DETERMINATION OF NATURAL FREQUENCY OF TOMATO

By

OKPALA ONYINYE

97/6116EA

BEING A FINAL YEAR PROJECT SUBMITTED TO THE DEPARTMENT OF AGRICULTURAL ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLOGY MINNA, IN PARTIAL FULFILLMENT FOR THE AWARD OF BACHELOR OF ENGINEERING.

October, 2003

CERTIFICATION

This is to certify that this project was carried out by Okpala Onyinye L. in the Department of Agricultural Engineering, Federal University of Technology, Minna.

....

Engr. P.A. Idah
Project Supervisor

03/12/03
....
Date

....
Engr. (Dr.) D. Adgidzi
(Head of Department)

03/12-03
....
Date

....
External Supervisor

28/11/03
....
Date

DEDICATION

I dedicate this project to God Almighty, who gave me the well-with-all to fulfil this dream.

To my parents Mr. and Mrs. E.C Okpala and the educationally less privileged.

ACKNOWLEDGEMENT

All praise belong to Almighty God for his mercy, guidance and protection throughout my stay in this school.

I thank my lecturers, who have impacted knowledge in me, my supervisor Engr. P. Idah for his kind support and constructive criticism on subject matters which helped to bring out the best in this research work.

To my parents Mr. and Mrs. Emmanuel and Rose Okpala for the love in all aspect to see to the success of my education. I am ever grateful and God will reward you. To my siblings Chigo, Obi, Chy, C.K and all my relatives that have been showing concern to my success in life, I appreciate you all.

My friends Hauwa, Chioma, Ify, Chacha, Emma, Izu, J.B, Tunde, Uche and the rest of my friends and colleagues, thanks for being there for me. Also my heartfelt gratitude to Bright Owiriwa, for his inspiration and love. I really do appreciate.

And finally to God most high, who in his infinite mercy and love, this study was accomplished.

Abstract

This project involves the determination of the natural frequency of three tomato varieties namely roma, chico and cherry at green and fully ripe stages of maturity. This was carried out using a loading device for compression test from which the modulus of elasticity was determined. The masses of the samples were categorized into four groups which were M_1 (Mass < 30g), M_2 (31g – 41g), M_3 (42g – 52g) and M_4 (Mass > 53g). The experiment was conducted by subjecting each of the samples to compression test using the loading device. The results shows that the average natural frequencies of the three tomato varieties at green stage of maturity were: cherry (13.242Hz), chico (14.6615Hz) and roma (14.1965). While the value for the fully riped samples were: cherry (9.097Hz), chico (14.8615Hz) and roma (17.6125Hz).

The data obtained were statistically analyzed. From the analysis of variance, certain observations were provided. It was noticed that mass and variety do not have any significant effect on the natural frequency of tomato at green maturity stage. The results also showed that at fully ripe maturity stage, variety do not have any significant effect on the natural frequency. However, masses of the sample seem to significantly influence the natural frequency of the fully ripe samples.

From the observations made, the firmness values of the three tomato varieties showed that roma variety has the highest firmness values at both green and ripe stages of maturity, when compared with cherry and chico varieties. This showed that roma is most suitable for long distance handling.

These precise data could be used to design suitable post harvest handling materials, which will enhance the quality of tomato fresh produce even to the end consumer.

TABLE OF CONTENTS

Chapter Four

Results and Discussion

Chapter Five

Conclusion and Recommendation

LIST OF FIGURES

LIST OF TABLES

CHAPTER ONE

INTRODUCTION

The vast and varied agro- ecological zones of this country stretching from the coastal area to the sub-sahelian region in the north favour the growth and production of a wide variety of horticultural crop which include carrot, lettuce, cabbage, tomatoes, okra, pepper e.t.c. They contain high moisture content ranging from 75% to 90% and also soft tissues, which make them susceptible to spoilage and damage during handling(Singh and Singh, 1999). They are thus perishable and deteriorate fast losing their intrinsic values. The losses could be biological, physiological, chemical and mechanical or combination of these, but mechanical damage constitutes the major (Olorunda and Tung, 1985).

Tomato (Lycopersicon esculentum) is a fresh berry-shaped fruit, which is depressed at both ends. It is green when mature and turn yellow or red when ripe. It belongs to the solanacea family. It was probably introduced into West Africa by the Portuguese trade mission and freed slaves from the West Indies or by the Europeans merchants and colonial masters (Villareal 1980). From southern Nigeria, the crop spread to other parts including the northern parts of the country and has now become an integral part of the diet of most Nigerians. The domesticated tomato is one of the world's most important food crops and its annual production is estimated to exceed $6x10^6$ tonnes (Macrae et al, 1997).

In the tropics, vegetable production forms 25% of the most minor food crops (Kra and Bani 1998). In Nigeria, enormous quantities of fruits and vegetable are produced and staggering figures are sometimes given as estimated annual production (Oyeniran 1988). An estimated 225,000 tons of tomato were produced yearly on 25,000ha between 1973-1977(Villareal 1980). Another production estimate was put at 600,000 tonnes from 50,000ha (federal Office of Statistics

Lagos,1985) as reported by Erinle (1985). Large quantities of tomatoes are produced all over Nigeria at different periods of the year.

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 given information 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 etc. 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 o the influence of minimum stress in the mechanical properties of tissues, which, requires the detection, and evaluation of such damages using special techniques and instrumentation(Moshenin 1988).

Assessing the impact and compression loads o tomato fruits can produce 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.

1.1 Areas of Producion and Utilisation

Tomato is produced mostly under irrigation in the major production areas of Nigeria. Tomato is principally cultivated in Southwestern and Northern part of Nigeria between latitudes 10^0N and 12^03^0'N in the Northern Guinea and Sudan savanna ecological zones. These areas are characterized by a district wet season from either April or May to September or October and a distinct dry season from October to March when production is possible only under irrigation(Quinn,1974).

The production areas are Sokoto, Kano, Kebbi, Kaduna and Jos areass of the Northern region. While Ibadan, Ogbomosho, Oyo, Ilorin, Edo areas of the Southwestern region of production (Erinle, 1989).

The fruit in these areas (northern) are harvested between March and May. The product under rainfall system is low and this is common in the southern part of Nigeria. Tomato in the southern part is harvested between September and October.

1.2 Importance of Tomato

Tomato is an indispensable constituent of the daily diet of over 100million Nigerians. It is widely consumed throughout Nigeria as soup and stew, which give essential complements to staple, based on cereals and root crops. Only a small portion of tomato crop is eaten raw.

Tomato fruit contain essential nutrients (minerals, vitamins, liquids, protein, fibre) e.t.c and its health benefit are numerous: Lycopene, a tomato constituent is a powerful anticancer properties, tomato helps to eliminate toxins in the body (USDA researchers 1997).

Economically, as an important vegetable, tomato fruit, which is in large quantity, enhance North-south trade (Erinle 1989). In addition tomato seeds contain 24% of oil and the press cake residue is also a source of animal feed and fertilizer.

1.3 Statement of Problem

As earlier stated above, tomato production especially the roma variety takes place under irrigation in the north, but the consumers are scattered all over the country. Transportation and distribution is therefore crucial.

One problem in production and handling of agricultural products especially, fruits and vegetable product is mechanical damage to the crops during harvesting and subsequent

Handling fruits and vegetables like tomato is highly susceptible to damages like bruises, puncture, cut e.t.c. Damage is the failure of the product under the excessive deformation when it is forced through given clearance force when it is subjected to impact.

Several factors are responsible for these damages and subsequent losses. They include the packaging containers, vehicle being used and the bad roads on which the produce are handled during distribution.

About 99% of the farmers package harvested tomato fruits in baskets made from palm fronds (Jonah et al, 1996, Williams, 1998). The baskets serve the purpose of handling and transporting the fruits and also as measure of sale. The baskets loads of the produce are usually transported in pick up van to central markets where traders from other parts of the country buy and transport to other parts. The long distance trips across the country are carried out using lorries, fuel, tankers e.t.c. Dry grasses are used to cushion the packed fruits in the baskets. Traders do acknowledge that about 45% loss in quality of the fruits do occur before the fruits reach the destination (Williams, 1998). The loss occur through the compression of the baskets,, as they are stacked in the lorries.

The vibration of the vehicles as they transverse potholes and bumps on the roads transmit further impacts on the produce. The damage to the produce is brought about when resonance occurs.

Resonance is a phenomenon which occurs whenever a particular body or system is set in oscillation at its own natural frequency as a result of impulses or signals received from some other system which is vibrating with the same frequency. When this happens, the amplitude of vibration will increase without bound and is governed only by the amount of damping present in the system. Therefore, in order to avoid disastrous effects resulting from very large amplitude of vibration at resonance, the natural frequency must be properly taken car of.

The problem of fresh produce damage during transportation can be studied from the context of this vibration theory. Based upon this, it will be possible to reduce the damage by avoiding resonance vibration. It is desirable to determine the natural frequency of the types of tomato fruits grown and handled in Nigeria.

1.4 Objectives

The broad objectives of this study are to reduce losses in fresh tomatoes from mechanical damage during transport. The specific objectives are;

(1) To determine the modulus of elasticity of tomato fruit commonly handled.

(2) To determine the natural frequency of vibration, which could be employed in reducing in transit damage by selecting appropriate transport speed.

1.5 Justification

This study is aimed at providing some basic information to prevent or reduce damages during handling. Most of the damages result from compression forces, due to applied pressure of load from standing. Other factors responsible for the damage are vibration and impact. During transport, if the resonance

frequency of the road or vehicle, then the acceleration of the fruit will increase considerably owing to resonance and the fruit will be damaged (Ogut et al, 1999). The resonance frequency of the produce in a container can be determined if the modulus of elasticity is known. Hence the need for this study.

Tomato production is very important and large quantities of this fruit are produced yearly. There is need to improve on the quality of the produce and reduce the losses being incurred. This will enhance further production. The benefits accruing from this cannot be overemphasized. A profitable assessments of tomato produced under Fadama Development Programme in Kaduna state where single descriptive statistics and farm budgeting techniques were used for the analysis was carried out. The results show that total production cost per hectare for tomato was ₦ 55,967.60 and the total revenue per hectare was ₦ 110,160.00. The net farm profit per hectare was ₦ 54,192.40 while the average profit per hectare was ₦ 45,654 (Alamu et al, 2002).

The tomato production trend in Nigeria evaluated in 1997 was;

Production (100 tonnes) =570

Yield kg/ha =10,364

Area harvested (1000 ha) =55

(Coker, 2002)

These figures clearly reviewed that the business of tomato production is not only profitable, but that there are rooms for increase in production if the quality of the produce can be maintained especially during the distribution and marketing.

This study is important as it gives insight into the factors that can affect the qualities like firmness, appearance, shape, texture e.t.c. of the fruits.

CHAPTER TWO

LITERATURE REVIEW

2.1 Tomato Production

Large quantities of fresh tomatoes are produced all over Nigeria. The production figures for various well known fruits and leaf vegetables in Nigeria as recorded in the 1995 annual Abstract of statistics of Federal Office of Statistics are given in Table 2.1 (Daramola 1998, Williams, 1998).

Fruits / vegetables	**Area 1000Ha**	**Production Figure (1000 Tonnes)**
Tomatoes	2448	1850
Pepper	1240	920
Onion	250	610
Mango	520	1300
Pineapple	120	360
Guava	102	70
Plantain	2004	3075
Banana	420	1620
Pawpaw	200	96
Cashew nut	150	216
Leaf vegetable	2760	980

(Daramola, 1998).

Looking at this production figures, it is clear that a great economic potential abounds in the area of this horticultural produce.

2.2 Post Harvest Losses of Fresh Produce

While empirical data are in most cases unavailable on the degree or level of losses incurred on some specific fruits and vegetables in Nigeria, the observed annual and/or seasonal losses in tomatoes, mangoes, sweet orange, plantain and bananas, leaf vegetables etc across the country showed a source of major concern to many Nigerians. Theses losses when translated to naira and kobo, will surely run into millions of naira (Daramola and Okoye, 1998). The complex and long chain of marketing systems of fruits and vegetables between the producer and consumer makes it difficult to accurately access the level of damage in many of the crops including tomatoes. However, some tomato farmers revealed that a loss of about 60% of the tomato fruits they produced do occur (Daramola, 1998). This loss is attributed to inadequate facilities for transportation, packaging, processing and storage. It is revealed FAO (1977) that fruits and vegetable loss in less developed countries of the world is of the range of 20 – 80% for bananas, 35 – 100% for plantain, 22 – 33% for citrus, 49 – 100% for pawpaw, 16 – 35% for onions and 20 – 50% for tomatoes. These figures represents ranges among the third world countries and when translated to loss in food value and cash, they are colossal and therefore, deserve very serious attention. The report also showed that the Nigerian fruits and vegetables have not been able to meet the world standard and the main reason being the poor post harvest handling of these commodities. Several factors are responsible for these losses. They include the properties of the produce, packaging materials, transport routes, vehicles and handling techniques.

A brief review of these factors and how they affect the produce quality is presented below.

2.3 Properties of Tomato Produce as Related To Handling

2.3.1 Physical Properties of Tomato Fruits

The physical properties of fresh tomato fruits are critical in assessing the fruit quality. These properties determine the consumers' preference or choice. These properties are the external colour, shape, size, texture, smoothness, firmness etc.

The fruit quality is mostly determined by the appearance of the skin colour. The skin colour which is the external colour is as a result of the pigmentation of both the fresh and skin. The colour pigmentation could be pink, yellow, orange, purple, red, dark yellow which varies in different cultivars but most consumers prefer the deep uniform red coloured tomatoes. It has been observed that the concentrated of the pigments, and hence the colour of fruits are being affected during handling and storage. This is due to the handling conditions. It is vital to improve the conditions under which these produce are handled in order to maintain the quality.

Tomato fruit shape differs greatly among cultivars. They may be spherical, oblate, elongated or pear-like (Messiaen, 1992). The varieties common in Nigeria are quite numerous and were introduced at various years from different sources. These varieties are preferred due to their high fruit-set and tolerance to viral disease (Erinle , 1985). They are Roma, Roma VF (TI 106), Ronita, Chico, Cirio 56, cherry, Early Stone, Gamad F, Ife 1, la - Bonita etc. The internal structures of these varieties are quite different but their flavour and texture are not really dependent on their shape. The tomato shape could influence the choice, design, construction and nature of the packaging containers. Also it influences the acceptability of the produce.

The size of tomato fruit influences the choice of consumers. The sizes vary greatly, the ranges are grouped as very small which is below 3cm, small (3 – 5cm), medium (5 – 8cm), large (8 – 10cm) and very large (>10cm). The range of fruit sizes vary among cultivars. Sizes of the fruits are of importance to the quality of the fresh produce, this is due to its influence in the physiological activities of the fruits. It has been observed that the rate of respiration of fruits are determined by the difference in their surface area to their volume ratio and nature of their surface coatings which influence their gas diffusion characteristics (Egharevba, 1995).

Also, tomato fruits sizes are important because they determines the selection design and construction of packaging containers in the fruit handling and distribution process.

Another important quality of fresh tomato fruits is the firmness of the fruit. The quantity is closely associated with ripeness stage. It also influences the fruit's textural quality like toughness and the internal structure. This also varies greatly among cultivars (Dewuft et al, 1999). Tomato firmness affects its susceptibility to physical damage and consequently their handling ability. Most consumers prefer firm fruits which do not loss too much juice when sliced. Thus, consumers' demand for high-quality products makes it necessary for growers and distributors to set up an integrated quality control system to monitor the quality of fruits from farm to the consumers. Proper knowledge about the properties are necessary as it will aid better and proper handling of the fresh produce for long distance distribution.

2.3.2 Chemical Properties of Tomato Fruits

Chemical properties of fresh tomato fruit influence the changes in the fruit during the process of post harvest activities. Thus it is of great importance in the study of the fruit handling.

Chemical properties are mostly chemical constituents of the fresh produce. These constituents play major roles in their ripening and also in their quality during handling and transportation. The changes these chemical components cause in fruits and vegetables are mostly when the fresh produce are detached from the plants. These chemical constituents are water, sugars, proteins, fibres, vitamins, minerals, lipids, organic acids etc. These constituents have different compositions in the fruits.

The quantity of some of the chemical constituents are shown in Table 2.1

Table 2.2 Chemical Constituents of Tomato Fruit

Constituents	Compositional values for 100g
Water	93.76
Carbohydrate (Sugar)	4.64
Protein	0.85
Lipid (Fat)	0.33
Fiber	1.1

Source (USDA Research 1997).

Due to the high water content of most fruits and vegetables (about 80%) like melons, lettuce, citrus, tomato, cucumber etc, these commodities are highly perishable which makes them susceptible to damages during handling. Water loss from the produce do occur under severe conditions. These cause weight loss, nutritional loss and loss in quality value. This loss is estimated to be more than 40 – 50% in the tropics and sub-tropics (Egharevba, 1995). Apart from the water content, other components which are active when the fruit was detached from the plant spontaneously react with each other causing loss of colour, texture, flavour.

Since it has been noted that the changes that occur in the fruits as they are been handled are influenced by the interactions of the chemical constituents, it is essential to have a firm knowledge of these properties so as to minimize the effects of subsequent interactions of these constituents, and hence improve the tomato quality.

2.3.3 Biological Properties of Tomato Fruits

The structural composition of the fruit is of importance as it determines the strength of the produce. The anatomy of the tomato fruits as shown in fig 2.1 gives more insight about the tomato structure.

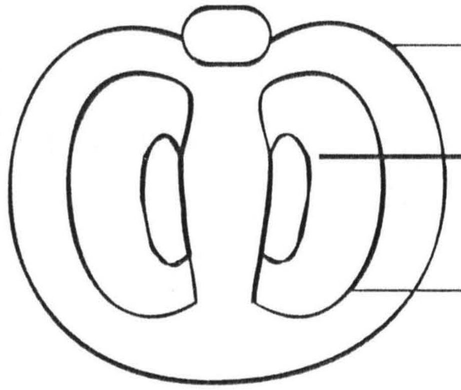

Fig. 2.1 Tomato Fruit Tissue

Source: Coombe (1976)

Tomato fruits are composed of the flesh (pericarp walls and skin) and pulp (placenta and locular tissue including seeds). The pericarp consists of an exocarp which is the skin, a mesocarp which is the parenchyma and an exocarp (a single-celled layer) which lines the locules. The mesocarp (i.e the parenchyma) consists of cellulose, haemicellulose and pectin (these are all polysccharides). These polyssacharides confers rigidity (strength) to the pericarp walls and determines the cell shape. Also the interaction between the rigidity of the walls and tugor (internal hydrostatic pressure) of the tomato cells provides the mechanical support of the fruit. Also it has been noted that the arrangement of the parenchyma is another factor that influences mechanical strength of tomato (Abott et al 2002).

It is noted that the resistance of tomato fruit depends on the flesh physiological characteristics (Altisent, 1991). Retention of substantial amount of their liquids depends on the skin which also affects their resistance to damage (Ajisegiri , 2002).

2.3.4 Biochemical Property of Tomato Fruits

Biochemical activities in fruits and vegetables arise mostly when the organic components react, giving undesirable results like deterioration in flavour, taste, colour, firmness etc. Thus, the biochemical properties of tomato fruits are important, as far as post harvest activities are concerned. This is because most of these undesirable reactions take place spontaneously. The biochemical property has to do with the way and rate at which these constituents react of which relative humidity; temperature and the maturity stage of the produce are influencing factors. Some of the changes that occur in the tomato fruit during the course of its biochemical activities are;

- Loss of chlorophyll
- Conversion of starch to sugars which weakens the cell walls, thus affecting the firmness and resistance to mechanicals damage (Egherevba, 1995).
- Increase in ratio of citric acid to maltic acid.
- Increase in glutanic acid.
- Synthesis of pigments such as 3 – carotene and lycopene.

Understanding these biochemical activities of fresh fruits and vegetables like tomato can help in the study of post harvest handling of the produce. This is by using appropriate handling conditions that will minimize the rate at which these changes occur because, these changes cause deterioration of the produce and make them prone to mechanical damage.

2.4 Tomato Packaging and Transportation

2.4.1 Transportation

Generally, transportation means the act of conveying people or goods from one place to another. Transportation basically has to do with two elements. They are the route (i.e the means of transportation) like roads, air, sea, while the second one is the device which refers to the equipment or system used for the conveyance (Ogaga, 2000).

Tomato transportation can then be defined as the movement of the fresh tomato from the farm gate to the collection centers, markets and the distribution from one area to the other. The farms are situated mostly in the rural areas, whereas the produce consumers reside in the major towns, this calls for transportation of the fresh produce from the farm to the urban centers where the markets are and futher interstate inter-country movements. This transport need could be categorized into on-farm movement (i.e movements within the farm) and off-farm movement (movement outside the farm).

Transportation of fresh tomato produce is inevitable because, tomato is grown in the semi-arid zone and Northern Guinea Savannah Zone and the consumers are scattered all over the country. This eventually promotes North-South trade. This type of transportation involves distant movements of the produce which is one of the major problems faced in post-harvest handling.

Most losses are incurred during the handling and transportation of fruits and vegetables especially in developing countries like Nigeria, where the roads (the major route of transportation), and the type of vehicles being used for the conveyance influence the quality of the produce. These losses are mostly significant when the weather condition during the course of the transportation is unfavourable and also the vibration of the vehicles due to bad roads. These losses that occur during this phase is estimated to be about 10% (O'Brien et al 1980). Also Mai and Fineh (1980) found appreciable damage of about 16% of apple fruits contained in bulk bins at various locations of different trucks during transportation. Singh and Singh (1992) measured the vibration on tomato, with the view to know tomato varieties that are suitable for long distance transportation. The results showed that tomato firmness decreased as storage period increased and that the firmness of round type tomato is generally lower compared to the pear shaped type.

Knowing that transportation is one of the most important factors in the marketing of fresh produce, the need to study the effects of the transportation system in order to reduce the losses incurred on fresh tomato is of great concern.

2.4.2 Packaging Materials

In developing countries like Nigeria and some developed countries, the common packaging system used for fresh fruits and vegetables are baskets made from palm fronds or bamboo, jute bags and cartons. Other improvised packaging containers used initially in packaging imported or locally manufactured goods are also being used. These containers could be made of metal, plastic and wood (Karen, 1991, Idah et al 1996, Oladapo, 1994).

The baskets made from palm fronds (raffia) or bamboo are the traditional containers commonly used as packaging containers for perishable fruits and vegetables like tomato. In developing countries, this packaging system is commonly used as they are of low cost and made from readily available materials (FAO, 1989). But, it has been observed that losses are being incurred using these baskets for packaging especially when it involves long distance transportation, thus making them unsuitable it for packaging. This is because the rough sides and sharp splitted edges of the basket, damage the contents that are highly susceptible to punctures and cuts. Also they are quite stable when they are placed on the trucks, which cause vibration of the produce, thus subsequent damages. Most times, the packers used dry leaves as linings for the inside of the baskets, the dry leaves are to serve as padding or cushioning materials, but it is not an effective method. Also the shape and size of the baskets determine the way the load will be positioned in the transport vehicle. Thus, it is observed that boxes in form of rectangles have more stability and capacity compared to the rounded baskets (FAO, 1989). Other disadvantages of this packaging system are the difficulty in cleaning it, its instability even when stacked especially for long distance transport and their role in enhancing microbial activities.

It has been noted that improvements in the design and construction of this indigenous packaging system might enhance the effectiveness in handling fresh fruits and vegetables.

Also, jute sack, bags and cartons are used for packaging fruits and vegetables like cabbage, orange, mango, onions, potatoes etc. The sacks and bags are made from natural fibers like sisal or from synthetic fibers. They have high loading capacity and are cheap, but lack rigidity. They are light-weight, smooth surfaced and easy to carry but they can easily be damaged by careless handling.

There are other packaging materials like wooden containers mostly in box or crate form and the molded plastics crates. But they are not commonly used, because of the high cost and unavailability. It has been noted that bruising damage reduced by 40% in pineapple packed in volume filled ventilated plywood crates, relative to those packed in traditional jute bags (Awoh and Olorunda 1988).

2.5 Transport and Handling Problems

2.5.1 Mechanical Damages

Mechanical damage occurs in a product when it is either under excessive deformation caused by applied load or excessive force when subjected to impact. Most damages are attributed to the action of static and dynamic forces resulting in stress and strain.

Agricultural products such as fruits and vegetables are highly susceptible to mechanical damage. This damage caused by external loading, leads to changes in colour, structure and taste of the vegetable tissue. Such damages are in form of puncture, cut, bruise, abrasion, loss in firmness etc. Researches on mechanical damage in fruits and vegetables especially the relationship between the applied load and its destructive effects have being going on for years with improvements and better understanding about the mechanism.

The study of the mechanism of mechanical damage mostly on materials like tomato is difficult to measure and control, this is because of the material's complexity in cell properties. Thus most of these studies involve the use of mathematical models and theories (Wu and Pitt, 1999). Some researchers have tried to apply the theories of elasticity and visco-elasticity to predict the result of a known deformation or impact on a continuous homogenous material. However, the assumption of a continuous homogenous material cannot take into account the cellular structures of fruits flesh, even if the results of the approach give some useful indicators of the consequences of mechanical effects (Roudot et al, 1991). A modeling method based on imaging techniques to study impact and compression damage to apple fruit has been used . This method is not interested in the mechanical behavior of cells, but in the mechanical response of a tissue made of cells, this was to discuss about cell arrangement or cell collapsing and to find a qualitative explanation of the mechanical behavior of apple flesh under compression and impact. The authors found out that cell collapsing occurs during impact and cell displacement occurs during compression (Roudot et al, 1991). Also, compression of tomato fruit was monitored via Magnetic Resonance Imaging (MRI). This was to know the importance of the fruit mechanical behavior in terms of damage resistance and maturity and also to measure the mechanical response of the tomato skin and examine the tomato structure at different levels of compression (Gonalez et al, 2002).

A mathematical model that enables the prediction of bruise size and depth of fruit deformation was developed. Some assumptions were made, that the fruit shape are spherical, configurations of two fruits that are in contact, a fruit in contact with a rigid plane and a fruit in spherical cup were all considered. The materials properties like non – linear relaxation modules were studied and compared with the classical Hertz contact theory of perfectly elastic and linear visco-elasticity spheres. Equations were developed for load forces like dead weight, continuous sinusoidal varying force etc. This model concluded that in applying load to the produce, the elasticity deformation would be recovered normally, and that residual deformation is considered as "bruise size" (Mohsenin,1978).

Indeed, studies have really shown that mechanical forces are among the most important cause of damage and loss of quality in agricultural products (Peters, 1996, Jones et al, 1991, Roudot et al 1991). Thus, such studies are relevant to understand the basic nature and mechanical behavior that can be used in characterizing agricultural produce and such information are also used to reduce mechanical damage and enhance quality.

2.5.2 Detection and Evaluation of Mechanical Damages

Detection and evaluation of mechanical damage is the ability to assess and measure the extent of damage to a material. These damages might be visible or invisible, when it is visible, it requires special techniques and instrumentation to detect and evaluate it. The visible damages are the symptoms of the damage produce, like in fresh tomatoes; the external symptom is that the fruit will be permanently pressed out of shape with flattened sides (deformation). Internal damages which accompany such damage are water-soaked tissues with signs of varying degrees of damage to the local tissue surrounding the seed

There are no standards for detecting and evaluating damages, rather researchers often design their own scale for detection and evaluation (Mohsenin, 1978). Some techniques are based on physical measurements such as volume of bruised tissue, length of cracks, depth of crack, weight loss measurement etc in fruits and vegetables. Like instance the bruise volume may be calculated using the formula for segment of a sphere together with values of maximum depth and maximum width of the bruise using the relationship.

$$V = \frac{\pi h}{24\left(3d^2 + 4h^2\right)}$$

Where;

V = *The volume of bruised section to be a segment of a sphere*

h = *Maximum depth of the bruise*

d = *Average diameter of the bruise*

However, in most cases, it is observed that injury in fresh produce cannot be detected by visual methods like the black spots in fruits and vegetables which are the results of invisible damage. The use of x – ray, light transmittance and chemical staining are techniques been used for such. Also the use of water soluble chemical,2,3,5-triphenyl tetrazolium chloride (TTC) method, which is based on reduction of the colourless TTC dye, which forms a red insoluble formazone upon exposure to reduce constituents released by injured peel citrus tissue has been investigated (Bela et al, 1998).

Evaluation of the firmness value of fresh produce is another way to detect mechanical damages to produce. This is because firmness is one of the parameters used in fruit quality. Singh and Singh (1992) observed that the firmness of fresh tomato transported over 200km decreased considerably compared to the untransported ones.This was due to vibration. Also Dewult et al (1999) employed the method of finite element model analysis to determine the firmness of pear fruit by measuring the mechanical resonance within the whole intact fruit. A periodic random force was applied at the point of the sample and the frequency response function was recorded at another point of the sample. A firmness index was determined which is $F_2m^{2/3}$ where F_2 is the lowest spherical eignfrequency and m is the mass of the fruit. The results of the analysis showed that the oblate-prolate model is the most sensitive model with respect to material characteristics.

The use of ultrasonics (frequencies > 20,000Hz) have been used for the detection of damages in fruits and vegetables (Cheng and Haugh, 1994). The commonly measured parameters are velocity attenuation and frequency spectrum composition. Punctual tester based on the original Magness-Taylor pressure tester is also used to measure firmness of numerous fruits and vegetables but its destructive (Abott et al, 2002). A non-destructive, non-contact firmness detector has been patented (Prussia et al, 1994). It uses a laser to measure deflection caused by a short puff of high-pressure air. Under fixed air pressure, firmer products deflects less than softer ones.

There are some other techniques employed in evaluating mechanical damages, like the use of respiration rate of the fresh produce. The respiration rate expressed in terms of the volume of carbon (IV) oxide (CO_2) evolved per unit weight of the produce, per unit time (Ajisegiri, 2000). It showed that wounds on living plant tissues caused by mechanical damages results in increased rate of respiration. The volume of the carbondioxide was measured using an established method which is the Infra Red Gas Analysis (IRGA). This method involves pressing exhaust air from the living tissue through the (IRGA) unit.

2.5.3 Application of Hertz Contact Theory

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

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

$$t = 4.53\left[\frac{A m_1 m_2}{\pi(m_1 + m_2)}\right]^{2/5} \left[\frac{R_1 + R_2}{V_1 R_1 R_2}\right]^{1/5} \quad \text{............ (2.2)}$$

$$S_{max} = 0.2515\left[\frac{\pi^4 V_1^2}{A^4}\left(\frac{m_1 m_2}{m_1 + m_2}\right)\left(\frac{R_1 + R_2}{R_1 R_2}\right)^3\right]^{1/5} \quad \text{............ (2.3)}$$

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

$$D_{max} = \left[\frac{15 v_1^2 A m_1 m_2}{16\sqrt{R_2}}\right]^{2/5} \quad \text{............ (2.4)}$$

$$t = 4.53\left[\frac{A m_1}{\pi\sqrt{R_1 V_1}}\right]^{2/5} \quad \text{............ (2.5)}$$

$$S_{max} = 0.2515\left[\frac{\pi^4 V_1^2 m_1}{A^4 R_1^3}\right]^{1/5}$$

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

$$A = \frac{1-\mu^2}{E_1} + \frac{1-\mu^2}{E_2} \quad \text{............ (2.7)}$$

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 fruits (Altisent, 1991). The elastic contact problem describes the internal stresses and strains created in and below the contact area between fruit and the impacter 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 strains appear. Also a finite element analysis of contact stresses for elastic as well as viscoelastic spherical bodies in contact and subjected to static and also impact load had been developed. This

Apart from the damages incurred to the fresh produce, the life of the vehicle components will be reduced too. It has been observed that the service life of the vehicle components could be reduced by 80% if the vehicle plys highways with 4-5 potholes per square meter of the carriage way width at a minimum speed of 60km/hr (Ogaga, 2000). It was also noted that a vehicle laden with fruits or vegetables traveling along a smooth road at constant speed may be at vertical static equilibrium. The forces between the various system elements are constant and there is no transformation of energy. However, when the vehicle encounters a discontinuity, on the road surface, a bump for example, some of the kinetic energy of the vehicle is dissipated in deforming the road (Jones et al, 1991). Damage to the produce are the direct result of the dissipation of the energy in the produce. Road irregularities are due to the failures caused by bad construction, excessive traffic loadings, lack of maintenance, etc. In developing countries like Nigeria, the terrible state of the roads is actually hampering many activities especially those related to agriculture. The transportation of agricultural produce from the rural areas to towns do really take time, due to bad roads. This delay causes deterioration of perishable fresh produce like tomatoes. Also it is difficult for extension workers to go to rural areas and educate them about new technological developments related to agriculture. Apart from these, the safety of lives on the roads are of great concern. The rate of road accidents is usually high due to bad conditions (Encyclopedia Brintanica, 2002).

The problems posed by bad roads is indeed of deep concern and considering the role the road plays in Nigeria as a major means of transportation, it is necessary to maintain the roads and reduce excitation through smooth ride. This will help to reduce damages incurred on fresh produce.

2.6.2 Vehicle – Road – Packaging Interaction

The interaction between the vehicle, the road it plys on and the packaging system, affects the quanlity of fresh produce like tomatoes. This interaction depends on the ride quality of the vehicle (because most Nigerian vehicle s are not adequately maintained), the road condition and the packaging material being used. As earlier stated the vibration excitation on the vehicle is caused by the failures on road, and the packaging materials absorb this vibration which sometimes in resonance at the same frequency. The basic mechanisms involved seem to be impact or vibration experience by individual items of the produce as the vehicle encounters sudden changes in road profile. It is this interaction that determines the amount of energy dissipated to the fresh produce, which will eventually cause mechanical damages.

It is noted that damages to fruits and vegetables during transportation are greatest on the top layers of the fruit and that under severe transport conditions, may extend down to other layers (Ogut et al, 1999). It is also noted that the damage resulting from this interaction can be reduced by avoiding resonance vibration. This can be achieved by letting the natural frequency of the container (i.e. packaging material) of the fruits to be away from the range of frequency of excitation force while in transit (Ogut et al, 1999).

2.6.3 Vibration Characteristics of Vehicle

The bumps on roads are slight elevations on the leveled roads, while potholes are deviations in elevation experienced by vehicle as it moves along it. Therefore, they both act as vertical displacement input to the wheels, thus causing vibration (Ogaga, 2000). This brings up a concept that deals with the characteristics of vibration and the properties of the vehicle. The concept has to do with the amplification factors, these factors are the ratio of amplitude measured on the vehicle and the frequency of excited amplitude. This can be achieved by subjecting the vehicle to vibrations at various frequencies using a vibrator table.

It has been observed that vibrations cause shaking of baskets of fresh produce and restrict ventilation. This restriction causes faster rate of ripening and softening of egg plants and okra respectively (Kra and Bani, 1988). Also, it has been observed that the dissipation of energy in a produce results to damage of the produce. The damage depends on the overall vehicle system response to the energy generated from the excitation which causes vibration. Thus, the need to understand the energy storage and energy dissipative characteristics of the constituent elements of the vehicle. This will help in selecting appropriate vehicle vibration hence having better quality of fresh produce delivered.

2.6.4 Vehicle Suspension System

The suspension system of a vehicle is the system that has to do with devices that provides an elastic support between loads-carrying system and the axles of the vehicle. The system decreases the dynamic loads on the load-carrying system and the wheels and as well serve as vibration dampers. This means that the system's main function is to prevent shock loadings and vibrations due to irregularities encountered on roads (Newton et al, 1996). The suspension system consists of components such as shock absorbers, guides and lateral stabilizer (Stockel et al, 1996, Hiller and Pittuch, 1990, Ogaga, 2000).

It is observed during the unloading of produce from vehicles at wholesale markets, that lightly loaded trucks appear to cause more damage than heavily loaded ones and that the worst damage occurs over or behind the rear axle and that this influenced by the stiffness of the suspension (Jones et al, 1991). Apart from the potholes and bumps that excite the wheels and the suspension, the load which cause vertical bounce, the non-uniformity of the wheels also adds to the vibration. It is observed that under good road conditions, a vehicle still subjects the load to bounce and pitch when the wheels are suddenly lifted or dropped or when there is sudden application of brakes (Ogaga, 2000).

Thus the truck (vehicle mostly used for farm produce distribution) suspension system influences the damage of farm produce especially the sensitive ones like tomatoes. It is important therefore, to understand the concept of load-vehicle-packaging interaction and how different resonant modes and their frequencies on the vehicle, packaging material and the load which is caused by the potholes on the road. This will help in understanding the mechanism of the suspension system and how to proffer solution to the posed problem thereby having better ride quality.

2.6.5 Acceleration of Simple Vehicle on Various Road Surfaces

It is noted that the acceleration produced on a vehicle is the most meaningful measure of ride vibration. This acceleration which is due to potholes and bumps on the road is used to deduce the vibrational strain on the vehicle (Ogaga, 2000). Two steps are used in analyzing this relationship. A vehicle speed is assumed, such that the elevation profile of the road profile can be transformed into displacement as a function of time. The value of the elevation profile is then transformed into;

(a) Velocity by the first differentiation

(b) Acceleration by the second differentiation

The resultant acceleration is transformed to peak dynamic loading or resonance. The input frequency or forcing frequency is obtained by dividing the vehicle velocity by the wavelength or by multiplying the spatial frequency (wave number) by the vehicle speed. Potholes viewed as acceleration inputs present its largest inputs to the vehicles at high frequency and thus the greatest vibration, unless attenuated by the dynamic properties of the vehicle.

This review in relation to the road condition is essential because of the vibrations resulting from such acceleration eventually determines the damages suffered by the produce. The way to reduce these damages is to assess the vibrations corresponding to the vehicle's natural frequency which could be made to vary from the natural frequency of the packaging containers and the produce, because it is noticed that damage to the produce will be more severe when these frequencies coincide during the handling process (Ogut, 1999). Determing the natural frequencies of the varieties of the tomatoes we have in Nigeria is very important. This will provide basic data that will help in curtailing this damage.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Theoretical Analysis

The problem of fresh produce handling which is basically damages, occur especially during transportation .This problem can be studied from the context of vibration as a result of potholes and rough roads the vehicle is plying on. This vibration is at a certain frequency and it travels from the truck tyres to the truck's load carrying. If the resonance frequency of a fruit column packed in a container coincides with excitation frequency of the road or vehicle, then the acceleration of the fruit increases due to resonance and this will cause damage to the fruit. The resonance in a fruit in a container can be determined if the modulus of elasticity is known. In determining the natural frequency of the fruit, the conditions that will lead to damages can be avoided by letting the natural frequency of the container of the fruits to be away from the range of frequency of the excitation forces of the vehicle while in transit (Ogut et al, 1999). Determining 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 frequencies of the fresh tomato fruits of three varieties would be determined. In order to facilitate the computation of the elasticity modulus from the experiment that will be conducted, the following assumptions were made;

(a) The fruits are spherical.

(b) Very small expansions 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;

$$E = \frac{0.388F(1-\mu^2)}{D^{3/2}}\left[K_U\left(\frac{1}{R_U}+\frac{1}{R'_U}\right)^{1/3}+K_L\left(\frac{1}{R_L}+\frac{1}{R'_L}\right)^{1/3}\right]^{3/2} \quad \text{.......................} (3.1)$$

Where

$E = Modulus\ of\ elasticity\ (Pa)$

$D = Deformation\ (m)$

$F = Force\ (N)$

$\mu = Poisson's\ ratio = 0.22$

R_U, R'_U = *minimum and maximum radii of curvature respectively at the point of contact for upper convex surface* (m)

R_L, R'_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 the Table 3.1 using* $\cos\theta$ *is given as*

$$\cos\theta = \frac{\frac{1}{R_1}-\frac{1}{R'_1}}{\frac{1}{R_1}-\frac{1}{R'_1}+\frac{1}{R_2}-\frac{1}{R'_2}} \quad \text{...} (3.2)$$

For K_U, $\cos\theta$ *is calculated using the radii of curvature of the upper surface where* $R_1 = R_U$ $R'_1 = R'_U$ *while* $R_2 = R'_1 = \infty$ *given* $R_2^{-1} + R_2'^{-1} = 0$

$$\therefore \cos\theta = \frac{\frac{1}{R_U}-\frac{1}{R'_U}}{\frac{1}{R_U}+\frac{1}{R'_U}+0}$$

$$\cos\theta = \frac{\frac{1}{R_U}-\frac{1}{R'_U}}{\frac{1}{R_U}+\frac{1}{R'_U}} \quad \text{..} (3.3)$$

For K_L, $\cos\theta$ *is calculated using the radii of curvature for the lower surface, where*

$R_1 = R_L$, $R_1' = R_L'$

while

$R_2 = R_2' = \infty$ *giving* $R_2^{-1} + R_2'^{-1}$

$$\cos\theta = \frac{\frac{1}{R_L} - \frac{1}{R_L'}}{\frac{1}{R_L} + \frac{1}{R_L' + 0}}$$

$$\cos\theta = \frac{\frac{1}{R_L} - \frac{1}{R_L'}}{\frac{1}{R_L} + \frac{1}{R_L'}} \quad \ldots\ldots (3.4)$$

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

$$F_n = \frac{1}{4\lambda}\sqrt{\frac{E.g}{\rho}} \quad \ldots\ldots (3.5)$$

Where

Fn = *Natural frequency*

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

ρ = *Density of fruit*

λ = *Depth of the column of fruit* $(m) = 0.01m$

3.2 INSTRUMENTATION

The equipment apparatus used are;

An equipment with a loading device for compression test was used (see plate 3.1), an electronic weighing balance, venier calipers, measuring cylinders, and oven.

- The electronic weighing balance was used to determine the tomato masses.
- The venier caliper was used to measure the minor, major and intermediate diameters.

- The measuring cylinders were used to measure the volume of tomatoes as shown in plate 3.2.
- The oven was used to dry sliced tomato fruits in order to determine the moisture content.

3.3 MATERIALS

Three known varieties of fresh tomato namely Chico, Roma and Cherry of two maturity stages (green and fully red riped) were used. These varieties are shown in plate 3.3

3.4 METHOD

Fresh tomatoes of the named three varieties at two maturity stages (green and fully red riped) were harvested. The samples were weighed using the electronic weighing balance to determine their masses and were sorted into four groups based on their masses. The groups were; M_1 (Mass<30.00g), M_2 (31g – 41g), M_3 (42g – 52g), and M_4 (Mass>53g). Then the diameters (minor, intermediate and major) were measured using venier calipers. The volumes were measured using the measuring cylinder on a platform (Mohsenin, 1979). The moisture content of the tomato varieties was determined. This was by slicing tomato fruit samples (green and fully red riped), determining their masses, then placing them in an oven and allowing them to dry at a temperature of about 105^o c for two hours.

After determining these parameters, each of the samples was then placed in between the two flat plates and loads of know values were applied and the corresponding deflections were recorded from the deformation scale. Some of the samples were placed longitudinally, while some placed transversely in between the flat plates. Using the deformation registered by the deformation scale, a load – deformation graph was established and hence the modulus of elasticity and the natural frequency of the samples was determined as earlier stated.

Table 3.1- value of K (dimensionless) for various values of Θ (degrees) ASAE(1998).

Θ	50	55	60	65	70	75	80	85	90
cos Θ	0.6428	0.5736	0.5000	0.4226	0.3420	0.2588	0.1736	0.0872	0.0
K	1.198	1.235	1.267	1.293	1.314	1.331	1.342	1.349	1.351

The experiment was conducted based on a three factor-factorial design (Montgomery, 1999).The three factors are fruit maturity (fully red riped and green), mass and the varieties. There are three (3) varieties, four mass categories and two maturity groups. The experiment is replicated five times. Hence we have 3x2x4x5=120 treatments. This is illustrated in table 3.2.

Table 3.2 Experiment Layout of Natural Frequency Determination

The structural model to be applied for the green and fully ripe stages of maturity will be;

MASSES	VARIETY A	VARIETY B	VARIETY C
M_1	$y_{A_{M11}}$	$y_{B_{M11}}$	$y_{C_{M11}}$
	$y_{A_{M12}}$	$y_{B_{M12}}$	$y_{C_{M12}}$
	$y_{A_{M13}}$	$y_{B_{M13}}$	$y_{C_{M13}}$
	$y_{A_{M14}}$	$y_{B_{M14}}$	$y_{C_{M14}}$
	$y_{A_{M15}}$	$y_{BA_{M15}}$	$y_{C_{M15}}$
M_2	$y_{A_{M21}}$	$y_{B_{M21}}$	$y_{C_{M21}}$
	$y_{A_{M22}}$	$y_{B_{M22}}$	$y_{C_{M22}}$
	$y_{A_{M23}}$	$y_{B_{M23}}$	$y_{C_{M23}}$
	$y_{A_{M24}}$	$y_{B_{M24}}$	$y_{C_{M24}}$
	$y_{A_{M25}}$	$y_{BA_{M25}}$	$y_{C_{M25}}$
M_3	$y_{A_{M31}}$	$y_{B_{M31}}$	$y_{C_{M31}}$
	$y_{A_{M32}}$	$y_{B_{M32}}$	$y_{C_{M32}}$
	$y_{A_{M33}}$	$y_{B_{M33}}$	$y_{C_{M33}}$
	$y_{A_{M34}}$	$y_{B_{M34}}$	$y_{C_{M34}}$
	$y_{A_{M35}}$	$y_{BA_{M35}}$	$y_{C_{M35}}$
M_4	$y_{A_{M41}}$	$y_{B_{M41}}$	$y_{C_{M41}}$
	$y_{A_{M42}}$	$y_{B_{M42}}$	$y_{C_{M42}}$
	$y_{A_{M43}}$	$y_{B_{M43}}$	$y_{C_{M43}}$
	$y_{A_{M44}}$	$y_{B_{M44}}$	$y_{C_{M44}}$
	$y_{A_{M45}}$	$y_{BA_{M45}}$	$y_{C_{M45}}$

$$y_{ijkl} = \mu + \tau_i + \beta_j + \gamma_k + (\tau\beta)_{ij} + (\beta\gamma)_{jk} + (\tau\beta\gamma)_{ijk} + \varepsilon_{ijkl}$$

Where

$$\begin{cases} i = 1,2,3,....,a \\ j = 1,2,....,b \\ k = 1,2,....,c \\ l = 1,2,....,n \end{cases}$$

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

CHAPTER FOUR

RESULTS AND DISCUSSION

The results of the experiment on natural frequency determination carried out are presented in Tables 4.1 - 4.4. Tables 4.1 and 4.2 show the results of the natural frequency and the average natural frequency of the tomato varieties at their green stages of maturity respectively. The natural frequency result and the average natural frequency of the tomato at fully ripe stage of maturity are shown in Tables 4.3 and 4.4 respectively

The moisture content of samples used are given in Table 4.5. The force – deformation graphical result of the three varieties at both stages of maturity are presented in Figure 4.1 – 4.6.

TABLE 4.1 RESULTS OF THE DETERMINED NATURAL FREQUENCY FOR THE GREEN TOMATO SAMPLES OBTAINED FROM THE EXPERIMENT

	Natural Frequency for MASS 1 (Hz)	Natural Frequency for MASS 2 (Hz)	Natural Frequency for MASS 3 (Hz)	Natural Frequency for MASS 4 (Hz)
ROMA	16.59	10.88	12.21	17.63
	20.11	11.67	17.76	13.00
	12.69	14.24	13.91	10.63
	15.88	12.23	11.42	13.25
	18.60	15.610	12.22	13.38
CHICO	15.540	14.74	24.47	7.73
	15.39	10.63	11.200	11.37
	15.86	8.77	11.43	15.44
	20.54	8.28	10.95	14.24
	11.02	24.47	26.19	14.97
CHERRY	10.98	14.96	14.96	14.09
	11.48	16.77	16.77	7.08
	13.41	15.66	15.66	11.14
	11.63	12.32	12.32	8.27
	12.14	12.43	12.43	14.85

TABLE 4.2

MEAN NATURAL FREQUENCY OF THE GREEN SAMPLES

	Natural Frequency for MASS 1 (Hz)	Natural Frequency for MASS 2 (Hz)	Natural Frequency for MASS 3 (Hz)	Natural Frequency for MASS 4 (Hz)	Overall Mean Natural Frequency (Hz)
CHICO	15.670	13.378	16.848	12.750	14.1965
CHERRY	11.928	15.526	14.428	11.086	14.661
ROMA	16.774	12.926	13.504	13.582	13.242

TABLE 4.3 RESULTS OF THE DETERMINED NATURAL FREQUENCY FOR THE FULLY RIPE TOMATO SAMPLES OBTAINED FROM THE EXPERIMENT

	Natural Frequency for MASS 1 (Hz)	Natural Frequency for MASS 2 (Hz)	Natural Frequency for MASS 3 (Hz)	Natural Frequency for MASS 4 (Hz)
ROMA	28.00	10.88	17.760	10.52
	9.10	11.67	11.93	8.50
	27.60	14.24	22.88	15.71
	13.90	12.23	15.51	20.28
	17.90	15.610	20.29	15.370
CHICO	12.48	14.74	10.59	18.53
	19.31	10.63	10.51	18.96
	14.76	8.77	12.04	14.20
	15.00	8.28	10.44	17.79
	13.99	24.47	18.41	15.60
CHERRY	7.87	7.12	6.90	14.82
	12.79	9.04	4.61	6.81
	12.22	7.48	7.91	4.91
	8.97	10.57	7.67	9.27
	10.96	15.41	9.18	7.43

TABLE 4.4 MEAN NATURAL FREQUENCY OF THE FULLY RIPE SAMPLES

	Natural Frequency for Mass 1 (Hz)	Natural Frequency for Mass 2 (Hz)	Natural Frequency for Mass 3 (Hz)	Natural Frequency for Mass 4 (Hz)	Overall Mean Natural Frequency (Hz)
CHICO	15.108	14.924	12.398	17.216	14.8615
CHERRY	10.562	9.924	7.254	8.648	9.097
ROMA	19.300	19.398	17.674	14.078	17.6125

TABLE 4.5 RESULT OF THE MOISTURE CONTENT OF THE TOMATO VARIETIES AT THEIR GREEN AND FULLY RED RIPE STAGES OF MATURITY

	GREEN (%)	RIPE (%)
CHICO	93.30	92.00
CHERRY	93.30	93.70
ROMA	93.30	95.00

The force-deformation graphs of the three tomato varieties at their green and fully ripe maturity stages are shown in Figures 4.1 – 4.6

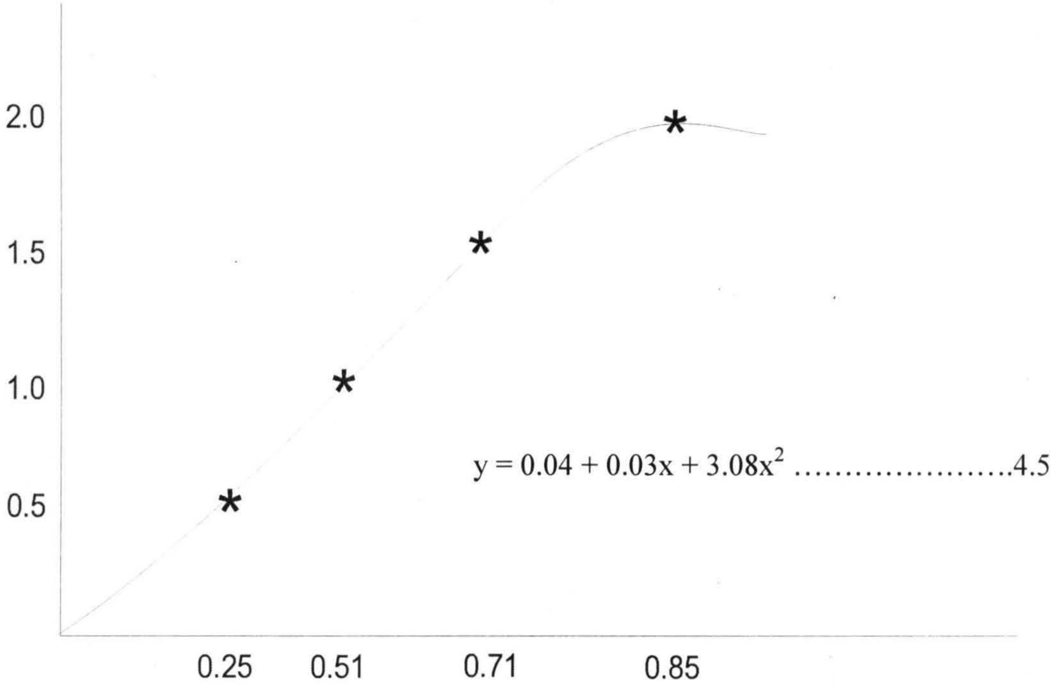

Fig 4.1 Force-Deformation Graph of Green Chico Variety

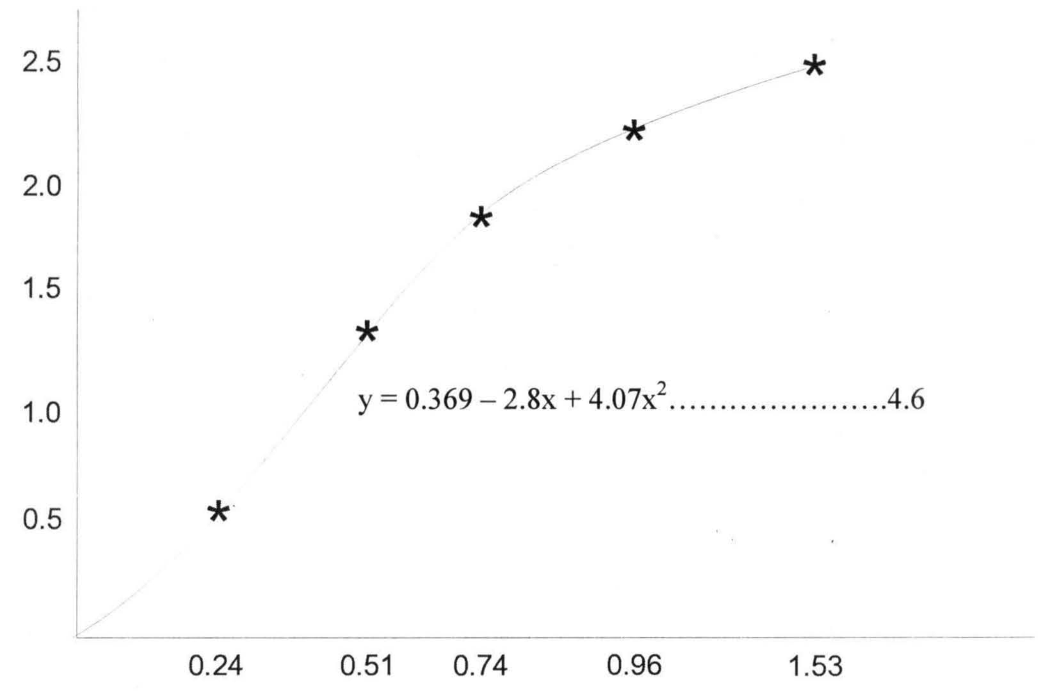

Fig 4.2 Force-Deformation Graph of Fully Ripe Chico Variety

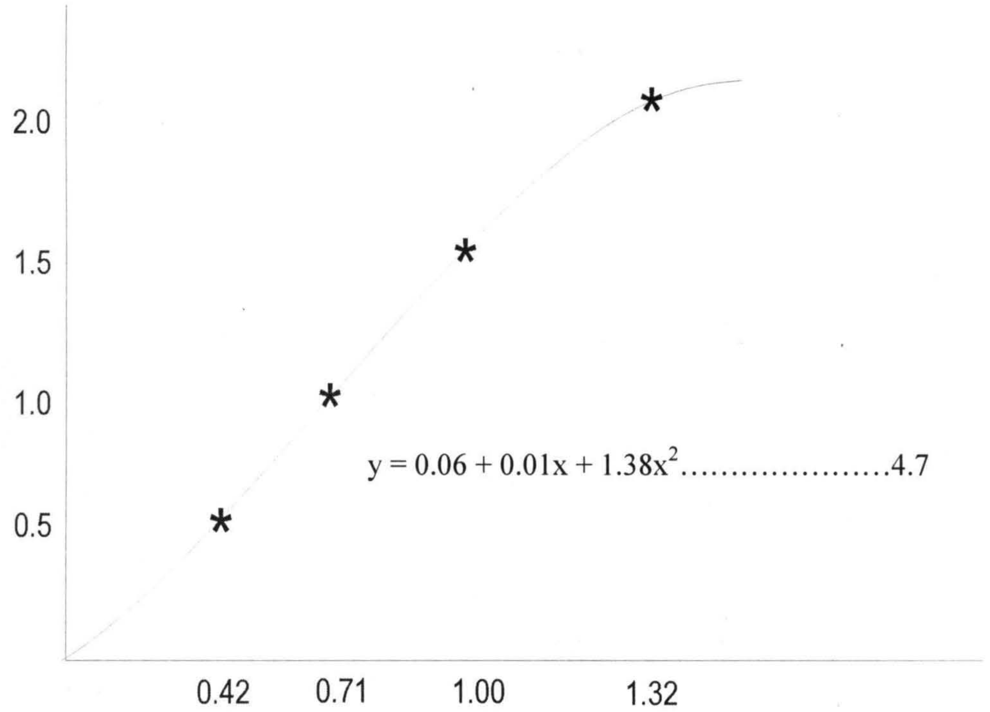

Fig 4.3 Force-Deformation Graph of Green Cherry Variety

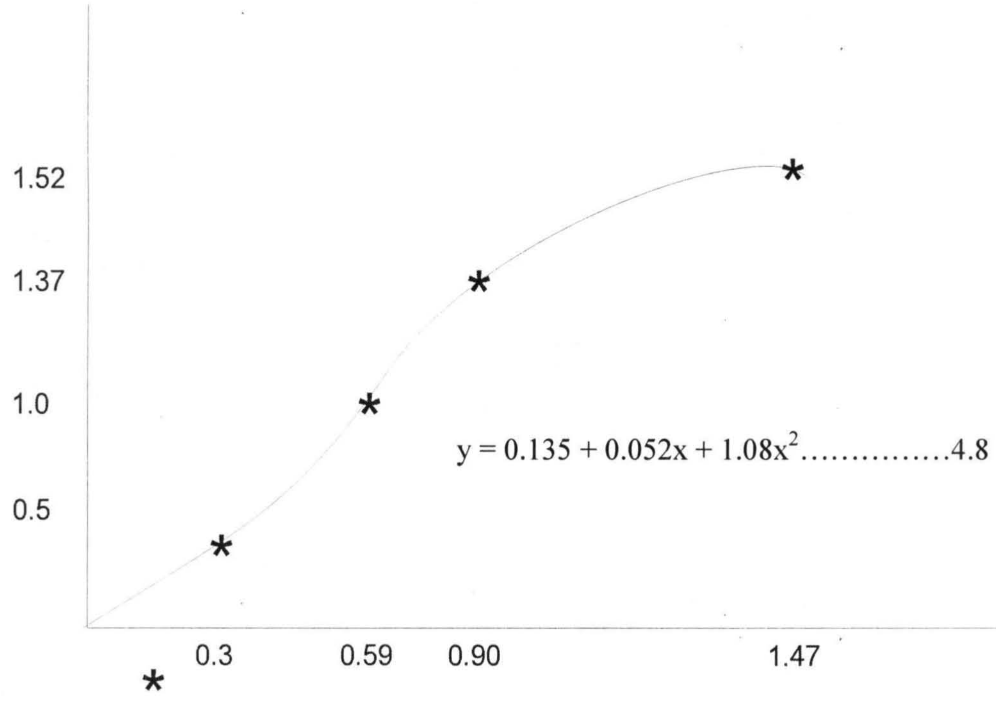

Fig 4.4 Force-Deformation Graph of Fully Ripe Cherry variety

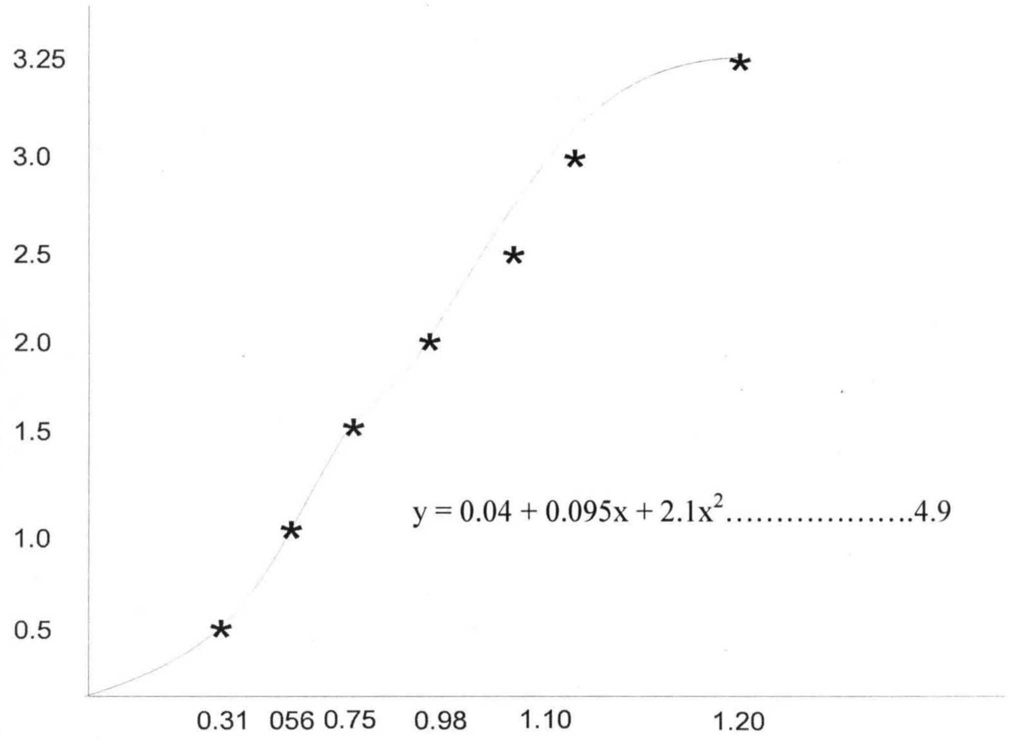

Fig 4.5 Force-Deformation Graph of Green Roma Variety

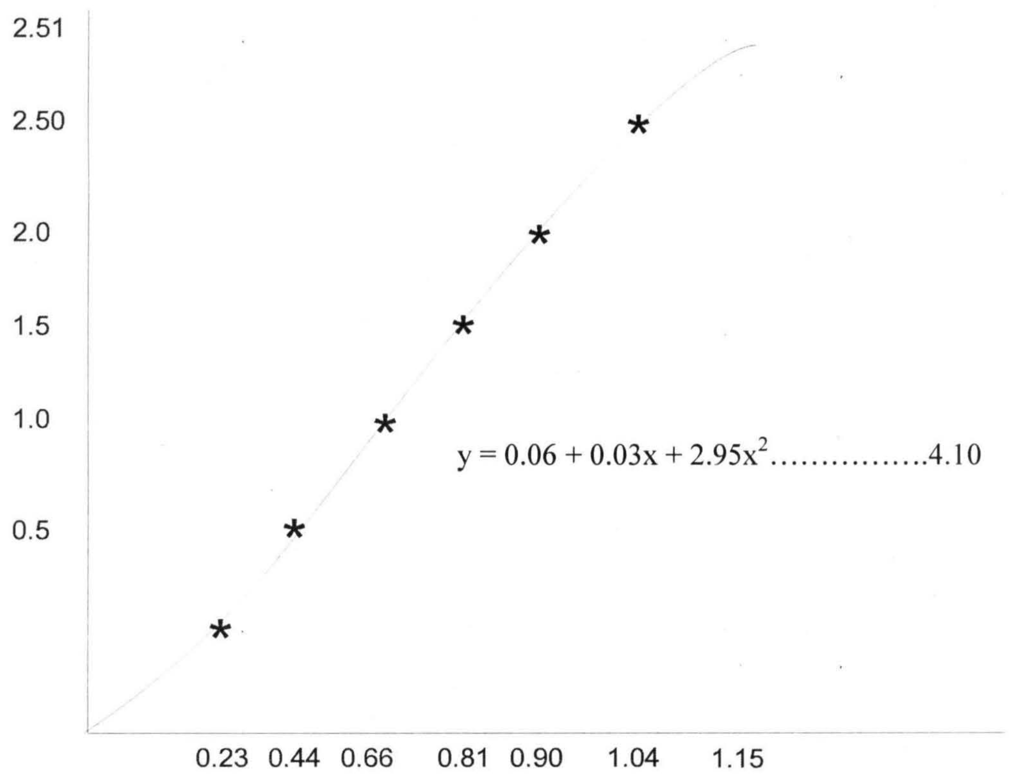

Fig 4.6 Force-deformation Graph of Fully Ripe Roma Variety

4.1 Analysis of the Result

The analysis of variance (ANOVA) was used to analyze the data obtained statistically in order to ascertain the effects of the three factors namely variety, mass and maturity of the samples of their natural frequency. The results of the analysis are presented as follows.

4.1.1 Analysis of Results for Green Samples

TABLE 4.6: SUMMARY OF ANALYSIS OF VARIANCE (ANOVA) FOR THE RESULTS OF GREEN SAMPLES

SOURCE OF VARIATION	DEGREE OF FREEDOM	SUM OF SOURCES	MEAN SQUARE	COMPUTED F RATIO	P
MASS	3	57.23	19.08	1.25	0.302
VARIETY	2	20.93	10.47	0.68	0.508
ERROR	54	825.73	15.29		
TOTAL	59	903.91			

α level = 0.05 (if $P < 0.05$, it has a significant difference, if $P > 0.05$, it has no significant difference).

The results in the table (4.6) shows that the effect of mass and variety on the natural frequency are not significant at $\alpha = 0.05$ level, since for mass, $P(0.302) > 0.05$ and for variety, $P(0.508) > 0.05$.

4.1.2 Analysis of Results for Fully Ripe Samples

TABLE 4.7: SUMMARY OF ANALYSIS OF VARIANCE (ANOVA) FOR THE RESULTS OF FULLY RIPE SAMPLES

SOURCE OF VARIATION	DEGREE OF FREEDOM	SUM OF SQUARE	MEAN SQUARE	COMPUTED F RATIO	P
VARIETY	2	66.29	22.26	1.26	0.296
MASS	3	755.41	377.70	21.45	0.000
ERROR	54	950.85	17.61		
TYPE	59	1773.05			

α level = 0.05 (if P< 0.05, it has a significant difference, if P> 0.05, it has no significant difference).

From the Table (4.7), it shows that at 0.05 level of confidence, the variety do not have any significant effect on the natural frequency of tomato. The mass however, influences the values significantly at α = 0.05 level.

Further analysis were carried out to ascertain the interactive effects of the mass groups. This is presented in Table 4.8

Table 4.8 SUMMARY OF ANALYSIS OF VARIANCE (ANOVA) FOR THE MASS GROUP INTERACTIVE EFFECTS

SOURCE OF VARIATION	DEGREE OF FREEDOM	SUM OF S SQUARE	MEAN SQUARE	COMPUTED F RATIO	F PROB.
BETWEEN GROUP	11	934.0876	84.9171	4.8584	.0001
WITHIN GROUP	48	838.9575	17.4783		
TOTAL	49	1773.0451			

From the Table (4.8), it shows that at $\alpha = 0.05$ level, there is a significant difference between the natural frequencies of the mass groups, since (F .Prob) 0.0001 < 0.05.

The mass groups were further analyzed. This was to ascertain the degree of variation between the various mass groups under each variety. Table 4.9 shows the result of the analysis of variance of the mass group while Table 4.10 shows the mean results of natural frequency of various mass groups.

TABLE 4.9 SUMMARY OF THE ANALYSIS OF VARIANCE (ANOVA) FOR THE MASS GROUPS INTERACTIVE EFFECTS UNDER EACH VARIETY

SOURCE OF VARIATION	DEGREE OF FREEDOM	SUM OF SQUARE	MEAN SQUARE	COMPUTED F RATIO	F PROB.
BETWEEN GROUP	2	755.4000	377.7040	21.1560	0.0000
WITHIN GROUP	57	1017.6371	17.8533		
TOTAL	59	1773.0451			

The results at Table 4.9 shows that at $\alpha = 0.05$ level, the interactive effect between the mass groups is highly significant on the natural frequency, since 0.0000 (F. prob) < 0.05. The means that there is a significant difference between the mass groups. This is elaborated in Table 4.10.

TABLE 4.10: RESULTS OF THE MEAN VALUES OF NATURAL FREQUENCY OF THE VARIOUS MASS GROUPS UNDER THE THREE VARIETIES

MEAN		CHERRY 3	CHERRY 4	CHERRY 2	CHERRY 1	CHICO 3
14.0780	ROMA 4	*				
14.9240	CHICO 2	*	*			
15.1080	CHICO 1	*	*			
17.0160	CHICO 4	*	*	*	*	
17.6740	ROMA 3	*	*	*	*	
19.3000	ROMA 1	*	*	*	*	*
19.3984	ROMA 2	*	*	*	*	*

(*) Indicates significant difference in the natural frequency of fully ripe tomato samples. The numbers indicate their respective mass groups.

The Table above shows the significant difference in terms of natural frequency between mass groups and varieties. For example, Roma variety of mass group 4 is significantly different from cherry variety of mass 3. Also chico of mass groups 2 and 1 respectively are significantly different from cherry of mass groups 3 and 4 respectively.

Chico of mass group 1 is significantly different from cherry of mass group 3 and 4 respectively. Chico of mass group 4 and roma variety of mass group 3 are significantly different from cherry of mass groups 1, 2, 3 and 4 respectively.

Also roma of mass groups 1 and 2 are significantly different from cherry of mass groups 1, 2, 3 and 4 and chico variety of mass groups 3 respectively.

The results were categorized into similar subsets based on the mean natural frequencies and this is shown in Table 4.11. Each subset shows the natural frequency of tomato samples that are not significantly different. The numbers indicate their mass groups respectively.

TABLE 4.11 FULLY RIPE TOMATO MASS GROUPS WITHIN THE VARIETIES THAT ARE NOT SIGNIFICANTLY DIFFERENT IN THEIR NATURAL FREQUENCY VALUES

SUBSET	CHERRY 3,	CHERRY 4,	CHERRY 2,	CHERRY1,	CHICO 3,	
A	7.2540	8.6480	9.9240	10,5620	12.3980	
SUBSET	CHERRY 4,	CHERRY 2,	CHERRY 1,	CHICO 3,	ROMA 4	
B	8.6480	9.9240	10.5620	12.3980	14.0780	
SUBSET	CHERRY 2,	CHERRY 1,	CHICO 3,	ROMA 4,	CHICO 2,	CHICO 1
C	9.9240	10.5620	12.3980	14.0780	14.9240,	15.1080
SUBSET	CHICO 3,	ROMA 4,	CHICO 2,	CHICO 1,	CHICO 4,	ROMA 3
D	12.3980	14.0780	14.9240	15.1080	17.0160	19.398
SUBSET	ROMA 4,	CHICO 2,	CHICO 1,	CHICO 4,	ROMA 3,	ROMA 1,
E	14.0780	14.9240	15.1080	17.0160	17.6740	19.398
	ROMA 2					
	19.398					

The table above shows that the highest and lowest means in each group are significantly not different. This means that they are the same. For instance in subset A, cherry variety of mass groups 3, 4, 2 and 1 and chico variety of mass group 3 are not significantly different. Also in subset B, cherry variety of mass groups 4, 2 and 1, chico variety of mass group 3 and Roma variety of mass group 4 are significantly not different. Likewise the same for the subsequent groups.

But each of the group are significantly different from each other. Group A is significantly different from other groups, likewise group B, group C, and group D and group E respectively.

From the graph of force-deformation Figures 4.1 – 4.6, the firmness of the samples were determined. The least square parabola was used to relate the relationship between the variables which is a nonlinear relationship which is $y=a + bx + cx^2$................(4.1) where a, b, c were determined from the normal equations;

$$\sum y = na + b\sum x + c\sum x^2 \text{.............................} 4.2$$
$$\sum xy = a\sum x = b\sum x^2 + c\sum x^3 \text{......................} 4.3$$
$$\sum x^2 y = a\sum x^2 + b\sum x^3 + c\sum x^4 \text{............} 4.4$$

These were obtained formally by summing both sides of equation a after multiplying successively by 1, x and x^2 respectively. Hence the required least-square parabole has the following equations for the force – deformation curve respectively are;

(1) For green chico force-deformation curve;

$y = 0.04 + 0.03x + 3.08x^2$..................4.5

(2) For ripe chico force – deformation curve;

$y = 0.369 - 2.8x + 4.07x^2$.................4.6

(3) For green cherry force – deformation curve;

$y = 0.06 + 0.01x + 1.38x^2$.................4.7

(4) For ripe cherry force-deformation curve;

$y = 0.135 + 0.052x + 1.08x^2$..............4.8

(5) For green roma force-deformation curve;

$y = 0.04 + 0.095x + 2.14x^2$................4.9

(6) For ripe roma force – deformation curve;

$y = 0.06 + 0.03x + 2.95x^2$..............4.10

The table below shows the means values of the firmness of the three tomato varieties at green and fully ripe maturity stages.

TABLE 4.12 MEAN FIRMNESS VALUES FOR THE TOMATO VARIETIES.

	GREEN (N/mm)	RIPE (N/mm)
CHICO	2.07	1.76
CHERRY	2.15	1.52
ROMA	2.9	2.36

The results from Table (4.12) shows that roma variety has the highest firmness value at both green and fully red riped stages of maturity. Chico variety firmness value is higher than cherry at fully red riped stage, also cherry variety firmness value is higher than that of chico variety at green maturity stage.

4.2 Discussion and Observation

The experimented on the determination of natural frequency of three tomato varieties was successfully carried out. Based on the experiment, it was observed that roma variety ruptures at higher force than other varieties at both stages of maturity. This observations corresponds with the graphs presented. Also the green tomato samples requires greater force to rupture than the ripe ones, this is also in accordance with graphs presented. It was also observed that the determined.

Firmness of the samples showed that roma variety has the highest firmness value at both green and fully ripe maturity stages. Cherry variety is higher in firmness value than chico variety at green maturity stage, while chico variety has higher value than cherry at ripe maturity stage.

From the analysed results using the analysis of variance (ANOVA), it was observed that at green maturity stage, the mass and variety do not affect the natural frequency of tomato. It was observed that mass affects the natural frequency of fully ripe tomato and variety do not affect the natural frequency of the fully ripe tomato. This further explains that variety does not have an effect on tomato's natural frequency at green and ripe maturity stages. Also that mass do not affect the natural frequency of tomato at its green maturity stage, rather it affects it's natural frequency at fully ripe maturity stage.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

From this study, vital information on very important property of tomato that is useful as far as handling and transit damage is concerned as been determined. This is the natural frequency of three types of tomato commonly grown in Nigeria. The knowledge of this property will help both designer and management of fresh produce and handlers on how to reduce in transit damage by letting the natural frequencies of vibration of the vehicle to be away from that of the produce so as to avoid resonance. Hitherto such information are lacking about the tomato varieties grown in Nigeria.

It can be concluded that the three factors that were used to access the data, the mass of the produce seems to be an influencing factor as far as the analysis is concerned. This revelation can also be utilized in selecting produce for long distance travel. The roma variety of mass group 2 seems to give the highest mean natural frequency which is 19.3980 Hertz.

5.2 Recommendation

The following requirements are recommended for better results based on this experiment.

1. The source (tomato farm) should be close to the research station. This isto avoid long distant trip which affects the tomato fruits.
2. A suitable compression testing machine with load indicating mechanism capable of showing the total compressive load (force) carried by the test specimen and a dial gauge that automatically record the change in distance or displacement as a function of load in the test specimen, it

should also be an automatic self loading machine with speed of testing which should be based on the sensitivity of the specimen to loading rate. The machine should also be essentially free of interia lag at the specified rate of loading.

3. The test specimen samples to be used should be conditioned for the desired temperature before the experiment. This is because; fruits and vegetables normally require few hours to adjust their temperature. Thus, a conditioning chamber is recommended so that moisture gains or losses of the specimen can be minimized.

4. A radius of curvature meter is recommended for measuring the radius of the samples at the points of contact for lower and upper convex surfaces respectively.

REFERENCES

Abott A.J, and F.R. Harker (2002); Produce Quality and Safety Laboratory, USDA, Beltsville, Maryland. U.S.A.

Adeoti J.S (1998);Paper Presentation on Assessment of Two-Dimensional Vehicle for Rural Transportation in the Savana Region of Nigeria, Journal of Agricultural Mechanization in Asia, Africa and Latin America vol. 29, No 1, Department of Agricultural Engineering, University of Ilorin.

Alamu.J.F, J.D Olanrewaju and A.A.A Coker (2002); Profitable Assessment of Tomato and Pepper produced under Fadama Development. Institute for Agriculture, Research/Faculty of Agriculture, Ahmadu Bello University Zaria. Nigerian Journal of Horticultural Science. Vol. 6, Pp (44 -47), May 2002.

Ajisegiri. E.S.A ,P.A Idah, .Kromer and L. Damerow (2003); Development of an Impact Testing Machine. Journal of Science, Technology and Mathematics Education (JOSTMED) vol. 6 No.1.

Altisent M.R (1991): Damage Mechanisms in the Handling of fruits. Progress in Agricultural Physics and Engineering. Edited by John Matthew. British Library Cataloguing in Publication Date Pp 281 – 255).

ASAE (1998); American society of Agricultural Engineers ASEA Standards 368 Vol. 3 Pp 554 – 559.

Awoh O.C and A.O.Olorunda (1988); Packaging and storage of fresh fruits and vegetables with special reference to Tropical conditions. Proceedings of National Workshop on improved packaging and storage systems for fruits and vegetables in Nigeria, Ilorin, Pp 15 – 89.

Bela R.N, J.H. Young and V. Jindal (1998); Techniques for determination of mechanical properties of fruits and vegetables as related to design and development of harvesting and processing machinery, Journal of Agricultural Engineering Research, Vol. 7 No. 4, Pp 300 –315.

Coombe M. (1976); Introduction to Biophysical Plant physiology. Journal in Biosciences Vol. 23, No. 6,Pp 27 –39.

Daramola. A.M and W.I Okoye (1995); Post Harvest Loss Prevention in Horticultural Crop. Nigerian Stored Products Research Institute, Ilorin, Nigeria.

Dewult .W, P. Jancsok, B. Nicolai, G. DeRoeck and D. Briassoulis (1999); Determining the Firmness of a Pear using Finite Element Model Analysis. Journal of Agricultural Engineering Research, Pp 217-220.

Egharevba R.K.A (1995);Post Harvest Physiology of Fruitsand Vegetables, Faculty of Agriculture, University of Benin, Nigeria.

Ibrahim R.,E.B.Amans, A.Ahmed and I.U. Abubakar (2000);Growth Indices and Yield of Tomato varieties as influenced by Crop Spacing at Samaru, Institute for Agricultural Research

Ahmed Bello University, Zaria. Proceeding on 18th HORTSON Conference, IAR,ABU, Zaria. Pp (40-45).

Encyclopedia Britannica (2000); Roads.

Erinle I.D (1989);Present Status and Prospects for Increased Production of Tomato and Pepper in Northern Nigeria. Horticultural Crops Research Programme, Institute for Agricultural Research, Ahmadu Bello University, Zaria.

Food and Agricultural Organization. FAO (1989); Prevention of Post harvest Losses on Fruits, Vegetables and Root crops, FAO Training manual series No 17/2 Italy.

Gonalez R.C, M.H Wilde and F. Arakelian (2002); Damage Enhancement and Restoration. In Handbook of Patterns Recognition and Image Processing (Young T.Y and Fu K. S eds). London, Academic Press, Pp 191-214.

Hiller V.A.M and F. Pittuck (1990); Fundamentals of motor Vehicle Technology. 3rd Edition. Stanley Thornes (Publishers) ltd, Lockhampton , Cheltenham, London.

Ibrahim.R and A.B. Lawal (2001); Journal of Tropical Biosciences vol. 1, Pp (1-4).

Idah P.A, J.S Adeoti and K. Oje (1996); Assessment of Packaging and Transport Devices in Inter- state fresh Tomato Transportation in Nigeria. Survey, Proceedings of the 18th Annual Conference, Nigerian Society of Agricultural Engineers, Proceedings of the 18th Annual Conference. Nigeria Society of Engineers, Ile Ife.

Jones C.S, J.E Holt and D. Schrool (1991); A Model to Predict Damage to Horticultural Produce during Transportation. Journal of Texture studies vol15 No. 6, Department of Mechanical Engineering, University of Queensland, Australia.

Karen B.G (1991); Post harvest Management of Commercial crops, containers and packaging. Kansas State University, Agricultural Experimental Station and Cooperation Extension Services, U.S.A.

Kra E. and R.J Bani (1988); Handling and Transportation of Vegetables in Ghana. A journal of Agricultural mechanization in Asia, Africa and Latin America Vol.19, No.2,Agricultural Engineering Division, Faculty of Agriculture, University of Ghana, Legon.

Macrae R., R.K Robinson and M.J.Sadler (1993); Encyclopedia of Food Science, Food Technology and Nutrition. Vol 7, Pp (3647 – 3649).

Mai S.C and A. Fineh (1980); Rheology of Apple and Pototo Tissue as affected by cell tugor pressure . Journal of Texture Studies, Vol 17, Pp 291-313.

Messiaen C.M (1992); The Tropical Vegetable Garden. Principles for Improved and Increased Production with Application to main vegetable types. Translated and adapted by P.R Maclrimmon, CIA MacMillian, London, Pp 187-207.

Mohesenin N.N (1988); Physical Properties of Plants and Animal Materials, 3rd Edition. Gordon and Breach Science Publishers, New York.

Newton K. , N. Steeds and T.K Garrett (1996); The Motor Vehicle. 12th Edition, British Library Cataloguing in Publication Data, Butterworth- Heinemann, London Hill, Oxford, Pp 896-900.

Ogaga A.O (2002); Designing Vehicle Suspensions to suite the Irregularities of Nigerian Roads. Allah- Day Concepts Nigerian Limited, Kwale, Nigeria.

Ogut H. ,A. Peker and C. Ayidin (1999);Simulated Transit Studies on Peaches. Effects of containers, cushion materials and vibration on Elasticity Modulus. Journal of Agricultural Mechanization for Asia, Africa and Latin America Vol. 30 ,No 5.

Oladapo M.A (1995); Controlling Post harvest Losses in Tomatoes and Peppers, Journal of Tropical Post harvest Vo.13, Pp 136-142.

Olorunda O.A and K. Tung (1985); Reducing Damage in Tomato by proper Handling After Harvest. Horticultural Crops Research Programme, Institute for Agricultural Research, Ahmadu Bello University Zaria, Nigeria.

Peters R. (1996); Damage of Potato Tubers. A Review Journal of Potato Research Vol. 31, Pp 479-484.

Prussia S.C, M.C Bourne and G.Perkins (1994); Some Aspects of elastic Behavior of selected Fruits. Transactions of ASAE Vol. 11, No1, Pp 78-83.

Quinn D.P (1947); Tomato and Pepper Production in the Tropics. Proceedings of the International Symposium on integrated management Practices, Asia.

Roudot A.C, F.Duprat and C.Wenian (1990); Modeling the Response of Apples to Loads. Journal of Agricultural Engineering Research. Vol.48, No. 4 Hacettepe University, Faculty of Engineering,Department of Physics Engineering, Ankara, Ghana.

Singh A. and Y.Singh (1992); Paper presentation on Effects of Vibrations during Transportation on the Quality of Tomatoes. A Journal of Agricultural mechanization in Asia, Africa and Latin America. Vol.2, No. 2. Department of Processing and Agricultural Structures, Dujab Agricultural University, India.

Stockel M.W, M.T. Stockel and C. Johnason (1996); Auto Fundamental, How and Why of the Design, Construction and Operation of Automobile, Applicable to All Masses and Models. The Good Heart – Willcox Company. Inc.

Villareal, R.L. (1980); Tomatoes in the Tropics. International Agricultural Development Scheme. Development Orientation Literature Series. West View Press / Boulder, Colorado, U.S.A.

Williams J.O (1998); Post Harvest Handling of Tomato (Lycoperison esculentum). Paper Presented as the NSPRI monthly seminar Ilorin, Nigeria.

Wu. N and N.J Pitts (1999); Development and Validation of a Finite Element Model of an Apple Fruit Cell. Post harvest Biology and Technology Vol.16.

http:// www.libs.uga.edu/ref/scifair.html

http://ipmwww.ncsu.edu/vegetables/veginews/veginw15.html

http://www.dietobio.com/aliments/en/tomato.html

APPENDIX A

PLATE 3.1 COMPRESSION TESTING MACHINE

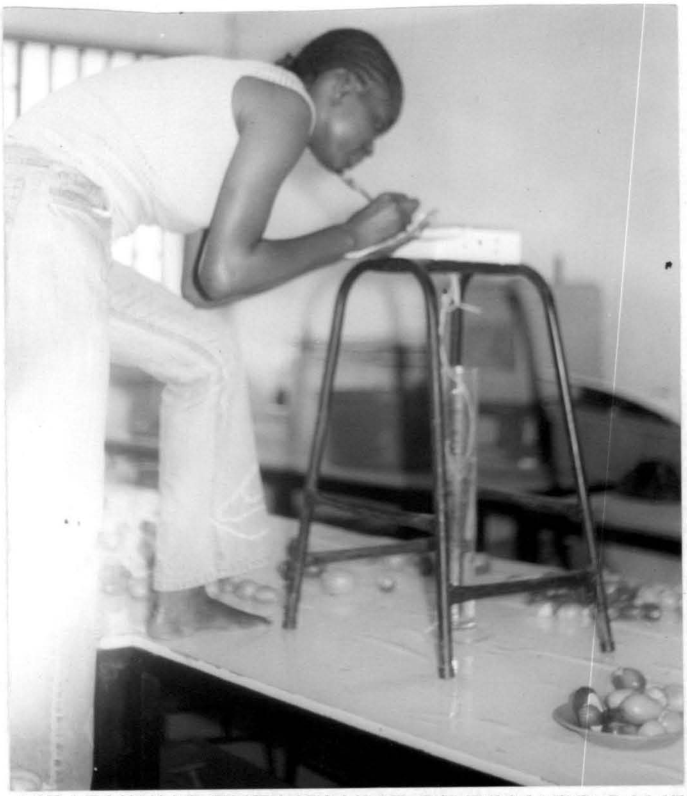

PLATE 3.2 MEASURING THE VOLUME OF TOMATO SAMPLES

APPENDIX B

PLATE 3.3 THREE TOMATOE VARIETIES AT GREEN AND FULLY RIPE STAGES OF MATURITY

L-R CHERRY, ROMA AND CHICO VARIETIES RESPECTIVELY

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

From this study, vital information on very important property of tomato that is useful as far as handling and transit damage is concerned as been determined. This is the natural frequency of three types of tomato commonly grown in Nigeria. The knowledge of this property will help both designer and management of fresh produce and handlers on how to reduce in transit damage by letting the natural frequencies of vibration of the vehicle to be away from that of the produce so as to avoid resonance. Hitherto such information are lacking about the tomato varieties grown in Nigeria.

It can be concluded that the three factors that were used to access the data, the mass of the produce seems to be an influencing factor as far as the analysis is concerned. This revelation can also be utilized in selecting produce for long distance travel. The roma variety of mass group 2 seems to give the highest mean natural frequency which is 19.3980 Hertz.

5.2 Recommendation

The following requirements are recommended for better results based on this experiment.

1. The source (tomato farm) should be close to the research station. This isto avoid long distant trip which affects the tomato fruits.
2. A suitable compression testing machine with load indicating mechanism capable of showing the total compressive load (force) carried by the test specimen and a dial gauge that automatically record the change in distance or displacement as a function of load in the test specimen, it

should also be an automatic self loading machine with speed of testing which should be based on the sensitivity of the specimen to loading rate. The machine should also be essentially free of interia lag at the specified rate of loading.

3. The test specimen samples to be used should be conditioned for the desired temperature before the experiment. This is because; fruits and vegetables normally require few hours to adjust their temperature. Thus, a conditioning chamber is recommended so that moisture gains or losses of the specimen can be minimized.

4. A radius of curvature meter is recommended for measuring the radius of the samples at the points of contact for lower and upper convex surfaces respectively.