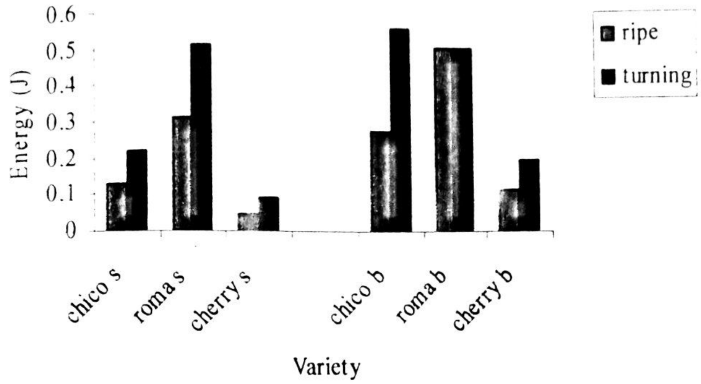

Fig 2 Average Energy absorbed by the tomato fruit at rupture point

The energy absorbed by the fruits under compression load is very important as far as the handling of tomato fruit is concerned. During transportation, it has been noted that the excitation from the road irregularities is usually dissipated as energy on the fresh produce and that it is this energy dissipated that usually result in produce damage (Jones *et al.*, 1992). The knowledge of the absorbed energy can assist greatly in curtailing mechanical damage to fresh tomato fruits especially during handling (Vursevus and Ozguven, 2004). Information on the energy absorbed can be used in the design of handling devices, processing machines and impact testing devices. Since the energy that a produce can sustain is a measure of its resistance to impact (Hyde *et al.*, 1993), the specific values obtained for the various tomato varieties popularly produced in Nigeria can greatly assist handlers in deciding on packaging of the fruits. Studies have also shown that impact energy threshold is a measure of resistance or susceptibility of any fresh produce to bruise damage especially during transportation and handling (Hyde *et al.*, 1993).

It can generally be seen from the results that the maturity stage greatly influenced the values of the energy absorbed by fruits. Just like in the case of the force discussed above, the results of the energy absorbed indicate that the samples at turning stage of maturity are less prone to mechanical damage as far as the ability to withstand the effect of this impact is concerned.

Young's Modulus and Stress

Figures 3 and 4 show the average values of the modulus of elasticity and the stress obtained. The elasticity modulus is a measure of the capacity of a material for sustaining elastic or recoverable deformation. It is one of the mechanical properties of fruits which is important and necessary in studying the handling and processing of agricultural products (Ogut *et al.*, 1999). The range of average values of the Young's modulus (0.0869 to 0.1729 N/mm^2) obtained from this study agrees with earlier studies conducted on *roma vf* variety using different compression testing machine (Idah *et al.*, 1999).

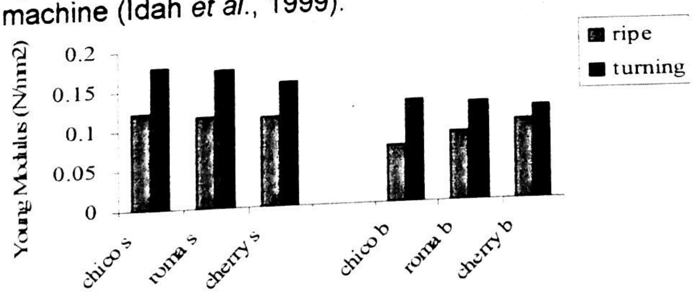

Fig 3 Modulus of elasticity of the fresh tomato fruit

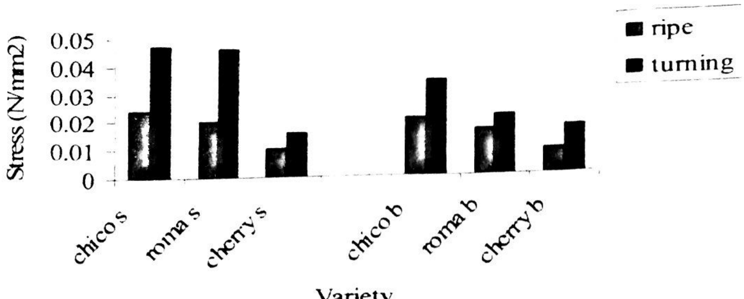

Fig 4 Average Stress sustained by the fresh tomato fruit at rupture pont

Furthermore, Table 1 indicates that the effects of the main factors of variety, stage of maturity and size of the fruits on these properties are highly significant at 5% level of probability. It is clear from the results that the *chico* and *roma* varieties are capable of taking more elastic or recoverable deformation than the *cherry* variety.

Deformation

Figure 5 shows the results of the average values of the deformation under gone by the various samples under the compression test. Generally, it is expected that the fully ripe samples should suffer more deformation under compression than the turning maturity samples. The deviations observed in this study may be due to some variations in the structural compositions of the samples.

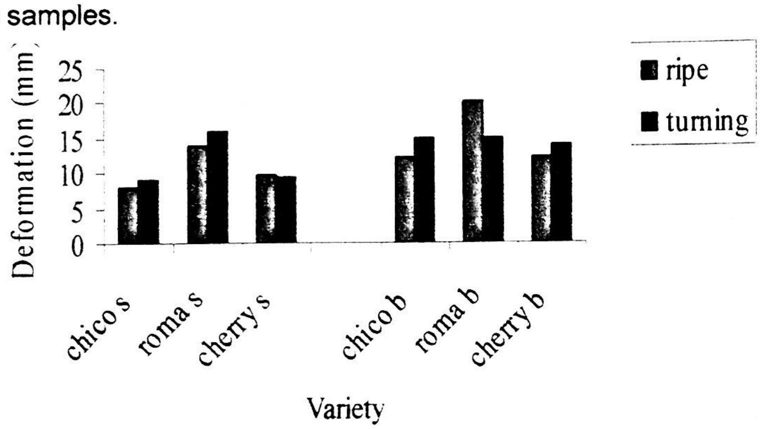

Fig 5 Average fresh tomato fruit deformation at rupture point

Deformation as an engineering property of fruit is very important in the handling and processing of the products. The relationship between deformation and force (load) is a measure of the fruit firmness which is one of the parameters used in quality assessment of fruits by consumers and processors (Altisent, 1991 and Batu, 1995).

Table 1 Summary of ANOVA of the data obtained from the experiment

Source of variation	Df	Load at yield	Load at break	Energy at yield	Energy at peak	Energy at break	Young's mod.	Stress at yield	Stress at peak	Stress at break	Def at yield	Def at peak	Def at break
Variety (V)	2	26.8*	34.3*	17.68*	23.06*	26.36*	0.03	2.49	0.24	10.54*	13.66*	15.64*	18.73*
Maturity (St)	1	9.88*	16.84*	4.37*	7.36*	8.19*	17.07*	13.86*	0.00	7.23*	0.08	0.59	23.11*
Size (S)	1	4.50*	2.47	7.32*	10.66*	14.13*	12.64*	7.82*	2.81	5.99*	6.73*	15.10	1.57
V vs St	2	1.36	2.28	0.92	0.71	0.98	0.52	1.18	0.94	1.03	0.79	1.38	0.79
V vs S	2	1.07	2.67	2.23	1.72	1.46	0.36	1.29	0.61	1.66	5.22*	0.52	0.46
St vs S	1	0.01	0.06	0.11	0.01	0.01	0.50	1.38	0.66	0.02	0.82	2.96	3.79*
V vs St vs S	2	0.33	1.39	1.05	1.86	2.24	0.14	0.67	1.53	0.14	1.22		
Error	48												
Total	59												

*Highly significance at 5 % level of probability (P<_ 0.05); Def = deformation. Df = degree of freedom. V = variety. S = size. St = stage of maturity. vs =

Conclusion

The major engineering properties of three varieties of fresh tomato fruits popularly grown in Nigeria have been determined. The data obtained for these properties are vital to food researchers and engineers involved in the food supply chain. It can be concluded from the analyses of the results that the variety of the fruits, the stage of maturity and the sizes of the fruits have significant effects on these properties at 5% level of probability. This is important especially in the design and selection of systems to handle and process these produce that will minimize mechanical damage and ensure quality of fresh fruits.

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