DESIGN, FABRICATION AND TESTING OF A MANUALLY OPERATED FRUITS AND VEGETABLES SLICER

BY

YUSUF OLAYIDE RISIKAT
(PGD/AGRIC. ENGR/1999/2000/73)

A PROJECT PRESENTED TO THE DEPARTMENT OF AGRICULTURAL ENGINEERING, FUT MINNA IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF PGD IN AGRICULTURAL ENGINEERING (CROP PROCESSING)

APRIL, 2001

DECLARATION

I, Yusuf Olayide Risikat do declared that this project is an original work of mine, and has never been presented else where for any award. Information desired from published and unpublished works of others have been acknowledged in the write up.

Sign ....

Date ....

CERTIFICATION

I, the undersigned hereby certify that I have read, approved and do recommend for acceptance by the school of post- graduate studies this project work titled "Design, Fabrication and Testing of a Manually Operated Fruits and Vegetables Slicer (Tomatoes, Okro and Vegetables)" by Yusuf Olayide Risikat.

--   --------------------------

ENGR. (DR) D. ADGIDZI   DATE
SUPERVISOR

--   --------------------------

ENGR. (DR) M. G. YISA   DATE
HEAD OF DEPARTMENT

--   --------------------------

EXTERNAL EXAMINAR   DATE

DEDICATION

This project is dedicated to my loving Children Maryam, Halimat and others yet unborn.

TABLE OF CONTENT

List of Tables

List of Figures

List of Plates

ACKNOWLEDGEMENT

My most sincerely appreciation goes to Almighty Allah for keeping me and My family alive and for successful completion of the post – graduate programme, also my profound gratitude goes to my supervisor Dr. D. Adgidzi for his excellent supervision and encouragement for the completion of the project.

I sincerely acknowledge the management of National Center for Agricultural Mechanization (NCAM) Ilorin for the sponsorship of the programme

I humbly thank Eng. S. I. Obiakor and Eng. M. M. Olownibi for their guidance in the fabrication of this project and the staff of fabrication workshop of N C A M Ilorin for their effort during the fabrication.

My gratitude goes to Professor J. C. Igbaka and Dr. A. Ajisegiri for their advice and encouragement to pursue this programme. My appreciation to my senior sister Mrs. N. A. AbdulRaheem for taking care of my children and to my darling children Maryam and Halimat for understanding my absence from home most of the time.

Finally, my thanks goes to Mr. P. Kwaya and Suleiman Samaila Alhaji and others too numerous to mention who have made the programme a success.

ABSTRACT

A manually operated machine for slicing fruits and vegetables (Tomatoes, Okro and Carrot) with claw cutters (Scissors) was designed, fabricates and tested.

It has cutting blades with sharp serrated edges to piece and slice the materials effectively, press bars pushes the materials against the cutting blades during slicing and at the same time push the individual slices into the tray.

From the test performed, average slice thickness produced are 4. 8mm, 5. 4mm and 4. 8mm for tomatoes, Okro and Carrot respectively. Maximum throughout capacity obtained was 37. 4kg/h, 19. 937kg/h and 15. 128kg/h and efficiency of 79. 30%, 96. 08% and 95. 30% for Tomatoes, Okro and Carrot respectively.

The machine is portable, relatively economical considering the operational cost, indicate cost here! Maintenance, servicing and purchase. ~~It is also portable.~~

CHAPTER ONE

1.1 INTRODUCTION

Tomato (Lycopersico Escolentum) is a herbaceous plant commonly grown as annual crops like other vegetables such as pepper, onion and green leaves. The bulk of the dry – season tomatoes (Roma type) is mostly grown in the Northern – part of Nigeria under irrigation (Idah, et al, 1996)

Like other horticultural crops it has soft tissue, high moisture content of 70 – 93% (Wet basis) and a high rate of physiological activities such as respiration and transportation, which make them liable to rapid deterioration resulting in heavy losses during handling, transportation and storage after harvesting (Aworh et al, 1988; Erinle et al, 1988; NSPRI, 1991; Oyeniran, 1985; singh et al, 1992)

Okro (Abelmoschum Esculentus (L) Moench) is a vegetable popular in Nigeria and produced and consumed throughout the country. They are planted in gardens or in mixed cropping with other staple crops like the tomatoes, it has moisture content of about 84% (Wet basis) and high rate of physiological activities and also deteriorate rapidly.

Carrots are produced predominately in the northern part of the country during the dry season, there are two kinds of carrot namely those having orange yellow skin and those having purple skin but white flesh, the former are preferred for slicing and carrot candy (Girdhari et al, 1986) This also have high moisture content of 86% (wet basis) with high physiological activities and deteriorate rapidly.

During peak production of tomatoes, Okro and carrot, collosal waste are experienced as a result of inadequate storage facilities and Technique, and during off – season, these fruits and vegetables are quite expensive or inavailable for use. They can be stored by canning in refrigerators but these processes are not popular with the local formers, therefore, they are preserved locally in the dried forms.

The storage potential of the fruits and vegetables is low. They do not store well in the fresh form and transportation is costly due to their bulkiness, this course damage to them therefore processing into non perishable and easily transportable produce offer an alternative to storage in the fresh form. Due to the high moisture content of these fruits and vegetables they can not dried easily unless the water is reduced by exposing the internal surface to drying and this can be achieved by slicing the materials

Slicing operation is achieved by cutting which involve moving, pushing or forcing thin sharp blade or knives through the materials resulting in minimum rapture and deformation of the materials (Raji and Igbeka, 1994). The slices produced by traditional method are not uniform and this may result in non-uniform drying or infected dried slices.

With technological advancement, there is the progressively increased awareness in the importance of using mechanical devices to slice tomatoes, okro and carrot and due to the peculiar nature of tomatoes (Skin) the mucilaginous properties of okro and the high texture of carrot and considering the demand for dried tomatoes, okro and carrot these factors were considered in designing a mechanical device to slice these fruits and vegetables.

1.2 SCOPE OF THE PROJECT

The project work is limited to Tomatoes, Okro and Carrot, which are most widely cultivated fruits and vegetables in Nigeria for drying.

The effect of slicing on these fruits and vegetables would be limited to uniformity of slices, time of slicing, capacity and physical assessment of dried products

1.3 JUSTIFICATION

The need to increase food supply has been recognized by many developing countries including Nigerian. Thus considerable research especially in the area of fruits and vegetables such as Tomatoes, Okro, Carrot, Pepper, Green leaves e. t. c. are being carried out. These have led to increasing yield in those produce (Idah et al, 1996). These fruits and vegetables are good sources of vitamines A and C, they generate rural employment through wide spread cultivation, increase farmers income and expand export (Villarreal, 1980)

It has been stated that tomatoes are the worlds most widely grown vegetables other then white potatoes commercially, 45 million tones of tomatoes are produced each year from 2. 2 million hectares excluding the large amount grown in gardens (Villarreal, 1980)

In Nigeria, figures like 6 million tones of Tomatoes have been quoted as annual production figures (Oyeniran, 1980). Slicing Tomatoes, okro and carrot for drying is very important but has not received any form of mechanization. Almost all other aspect of vegetables have been mechanized. For examples Tomato canning, Ketchup, Okro and carrot canning and little is done on their slicing for drying.

Majority of the slicing machines are imported, expensive and sophisticated which may not be easily operated and maintained by the local farmers. Also some of these machines are designed for a particular type of crop and cannot be used for tomatoes (skin) okro (mucilaginous) and carrots.

Considering the present need for increased fruits and vegetables preservation in the country most farmers dry some of their produce in order to prolong storage period. Therefore to boost the preservation of fruits and vegetables in large quantity and retain their quality, the need to design and construct a machine that will enhance this operation cannot be over emphasized.

The designed machine is aimed at solving the problem of small – scale farmers with all the above problems put into consideration. This major aspect of slicing and drying should not be left out because of it importance and usefulness both domestically and industrially.

1.4 OBJECTIVES

1. To design and construct a manually operated fruits and vegetables (Tomatoes, Okro and Carrot) slicer.
2. To carry out test performance of the machine

CHAPTER TWO

2.1 LITERATURE REVIEW

Slicing operation is a form of size reduction and this is brought about by mechanical means without changes in chemical properties of the material. Size reduction is achieved by cutting, involving pushing and forcing a thin sharp knife through the materials resulting in minimum rupture and deformation (Raji and Igbeka, 1994)

In materials with high moisture content (Tomatoes, Okro and Carrot e. t. c) slicing assists in the removal of some of the high moisture by loosing water easily, the internal flow of moisture is rapid in these materials thus exposes a large surface area of the material for quick and uniform drying

Tomatoes, Okro and Carrot are fruits and vegetables whose industrial potentials seem to have been overlooked for a very long time, their utilization has been largely confined to processing into paste, puree, juice, ketchup, canning e. t. c. Processing of these fruits and vegetables has been characterized by manual operations, very little emphasis is placed on the investigation of the machine parameters affecting the performance of various fruits and vegetables processing machines. This probably accounts for the dearth of quantified scientific standards for most of the available fruits and vegetables. Nevertheless an attempts is made to reduce and cite some relevant information found in literature.

From the survey of the traditional way of slicing carried out at four different locations in Ilorin town, it was noticed that the mean maximum thickness of tomatoes Okro and carrot were 5mm, 6mm and 5mm respectively while the mean minimum thickness are 4mm, 5mm and 4mm receptively. These were obtained by using visual observations, nevertheless they still have some slices that measured up to a maximum of 5mm, 7mm and 8mm thick, while some as less as 3mm, 2mm and 3mm for tomatoes Okro and carrot receptively. Also, they were able to slice about one basket each of these fruits and vegetables, which weighed about 30kg per day. Based on the slice thickness of these local farmers a standard slice thickness of 5mm was adapted for the machine to produce uniform slices at much higher capacity per unit time.

2.2 UTILIZATION OF TOMATOES, OKRO AND CARROT

Fresh tomatoes and carrot are consumed when used raw in green salads. These fruits and vegetables are also consumed as processed products or carrot juice and prickle, ketchup, pastes, puree, stuffed as in the case of tomatoes

The general composition of fresh tomatoes is water 93%, protein 1.1% and fat 0. 3% (Ihekosonye and Ngoddy, 1985)

2.3 ENGINEERING PROPERTIES OF AGRICULTURAL MATERIALS

The increasing economic importance of food materials together with the complexity of modern technology with their production, handling, storage, processing, preservation,,quality, evaluation, distribution, marketing and utilization demand a better knowledge of the significant physical and mechanical properties of these materials.

Modern agriculture has brought about the handling and processing of plant and animal materials by various means such as mechanical, thermal, electrical techniques and devices. These properties include specific heat, thermal characteristic, electrical conductivity, dielectric constant, and light transmittance characteristic and such mechanical properties as stress-strain behavior, resistance to compression, impact, shear and coefficient of friction.

A knowledge of these properties constitute important and essential engineering data in design of machine, structures, processes and control in analyzing and determining the efficiency of a machine or an operation (Idah 2000)

PHYSICAL PROPERTIES OF FRUITS AND VEGETABLES

In talking about any product in terms of grain, fruits and vegetables e. t. c. as individual units or in bulk it is important to accurate estimate their shape, size, volume, specific gravity, surface area and other physical characteristic which may be considered as engineering properties for these materials. These parameters are used in the design of specific machines and equipment for slicing or separating grains from stones (Idah, 2000)

The physical properties of the fruits and vegetables considered here are the length, the external diameter and their shape. The mean length of the Tomatoes carrot and okro are 37mm, 89mm and 69mm respectively and their mean diameter are 67mm for tomatoes while that for okro and carrot are 13.00mm and 15. 33mm respectively.

MECHANICAL PROPERTIES OF FRUITS AND VEGETABLES

These include mechanical damage which has its own economic significant particularly in processing. This can be noticed in the quality assessment of the product before and after processing, therefore, mechanical damage has to be minimized in order to enhance the quality of the product. Mechanical damage to kernel of seed grains, fruits and vegetables increases the tendency toward mould development, rotting of the materials and thus affect the quality of the product. Therefore it is very important that mechanical damage can be reduced by careful handling of agricultural produce.

RHEOLOGICAL PROPERTIES OF AGRICULTURAL MATERIALS

This is the behavior of agricultural materials under static or dynamic loading and flow characteristics either in air or water (Fluid) To be able to predict or evaluate the behavior of tomatoes, okro carrot under conditions of applied load, force, thermal design for the industrialization of various processing operations or analyses, knowledge of the physical characteristics, mechanical, thermal and other engineering properties of the materials are essential. Unfortunately, very little work, if any has been done or reported in this area of engineering characteristic of tomatoes, okro and carrot products.

A force – deformation test conducted on tomatoes in Canada by Olorunda and Tung (1985) indicated that a tomato fruits can withstand a maximum allowable pressure (Bioyield) of 5283, 2852, and 2100 kg/m^2 for green, breaker (turning and red tomato) maturity respectively. The variety used was the culture in Reento grown hydroponics glass house culture in Canada

Therefore, the rheological properties of the fruits and vegetables was determined using universal instron testing machine to determine the load deflection and strain of the slicer on the materials. These are shown in tables 1, 2, and 3.

2.4 MODERN METHODS OF PRESERVATION OF FUITS AND VEGETABLES

1. PHYSICAL METHODS

a. By removal of heat (preservation by cold)
- I Refrigeration
- ii Freezing preservation
- iii Dehydro freezing
- iv Carbonation

b. By addition of heat (thermal processing)
- I Stationary pasterderization
- ii Agitating pasteurization/ sterilization.
- Iii Flash pasteurization/ HTST processing e.t.c.

c. By removal of water (Evaporation or dehydration)
- I sun drying
- ii Dehydration
- iii Low temperature Evaporation or Concentration.
- Iv Freeze – drying
- V Accelerated freeze drying

		Vi	Foam – mat drying
		Vii	Puff drying e. t. c.
d.	By irradiation	i.	Dosing with u. v. or ionizing radiation e. t. c.

2.	**CHEMICAL METHODS**		
a.	By addition of acid such as vinegar or Lactic acid	I	Prickled vegetables, fish and meat
b.	By salting or brining	I	Vegetables and fruit prickles, salted fish e. t. c. salt – cured meat and pork e. t. c.
c.	By addition of sugar and heating	I	Fruit preservers, jams jellies, Marmalades e. t. c.
d.	By addition of chemical preservation	I	Using water soluble salt of sulphur dioxide, benzoic acid, ascorbic acid and a few like hydrogen peroxide

			sodium benzoate e.t.c. which are permitted as harmless in food
		ii	By means of substances of bacterial origin such as tylosin resin e.t.c which are permitted to a limited extent, in some cases as harmless additives
3.	By fermentation	I	Alcoholic and acetous fermentation as in the case of fruit wines, apple cider, fruit and vinegar, e.t.c
4.	By other methods	I	A judicious combination of one or more of the methods mentioned

above for synergistic

preservation.

2.5 SLICING AND SIZE REDUCTION

Slicing is a form of size reduction, and the general term "size reduction" includes slicing, cutting, crushing, chopping, grinding and milling. The reduction in size is brought about by mechanical means without change in chemical properties of the material and uniformity in size and shape of individual units of the end product.

Such processes as cutting fruits or vegetables for canning, shredding sweet potatoes for drying, chopping corn fodder, grinding grain for lives stock feed and milling flour are size reduction. Reducing the size of food raw materials is an important operation to achieve a definite size range (Henderson S. M. and R. L. Perry. Agricultural process Engineering, page 185)

Size reduction may help in the extraction of desirable constituents from raw materials e.g. crushing palm fruits for extraction of palm oil, milling grains for the production of flour, crushing fruits for juice or for fermentation.

Some other operations in food processing and preservation are facilitated by smaller size particles, for example, when a food raw materials such as yam is to be dried, it is cut into slices to expose more surface area to the drying medium, similarly in drying of okro or tomatoes, the vegetables and fruits are sliced into, smaller pieces to facilitate heat transfer and removal of moisture from the pieces.

2.9 EXISTING SLICERS

Several slicing and chipping machines have been designed and tested in various developing countries especially the Caribbean and south East Asian countries as reported by Clark (1987)

Various types of machines are manufacture from small hand operated batch –types to large automatic continuous operation, Some are petrol, diesel or electric motor operated. There are cassava chipper, tomatoes slicer, okro slicer and other root and vegetable chopper originally developed in Malaysia (Anon, 1974).

Ingrain (1972) found out that peeling and slicing of tubers are done manually. In Nigeria a number of researcher have work on production of slicer for various crops (Okro, tuber e.t.c) Odigbo and Ahmed (1982) reported that there have been effort at mechanizing tubers processing in the very few processing plant in Nigeria.

Raji and Igbeka (1994) designed, fabricated and tested a pedal operated chipping and slicing machine for tubers and it was reported that the machine performed satisfactorily with production of slices of uniform thickness ranging from 1mm to 13mm thickness and a throughput of about 376kg/hr at an efficiency of about 83%

Olajide, Olowonibi and Onwualu (1997) evaluated an okro slicer and found out that there is higher losses in the manual knife slicing of okro than in the okro slicer

There are also several manually operated kitchens –size chipping and slicing machines in the market. Some of these chipping and slicing machines are either imported or fabricated locally.

The imported ones are sophisticated and may not be easily operated and maintained by local user, therefore adaptability of the techniques locally is difficult. Moreso some of these slicing machines are designed for only a particular type of vegetables and fruits and cannot be used for tomatoes, okro and carrot because of their peculiar (Rheological) nature.

CHAPTER THREE

3.1 MATERIALS SELECTION

To have a good judgement of selection and use of materials for construction we must know their basic characteristics and general knowledge of how materials react to various conditions of usage. Many materials for the construction have been taken into consideration in terms of mechanical properties including strength under various types of loading and wear resistance.

Physical properties such as the thermal conductivity, the dimension in which the materials are usually soldered, flexibility of the materials for forging and welding and chemical properties such as resistance to corrosion. Durability is also put into consideration to ensure that the materials retain it's working capacity.

In order to choose suitable materials for the construction of the slicer, the following factors were taken into consideration.

1. Rigidity
2. Wear resistance
3. Heat resistance
4. Vibration stability
5. Reliability
6. Resistance to corrosion
7. Strength

3.2 DESIGN CONSIDERATIONS

A number of factors were considered in the design of the fruits and vegetables slicer these include the agro – technical factors of the material such as the physical and mechanical properties and the properties of the materials for construction. The universal testing machine was used to determine some of the engineering properties of the materials.

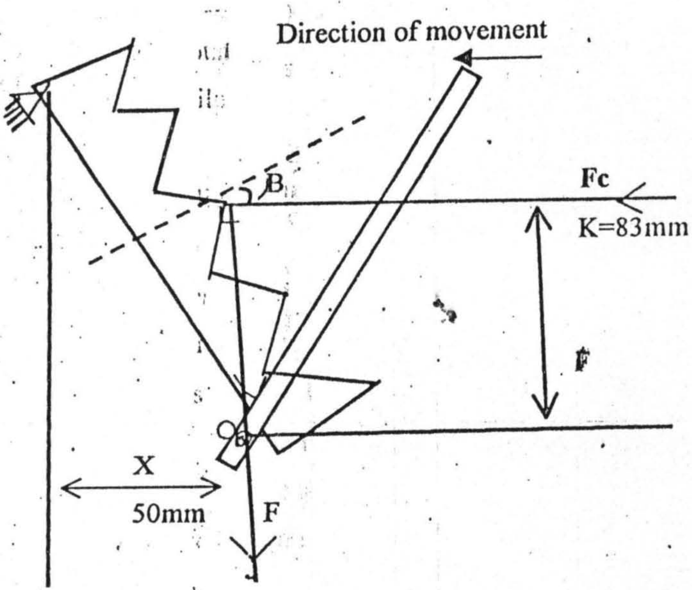
Tomatoes have tough thin skin, soft mesocarp and contains a lot of water (High moisture content 93%), okro is a draw or mucilaginous vegetable while carrot is a turgid fruit.

Due to these inherent natural phenomena, a device for slicing these fruits and vegetable requires to be thin and sharp. It must require little force for the blades to penetrate the fruits and vegetables, the materials needed for construction must not be capable of contaminating the fruits and vegetables, that is the materials must not be corroded when in contact with water.

Stainless materials are strictly recommended as construction materials because of the following reasons.

1. Hardness to resist abrasion
2. The ability to retain their hardness at high temperature
3. Toughness to withstand any shock load impart
4. It is not corrosive

.3 DESIGN CALCULATION



1: A schematic diagram showing forces acting on the blade edges

The cutting edges were designed to have pointed edges so that it can erce the materials and slice effectively. The edge angle was designed to be at 5^0 and its oblique angle β for Tomatoes, Okro and carrot are $101.\ 25^0$; 97.5^0 and $2.\ 5^o$ respectively.

The blades were coupled together as a unit and connected to an angle eel to enable the blades carry out its function, the fruits and vegetable to be ced is placed in the middle of these blades and the presser

The lower end of the blades lies in between the flat steel bars at the base. e bars act as pusher to press the fruits or vegetables against the pointed rrated blades for slicing.

THE FRAME

This is made of aluminum square pipe of 3mm thickness, with length, width and height of 450 x 250 x 25mm. It is rectangular in shape.

THE TRAY

This is made of galvanized iron sheet of 3mm thickness, with length, width and height of 147 x 270 x 25mm.

THE HOPPER

The configuration of the blades and the presser forms the hopper, which form a v – shape

3. 5 OPERATIONAL PRINCIPLES

The materials to be sliced are placed in the cutting unit. The number of materials to be sliced depends on the size and length of the materials and should be arranged horizontally along the direction of cut.

The handle is pushed which also pushed the presser and in turn presses the materials against the sharp pointed stationary slicing blades and thus slices the materials. The presser at the same time pushes out the sliced materials into the tray.

3.2 MAINTENANCE

The maintenance of any slicing machine in good working order is very important for successful operation and to extend the life span of the machine. The followings are maintenance tips after using the slicer.

Remove the blades and clean with water and allowed to dry before assembling back.

Rinse the presser with water and hard wire brush to remove any material particles that may be sticked to it.

Grease the moving parts.

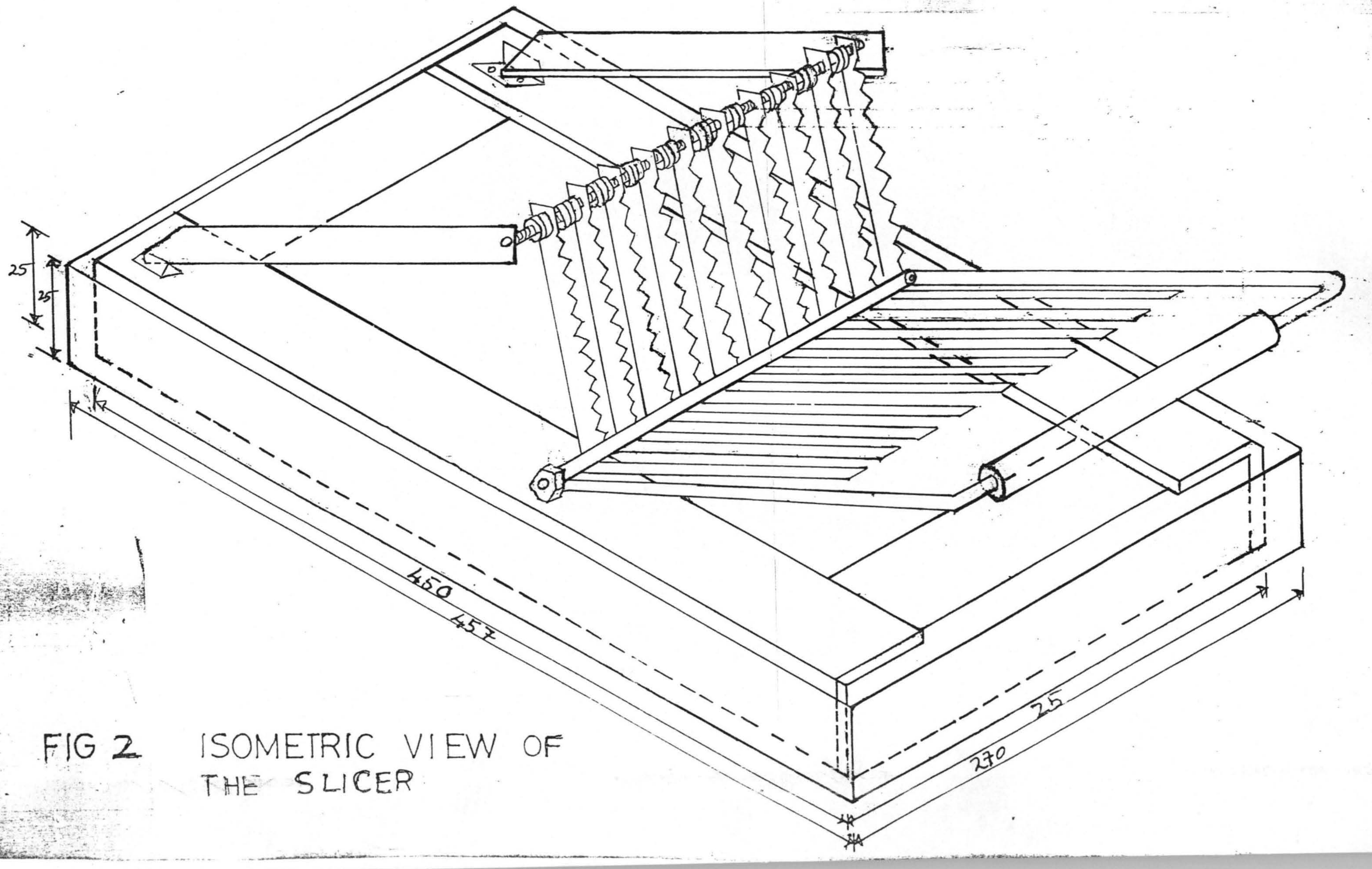


FIG 2 ISOMETRIC VIEW OF THE SLICER

CHAPTER FOUR

4.1 FINDINGS OF ENGINEERING PROPERTIES OF TOMATOES, OKRO AND CARROT

The physical properties were mainly on the length, diameter, shape, weight of the fruits and vegetables. These are 60mm, 80mm and 140mm length for Tomatoes, Okro and Carrot also 5mm, 15mm and 20mm diameter respectively while the shapes are on oblong for Tomatoes and cylindrical for okro and carrot and the average weights are 1. 5g, 0.6g and 1. 2g for Tomatoes, Okro and Carrot respectively.

The mechanical properties was conducted on the force - deformation under applied load of the material and this was determined using universal testing machine

The findings are on load, deflection and strain are shown in tables 1, 2 and 3, the load Vs deflection graph in fig 3, 4, and 5 for the samples respectively. The loads Vs deflection graphs indicates that the sample has maximum load peak of 34. 200N, 105. 400N and 83. 700N for Tomatoes, Okro and Carrot, these are the maximum forces required to be applied to slice the vegetables. After this point there is a deflection of 19. 496mm, 16. 887mm and 12. 675mm respectively at this point there is complete rupture of the fruit and vegetables.

SAMPLE : Tomatoes
VARIETY : Roma
MOISTURE : 70.6%

Test : VEGTABLE
Test Type : Compression
Date : 15-03-01
File : A:VEGTABLE\TST0001.DAT
Test Speed : 025.00 mm/min
Sample Type : NONE
Pre-Load : OFF

Test No.	Height mm	Load @ Peak N	Def. @ Peak mm	Strain @ Peak %	Energy @ Peak N.m	Load @ Break N	Def. @ Break mm	Strain @ Break %	Energy @ Break N.m	Load @ Yield N	Def. @ Yield mm
1	41.000	34.200	19.496	47.551	0.3094	11.800	24.682	60.200	0.4217	7.4000	5.4020
2	38.000	18.000	15.071	39.661	0.1263	8.700	17.765	46.750	0.1666	4.0000	4.1030
3	34.000	33.600	18.812	55.329	0.2342	14.400	21.035	61.868	0.2921	6.8000	5.9730
Minimum	34.000	18.000	15.071	39.661	0.1263	8.700	17.765	46.750	0.1666	4.0000	4.1030
Mean	37.667	28.867	17.793	47.514	0.2233	11.633	21.161	56.273	0.2935	6.0667	5.1593
Maximum	41.000	34.200	19.496	55.329	0.3094	14.400	24.682	61.868	0.4217	7.4000	5.9730
Std Dev	3.512	8.723	2.302	7.835	0.0921	2.854	3.460	8.209	0.1276	1.8148	0.9583

Test No.	Strain @ Yield %	Energy @ Yield N.m
1	13.176	0.0195
2	10.797	0.0063
3	17.568	0.0147
Minimum	10.797	0.0063
Mean	13.847	0.0135
Maximum	17.568	0.0195
Std Dev	3.435	0.0067

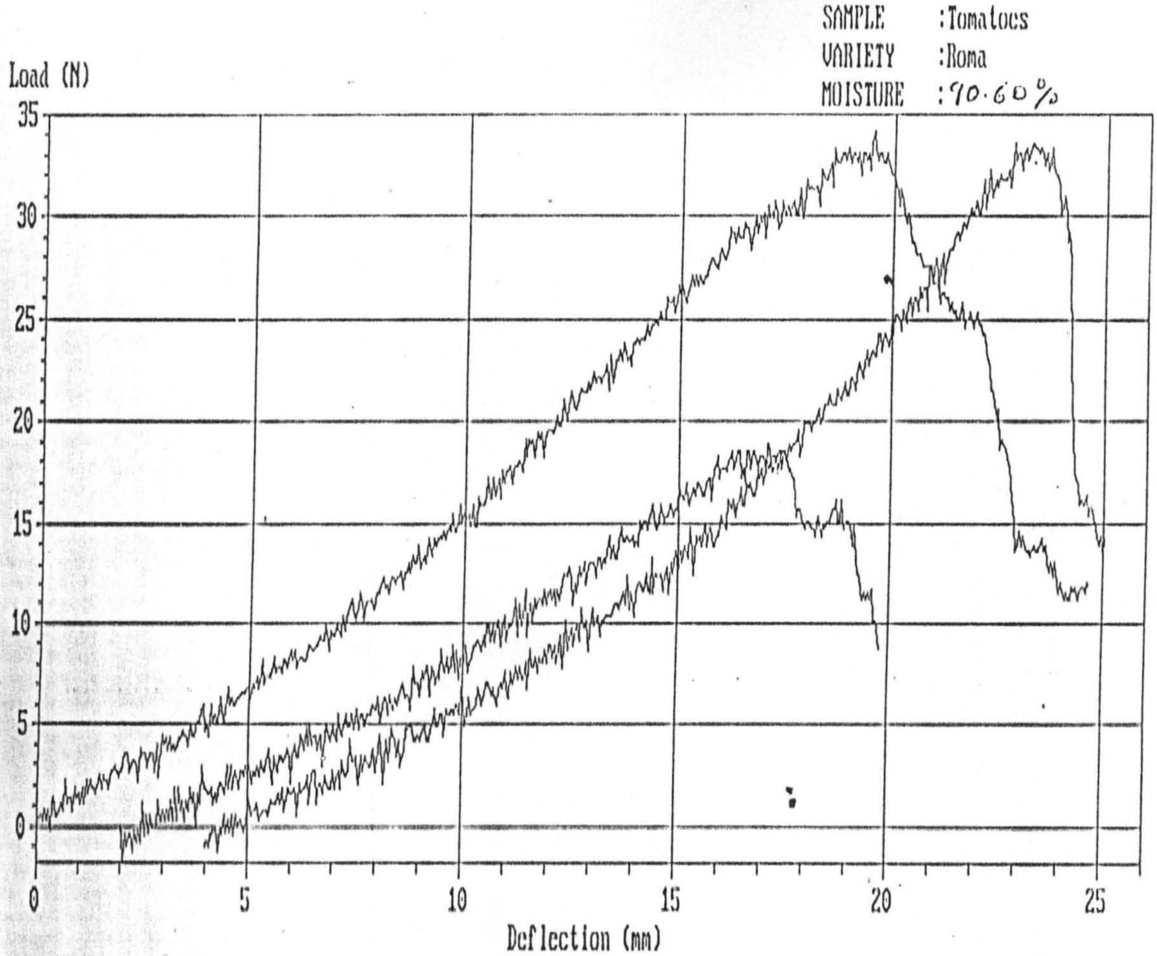


Fig. 3 : Land Vs deflection of Tomatoes.

Table 2. Rheological Properties of Okro

AMPLE : Okro
ARIETY All Varieties
OISTUR : 84.20%

Test : VEGTABLE
Test Type : Compression
Date : 15-03-01
File : A:VEGTABLE\TST0002.DAT
Test Speed : 025.00 mm/min
Sample Type : NONE
Pre-Load : OFF

est No.	Height mm	Load @ Peak N	Def. @ Peak mm	Strain @ Peak %	Energy @ Peak N.m	Load @ Break N	Def. @ Break mm	Strain @ Break %	Energy @ Break' N.m	Load @ Yield N	Def. @ Yield mm
1	16.000	105.40	16.887	105.54	0.6689	51.000	19.516	121.98	0.8879	25.200	7.5530
2	12.000	47.10	13.409	111.74	0.2896	36.200	16.484	137.37	0.3998	13.100	5.1500
3	11.000	24.30	13.303	120.94	0.2006	21.100	14.649	133.17	0.2279	5.500	2.4280
nimum	11.000	24.30	13.303	105.54	0.2006	21.100	14.649	121.98	0.2279	5.500	2.4280
an	13.000	58.93	14.533	112.74	0.3864	36.100	16.883	130.84	0.5052	14.600	5.0437
ximum	16.000	105.40	16.887	120.94	0.6689	51.000	19.516	137.37	0.8879	25.200	7.5530
d Dev	2.646	41.82	2.039	7.74	0.2487	14.950	2.458	7.96	0.3424	9.935	2.5642

est No.	Strain @ Yield %	Energy @ Yield N.m
1	47.206	0.0706
2	42.917	0.0212
3	22.073	0.0044
imum	22.073	0.0044
n	37.399	0.0321
imum	47.206	0.0706
Dev	13.445	0.0344

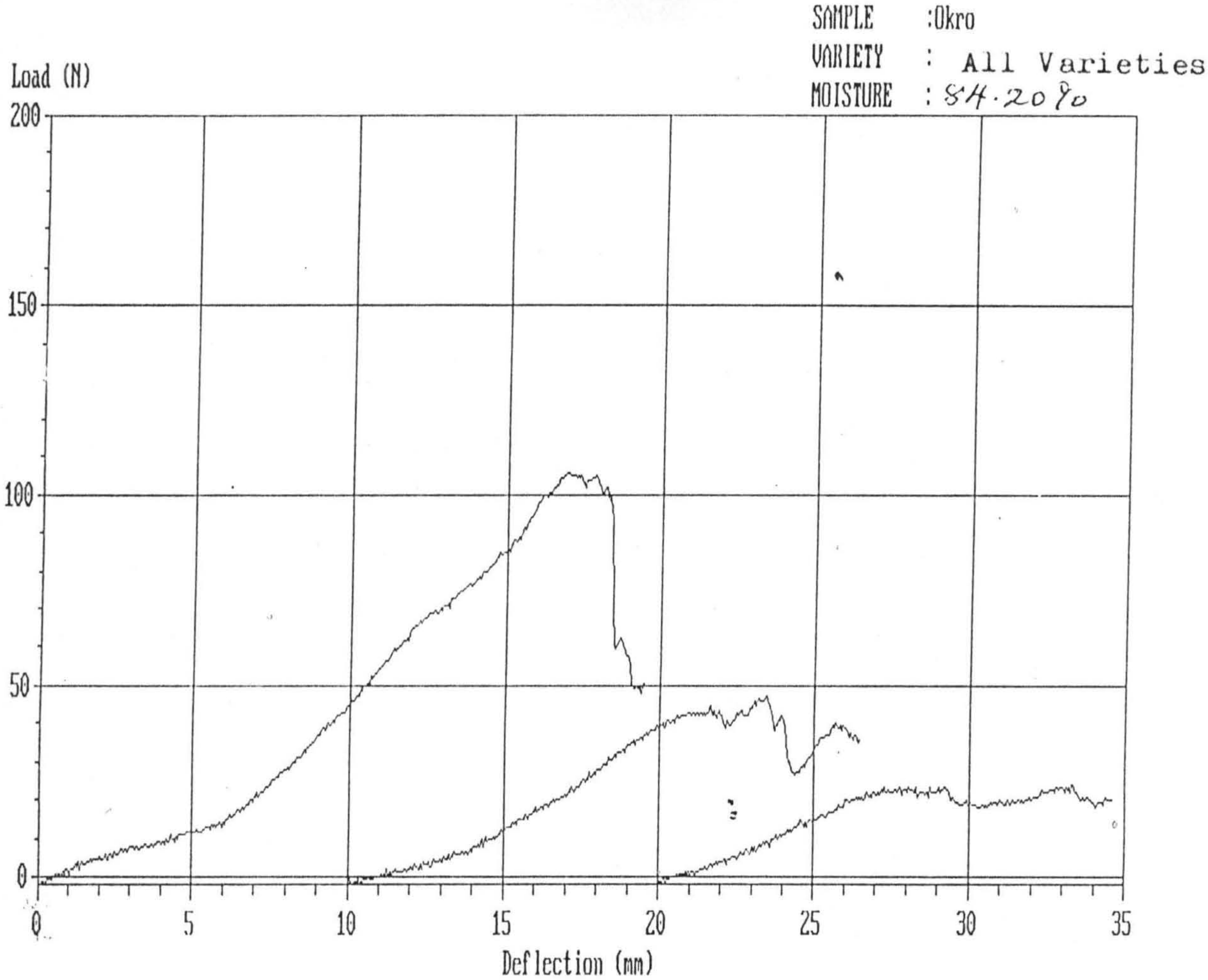


Fig. 4 : Load Vs deflection of Okro

Table 3: Rheological Properties of carrot

SAMPLE : Carrot
VARIETY : Yellow
MOISTURE : 86.74%

Test : VEGTABLE
Test Type : Compression
Date : 15-03-01
File : A:VEGTABLE\TST0002.DAT
Test Speed : 025.00 mm/min
Sample Type : NONE
Pre-Load : OFF

Test No.	Height mm	Load @ Peak N	Def. @ Peak mm	Strain @ Peak %	Energy @ Peak N.m	Load @ Break N	Def. @ Break mm	Strain @ Break %	Energy @ Break N.m	Load @ Yield N	Def. @ Yield mm
1	18.000	83.700	12.675	70.417	0.6760	82.600	12.719	70.661	0.6797	35.300	2.8280
2	15.000	53.800	4.812	32.080	0.1433	52.200	6.065	40.433	0.2085	44.700	3.5300
3	13.000	57.600	5.971	45.931	0.2139	57.400	6.015	46.269	0.2165	31.900	1.5330
Minimum	13.000	53.800	4.812	32.080	0.1433	52.200	6.015	40.433	0.2085	31.900	1.5330
Mean	15.333	65.033	7.819	49.476	0.3444	64.067	8.266	52.455	0.3682	37.300	2.6303
Maximum	18.000	83.700	12.675	70.417	0.6760	82.600	12.719	70.661	0.6797	44.700	3.5300
Std Dev	2.517	16.277	4.245	19.413	0.2894	16.260	3.856	16.035	0.2698	6.630	1.0131

Test No.	Strain @ Yield %	Energy @ Yield N.m
1	15.711	0.0498
2	23.533	0.0807
3	11.792	0.0269
Minimum	11.792	0.0269
Mean	17.012	0.0525
Maximum	23.533	0.0807
Std Dev	5.978	0.0270

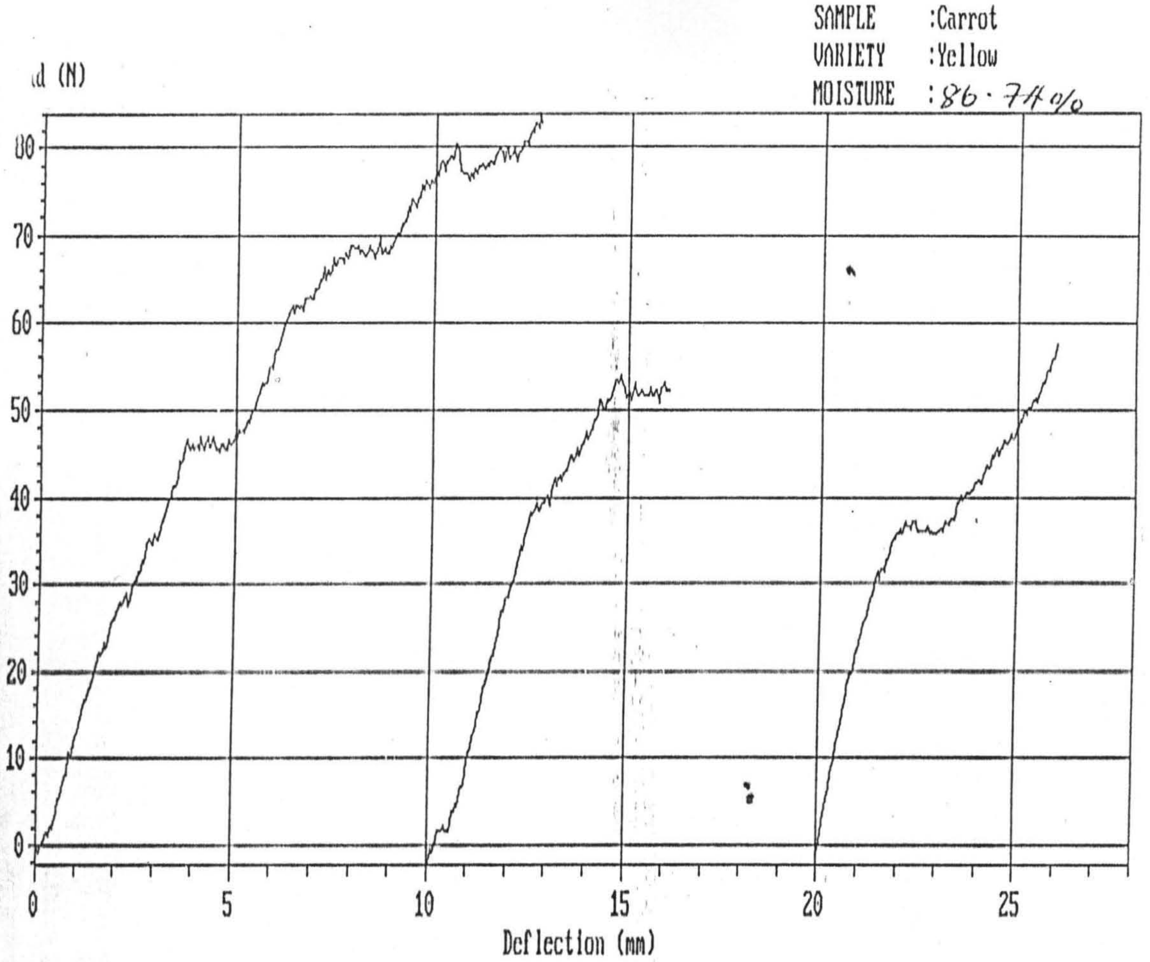


Fig.5 : Load Vs deflection of Carrot.

4. 2 PERFORMANCE TEST OF THE MACHINE

Some tests were carried out to evaluate the performance of the machine on the basis of

a. Capacity

b. Effectiveness of slicing

c. Uniformity in product dimensions

d. Physical assessment of dried products

The input weight (W_1) and output weight for normal slices (W_2) crushed products (W_3) duration of operation and dimension of products were recorded. This is shown in tables 4, 5, 6 and 7.

4. 3 PERFORMANCE TEST OF KNIVES SLICING

Five persons (men and women) were selected to use knives for slicing. The purpose was to compare with machine slices. Certain factors were compared, such as the quantity of sliced fruits and vegetables (Tomatoes, Okro and Carrot), time spent for slicing and quality of sliced products.

One kilograms each of Tomatoes, Okro and Carrot with moisture content of 90. 60%, 84. 2% and 86. 74% respectively was given to each person. Assessment of such nature depends on number of factors like individual energy, moisture content, varieties of the fruits and vegetables and sharpness of the knives tables 5, 6, 7 and 8 shows detailed performance of the people.

TABLE 4: PERFORMANCE EVALUATION TEST OF THE MANUAL FRUITS AND VEGETABLE SLICER ON TOMATOES

VARIETY – ROMA TYPE

STATION – NCAM, ILORIN

DATE – 22ND MARCH, 2001

SAMPLE	Original weight of Tomatoes W_1 (kg)	Moisture content (W.b) (%)	Weight of normal slices W_2 (kg)	Weight of crushed slices W_3 (kg)	Duration of operation T (min)	Thickness of slices (mm)	Output capacity W_1/T (kg/h)	Slici effici W_2/w 100 (
A	1	90	. 680	. 310	1. 450	4. 67	41. 379	68. 0
B	1	91	. 800	. 185	1. 667	4. 73	36. 145	80. 0
C	1	90	. 860	. 135	1. 733	5. 10	34. 622	86.00
D	1	92	. 850	. 140	1. 700	5. 00	35. 294	85. 00
E	1	90	. 775	. 220	1. 500	4. 89	40. 00	77. 50

TABLE 5: PERFORMANCE EVALUATION OF THE MANUAL FRUITS AND VEGETABLES SLICER ON OKRO.

VARIETY – ANY TYPE

STATION – NCAM, ILORIN

DATE – 22ND MARCH, 2001

SAMPLE	Original weight of Okro W_1 (kg)	Moisture content (W.b) (%)	Weight of normal slices W_2 (kg)	Weight of crushed slices W_3 (kg)	Duration of operation T (min)	Thickness of slices (mm)	Output capacity W_1/T (kg/h)	Slicing efficien W_2/W_1 100 (%)
A	1	85	. 990	. 001	3. 967	5. 50	15. 125	99.90
B	1	83	. 950	. 0491	3. 000	6. 13	28. 800	95. 0
C	1	86	. 985	. 014	3. 683	6. 03	19. 460	98. 5
D	1	84	. 875	. 023	2. 083	6. 07	20. 000	87. 5
E	1	83	. 995	. 004	3. 667	5. 97	16. 300	99. 5

TABLE 6: PERFORMANCE EVALUATION OF THE MANUAL FRUITS AND VEGETABLES SLICER ON CARROT

VARIETY – YELLOW TYPE

STATION – NCAM, ILORIN

DATE – 22ND MARCH, 2001

SAMPLE	Original weight of Tomatoes W_1 (kg)	Moisture content (W.b) (%)	Weight of normal slices W_2 (kg)	Weight of crushed slices W_3 (kg)	Duration of operation T (min)	Thickness of slices (mm)	Output capacity W/T (kg/h)	Slicin efficie W_2/W 100 (%)
A	1	87. 20	. 995	0. 025	4. 333	4. 97	13. 846	99. 50
B	1	86. 80	. 970	0. 030	4. 017	5. 10	14. 063	97. 00
C	1	87. 00	. 930	0. 070	4. 267	4. 67	17. 143	93. 00
D	1	86. 90	. 925	0. 075	3. 833	4. 73	15. 652	92. 5
E	1	85. 80	. 950	0. 050	3. 500	5. 00	14. 938	95. 00

TABLE 7: AVERAGE PERFORMANCE DATA OF THE FRUITS AND VEGETABLES SCLICER

CROPS	Original weight of Tomatoes W_1 (kg)	Moisture content (W.b) (%)	Weight of normal slices W_2 (kg)	Weight of crushed slices W_3 (kg)	Duration of operation T (min)	Thickness of slices (mm)	Output capacity W/T (kg/h)	Slicing efficiency W_2/W_1x 100 %
Tomatoes	1	90. 60	0. 793	0. 198	1. 610	4. 878	37. 488	79. 30
Okro	1	84. 20	0. 961	0. 018	3. 280	5. 940	19. 937	96. 08
Carrot	1	86. 74	0. 954	0. 050	3. 989	4. 886	15. 128	95. 30

TABLE 8: PERFORMANCE EVALUATION TEST USING KNIVES TO SLICE TOMATOES

VARIETY – ROMA TYPE
STATION – NCHM
DATE - 22^{nd} MARCH, 2001.

Samples	Original weight of tomatoes W1 (kg)	Moisture content (wb) (%)	Weight of normal slice W_2 (kg)	Weight of crushed slices W_3 (kg)	Duration of operation in (mm)	Thickness of slice in (mm)	Output capacity W_1/T (Kg/h)	Slicing Efficiency W_2/W_1 x 100 (%)
A	1	90	.685	.314	8.917	7.770	6.728	68.50
B	1	91	.625	.370	9.700	8.200	6.186	62.50
C	1	90	.770	.230	12.080	8.170	4.967	77.00
D	1	92	.710	.290	10.000	8.033	6.000	71.00
E	1	90	.786	.213	14.600	8.267	4.120	78.60

TABLE 9: PERFORMANCE EVALUATION TEST USING KNIVES TO SLICE OKRO

VARIETY – ANY TYPE
STATION – NCHM
DATE - 22nd MARCH, 2001.

Samples	Original weight of Okro W1 (kg)	Moisture content (wb) (%)	Weight of normal slice W_2 (kg)	Weight of crushed slices W_3 (kg)	Duration of operation T (min)	Thickness of slice in (mm)	Output capacity w/t (Kg/h)	Slicing e W_1 x 10 (%)
A	1	85	.850	.159	19.000	7.83	3.158	85.00
B	1	83	.900	.099	17.333	8.97	3.462	90.00
C	1	86	.895	.104	16.000	8.50	3.750	89.50
D	1	84	.850	.158	15.000	8.40	4.000	85.00
E	1	83	.975	.024	18.00	8.20	3.333	97.50

TABLE 10: PERFORMANCE EVALUATION TEST USING KNIVES TO SLICE CARROT

VARIETY – ANY TYPE
STATION – NCHM, ILORIN
DATE - 22nd MARCH, 2001.

Samples	Original weight of Carrot W_1 (kg)	Moisture content (wb) (%)	Weight of normal slice W_2 (kg)	Weight of crushed slices W_3 (kg)	Duration of operation in T (min)	Thickness of slice in (mm)	Output capacity w/t (Kg/h)	Slicing efficienc W_2/W_1 x 100 (%)
A	1	87.20	.999	0.001	11.030	8.27	5.440	99.90
B	1	86.80	.925	0.075	11.917	8.03	5.035	92.50
C	1	87.00	.930	0.069	15.000	8.03	4.000	93.00
D	1	86.90	.975	0.025	10.250	8.13	6.000	97.50
E	1	85.50	.990	0.010	10.210	8.40	5.877	99.00

TABLE 11: AVERAGE PERFORMANCE DATA OF THE FRUITS AND VEGETABLE USING KNIVES FOR SLICING.

CROP	Original weight of Crops W_1 (kg)	Moisture content (wb) (%)	Weight of normal slice W_2 (kg)	Weight of crushed slices W_3 (kg)	Duration of operation T (min)	Thickness of slice in (mm)	Output capacity W_1/T (Kg/h)	Slici effic W_2/\ 100 (%)
TOMATOES	1	90.60	.715	0.283	11.059	8.088	5.599	71.5
OKRO	1	84.20	0.894	0.109	17.067	8.380	3.541	89.2
CARROT	1	86.94	0.964	0.036	11.689	8.172	5.270	96.3

4.3 STATISTICAL ANALYSIS

The dimension of five representative samples from each test was taken to assess the product for uniformity and effectiveness of the machine.

The student t-test and f-distribution was used, and the level of significance and deviation from the expected dimension were determined by comparing the t-value and F-value obtained for each value and F-value obtained for each set sample with the expected t- and values obtained from statistical table at 5% level of significance.

Table 12: STATISTICAL ANALYSIS OF SLICES UNIFORMITY OF FIVE SAMPLES OF TOMATOES

SAMPLES (Y)	SLICE THICKNESS IN (MM) (Y)	DIFFERENCE BETWEEN VARIETES MEANS (Y), (Y-Ý)	SUM OF SQUARES OF DEVIATE $(Y-Y)^2$
Y_1	5	0.2	0.04
Y_2	6	1.2	1.44
Y_3	2	-1.8	7.54
Y_4	6	1.2	1.44
Y_5	5	0.2	0.04
	24.0	0	10.80

Mean (Y) = Y/r = 4.8

Variance $S^2 = \square_{i\,-I}^{r} \frac{(Yi - Y)^2}{r - i} = 2.7$

Standard Deviation $S = \sqrt{S^2}$ $\sqrt{2.7} = 1.64$

Where

R = Total number of samples

Y = Samples thickness

Y = Mean of samples

S^2 = Variance

S = Standard Deviation

COEFFICIENTS OF VARIATION FOR THE SLICES

These expresses the variability among the different slice thickness of tomatoes slices.

Coefficient of variation (CV) = $\frac{\text{Standard Deviation}}{\text{Mean of sample}} \times 100$

CV = 34.17%

From the value obtained, it implies that slices from the machine are within the required slice thickness because the coefficient is below 50%

Table 13: TOMATOES SLICES FROM FIVE SAMPLES IN THIRTY REPLICATIONS

SAMPLES						TOTAL $\acute{Y}_I$	MEAN Y_1
1	5	6	2	6	5	24	4.80
2	5	5	5	5	3	23	4.60
3	6	5	6	4	6	27	5.40
4	6	5	5	6	5	27	5.40
5	5	4	5	5	4	23	4.60
6	5	4	6	5	6	26	5.20
7	4	5	5	6	5	25	5.00
8	3	5	6	5	6	25	5.00
9	6	5	5	4	3	23	4.60
10	4	6	5	5	5	25	5.00
11	5	3	5	6	5	24	4.80
12	6	4	6	5	4	25	5.00
13	5	5	7	5	6	28	5.60
14	3	5	7	4	5	19	3.80
15	4	5	6	5	5	25	5.00
16	5	4	5	5	5	24	4.80
17	5	3	5	5	5	23	4.60
18	3	5	6	5	5	24	4.80
19	6	5	5	5	5	26	5.20
20	5	5	6	4	5	25	5.00
21	3	5	5	5	4	22	4.40
22	5	4	6	4	5	24	4.80
23	6	5	2	5	5	23	4.60
24	3	5	5	5	5	23	4.60
25	4	5	5	5	5	24	4.80
26	5	5	5	4	5	24	4.80
27	6	5	6	5	5	27	5.40
28	6	4	5	5	5	25	5.00
29	5	5	4	5	5	24	4.80
30	3	5	5	6	5	24	4.80

Y_j	139	141	153	150	149	732.0	146.4
Mean	4.63	4.70	5.10	5.00	4.97	146.4	4.88

Yj = 139+141+153+150+149

= 732.00

Yj = 146.4

General mean

$= \bar{Y}_j = 4.88$

Sum of squares among rows

$SS = \Sigma (Y_{ij} - \bar{Y}..)^2 = 2.617$

Sum of squares computed from column means

$SSC = \mu \Sigma (\bar{Y}_j - \bar{Y}..)$

$= 30(0.1658)$

$= 4.974$

Sum of squares computed from column total

$$SSC = \left(\frac{\bar{Y}_j}{n}\right)^2 - \frac{\bar{Y}_j}{nr}$$

$$= \frac{107312}{30} - \frac{535824}{150}$$

3577.067 - 3572.16

= 4.907

Where

Y_i = samples along the row

Y_j = Samples along the column

N = Number of replication

r = Number of samples

t – Distribution

The machine is designed to slice 5mm thick slices of tomatoes, to determine whether the machine is in proper working order 1 kg of five (5) samples of tomatoes fruits was chosen for which the mean thickness is 4.80mm and sample standard error is 0.54.

The students test t is $t = \frac{\bar{Y} - u}{S_y}$

$\bar{Y} = 480$

$\mu = 5$

$S_Y = 0.54$

$t = \frac{4.80 - 5}{0.54}$

$t = -0.3704$

Comparing the calculated t-value with the tabular t-value at 5% level of significance the calculated t – value lies inside – $t_{0.95}$ to $t_{0.95}$ for 5% level of significance for which 5 – 1 = 4 degree of freedom is the interval = - 2. 132 to 2. 132. From the calculated t – value it lies in the range of the tabular t – value. This implies that the machine is highly significant

CONFIDENCE LIMITS (CL)

This expresses the range of value within which the true mean of the slice thickness of tomatoes slices will fall and this can be accepted as the representation of the entire slice thickness.

Confidence limit (CL) = $\bar{Y} \pm t \cdot s_y$

Where

$\bar{Y}$ = Mean of sample

T = student t – test

Sy = standard error

Choosing 2. 5% level of significance

CI = 4. 80 + 2. 776 + 0. 54 = 6. 299

r = 4. 80 – 2. 776 + 0. 54 = 3. 301

The range 6. 299 and 3. 301 is the range of values within which the true mean of the slices thickness must fall.

F – DISTRIBUTION (TOMATOES)

An F – test is a ratio between two variance and is used to determine whether two independent estimates of variance can be assumed to be estimates, of the same variance.

Table 14

1 kg each of five samples of tomatoes

Table 14: F – DISTRIBUTION (TOMATOES)

1 kg each of five samples of tomatoes

	Sample 1			Sample 2			Sample 3		
	Slice thickness	Y–Y deviates	Sum of squares $(Y-Y)^2$	Slice thickness	Y–Y deviates	Sum of squares $(Y-Y)^2$	Slice thickness	Y–Y deviates	Sum square (Y – Y
1	5	0.37	0.1369	5	0.3	0.09	2	-3.1	9.61
2	5	0.37	0.1369	5	0.3	0.09	5	-0.1	0.01
3	6	1.37	1.8769	5	0.3	0.09	6	0.9	0.81
4	6	1.37	1.8769	4	-0.7	0.49	5	-0.1	0.01
5	5	0.37	0.1369	4	-0.7	0.49	5	-0.1	0.01
6	5	0.37	0.1369	5	0.3	0.09	6	0.9	0.81
7	4	-0.63	0.3969	5	0.3	0.09	5	-0.1	0.01
8	3	-1.63	2.6569	5	0.3	0.09	6	0.9	0.81
9	6	1.37	1.8769	6	1.3	1.69	5	-0.1	0.01
10	4	-0.63	0.3969	3	-1.7	2.89	6	0.9	0.81
11	5	0.37	0.1369	4	-0.7	0.49	5	-0.1	0.01
12	6	1.37	1.8769	5	0.3	0.09	6	0.9	0.84
13	5	0.37	0.1369	5	0.3	0.09	7	1.9	3.61
14	3	-1.63	2.6569	5	0.3	0.09	2	-3.1	9.61
15	4	-0.63	0.3969	4	-0.7	0.49	6	0.9	0.81
16	5	0.37	0.1369	3	-1.7	2.89	5	-0.1	0.01
17	5	0.37	0.1369	5	0.3	0.09	5	-0.1	0.01
18	3	-1.63	2.6569	5	0.3	0.09	6	0.9	0.81
19	6	1.37	1.8769	5	0.3	0.09	5	-0.1	0.01
20	5	0.37	0.1369	5	0.3	0.09	6	0.9	0.81
21	3	-1.63	2.6569	4	-0.7	0.49	5	-0.1	0.01
22	5	0.37	0.1369	5	0.3	0.09	6	0.9	0.81
23	6	1.37	1.8169	5	0.3	0.09	2	-3.1	9.61
24	3	-1.63	2.6569	5	0.3	0.09	5	-0.1	0.01
25	4	-0.63	0.3969	5	0.3	0.09	5	-0.1	0.01
26	5	0.37	0.1369	5	0.3	0.09	6	-0.1	0.01
27	6	1.37	1.8769	5	0.3	0.09	6	0.9	0.81
28	4	-0.63	0.3969	5	0.3	0.09	5	-0.1	0.01
29	3	-1.63	2.6569	5	0.3	0.09	5	-0.1	0.01
30	4	-0.63	0.3969	4	-0.1	0.49	5	-0.1	0.01
j	139		32.967	141		12.31	153		41.52
Mean	4.63			4.7			5.10		

Sample 4 | Sample 5

	Sample 4: Slice thickness Y	Sample 4: Y-Ȳ Deviates	Sample 4: Sum of squares $(Y-\bar{Y})^2$	Sample 5: Slice thickness Y	Sample 5: Y-Ȳ Deviates	Sample 5: Sum of squares $(Y-\bar{Y})^2$
1	6	1	1	5	0.03	0.0009
2	5	0	0	3	-1.97	3.8809
3	4	-1	1	6	1.03	1.0609
4	6	1	1	5	0.03	0.0009
5	5	0	0	4	-0.97	0.9409
6	5	0	0	6	1.03	1.0609
7	6	1	1	5	0.03	0.0009
8	5	0	0	6	1.03	1.0609
9	4	-1	1	3	-1.97	3.8809
10	5	0	0	5	0.03	0.0009
11	6	1	1	5	0.03	0.0009
12	5	0	0	4	-0.97	0.9409
13	5	0	0	6	1.03	1.0609
14	4	-1	1	5	0.03	0.0009
15	5	0	0	5	0.03	0.0009
16	5	0	0	5	0.03	0.0009
17	5	0	0	5	0.03	0.0009
18	5	0	0	5	0.03	0.0009
19	5	0	0	5	0.03	0.0009
20	4	-1	1	5	0.03	0.0009
21	5	0	0	4	-0.97	0.9409
22	4	-1	1	5	0.03	0.0009
23	5	0	0	5	0.03	0.0009
24	5	0	0	6	1.03	1.0609
25	5	0	0	5	0.03	0.0009
26	4	-1	1	5	0.03	0.0009
27	5	0	0	5	0.03	0.0009
28	6	1	0	6	1.03	1.0609
29	5	0	0	5	0.03	0.0009
30	6	1	1	5	0.03	0.0009
j	150		12	149		16.967
mean $\bar{Y}$	5.0			4.97		

Calculating variance for the five samples

$$S^2 = \frac{S^2_1 + S^2_2 + S^2_3 + S^2_4 + S^2_5}{5}$$

$$= \frac{32.967}{30-1} + \frac{12.31}{30-1} + \frac{41.52}{30-1} + \frac{12}{30-1} + \frac{16.967}{30-1}$$

$$= \frac{3.9919}{5}$$

$= 0.79838$

Variance of mean δ_Y^2 from the mean of the five samples

$$\delta^2_{\bar{Y}} = \sum (Y_i - \bar{Y}..)^2$$

$$= (4.63-4.88)^2 + (4.70 - 4.88)^2$$

$$= \frac{(5.10 - 4.88)^2 + (5-4.88)^2 + (4..97-4.88)^2}{5-1} = \frac{0.1658}{4}$$

$= 0.04145$

Estimating $\delta^2_{\bar{Y}}$ from the variability among the sample mean.

$$\delta^2_{\bar{Y}} = rS^2_{\bar{Y}}$$

$= 30\ (0.0145)$

$= \quad 1.2436$

$$F = \frac{S^2 \text{ calculated from sample means}}{S^2 \text{ calculated from pooling sample variance}}$$

$$= \frac{1.2439}{0.79838}$$

$F = 1.5575$

Comparing the calculated F-value with the table F-value at 5% level of significance. The degree of freedom 5-1=4 numerator and 30-1 = 29 for degree of freedom denomarator, t-lies inside the interval which is –2.700 to 2.700

Since the calculated F-value lies inside this interval it implies that the machine is highly significance.

Table 15: STATISTICAL ANALYSIS OF SLICES UNIFORMITY OF FIVE SAMPLES OF OKRO

SAMPLE	SLICE THICKNESS IN (mm) (Y)	DIFFERENCE BETWEEN VARIETIES MEANS (Y) AND DEVIATION (Y-Y)	SUM OF SQUARES OF DEVIATE $(Y- Y)^2$
Y_1	5	-0.4	0.16
Y_2	6	0.6	0.36
Y_3	7	1.0	2.56
Y_4	5	-0.4	0.16
Y_5	4	-1.4	1.96
	27.0	0	5.2

Mean (Y) = Y/r = 5.4

Variance $S^2 = \frac{\square_i^n (Y_I - Y)^2}{r-1} = 1.3$

Standard Deviation $S = \sqrt{S^2} = 1.14$

COEFFICIENTS OF VARIATION FOR THE SLICES

Coefficient of variation (CV) = $\frac{\text{Standard deviation}}{\text{Mean of sample}} \times 100$

CV = 21.1%

From the calculated coefficient of variation which is 21.1% it implies that the slices from the machine are within the required slice thickness because CV is below 50%

TABLE 16: OKRO SLICES FROM FIVE (5) SAMPLE IN THIRTY REPLICATIONS

Samples						TOTAL Y_I	MEAN Y_I
1	5	6	7	5	4	27	5.4
2	7	7	6	7	5	32	6.4
3	6	5	5	6	7	29	5.8
4	6	6	7	7	6	32	6.4
5	5	6	4	5	5	25	5
6	7	6	7	6	7	33	6.6
7	6	8	6	7	7	24	6.8
8	5	6	4	5	5	25	5.0
9	4	7	6	7	7	31	6.2
10	6	5	5	6	6	28	5.6
11	5	6	4	5	7	27	5.4
12	7	6	7	7	5	32	6.4
13	6	7	6	5	6	30	6.0
14	5	8	5	7	7	32	6.4
15	5	6	7	6	4	28	5.6
16	6	5	5	4	6	26	5.2
17	6	5	6	7	5	29	5.8
18	7	6	7	7	7	27	5.4
19	7	6	8	5	6	27	5.4
20	6	5	7	7	5	30	6.0
21	6	7	6	6	7	32	6.4
22	7	6	5	7	7	32	6.4
23	5	6	6	5	5	27	5.4
24	6	6	7	7	6	32	6.4
25	4	6	6	6	7	29	5.8
26	6	5	7	7	5	30	6.0
27	5	6	4	5	7	27	5.4
28	7	6	5	6	7	31	6.2
29	6	9	7	7	5	34	6.8
30	7	6	4	5	6	34	6.8
Y_j	165	184	181	182	179	891	178.8

Y_j = 165 + 184 + 181+182+179 = 891

Y_j = 178.2

General Mean = $\bar{Y}..$

= 5.94

Sum of squares among rows

$\Sigma (Y_{ij} - \bar{Y}..)^2$

= 8. 4598

Sum of squares computed from column mean

SSC = $\mu \, \Sigma(\bar{Y}_j - \bar{Y}..)2$

= 30 (0. 25559) = 7. 677

Sum of squares computed from column total

$$SSC = \Sigma\left(\frac{\bar{Y}_j}{n}\right)^2 - \frac{\bar{Y}..}{nr}$$

$$= \frac{159,007}{30} - \frac{793881}{30x5}$$

5300.23 - 5292.54

=7.693

t – DISTRIBUTION

The machine is also designed to slice 6mm thick of okro. To determine whether the machine is slicing up to specification one kilogramme (1kg) of five samples of okro was sliced and the mean thickness is 5.94mm and sample standard error is 0.51

Student test $t = \frac{\bar{Y} - \mu}{S_Y}$

$\bar{Y}$ = 5.4

$\mu = r = 5$

$S_Y = 0.51$

t = -1.1765

Comparing the calculated t-value with the table t-value at 5% level of significance, t lies inside $-t_{0.95}$ to $t_{0.95}$ for which 5-1 degree of freedom is the interval –2.132 to 2.132. This implies that the machine is highly significance.

CONFIDENCE LIMITS (CL)

This expresses the range of values within which the true mean of the slice thickness of okro slices will fall and this can be accepted as the representation of the entire slice thickness. Confidence limit (CL) = $\bar{Y} \pm t \,.S_Y$, choosing 2.5% level of significance

CL = 5.4 + 2.776 x 0.51 = 6.816

CL = 5.4 - 2.776 x 0.51 = 3.984

This values 6.816 and 3.984 is the range of values within which the true mean of the slice thickness of the okro must fall.

F- DISTRIBUTION

The F test is a ratio between two variance and is used to determine whether two independent estimates of variance can be assumed to be estimates of the same variance.

TABLE 17: F- DISTRIBUTION – OKRO IKG EACH OF FIVE SAMPLES OF OKRO

	Sample 1			Sample 2			Sample 3		
	Slice thickness (mm)Y	Y-Y deviate	Sum of squares $(Y-Y)^2$	Slice thickness (mm)	Y-Ý deviate	Sun of squares $(Y-Y)^2$	Slice thickness Y	Y- Ý Deviate	Sum of squares $(Y-Y)^2$
1	5	-0.5	0.25	6	-0.13	0.0169	7	0.97	0.9409
2	7	1.5	2.25	7	0.87	0.7569	6	-0.03	0.0009
3	6	0.5	0.25	5	-1.13	1.2769	5	-1.03	1.0609
4	6	0.5	0.25	6	-0.13	0.0169	7	0.97	0.9409
5	5	-0.5	0.25	6	-0.13	0.0169	4	-2.03	4.1209
6	7	1.5	2.25	6	-0.13	0.0169	7	0.97	0.9409
7	6	0.5	0.25	8	1.87	3.4969	6	-0.03	0.0009
8	5	-0.5	0.25	6	-0.13	0.0169	4	-2.03	4.1209
9	4	-1.5	2.25	7	0.87	0.7569	6	-0.03	0.0003
10	6	0.5	0.25	5	-1.13	1.2769	5	-1.03	1.0609
11	5	-0.5	0.25	6	-0.13	0.0169	4	-2.03	4.1209
12	7	1.5	2.25	6	-0.13	0.0169	7	0.97	0.949
13	6	0.5	0.25	7	0.87	0.7569	6	-0.03	0.0009
14	5	-0.5	0.25	8	1.87	3.4969	5	-1.03	1.0609
15	5	-0.5	0.25	6	-0.13	0.0169	7	0.97	0.9409
16	6	0.5	0.25	5	-1.13	1.2769	5	-1.03	1.0609
17	6	0.5	0.25	5	-1.13	1.2769	6	-0.03	0.0009
18	7	1.5	2.25	6	-0.13	0.0169	7	0.97	0.9409
19	7	1.5	2.25	6	-0.13	0.0169	8	1.97	3.8809
20	6	0.5	0.25	5	-1.13	1.2769	7	0.97	0.9409
21	6	0.5	0.25	7	0.87	0.7569	6	-0.03	0.0009
22	7	1.5	2.25	6	-0.13	0.0169	5	-1.03	1.0609
23	5	-0.5	0.25	6	-0.13	0.0169	6	-0.03	0.0009

24	6	0.5	0.25	6	-0.13	0.0169	7	0.97	0.9409
25	4	-1.5	2.25	6	-0.13	0.0169	6	-0.03	0.0009
26	6	0.5	0.25	5	-1.13	1.2769	7	0.97	0.9409
27	5	-0.5	0.25	6	-0.13	0.0169	4	-2.03	4.1209
28	7	1.5	2.2	6	-0.13	0.0169	5	-1.03	1.0609
29	6	0.5	0.25	9	2.87	8.2369	7	0.97	0.9409
30	7	1.5	2.25	6	-0.13	0.0169	4	-2.03	4.1209
Y_j	$\frac{165}{30}$		27.5	$\frac{184}{30}$		22710	$\frac{181}{30}$		39.41
Mean	5.50			6.13			6.03		

SAMPLE 4				SAMPLE 5		
	Slice thickness Y (mm)	$Y-\bar{Y}$ deviate	Sum of squares $(Y-\bar{Y})^2$	Slice thickness (Y) (mm)	$Y-\bar{Y}$ deviates	Sum of Squares $(Y-\bar{Y})^2$
1	5	-1.07	1.1449	4	-1.97	3.8809
2	7	0.93	0.3649	5	-0.97	0.9409
3	6	-0.07	0.0049	7	1.03	1.0609
4	7	0.97	0.8649	6	0.03	0.0009
5	5	-1.07	1.1449	5	-0.97	0.9409
6	6	-0.07	0.0049	7	1.03	1.0609
7	7	0.97	0.8649	7	1.03	1.0609
8	5	-1.07	1.1449	5	-0.97	0.9409
9	7	0.97	0.8644	7	1.03	1.0609
10	6	-0.07	0.0049	6	0.03	0.0009
11	5	-1.07	1.1449	7	1.03	1.0609
12	7	0.97	0.8649	5	0.97	0.9409
13	5	-1.07	1.1449	6	0.03	0.0009
14	7	0.97	0.8649	7	1.03	1.0609
15	6	-0.07	-0.0049	4	-1.97	3.8809
16	4	-2.07	4.2849	6	0.03	0.0009
17	7	0.97	0.8649	5	-0.97	0.9409
18	7	0.97	0.8649	7	1.03	1.0609
19	5	-1.07	1.1449	6	0.03	0.0009
20	7	0.97	0.8649	5	-0.97	0.9409
21	6	-0.07	0.0049	7	1.03	1.0609
22	7	0.97	0.8649	7	1.03	1.0609
23	5	-1.07	1.1449	5	-0.97	0.9409
24	7	0.97	0.8649	6	0.03	0.0009
25	6	-0.07	0.0049	7	1.03	1.0609
26	7	0.97	0.8649	5	-0.97	0.9409
27	5	-1.07	1.1449	7	1.03	1.0609
28	6	0.07	0.0047	7	1.03	1.0609
29	7	0.97	0.5649	5	-0.97	0.9409
30	5	-1.07	1.1449	6	0.03	0.0009
Y_j	182			179		
Mean	6.02			5.92		

Calculating variance from the five samples

$$S^2 = \frac{S^2_1 + S^2_2 + S^2_3 + S^2_4 + S^2_5}{5}$$

$$S^2 = \frac{\frac{27.5}{30-1} + \frac{22.70}{30-1} + \frac{39.417}{30-1} + \frac{25.867}{30-1} + \frac{28.967}{30-1}}{5}$$

$$= \frac{4.9815}{5}$$

$$= 0.9963$$

Computing variance of mean of δY^2 from the mean of the five samples

$$\delta^2_{\bar{Y}} = \frac{\Sigma(Y_i - \bar{Y})^2}{5-1}$$

$$\delta^2_{\bar{Y}} = \frac{0.2559}{4}$$

$$= 0.06398$$

Estimate $\delta^2_{\bar{Y}}$ from the variability among the sample means:

$$\delta^2_{\bar{Y}} = rSY$$

$$= 30\ (0.06398)$$

$$\delta^2_{\bar{Y}} = 1.9194$$

$$F = \frac{S^2 \text{ calculated from sample means}}{S^2 \text{ calculated from pooling sample variance}}$$

$$F = \frac{1.91925}{0.9963}$$

$$F = 1.9264$$

Comparing the computed F-value with the table F-value at 5% level of significance of which the degree of freedom 5-1 = 4 numerator and 30-1 = 29 for degree of freedom denomarator lies inside the interval $-t_{0.95}$ to $t_{0.95}$ which is –2.700 and 2.700. The computed F-value lies inside the table F-values this implies the machine is highly significant.

TABLE 18: STATISTICAL ANALYSIS OF UNIFORMITY OF FIVE SAMPLES OF CARROT

SAMPLE (r)	Slice thickness (mm) (Y)	Difference between variates means (Y) and deviation (Y-Y)	Sum of squares of deviate $(Y-Y)^2$
Y_1	5	0.2	0.04
Y_2	2	-2.8	7.84
Y_3	5	0.2	0.04
Y_4	6	1.2	1.44
Y_5	6	1.2	1.44
	24	0	10.88

Mean (Y) = Y/r = 4.8

$$\text{Variance } S^2 = \square^r_i \frac{(Y_i-Y)}{r-1} = 2.7$$

$$\text{Standard Deviation } S = \sqrt{S^2} \; \sqrt{2.7} = 1.64$$

COEFFICIENT OF VARIATION FOR THE SLICER

This expresses the variability among the different slice thickness of carrot slices.

$$\text{Coefficient of Variation (CV)} = \frac{\text{Standard Deviation}}{\text{Mean of Sample}} \times 100$$

CV = 34.17%

From the value obtained, it implies that the slices from the machine are within the required thickness because the CV is below 50%

TABLE 19: CARROT SLICES FROM 1KG EACH OF FIVE SAMPLES IN THIRTY REPLICATIONS

SAMPLES						TOTAL Y_I	MEAN Y_I
1	5	2	5	6	6	24	4.8
2	5	2	3	5	5	23	4.6
3	6	6	6	5	4	27	5.4
4	6	5	5	5	6	27	5.4
5	5	5	4	4	6	23	4.6
6	5	6	6	4	5	26	5.2
7	4	5	5	5	6	25	5.0
8	3	6	6	5	5	25	5.0
9	6	5	3	5	4	23	4.6
10	4	6	5	6	5	26	5.2
11	5	5	5	3	6	24	4.8
12	6	6	4	4	5	25	5.0
13	5	7	6	5	5	28	5.6
14	3	2	5	5	4	19	3.8
15	4	6	5	5	5	25	5.0
16	5	5	5	4	5	24	4.8
17	5	5	5	3	5	23	4.6
18	3	6	5	5	5	24	4.8
19	6	5	5	5	5	26	5.2
20	4	6	5	5	4	24	4.8
21	3	5	4	5	5	22	4.4
22	5	6	5	4	4	24	4.8
23	6	2	5	5	5	23	4.6
24	3	5	6	5	5	24	4.8
25	4	4	5	5	5	23	4.6
26	5	5	5	5	4	24	4.8
27	6	6	5	5	5	27	5.4
28	4	5	6	5	6	26	5.2
29	5	5	5	4	5	24	4.8
30	3	5	5	5	6	24	4.8
Y_j	139	152	149	142	150	732	146.4

Mean Y_i = 139+152+149+142+150

Mean $\bar{Y}_i$ = 139+152+149+142+150

= 732

$\bar{Y}_i$ = 146.4

General Mean = $\bar{Y}..$

$\bar{Y}..$ = 4.88

Sum of squares among rows

$SS = \sum(\bar{Y}_{ij} - \bar{Y}..)^2$

= 2.6166

Sum of square computer from column means

$SSC = \mu \sum(\bar{Y}j - \bar{Y}..)^2$

= 30(0.1658)

= 4.974

Sum of squares computed from column total

$$SSC = \sum\left(\frac{\bar{Y}_{ij}}{n} - \frac{\bar{Y}..}{nr}\right)$$

$$= \frac{107312}{30} - \frac{535824}{150}$$

= 3577.067 – 3572.16

= 4.907

t- DISTRIBUTION

The machine is designed to slice 5mm thick slices of carrot. To determine whether the machine is slicing up to specification one kilogramme of five samples of carrot was sliced and the mean thickness is 4.80mm and sample standard error is 0.54.

The student test $t = \frac{\bar{Y}-u}{S_Y}$

$\bar{Y}i = 4.50$

$\mu = 5$

$SY = 0.54$

$t = -0.3704$

Comparing the calculated t-value with the table t-value at 5% level of significance, the calculated t-value lies inside $-t_{0.95}$ to $t_{0.95}$ for 5% level of significance for which 5-1 = 4 degree of freedom is the interval -2.132 to 2.132.

From the calculated t-value = -2.132 to 2.132 lies in the range of the table t-value. It implies that the machine is highly significant.

CONFIDENCE LIMITS (CL)

This expresses the range of value within which the true mean of the slice thickness of carrot slices will fall and this can be accepted as the representation of the entire slice thickness.

Confidence limit (CL) = $\bar{Y} \pm t.SY$

Choosing 2.5% level of significance

$CL = 4.80 + 2.776 \times 0.54 = 6.299$

$CL = 4.80 - 2.776 \times 0.54 = 3.301$

This is the range of values within which the true mean of the slice thickness must fall.

F- DISTRIBUTION

The F- distribution is a ratio between two variance and is used to determine whether two independent estimates of variance can be assumed to be estimates of the same variance.

Table 20 F – Distribution – Carrot

1kg of each of five (5) samples of Carrot

SAMPLE 1				SAMPLE 2			SAMPLE 3		
S/N	Slice thickness	$Y - \bar{Y}$ Deviates	Sum of square $(Y-\bar{Y})^2$	Slice thickness	$Y - \bar{Y}$ Deviates	Sum of square $(Y-\bar{Y})^2$	Slice thickness	$Y - \bar{Y}$ Deviates	Sum of square $(Y-\bar{Y})^2$
1	5	0.37	0.1369	2	-3.1	9.61	5	0.03	0.0009
2	5	0.37	0.1369	5	-1.0	0.01	3	-1.97	3.3809
3	6	1.37	1.8769	6	0.9	0.81	6	1.03	1.0609
4	6	1.37	1.8769	5	-0.1	0.01	5	0.03	0.0009
5	5	0.37	0.1369	5	-0.1	0.01	4	-0.97	0.9409
6	5	0.37	0.1369	6	0.9	0.81	6	1.03	0.0009
7	4	-0.63	0.3969	5	-0.1	0.01	5	0.03	0.0009
8	3	-1.63	2.6569	6	0.9	0.81	6	1.03	0.9409
9	6	1.37	1.8769	5	0.1	0.01	3	-1.97	3.8809
10	4	-0.63	0.3969	6	0.9	0.81	5	0.03	0.0009
11	5	0.37	0.1369	5	-0.1	0.01	5	0.03	0.0009
12	6	1.37	1.8769	6	0.9	0.81	4	-0.97	0.9409
13	5	0.37	0.1369	7	1.7	3.61	6	1.03	0.9409
14	3	-1.63	2.6569	2	-3.1	9.61	5	0.03	0.0009
15	4	-0.63	0.3969	6	0.9	0.81	5	0.03	0.0009
16	5	0.37	0.1369	5	-0.1	0.01	5	0.03	0.0009
17	5	0.37	0.1369	5	-0.1	0.01	5	0.03	0.0009

8	3	-1.63	2.6569	6	0.9	0.18	5	0.03	0.0009
9	6	1.37	1.8769	5	-0.1	0.01	5	0.03	0.0009
0	4	0.37	0.1369	6	-0.9	0.81	5	0.03	0.0009
1	3	1.63	2.6569	5	-0.1	0.01	4	-0.97	0.9409
2	5	0.37	0.1369	6	0.9	0.18	5	0.03	0.0009
3	6	1.37	1.8769	2	-3.1	9.16	5	0.03	0.0009
4	3	-1.63	2.6569	5	-0.1	0.01	6	1.03	0.9409
5	4	-0.63	0.3969	4	-1.1	1.21	5	0.03	0.0009
6	5	0.37	0.1369	5	-0.1	0.01	5	0.03	0.0009
7	6	1.37	1.8769	6	0.9	0.81	5	0.03	0.0009
8	4	-0.63	0.3969	5	-0.1	0.01	6	1.03	0.9409
9	5	-0.37	2.6569	5	-0.1	0.01	5	0.03	0.0009
0	3	-1.63	0.3969	5	-0.1	0.01	5	0.03	0.0009
Y_j	139		32.967	152	41.52		149		16.967

Mean $\bar{Y}$ 4.63 5.1 4.97

1 KG EACH OF FIVE (5) SAMPLES

	SAMPLE 4			SAMPLE 5		
	slice thickness Y	Y-Ȳ deviates	sum of squares $(Y-\bar{Y})^2$	slice thickness	Y-Ȳ deviates	sum of squares $(Y-\bar{Y})^2$
1	6	1.27	1.6129	6	1	1
2	5	0.27	0.0729	5	0	0
3	5	0.27	0.0729	4	-1	1
4	5	0.27	0.0729	6	1	1
5	4	-0.73	0.5329	6	1	1
6	4	-0.73	0.5329	5	0	0
7	5	0.27	0.0729	6	1	1
8	5	0.27	0.0729	5	0	0
9	5	0.27	0.0729	4	-1	1
10	6	1.27	1.6129	5	0	0
11	3	-1.73	2.9929	6	1	1
12	4	-0.73	0.05529	5	0	0
13	5	0.23	0.0729	5	0	0
14	5	0.23	0.0729	4	-1	1
15	5	0.23	0.0729	5	0	0
16	4	-0.73	0.05329	5	0	0
17	3	-1.73	2.9929	5	0	0

18	5	0.23	0.05329	5	0	0
19	5	0.23	0.0729	5	0	0
20	5	0.23	0.0729	4	-1	1
21	5	0.23	0.05329	5	0	0
22	4	-0.73	0.05329	4	-1	1
23	5	0.23	0.0729	5	0	0
24	5	0.23	0.0729	5	0	0
25	5	0.23	0.0729	5	0	0
26	5	0.23	0.0729	4	-1	1
27	5	0.23	0.0729	5	0	0
28	5	0.23	0.0729	6	1	1
29	4	-0.73	0.0729	5	0	0
30	5	0.23	0.0729	6	1	1
142				150		12

Calculating variance from the five samples

$$S^2 = \frac{S^2_1 + S^2_2 + S^2_3 + S^2_4 + S^2_5}{5-1}$$

$$S^2 = \frac{\frac{32.967}{30-1} + \frac{41.52}{30-1} + \frac{16.967}{30-1} + \frac{12.31}{30-1} + \frac{12}{30-1}}{5-1}$$

$S^2 = 0.79838$

Variance of means of δ_Y^2 from the means of the five samples

$$\delta^2_{\bar{Y}} = \frac{\sum(Y_i - \bar{Y}_{..})^2}{5-1}$$

$$\hat{\sigma}^2_{\bar{Y}} = \frac{(4.63 - 4.88)^2 + (5.1 - 4.88)^2 + (4.97 - 4.88)^2 (4.73 - 4.88)^2 + (5.4.88)^2}{5-1}$$

= 0.4145

Estimate $\hat{\sigma}^2_{\bar{Y}}$ from the variability among the sample mean

$\hat{\sigma}^2_{\bar{Y}} = rS^2Y = 30(0.4145)$

= 1.2436

$$F = \frac{S^2 \text{ calculated from sample means}}{S^2 \text{ calculated from pooling sample variance}}$$

$$= \frac{1.2439}{0.79838}$$

= 1.5575

Comparing the computed F- value with the table F-value at 5% level of significance of which the degree of freedom 5-1 =4 numerator and 30-1 = 29 for degree of freedom denomarator, t lies inside the interval $-t_{0.95}$ to $t_{0.95}$ which is – 2.700 and 2.700.

The computed F-value lies inside table F-value. This implies that the machine is highly significant.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

From the result obtained from the use of the machine for slicing tomatoes, okro and carrot the following conclusion can be drawn.

1. The machine can slice the Roma type Tomatoes, all the varieties of okro and carrot satisfactorily.
2. Uniform slices of 4.828mm, 5.940mm and 4.886mm for Tomatoes, okro and carrot was obtained with the use of the machine for slicing
3. The throughput capacity per unit time is considerably high compared to the use of knives for slicing
4. A high efficiency is obtained because it handles the fruits and vegetables with minimum rupture

5. 2 RECOMMENDATION

The basic objective of this machine was to produce uniform slice of fruits and vegetables (Tomatoes, okro and carrot) with minimum time and rupture also high capacity for fast drying but the following is also recommended.

The machine should be further developed to accommodate much smaller slice thickness so that it can be use by hoteliers for the preparation of vegetable salad.

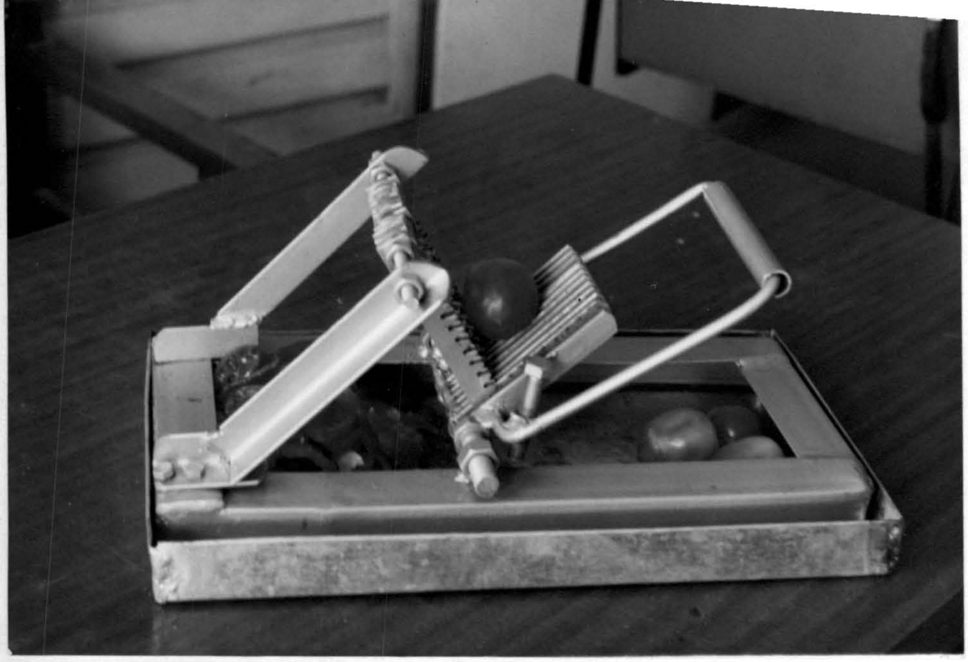


Plate 1 The Fruits and Vegetables Slicer

Plate 2 The Slicer Being used to Slice Tomatoes

Plate 3 Machine Sliced Tomatoes And Tomatoes Fruit

Plate 4 Machine Sliced Dried Tomatoes

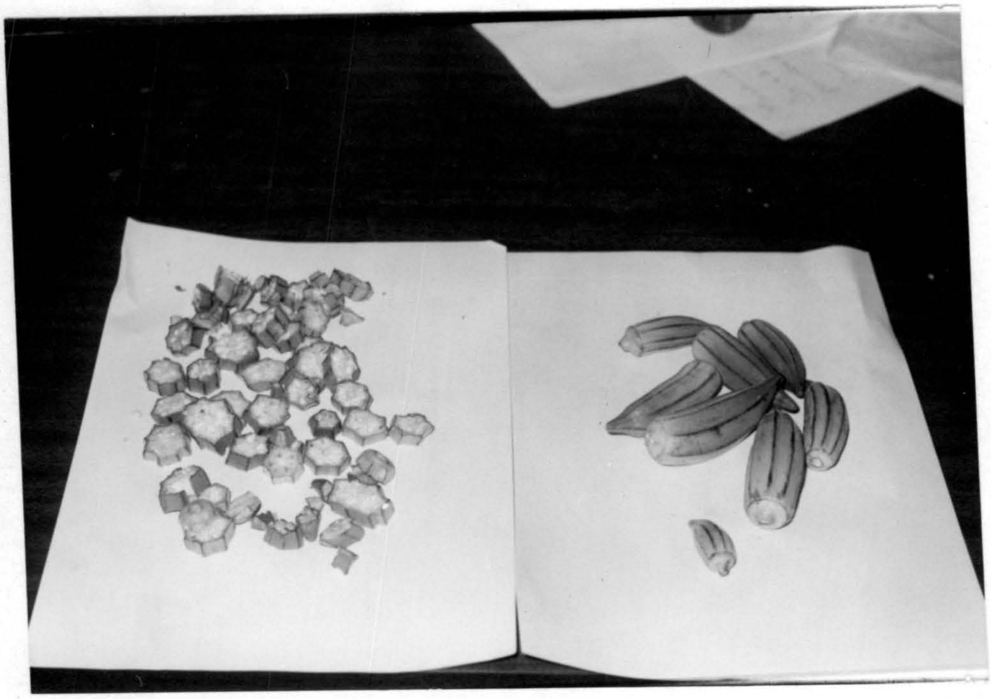


Plate 5 Machine Sliced Okro And Whole Okro

Plate 6 Machine Sliced Dried Okro

Plate 7: Machine Sliced Carrot And Whole Carrot

REFERENCES

Idah P. (2000): Lectures on Engineering properties of Biological materials. Federal University of Technology Minna.

Adgidzi D. (2000): Summary of lectures on statistical Method in Experimentation. Federal University of Technology Minna

Ahmed D. and Roy S. K. (2000): Evaluation of Design parameters of sickle cutter and claw cutter for cutting oil palm froud. Agricultural mechanization in Asia, Africa and Latin America vol. 31 No 2 (2000).

Aworh O. C. and Olorunda A. O. (1988): Packaging and storage Technology of fruits and vegetables with specific reference for Tropical condition. Proceedings of the National workshop on improved packaging and storage system for fruits and vegetables in Nigeria – Ilorin.

Erinle I D. and Karikari K. S (1988): Physiology biochemistry and pathology of fruits and vegetables in relation to post harvest handling and storage. Proceedings of the national workshop on improved packaging and storage system for fruits and vegetables in Nigeria – Ilorin.

Girdeari Lai, Silddeppa S. G. and Tandon I. G: Preservation of fruits and Vegetables. Publications and information Division Indian Council of Agricultural Research New Delhi 110012.

S. M Henderson and R. L. Perr – Agricultural process Engineering – P. 185.

Ihehosonye and Ngoddy (1985): Integrated food science and Technology (P. 306)

NSPRI (Jan Dec 1984): Nigerian stored product Research Institutes annual Report.

Odigboh E. U. and Osoagwu C. C (1998): Effective communication of Technical Ideas in Science and Technology.

Olajide T. D., Olowombi M. M. and Onwualu P. (1997): Testing and Evaluation of manually operated Okro slicer.

Olorunda A. O. and Tunga A. M. (1985): Stimulated Transit studies on tomatoes effects of compressive load, container, vibration and maturity on mechanical damage. Journal of food Technology 20: 669 – 678.

Oyeniran J. O, (1988): Report of activities of national Coordinated Research on fruits and vegetables storage in Nigeria. Proceedings of the National workshop and storage system for fruits and vegetable – Ilorin.

Raji O. A. and Igbeka J. C. (1994): Pedal operated chipping and slicing Machine for Tuber – Journal Agricultural Engineering Technical Vol. 2 p.90 – 99.