DETERMINATION OF SOME PROPERTIES OF FRESH TOMATO FRUITS AS RELATED TO DAMAGE DURING HANDLING

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CERTIFICATION

This is to certify that this project was carried out by Olaremu Linda Olubunmi in the Department of Agricultural Engineering, Federal University of Technology, Minna; in partial fulfillment of the requirements for the award of Post Graduate Diploma in Agricultural Engineering.

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ABSTRACT.

This project involves the determination of some engineering properties of three tomato varieties namely roma, cherry and local at green and fully ripe stage of maturity of about 50% pink and 80 – 100% red skin respectively, and also grouped into small and big. A standard compression-testing machine, the Testometic Universal Testing machine (UTM) was used for applying force from which modulus of elasticity, force-determination curve, firmness, energy at different stages of deformation and other parameters were obtained. Each of these was subjected to the compression test and the result were automatically plotted and printed out via the computer accessories attached to the equipment. The result show that the average natural frequencies of the three varieties (Local, roma and cherry at ripe stage of maturity were (23.03, 23.92 and 23.65) Hz respectively for big samples, while for small local, roma and cherry, the values (22.90, 26.21 and 17.21)Hz respectively. For the unripe local roma and cherry the mean value were (27.10, 27.93 and 26.63) Hz for big samples. However, for small unripe local, roma and cherry the values were (28.53, 31.99 and 23.38) Hz respectively. It was observed that at both stages of maturity roma varieties has the highest natural frequency of vibration when compared with cherry and local. This shows that roma is most suitable for long distances handling. The knowledge of these data will assist handlers, designers of containers and managers of most harvest handling of these fruit to reduce damage during handling and ensure quantity of fruit.

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CHAPTER ONE

INTRODUCTION

The botanical name for tomato is lycopersicon esculentum. It is native to central and South America, but it is today grown all over the world, both in temperate and tropical countries. The very large numbers of different cultivated types are adapted to different geographical regions.

The tomato plant is an annual or short-lived perennial, although it is always cultivated as an annual. The seedling has a taproot, but later on a fibrous root system develops. Adventitious roots are also produced from the base of the stem.

The stem is weak and herbaceous. It is green in colour and is covered by yellowish hairs, some of which secrete a smelly yellow juice. The leaves are alternately arranged and pinnately compound. The leaflets on each leaf are of different sizes, and the number of leaflets per leaf is variable. Flowers are borne at the internodes instead of at the nodes. Inflorescence is cymose (arising from side shoots). (William 1998).

The tomato fruit is a berry. The unripe fruit is greenish in colour, while the ripe is reddish or yellowish. Fruit shape is most commonly spherical but pear-shaped and ovoid types of tomato also exist. William 1998).

Most of the tomatoes grown in West Africa are local cultivars whose yields and fruits quality are generally poor, But whose resistance to diseases is usually good. Many of them have fruits that are wrinkled, crack easily and are too acidic. Several improved cultivars have been produced in West Africa through plant breeding efforts, while other cultivars have been introduced from other parts of the world. Improved cultivars now grown in West Africa include Marzanimo, Ife No.1, Marglobe, Money-maker Ronita, Harvester, RomaVF and enterpriser.

1.1 Handling Problem

Tomato is highly susceptible to mechanical damage caused by external loading. This causes mechanical injuries and skin cracks on the fresh fruits. These external loadings are forces under static and dynamic conditions. Researches based on properties of tomatoes which give information or data, are being carried out. Technique for evaluating and assessing tomato damage are also in progress such as deformation test (plastic and elastic deformation), compression test, strain and stress tests, detection of mechanical load and subsequent damage, the use of non-destructive quality evaluation e.t.c.

These will help in developing scale and equipment for such study and also provide ways or means of reducing the mechanical damage on tomato, which influence infection, defects and thus affect the quality of the product. Proffering solution to the problems in fresh fruits and vegetables deterioration in fruits like tomato requires establishing the relationship between the load applied and its destructive effects. This is based on the influence of minimum stress in the mechanical properties of tissues, which, requires the detection, and evaluation of such damages using special technique and instrumentation.

Assessing the impact and compression loads on tomato fruits can provide significant results and data. Such assessments could further give basic data that can be used to bring about concepts that will help in developing appropriate handling devices that will minimize the damages during handling. A proper understanding of some of these basic properties of fresh produce under load is crucial in the maintenance of good quality (Okpala 2003), during handling and distribution.

The distribution of fresh tomatoes involves packaging in containers in the vehicle. The load which the fresh fruits (especially those at the bottom of the containers) are subjected to do greatly affect their keeping quality. Apart from that, the vibration and impact received by the fresh produce during transportation is crucial. Understanding the properties of these fruits is therefore important if prevention of the damage incurred is to be effected. The physical and mechanical properties of fresh produce such as tomatoes are located specific and even differ for different varieties. It is therefore important to generate such data or information which could be used by designer, and managers of horticultural produce during handling. Such information are also important in other post harvest processes of produce.

1.2 OBJECTIVES

The main objectives of this project are to reduce losses in fresh tomatoes fruit from mechanical damage in transit.

- To determine the natural frequency of vibration, of some tomato varieties common in Nigeria.
- To determine the modulus of elasticity, energy, stress, bio-yield point and maximum load under compression with the view to generate basic data.

1.3 JUSTIFICATION

This project is aimed at providing some basic information that can be used to prevent or reduce damages during handling. Most of the damages result from compression load, due to applied pressure. Other factors responsible for the damage are vibration and impact. If during transport the resonance frequency of fruits column packed into a container coincides with the excitation frequency of the road or vehicle, then the acceleration of the fruit will increase and it will be damaged by impact.

It is possible to reduce the damage by avoiding resonance vibration; this condition can be avoided by letting the natural frequency of the container of fruits to be away from the range of frequency of the excitation force while in transit. This study is aimed at generating these basic properties of the popular varieties that are grown in Nigeria which are hitherto very scarce to come across.

CHAPTER TWO

LITERATURE REVIEW

2.1 Tomato Fruit Handling

Tomatoes are highly perishable. If they are to be stored, they should be picked while still green and kept in cool, dark, moist place. Since the fruits bruise easily, they should not be piled on top of each other. If there is no space to spread them out, put some protective materials between each layer. Raw materials and finished goods from farm and agro-allied industries have to be transported from one location to the other.

This can be intra-city or inter city depending on the circumstances. A number of service industries are involved in this business, ensuring that the food products are transported safely to their destinations. Handling and transporting of tomato (Lycopersicon esculentum L. Mill) fruits from the producing to the consuming center is one of the major sources of mechanical damage which may initiate infestation by both fungi and worms and reduce the economic value of the fruit considerably. In most countries and in Nigeria the fruits are transported in trailer trucks. In Nigeria the fruits are loaded into trapezoidal shaped basket (narrow at the base) and pilled up in the trailer.

Usually, several of the fruits get crushed or cracked by the time they reach the distributing center. Such centers are usually infested with flies, which breed worm in the crushed or cracked fruits, which might have been attacked by fungi before they get to the center. Several times the damaged and infested fruits had to be removed in order to enhance better market price and increase the storage life of the rest of the fruits. Mechanical damage does reduce farmers' income and also lower the profit margin for the traders.

Tomato fruits, like many agricultural produce, display characteristics of both elastics bodies and viscous fluids when mechanically loaded and are therefore described as viscoelastic. The epidemics has been identified as the single most important component of the tomato as related to mechanical strength (Voisley and Lyall, 1965). When the epidermis ruptures, there is usually loss of juice and exposure of the internal cells.

The study of mechanical strength and viscoelastic behavior of agricultural produce has been carried out, under two modes of loading, viz: thermal loading and mechanical loading agricultural produce has been carried out mainly to predict stresses developed during drying or in cold storage. The cells expand when heat is applied during drying and as moisture is removed the cells contract. This alternate expansion and contraction set-up stresses which may result in failure in the produce. The stresses have been investigated by several researchers such as (Rao, Hammerle, Floyd et al, 1975). The conventional approach to the study of mechanical and viscoelastic behavior under externally applied load has been to adopt the phenomenological theories of linear isothermal elasticity and viscoelasticity (Mohsenin, 1978).

The physical distribution of fresh produce such as tomatoes is affected by several factors which usually combine to determine the state of the final product. The properties of tomatoes just like any other agricultural product influence the quality of the produce during handling. Damages suffered by such produce are normally influence by their properties. It has been observed that knowledge of the properties of food and their responses to process conditions is pertinent to the preservation and shelf life of such produce (Nwanekezi and Ukagu, 1999).

Fruit firmness is considered very important during handling because it shows how strong the produce is under certain load (Jain et al, 1997, Batu, 1998). The damaging load usually occur in several ways and so it is important to review some of these mechanical damage nad the ways they occur during handling.

2.2 VIBRATION DAMAGE

Little work has been reported in relation to vibration damage during transport of agricultural products. Transit injury to fruits has been investigated by O'Brien et al (1960). According to these investigators transport damage in fruits referred to as "roller bruising" is an important factor affecting the quality of fresh and processed fruit. The cause of damage is stated to be fatigue due to repeated forces of vibration on the fruit resulting in cell rupture beneath the skin. The intensity and duration of vibration will determine the severity of damage. In an attempt to determine the cause of in-transit fruit damage, accelerometers and the appropriate readout and recording system were employed in simulated transport tests.

Since vibration damage is due to the motion of the fruit in the pack (bin or in boxes), the magnitude of acceleration measured in gram was considered as the criterion for evaluating the intensity of vibration.

2.3 MECHANICAL DAMAGE IN FRUITS AND VEGETABLES

Transportation is a major cause of mechanical damage in fruits and vegetables (O'Brien et al, 1960). It is reported that fruit bruising on trucks has long been a problem and that about 12-40% of peaches were bruised during a journey of 160 miles on trucks having different types of suspension systems. Coursey and Proctor report transport losses of 15% for tomatoes and increased shearing of bananas from 1%-25.1% after a 45 miles lorry journey. There is clearly a need to understand the factors affecting these produce during transport and the damages thereafter.

The effects of speed, vehicle load and road surface profile were investigated and it was shown that the most drastic increase in bridge response resulted from abrupt changes in road profile. Further, it was found that the magnitude of the vertical rise was the major factor in producing this response. This work has obvious implications for the transport of fruits and vegetables; the factors generating bridge response as the vehicle transverses a pot hole or bump will also be experienced in modified form by the load the truck is carrying.

The damage takes place when the road conditions are bad and the suspension systems of the trucks are either soft or too hard. The damaged to the fruits are bruising and tearing of skin and internal damage (Kaynap et al, 1989; Kaynap et al, 1990; Mohsenin, 1970; Olorunda and Tung, 1985). The damage naturally reduces the value of the fresh fruit. Mechanical damage is significantly affected by the stage of tomato maturity, container type, vibration and compressive load in the simulated transit study (Olorunda and Tung, 1985). There is significant amount of damage to the fruits and vegetables during transportation.

The damage is always greatest on top layer of fruit, and under severe transport conditions. Understanding the behaviour of the produce under static and dynamic loads can provide useful information in reducing mechanical damage and enhancing quality of the fresh produce during transportation. This is so because damage to fresh produce due to mechanical forces is among the most important causes of losses of quality (Peters, 1996, Jones et al 1991, Roudot et al., 1991; Jan et al., 1997, Dewulf et al., 1999). Several researches have been carried out on mechanical properties of food materials generally but most of these properties are product and local specific, and so can not generally be applied every product. A review of some of the basic principles used in assessing the behaviour of biomaterials under load is given briefly.

(Bata et al, 1970) studied the relationship between stress- strain properties of tomato skin to cracking of the fruit. They suggested that the percentage increase in length until failure, along with the ultimate force at failure might be related to cracking resistance. The value of elastic modulus determined at a selected value of force from the stress-strain curve was said to be totally unrelated to cracking. Voisey et. al., (1965) used bursting test, puncture test, and tensile test respectively to relate tomato skin strength to the fruit cracking and concluded that puncture test be used as an index to cracking resistance.

Close relationship has been found to exist between tomato fruit cracking and water absorption Fraizer, (1934). Chaney and koziloski, (1971) reported that water absorption cause increased turgor pressure in cells and results in cell expansion. This cell increase results in fruit expansion that might lead to fruit cracking.

Murase and Merva, (1977), studied the static elastic modulus of tomato epidermis as affected by water potential using instron device. From their results they suggested a value of 5000kpa as the actual static elastic modulus of tomato epidermis. They also felt that it might be necessary to allow the relaxation component of the elastic modulus to disappear in order to improve correlations between experimental results. They concluded that the fact that water is instrumental to development of stress and also affects the mechanical properties of the epidermis which is the only protection against cracking, complicated the problem and calls for more research to improve knowledge on the topic.

Experience has shown that the mechanical strength of the epidermis decreases as the fruits get ripe. Thus when the ultimate strength of the epidermis is low the stress developed by tugor pressure might be high enough to result in cracking of the fruit under little external load.

Some assumptions were made:

1. Tomato epidermis is the main protector against cracking.
2. The fruit juice exerts pressure on the epidermis under load thus behave like thin –walled pressure vessels.

2.4 Determination of Natural Frequency of Vibration of Tomato Fruit

Determining the natural frequency of the tomato fruits involves the determination of modulus of elasticity which can be obtained from compression test. In this study, the natural frequency of the fresh tomato fruits of two varieties would be determined. In order to facilitate the computation of elasticity modulus from the experiment that will be conducted, the following assumptions were made

a. The fruits are spherical.

b. Very small expansion in the horizontal plane occurred with compression in vertical plane.

c. Each side of the fruit in contact with the flat plates will have equal deflection.

Under the above conditions and based on ASAE standards (American Society of Agricultural Engineers, 1998), the apparent modulus of elasticity for parallel plate contact is given by:

$$\mathbf{E} = \frac{\left(0.388F\left(1-\mu^{2}\right)\right)}{D^{3/2}}\left[k_{U}\left(\frac{1}{R_{U}}+\frac{1}{R_{u}^{1}}\right)^{1/3}+K_{L}\left(\frac{1}{R_{L}}+\frac{1}{R_{L}^{1}}\right)^{1/3}\right]^{3/2} \quad \text{------(3.1)}$$

where

E = Modulus of elasticity (Pa)

D = Deformation (m)

F = Force (N)

μ = Poisson's ratio = 0.22

R_u, R^1_u = minimum and maximum radii of curvature respectively at the point of contact for upper convex surface (m).

R_L, R^1_L = minimum and maximum radii of curvature respectively at the point of contact for lower convex surface (m)

R_u and R_L = constants, they are determined from equation 3.1 using cosθ is given as

$$COS\theta = \frac{1/R_L - 1/R_L^1}{1/R_L - 1/R_L^1 + \left(1/R_L + 1/R_L^1\right)} \quad \text{------------3.2}$$

For K_u, Cosθ, is calculated using the radii of the upper surface where $R_1 = R$, $R_1^1 = R_u^1$, while $R_2 = R_1^1 = \infty$ given $R_2^{-1} + R_2^{1\text{-}1} = 0$

$$COS\theta = \frac{1/R_U - 1/R_U^1}{\left(1/R_U + 1/R_U^1 + 0\right)}$$

$$COS\theta = \frac{1/R_U - 1/R_U^1}{\left(1/R_U + 1/R_U^1\right)} \quad \text{--------------3.3}$$

For K_L, Cosθ is calculated using the radii of curvature for the lower surface, where $R_1 = R_L$, $R^1_1 = R^1_L$ while

$R_2 = R^1{}_2 = \infty$ giving $R^{-1}{}_2 + R^{1-1}{}_2$.

$$COS\theta = \frac{\frac{1}{R_L} - \frac{1}{R_L^1}}{\left(\frac{1}{R_L} + \frac{1}{R_L^1}\right)} + 0$$

$$COS\theta = \frac{\frac{1}{R_L} - \frac{1}{R_L^1}}{\left(\frac{1}{R_L} + \frac{1}{R_L^1}\right)} \qquad \text{----------------3.4}$$

From the computed elasticity modulus; the natural frequency of the tomato fruit varieties was calculated from the relationship

$$F_n = \left(\frac{1}{4\lambda}\right)\sqrt{\frac{E * g}{p}} \qquad \text{------------3.5}$$

Where

Fn = Natural frequency

g = Acceleration due to gravity = 9.8 ms^{-2}

ρ = Density of fruit

λ = Depth of the column of fruit (m) = 0.01m.

2.5 APPLICATION OF HERTZ CONTACT THEORY

A fruit is a physical body that continuously changes its properties when subject to various conditions. The response of fruits to contact loading very much depends on the type of loadings. There are many types of loading, impact, compression, shearing, twisting, bending, vibration, and puncture e.t.c.

These loadings cause stress and strain to the internal tissues of the produce. The stress is the force per unit area and strain is the deformation from the initial length to the final length. A measure based on the stress / strain ratio is the modulus of elasticity.

Hertz theory of contact provides a good description about force deformation relationship or stress- strain relationship of elastic bodies. This theory could be employed to examine the collision of elastic bodies. This force deformation law of Hertz was combined with Newton's second law of motion (Goldsmith, 1960) as reported in Mohsenin (1978), to determine the maximum deformation, time of contact and maximum contact stress or pressure for two spheres of radii, R_1 and R_2 using the relationship below:

$$D_{max} = \left[15v_1^2Am_1m_2/16(m_1+m_2)\right]^{2/5} \left[R_1+R_2/R_1R_2\right]^{1/5} \quad \text{-----2.1}$$

$$t = 4.53Am_1m_2/\prod(m_1+m_2)\Big]^{2/5} \left[R_1+R_2/V_1R_1R_2\right]^{1/5} \quad \text{-----2.2}$$

$$S_{max} = 0.2515\left[\prod^4 v_1^2/A^4 \left[m_1m_2/m_1+m_2\right] \left[R_1+R_2/R_1R_2\right]^3\right]^{1/5} \quad \text{--2.3}$$

For a sphere of radius R_1 and a massive plane surface,

$$D_{max} = \left[15v_1^2 Am_1m_2/16\sqrt{R_2}\right]^{2/5} \quad \text{--------------------------2.4}$$

$$t = 4.53\left[Am_1/\prod\sqrt{R_1v_1}\right]^{2/5} \quad \text{--------------------------2.5}$$

$$S_{max} = 0.2515\{\prod^4V_1^2m_1/A^4R_1^3\}^{1/5} \quad \text{--------------------------2.6}$$

Where D_{max} is approach or maximum combine deformation, t is contact time, V_1 is the initial relative velocity, m_1 and m_2 are masses of the two bodies and A is given as

$$A = 1 - \mu^2 / E_1 + 1 - \mu^2 / E_2 \qquad \text{-------------------------2.6}$$

Where E = Modulus of elasticity and μ = Poisson's ratio.

The Hertz theory has however yielded much information on many fruits especially those referred to as hard or rigid (Altisent 1991).

The elastic contact problem describes the internal stresses and strains created in and below the contact area between fruits and the impacted of elastic, rigid and semi- infinite bodies. It states that bruising can be initiated at a certain depth below the skin, where the maximum shear stresses and strain appear. Also a finite element analysis of contact stresses elastic as well as viscoelastic spherical bodies in contact and subjected to static and also impact load had been developed.

This method is most appropriate for calculating internal stresses caused by elastic or impact loading. This is because material properties vary within the body and they are heterogeneous in nature. It was observed that result from the analytical method used in measuring stresses is not different from the finite element procedure. However, it is noted that these theoretical approaches for the calculation of internal stresses resulting from static contact and impact are only applicable for very small strains. Thus their application to solve problems where large strains occur especially in agricultural products is questionable (Altisent 1991). But all the same, the theoretical description of the stresses and strains distribution as a result of loading gives useful information when compare with empirical observation.

CHAPTER THREE

METHODS

Fresh tomatoes of three varieties at two maturity stages (green and ripped) were harvested. The samples were weighed using the electronic weighing balance to determine their masses and were sorted into two groups (small and big) based on their masses. The groups were ranges from M_1 (masses < 30.00 to 55g) and 126 to 75 respectively. Then the diameters (minor, intermediate and major) were measured using the vernier calipers. The volumes were measured using the measuring cylinder on a platform (Mohsenin, 1979).

3.1 Equipment and Materials

The apparatus used are;

- Apparatus for compression test.
- An electronic weighing balance, venier calipers, measuring cylinders and oven.
- The electronic weighing balance – To determine the tomato masses.
- The venier caliper – To measure the minor, major and intermediate diameters.
- The measuring cylinders – To measure the volume of tomatoes.
- The oven – To dry sliced tomato fruits in order to determine the moisture content.

3.2 Method and procedure

Fresh tomato of three varieties Local, Roma and Cherry were obtained from the market and were sorted for reasonable uniformity in size of groups (small and big). The small sizes were of the range 3cm to 4.5cm in diameter while the big sizes were about 5cm in diameter. The fruits were purchased when at two stages of ripening, which were designated as ripe and unripe. The unripe stage was the green pink stage, consisting of the first point of skin colour change from complete green to 50% pink. This represented the usual stage at which subsequent ripening of tomatoes is assured during marketing. The ripe stage consisted of 80 to 100% red skin but still firm.

A standard compression testing machine the Testometric Universal Testing Machine (UTM) was used for applying force. The deformation and other parameter of interest, force deformation curves (load-deflection) were obtained from the machine. The equipment was installed in the UTM laboratory of the National Center for Agricultural Mechanization, Ilorin. The machine, which was manufactured by the Testometric Co, Ltd. UK, has a force exerting capacity of 50kN and its functional parts include a load frame, cross head, load cell, printer and control console. The moisture content of the tomato varieties was determined. This was slicing the tomato fruit samples (green and ripped), determining their masses, then placing them in an oven and allowing them to dry at a temperature of about 105^0c for two hours. Samples of fresh tomatoes from each of the varieties and each maturity stage were subjected to the compression test using a loading rate of 2.5mm per minute. The results of the various parameters were printed out from the machine.

3.3 Design and Techniques of analysis

The experimental design was a completely randomized design. There were three factors, variety, maturity and size of fruits. That is, we have variety (3), maturity (2), and size (2), and 5 replicates were used hence we have a 3*2*2*5 treatments.

Table 3.1 **Experimental Layout of Natural Frequency Determination**

Variety	Small	Big	Small	Big
Local	$Y_{L1}rMs$	$Y_{L2}rMb$	$Y_{L1}uMs$	$Y_{L1}uMb$
	$Y_{L2}rMs$	$Y_{L2}rMb$	$Y_{L2}uMs$	$Y_{L2}uMb$
	$Y_{L3}rMs$	$Y_{L3}rMb$	$Y_{L3}uMs$	$Y_{L3}uMb$
	$Y_{L4}rMs$	$Y_{L4}rMb$	$Y_{L4}uMs$	$Y_{L4}uMb$
	$Y_{L5}rMs$	$Y_{L5}rMb$	$Y_{L5}uMs$	$Y_{L5}uMb$
Roma	$Y_{R1}rMs$	$Y_{R1}rMb$	$Y_{R1}uMs$	$Y_{R1}uMb$
	$Y_{R2}rMs$	$Y_{R2}rMb$	$Y_{R2}uMs$	$Y_{R2}uMb$
	$Y_{R3}rMs$	$Y_{R3}rMb$	$Y_{R3}uMs$	$Y_{R3}uMb$
	$Y_{R4}rMs$	$Y_{R4}rMb$	$Y_{R4}uMs$	$Y_{R4}uMb$
	$Y_{R5}rMs$	$Y_{R5}rMb$	$Y_{R5}uMs$	$Y_{R5}uMb$
Cherry	$Y_{C1}rMs$	$Y_{C1}rMb$	$Y_{C1}uMs$	$Y_{C1}uMb$
	$Y_{C2}rMs$	$Y_{C2}rMb$	$Y_{C2}uMs$	$Y_{C2}uMb$
	$Y_{C3}rMs$	$Y_{C3}rMb$	$Y_{C3}uMs$	$Y_{C3}uMb$
	$Y_{C4}rMs$	$Y_{C4}rMb$	$Y_{C4}uMs$	$Y_{C4}uMb$
	$Y_{C5}rMs$	$Y_{C5}rMb$	$Y_{C5}uMs$	$Y_{C5}uMb$

For each test run the machine was loaded with the test materials and the electronic computing unit of the UTM was set to measure selected mechanical properties of the tomato samples. Measured parameters were deformation at peak (mm), stress at peak (N\mm), energy at peak (N\m), load at break (N\mm), energy at break (N\m), load at yield (N), deformation at yield (mm), energy at yield (Nm), and young's modulus (N\mm). All values were read or recorded directly from data sheets. The results were printed out from the printer with their respective graphs of Force Deformation (or load-deflection.)

The analysis of statistic variance will be used to analyze the data.

CHAPTER FOUR

RESULTS AND DISCUSSION

The results of the compression test carried out to determine the selected properties of the fresh tomatoes are shown in tables 4.7c to 4.7n. The maximum, minimum and the mean values of these properties are presented with the values of standard deviation. These results were printed out directly from the machine during the tests. The samples of force-deformation curve showing the behaviour of the samples under test are given in figure 4.1 to 4.12.

The details of the results are presented thus.

The results of the young's modulus of the tomato samples at various stages are presented in table 4.7c The average values of this modulus of elasticity (N/M^2) for the three varieties of ripe stage were local 0.0721 (big) and 0.1214 (small), roma 0.0869 (big) and 0.1160 (small) while for cherry the values were 1.006 (big) and 0.1134 for (small) samples. For the unripe samples the values were 0.1207 (big) and 0.1774 (small) while for cherry the values were 0.1132 (big) and 0.1593 (small).

These shows the maximum, minimum and mean values which each sample can withstand when subjected to compression or load before deterioration.

Table 4.7d Deformation at peak (mm) gives the maximum, minimum and mean values showing the peak values at which each sample can reach before deformation under compression The mean values of deformation at peak for samples were local (ripe) 12.086 (big) and 7.898 (small) and roma 18.958 (big) and 13.372 (small) while for cherry were 9.905 (big) and 8.874 (small). For the unripe samples the values were local 14.190 (big) and 8.715 and roma (small) 14.171 (big) and 15.165 (small) for cherry were 13.459 (big) and 9.738 (small).

Table 4.7e Energy at break (NM) showing the maximum, minimum and mean values so, in this table we can deduce that the samples(s) subjected to load or applied force will break at these levels. The mean values energy at break for the sample were local (ripe) 0.2727 (big) and 0.1295 (small)) and roam 0.5138 (big) and 0.3080 (small), for the values of cherry 0.1178 (big) and 0.0476 (small) for the unripe local 0.5601 (big) and 0.1045 and roma 0.5326 (big) and 0.5033 for the values of cherry were 0.1806 and 0.101 (small).

Table 4.7f Stress at peak these values shows the peak at which each sample can be stressed during transportation so that they can still maintain their quality before getting to final point. The mean values of stress at peak for the values of the samples were local 0.0227 (big) and 0.0273 (small) and roma 0.0239 (big) and 0.0329 (small) while for cherry were 0.0191 (big) and 0.0237 (small). For the unripe values, were local 0.0362 (big) and 0.0514 small and roma 0.027 (big) and 0.0309 (small).

Table 4.7g Deformation at break these values shows the points at which deformation will occur when the tomato samples are under compression, therefore at these points during transportation the samples will be ruptured. The mean values of deformation at break (mm) for the samples were local (ripe) and 13.148 (small) and roma 20.146 (big) and 13.785 (small) while cherry were 12.039 (big) and 9.744(small), for the values of unripe samples were local 15.006 (big) and 8.939 (small) and roma 15.511 (big) and 15.884 (small), for values of cherry were 13.988 (big) and 10.575 (small).

Table 4.7h Load at break, the results at this table shows the maximum and minimum loads that can be applied to each tomato samples under compression before break. This means that the tomato samples transporting at these mean values will experience break and also the quality has been deteriorated. The mean values of load at break (N) of the samples were local (ripe) 47.380 (big) and 33.0202 (small), and roma 37.960 (big) and 31.380 while values for cherry were 9.24 (big) and 4.0400 (small). For the values of unripe samples were local 81.28 (big) and 52.520 small and roma 54.675 (big) and 59.860 (small) while values for cherry were 15.525 (big) and 9.250 (small).

Table 4.7i Deformation at yield the values shows the yielding point at which tissue of the tomatoes samples will fail. The mean values of deformation at yield for the samples were local (ripe) 3.6442 (big) and 2.8432 (small) and roma 0.48620 (big) and 3.9320 (small) while for the values of cherry were 2.3364 (big) and 1.5980 (small) for the unripe samples the values were local 3.8592 (big) and 2.9066 (small) and roma 3.1597 (big) and 3.7676 (small) while for the values of cherry were 3.2998 (big) and 2.6610 (small).

Table 4.7j Energy at yield (Nm) the values shows the force that will be applied to the tomatoes samples when is under compression or during transportation, at these points the quality is still maintained and any value exceed this value will result in breakage. The mean absorbed energy at yield for the samples were local (ripe) 0.016 (big) and 0.0084 (small) and roma 0.016 (big) and 0.022 (Small) while for cherry the values were 0.003 (big) and 0.001 (Small). For the unripe samples the values were local (0.032) (big) and 0.012 (small) and roma 0.020 (big) and 0.0100 (small) while for cherry the values were 0.006 (big) and 0.003 (small).

Table 4.7k Stress at yield (N/m^2) these values shows that any further load at these points will result in deformation of the tomatoes samples. These are the limit for which the samples can stressed under compression. The mean values of stress at yield for the samples were local (ripe) 0.0046 (big) and 0.0055 (small) roma 0.0049 (big) and 0.0064 (small) for the value of cherry were 0.0040 (big) and 0.0048 (small). For the unripe samples for local 0.073 (big) 0.9103 (small) and roma 0.028 (big) and 0.0100 (small) while for cherry the values were 0.0061 (big) and 0.0062 (small).

Table 4.7L Stress at break the values shows the points at which the tomatoes sample will break when stressed under compression. The mean values of stress at break for the samples were local (unripe) 0.0351 (big) and 0.047 (small) and roma 0.022 (big) and 0.0466 (small) for the values of cherry were 0.0165 (big) and 0.148 small for the ripe values of samples were local 0.021 (big) and 0.0239 (small) and roma 0.164 (big) and 0.0203 (small) white for cherry were 0.0091 (big) and 0.0091 (small).

Table 4.7m Energy at peak (Nm) these values shows the peak at which the tomatoes samples can no longer withstand other load or force when under compression. The average values of energy at peak for local (ripe) 0.2670 (big) and 0.1225 (small) and roma 0.4694 (big) and 0.2920 (small) while for cherry were 0.984 (big) and 0.0437 (small), for the values of unripe local 0.5133 (big) and 0.2088 (small) and roma 0.4499 (big) and 0.4734 (small).

Table 4.7n Load at yield these results shows the load that can be applied to the tomatoes sample at various stages when subjected to compression. The mean values of load at yield (N) for the sample were local (ripe) 10.320 big) and 7.480 (small) and roma 11.60 (big) and 9.840 and 2.100 (small). For the unripe samples the values were local 16.980 (big) and roma 12.950 (big) and 12.880 (small) while for cherry values were 5.625 (big) and 3.9000 (small).

These parameters show the properties of fresh tomato fruits at which they can withstand or resist load. And at every stages it was observed that roma has the highest resistance to deformation or crushing while local varieties can easily deformed. And Table 4.1a, 4.1b, 4.2a and 4.2b shows the result of the experiment on natural frequency of vibration determination and the average natural frequency of vibration of fresh tomato varieties at their green or unripe stages of maturity table 4.3a, 4.3b, 4.4a and 4.4b. The natural frequencies of vibration of tomato at fully ripe stage of maturity are as shown in table 4.5a and 4.5b respectively.

The analyses of results for unripe samples used are given in table 4.6a & 6b respectively. Table 4.7a and 4.7b shows the summary of analysis of variance for variety interactive defects. The force-deformation graphical result of the three varieties at both stages of maturity sorted into small and big are presented.

Table 4.1a Ripe Big

	LOCAL	ROMA	CHERRY
Natural frequency of vibration for mass 1	19-39	24.05	23.08
Natural frequency of vibration for mass 2	23.28	22.03	28.23
Natural frequency of vibration for mass 3	23.72	23.19	30.18
Natural frequency of vibration for Mass 4	26.52	25.60	20.17
Natural frequency of vibration for Mass 5	22.21	24.75	16.59

Table 4.1b Ripe Small

	LOCAL	ROMA	CHERRY
Natural frequency of vibration for mass 1	17.73	19.07	21.90
Natural frequency of vibration for mass 2	24.67	25.64	15.64
Natural frequency of vibration for mass 3	26.70	29.95	18.98
Natural frequency of vibration for Mass 4	18.73	28.87	15.66
Natural frequency of vibration for Mass 5	26.67	27.53	13.86

vibration for mass 1	19.14	26.76	26.61
Natural frequency of vibration for mass 2	25.46	26.96	32.75
Natural frequency of vibration for mass 3	19.96	27.20	24.95
Natural frequency of vibration for Mass 4	42.82	30.79	22.21
Natural frequency of vibration for Mass 5	28.12	-	-

Table 4.2b Unripe Small

Natural frequency of vibration for mass 1	LOCAL	ROMA	CHERRY
	27.55	33.63	20.91
Natural frequency of vibration for mass 2	29.59	33.85	22.06
Natural frequency of vibration for mass 3	30.65	35.71	26.38
Natural frequency of vibration for Mass 4	24.02	25.35	24.16
Natural frequency of vibration for Mass 5	30.82	31.40	-

Result of the determined the Mean Natural frequency of vibration for the ripe and unripe stages sorted into Big and small respectively.

Table 4.3a

The mean Natural frequently of vibration for masses at the maturity stages

Big Ripe Mean		
Local	Roma	Cherry
23.02	23.92	23.65

Table 4.3b

Small Ripe Mean		
Local	Roma	Cherry
22.90	26.21	17.21

Table 4.4a

Big Unripe Mean		
Local	Roma	Cherry
27.10	27.93	26.63

Table 4.4b

Small unripe Mean		
Local	Roma	Cherry
28.53	31.99	23.38

Table 4.4c ANOVA TABLE

Source of Variation	Degree of Freedom	Sum of Squares (Ss)	Mean Square (Ms)	F
Tomatoes (Treatment)	$t-1$	$\frac{\sum_i y_i^2}{t-1} - \frac{\left(\sum_i \sum_j y_{2j}^2\right)^2}{n-1}$	$\frac{ss_t}{t-1}$	$\frac{MS_t}{MS_\varepsilon}$
Error	$n-t$	$\left(\sum_i \sum_j y_{2j}^2\right) - \frac{\sum_i y_i^2}{t-1}$	$\frac{SS_\varepsilon}{n-t}$	
Total	$n-1$	$\frac{\sum_i y_i^2}{t-1} - \frac{\left(\sum_i \sum_j y_{2j}^2\right)^2}{n-1}$		

Where t = no of tomatoes

y_{ij} = each of the readings

Analysis of the result

Analysis of variance (ANOVA) was used to analysed data obtained statistically to the effects of the three factors namely variety and maturity of the samples of their natural frequency of vibration. The results are presented below

Table 4.5a Ripe Samples

ANALYSIS OF VARIANCE FOR THE RIPE SAMPLES.

ANOVA

		Sum of Squares	df	Mean Square	F	P-value
HEIGHT	Variety	3589.871	5	717.974	32.594	.000
	Error	528.670	24	22.028		
	Total	4118.541	29			
DIAMETER	Variety	3137.722	5	627.544	37.102	.000
	Error	405.934	24	16.914		
	Total	3543.656	29			
LOADYL	Variety	335.462	5	67.092	6.976	.000
	Error	230.832	24	9.618		
	Total	566.294	29			
DEFYL	Variety	34.674	5	6.935	6.424	.001
	Error	25.909	24	1.080		
	Total	60.583	29			
LOADBR	Variety	7120.390	5	1424.078	6.477	.001
	Error	5276.500	24	219.854		
	Total	12396.890	29			
DEFBR	Variety	433.798	5	86.760	8.257	.000
	Error	252.181	24	10.508		
	Total	685.979	29			
STRESSPK	Variety	.001	5	.000	.805	.557
	Error	.003	24	.000		
	Total	.004	29			
ENERGYPK	Variety	.625	5	.125	8.042	.000
	Error	.373	24	.016		
	Total	.998	29			
STRESSBR	Variety	.001	5	.000	2.040	.109
	Error	.002	24	.000		
	Total	.003	29			
STRESSYL	Variety	.000	5	.000	.655	.660
	Error	.000	24	.000		
	Total	.000	29			
ENERGYYL	Variety	.002	5	.000	6.149	.001
	Error	.001	24	.000		
	Total	.003	29			
ENERGYBR	Variety	.722	5	.144	8.542	.000
	Error	.406	24	.017		
	Total	1.128	29			
DEFPK	Variety	405.802	5	81.160	7.384	.000
	Error	263.783	24	10.991		
	Total	669.585	29			
YOUNGSMD	Variety	.009	5	.002	1.824	.146
	Error	.024	24	.001		
	Total	.033	29			

If $P < 0.05$, the there is a significant difference in the readings of the machine on the various types of tomato, if $P > 0.05$ it has no significant difference.

The results in the table above shows that the effect of variety on the natural frequency of vibration are significant since variety at height, diameter, load at yield, deformation at yield, load at break, deformation at break, and deformation at peat, energy at peak, energy at yield, energy at break, and deformation at peak are $P(0.00) < 0.05$ while variety on the natural frequency of vibration has no significant difference since varieties at stress at peak, stress at break, stress at yield and young modulus are P(0.557,0.109,0.550 and 0.146) > 0.05 respectively

Analysis of the result for green or the unripe samples

If $P < 0.05$, then there is a significant difference, in the readings of the machine on the various types of tomato.

TABLE 4.6a ANALYSIS OF VARIANCE FOR THE UNRIPE SAMPLES.

ANOVA

		Sum of Squares	df	Mean Square	F	P-value
HEIGHT	Variety	3067.543	5	613.509	33.570	.000
	Error	383.790	21	18.276		
	Total	3451.333	26			
DIAMETER	Variety	2718.479	5	543.696	65.313	.000
	Error	174.814	21	8.324		
	Total	2893.293	26			
LOADYL	Variety	531.055	5	106.211	4.604	.005
	Error	484.445	21	23.069		
	Total	1015.501	26			
DEFYL	Variety	5.142	5	1.028	1.590	.206
	Error	13.581	21	.647		
	Total	18.723	26			
LOADBR	Variety	16742.587	5	3348.517	5.463	.002
	Error	12872.233	21	612.963		
	Total	29614.820	26			
DEFBR	Variety	194.154	5	38.831	5.003	.004
	Error	162.977	21	7.761		
	Total	357.131	26			
STRESSPK	Variety	.002	5	.000	1.212	.338
	Error	.006	21	.000		
	Total	.008	26			
ENERGYPK	Variety	.736	5	.147	4.681	.005
	Error	.660	21	.031		
	Total	1.396	26			
STRESSBR	Variety	.005	5	.001	3.584	.017
	Error	.006	21	.000		
	Total	.010	26			
STRESSYL	Variety	.000	5	.000	2.242	.088
	Error	.000	21	.000		
	Total	.000	26			
ENERGYYL	Variety	.002	5	.000	3.904	.012
	Error	.003	21	.000		
	Total	.005	26			
ENERGYBR	Variety	.918	5	.184	5.855	.002
	Error	.659	21	.031		
	Total	1.577	26			
DEFPK	Variety	166.574	5	33.315	3.977	.011
	Error	175.898	21	8.376		
	Total	342.472	26			
YOUNGSMD	Variety	.018	5	.004	1.254	.320
	Error	.059	21	.003		
	Total	.076	26			

From the table above, shows that the effect of variety are significant since varieties at height, diameter, load at yield, load at break, deterioration at break, energy at peak, stress at break, energy at yield, energy at break deformation at peak are value of P ranges from (0.000 to 0.005) < 0.05 while variety on the natural frequency of vibration has no significant difference since varieties at deformation at yield, stress at peak, stress at yield and young modulus are P (0.206, 0.338,0.088 and 0.320) > 0.05 respectively.

Table 4.6b Summary of the Duncan Multiple Range test for the Mean of the ripe samples. Subset for alpha (a,b,c,d&d) = .05

Varieties	Height	Diameter	Load YL	Def YL	Load BR	DefBR	Str PK	Ener PK	Str BR	Str YL	Ener YL	Ener BR	DefPK	YMD
1	26.15a	37.03ab	11.66bc	2.91a	52.52b	8.94a	0.04a	0.21	0.05c	0.011b	0.012ab	0.22a	8.72a	0.18a
2	48.68b	40.32c	12.88c	3.77a	59.86b	15.88c	0.05a	0.47c	0.05c	0.010ab	0.020bc	0.50b	15.16c	0.17a
3	44.82b	27.86a	3.90a	2.66a	9.25a	10.58ab	0.03a	0.09a	0.01a	0.006ab	0.003a	0.10a	9.74ab	0.16a
4	44.14b	54.61d	16.98c	3.86a	81.28b	15.01c	0.04a	0.51c	0.04ab	0.007ab	0.031c	0.56b	14.19c	0.13a
5	62.11c	55.78d	12.98c	3.16a	54.68b	15.51c	0.03a	0.45bc	0.02ab	0.005a	0.020abc	0.53b	14.17c	0.12a
6	48.46b	34.48b	5.63ab	3.30a	15.53a	13.99b	0.03a	0.17a	0.01a	0.006ab	0.006ab	0.18a	13.76bc	0.11a

Uses Harmonic Mean Sample Size = (4.444 -5.000)

TABLE 4.7 a Summary of analysis of variance (ANOVA) for variety interactive effects.

ANALYSIS OF VARIANCE (ANOVA) OUTPUT

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
HEIGHT	Tomatoes	6657.579	11	605.234	29.848	.000
	Error	912.460	45	20.277		
	Total	7570.038	56			
DIAMETER	Tomatoes	5856.285	11	532.390	41.253	.000
	Error	580.748	45	12.906		
	Total	6437.033	56			
LOADYL	Tomatoes	1044.784	11	94.980	5.975	.000
	Error	715.277	45	15.895		
	Total	1760.061	56			
DEFYL	Tomatoes	39.957	11	3.632	4.139	.000
	Error	39.490	45	.878		
	Total	79.446	56			
LOADBR	Tomatoes	29794.236	11	2708.567	6.716	.000
	Error	18148.733	45	403.305		
	Total	47942.969	56			
DEFBR	Tomatoes	633.692	11	57.608	6.244	.000
	Error	415.158	45	9.226		
	Total	1048.850	56			
STRESSPK	Tomatoes	.004	11	.000	1.890	.067
	Error	.009	45	.000		
	Total	.013	56			

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
ENERGYPK	Tomatoes	1.535	11	.140	6.079	.000
	Error	1.033	45	.023		
	Total	2.568	56			
STRESSBR	Tomatoes	.009	11	.001	4.719	.000
	Error	.008	45	.000		
	Total	.017	56			
STRESSYL	Tomatoes	.000	11	.000	2.891	.006
	Error	.000	45	.000		
	Total	.001	56			
ENERGYYL	Tomatoes	.005	11	.000	4.658	.000
	Error	.004	45	.000		
	Total	.009	56			
ENERGYBR	Tomatoes	1.868	11	.170	7.179	.000
	Error	1.064	45	.024		
	Total	2.932	56			
DEFPK	Tomatoes	580.099	11	52.736	5.397	.000
	Error	439.680	45	9.771		
	Total	1019.780	56			
YOUNGSMD	Tomatoes	.056	11	.005	2.758	.008
	Error	.083	45	.002		
	Total	.139	56			

α = 0.05 level of significant, the interactive effect between the two varieties is highly significant on the natural frequency of vibration since P(0.000) < 0.05 except on stress at peak with no significant difference since P(0.067)> 0.05.

Table 4.7b Summary of the Duncan Multiple Range test for the Mean of the output for the variety interactive effects
Subset for alpha (a,b,c,d & e) = .05

Varieties	Height	Diameter	Load YL	Def YL	Load BR	DefBR	Str PK	Ener PK	Str BR	Str YL	Ener YL	Ener BR	DefPK	YMD
1	29.38ab	41.77de	7.48abc	2.84abc	33.02abc	8.15a	0.027ab	0.123ab	0.024ab	0.006ab	0.008abcd	0.129ab	7.90a	0.121abc
2	26.15a	37.03bcd	11.66cd	2.91abc	52.52c	8.94a	0.042bc	0.209ab	0.048c	0.011c	0.012abcd	0.219ab	8.72a	0.177c
3	45.37c	44.41e	9.84bc	3.93cd	31.38abc	13.70abcd	0.033abc	0.293abc	0.020ab	0.006ab	0.015bcd	0.308bc	13.37bcd	0.116abc
4	48.68cd	40.32cde	12.88cd	3.77cd	59.86cd	15.88d	0.050c	0.473cd	0.047c	0.01bc	0.021de	0.503cd	15.16de	0.173c
5	45.12c	23.80a	2.10a	1.60a	4.24a	9.74ab	0.024ab	0.044a	0.010a	0.005a	0.001a	0.047a	8.87ab	0.113abc
6	44.82c	27.86a	3.90a	2.66abc	9.25ab	10.58abc	0.031abc	0.089ab	0.015a	0.006ab	0.003ab	0.101ab	9.74abc	0.159bc
7	34.35b	52.37f	10.32bc	3.64bcd	47.38c	12.20abcd	0.023ab	0.267abc	0.021ab	0.005a	0.019cde	0.273ab	12.09abc	0.072a
8	44.14c	54.61f	16.98d	3.86cd	81.28d	15.01cd	0.036abc	0.513d	0.035ab	0.007abc	0.031e	0.560d	14.19cd	0.129abc
9	62.02e	53.99f	11.06bc	4.86d	37.96bc	20.15e	0.024ab	0.469cd	0.016ab	0.005a	0.022de	0.514cd	18.96e	0.087a
10	62.11e	55.78f	12.95cd	3.16bc	54.68cd	15.51cd	0.027ab	0.450cd	0.023ab	0.006ab	0.020cde	0.533d	14.17cd	0.121abc
11	53.43d	35.74bc	4.06a	2.34ab	9.24ab	12.04abcd	0.019a	0.098ab	0.009a	0.004a	0.003ab	0.118ab	9.90abc	0.101ab
12	48.46cd	34.48b	5.63ab	3.30bc	15.53ab	13.98bcd	0.030abc	0.171ab	0.017ab	0.006ab	0.006abc	0.181ab	13.46bcd	0.113abc

Uses Harmonic Mean Sample size = 4.706
The Group sizes are unequal. The Harmonic Mean of the group sizes is used.
Type 1 error level are not guaranteed

Table 4.7c The mean values of Elastic Young Modulus (N/mm^2) of the sample at maturity stages

	Ripe								Unripe							
	Small				Big				Small				Big			
Variety	Min	Max	Mean	Std Dev	Min	Max	Mean	Std Dev	Min	Max	Mean	Std Dev	Min	Max	Mean	Std Dev
Local	0.0708	0.1800	0.1214	0.0437	0.0552	0.0877	0.0721	0.0142	0.1131	0.2422	0.1774	0.0555	0.0544	0.02939	0.1289	0.095
Roma	0.0627	0.1564	0.1160	1.0347	0.0720	0.0958	0.0869	0.0093	0.1064	0.2082	0.1729	0.0399	0.1073	0.1472	0.1207	0.0182
Cherry	0.0615	0.1596	0.1134	0.0398	0.0640	0.1338	0.1006	0.0318	0.1468	0.1713	0.1593	0.0106	9,9762	0.1401	0.1132	0.0246

Table 4.7d The mean values of Deformation at Peak (mm) of the samples at maturity stages

					Big											
Local	4.177	10.404	7.898	2.379	7.987	15.124	12.086	3.062	5.441	11.554	8.715	2.834	10.758	18.526	14.190	2.901
Roma	9.689	17.743	13.372	3.098	15.424	24.543	18.958	3.604	10.224	17.780	15.165	2.956	12.047	16.379	14.171	2.011
Cherry	3.543	11.639	8.874	3.172	4.784	16.419	9.905	4.273	4.109	12.796	9.738	4.231	11.685	15.807	13.459	1.763

Table 4.7e The mean values of Energy at Break (N/m) of the samples at maturity stages

	Small				Big						Small			Big		
Local	0.0112	0.2341	0.1295	0.0840	0.0750	0.4918	0.2727	0.15666	0.0542	0.3891	0.1045	0.1507	0.3787	0.9947	0.5601	0.2510
Roma	0.0858	0.4671	0.3080	0.1505	0.3368	0.8104	0.51380	0.1873	0.1408	0.6093	0.5033	0.2930	0.3890	0.8203	0.5326	0.1993
Cherry	0.0053	0.0799	0.0476	0.0343	0.0264	0.2883	0.1178	0.1045	0.0165	0.1586	0.1010	0.0639	0.0926	0.2652	0.1806	0.0811

Table 4.7f The mean values of Energy at Yield (N/m) of the sample at maturity stages

	Ripe								Unripe							
	Small				Big				Small				Big			
Variety	Min	Max	Mean	Std Dev	Min	Max	Mean	Std Dev	Min	Max	Mean	Std Dev	Min	Max	Mean	Std Dev
Local	0.000	0.016	0.008	0.007	0.003	0.033	0.016	0.011	0.002	0.025	0.012	0.010	0.011	0.060	0.032	0.020
Roma	0.002	0.036	0.016	0.009	0.016	0.030	0.022	0.006	0.0043	0.0129	0.0100	0.0033	0.013	0.031	0.020	0.008
Cherry	0.000	0.003	0.001	0.001	0.000	0.013	0.003	0.005	0.000	0.006	0.003	0.002	0.003	0.010	0.006	0.003

Table 4.7g The mean values of Stress at Break of the samples at maturity stages N/mm^2

Small					Big						Small		Big			
Local	0.0021	0.0089	0.0055	0.0032	0.0029	0.0054	0.0046	0.0010	0.0040	0.0152	0.0108	0.0046	0.0040	0.0128	0.0073	0.0036
Roma	0.0022	0.0089	0.0064	0.0026	0.0038	0.0060	0.0049	0.0010	0.0043	0.0129	0.0100	0.0033	0.0041	0.0074	0.0054	0.0015
Cherry	0.0019	0.0076	0.0048	0.0026	0.0017	0.0084	0.0040	0.0026	0.0038	0.0079	0.0062	0.0020	0.0043	0.0084	0.0061	0.0019

Table 4.7h The mean values of Stress at Break of the samples at maturity stages N/mm^2

	Small				Big						Small		Big			
Local	0.0054	0.0370	0.0239	0.0143	0.0098	0.0268	0.0210	0.0065	0.0185	0.0745	0.0476	0.0256	0.0177	0.0613	0.0351	0.0179
Roma	0.0056	0.0322	0.0203	0.0121	0.0101	0.0204	0.0164	0.0039	0.0162	0.599	0.0466	0.0173	0.0173	0.0347	0.0226	0.0081
Cherry	0.0011	0.0239	0.0096	0.0103	0.0015	0.0166	0.0091	0.0062	0.0049	0.0275	0.0148	0.0098	0.0099	0.00218	0.0165	0.0049

Table 4.7i The mean values of Energy at Peak of the samples at maturity stages (N / m)

	Small				Big	Energy at Peak					Small		Big			
Local	0.0079	0.2297	0.1225	0.0822	0.0708	0.4694	0.2670	0.1507	0.0518	0.3813	0.2088	0.1464	0.2964	0.9763	0.5133	0.2714
Roma	0.0780	0.4585	0.2930	0.1480	0.3280	0.7385	0.4694	0.1720	0.0983	0.5807	0.4734	0.2099	0.3154	0.0596	0.4499	0.1569
Cherry	0.0043	-.0776	0.0437	0.0324	0.0154	0.2819	0.0984	0.1061	0.0140	0.1435	[illegible]					

Table 4.7j **Mean Values of Stress at Peak of the Samples at Maturity Stages N/m2**

	Ripe								Unripe							
	Small								Small				Big			
Variety	Min	Max	Mean	Std Dev	Min	Max	Mean	Std Dev	Min	Max	Mean	Std Dev	Min	Max	Mean	Std Dev
Local	0.0036	0.0440	0.0273	0.0163	0.0142	0.0271	0.0227	0.0042	0.0200	0.0745	0.0514	0.0221	0.0189	0.0624	0.0362	0.0177
Roma	0.0124	0.0449	0.0329	0.0127	0.0189	0.0295	0.0238	0.0047	0.0199	0.0639	0.0496	0.0171	0.0202	0.0382	0.0271	0.0080
Cherry	0.0092	0.0378	0.0237	0.0135	0.0080	0.0400	0.0191	0.0126	0.0182	0.0390	0.0309	0.0095	0.00198	0.0399	0.0297	0.0105
Table 4.7k						Deformation at Break (mm)										
Local	4.703	10.487	8.148	2.206	8.200	15.440	12.202	3.067	5.895	11.653	8.939	2.745	10.942	18.674	15.006	2.887
Roma	10.250	17.887	13.785	2.880	16.303	26.079	20.146	3.973	12.301	18.018	15.884	2.245	13.878	18.323	15.511	2.110
Cherry	4.995	12.701	9.744	2.889	6.709	16.680	12.039	4.044	4.830	14.447	10.575	4.407	12/518	16.219	13.988	1.604
Table 4.7L						Load a t Break (N)										
Local	4.900	47.100	33.020	18.279	15.900	57.400	47.380	21.028	17.900	79.00	52.520	29.862	40.30	123.70	81.28	39.39
Roma	9.400	53.600	31.380	19.360	19.700	47.600	37.960	10.743	20.00	76.600	59.860	22.693	40.800	79.300	54.675	16.937
Cherry	0.5000	7.6000	4.0400	3.8220	1.500	17.200	9.240	6.332	2.300	16.300	9.250	5.923	8.300	19.000	15.525	4.943
	Table 4.7m					Deformation at Yield (mm)										
Local	1.7730	3.8090	2.8432	0.9568	2.5730	4.7290	3.6442	0.8970	1.9960	3.8660	2.9066	0.7902	3.0560	5.4250	3.8592	0.9466
Roma	2.6260	5.5440	3.9320	1.2217	4.0400	5.6580	4.8620	0.6909	3.2370	4.2750	3.7676	0.4221	2.4320	2.9000	3.1597	0.6365
Cherry	0.4260	2.7840	1.5980	0.9686	0.6890	4.0320	2.3364	1.3597	1.0460	4.0730	2.6610	1.3041	2.8390	3.7600	3.2998	0.3957

Table 4.7n The mean values of Load at Yield (N) of the sample at maturity stages

	Ripe								Unripe							
	Small				Big				Small				Big			
ariet y	Min	Max	Mean	Std Dev	Min	Max	Mean	Std Dev	Min	Max	Mean	Std Dev	Min	Max	Mean	Std Dev
ocal	1.9000	12.00	7.480	4.026	4.700	15.100	10.320	4.128	4.900	16.100	11.660	5.477	8.300	25.200	16.980	7.910
oma	3.700	12.700	9.840	3.754	9.300	12.800	11.060	1.656	5.300	16.500	12.880	4.355	10.700	16.900	12.950	2.886
herry	0.8000	3.30000	2.10000	1.1023	1.6000	8.1000	4.0600	2.5304	1.8000	5.2000	3.9000	1.4989	4.1000	7.3000	5.6250	1.4818

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

From this study, it can be concluded that there is implication in tomato transportation affected by vehicular vibration which reduce load at break more in the ripe fruits or tomatoes than the unripe ones. The unripe fruit is lightly affected by vibration caused from vehicle movement. But in other words to reduce damage in transit the natural frequency of vibration of the vehicle should be away from that of produce so as to avoid resonance.

From this study, it enables the producer to select which of the vehicle can be used to transport tomato in order to reduce damages and also to select the produce for long distance travel.

5.2 RECOMMENDATION

For better result on this a experiment

1 Different containers should be used to know which of containers will be best for packaging tomato

2 Temperature of the environment where tomatoes is being transported should also be taking into consideration, so as to use refrigerated van or vehicle

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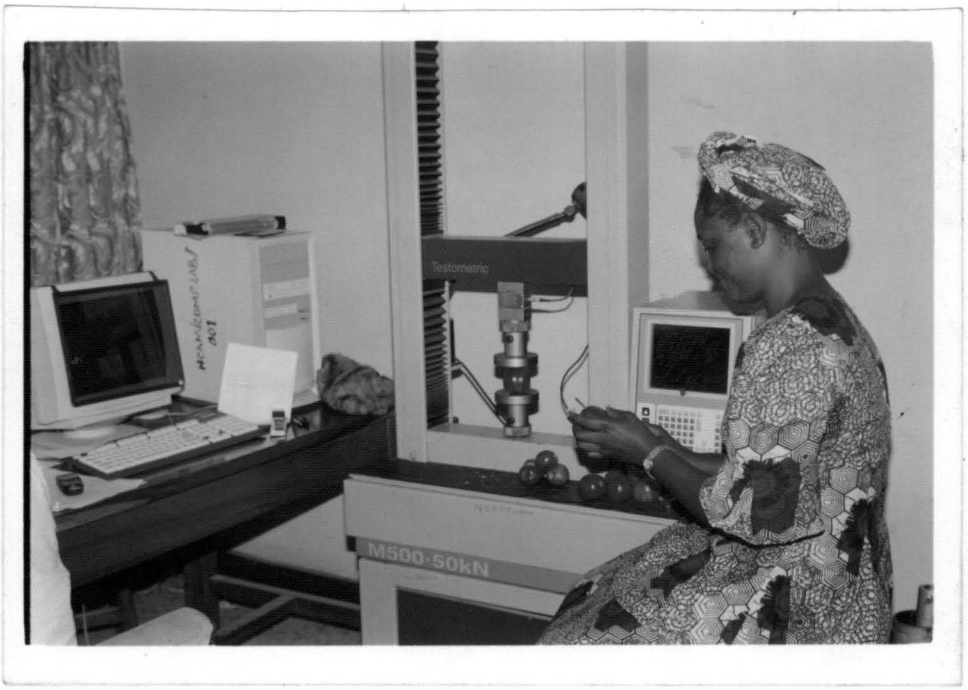
APPENDIX A



TESTOMETRIC UNIVERESAL TESTING (UTM)

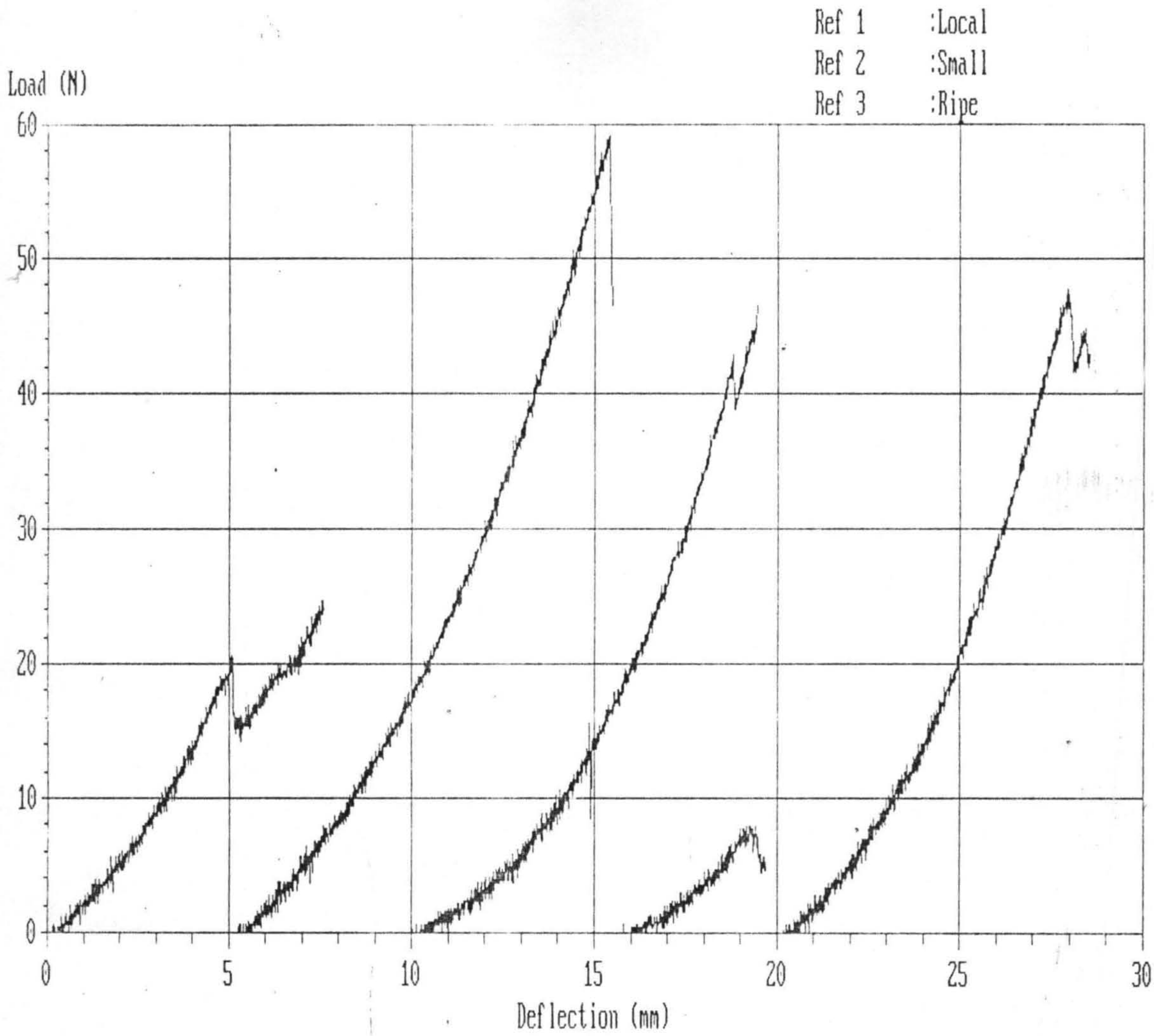
APPEDIX B

Local
Small
Ripe

Test : TOMATOES
Test Type : Compression
Date : 18-01-05
File : C:TOMATOES\TST0015.DAT
Test Speed : 002.50 mm/min
Sample Type : CIRCULAR
Pre-Load : OFF

Height mm	Diameter mm	Load @ Yield N	Def. @ Yield mm	Load @ Break N	Def. @ Break mm	Stress @ Peak N/mm²	Energy @ Peak N.m	Stress @ Break N/mm²	Stress @ Yield N/mm²	[illegible]
30.260	50.900	4.900	1.7730	24.200	7.589	0.0121	0.0866	0.0119	0.0024	0.002
31.370	41.430	12.000	3.6860	47.100	10.487	0.0440	0.2297	0.0349	0.0089	0.016
30.140	44.390	9.300	3.8090	46.500	9.442	0.0300	0.1528	0.0300	0.0060	0.012
28.950	33.890	1.900	1.9260	4.900	4.703	0.0086	0.0079	0.0054	0.0021	0.000
26.180	38.220	9.300	3.0220	42.400	8.518	0.0415	0.1355	0.0370	0.0081	0.010
26.180	33.890	1.900	1.7730	4.900	4.703	0.0086	0.0079	0.0054	0.0021	0.000
29.380	41.766	7.480	2.8432	33.020	8.148	0.0273	0.1225	0.0239	0.0055	0.008
31.370	50.900	12.000	3.8090	47.100	10.487	0.0440	0.2297	0.0370	0.0089	0.016
1.984	6.423	4.026	0.9568	18.279	2.206	0.0163	0.0822	0.0143	0.0032	0.007

Energy @ Break N.m	Def. @ Peak mm	Youngs Modulus N/mm²
0.0877	7.541	0.0708
0.2341	10.404	0.1392
0.1528	9.442	0.1309
0.0112	4.177	0.0861
0.1615	7.924	0.1800
0.0112	4.177	0.0708
0.1295	7.898	0.1214
0.2341	10.404	0.1800
0.0840	2.379	0.0437

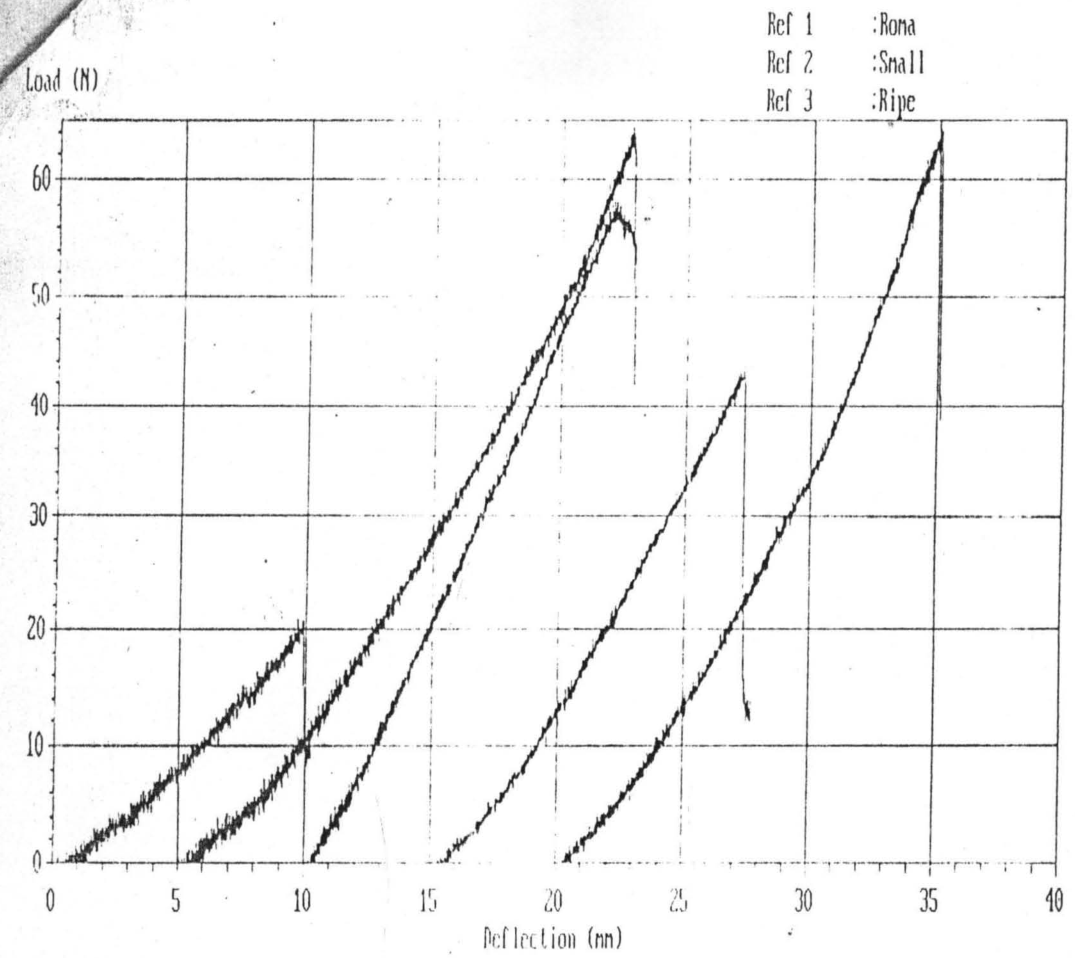

Ref 1 :Local
Ref 2 :Small
Ref 3 :Ripe
Load (N)
60
50
40
30
20
10
0
0
5
10
15
20
25
30
Deflection (mm)

1 : Roma
2 : Small
3 : Ripe
4 :

Test : TOMATOES
Test Type : Compression
Date : 18-01-05
File : C:TOMATOES\TST0018.DAT
Test Speed : 002.50 mm/min
Sample Type : CIRCULAR
Pre Load : OFF

No	Height mm	Diameter mm	Load @ Yield N	[illegible] Yield mm	Load @ Break N	[illegible] Break [illegible]	Stress @ Peak N/mm	Energy @ Peak N.m	Stress @ Break N/mm²	Stress @ Yield N/mm²	Energy @ [illegible]
1	46.220	46.330	3.700	2.6260	9.400	10.250	0.0124	0.0780	0.0056	0.0022	[illegible]
2	42.670	44.420	12.200	[illegible]	41.500	[illegible]	0.0415	0.4585	0.0270	0.0079	[illegible]
3	50.510	46.070	[illegible]	[illegible]	53.600	[illegible]	0.0349	0.3181	0.0322	0.0071	[illegible]
4	46.790	42.620	[illegible]	[illegible]	12.700	12.719	0.0306	0.2245	0.0089	0.0062	[illegible]
5	40.680	42.590	[illegible]	[illegible]	[illegible]	15.172	0.0449	0.3860	0.0276	0.0089	[illegible]
[illegible]	40.680	42.590	3.700	[illegible]	9.400	[illegible]	0.0124	0.0780	0.0056	0.0022	[illegible]
[illegible]	45.374	44.406	9.840	[illegible]	[illegible]	[illegible]	0.0328	0.2930	0.0203	0.0064	[illegible]
[illegible]	50.510	46.330	[illegible]	[illegible]	53.600	[illegible]	0.0449	0.4585	0.0322	0.0089	[illegible]
[illegible]	3.822	1.800	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.1480	0.0121	0.0026	[illegible]

No	Energy @ Break N.m	Def. @ Peak mm	Young's Modulus [illegible]
1	0.0858	9.689	[illegible]
2	0.4671	17.743	[illegible]
3	0.3647	12.067	[illegible]
4	0.2318	12.297	[illegible]
5	0.3907	15.066	[illegible]
[illegible]	0.0858	9.689	[illegible]
[illegible]	0.3080	13.372	0.1160
[illegible]	0.4671	17.743	[illegible]
[illegible]	0.1505	3.098	0.0347

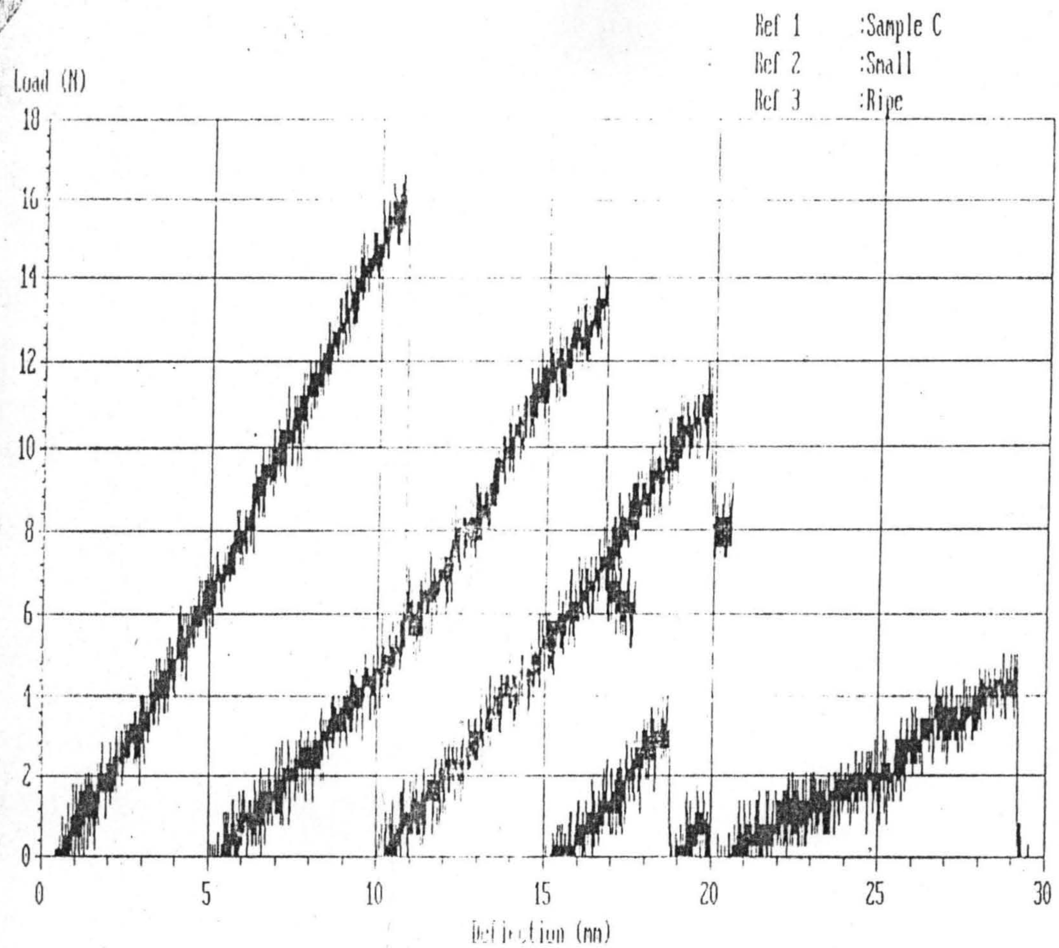

Ref 1 :Roma
Ref 2 :Small
Ref 3 :Ripe
Load (N)
0
10
20
30
40
50
60
0
5
10
15
20
25
30
35
40
Deflection (mm)

1 : Sample C
2 : Small
3 : Ripe
4 :

Test : TOMATOES
Test Type : Compression
Date : 17-02-05
File : C:TOMATOES\TST0021.DAT
Test Speed : 002.50 mm/min
Sample Type : CIRCULAR
Pre-Load : OFF

No.	Height mm	Diameter mm	Load @ Yield N	Def. @ Yield mm	Load @ Break N	Def. @ Break mm	Stress @ Peak N/mm²	Energy @ Peak N.m	Stress @ Break N/mm²	Stress @ Yield N/mm²
1	40.300	24.180	3.3000	2.7840	6.5000	10.942	0.0368	0.0776	0.0142	0.0072
2	49.710	27.810	2.9000	2.1970	6.3000	12.701	0.0235	0.0701	0.0104	0.0048
3	42.810	20.110	2.4000	1.7530	7.6000	10.534	0.0378	0.0506	0.0239	0.0076
4	38.510	23.170	0.8000	0.4260	0.3000	4.995	0.0092	0.0043	0.0007	0.0019
5	54.270	23.720	1.1000	0.8300	0.5000	9.545	0.0113	0.0162	0.0011	0.0025
um	38.510	20.110	0.8000	0.4260	0.5000	4.995	0.0092	0.0043	0.0011	0.0019
	45.120	23.798	2.1000	1.5980	4.0400	9.744	0.0237	0.0437	0.0096	0.0048
um	54.270	27.810	3.3000	2.7840	7.6000	12.701	0.0378	0.0776	0.0239	0.0076
ev	6.653	2.750	1.1023	0.9686	3.8220	2.889	0.0135	0.0324	0.0103	0.0026

No.	Energy @ Break N.m	Def. @ Peak mm	Youngs Modulus N/mm²
1	0.0799	10.712	0.1462
2	0.0777	11.639	0.1056
3	0.0572	9.762	0.1596
4	0.0053	3.545	0.0941
5	0.0180	8.713	0.0615
um	0.0053	3.545	0.0615
	0.0476	8.874	0.1134
um	0.0799	11.639	0.1596
ev	0.0343	3.172	0.0398



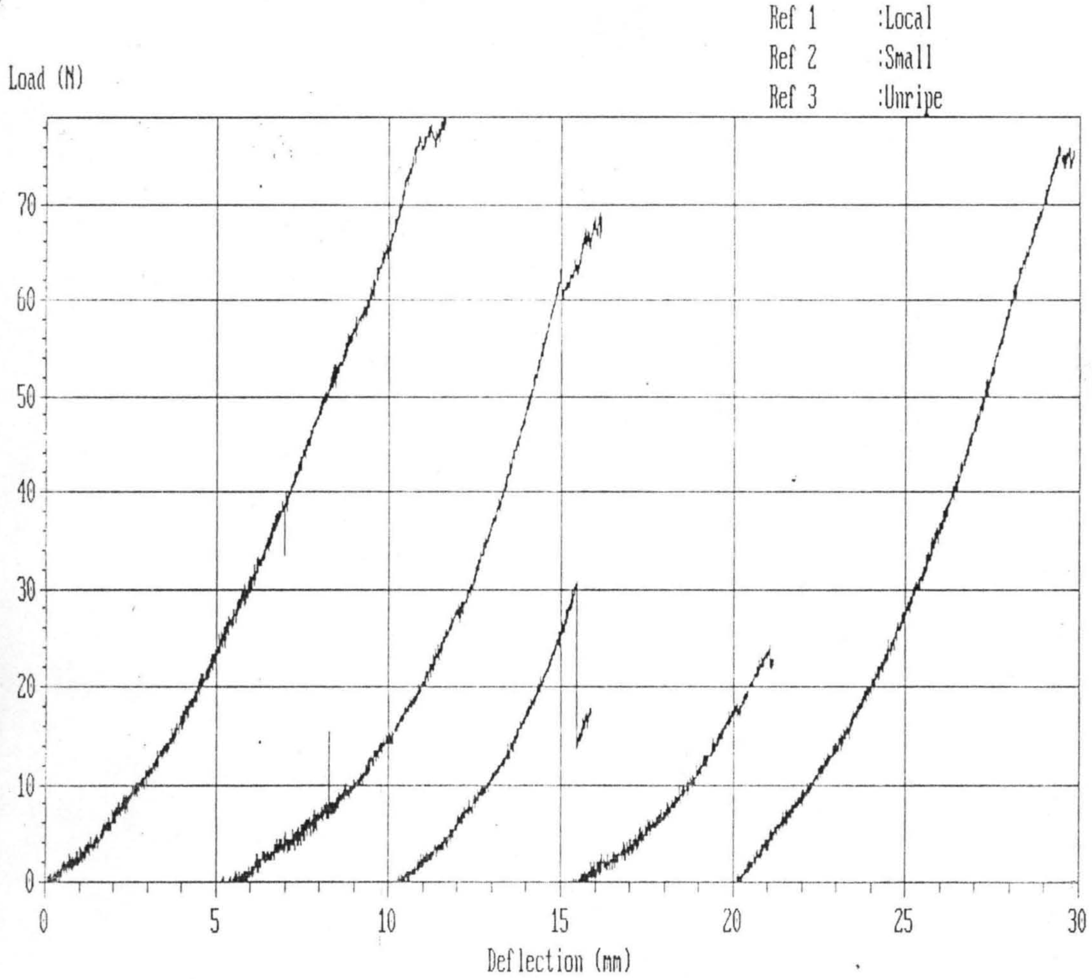
Ref 1 :Sample C
Ref 2 :Small
Ref 3 :Ripe
Load (N)
18
16
14
12
10
8
6
4
2
0
0
5
10
15
20
25
30
Deflection (mm)

ε 1 : Local
ε 2 : Small
ε 3 : Unripe
f 4 :

Test : TOMATOES
Test Type : Compression
Date : 18-01-05
File : C:TOMATOES\TST0016.DAT
Test Speed : 002.50 mm/min
Sample Type : CIRCULAR
Pre-Load : OFF

st No.	Height mm	Diameter mm	Load @ Yield N	Def. @ Yield mm	Load @ Break N	Def. @ Break mm	Stress @ Peak N/mm²	Energy @ Peak N.m	Stress @ Break N/mm²	Stress @ Yield N/mm²	[illegible]
1	25.340	36.740	16.100	3.8660	79.000	11.653	0.0745	0.3813	0.0745	0.0152	0.025
,2	24.180	37.250	15.400	3.2630	67.900	11.168	0.0633	0.2706	0.0623	0.0141	0.005
3	24.610	32.160	6.500	1.9960	17.900	5.895	0.0378	0.0593	0.0220	0.0080	0.004
4	26.550	39.250	4.900	2.1850	22.400	6.156	0.0200	0.0518	0.0185	0.0040	0.002
5	30.050	39.730	15.400	3.2230	75.400	9.825	0.0613	0.2808	0.0608	0.0124	0.022
imum	24.180	32.160	4.900	1.9960	17.900	5.895	0.0200	0.0518	0.0185	0.0040	0.007
n	26.146	37.026	11.660	2.9066	52.520	8.939	0.0514	0.2088	0.0476	0.0108	0.012
imum	30.050	39.730	16.100	3.8660	79.000	11.653	0.0745	0.3813	0.0745	0.0152	0.029
l Dev	2.360	3.003	5.477	0.7902	29.862	2.745	0.0221	0.1464	0.0256	0.0046	0.016

st No.	Energy @ Break N.m	Def. @ Peak mm	Youngs Modulus N/mm²
1	0.3891	11.554	0.1996
2	0.2743	11.113	0.1259
3	0.0665	5.441	0.2062
4	0.0542	6.049	0.1131
5	0.3112	9.418	0.2422
nimum	0.0542	5.441	0.1131
an	0.2191	8.715	0.1774
ximum	0.3891	11.554	0.2422
d Dev	0.1507	2.834	0.0555



Ref 1 :Local
Ref 2 :Small
Ref 3 :Unripe
Load (N)
70
60
50
40
30
20
10
0
0
5
10
15
20
25
30
Deflection (mm)

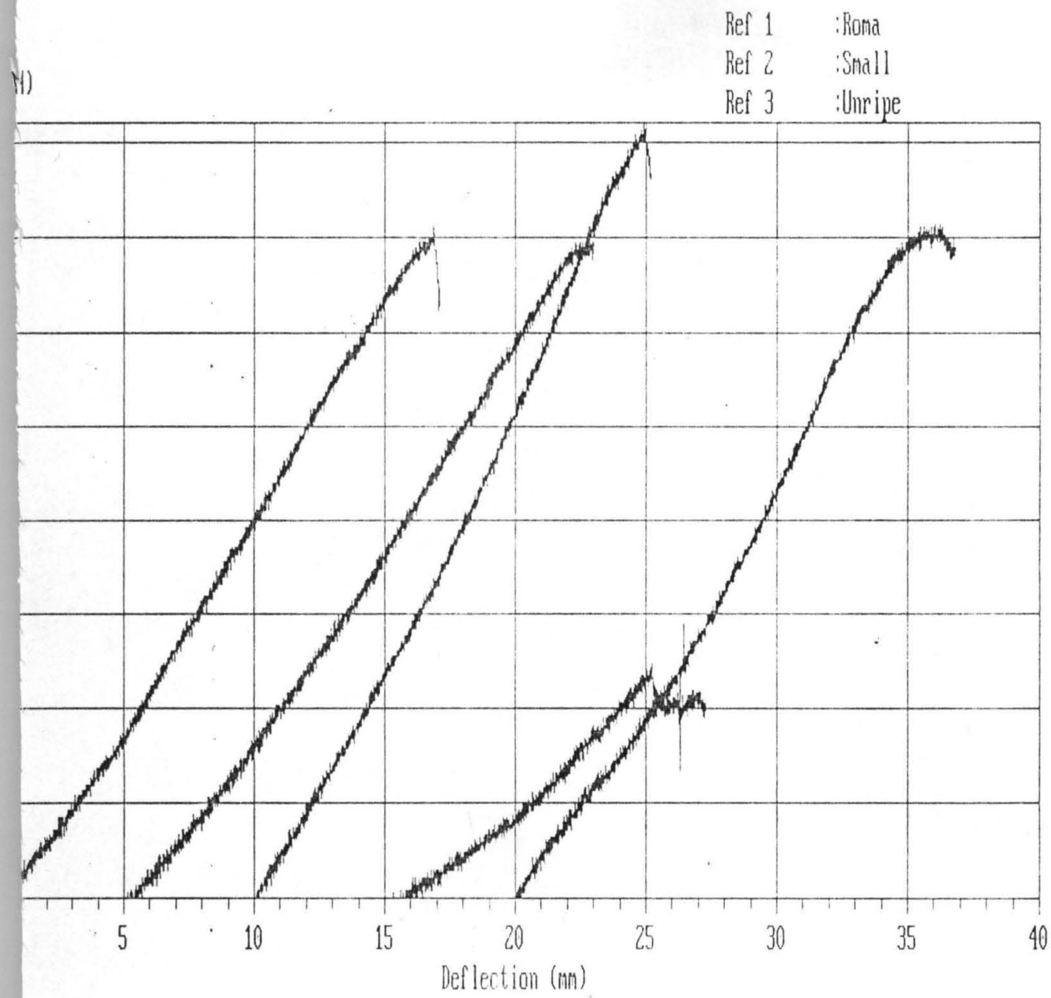
4

1 : Roma
2 : Small
3 : Unripe
4 :

Test : TOMATOES
Test Type : Compression
Date : 18-01-05
File : C:TOMATOES\TST0017.DAT
Test Speed : 002.50 mm/min
Sample Type : CIRCULAR
Pre-Load : OFF

t No.	Height mm	Diameter mm	Load @ Yield N	Def. @ Yield mm	Load @ Break N	Def. @ Break mm	Stress @ Peak N/mm²	Energy @ Peak N.m	Stress @ Break N/mm²	Stress @ Yield N/mm²	[illegible]
1	51.210	40.210	14.300	4.1010	64.700	17.090	0.0559	0.5625	0.0510	0.0113	024
2	54.040	40.750	14.000	4.2750	69.400	18.018	0.0534	0.5807	0.0532	0.0107	024
3	45.030	40.360	16.500	3.5280	76.600	15.204	0.0639	0.5689	0.0599	0.0129	027
4	47.660	39.630	5.300	3.2370	20.000	12.301	0.0199	0.0983	0.0162	0.0043	005
5	45.640	40.630	14.300	3.6970	68.600	16.806	0.0550	0.5565	0.0529	0.0110	.0263
mum	45.030	39.630	5.300	3.2370	20.000	12.301	0.0199	0.0983	0.0162	0.0043	005
	48.716	40.316	12.880	3.7676	59.860	15.884	0.0496	0.4734	0.0466	0.0100	021
mum	54.040	40.750	16.500	4.2750	76.600	18.018	0.0639	0.5807	0.0599	0.0129	025
Dev	3.832	0.439	4.355	0.4221	22.693	2.245	0.0171	0.2099	0.0173	0.0033	009

t No.	Energy @ Break N.m	Def. @ Peak mm	Youngs Modulus N/mm²
1	0.5783	16.855	0.1873
2	0.5970	17.780	0.1798
3	0.5914	14.920	0.2082
4	0.1408	10.224	0.1064
5	0.6093	16.045	0.1827
imum	0.1408	10.224	0.1064
n	0.5033	15.165	0.1729
imum	0.6093	17.780	0.2082
Dev	0.2030	2.956	0.0388

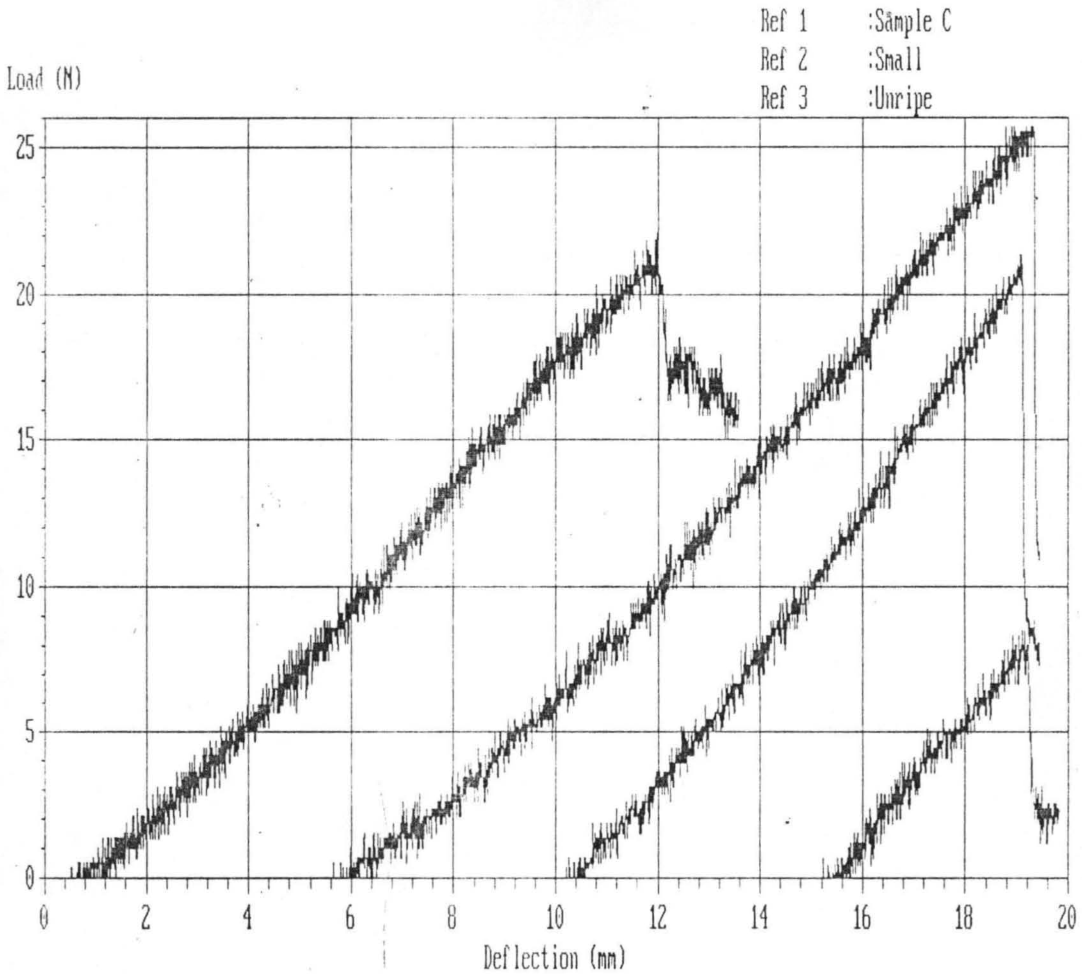

Ref 1 :Roma
Ref 2 :Small
Ref 3 :Unripe
N)
5
10
15
20
25
30
35
40
Deflection (mm)

f 1 : Sample C
f 2 : Small
f 3 : Unripe
f 4 :

Test : TOMATOES
Test Type : Compression
Date : 18-02-05
File : C:TOMATOES\TST0023.DAT
Test Speed : 002.50 mm/min
Sample Type : CIRCULAR
Pre-Load : OFF

st No.	Height mm	Diameter mm	Load @ Yield N	Def. @ Yield mm	Load @ Break N	Def. @ Break mm	Stress @ Peak N/mm²	Energy @ Peak N.m	Stress @ Break N/mm²	Stress @ Yield N/mm²	Energ @ Yie N.m
1	49.810	27.470	4.7000	3.2520	16.300	13.576	0.0373	0.1139	0.0275	0.0079	0.[illegible]
2	45.930	28.960	5,2000	4.0730	11.100	14.447	0.0390	0.1435	0.0169	0.0079	0.006
3	47.700	30.590	3.9000	2.2730	7.300	9.447	0.0290	0.0837	0.0099	0.0053	0.003
4	35.850	24.400	1.8000	1.0460	2.300	4.830	0.0182	0.0140	0.0049	0.0038	0.00[illegible]
imum	35.850	24.400	1.8000	1.0460	2.300	4.830	0.0182	0.0140	0.0049	0.0038	0.000
h	44.823	27.855	3.9000	2.6610	9.250	10.575	0.0309	0.0888	0.0148	0.0062	0.[illegible]
imum	49.810	30.590	5.2000	4.0730	16.300	14.447	0.0390	0.1435	0.0275	0.0079	0.[illegible]
Dev	6.188	2.632	1.4989	1.3041	5.923	4.407	0.0095	0.0555	0.0098	0.0020	0.002

st No.	Energy @ Break N.m	Def. @ Peak mm	Youngs Modulus N/mm²
1	0.1411	11.991	0.1713
2	0.1586	13.796	0.1468
3	0.0879	9.057	0.1637
4	0.0165	4.109	0.1556
imum	0.0165	4.109	0.1468
h	0.1010	9.738	0.1593
imum	0.1586	13.796	0.1713
Dev	0.0639	4.231	0.0106

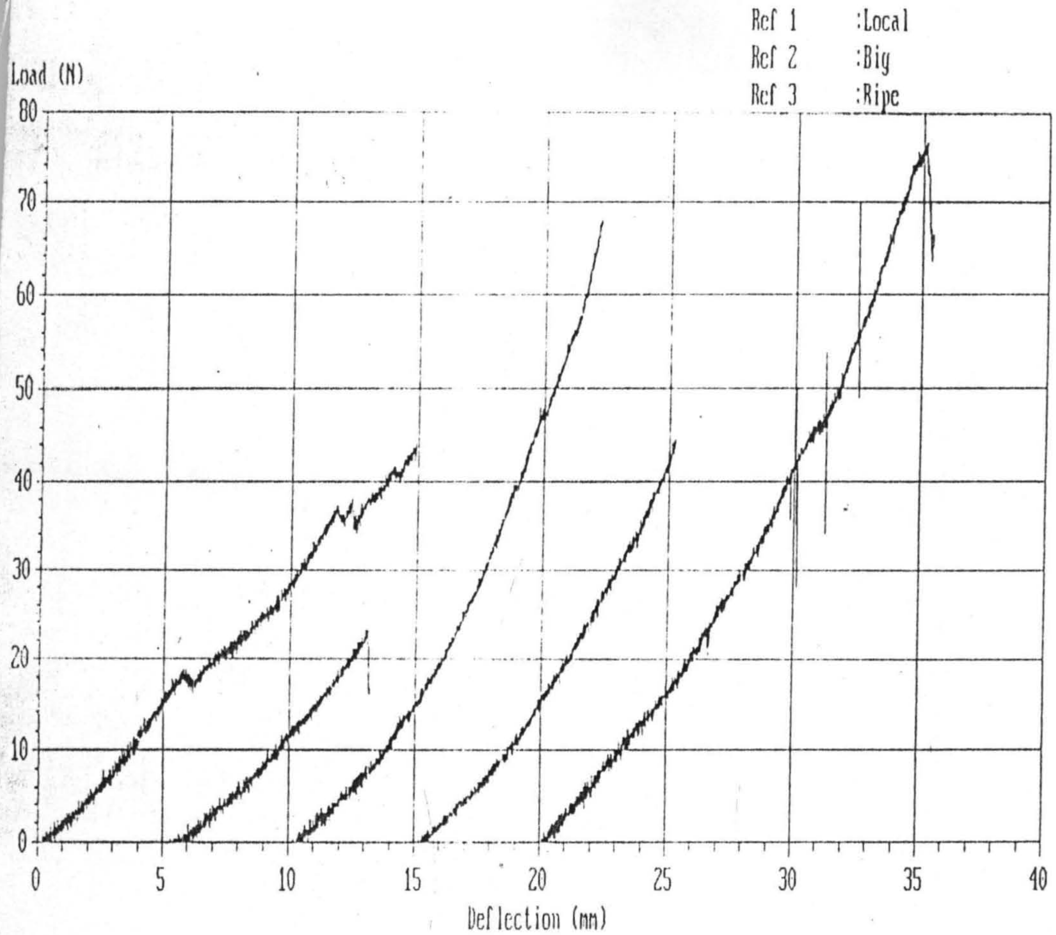

Ref 1 :Sample C
Ref 2 :Small
Ref 3 :Unripe
Load (N)
25
20
15
10
5
0
0
2
4
6
8
10
12
14
16
18
20
Deflection (mm)

ef 1 : Local
ef 2 : Big
ef 3 : Ripe
ef 4 :

Test : TOMATOES
Test Type : Compression
Date : 18-01-05
File : C:TOMATOES\TST0013.DAT
Test Speed : 002.50 mm/min
Sample Type : CIRCULAR
Pre-Load : OFF

est No.	Height mm	Diameter mm	Load @ Yield N	Def. @ Yield mm	Load @ Break N	Def. @ Break mm	Stress @ Peak N/mm²	Energy @ Peak N.m	Stress @ Break N/mm²	Stress @ Yield N/mm²	Ene[illegible] @ Yi[illegible] N.m
1	36.670	50.000	9.100	3.[illegible]230	44.000	14.910	0.0224	0.3155	0.0224	0.0046	0.0112
2	36.990	45.540	4.700	2.5730	15.900	8.200	0.0142	0.0708	0.0098	0.0029	0.0[illegible]4
3	32.420	56.540	13.600	4.1110	67.400	12.203	0.0271	0.3011	0.0268	0.0054	0.0[illegible]3
4	32.910	49.520	9.100	[illegible].2850	43.500	10.256	0.0231	0.1783	0.0226	0.0047	0.0[illegible]3
5	32.770	60.250	15.100	4.[illegible]250	66.100	15.440	0.0269	0.4694	0.0232	0.0053	0.0339
inimum	32.420	45.540	4.700	2.5730	15.900	8.200	0.0142	0.0708	0.0098	0.0029	0.003
ean	34.3[illegible]	52.370	10.320	[illegible]	47.380	12.202	0.0227	0.2670	0.0210	0.0046	0.01[illegible]
aximum	36.990	60.250	15.100	[illegible]	67.400	15.440	0.0271	0.4694	0.0260	0.0054	0.0[illegible]
td Dev	2.272	5.913	4.128	0.89[illegible]	21.028	3.067	0.0052	0.1507	0.0065	0.0010	0.011

Test No.	Energy @ Break N.m	Def. @ Peak mm	Youngs Modulus N/mm
1	0.3157	14.906	0.0552
2	0.0750	7.987	0.0751
3	0.3013	12.199	0.0877
4	0.1802	10.212	0.0830
5	0.4913	15.124	0.0597
inimum	0.0750	7.987	0.0552
ean	0.2727	12.086	0.0721
aximum	0.4913	15.124	0.0877
td Dev	0.1566	3.062	0.0142

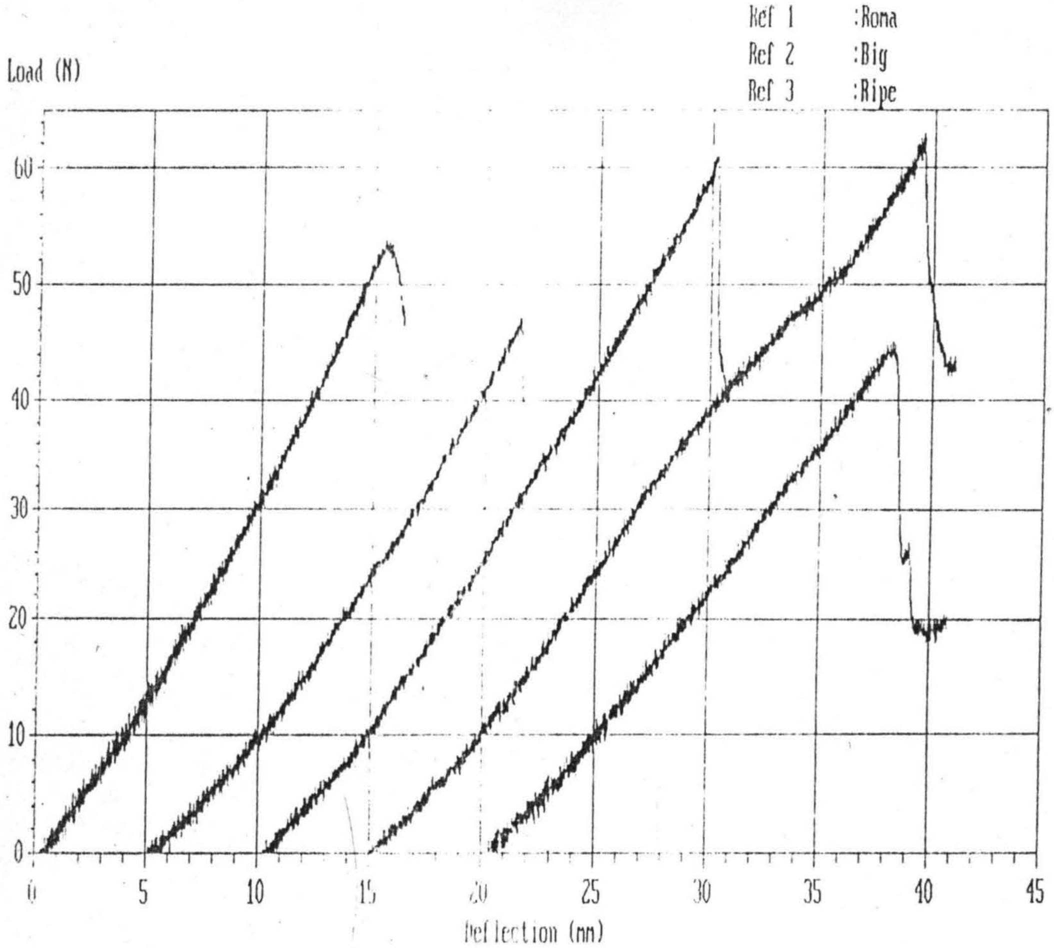

Ref 1 :Local
Ref 2 :Big
Ref 3 :Ripe
Load (N)
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
30
35
40
Deflection (mm)

1 : Roma
2 : Big
3 : Ripe
4 :

Test : TOMATOES
Test Type : Compression
Date : 17-02-05
File : C:TOMATOES\TST0019.DAT
Test Speed : 002.50 mm/min
Sample Type : CIRCULAR
Pre-Load : OFF

No.	Height mm	Diameter mm	Load @ Yield N	Def. @ Yield mm	Load @ Break N	Def. @ Break mm	Stress @ Peak N/mm²	Energy @ Peak N.m	Stress @ Break N/mm²	Stress @ Yield N/mm²	Ene… @ Yi… N…
	64.030	58.600	10.900	[illegible]	47.600	16.303	0.0199	0.3630	0.0176	0.0040	0.01…
2	55.970	56.380	9.600	4.6190	39.000	16.656	0.0189	0.3280	0.0156	0.0038	0.01…
3	56.110	53.050	12.800	5.4990	40.100	20.882	0.0276	0.5433	0.0181	0.0058	0.0…
4	67.450	52.070	12.700	5.6580	43.400	26.079	0.0295	0.7385	0.0204	0.0060	0.03…
5	66.520	49.830	9.300	4.4540	19.700	20.808	0.0231	0.3740	0.0101	0.0048	0.01…
ıum	55.970	49.830	9.300	[illegible]	19.700	16.303	0.0189	0.3280	0.0101	0.0038	0.…
	62.016	53.986	11.060	4.8620	37.960	20.146	0.0238	0.4694	0.0164	0.0049	0.02
ıum	67.450	58.600	12.800	5.6580	47.600	26.079	0.0295	0.7385	0.0204	0.0060	0.03…
ev	5.597	3.494	1.656	0.6909	10.743	3.973	0.0047	0.1720	0.0039	0.0010	0.0…

No.	Energy @ Break N.m	Def. @ Peak mm	Youngs Modulus N/mm²
1	0.4079	15.424	0.0916
2	0.3368	16.459	[illegible]
3	0.5767	20.165	0.0840
4	0.8104	24.543	0.0958
5	0.4369	18.200	0.0910
mum	0.3368	15.424	0.0720
n	0.5138	18.958	0.0869
mum	0.8104	24.543	0.0958
Dev	0.1873	3.604	0.0093



Ref 1 :Roma
Ref 2 :Big
Ref 3 :Ripe
Load (N)
0
10
20
30
40
50
60
0
5
10
15
20
25
30
35
40
45
Deflection (mm)

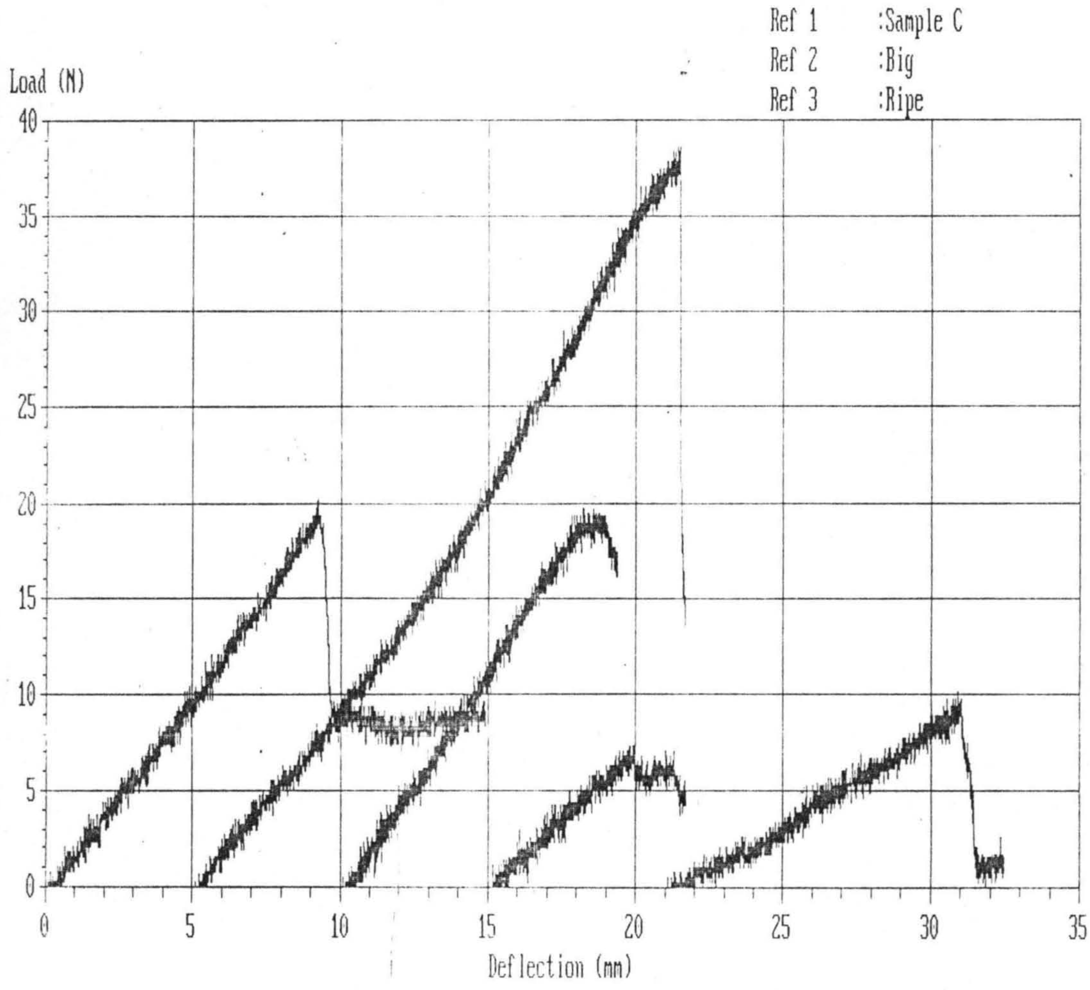
11

: Sample C
: Big
: Ripe
:

Test : TOMATOES
Test Type : Compression
Date : 17-02-05
File : C:TOMATOES\TST0020.DAT
Test Speed : 002.50 mm/min
Sample Type : CIRCULAR
Pre-Load : OFF

.	Height mm	Diameter mm	Load @ Yield N	Def. @ Yield mm	Load @ Break N	Def. @ Break mm	Stress @ Peak N/mm²	Energy @ Peak N.m	Stress @ Break N/mm²	Stress @ Yield N/mm²	Energ @ Yie N.m
	52.740	38.020	4.4000	1.9700	8.900	14.932	0.0178	0.0825	0.0078	0.0039	[illegible]
	48.680	35.040	8.1000	4.0320	13.600	16.680	0.0400	0.2819	0.0141	0.0084	[illegible]
	56.600	36.340	3.9000	1.5950	17.200	9.411	0.0191	0.0735	0.0166	0.0038	[illegible]
	47.620	34.120	1.6000	0.6890	5.000	6.709	0.0080	0.0154	0.0055	0.0017	0.000
	61.470	35.180	2.3000	3.3960	1.500	12.461	0.0104	0.0388	0.0015	0.0024	0.000
	47.620	34.120	1.6000	0.6890	1.500	6.709	0.0080	0.0154	0.0015	0.0017	0.000
	53.422	35.740	4.0600	2.3364	9.240	12.039	0.0191	0.0984	0.0091	0.0040	[illegible]
	61.470	38.020	8.1000	4.0320	17.200	16.680	0.0400	0.2819	0.0166	0.0084	[illegible]
	5.733	1.499	2.5304	1.3597	6.332	4.044	0.0126	0.1061	0.0062	0.0026	[illegible]

No.	Energy @ Break N.m	Def. @ Peak mm	Youngs Modulus N/mm²
	0.1344	9.224	0.1009
	0.2883	16.419	0.1304
	0.0959	8.194	0.1338
	0.0264	4.784	0.0738
	0.0438	10.903	0.0640
um	0.0264	4.784	0.0640
	0.1178	9.905	0.1006
um	0.2883	16.419	0.1338
ev	0.1045	4.273	0.0318



Ref 1 :Sample C
Ref 2 :Big
Ref 3 :Ripe
Load (N)
40
35
30
25
20
15
10
5
0
0
5
10
15
20
25
30
35
Deflection (mm)

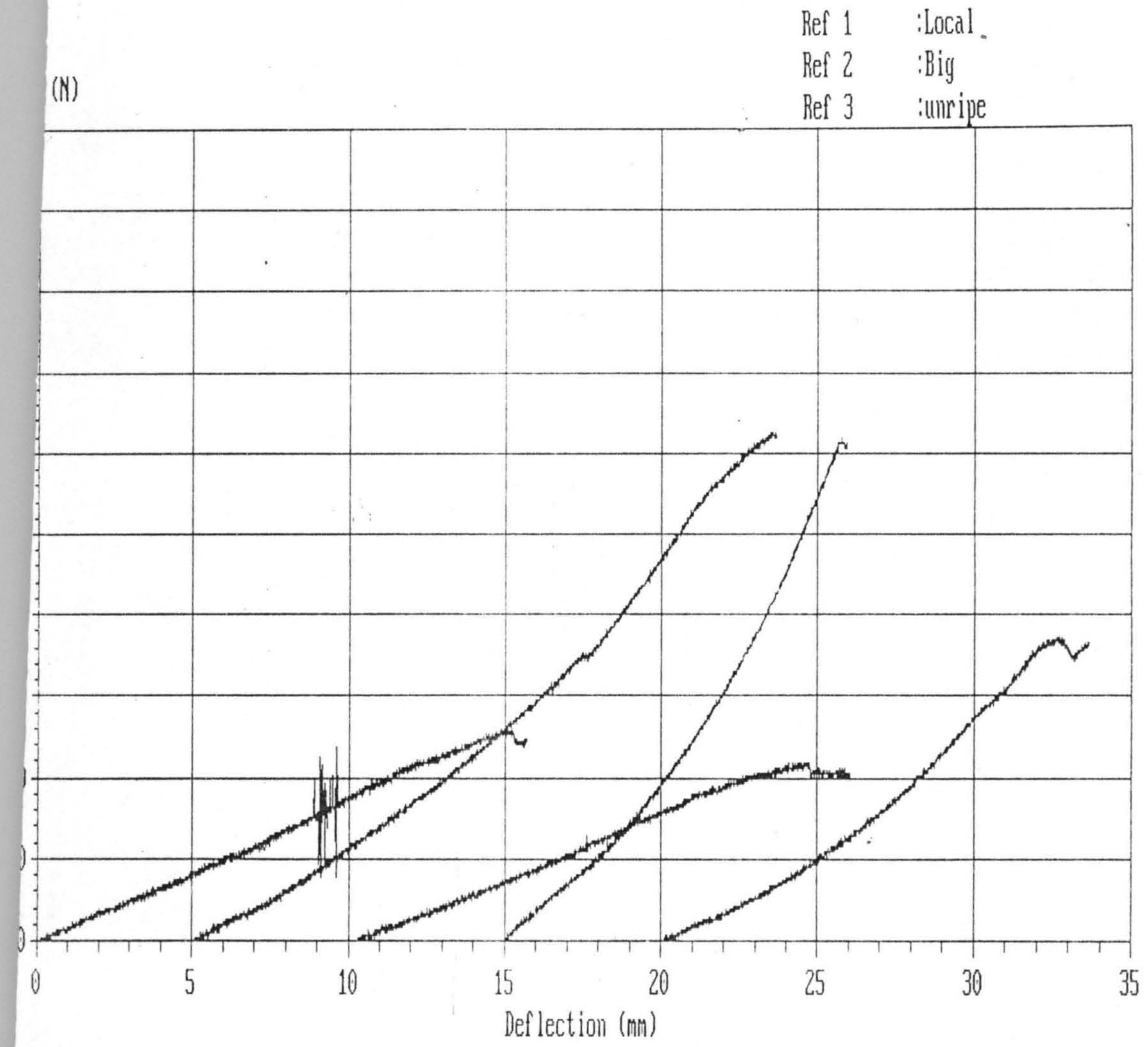
8

ocal
ig
nripe

Test : TOMATOES
Test Type : Compression
Date : 18-01-05
File : C:TOMATOES\TST0014.DAT
Test Speed : 002.50 mm/min
Sample Type : CIRCULAR
Pre-Load : OFF

eight mm	Diameter mm	Load @ Yield N	Def. @ Yield mm	Load @ Break N	Def. @ Break mm	Stress @ Peak N/mm²	Energy @ Peak N.m	Stress @ Break N/mm²	Stress @ Yield N/mm²	[illegible] N.m
1.120	59.250	10.900	3.2460	48.80	15.712	0.0189	0.3795	0.0177	0.0040	0.016
1.120	60.160	25.200	5.4250	123.70	18.674	0.0440	0.9763	0.0435	0.0089	0.060
2.560	50.160	8.300	3.0560	40.30	16.039	0.0222	0.2964	0.0204	0.0042	0.011
5.120	50.160	25.200	3.5610	121.20	10.942	0.0624	0.5244	0.0613	0.0128	0.043
0.770	53.320	15.300	4.0080	72.40	13.663	0.0334	0.3899	0.0324	0.0069	0.026
0.770	50.160	8.300	3.0560	40.30	10.942	0.0189	0.2964	0.0177	0.0040	0.011
4.138	54.610	16.980	3.8592	81.28	15.006	0.0362	0.5133	0.0351	0.0073	0.032
5.120	60.160	25.200	5.4250	123.70	18.674	0.0624	0.9763	0.0613	0.0128	0.060
6.178	4.837	7.910	0.9466	39.39	2.887	0.0177	0.2714	0.0179	0.0036	0.020

nergy Break N.m	Def. @ Peak mm	Youngs Modulus N/mm²
.4158	14.979	0.0544
.9947	18.526	0.0928
.3787	14.063	0.0724
.5468	10.758	0.2939
.4644	12.623	0.1313
.3787	10.758	0.0544
.5601	14.190	0.1289
.9947	18.526	0.2939
.2510	2.901	0.0965



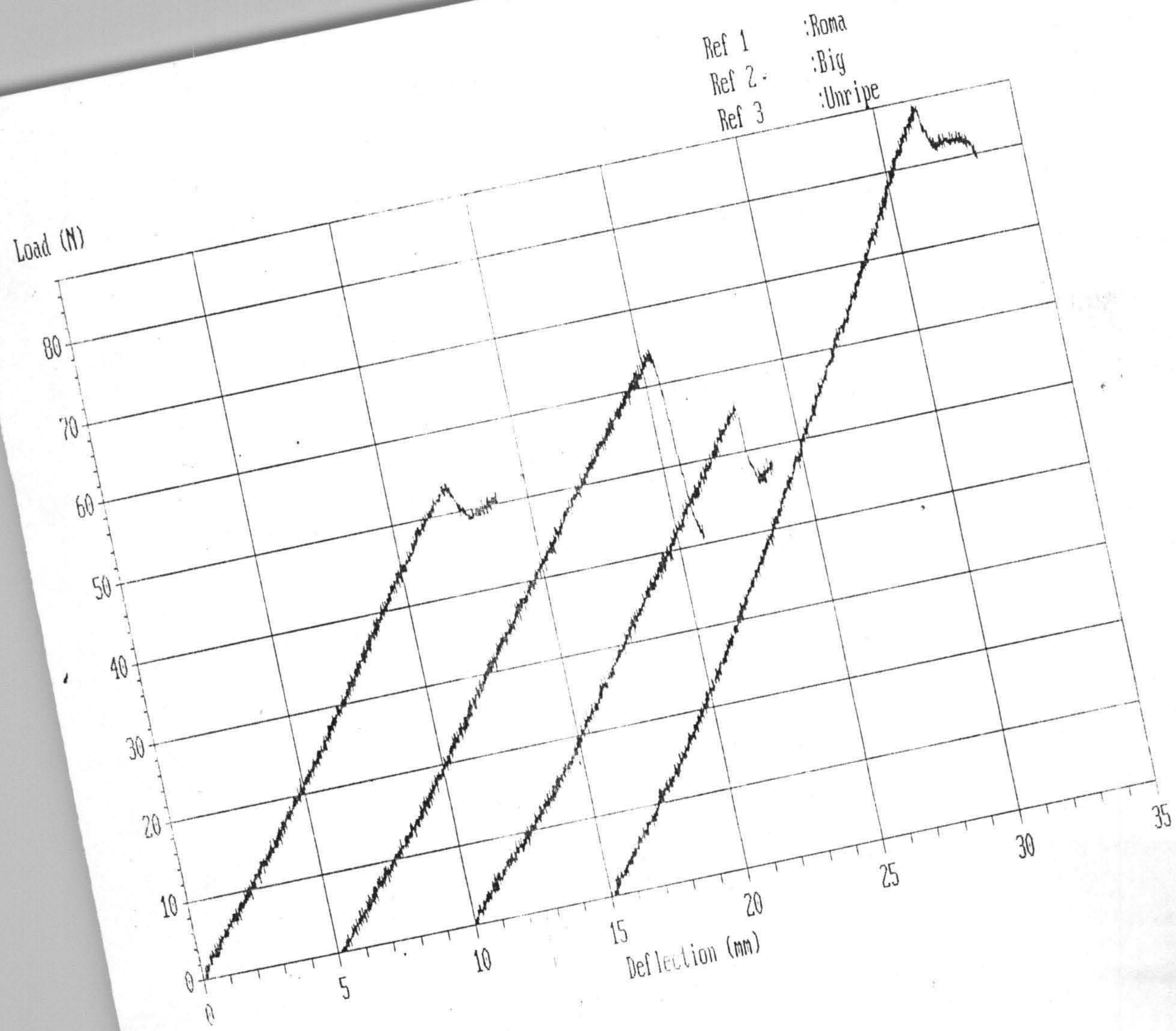
Ref 1 :Local
Ref 2 :Big
Ref 3 :unripe
(N)
0
5
10
15
20
25
30
35
Deflection (mm)

Test : TOMATOES
Test Type : Compression
Date : 18-02-05
File : C:TOMATOES\TST0024.DAT
Test Speed : 002.50 mm/min
Sample Type : CIRCULAR
Pre-Load : OFF

1 : Roma
2 : Big
3 : Unripe
4 :

No.	Height mm	Diameter mm	Load @ Yield N	Def. @ Yield mm	Load @ Break N	Def. @ Break mm	Stress @ Peak N/mm²	Energy @ Peak N.m	Stress @ Break N/mm²	Stress @ Yield N/mm²	Energ @ Yie N.m
1	62.750	58.180	10.900	2.4320	50.700	13.900	0.0202	0.3154	0.0191	0.0041	[illegible]
2	60.210	54.810	13.300	3.4160	40.800	15.944	0.0274	0.4795	0.0173	0.0056	0.020
3	64.950	56.140	10.700	2.8910	47.900	13.878	0.0227	0.3452	0.0194	0.0043	[illegible]
4	60.520	53.980	16.900	3.9000	79.300	18.323	0.0382	0.6596	0.0347	0.0074	0.031
mum	60.210	53.980	10.700	2.4320	40.800	13.878	0.0202	0.3154	0.0173	0.0041	0.013
	62.108	55.778	12.950	3.1597	54.675	15.511	0.0271	0.4499	0.0226	0.0054	0.020
mum	64.950	58.180	16.900	3.9000	79.300	18.323	0.0382	0.6596	0.0347	0.0074	0.031
Dev	2.207	1.832	2.886	0.6365	16.937	2.110	0.0080	0.1569	0.0081	0.0015	0.008

t No.	Energy @ Break N.m	Def. @ Peak mm	Youngs Modulus N/mm²
1	0.4087	12.047	0.1073
2	0.5125	15.301	0.1105
3	0.3890	12.958	0.1179
4	0.8203	16.379	0.1472
imum	0.3890	12.047	0.1073
n	0.5326	14.171	0.1207
imum	0.8203	16.379	0.1472
Dev	0.1993	2.011	0.0182



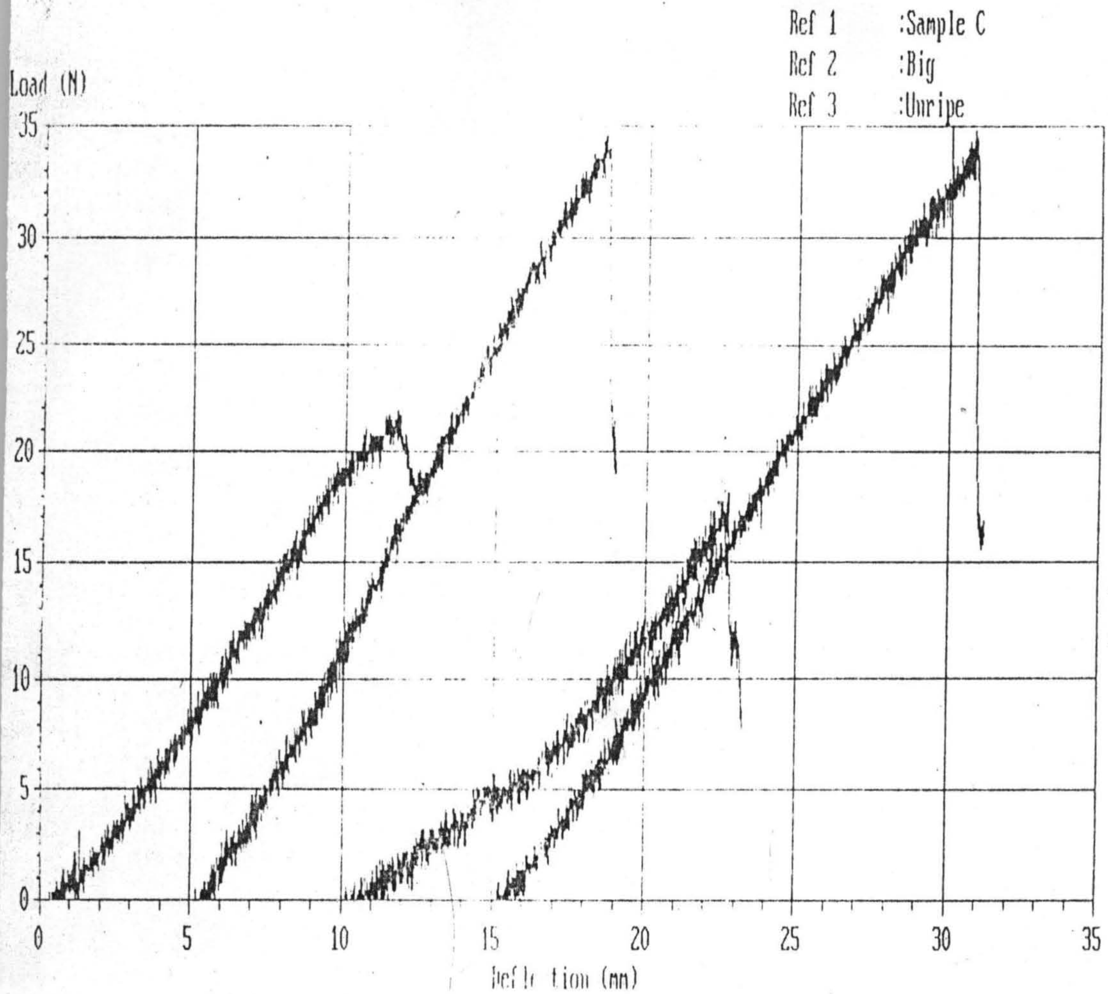
Ref 1 :Roma
Ref 2 :Big
Ref 3 :Unripe
Load (N)
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
30
35
Deflection (mm)

Test : TOMATOES
Test Type : Compression
Date : 17-02-05
File : C:TOMATOES\TST0022.DAT
Test Speed : 002.50 mm/min
Sample Type : CIRCULAR
Pre-Load : OFF

: Sample C
: Big
: Unripe
:

No.	Height mm	Diameter mm	Load @ Yield N	Def. @ Yield mm	Load @ Break N	Def. @ Break mm	Stress @ Peak N/mm²	Energy @ Peak N.m	Stress @ Break N/mm²	Stress @ Yield N/mm²	Energy @ Yield N.m
1	50.440	37.500	4.7000	2.8390	18.400	12.518	0.0198	0.1171	0.0167	0.0043	[illegible]
2	45.050	33.330	7.3000	3.1490	19.000	13.985	0.0399	0.2242	0.0218	0.0084	[illegible]
3	47.620	32.730	4.1000	3.4510	8.300	13.228	0.0215	0.0859	0.0099	0.0049	[illegible]
4	50.740	34.370	6.4000	3.7600	16.400	16.219	0.0375	0.2563	0.0177	0.0069	[illegible]
Minimum	45.050	32.730	4.1000	2.8390	8.300	12.518	0.0198	0.0859	0.0099	0.0043	[illegible]
Mean	48.463	34.482	5.6250	3.2998	15.525	13.988	0.0297	0.1709	0.0165	0.0061	[illegible]
Maximum	50.740	37.500	7.3000	3.7600	19.000	16.219	0.0399	0.2563	0.0218	0.0084	[illegible]
S.Dev	2.674	2.123	1.4818	0.3967	4.941	1.604	0.0105	0.0822	0.0049	0.0019	[illegible]

No.	Energy @ Break N.m	Def. @ Peak mm	Youngs Modulus N/mm²
1	0.1333	11.685	0.0983
2	0.2312	13.671	0.1401
3	0.0926	12.673	0.0872
4	0.2652	15.807	0.1272
Minimum	0.0926	11.685	0.0872
Mean	0.1806	13.459	0.1132
Maximum	0.2652	15.807	0.1401
S.Dev	0.0811	1.763	0.0246



Ref 1 :Sample C
Ref 2 :Big
Ref 3 :Unripe
Load (N)
35
30
25
20
15
10
5
0
0
5
10
15
20
25
30
35
Deflection (mm)