DETERMINATION AND EVALUATION OF DRYING TEMPERATURE – TIME OF SOME SELECTED VEGETABLES

BY

GRACE OMOLARA OMOJIBA

(PGD / AGRIC / 98 / 99 / 63)

A PROJECT REPORT IN THE DEPARTMENT OF

AGRICULTURAL ENGINEERING SUBMITTED TO THE

POST – GRADUATE SCHOOL IN PARTIAL FULFILMENT OF THE

REQUIREMENT FOR THE AWARD OF POST-GRADUATE

DIPLOMA IN FOOD ENGINEERING

OF THE

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

NIGER STATE, NIGERIA

JUNE, 2000.

APPROVAL AND CERTIFICATION

This thesis has been read and approved as meeting the requirement of the department of Agricultural Engineering, Federal University of Technology, Minna for the Award of Post graduate Diploma (PGD) in Food Engineering

-------------------------------------	---------------------------------
PROJECT SUPERVISOR **ENGR. P.A. IDAH**	**DATE**
-------------------------------------	---------------------------------
HEAD OF DEPARTMENT **ENGR. M.G. YISA.**	**DATE**

DEDICATION

This work is dedicated to the Almighty God the author of knowledge, who is my refuge and my fortress, in whom I will always trust. Life is full of ups and downs.

To those who truly know God and walk in His way, He has plans for their lives and He watches over them. For they seek purity of the heart through their journey here on Earth. To this very God, this project is dedicated and to the memory of my loving son LATE ISRAEL OLUWATOMI OMOJIBA.

ACKNOWLEDGEMENT

I am most grateful to the Almighty God, who saw me through this academic pursuit, with the provision of guidance, courage and grace along every step I took.

I wish to express my profound gratitude to my project supervisor, Engineer Peter Idah, who under numerous task, was able to supervise every step of this project.

I am highly delighted to acknowledge the valuable assistance and moral support accorded my husband and I by the family of Dr and Mrs Donald Adgidzi, during the period of this study.

I gratefully acknowledge the love, care and support given me through out my career, by my dearly and loving parents, Late Pa Elisha Komolafe and Mrs Sarah Komolafe, as well as the families of Engineer and Mrs M.B. Osho, Prof. And Mrs Balogun and Mr & Mrs R.T Famodile.

I sincerely appreciate all the staff of Agricultural Engineering Department for their advice, corrections and whose co-operation has enhanced the success of this course and project in particular.

I wish to thank the Management of Kaduna Polytechnic, for sponsoring me for this course.

My warm appreciation also goes to my darling children Tosin, Makinde and Tolu, who have to bear with me for not having sufficient time with them to shear my motherly love, as a result of my work-load.

I also appreciate the co-operation of Mallam Sirajo to use the drying equipments in their care.

To all those whose names could not be mentioned, but had contributed in making it possible to acquire this knowledge and also enhance the success of this project work, I say thank you and God bless.

GRACE OMOLARA OMOJIBA

JUNE, 2000.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure **Page**

ABSTRACT

Fruits and vegetables, though known to be the major source of vitamins in our diet, are highly perishable. After harvest, they undergo chemical changes and spoilage by bacteria yeast and fungi, leading to gross reduction or total loss of nutrients, colour, flavour and good texture, which tend to be the major causes of wastage in fruit and vegetables during time of glut, resulting in very low selling price for farmers and also responsible for its inability to be easily preserved against off – season, resulting to extremely high price for users. Drying which seems to be the most suitable preservation method for vegetables is faced with the problem of the effects of drying temperature – time on the quality parameters of the resultant dried vegetables, since vegetables are known to be highly heat – sensitive, hence the need to determine a suitable drying temperature – time for vegetables, to avoid wastage and to stabilise price, in order to enhance commercial vegetable farming Nigeria in particular. In this study, a 2^2 full factorial experimental design technique is employed. The results showed that a temperature of 65^0c and drying time of 5 hours seemed to be the most appropriate for drying the produce. The result of the evaluation of the physical quality parameters of the resultant dried vegetables under the fitted models indicates a well acceptable colour and texture for tomatoes and sweet pepper except for okro which indicated a gross loss of green colour after drying. Shrinkage is also generally observed with the dried vegetables which shows reduction in size and shape from that of the fresh ones. The resultant moisture content observed are 3.69%, 3.2% and 3.1% for tomatoes, okro and sweet pepper respectively which falls within the recommended safe keeping and storage life for dried vegetables.

CHAPTER ONE

INTRODUCTION

1.1.0 PERISHABILITY OF FRUITS AND VEGETABLES

Fruits and vegetables particularly Tomato, Okra and pepper, which are widely grown and commonly eaten in Nigeria, are very valuable and useful agricultural crops. They serve as one of the main sources of vitamins and minerals, which are essential to maintain good health. Unfortunately, they are not only seasonal crops, but they are highly perishable and deteriorate few days after harvest, lossing almost all their required quality attributes and some may likely result to total waste. A greater percentage of fruits and vegetables production, as high as 50% according to FAO report (Oyeniran, 1988) are loss between rural production and town consumption in tropical areas.

1.2.0 PRESEVATION AND STORAGE OF FRUITS AND VEGETABLES

Several storage systems have been designed and are been used for the storage of some of these fruits and vegetables. The problem however is what happens to the quality parameters of these fruits and vegetables, during this period of storage of considerable importance among these parameters are those that have to do with the appearance or physical qualities. Prices of these fruits and vegetables sometimes depend mostly on their physical appearance.

Nigeria because of the initial running and maintenance cost, sophisticated cold storage facilities often supposed for fruits and vegetable storage are in most cases, not affordable and hence not available for most rural dwellers due to cost, the advanced technology they entail. They are also in appropriate to be used in many development countries, particularly in the tropics because of the operating temperatures, as most of these crops are prone to chilling injuries.

Chilling injuries causes death of small group of epidermal and associated cells, which dries up and becomes sunless. As a result of excessive moisture loss, accumulation of toxins and mycotocins occurs in the fruits, leading to disorderliness at lower temperatures in the structure of the crops, thus, loss of freshness and flavour of fruits and vegetables occurs when stored in refrigerators.

It is realised that the use of 'storage systems' for these fruits and vegetables, do not give them any considerable long term "keeping quality". Alternatively processing these fruits and vegetables product into produce through various processing techniques, tend to prolong this "keeping quality". In the case of Tomato for instance, which seems to have receive considerable attention internationally, are processed and preserved into various forms such as canned whole tomatoes, tomato juices, tomato puree, tomato paste, ketchup and chill source.

In Nigeria, little consideration and attention is given to the preservation aspect of agricultural products, especially in regard to fruits and vegetables production in particular. Lack of processing and storage facilities, result in lots of post harvest losses encountered by Nigerian farmers who engage in production of fruits and vegetables.

The economical growing of fruits and vegetables is limited in many countries to certain season and localities, and to meet the demand during the entire year in all areas, the commodities are preserved is different techniques.

1.3.0 DRYING AS A PRESERVATION METHOD FOR FRUITS AND VEGETABLES

Drying technologies, as a process for food conservation and preservation, seem to be on adequate method under most conditions in developing economies (Ali and Sakr, 1981). New drying technology has given significant boost to the demand for dried foods in the past and some researchers food that this can be repeated, if more attention is given to food quality, during drying. This tend to be a major challenge for food industry (MacCarthy, 1986).

1.3.1 PURPOSE OF DRYING

Drying can be said to be a process of moisture removal from a product, where by the moisture content of the product is reduced to a predetermined value, usually by movement of heated air through the product. Foods are dried generally, to prolong their keeping quality. The preservation of food and crops by drying remains the most commonly used methods world-wide.

Nowadays, people all over the world have been influenced by new food-eating habits, grow non-traditional crops and have packaging systems that will protect the food, once dry, from the local climate. This often means that they wish to dry foods that are not even naturally in balance with and suited to the local climate.

1.3.2 PRINCIPLES OF DRYING

Drying basically involves the removal by evaporation of water, from the surface of the product, to the surrounding air. The amount of water vapour present in air is referred to as Humidity. Absolutely dry air, with no water vapour present in it is said to have relative humidity (RH) of 0%, while air that is saturated with water has an R.H of 100%. The amount of water Vapour that air can absorb is greatly dependent on its temperature. As air is heated, its relative humidity falls or it becomes drier and it is therefore able to absorb more moisture. Therefore heating the air around the product will course it to dry more quickly.

Increasing the rate of flow of the air will also increase the speed with which water is removed from the product being dried (resulting into shorter drying time).

1.4 WHAT FRUITS AND VEGETABLES ARE

Fruits can be defined botanical as a matured Ovary of a plant with or without seeds. Some fruits however, are formed from other flower parts or from the area (receptacle) example is pineapple. Fruits that are formed from inferior ovaries have their enlarged floral tube still present in them. In some cases these accessory structures may become a prominent part of the fruit, as in apples and pears.

Further more, a fruit may consist of several natural ovaries remaining together as a unit and may over include the matured ovaries of an entire inflorescence (Hills, 1982) Fruits can also be classified into true fruits for those derived from the corpel(s). True fruits may be fleshy or dry. Fleshy fruits include Drupes such plums and cherries as well as tomatoes, gooseberries and currents Dry fruits are numerous and varied and include the caryopsis of greases and the pods of pees. False fruits are those containing parts of other organs which include applies and strawberries the flesh of which are actually swollen Receptacles. (Clayton, 1986).

VEGETABLES:- generally refers to plants other than fruits that are cultivated for human consumption or for stock – feeding for example potatoes Carrots, cabbages. Some fruits such as tomatoes cucumbers, Okro and pepper and some seeds such as peas, beans are also considered as vegetables as vegetables. Most vegetables contain useful amount of vitamin C and minerals. Root vegetables contain stored carbohydrates and seed vegetables are rich in protein. (Clayton, 1986).

Most Vegetables are leaves, roots or stems of her because plants, although flowers, calyees, immature seeds or fruits may also be consumed as vegetables. Tomatoes and peppers are vegetables belonging to the same plant family (sola naceae) but like the other fruits (sydenhem, 1985).

1.5. PRODUCTION OF VEGETABLES

Vegetable production, like most agricultural commodities are seasonal. Vegetable production forms 25% of the minor food crops grown in the tropics (Eric and Bani, 1988).

In Nigeria, enormous quantities of fruits and Vegetables are produced and staggering figures are sometimes given as estimated annual production for instance figures such as 3.8 millions tons of Onions, 6 millions tons of Tomatoes and 3.8 millions tons of citrus have been quoted as annual production figures for some fruits in Nigeria (Oyeniran 1988).

1.5.1 **Tomato** – Tomatoes (lycopersicum esculentum) probably originated In central and South America. They are of many hundreds of varieties some tomatoes are golden yellow, some red; some are spherical others elongated; some plants are tall and must be staked, other are short. Tomatoes are grown almost universally as there are varieties which grow out doors in hot tropical conditions and others can be grown under glass in quite cold climates. They are sun-loving and do best in low rainfalls when they can be irrigated from below (as the upper plant does not like to be wetted) A single plant may give up to 20kg of fruit or more (Derek and wibberley, 1979).

Most African cultures are pale – skinned and better for cooking than salads (Penny, 1988).

1.5.2. OKRA – (Hibiscus esculentus)

Okra is a herb of the family Malvaceae. It is widely spread in tropical regions and in African in particular. There are many varieties, annual, biennial and short-lived perenniais with differences in the height of the stems, the size of leaves and fruits and the habit of the plant that is branched to a greater or lesser degree.

1.5.3. Sweet Pepper (Capsicum annuum)

They belong to the family solenaceae. The many varieties are usually divided into two main species. Small chillies called birdchillies (capsicum frutescens) and large chillies called have very hot fruits while sweet peppers are milder.

1.6. ADVANTAGES OF DRYING AS FOOD PROCESSING TECHNIGUE

Foods processing and particularly drying are essential to our civilisation as they provide advantages in respect of food hygiene distribution and storage as well as convenience. It is noted that dehydrated products have advantage over the other form of preserved foods in that they are easily packaged and stored at ambient temperature conditions. (Maud Kordylas 1991) The quality of dried fruits and vegetable studies have shown to depend mostly on the drying temperature time and method of drying. (Maud Kordylas, 1991).

1.7. UTILIZATION/IMPORTANCE OF FRUITS AND VEGETABLES

Vegetables (Tomatoes, Okra and pepper) are widely consumed in Africa, Nigeria in particular by many households as sauces, stew, soup as well as condiments in other food items. They are also consumed as side – dish or relish, with the staple foods. They are sometimes used as flavour in foods. Sweet pepper (Capsicum annuum) as well as Tomatoes are sometimes eaten raw as salads, or as fresh fruit in the case of tomatoes. They are sometimes processed into juice, puree, paste ketchup and chilli cause and canned whole the tender leaves of sweet pepper and Okra are also eaten as cooked vegetables. Okra is mucilaginous and give sauces a typically thick and sticky texture. Nutritiously it has been revealed that vegetables are good source of vitamins especially vitamin C and A, minerals such as calcium, Iron, Riboflavin and Magnesium as well as carbohydrate, to a little extent are also contained in vegetables. Vitamin C that is mainly found in fruit and vegetable is known to be very essential to the body in helping to maintain collagen, healthy gums and enhances fast wound healing (Maudkordylas, 1991). Fruits and vegetables are also useful source of dietary fibre, which is found on the skins, seedspith and their fibrous parts. They also contain pectin, which helps to remove waste products from the body. They are good sources of folic acid in the diet. Apart from other medicinal uses, chillies are recommended for constipation and as a pain killer (Anita, 1999) they have frequently been used as a maker for nutrient looses. In the absence of on adequate animal protein intake, vegetable and fruits are the cheapest and most available sources of these micronutrients. (Maudkordylas, 1991).

1.8. STATEMENT OF THE PROBLEMS

Fruits and Vegetables are highly perishable in their fresh form, after harvest particularly under hot tropical conditions. In Nigeria, enormous quantities of fruits and vegetables are produced however, a greater percentage (50%) are lost between rural production and town consumption. In Nigeria at present, the increase in production of vegetables causes gluts at harvest time, this results to very low prices followed immediately (within a period of 3 months) by extremely high prices when the vegetables are out of season. (Anita, 1999).

Several storage systems and conditions are been employed for storing fruits and vegetables, but the maintenance of good quality vegetable on a long term basis which is yet to receive solution which shows that the present storage systems are not adequate in the long-term preservation and conservation of fruits and vegetables. For instance Okra that appears bright green, firm, free of blemishes soon deteriorate, looses colour, crispness good texture, unless is cooled and kept below 15°c (Anita, 1999) packed the heat of respiration coursed the temperature in the package to rise quickly and result in repid deterioration. Inspite of this situation hydrocooling generally is not recommended because the water can cause spotting as prolong contact with ice or ice water does. Control Atmosphere effects on Okra have not been adequately evaluated, however work on packaging suggested that 5 –10% CO_2 lengthens shelf-life of Okra at 11°c ⁻ 13°c by only about a week (Desrosier et al, 1977) which is evidently too short a keeping time. Although peppers are hydrocooled, the practice cannot be recommended without reservation. The processing of these vegetables through various forms, to preserve and further extend their keeping quality, tend to have a lot of difficulties and limitations with most of the processing systems apart from the fact that they are highly sophisticated and capital intensive.

The canning of whole tomatoes for instance is relatively difficult because the fruit vary in acidity. The food processing companies have to check the acidity of each batch and add acid where necessary if not lethal toxin Botulinus may develop. Preservation of fruits and vegetables in a state that will have considerable long shelf life as well as maintaining their good qualities has remained a problem yet unsolved.

1.9 JUSTIFICATION OF THE PROJECT

In this era of galloping inflation, especially in Nigeria, commercial vegetables gardening could be encouraged, to serve as a good economic crop since they can produce large yields in small areas and yet sell for higher prices when compared to crops such as yams, maize or Rice.

Drying as a process of preservation and conservation seems to be the adequate method under most conditions in developing Countries and in Nigeria in particular, in solving this serious problem of glut and waste the Nigerian vegetable farmers face, in the production of these seasonal and perishable food crops which has been rendering all their hectic vegetable farming a non rewarding effort, due to inability to preserve the vegetables in such a way that it can keep for quite a considerable long time and still maintain its desired quality, pleasantness and acceptability to consumers, to command good and stable price.

Okro and pepper are known to be best preserved by drying. Drying being the cheapest and the most common form of fruit and vegetable preservation Nigeria, the quality of the resultant dried product is said to be highly affected by both the drying temperature as well as the time lag for the drying to be completed. The primary objective in removing water from any food material, is to reduce its bulk, so that it can be economically handled transported, and distributed. The other objective is to improve its keeping quality by reducing the moisture level. Fruit and vegetables have a high moisture content and are highly perishable. But when this moisture has been removed, they can be preserved over a long period with minimal microbial attack. Fruit and vegetable are heat-sensitive and therefore present special problems when drying Dehydration has to be carried out under carefully controlled conditions prolonged heat treatment results in a loss of flavour, a decrease in nutritional quality, vitamin losses, and a marked deline in the acceptability of the product. Successful dehydration therefore involved minimal heat treatment as well as careful handing., (Maudkordylas, 1990) If the drying temperature and time is not properly and correctly monitored, it might result to gross deterioration and probably total spoilage of such vegetables being dried. Prices of these dried vegetables depend mostly on their Physical appearance. It is therefore necessary to determine temperature - time for drying some of these vegetables, obtain well dried, well acceptable as well as well preserved dried vegetables, hence the need for this project

1.10. OBJECTIVE:

1. To determine suitable temperature-time relationship for drying some selected vegetables (tomatoes, okro, sweet pepper)
2. To evaluate some physical quality parameters of the dried vegetables (colour, texture, size/shape.
3. To determine the storage moisture content for the selected vegetables.

1.11. SCOPE OF THE PROJECT

The project work is limited to Tomato, Okro and sweet pepper being the most widely grown and consumed vegetablesin Nigeria. The studies of the effect of drying temperature-time on the selected vegetables would be limited to some physical quality parameters namely, colour, Texture, Moisture content, size and shape.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1.0 The preservation of food and crops by drying remains the most commonly used method world-wide .

New drying technology has given a significant boost to the demand for dried foods in the past and some researchers feel that this can be repeated, if more attention is given to food quality, during drying. (MacCarthy, 1986) several Nigerian Fruits and Vegetables cannot be stored in the domestic refrigerator as they are susceptible to chilling injury (Nigeria stored products Research No 4 1990)

2.1.1. THEORY OF DRYING

Drying of food refers to the removal of water from foodstuff. It is important to consider first the composition and nature of the food material and the nature of the conventional medium of moisture removal which is the atmospheric air (Ihekoronye and Ngoddy, 1985).

Drying is the process of reversibly removing water from a material so that the storage life is extended by the prevention of microbial, growth. The level of moisture required to prevent microbial, growth is usually less than 10% where as that for preventing of biochemical deterioration is much lower, less than 5% (Hall et al;, 1986).

According to Hall et al. (1986), scientifically dehydration or drying involves simultaneous heat transfer and moisture diffusion (mass transfer the conversion of liquid to vapour demands the supply of latent heat to the product.

Drying of food is achieved and controlled by transfer of heat, to provide the necessary latent heat of vaporisation and the movement of water or water vapour through the food material and then away from it, to effect the separation of water from the food material (Earle, 1976).

During drying of wet solid in heated air, the air supplies the necessary sensible and latent heat of Vaporisation to the moisture and also acts as a carrier gas for the removal of the water Vapour formed from the environment of the evaporating surface (Brennan et al. 1976).

According to Brennan et al. (1976), it is also important to note that drying process consists of stages.

The setting down stage- in which the condition of the solid surface comes into equilibrium with the drying air which is often negligible

The constant rate period – during which the surface of the solid remains saturated liquid water by virtue of the feet that movement of water Vapour from the saturated surface through stagnant air film into the main stream of the drying air.

2.1.2. DRYING MECHANISM

When air is blown over a wet food, heat is transferred to the surface and latent heat of vaporisation courses water to evaporate, water diffuses through a boundary film of air and is carried away by moving air, which allows for increase in a region of lower water vapour pressure at the surface of the food and a water pressure giddiest is this established from the most interior of the food to the dry surface, which provides the drying force for water removal from the food.

According to Ya ciuk (1982), the mechanism with which water moves to the surface of food stuffs during drying involves, the liquid moving by capillary forces or by diffusion caused by differences in the concentration of solutes in different regions of the food, the diffusion of liquid which are of the absorbed in layers at the surfaces of solid components of the food and water vapour pressure gradient.

Brennan et al. (1981) also noted that water Vapour pressure gradient between the drying surface and the main stream of drying air is the driving – force that courses vapour movement through the stagnant air film.

The components of foods include proteins, fats, carbohydrates, and vitamin, enzymes and inorganic salts, many of which are strongly hydrated. The water present is not pure, but may be in the form of a solution of solid, gel, emulsion or bound in various ways with the solid constituents. The cellular nature of plants also affects their drying behaviour hence the movement of soluble solids, which occur during drying.

According to Dresrosier and Desrosier (1977), if there is a flow of liquid water to the surface during drying, the water carries with it various soluble materials, this movement can be hindered by cell walls acting as semi-permeable membranes. Also this movement can be hindered by shrinkage. Nigeria of soluble solids in the opposite direction towards the centre of the places can also occur. As the surface dries out, a concentration greediest is set up between it and the wet centre of the piece, which could result in the diffusion of soluble material to the centre.

2.1.3 DRYING RATE

The rate of evaporation of moisture from the free surface of a food material is said to be dependent upon several factors such as the nature of the food material, the particle size, the bed depth (in case of pieces placed on a surface), humidity, temperature and the velocity of air. Larger particles take longer rate of drying thon smaller ones because moisture travels out of the food from inside. The time for piece of Okro to dry in a tunnel dryer is lower than when a whole Okro is dried in the same condition (Okaka and Awan, 1992).

FACTORS AFFECTING DRYING RATE:

It has been noted by Hall et al. (1986) that the most important requirement for food processor is that the rate of drying be as rapid as possible, provided that the product quality is maintained at high level. A study of the rate of drying on a small scale employing widely varying conditions, is essential before the design of large-scale plants can be undertaken. The main factors that affect the rate of drying and the time of drying cycle are:-

1. Physical properties of the product
2. Geometrical Arrangement of the product relation to heat transfer surface or medium.
3. Physical properties of the drying environment
4. Characteristic of the drying equipment.

PHYSICAL PROPERTIES:- The main aspect to be considered are the particle size and geometry. Any theoretical formulator drying time must incorporate a term expressing the fact that the thicker the product, the larger the time it will take to moisture to be removed.

The physical properties of the drying environment, humidity and velxity of the air being used for drying have a predominant effect on the note of drying and on the economics of the process. The combined effect of the humidity and temperature of air is determined by the psycrometic relationship and is obtained by measuring the wet bulb temperature (a diabetic saturation temperature for water).

The drying rate is said to have been shown to be proportional to the wet bulb depressing for a number of food products. However, when the relation humidity of the air is less than about 40%, the rate of drying is said to be often independent of wet bulb depression. The dry bulb temperature of the air is said to have considerable effect on the rate of drying at low moistures that is below 0.1% moisture content.

At these low moisture levels, the cooling effect of the evaporation is very small and consequently the heat is utilised in the internal redistribution of moisture. The limiting temperatures are determined by the biochemical changes that will cause the development of off-flavours and discoloration. (Hall et al; 1986)

Hall et al. (1986) also noted that the effect of air velocity on the rate of drying is very complex. For individual particles the rate of initial drying period is proportional to $V^{0.7}$ -$V^{0.8}$ where V = velocity.

This corresponds to evaporation from free water surface; but as the drying proceeds the effect is reduced – this assumes that radiation and conduction are absent since these processes reduce the effect of varying the air velocity. For the rate of drying for airflow; parallel to the surface of the product is proportional to 0.8 and perpendicular to be surface is proportionally to 0.2 and the constants of proportionality is 0.01 and 1.31 respectively where G = the mass velocity of the gas in pounds of total gas per hour per square foot. These are applicable for the range of G – 0.65 to 7.8 kg/Sm2 (500 – 6000 lb/hr ft^2)

H = 1 to 5.2 kg/sm2 (800 – 4000 lb/hr ft^2) respectively.

It has also been noted by Hall et al. (1986) that the rate of drying is said to be dependent on the rate of heat transfer to the drying surface. It has been noted by Ihekoronye and Ngoddy (1985) that the rate of mass transfer balances the rate of heat transfer and so the temperature of the drying surface remains constant. This temperature corresponds to wet – bulb temperature of the drying air.

Awan and Okaka (1992) stated that the rate of evaporation of moisture from free surface of food material is directly proportional to the velocity of air provided that all the factors mentioned above are kept constant. At low relation humidity and high velocity of drying air, food surfaces can get dried and the moisture inside the food is made unable to move towards the outer surface and results into what is known as "case hardening".

According to Earle (1988) the different areas of food surface dry out at different rates, the rate of drying declines gradually during 'constant rate period'. This leads to the fact that critical point of the given food is not fixed and depends on the amount of food in the drier and the rate of drying.

It has also been noted by Earle (1988) that a moderately high dry – bulb temperature, a low relative humidity and high air velocity play important role in drying in the constant rate period

Brennan et al. (1976) noted that the film of air surrounding the food acts as a barrier to the transfer of both heat and water vapour during drying, the thickness of this is determined by 'air velocity.' If the air velocity is too low, water vapour leaves the surface of the food and increases the humidity of the surrounding air, to cause a reduction in the water vapour pressure gradient and the rate of drying. Similarly, if the temperature of the drying air falls, or the humidity rises, the rate of evaporation falls and drying slows. When moisture content of food falls below the critical moisture content, the rate of drying slowly decreases until it reaches zero at the equilibrium moisture content which means that the food comes in equilibrium with the drying air, which is referred to as the "falling rate period" Drying the "Falling rate period" the rate of water movement from the interior of the food to the surface falls below the rate at which water evaporates to the surrounding air. The surface therefore dries out, this is usually the longest period of a drying operation. However, in some foods where initial moisture content is below the critical moisture content, the falling rate period is the only part of the drying cures observed such as in grain drying.

Drying the falling rate period the factors that control the rate of drying changes. Initially the important factors are similar to those in constant rate period but gradually the rate of mass transfer becomes the controlling factor, depending mostly the temperature of the air and the thickness of the food.

Earle (1988) noted that the size of food pieces has on important effect on the drying rate in both the constant and falling rate periods. In the constant rate period smaller pieces have larger surface area available for evaporation, but in the falling rate, smaller pieces have a shorter distance to move through the food. The fat content of food (higher fat contents) results in slower drying, as water is trapped within the food. The method of preparing the food for drying (as outer surfaces lose moisture more quickly than it losses through the skin).The amount of food placed into a drier in relation to its size (as in a given drier, faster drying is achieved with smaller quantities of food.

2.1.4. CALCULATION OF DRYING RATE

The rate of heat transfer is found to be (Brennnan et al, 1976)

$Q = hs\, A\, (\theta a - \theta s)$ ---------- 2 .1

Where:

Q = rate of heat transfer

A = Area for heat transfer

θa = Dry bulb temperature of air

θs = Wet bulb temperature of air.

Rate of mass transfer:-

$- mc = kg\, A\, (H_s - H_a)$ ---------2.2

Where Mc = Rate of drying

Kg = mass transfer coefficient

H_s = Humidity at surface

H_a = Humidity of air.

However, since during the constant rate period, equilibrium exists between the rate of heat transfer to the food and the rate of mass transfer in the form of moisture loss from the food. These rates are related by (Brennan et al., 1976)

$$-mc = hc\, A\, (\theta_a - \theta_s) \text{ ------------------------------ } 2.3$$

Where

λ = Latent heat of evaporation at θs

hc = surface heat transfer coefficient

The surface heat transfer coefficient is related to both mass flow rate of air using the following equations.

For parallel flow of air

$$h_c = 14.3\, G^{0.8}$$

Perpendicular air flow

$$h_c = 24.2\, G$$

For a tray of food in which water evaporated only from the upper surface, the drying rate is found using:-

$$-mc = hc \frac{(\theta_a - \theta_s)}{Ps \lambda X} \text{ ------------------------------------ } 2.4$$

Where

Mc = rate of drying

X = depth of material to be dried

P_s = Bulk density of sample

Plus the drying time in the constant rate period is found using:-

$$T_c = \frac{P_s x\ (m_1 - mc)}{Hc\, (\theta_a - \theta_s)} \text{ ----------------------------- } 2.5$$

Where:-

Tc	=	constant rate drying time
M_1	=	initial moisture content of solid
Mc	=	moisture content at end of constant rate period.
d	=	diameter of the material.

Drying diameter rates of sample of the material can this be estimated using:-

$$\frac{(dw)c}{d_t} = \frac{-hc\,(O_a - O_s)}{P_s - d} \quad \text{equation 2.6}$$

Where:-

$\frac{(dw)c}{dt}$	=	content rate of drying
hc	=	heat transfer coefficient
p	=	bulk density
L	=	latent heat of vaporisation
d	=	diameter of the material
O_a	=	Temperature of drying air
O_s	=	surface temperature of material (wet bulb)

The critical moisture contents of dried samples are obtained from the plots of drying rate against time (Brennan et al. 1976)

2.2. METHODS OF DRYING

It has been noted by Brennan et al. (1976) that the drying of foods results in savings in weight and usually bulk to be carried per unit food value, and in products with extended shelf lives as compared with fresh material. For the purpose of drying therefore, various methods are available to achieve such, depending on the type of material to be dried and the mode of drying

Hall et al. (1986) also noted that the conversion of liquid to vapour depends on the supply of latent heat to the product; this can be achieved by a variety of methods: -

The latent energy is supplied in various forms as in: -

Conduction – by contact with a heated metal plate

Convection – from a heated gas (usually air)

Radiation – from an infra red source, or

Microwave – energy. The process may be accelerated by the application of vacuum. These forms are applied in various methods.

2.2.1 SUN DRYING

Drying is said to be achieved by direct radiation of heat energy by the sun on the food material after it has been spread (Jackson et al., 1969).

2.2.2 DRYING BY APPLICATION OF ENERGY

This is done by radiating microwave or by use of dielectric stove.

2.2.3 DRYING BY DIRECT CONTACT WITH A HEATED SURFACE:

Here heat is supplied to the product mainly by conduction.

2.2.4. FREEZE DRYING

The moisture in the food is frozen and then sublimed to vapour usually by the application of heat under very low-pressure conditions. (Hall et al., 1986)

2.2.5. DRYING BY THE USE OF HEATED AIR

The food is placed in contact with a moving stream of heated air. Heat is supplied to the product mainly by convection.

This shall be the method employed in this project work since the temperature of the heated air as well as the holding time can easily be monitored and controlled to determined the best temperature/time required to obtain dried vegetables with optimum physical and nutritive quality as well as optimal keeping quality.

2.3 EQUIPMENTS USED IN DRYING

It has been investigated that apart from local sun drying, in which crops are often spread on roads, beaches and house roofs, to dry, taking advantage of the heat absorbed by the surface, which do not require the use of any equipment, there exists numerous equipments used for the purpose of drying of foods (Boateng et al., 1993).

According to Boateng et al. (1993).The simple sun drying method of drying even though involved virtually no cost have many limitation. Moisture loss can be intermittent and is dependent on good weather

Drying rates are low and often the product wills not dry fully in are day and so has to stand wernight to be finished off the next day. This increases the risk of spoilage, particularly from mould growth.

Final moisture leads are often not sufficiently low which can lead to deterioration in storage. On other occasions, over drying can occur.

The product is liable to contamination by dust and dirt and is open to insect infestation.

Theft and damage by dries and animals occurs.

More labour is required than might be expected to spread, firm and bring in the crop if rain is likely

Product darkening may occur and the level of certain nutrients, particularly vitamins, may be reduced by direct exposure to the sun.

2.3.1. SOLAR DRIERS

Peggy et al. (1993) has noted that broadly, there are two types of solar drier. Direct solar drier in such drier, the air is said to be heated in the drying chamber which acts as both the solar collector and the drier. The sun's radiation passes through the transparent drier roof, usually glazed with plastic sheeting, or occasionally glass, and heats the drier chamber which ideally is painted black, to absorb the maximum amount of heat. The heated air then rises and leaves the chamber through the exit holes in the upper part of the back wall, being replaced by cold air entering through the entry holes in the dry base. And airflow is thus said to be established which, combined with reduced Relative Humidity of the heated air, removes moisture from the product. The drier cover is double-glazed for maximum efficiency by reducing heat loss. Heat losses through the wood wells of the drier are low but insulated walls are added advantage. Examples of direct solar drier is the cabinet drier (Brace or low land type, and chimney drier Indirect solar drier – An indirect drier is said to be comprised of two parts, a solar collector receiving the sun's radiation, which is connected to the drying chamber containing the crop. Air enters the collection where it is heated. Its humidity is reduced and the hot air rises to the drying chamber by natural convection. Such drier must be adopted to suit local climatic conditions and the crops to be dried. Examples of this type of dries is a solar collector drier. (Peggy et al., 1993).

Solar drier is noted to suffer from certain major limitations. They cannot be used at night and their efficiency declines in cloudy or rainy weather. Very often the product may not be completely dried in one day which may result in deterioration, particularly mould growth, during the night.

They also do not lend themselves to being scaled up easily into larger units without introducing problems and fragile structures (Peggy et al; 1993).

2.3.2. ARTIFICIAL / MECHANICAL DRIERS

It has been noted that there are drier, which rely on the heat from burning wood, gas, oil or electricity and often have fans. They are independent of weather condition they have greater degree of control of drying process as well as greater capacity (Peggy et al; 1993).

Kiln-Drier is said to consists basically two-storey building, with a furnace or burner located on the floor. The heated air and the products of combustion rise, by natural or forced convection through the slated floor of the second storey, on which the wet material is spread in on even layer, usually 0.1 – 0.2 m deep. The humidified air is exhausted through the upper storey. Regular turning of the product is necessary (Brennan et al, 1979).

TUNNEL DRIER

This drier is said to be a type of equipment which provides a means of drying fruits and vegetables in pieces form on a semi- continuous basis at high through puts. It consists of a tunnel, the wet food material is spread in even layers on trays of slatted wood or metal mesh. The trays are assembled in stacks on struck, clear spaces being provided between the trays to permit passage of the drying air (Ihekoronye and Ngoddy, 1985).

CABINET TRAY OR COMPARTMENT DIRER

This is said to be essentially insulated cabinet containing an air circulating fan, which moves the air through a heater and then through adjustable baffles, which direct it either horizontally between trays of food In material or vertically through the trays and food. Dampers are provided, to control the rate of fresh air intake and the amount of air recirculation as required. In cross-flow systems, air velocities of the order of 2-5 m/s are used while through flow systems required 0.5 - .25 m^3/s cabinet driers are relatively flexible. They are used single or in-groups, mainly for drying Fruits and vegetables (Earle, 1988).

2.3.4. PROCESSING EFFECTS ON PRODUCT QUALITY

CASE HARDENING:

It has been observed that during the drying of some fruits, meat and fish, a hard impermeable skin often forms at the surface. This usually results in a reduction rate, and phenomenon called case hardening. The exact mechanism of case hardening is yet to be fully under stood, but is probably influenced by a number of factors including migration of solube solids to the surface and high surface temperature toward the end of the drying resulting to complex physical and chemical changes in the surface layer (Brennan et al, 1976).

SHRINKAGE:- Brennan et al. (1976) also noted that vegetables tissue undergo some degree of shrinkage during drying by all the drying methods. Colloidal materials also shrink in the early stages of drying, at low rates the amount of shrinkage bears a simple relationship to the amount of moisture removed towards the end of drying, shrinkage is reduced so that the final size and shape of the material is fixed before drying is completed. At low initial drying rates the pieces will shrink inwards, to give a product of high bulk density, shrinkage of food stuffs during drying may influence their drying rates because of the changes in drying surface area and setting up of pressure gradients within the material.

2.4. REVIEW OF RELATED EXPERIMENTAL RESEARCH

The effect of drying on vegetables was investigated by Ali and Sarkr (1981) and was reported that dryer was used to dry Jew's mallow (corchorus olitorius L) and Okra (Hibiscus esculentus L.) the drying procedure depends on using heated air of 60^{o}c on average. The results revealed that the rate of drying was high in the first 3 hours and then slowed down during the remainder of the drying time. The duration of drying for both Jew's mallow and Okra was on average 22.5 hours and 40 hours respectively.

The moisture removed during that period was about 72-75%. The guality of the dried product was acceptable to the consumer and was considered nutritionally satisfactory. The storage of dried products for 32 weeks at room temperature showed no effect on quality or change in chemical composition.

The effects of drying on the nutritive value fruits and vegetables in kenya were analyzed for vitamin C and carotene content by Gomez (1982) four selected species were subjected to solar dehydrate with and without photo protection. Two pre-treatments, steam blanching and sulfiting were applied and carotene retention in the resulting dried products were evaluated. A control study was conducted with ambient temperature shade – dried material subjected to the same pre-treatments. Mango and papaya were similarly subjected to blanching and citric acid and sucrose pre-treatment respectively and retention of carotene and vitamin C in the products was observed. Carotene retention in the ambient temperature was lower than in the solar – dried treatments with continued losses in storage. Light – protected drying resulted in higher retention than light – exposed drying and steam blenching improved retention significantly.

Papaya showed appreciably higher retention of vitamin C on drying then did mango while the latter showed significantly higher carotene retention. Steam blanching of mango prior to drying resulted in appreciable losses of both ascorbic acid and carotene.

The drying characteristics of some Nigerian fruits and vegetables were investigated (Solanke,1998) samples of Banana, Okro, pepper and carrot were dehydrated using the tray drier at 60°c and 80°c. 1cm thick of slices of the materials were blanched at 80°c for 2 minutes before they were dried.

The average sun-drying temperature was estimated to be 35°c. Dehyration at 60°c using tray drier, gave the best result in terms of colour changes and bulkiness.

An attempt made by Eke (1995) to locally dry tomato after they were cut cross wise and dried in a locally fabricated solar dryer for several hours until they were bonedry at about 3% moisture content and were then grounded to powder, observed that the red dish colour of the fruit changed to brown due to the intense heat of the sun and the long period of exposure. The colour change was as a result of loss of carotene (vitamin A) which is responsible for the red - dish tomato colour.

2.5 EFFECT OF DRYING ON QUALITY OF VEGETABLES

Dehydrated commodities are said to lose some of their nutrients during the dehydration process. Oxidation is a primary cause of loss, particularly in the case of ascorbic acid, but non-oxidative losses also occur (Hendel, 1960) it has also been noted text non-enzymatic browning reduces the occlude of the protein (Hendel, 1960) it was observed that glucose reacts with acetic, citric, or lactic acid in a model system, to produce brown pigments and carbon dioxide. Oxygen accelerates the process. Heat is also considered as a main factor responsible for protein damage. Heat damage is due to a time temperature relationship (Ali and sakr, 1982)

Ali and sakr (1982) also recorded that there is evidence that heat damage is much more likely to occur when the initial moisture content is high based on the results of the regional research laboratory of united states department of Agriculture, that metal grid trays reduces losses during drying, stainless steel trays are used, to hasteen drying and reduce length of drying time. It is also very important when drying green vegetables to have a final product that meet the consumer acceptance. Good colour and consequently carotene content can be retained by blanching. Appropriate storage condition can help to retain the desired qualities.

Hall et al. (1986) also observed that it is necessary to control drying processes carefully, in order to prevent thermal degradation of the product. The level of moisture required to prevent microbial growth is said to be usually less than 10% where as that for prevention of biochemical determination is much lower, less than 5%.

2.6.1 FACTORS THAT INFLUENCE THE SELECTION OF A DRYER FOR INDUSTRIAL DEHYDRATION.

The method of industrial drying adopted for fruit and vegetable processing is said to be influenced by factors, such as the type of raw material, its sugar or starch content, the type of end product expected: (weather crips, Pliable or leather), the tendency to brown, and the quality and cost of the raw materials.

These factors are also said to be taken into consideration, when a dryer is selected. (Maud kordylas, 1990).

In addition, Maud kordylas (1990) also noted that the product characteristics, like bulk density, ease of reconstitution, speed of dehydration. and flavour retention is also considered.

It has been noted that the method selected must be one, which minimises the cost of moisture removal, while maximising desirable product qualities. The cost of the final product is also considered. It has been noted that the dehydrated and product is to be of low cost, the drying method adopted should be in expensive Hot air drying is said to be by far the cheapest method (Maudkordylas, 1990).

2.7 FUNDAMENTAL CONCEPTS IN EXPERIMENTAL DESIGN

2.7.1 THE EXPERIMENT

A designed experiment is said to be a test or series of tests, in which purposeful changes are made to the input variables of a process, so that observation and identification of the reasons for changes in the output responses could be made. (Douglas, 1991).

In any experiment, the experimenter attempts to draw certain inferences or make a decision about some hypothesis concerning the situation being studied. Uncertainty does not imply no knowledge, but only that the exact outcome is not completely predictable.

Since decision making based on the use of statistical tools almost always involves collection of data, the way in which the data are collected is said to be extremely important. (Hicks, 1973) the design of on experiment therefore is said to be the order in which an experiment is run. Hicks (1973) noted that experimental designs are used to help reduce the experimental error in the data collected. Randomisation is also said to be employed to help average out the effect of many extraneous variables, which may be present in an experiment. Other factors are purposefully varied during an experiment, in order to make results more valid for a large variety of situations, which might occur in practice.

2.5 EFFECT OF DRYING ON QUALITY OF VEGETABLES

Dehydrated commodities are said to lose some of their nutrients during the dehydration process. Oxidation is a primary cause of loss, particularly in the case of ascorbic acid, but non-oxidative losses also occur (Hendel, 1960) it has also been noted text non-enzymatic browning reduces the occlude of the protein (Hendel, 1960) it was observed that glucose reacts with acetic, citric, or lactic acid in a model system, to produce brown pigments and carbon dioxide. Oxygen accelerates the process. Heat is also considered as a main factor responsible for protein damage. Heat damage is due to a time temperature relationship (Ali and sakr, 1982)

Ali and sakr (1982) also recorded that there is evidence that heat damage is much more likely to occur when the initial moisture content is high based on the results of the regional research laboratory of united states department of Agriculture, that metal grid trays reduces losses during drying, stainless steel trays are used, to hasteen drying and reduce length of drying time. It is also very important when drying green vegetables to have a final product that meet the consumer acceptance. Good colour and consequently carotene content can be retained by blanching. Appropriate storage condition can help to retain the desired qualities.

Hall et al. (1986) also observed that it is necessary to control drying processes carefully, in order to prevent thermal degradation of the product. The level of moisture required to prevent microbial growth is said to be usually less than 10% where as that for prevention of biochemical deterioration is much lower, less than 5%.

2.6.1 FACTORS THAT INFLUENCE THE SELECTION OF A DRYER FOR INDUSTRIAL DEHYDRATION.

The method of industrial drying adopted for fruit and vegetable processing is said to be influenced by factors, such as the type of raw material, its sugar or starch content, the type of end product expected: (weather crips, Pliable or leather), the tendency to brown, and the quality and cost of the raw materials.

By the use of certain special designs, the effects of many important factors are said to be studied in one experiment, as well as the interrelationship between these factors. This is done to obtain a maximum reliability of information at the minimum cost (Hicks, 1973).

Choice is said to be made as to the dependent variable or variables to be studied. It is also noted that it is necessary to define the independent variables or factors which may affect the dependent or response variables. (Hicks, 1973).

2.7.2. THE DESIGN

It has been noted that of primary importance, are how data are collected how the many observations are to be taken, how large a difference is to be detected, how much variation is present as well as what size of risks to be tolerated, in deciding on the sample size for a experiment. (Hicks, 1973) it is also noted that of prime importance also is the order in which the experiment is to be run which should be randomised. This tends to average out, the effect of uncontrollable variables.

A material model is said to be set up to describe the experiment. This model shows the response variable as a function of all factors, which are to be studied and any restrictions imposed on the experiment, due to the method of randomisation (Hicks, 1973).

2.7.3. THE ANALYSIS

The analysis includes the procedure for data collection and processing, computation of test statistics such as t, F, chi-square and the corresponding decision rules for testing hypotheses about the mathematical model as well as interpretation of the results (Hicks, 1977).

2.8 OPTIMIZATION TECHNIQUES:

Optimisation is said to is the act of obtaining the best result under given conditions. Since the goal in any practical situation can be expressed as a function of certain decision variables, optimisation can be defined as the process of finding the conditions that give the maximum value of a function (Rao, 1977).

A number of Optimisation methods are said to have been developed for solving different types of optimization problems (Rao, 1977) Optimisation methods are also said to be generally studied under operations research, which is a branch of mathematics, concerned with the application of scientific methods and techniques, to decision making problems with establishing the best or optimal solution.

a. The mathematical programming techniques help to find the minimum of a function of several variables under a prescribed set of constrains.

b. The statistical methods enable one to analyse experimental data and build empirical models, to obtain the most accurate representation of the physical situation or phenomenon.

c. The statistical process techniques is said to be used to analyze problems, which are described by a set of random variables having known probability distributions, involving situations where some or all the parameters of the optimisation problems are described by stochastic (random on probabilistic) variables rather than by deterministic of quantities (Rao 1977).

2.8 ANALYSIS OF EXPERIMENT DATA

Experiments are usually performed, when the objective of the scientific investigations, is to understand and explain the relationship among variables, knowing how and to what extent a certain response variable is related to a set of independent variables.

In most cases the functional relationships among variables are not known. In such cases, approximation of the relationships are made and models that characterise their main features are developed. (Douglas 1991) It has been noted that there are essentially two ways in which the functional relationship between the dependent or response variable Y and the K independent variables X_1 X_2 ....X_k may be specified.

a. Based on accepted biological concepts or past experiences, even before data is gathered, the researcher could postulate one or more functional forms, that would adequately describe the relationship among the variables of interest, (Douglas, 1991).

b. Based on data gathered in the experiment itself, the researcher could identify one or more functional forms that are most likely to best fit the current data (Douglas, 1991).

2.8.1. REGRESSION ANALYSIS

Is said to be a statistical analysis used employed on statistical problems where the observation on each object consists of a pair, a triple on even a higher number of measurements. For instance, in certain production (Drying) processes, the yield of a product n may depend upon the amount of heat applied X_1, the drying time X_2 the amount of feed X_3, and so on. The response n = f (X_1, X_2,.......X_k) is a function of the variables X_1 X_2, ...X_k.

Regression analysis is said to be employed as the statistical procedure to deal with this situation in which n is measured with error, that is we observe a response y where

$$Y = n + \varepsilon, \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2.7)$$

Where

ε = is a random variable with E (e) = 0,

Var (e) = 6^2 or

ε (y) = n and v(y) = 6^2 (Irwin et al; 1982)

Regression analysis is said to be concerned with development of such approximating models. It is a very useful and widely employed tool in data analysis. An adequate description of observed phenomenon in terms of a few meaningful variables as possible. It leads to simple, yet often powerful descriptions of the main features of the relationship among variable and it is highly useful in designed experiments (Samprit, 1991) Regression models can be classified into four type:-

i. The simple linear regression model – this involves a single regressor variable X_I assume that the statistical relationship between the response variable Y and this regressor variable is linear. The model is written as

$$Y = bo + b_i X_i + \mathcal{E}_i, I = 1, 2, \ldots, n \ldots (2.8)$$

Where X_i = the observation the regression variable

Y = the response that corresponds to the setting X_i of the regression variable

bo and b_i= regression coefficients

E I = the random errors that create the scatter around the linear relationship. It is assumed that these errors are mutually independent and normally distributed with mean zero and variable 52. (Owen, 1976)

ii. Multiple linear regression model:- Frequently, more than one variable has an influence on the response. The general problem of fitting the model is called the multiple linear regression.

$$Y = b_o + b_i X_i = b_2 X_2 + \ldots\ldots + b_k X_k + \mathcal{E}i \ldots\ldots (2.9)$$

The unknown parameters b_i are the regression coefficients. The model describe a hyperplane in the k dimensional space of the regression variable X_i are often good approximations of complicated non-linear functional relationships, especially if the ranges of the X_i values are not too large over a small enough region, many complicated non-linear functions can be approximated by a linear one. (Owen 1976)

iii. Simple non linear regression model:- There are cases, where non linear relationships are needed, the quadratic function is fitted,

$Y = b_o + b_1 X_i + b_2 X_2 + \mathcal{E}i \ldots\ldots$ (2.10) (Owen, 1976).

iv. Multiple non-linear regression model:- in this case, the polynomial

$$Y = b_o + b_i X_I + \ldots\ldots b_k X_k + \mathcal{E}_i \ldots\ldots (2.11)$$

can be fitted (Irwin et al; 1982, Owen, 1976). Thomas,1978)

2.8.2 ANALYSIS OF VARIANCE

In many experiments, the main objective is to determine the effect of various factors on some response variable Y of basic or primary interest. Experiments designed and analysed in accordance with certain principles, (Analysis of variance) make it possible to arrive at cleaner and more trustworthy inferences about effects of factors, with a minimum of computational complexity. (Irwin et al. 1982).

THE MODEL AND ITS ANALYSIS:- in the testing hypotheses about the difference of two normal populations or samples on the basis of samples from these populations, if the two population variances are unknown, but could be assumed to be equal, the statistic used for making the test Is a student test statistic involving the two sample average and the two sample variances.

In the experiment involving samples from three on more populations, the test of a hypothesis concerning the means of the populations from which the samples are drawn as follows:- suppose A_1, ..., A_m are levels of some factor A_i and that the effects of A, ... A_m. On some response variable Y of primary interest is to be studied. Experiment is set up, in which n_1 observations are mode on Y when level A, is present, n_2 observations are made on Y when level A2 is present, ...a and finally n_m observations are made, when level Am is present. Commonly, the levels of A are called "treatments" there being m treatments in this experiential design.

Suppose (Y_{11}, Y_{21}, ... Y_{ni1}) is a sample of size n_i from a population having the normal distribution N (u + si, б2), (Y_{12}, Y_{22}, ..., Y_{nm}) is a sample of size n_m from N (u + 5m, 52), the samples all being independent and where (u, 5,....8m, 52) are unknown parameters, with 5l, ..., 5m satisfying the condition.

N, б, + ... + n_m $б_m$ =0 ....(2.12).

The parameters 51 ....5m are referred to as differential effects or sample effects due to A1,....., Am, respectively. The parameter u is sometimes called the over all mean and б2 is the common variable of the Y_{ij} I = 1, ..., nj, j=1,....., m.

This fact could also be written as Y_{ij} = U + $б_j$ + E_{ij}, j=l, ..., m; I = l, ...,n_j (Irwin et al. 1982).

2.9 QUALITY EVALUATION

Quality of a foodstuff is said to be assessed on the basis of balancing specific characteristics, each of, which has significance in determining the acceptability of the product, thus determining overall quality. Drescrosier, (1977) declared that each of these characteristics should be measured and controlled independently.

Quality is said to be commonly thought of, as degree of excellence. Dresrosier, (1977) also noted that it may be considered as a specific action or set of specifications, which are to be met, within given tolerances or limits. Therefore the level of the excellence of the product may be considered as the average or mean level of quality required in the market place, and not necessarily the highest quality that is obtainable regardless of cost.

The uniformity of the product may be described in terms of minimum limits, or a tolerance between upper and lower control. Limits.

An important aspect of quality control is said to be the utilisation of reliable methods of measurement in establishing standards or specifications of quality, and grading procedures, to control the quality of raw materials as well as the processing operations and the finished product. (Williams, 1982).

2.9.1. OBJECTIVE AND SUBJECTIVE METHODS

Subjective or sensory evaluation is said to be made up by human judgement, using human senses. It has been noted by Williams (1982), that sensory evaluation suffers from being influenced by environmental conditions, mood and health of the individual, lack of an absolute reference point, tendency for comparative rather than absolute evaluations and above all personal bias, which may enter the evaluation consciously on subconsciously.

Objective evaluation is said to refer to the use of calibrated instruments, to measure physical or chemical components, which is less dependent on the human element. However, it has been noted by Williams (1982) that unless correctly conducted, it can lead to greater error than subjective evaluation.

It has also been noted by Williams (1982) that human evaluation is the ultimate criterion of the accuracy of any objective method, hence if a subjection evaluation is possible, it is generally used in preference to an objective evaluation. With all products destined for consumption.

Williams (1982) has noted that the only way to Judge their success or failure is to have then examined by human assessors.

2.9.2. QUALITY ATTRIBUTES

Quality attributes are said to be classified as either sensory on hidden, sensory characteristics are those which can be detected with human – senses, including sense of sight, touch, taste and smell whereas hidden characteristics are said to be these which cannot be evaluated with senses but are of importance to health (Williams et al, 1977).

Appearance – Factors of quality included in appearance are said to be those evaluated with the eye and hence the first noticed by the consumer. It has been noted by Williams et al; (1977) that it is often on its appearance that product is accepted or rejected, and therefore good appearance is most important.

Colour is said to be an appearance property attributable to the spectral distribution of light.

The most complex and expensive instrument used for colour measurement is the spectrophotometer which measures the amount of light reflected from the surface of an object at each wave length in the range of approximately 380 to 770μm.

A quicker and cheaper method is the Munsell system – which uses 3 or 4 colour discs, each of which is calibrated in terms of hue (red, green), value (lightness or darkness), chroma (strength of the colour) each of these is expressed on a scale. The discs are overlapped so that the proportion of each disc, which is exposed, may be adjusted until blend of colour obtained by spinning the discs, matches the object whose colour is being measured.

The percentage of each disc exposed, and the disc notations are converted to Munsell notations, using tables and charts.

The other main colour instrument is the Hunter colour difference meter. It is less expensive than the spectrophotometer but more costly than the Munsell system. It measures the value, the amount of redness or greenness and the amount of yellowness or blueness that is Hunter values, which can be converted to Munsell notations.

Some important properties are said to be determined by instruments or by chemical analysis, but William et al. (1977) noted that such measurements must be related to consumer preferences by sensory evaluation, hence direct sensory evaluation is often the only practicable method, especially when the combined effect of several different properties is concerned.

2.9.3. SENSORY EVALUATION

In sensory evaluation the reactions of a selected group of people testing the product under controlled conditions are used to predict the ultimate acceptability of the product. Useful informations are obtained only the right questions are asked of the right people.

To choose satisfactory test procedure, depending on the type of product being tested, different assessors are required

i. Expert assessors:- Expert assessor are said to be those who know a great deal about the production, uses and marketing of a commodity. They are said to be able to describe all the attributes of a sample in detail and can usually indicate the causes of any defects. Their training is a long and expensive process and they are usually to be found working in the product development department of food manufacturing companies or consultancy and specialist commodity dealers. They are full-time assessors (Dresrosier, 1977)

ii. Experienced Assessors: - These are said to be people selected for their ability to recognise, describe and qualify basic characteristics of foods and to detect small differences between samples.

They may or may not specialise in one commodity. Experienced assessors are usually employed to spend only part of their time as assessors. They work in panel of 10 to 15 members. Most quality control and product development work is done with assessors of this type (Dresrosier, 1977).

iii. Untrained assessors:- are said to be selected as typical as possible of the consumers of potential consumers of the product concerned. They work in panels of 10 to 30, usually assessing acceptability and preference before consumer trials are begun (Dresrosier, 1977).

iv. Consumer panels:- consumer panels are said to be of large untrained groups of at least 100 members they are selected at random from the section of the population whom the product is aimed and are usually concerned with preference and acceptability untrained assessors are selected only for availability, in which case they must be willing and able to take part in as many test, as is necessary.

v. They are also selected for interest purpose, in which case, they must be interested in the product and in taking part in the tests. They should normally be consuming similar product themselves. This group is also selected for consistency therefore they must be consistent in their assessment. If they are presented with the same sample several times, they would express the same preference in a significant proportion of these tests. (Dresrosier, 1977).

It has been noted by Dresrosier (1977) that Experienced assessors would be able to:-

Detect small differences between samples, use Separate scales for each attribute of a product in addition to the simple hedonic scale as well as give brief, clear reasons for their assessments.

It has also been noted by Dresrosier (1977) that it is best to select assessors, on the basis of the results of practice sessions, using the product to be tested.

1. Paired Comparison:

   This test is more efficient when R is always the control sample. This method should not be used when there are more than two treatments. Statistical Tables can be used to determine the significance of results. Drescrosier, 1977)

2. Ranking the panellists is asked to rank several coded samples according to the intensity of some particular characteristic.

   The ranking method is said to be generally used for screening 1 or of the best samples from a group of samples rather than to test all samples thoroughly. This method is rapid and allows for testing of several samples, but no more than six samples of any product should be ranked at a time. Ranking gives no indication of the amount of difference between the samples since samples are evaluated only in relation to each other; results from one set of ranks cannot be compared directly with results (Dresrosier, 1977).

3. Multiple Comparisons. – A reference or standard sample is labelled R and presented to the panellist with two or more coded samples. The panellist is asked to compare each coded sample with R. He decides whether it is better than, equal to or inferior to the reference and indicates the size of the difference.

   A coded reference sample is often included with the other coded samples to serve as a check on the panellists.

   Multiple comparisons is said to be used very efficiently to evaluate 4-5 samples at a time. Information regarding the direction and the magnitude of the difference is obtained.

Dresrosier, (1977) noted that in order to analyse the results of paired comparison tests, numerical values are assigned to the responses of the panellists. Analysis of variance is then calculated.

4. Scoring – Coded samples are evaluated for some specified characteristic by the panellist who records his evaluation on a descriptive graduated scale.

Scoring is said to give indication of the size and the direction of the differences among samples. It has broad application and can be used to evaluate different characteristics by modifying the wording of the questionnaire. A great variety of scales has been developed. The scale should have at least 5 categories but not more than 9. The number of categories should not exceed the number of degrees of the characteristic that can be perceived. There is a tendency for the panellists to refrain from using the extreme ends of the scale.

The characteristic being measured must be understood by the panellists and the different degrees of quality recognized.

There is a tendency for the scales to drift in meaning with time. This instability is a marked disadvantage when scoring is used in storage stability studies over an extended period. Standard products to represent different points in the scale will act as anchors and will help minimize panel variability.

Scoring yields more information than ranking and is more efficient than paired comparisons.

A numerical scale can be used rather than a verbal scale; however, descriptive terms are usually more meaningful to the panellists unless they are very well trained. Descriptive terms are a help to the panellists but the descriptive words must be carefully chosen if the scale is to be meaningful.

The categories on the scale are asigned numerical values and results are analysed by analysis of variance, (Dresrosier, 1977).

A particular type of scoring system is said to be hedonic scale which measures the degree of like or dislike for a product. It is simple and requires no experience by the panellists. The verbal categories can be replaced by caricatures. (Dresrosier, 1977).

5. Descriptive Sensory Analysis. – one of the best –known descriptive methods is the "flavor profile" developed at Arthur D. Little, Inc. This method requires a panel of 4-6 trained persons who function as a unit under the direction of a panel leader to produce a verbal description of a product. The flavor complex is described in terms of character notes, intensity, order of appearance, after-taste, and amplitude. The panellists evaluate the product independently and then discuss results in order to arrive at a common opinion.

   The selection and training of a profile panel is a lengthly process usually taking 6-12 months. However, once trained it is very efficient since several factors can be evaluated in one session. Profile panels have been found to be very reliable.

   A descriptive method of analysing texture has been developed, called the "texture profile" method. It is defined as the organoleptic analysis of the texture complex of a food in terms of its mechanical, geometrical, fat, and moisture charactistics, the degree of each present, and the order in which they appear from first bite through to complete mastication. The panel must be intensively trained in order to use this method reliably. (Dresrosier, 1977).

2.9.4 DESIGN OF SENSORY EXPERIMENTS AND ANALYSIS OF DATA

Desrosier (1977) noted that when planning an experiment involving sensory evaluation the most appropriate method should be selected, the number of samples that can be tested in one session should be determined, and the number of testing sessions should be estimated. With this information the amount of experimental material required can be calculated and sufficient material can be prepared in advance.

The advice of a statistician is valuable in planning experiments since the method of analysis must be decided upon before the testing is done.

The use of experimental "designs" makes the test more efficient and saves time and material. Replication will strengthen results.

Because of the quantity of data obtained from sensory evaluation and its variability, results cannot usually be interpreted by direct examination. The data must be summarised and analysed statistically. There are several techniques available and special treatments have been developed for use in particular situations. For some types of tests, statistical Tables have been developed for rapid analysis of the data, e.g., paired comparison, triangle, and duo-trio tests. For most other methods a t-test or analysis of variance can be used to analysed results.

Statistical analysis is used to determine the probability that the results obtained in the experiment would occur if chance alone were operating. The probability is commonly expressed in degrees of significance.

In the paired comparison, triangle, and duo-trio tests, a greater degree of significance of results does not mean a greater degree of difference between the samples. The significance is related to the number of evaluations. In order to measure the amount of difference in these tests the percentage of correct responses should be calculated.

It has also been noted by Dresrosier (1977) that although statistical analysis are essential for interpretation of results, they will not correct erroneous data, improve a poor method, or compensate for inadequate control of experimental variables.

Descriptive sensory analysis is said to provide information on a food, which is much more comprehensive and useful than straightforward difference testing. By coupling this with a scoring system. William (1982) noted that it provides the research worker with a powerful tool, for understanding sensory quality, the results from which are amenable to statistical analysis.

Thomas,(1978) noted that date based on counts of individuals belonging to each several classes generally require a different kind of statistics analysis than that commonly used for measurements. Data base on counts are said to be transformed and analyse validly as though they were measurement (represented by the symbol X^2) are mostly used to analyse enumeration data

2.9.5. INTERPRETING RESULTS FROM SCORED DATA

The data obtained from any scoring system is said to be subjected to statistics analysis. Examination of population distributing within each category and evaluation of the significance of any difference by comparing results with probability table is said to be the usual approach adopted for simple category data (Dresrosier 1977). Williams (1982), also noted that with most scored data in which there is an underlying continue, however, one may use an analysis of variance coupled with F tables to determine the significance of difference. Univariate techniques are said to be used when dealing with one attribute, but multivariate approaches often provide a much clearer picture when handling several attributes (Williams, 1982.)

CHAPTER THREE

3.0 MATERIALS AND METHOD

3.1 MATERIALS

Samples of Tomatoes (Lycopersicum esculentum)

Samples of Okro (Hibiscus esculentus)

Samples of Sweet pepper (capsicum annum)

Tray dryer

Weighing mettler balance

De siccator

Forceps or pair of tongs

Stainless steel knife

Chopping board

Boiler or blancher

Digital thermometer

Crucibles

Oven

Stop clock

Tap or clean water

Blender

Colander or stainless steel basket

Basin.

3.2.0. EXPERIMENTAL DESIGN METHOD

3.2.1. THE 2^k FACTORIAL DESIGN:-

A factorial experimental method is employed for this experimentation. For experiments involving the study of the effects of two or more factors the factorial design method is most efficient in obtaining the response function or response surface (Iwin et al; 1982). A factorial experiment is said to be one in which the treatments consist of all combinations of the selected levels in two or more factors. In a factorial experiment, each complete trial or replication of the experiment, all possible combinations of the levels of the factors are investigated (Irwin et al; 1982).

The 2k factorial experimental study for this particular research work, is illustrated as shown in figure 3.1 below:

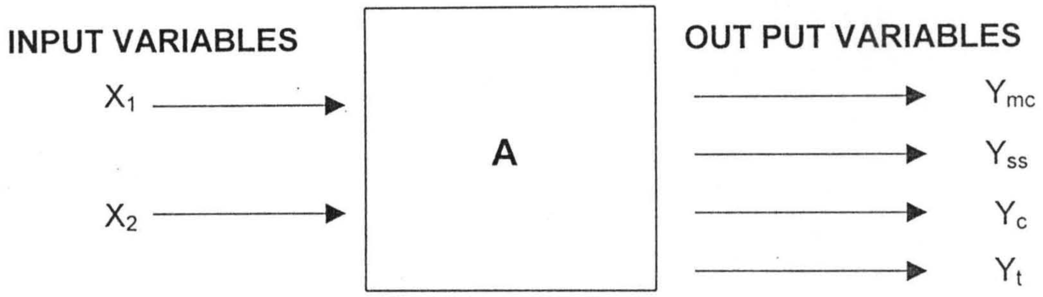

Fig 3.1: Input and output variables for complete 2k factorial experiment.

Each of the fruits and vegetables samples Tomatoes are Okro and sweet pepper passed through the same or uniform drying process **A**

Input variables:

X_1– Drying temperature from heated air in degree centigrade

X_2 – Drying time or Retention time in hours

Y_{mc} – Output variable the moisture content of the product at the end of each particular drying temperature and time.

Y_{ss} – The size and shape of the product

Y_c - The resultant colour of product

Y_t – The texture of the product.

For this experiment, two factors namely Temperature X_1 and time X_2 are of interest. The effect of one factor changes as the level of the other factor changes.

The 2^k full factorial design provides the time frame and order of experimental runs with which factors could be studied. With a 2^k design it is easy to write down experimental runs in standard order at the on set, and the effects of factors and/or their interactions are easily estimated.

Factorial design denote a design that is constructed by taking all combinations of I levels of factor A, with the l_2 levels of factor B, with the 1_3 levels of factor C, ...,and, finally, the 1_k levels of factor K. the complete factorial design would contain a total of t = l, x l_2 x l_3 x ....x l_k "treatments" with rj observations per treatment. (Usually, but not necessarily, a fixed number of replicate observations say r, and taken on each treatment, providing a total of $N = r \times 1_1 \times l_2 \times l_3 \times \ldots\ldots l$ experiment). A single observation, Y_{ij}, j = 1, 2,....., r_j and j = 1, 2 ...., t, is recorded. For each experiment. If $r_j = r$ for all j, then it is said that each treatment is replicated r number of times – Ideally the entire program of experiments is run in a random sequence (Irwin et al;1982).

A 2^2 full – factorial experiment (FFE) provide the framework for designing the effect of Drying temperature X_1 and drying time X_2 on the physical quality parameters of fruits and vegetables. The following assumptions are made:

a. The values of independent variables X_1 and X_2 are selected in advance.

b. Based on related literatures, a first – order multiple linear or fitted model is employed with all the points uniformly or equally replicated, to provide an acceptable approximation to the true functional relationship between the regression variables (X_i) and the independent variable (Y).

c. The design is completely randomised. For every fixed value of X_i the $\sum$s are random quantities independently distributed with mean zero and a common for variance this experimenter work, the effects of temperature is studied at two levels, and two levels of time. The factorial design needed for this experiment would then consist of 2x2 = 4 treatments Since it is a 2^k factorial design consisting of N =number of treatment formed all possible combinations of two versions of each of the K factors under control.

K – represents the number of factors. To provide a measure of experimental error each treatment is performed three times to give a total of N = 2x2x3 =12 number of experiments. The program is then run in random order. The primary concern in this experiment, rest in comparisons between the various then run in random order treatment means to determine whether there is a meaningful linear trend associating the process yield (Physical quality parameters namely moisture content, size and shape, colour and texture), with the various temperature levels, at the various retention drying time, as well as the effects of the interaction of the two factors to a estimate these, a statistical method called contracts is used (Irwin et al; 1982).

In a collection of N observations Y_u, u = 1, 2 ...., N.

A contrast is a linear combination of the observations of the form

$$\sum_{U=1}^{N} d_u Y_u, \text{ subject to the constrain that } \sum_{U=1}^{N} d_u = 0$$

similarly contrast between t treatment averages Yn, 5 = 1, 2 ....., t each based on r observations could be defined by

$$\sum_{J=1}^{N} C_j Y_j, \quad \text{where} \quad \sum_{J=1}^{N} c_j = o$$

Two contrast $\sum_{U=1}^{N} d_u y_u$ and $\sum_{U=1}^{N} d_u \; y_u$ are

orthogonal whenever $\sum_{U}^{N} d_u \; d_u = 0$

Occasionally, contrasts may be required between t - treatment averages Y_j each based on the different number of observations r_j, j = 1, 2, ..., t under these circumstances the contrast must be of the form

$$\sum C_j r_j Y_j \quad \text{and subject to the constraint that } \sum C_j r_j = 0$$

Given the constrains on the constants du, it is possible to construct V = (N – 1 or thorgonal contrasts. (Irwin et al; 1982).

3.2.2. FACTORS AND LEVEL OF VARIANCE FOR 2^2 FACTORIAL DESIGN

The level of variation for this experiment is chosen based on literature review of related experimental study (Solanke, 1998; Yaciuk, 1988).

LEVEL OF VARIATION

Drying temperature (^oc) X_1 30 – 70

Drying time Td (hour) X_2 2 – 6

This is used as a guide in selecting the upper level base and lower level of variation as shown in Table 3.1

TABLE 3.1 FACTORS AND LEVEL OF VARIANCE

FACTORS/LEVELS	DRYING TEMPERATURE t (^{O}C) X_1	DRYING TIME Td (HOUR) X_2
Upper level	65	5
Base level	50	4
Lower – level	35	3
Level of variation	15	1

3.2.3. EXPERIMENTAL MATRIX PLAN

The experimental matrix plan is then constructed as a guide to the experimental plan by setting out the plus (+) and the minus (-) signs for each factorial effect as shown in Table 3.2 below.

TABLE 3.2 THE DESIGN MATRIX FOR 2^2 FACTORIAL IN YATES ORDER

NUMBER OF EXPERIMENT	X_O	X_1	X_2	X_1 X_2
Y_1	+	+	-	-
Y_2	+	-	-	+
Y_3	+	+	+	+
Y_U	+	-	+	-

Where

X_o = Standard control or representing no drying at all

X_1 = Drying temperature, ^oc

X_2 = Drying time, hour(s)

X_1 X_2 = Interaction of X_1 X_2

Y = response or product yield.

This design matrix plan together with the factors develop the working order in which the experiment is to be carried out as shown in table 3.3

TABLE 3.3 EXPERIMENTAL ORDER FOR THE 2^2 FACTORIAL DESIGN AT TWO LEVELS EACH.

NUMBER OF EXPERIMENT	TEMPERATURE t °c X_1	DRYING TIME T_d (hour) X_2	OBSERVATIONS Y
1	65	3	Y_1
2	35	3	Y_2
3	65	5	Y_3
4	35	5	Y_4

3.3. COLLECTION OF SAMPLES

All the samples of Tomatoes (Lycopersicum esculentum) Okro (Hibiscus esculentus) and sweet pepper (Capsicum annuum) used for this particular experiment are collected fresh, whole from a vegetable farm located at the by pass road of Sadauna crescent Kaduna, kaduna State.

3.4. DEHYDRATION PROCEDURE

3.4.I PREPARATION OF SAMPLES

The initial preparation of fruits and vegetables for processing is usually closely related and similar inspite the various subsequent preservation method to be applied.

Although the sequence of operation varies considerably according to the individual requirements of each particular commodity. The chart for the drying unit operations is as shown in figure 3.3.

3.4.2. SORTING

The fresh produce are sorted out, to remove and separate, those having defects, over mature, diseased as well as insect infested vegetables.

3.4.3. CLEANING/ WASHING

The fresh vegetable produce as obtained fresh from farm are commonly contaminated with soil and other foreign materials. For a high quality product to be obtained the foreign materials are removed and the produce are washed with clean water.

3.4.4. TRIMMING

The unwanted parts of the vegetables of the Tomatoes, Okro and sweet pepper, such as the stalk are removed.

3.4.5. WEIGHING

20 grammes sample each of Tomatoes (Lyco persicum esculentum), Okro (Hibiscus esculentus) and sweet pepper (Capsicum annuum) are weighed to get their weight prior to drying.

3.4.6. BLANCHING

Two methods of blanching are available, one employs steam and the other water.

When steam is used, fewer nutrients leak out, but it takes longer time for the heat to penetrate to the centre of the food batch. If the water used contains soluble iron salts and other undesirable mineral compound, steam blanching is said to be the best (Maudkordylas, 1990). The vegetables are therefore steam blanched at $100^{o}c$ for 4 minutes. Blanching is said to be very necessary for the following reasons: -

Blanching stops all life processes in the vegetables, and destroys yeast and moulds; to inactivate enzymes that would cause discoloration and changes in flavour and aroma, to render the product limp, to fix the colour, to remove certain harsh flavours commonly in vegetables such as Okro, it helps to stabilise vitamins and in general improves the palatability and nutritional quality retainment of the product. (Maud kordylas, 1990)

To steam blanch, water is put into a blancher (a large pot with lid), to a depth of about 5cm and is brought to the boil. The washed and prepared fruit and vegetables sample is put in a stainless steel basket to hold it. The basket is placed in the pot, above the water. The lid is tightly closed and the water is made to remains just at boiling point. The blanching is allowed to stay for about 4 minutes.

The blanched vegetables are then spread on a cleaned stainless steel tray to cool.

3.4.7. SLICING

The blanched samples are then sliced into 1 centimetre thick, uniformly sliced pieces, using stainless steel knife. They are then spread uniformly on the drying trays in a single layer.

3.4.8. DRYING

The trays are then loaded into the dryer, to dry in accordance to Field (1977). The vegetables are dried separately at various planned temperatures and at the corresponding drying time. The tray dryer used, is as described in Figure 3.2.

For the purpose of this particular experimental treatments, the samples are subjected to the following drying temperature and drying time.

Drying temperature (t)(^{o}c)	Drying time (T_d) (hour)
65	3
35	3
65	5
35	5

3.4.9. COLLECTION OF DRIED PRODUCT

The dried products, at the end of the various planned drying times are collected. The dried samples are weighed at the end of each designated drying time, to determine weight loss or their moisture content. The same dried product is also observed for changes in colour, size and shape as well as for texture.

3.4.10. PACKAGING

The dried samples are packaged in 2mm thick polythene packages and stored in dry condition at ambient temperature.

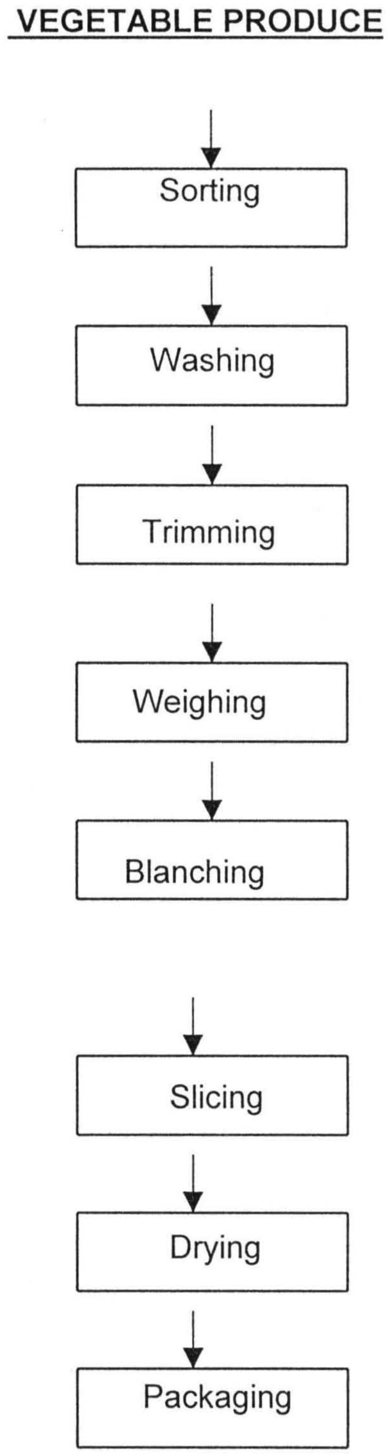

Figure 3.3 ; FLOW CHART FOR DRYING UNIT OPERATIONS

3.5.1 MOISTURE CONTENT DETERMINATION

METHOD

The moisture content of both fresh produce as well as that of the product yield at different planned drying temperatures drying time are determined using Vacuum Oven drying method, at 70°c for 6 hours.

PRINCIPLE:- this method is based on the loss of moisture on drying at oven temperature of 70°c.

3.5.2 APPARATUS/PROCEDURES

Vacuum Oven

Metler balance

Flat silica dishes

Desiccator

Blender

PROCEDURE:- 10g prepared sample is chopped into a flat dish which has previously been dried in the oven weighed and recorded as (W1)

10g of the blended sample is weighted and spread in the dried dish and recorded as (W2)

The dish together with the sample are placed in the vacuum oven at 70°c and dried for six hours.

The dish is removed into the desiccator, to cool.

The dish and the dried sample is now weighed after cooling and recorded as W4 the weight of the dried sample is also the recorded as W5

moisture content of a substance is usually expressed in percentage by weight on the wet basis, that is in grams of moisture per 100g of samples

$$\% \text{ Moisture} = \frac{\text{sample weight before drying} - \text{weight after drying.}}{\text{Sample weight before drying}} \times 100$$

$$\frac{W_2 - W_5}{W_2} \times 100 = X$$

If x is percentage moisture on wet basis. (Fields, 1977).

This expression when applied to drying is expressed rather on a dry basis.

$$\% \text{ Moisture (dry basis)} = \frac{\text{Moisture on wet basis}}{100 - \text{Moisture on wet basis}}$$

$$T = \frac{X}{100 - X} \times \frac{100}{1} \quad \text{(Field, 1977)}$$

3.5.3. STASTISTICAL ANALYSIS OF EXPERIMENTAL DATA

The values of varying factors and their coded levels are recorded. The data generated, which consists of four numbers of experiments, replicated three times each, are recorded as shown in Table 3.4

The data is then analysed, following the formulars and the equations recorded below X

The mean, $Y_i = \frac{1}{r} \sum_{J-1}^{N} Y_{ij}$, ...3.4

The dispersion $s^2_U = \frac{1}{r-1} \sum_{j-1}^{N} (Y_{tj} - Y_j)^2$ 3.5

The sum of the dispersion $\sum_{u-1}^{N} s^2_{tj}$ 3.6

The maximum dispersion = s^2_u maximum

The assumed functional relationship between the two independent variables X_i = 1, 2 ... is formulated as a linear model, response equation for fitted model

$$\hat{Y} = b_0 + \sum b_i X_i + \sum b_{ij} X_{ij} + \sum_i \text{ .... 3.7}$$

$$\hat{Y} = b_o + b_1 x_1 + b_2 x_2 + b_{12} x_{12} \text{ .... 3.8}$$

Where the bs are the regression coefficients of the model, the x's are the code variables, and which measures the discrepancy in the functional relationship, is a random error with zero mean and constant variance. (irwin et al. 1982; Douglas, 1991)

The G- Test:-

The G – Test (Cochran Criteria) is used to ascertain the possibility of carrying out regression analysis. It is used to check if the output factors of the replication have maximum accuracy of the replication. The test verifies the homogeneity of dispersion of the replicate experiments. The calculated G – value is given as (Douglas, 1991).

$$G_{cal} = \frac{S^2_u \max}{\sum_{u=1}^{N} S^2_u} \quad \ldots\ldots 3.9$$

N = 4

The calculated G – value is compared with an appropriate table value. The condition of homogenuity is given as:

$G_{cal} < G_{(N,\ r-1\ X - 0.05)}$

When N = Number of experiment

r = number of replicate

$\propto$ = level of significance.

If this condition is satisfied, calculation is then proceeded to regression analysis (Douglas, 1991)

3.5.4. DETERMINATION OF DISPERSION AND EXPERIMENTAL ERROR:

The dispersion, taken as mean squared error, is given as (Douglas, 1991)

$$S_{(y)} = \frac{1}{N} \sum_{u=1}^{N} S^s_u \quad \ldots\ldots 3.10$$

It is the average sample variance estimate. The experimental error is given as.

$$S(y) = \sqrt{S^2_{(y)}} \quad \text{......} \quad 3.11$$

$$S(y) = \sum \frac{S^2_u}{N} \quad \text{......} \quad 3.12$$

3.5.5. ESTIMATION OF MODEL REGRESSION COEFFICIENTS

To estimate an effect or to compute the sum of squares of an effect, the contrast associated with that effect is first determined. This is always done by using the design matrix (i.e Table 3.2) The evaluation of the regressive coefficients is then obtained, by multiplying the signs in the appropriate column of the table by the corresponding experimental mean result (y_i), and add. this holds only for complete, orthogonalised designs) Douglas, 1991). The orthogonality relation between the independent variable, provide the method of estimating their effects on the response.

Once the contrasts for the effects have been computed, the effects could be estimated by computing the sums of squares for the effects. The mean effect is estimated by

$$b_o = \frac{1}{N} \sum_{U=1}^{N} (X_o \; Y_u) \quad u = 1, 2 \quad \text{......} \quad 3.13$$

Where X_o are the coded signs in the X_o column of the design matrix each of the effects are estimated by

$$b_i = \frac{1}{N} \sum_{U=1}^{N} (X_i \; Y_u) \quad I = 1, 2; u=1, 2, 3, 4 \quad \text{......} \quad 3.14$$

$$b_1 = \frac{1}{N} \sum_{u=1}^{N} (X_1 \; Y_u) \quad \text{......} \quad 3.15$$

Xi are the coded signs in the Xi columns of the design matrix.

$$b_2 = \frac{1}{N} \sum X_2 Y \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 3.16$$

The interactions can be estimated by

$$b_{ij} = \frac{1}{N} \sum_{u=1}^{N} (x_{ij} Y_u) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 3.17$$

where x_{ij} are the coded signs in the x_{ij} column of the design matrix

$$b_{12} = \frac{1}{N} \sum_{u=1} X_{12} Y \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 3.19$$

In equation (3.13) through (3.18), the quantities in brackets are contrasts in the treatment combinations. A contrast is called the total effect of a factor. (Irwin et al. 1982; Douglas, 1991).

3.5.6. TESTING STATISTICAL SIGNIFICANCE OF THE REGRESSION COEFFICIENTS

Construction of confidence interval and testing of hypothesis about individual regression coefficients in the regression model are frequently used in assessing their statistical significance (Samprit et al, 1991).

Confidence interval for the regression coefficient with confidence coefficient X are the general form b's + t {X, N (r-1) $S^{'s}_{b}$

That is

$$b's + b's \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad 3.19$$

Where $s^{'s}_{b}$ = the estimated standard error in regression coefficients b's.

$t_{(x,N\,(r-1))}$= an appropriate tabulated t criteria with N(r-1) degree of freedom

For this purpose of experiment, a level of signifcance of 5% (that is x = 0.05) is chosen. With this the confidence limits is established for 99% of the variable measurements, using a 95% confidence interval. This can be said to indicate that approximately 95% out of 100 similarly constructed confidence intervals, will contain 99% of the variable measurements in the population (Irwin et al. 1982; Douglas 1991).

For full factorial experiments, errors in each regression coefficient is said to be the same and is determined by

$$=S_{bo} = \quad S_{bi} \quad = sbij = \frac{s(y)}{\sqrt{N.r}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.20$$

Where s(y) = the experimental error (Irwin et al. 1982; Douglas 1991).

The statistical significance of the regression coefficients are tested by(Douglas 1991)

$$t_o = \frac{b_o}{S_{bo}}$$

$$t_1 = \frac{bi}{S_{bi}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.\ 21)$$

$$t_2 = \frac{b_2}{Sb_2}$$

$$t_{12} = \frac{b_{12}}{S_{b12}}$$

The test is carried out by comparing these calculated t – values with the appropriate critical table values. A coefficient of regression is said to be statistically significant only if.

$$t > t_{(X,\ N\ (r\text{-}1)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.22$$

If any coefficient is statistically insignificant that is t cal < t table, such a coefficient is left out of the regression model Irwin et al. 1982; Douglas, 1991).

The summary of the estimated effects, the confidence intervals and the calculated t – values are usually presented in a table form as shown in Table 3.5

TABLE 3.5 THE ESTIMATED EFFECTS, CONFIDENCE INTERVAL AND CALCULATED T -VALUES

REGGRESSION COEFFICIENT	ESTIMATED EFFECT	CONFIDENCE INTERVAL	t - VALUE
b_o		+ -	
b_1		+ -	
b_2		+ -	
b_{12}		+ -	

In significance of an effect is said not to necessarily mean that the particular factor or interaction is un important. It is said to only implies that response is un affected in the factor is varied over the range considered, that is (-1 to +1 in coded units) for example, it could be that the factor or interaction is very important, but that a change over the range considered, has no effect on the response (Irwin et al. 1982; Douglas 1991).

Using only the statistically significant regressions coefficients, the fitted or predicted model is then defined, using equation 3.23

$$\hat{Y} \quad (b_o + \ldots\ldots\ldots\ldots) \ldots\ldots\ldots\ldots 3.23$$

$$\hat{Y} \quad (\pm \ldots\ldots\ldots\ldots)$$

The calculation of the above expression at the levels $X_1 \ldots . X_{ir}$ of the independent variables provide the fitted values. The respective differences between the mean experimental observations Y_1 Y_2 .... YN and the fitted or predicted values Y_1 Y_2 .....YN are called the residuals, which are given by

$$e_u = Y_u - \hat{Y}_u \ldots\ldots\ldots\ldots 3.24$$

$$U = 1, 2.$$

Thus, the model is used to generate the predicted value s in the range of the observation studies. (Over the range of the factor levels chosen) the residuals are said to be useful in examining the adequacy of the least squares fit (Irwin et al. 1982; Douglas 1991).

The observed values (Y_u), the fitted values (Y), the residuals $e_u = Y_u - Y_u$ and the squares of the residuals $e^2_u = (Y_u - Y_u)^2$ can be presented in table form as shown in Table 3.6.

Table 3.6 The observed values, the fitted values, the residuals and the squares of the residuals.

RUN No.	Y_u	Y_u	$e_u = (Y_u - Y_u)$	$e^2_u = (Y_u - Y_u)^2$
1				
2				
3				
4				

The residuals are the deviations of the measured values Y_u from their predicted corresponding Y_u (Irwin et al. 1982; Douglas 1991).

3.5.7. EVALUATION OF MODEL ADEQUACY

The adequacy of the regression model is evaluated by testing hypothesis on the individual regression coefficients. This test is said to be useful in confirming the magnitude of the estimated effects. (Irwin et al. 1982; Douglas 1991).

The model for instance might be more effective with the deletion of one or more variables already in the model (for condition when more than two variables are considered).

The analysis of variance is then conducted to confirm the magnitude on significance of the effects. This is said to involve determining the sum of squares, for each component in the model and the number of degree of freedom associated with each sum of square. (Irwin et al. 1982; Douglas 1991).

To construct appropriate test statistics, the expected mean squares must be determined. The sum of squares for the effects are calculated from the contrasts used in estimating the effects.

In the 2^k factorial design with replicates, the regression sum of squares for any effect is

$$SS_R = \frac{r}{N}(\text{contrast})^2 \qquad 3.25$$

and has a single degree of freedom. Consequently, for the main effects,

$$SS_{bi} = \frac{r}{N} \sum_{u=1}^{N} (X_i\ Y_u)^2 \qquad 3.26$$

Where X_i are the coded signs in the X_1 column of the design matrix. For the two factors interactions.

$$SS_{bij} = \frac{r}{N} \sum_{u=1}^{N} (X_{ij}\ Y_u)^2 \qquad 3.27$$

Where X_{ij} are the coded signs in the X_{ij} column of the design matrix (Irwin et al 1982; Douglas 1991)

It must be noted that $N = 2^k$

If all possible interactions between k factors exist, then there are 2^k two factors interactions.

The sum of squares is then calculated in the same manner.

$$SS_T = \sum_{U=1}^{N.r} Y^2_{uv} - \frac{(\sum_{u=1}^{N.r} Y_{uv})^2}{N.r} \qquad 3.28$$

The error sum of squares

$$SS_E = SS_T - \sum SS_R \qquad 3.29$$

which indicate that

$$SS_E - SS_T\ [SS_{bi} + SS_{bj} + SS_{bij}] \qquad 3.30$$

In multiple linear regression testing, the significance or contribution of individual coefficient is accomplished by testing the null hypothesis Ho : $b_i = 0$

The appropriate statistics for the F – test is said to be (Douglas, 1991)

$$F \text{ calculated} = \frac{MS_R}{MS_E} = \frac{SS_R / df_R}{SS_E \; N(r-1)} \quad \ldots\ldots\ldots\ldots\ldots\ldots \; 3.31.$$

The null hypothesis will be rejected if

$$Fcal > F(x, df_R, N(r-1) \quad \ldots\ldots\ldots\ldots\ldots\ldots \; 3.32$$

The conclusion is then made that the coefficient contributes significantly to the regression (Irwin et al. 1982; Douglas 1991).

The complete analysis of variance is then summarised in the form shown in Table 3.7

TABLE 3.7 ANALYSIS OF VARIANCE FOR REPLICATED 22 FACTORAL EXPERIMENT.

SOURCE OF VARIATION	EFFECT	SUM OF SQUARES S_S	DEGREE OF FREEDOM df	MEAN SQUARES MS	F - RATIO
Main effects					
b_1		Ssb_1	1		
b_2		Ssb_2	1		
Two-factor					
interactions					
b_{12}		SS_{b12}			
Error		SS_E	N. (r-1)		
TOTAL		SS_T	(N-1).r		

* Indicates insignificance at 5 percent (Irwin et al. 1982; Douglas 1991)

The adequacy of the model is further checked, using a method of validating the adequacy for the replicate experiment and compare the magnitude with the variance estimate given by the mean squared error. The dispersion of adequacy for the replicate experiment is given as

$$SS^2_{(ad)} = \frac{r}{N - \Lambda} \sum_{u=1}^{N} (Y_u - Y_u)^2 = \frac{r}{df_{(ad)}} \sum_{u=1}^{N} (Y_u - Y_u)^2 \quad ....3.33$$

Where Λ = number of adequate coefficients. (Irwin et al. 1982; Douglas1991).

The adequacy of regression model is then estimated by Fisher's criteria (F = test) F calculated $= \frac{S^2_{(ad)}}{S^2_{(y)}}$ 3.34

Where $S^2_{(y)}$ = variance estimate given by the mean square error. The F = value is then compared with the appropriate table value. The condition of adequacy is given as

$F_{cal} < F_{(X,\, N-r,\, N\,(r-1))}$ 3.35

If this condition is satisfied, we could then conclude that the fitted or predicted regression model is adequate. (Irwin et al. 1982; Douglas 1991)

Based on the significant regression coefficient only, the final fitted or predicted model could then be expressed as

$\hat{Y}_u$ = (b_o + ...)

(+ ....)...........................3.36

The fitted model is said to relate the response to the factors and it could be used for predicting the response at factor levels between those actually used in the experiment. This is used to forecast the values of Y for a given set of independent variables. However, the model is said to be valid only for values of the independent variables that fall within the intervals of values used in producing the model.

This model, if used for values outside the given interval is termed a wrong extrapolation. (Irwin et al. 1982; Douglas 1991).

3.6.0. SIZE AND SHAPE EVALUATION

Shape and size are inseparable in a physical object, and both are generally necessary, if the object is to be satisfactorily described. In defining the shape, some dimensional parameters of the object is measured (Mohsenin, 1986) Evaluation of size and shape of agricultural products, is said to be of importance, in determining the volume and surface area the product will occupy, by applying this formula. (Moh Senin, 1986)

$$V = 4/3 (\pi ab^2);\ S = 2\pi b_2 + 2\pi \frac{ab}{e} \sin^{-1} e \ldots\ldots\ldots\ldots 3.37$$

Where: a and b are respectively major and minor semi – axes of the ellipse of rotation. e is eccentricity given by $e = [1 - (\frac{b}{a})^2]^{1/2}$

The volume V and the surface area, S, of an oblate spheroid are given by

$$V = 4/3 (\pi a^2 b)$$

$$S = 2\pi a^2 + \pi \frac{b^2}{e} \frac{l_n 1 + e}{1 - e} \ldots\ldots\ldots\ldots 3.38$$

Where V and surface area S of Frustum of a right cone are given by

$$V = (\pi/3)\ h\ (r^2_1 + r_1 r_2 + r^2_{2})$$

$$S = (r_1 + r_2)(h^2 + (r_1 - r_2)^2]^{1/2} \ldots\ldots\ldots\ldots 3.39$$

Where

r_1 and r_2 are respectively the radi of base and top and h is the altitude.

Where, V, and surface area S of Frustum of a right cone are given by

Having volume and surface area estimated in this manner, the actual volume and surface area are then determined experimentally and a correction factor could then be established for the typical shape of each variety of the product. (Mohsenin, 1986)

3.6.1 MEASUREMENT OF SHAPE AND SIZE USING ROUNDNESS METHOD.

Roundness is said to be a measure of the sharpness of the corners of the solid. Several methods are said to have been proposed for estimating roundness, the least objectionable as given below are employed for this product.

The shape and size of the vegetables both before and after drying are done by tracing the lateral cross sections of the sliced vegetables (Appendix R)

The roundness measurement is then done by measuring the sharpness of the corners of the traced vegetables using the formular below:- (Mohsenin, 1986)

$$\text{Roundness} = \frac{A_P}{A_C} \quad \ldots\ldots 3.40$$

Where A_P = largest projected area of object in natural rest position

A_C = Area of smallest circumscribing circle'

The object are is obtained by projection or training

$$\text{Roundness} = \frac{\sum r}{N} \quad \ldots\ldots 3.41$$

Where r = radius of curvature as defined in figure 3.3

R = radius of the maximum inscribed circle

N = total number of corners summed in numerator

$$\text{Roundness ratio} = \frac{r}{R} \quad \ldots\ldots 3.42$$

Where r = radius of curvature of the sharpest corner

R = mean radius of the object

3.6.2. MEASUREMENT OF SPHERICITY:

The geometric foundation of the concept of the concept of sphericity is said to rest on the isoperimetric property of a sphere. The sphericity of the fresh and dried vegetables are measured using the formular below (Mohsenin, 1986)

$$\text{Sphericity} = \frac{d_i}{d_c} \qquad \ldots\ldots 3.43$$

Where:

d_i = diameter of largest inscribed circle

d_c = diameter of smallest circumscribed circle.

3.7 DETERMINATION OF COLOUR AND TEXTURE QUALITY PARAMETERS

3.7.1 SENSORY EVALUATION METHOD

The colour and texture qualities of the dried vegetables are determined, using sensory evaluation method. Sensory evaluation is used in studies involving product development, product improvement, quality maintenance as well as in acceptability studies of newly formulated product.

The test essentially employs senses of Sight, feel or touch, to ascertain the quality of the food product. This method is important, as it makes research into consumers preference of organoleptic quality (such as that of colour and texture in this particular research work) thereby, ascertain the product's acceptability.

A ten-panel, chosen from Lecturers, laboratory technicians, caterers from Kaduna polytechnic, as well as market women, from the central market kaduna are used, to evaluate the colour and texture qualities of the dried vegetable products, using eight-point Hedonic scoring scale method. (Desrosier, 1977)

3.7.2 EIGHT – POINT HEDONIC SCALE METHOD

Coded samples are evaluated for some specific characteristics (colour and texture), by the panellists, who records his evaluation on a descriptive graduated scale as shown in Appendix 1 to 6. Scoring gives an indication of the size and the direction of the differences or variation from the standard sample, which is the fresh undried vegetables. The categories on the scale are assigned numerical values and the results of the scoring are recorded as shown in table 3.8

TABLE 3.8: OBSERVED PANELLISTS SCORES FOR THE DRIED VEGETABLES

PANELISTS	65^0C FOR 3 HOURS (Y_1) REPLICATIONS Y_{11} Y_{12} Y_{13}	35^0C FOR 3 HOURS (Y_2) REPLICATIONS Y_{21} Y_{22} Y_{23}	65^0C FOR 5 HOURS (Y_3) REPLICATIONS Y_{31} Y_{32} Y_{33}	35^0C FOR 5 HOURS (Y_4) REPLICATIONS Y_{11} Y_{12} Y_{13}

Where

Y_{11}, Y_{12}, Y_{13} are the panellists score for each replication 1, 2, 3 of sample 1 respectively.

3.7.3 CHI – SQUARE TEST

The data collected is then transformed and analyzed using Chi-square method (for analysing enumeration data) using the formular below

$$X_2 = \sum \frac{(0 - E)^2}{E} \quad \text{.................................3.44}$$

Where 0 = the observed value for each sample

E = corresponding expected value (Kwan chai et al. 1984; Thomas et al, 1978; Murray, 1992).

To evaluate this expression, the expected value is first determined, according to our hypothesis. The expected value is then subtracted from the observed value the resulting difference is squared and then divided by the expected value. These quotients are summed over all the samples. The sum is then compared with values in a chi - square table at the appropriate degrees of freedom.

The chi-square test is the classical method of analysing frequencies. The test involves computing a test statistic, which is compared with a chi – square (X_2) distribution at a given degree of freedom (df) called the critical value at the significance, level we are interested in that is P=0.05 and 0.01 (5% and 1% levels) each are commonly employed (Murray, 1992).

The chi – square test which are sometimes referred to as test for homogeneity, randomness as well as goodness fit. The various of the test, which compare observed frequencies with those expected from a model are called goodness of fit, while that which compare the observed frequencies with those expected from samples data deviation are called chi-square test for homogeneity. It is assumed that samples are random and observations are independent.

The observed frequencies are then compared with the expected frequencies on the basis of some null hypothesis. A null hypothesis is set up that is that there is no relation between treatment of the vegetables (drying temperature – time) and the incidence of reduction in colour quality of the dried vegetables.

It the difference between the observed and expected frequencies is great, the value of the calculated test statistic will exceed the critical value at the appropriate number of degree of freedom we are thus to reject the null hypothesis in favour of some alternative, usually the convenience of the null hypothesis known as the citrate hypothesis (Murray, 1984).

A measure of the discrepancy existing between the observed and expected frequencies is supplied by the statistic.

X^2 (chi – square) which is given by (Murray 1992)

$$X_2 = \frac{(0_1 - E_1)^2}{E_1} + \frac{(0_2 - E_2)^2}{E_2} + \text{------} + \frac{(0_k - E_k)^2}{E_k}$$

$$= \sum_{j=1}^{k} \frac{(0_j - E_j)^2}{Ej} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 3.45$$

Where if the total frequency is N

$$\sum 0_j = \sum Ej = N \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 3.46$$

$$X_2 = \frac{\sum 0j - N}{Ej} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 3{,}47$$

If $X_2 = 0$, the observed and expected frequencies agree exactly, while if $X_2 > 0$, they do not agree exactly the larger the value of X_2, the greater is the discrepancy between the observed and expected frequencies.

In practise (Murray, 1992) frequencies are computed on the basis of a hypothesis Ho. If under this hypothesis, the computed value of X_2 is given by equation (3.45) or (3. 47) is greater than some critical value (such as X_2.........95 or X_2 99, which are the critical values of the 0.05 and 0.01 significance levels respectively), we would conclude that the observed frequencies differ significantly from the expected frequencies and would reject Ho at the correspondence level of significance, other wise we would accept it (or at least not reject it).

CHAPTER FOUR

4.0 RESULTS / ANALYSIS OF EXPERIMENTAL DATA

4.1 RESULTS OF EXPERIMENT (MOISTURE CONTENT)

Two variables, two – level factorial experiments were conducted in a randomised order in three replicates (for each experimental sample) according to the design matrix plan given in Table 3.2 the coded levels of the factors and the results of each sample experiments are given in Table 4.1

4.1.1 QUALITY APPRAISAL FOR DRIED TOMATOES (MOISTURE CONTENT)

For dried tomatoes, with data shown in table 4.2, .

$Y_{uj} = \mu + \delta_u + \delta_j + \varepsilon_{\cdot uj}$,

Where: Y_{uj} = observed values of moisture content (on dry basis)

U = 1 –3
j = 1-4

δu = the batch or sample effects
δj = the treatment effects
ε_{uj} are independent N.D $(0,\delta^2)$

Applying equation (3.3) through (3.5)
The various means and dispersion are as shown in table u.2, the maximum dispersion is
S^2_u Max = 0.411.

$$S^2_1 = \frac{(9 - 8.39)^2 = (8.09 - 8.39)^2\ (8.09 - 8.39)^2}{3-1} = 0276.$$

$$S^2_2 = \frac{(1.3.29-12.65)^2 + (12.33-12.65)^2 + (12.33-12.65)^2}{3-1} = 0.307$$

$$S^2_3 = \frac{(3.76-3.69)^2 + (3.76 - 3.69)^2 + (3.55-3.69)^2}{3-1} = 0.015$$

$$S^2_4 = \frac{(10.11-9.37)^2 + (9-9.37)^2 + (9-9.37)^2}{3-1} = 0.41$$

Applying equation (3.6) to the dried tomato data yields

$$\sum_{u=1}^{4} = S^2_u = 1.009$$

To ascertain the possibility of carrying out regression analysis, using the G-Criteria, we have

$$G_{cal} = \frac{S^2_u max}{\sum_{u=1}^{4} S^2_u} = \frac{0.411}{1.009} = 0.407$$

This calculated G-value is compared with and appropriate table value $G_{table\ \{N,\ r-1\ x\ 0.05\}}$

$G_{(4,2,0.05)} = 0.768$

Homogeneity condition: $G_{cal} < G_{table\ (N,r-1,\ x\ -0.50)}$

Since $G_{cal} < G^{table}$

0.407 < 0.768 thus fulfilling homogeneity condition, the analysis is then proceeded to regression analysis, to determine the experimental errors.

Applying equations (3.10) through (3.12), the average sample variance and the experimental errors are:-

$$S^2_{(y)} = \frac{1}{4}\sum_{U=1}^{4} S^2_u = \frac{1}{4}(1.009) = 0.2523$$

$$S_{(y)} = \sqrt{S^2_{(y)}} = \sqrt{0.2523} = 0.5022$$

Since the experimental design is orthogonal, the regression coefficients are estimated using Table 3.2 and equation (3.13) through (3.18)

$$b_o = \frac{1}{4}\sum_{u=1}^{4} X_o Y_u = \frac{34.1}{4} = 8.526$$

$$\begin{aligned} b_1 &= \tfrac{1}{4}[+8.39 - 12.65 + 3.69 - 9.37] \\ &= \tfrac{1}{4}(-9.94) \\ &= -2.485. \end{aligned}$$

$$\begin{aligned} b_2 &= \tfrac{1}{4}[-8.39 - 12.65 + 3.69 + 9.37] \\ &= \tfrac{1}{4}(-7.98) \\ &= -1.995 \end{aligned}$$

$$\begin{aligned} b_{12} &= \tfrac{1}{4}[-8.39 + 12.65 + 3.69 - 9.37] \\ &= \tfrac{1}{4}(-1.42) \\ &= -0.355. \end{aligned}$$

To assess the statistical significance of the regression coefficients estimated above, the confidence interval is contrasted and test hypothesis on individual regression coefficient is carried out. Confidence intervals for the regression coefficients are of the general form given in equation (3.19) that is,

$b_i \pm \Delta b_I$

Where Δb_i = $t_{(\propto, N (r-1) Sb}$

From statistical table, $t_{(0.05,8)} = 1.860$

Applying equation (3.20), the error in each regression coefficient is

$$S_{bi} = \frac{S_{(y)}}{\sqrt{N \therefore r}} = \frac{0.5022}{\sqrt{4x3}} = 0.145$$

$\Delta b_{'s} =$ 1.860 x 0.145 = 0.270

Applying equation (3.21), the calculated t – values for testing the significance of each regression coefficients are;

$$t_o = \frac{(b_o)}{S_b} = \frac{8.526}{0.145} = 58.8$$

$$t_1 = \frac{(b_1)}{S_b} = \frac{2.485}{0.145} = 17.138$$

$$t_2 = \frac{(b_2)}{S_b} = \frac{1.995}{0.145} = 13.759$$

$$t_{12} = \frac{(b_{12})}{S_b} = \frac{0.3.55}{0.145} = 2.448$$

The summary of the estimated effects, the confidence intervals and the calculated t- values are presented in Table 4.3

Table 4.3:- The estimated effects, confidence intervals and calculated t – values

REGRESSION COEFFICIENT	ESTIMATE EFFECT	CONFIDENCE INTERVAL	t-VALUES OBSERVED	t-VALUES REQUIRED 5%	1%
bo	8.526	± 0.270	58.8	1.86	2.90
b_1	-2.485	± 0.270	17.138		
b_2	- 1.995	± 0.270	13.759		
* b_{12}	- 0.355	± 0.270	2.448		

* Insignificant at one percent (1%) level.

Comparing the calculated t – values with the appropriate critical table value

$t_{(0.05,\ 8)}$ = 1.860 (at 5% level) reveals that all the regression coefficients are all statistically significant. Using these statistically significant regression coefficients, to define the fitted or predicted model.

$$\hat{Y}_u = b_o + b_1 X_1 - b_2 X_2 + b_{12} X_{12} \quad \text{.......................... 4.1}$$

$$\hat{Y}_u = 8.526 - 2.485 X_1 - 1.995 X_2 - 0.355 X_{12} \quad \text{....................4.2}$$

The calculation of equation (4.2) at the levels of the independent variables provide the fitted values. Using the fitted model, the predicted values of Y at the four points in the design, could be generated as:-

$\bar{Y}_1$ = 8.526 – 2.485 (+1) – 1.995 – (-1) – 0.355 (-1)

= 8.526-2.485 + 1.995 + 0.355

= 8.391

$\bar{Y}_2 = 8.526 - 2.485\ (-1) - 1.995(-1) - 0.355\ (+1)$

$= 8.526 + 2.485 + 1.995 - 0.355$

$= 12.651.$

$\bar{Y}_3 = 8.526 - 2.4885(+1) - 1.995\ (+1) - 0.355\ (+1)$

$= 8.526 - 2.485 - 1995 - 0\ 355$

$= 3.69$

$\bar{Y}_4 = 8.526 - 2.485\ (-1) - 1.995\ (+1) - 0.355\ (-1)$

$= 8.526 + 2.485 - 1995 + 0\ 355$

$= 9.37$

The mean experiment observations Y_u, the fitted value (Y,) the residuals e = $(\bar{Y}_u - \bar{Y}_i)$, and the squares of the residuals $e^2_i = (\bar{Y}_u - \bar{Y}_i)^2$ are summarised in Table 4.4. The residuals are the deviations of the measured values Y_u from their predicted counterparts Y_I

TABLE 4.4: - THE MEAN EXPERIMENTAL OBSERVATIONS, THE FITTED VALUES, THE RESIDUALS AND THE SQUARES OF THE RESIDUALS AT 5% LEVEL.

RUN NO	Y_u	Y_i	$e_i = Yu - Yi$	$e^2_i = (Y_u - Y_i)^2$
1	8.390	8.391	-0.001	0.000001
2	12.650	12.651	-0001	0.000001
3	3.690	3.691	-0.001	0.000001
4	9.370	9.371	-0.001	0.000001

The adequacy of the fitted model (that is eqn. 4.2) could be evaluated by testing hypothesis on the individual regression coefficients. Applying equations (3.25) through (3.27) the sum of squares for the effects are:-

$$S_{sbi} = \frac{r}{N} \sum_{U=1}^{N} (X_i\ Y_u)^2$$

$S_{sbi} = \frac{3}{4}(\text{contrast})^2 = \frac{3}{4}(-9.94)^2 = 74.103$

$S_{Sb2} = \frac{3}{4}(\text{contrast})^2 = \frac{3}{4}(-7.98)^2 = 47.760$

$S_{Sb12} = \frac{3}{4}(\text{contrast})^2 = \frac{3}{4}(-1.42)^2 = 1.512$

The total sum of squares is calculated using equation (3.28), that is,

$$SS_T = \sum_{u-1}^{N.r} Y^2_{uv} - \frac{(\sum^{N.r} Y_{uv})^2}{N.r}$$

Where

$$\sum_{u=1}^{12} Y^2_{uv} = +(9)^2 + (13.29)^2 + (3.76)^2 + (10.11)^2 + (8.09)^2 + (12.33)^2 + (3.76)^2 + (9)^2 + (8.09)^2 + (12.33)^2 + (3.55)^2 + (9)^2$$

$$= 997.665$$

and

$$(\sum_{u=1}^{12} Y_{uv}) = (9 + 13.29 + 3.76 + 10.11 + 8.09 + 12.33 + 3.76 + 9 + 8.09 + 12.33 + 3.55 + 9)^2$$

$$= (102.31)^2$$

$$= 10467.336$$

Therefore, the total sum of squares $SS_T = 997.665 - \frac{10467.336}{4x3} = 125.387$

From equations (3.29) and (3.30), the error sum of squares

$$SS_E = SS_T - \sum Ss_R$$

$$SS_E = SS_T - (SS_{b1} + SS_{b2} + SS_{b12})$$

$$SS_E = 125.387 - 123.375$$

$$= 2.012$$

The complete analysis of variance is summarised in Table 4.5
The F. ratios are calculated using equation (3.31)

$$F\ \text{calculated} = \frac{MS_R}{MS_E} = \frac{SS_R/_{dfR}}{SS_E/N(r-1)}$$

Since the degreases of freedom regression = 1
F- ratios are therefore calculated as:

$$F_{b1} = \frac{74.103}{0.252} = 294.06$$

$$F_{b2} = \frac{47.760}{0.252} = 189\ .524$$

$$F_{b12} = \frac{1.512}{0.252} = 6$$

TABLE 4.5: ANALYSIS OF VARIANCE FOR REPLICATED 2^2 FACTORIAL ANOVA FOR DRIED TOMATOES

SOURCE OF VARIATION	EFFECT	SUM OF SQUARES (SS)	DEGREE OF FREEDOM (dfr)	MEAN SQUARES (MS)	F-RATIOS OBSERVED	F-RATIOS REQUIRED 5%	1%
b_1	2.485	74.103	1	74.103	294.06	5.32	11. 26
b_2	-1.995	47.760	1	47.760	189.524		
b_{12}	-0.355	1.512	1	1.512	6		
Error		2.012	8	0.252			
Total		125.387	11				

Comparing the calculated F – ratio individually, with the appropriate critical table value $F_{(\propto,dfR,N\,(r-1)}$

$= F_{(0.05,1,8)} = 5.32$ reveals that all the coefficients are significant

The adequacy of the overall regression model could be checked further, by calculating the dispersion of adequacy for the replicated experiment and compare the magnitude, with the variance estimate given by the mean squared error.

Apply equation (3.33), the dispersion of adequacy for the replicate experiment is

$$SS_{2(ad)} = \frac{r}{N-\lambda} \sum_{u=1}^{N} (\bar{Y}_u - \hat{Y}_u)^2 = \frac{r}{df_{(ad)}} \sum_{u=1}^{N} (\breve{Y}_u - \hat{Y}_u)^2$$

From Table 4.4 $\sum_{U=1}^{4} e^2_u = \sum_{u=1}^{4} (\bar{Y}_u - \hat{Y}_u)^2 = 0.000004$

λ = number of inadequate coefficient = 0 degree of freedom of adequate experiment = 4

SS^2_{ad} = ¾ (0.000004) = 0.000003

Applying the Fishers criteria (equation 3.34)

$$F_{cal} = \frac{S^2_{ad}}{S^2_{(y)}} = \frac{0.000003}{0.2523} = 0.000012$$

From statistical table $F_{(0.05, 4, 8)}$ = 3.84

As F_{cal} < F (0.05, 4, 8) the fitted regression model could be required adequate that is the fitted model at 5% level.

$$\hat{Y}_u = 8.526 - 2.485 X_1 - 1.995 X_2 - 0.355 X_{12} \text{ ------- } 4.2$$

Comparing the calculated t – values in table 4.3, with the appropriate critical table value at 1% level

$t_{(0.01,8)}$ = 2.900 reveals that the regression b_{12} is slightly insignificant at 1% level using only the statistically significance, regression coefficients to define the fitted or predicted model,

$$\hat{Y}_u = b_o + b_1 X_1 + b_2 X_2 \text{ .... } 4.3$$

$$\hat{Y}_u = 8.526 - 2.485 X_1 - 1.9955 X_2 \text{ ....} 4.4$$

The calculation of equation (4.4) at the levels of the independent variables provide the fitted values. Using the fitted model, the predicted values of Y at the four points in the design, could be generated as:-

$$\bar{Y}_1 = 8.526 - 2.485\ (+1) - 1.995\ (-1)$$
$$= 8.526 - 2.485 + 1.995$$
$$= 8.036$$

$$\bar{Y}_2 = 8.526\ - 2.485\ (-1)\ -1.995\ (-1)$$
$$= 8.526 + 2.485 + 1.995$$
$$= 3.006.$$

$$\bar{Y}_3 = 8.526 - 2.485\ (+1) - 1.995\ (+1)$$
$$= 8.526 - 2.485\ (-1)\ \ 1.995$$
$$= 4.046$$

$$\bar{Y}_4 = 8.526 - 2.485(-1) -1\ 1.995\ (+1)$$
$$= 8.526 + 2.485 -1.995$$
$$= 9.016.$$

The mean experimental observations

Y_u, the fitted value Y_i, $e_i = (\bar{Y}_u - \bar{Y}_i)$ and the squares or the residuals $e^2 = (\bar{Y}_u . \bar{Y}i)^2$ are summarized in Table 4.6 The residuals are the deviation of the measured values Y_u from their predicted counter parts.

TABLE 4.6: THE MEAN EXPERIMENTAL OBSERVATIONS, THE FITTED VALUES, THE RESIDUALS AND THE SQUARES OF THE RESIDUALS AT 1% LEVEL

RUN NO.	Y_U	Y_l	$e_1 = Y_u - Y_u$	$e_{2l} = (Y_u - Y_l)^2$
1	8.390	8.036	0.354	0.125
2	12.650	13.006	-0.356	0.127
3	4.046	4.046	-0.356	0.127
4	9.370	9.016	0.354	0.125

The adequacy of the fitted model adequate equation (4.3) could be evaluated by testing hypothesis on the individual regression coefficient applying equations (3.25) through (3.27) the sum of squares for the effects are

Ss_{b1} = 74.103

SS_{b2} = 47.760

SSb_{12} = 1.512

The total sum of squares as found in equation (3.28) = 125.387

The error sum of squares = 2.012

The F-ratios as calculated using equation (3.31)

F_{b1} = 294.06

F_{b2} = 189.524

F_{b12} = 6

Using table 4.5, comparing the calculated F- ratio individually, with the appropriate critical table value of $F_{(0.01,1,8)}$ = 11.26.

reveals that only coefficient b_1 and b_2 are significant at 1% level. However this coefficient b_{12} has earlier been found statistically insignificant.

The adequacy of the overall regression model could be checked further, by calculating the dispersion of adequacy for the replicate experiment and compare the magnitude, with the variance estimate given by the mean squared error.

Applying equation (3.33) the dispersion of adequacy for the replicate experiment is

$$SS_{(ad)} = \frac{r}{N - \lambda} \sum_{u=1}^{N} (Y_u - Y_i)^2 = \frac{r}{df_{(ad)}} \sum_{u=1}^{N} (Y_u - Y_u)^2$$

From Table 4.6 $\sum_{u=1}^{4} (Y_u - Y_u)^2 = 0.504$

λ = number of inadequate coefficient = 1

degree of freedom of adequate experiment, $df_{ad} = 4 - 1 = 3$

$S^2_{ad} = 3/3\ (0.504) = 0.0504$

Applying the Fisher's criteria (equation 3.34)

$$F_{cal} = \frac{S^2_{ad}}{S^2_Y} = \frac{0.504}{0.2523} = 1.998$$

From Statistical table $F_{(0.01,3,8)} = 7.59$

Since $F_{cal} < F_{(0.01,3,8)}$

$1.998 < 7.59$ the fitted regression model could be regarded adequate that is the fitted model at 1% level is

$$\hat{Y}_u = 8.526 - 2.485 X_1 - 1.995 X_2 \qquad \text{.................................... } 4.4$$

4.1.2. QUALITY APPRAISAL FOR DRIED OKRO (MOISTURE CONTENT)

Table 4.7 observed moisture content and statistical analysis of dried okro (Hibiscus esculentus)

For dried Okro with data shown in Table 4.7, apply equations (3.3) through (3.5) the various means and dispersions are shown:

$$S^2_1 = \frac{(5.67 - 5.83)^2 + (6.14 - 5.83)^2 + (5.67 - 5\ .83)^2}{3-1} = 0.074$$

$$S^2_2 = \frac{(9 - 8\ .\ 39)^2 + (8/09 - 8.39)^2 + (8.09.8.39)^2}{3-1} = 0.276$$

$$S^2_3 = \frac{(3.35 - 3.23)^2 + (3.17-3.23)^2 + (3.17-3.23)^2}{3-1} = 0.011$$

$$S^2_4 = \frac{(6.14 - 5.98)^2 + (5.67 - 5.98)^2 + (6.14-5.98)^2}{3-1} = 0.074$$

Applying equation (3.6) to the dried Okro data yields,

$$\sum_{u=1}^{4} S^2_u = 0.435$$

To ascertain the possibility of carrying out regression analysis, using G-Criteria, we have

$$G_{Cal} = \frac{S^2_u Max}{\sum^4_{u=1} S^u_2} = \frac{0.276}{0.435} = 0.634$$

This calculated G = value is compared with an appropriate table value $G_{N, (r-1), \propto 005)}$ $= G_{(4,2, 0.05)}$

Homogeneity condition: $G_{cal} < G\ table_{(N\ (r-1) \propto 0.05)} = 0.768$

$0.634 < 0.768$

Since $G_{cal} < G_{table}$ that is $0.634 < 0.768$ thus fulfilling homogeneity condition, the analysis is then proceeded to regression analysis to determine the experimental error.

Applying equation (3.10) through (3.12), the average sample variance and the experimental error are:-

$$S^2_{(y)} = \frac{1}{4} \sum_{u-1}^{u} S^2_u$$

$$= \frac{1}{4}(0.435) = 0.1088$$

$$= 0.109$$

$$S_{(y)} = \sqrt{S^2_{(y)}}$$

$$S_{(y)} = \sqrt{0.109} = 0.330$$

Since the experimental design is orthogonal the regression are estimated using table 3.2 and equations (3.13) through (3.18)

$$b_o = 1/N \sum_{I=1}^{N} X_o Y_i$$

$$= \frac{23.43}{4} = 5.85\ 75$$

$$b_1 = \frac{1}{4} \sum X_1 Y_1 = \frac{1}{4}(5.83 - 8.39 + 3.23 - 5.98)$$

$$= \frac{1}{4}(-5.31) = -1.3275$$

$$= -1.328$$

$b_2 \quad = \quad 1/N \sum X_2 \; Y_2 \quad = \frac{1}{4}(-5.83 - 8.39 + 3.23 + 5.98)$

$= \frac{1}{4}(-5.01)$

$= -1.2525$

$= -1.253$

$b_{12} \quad = \quad \frac{1}{4}(-5.83 + 8.39 + 3.23 - 5.98)$

$= \frac{1}{4}(-0.19) \quad = \quad -0.0475$

$= 0.048$

To assess the statistical significance of the regression coefficients estimated above, the confidence interval is constructed and test on individual regression coefficient is carried out. Confidence intervals for the regression coefficients are of the general form given in equation (3.19) that is

$b_i \pm \Delta b_i$

Where $\Delta b_i = t_{(\propto, N (r-1) Sb}$

From statistical table $t_{(0.05,8) = 1.860}$

Applying equation (3.20), the error in each regression coefficient is

$$S_b = \frac{S_{(y)}}{\sqrt{N.r}} = \frac{0.330}{3.464} = 0.095$$

$b_i \quad = \quad t_{(N (r-1) X 0.05) = 1.860}$

$\Delta b_{'s} \quad = \quad 1.860 \text{ X } 0.095 = 0.177$

Applying equation (3.21) the calculated t-values for testing the significance of each regression coefficients are:-

$$t_o = \frac{b_o}{S_b} = \frac{5.8575}{0.095} = 61.658$$

$$t_1 = \frac{b_1}{S_b} = \frac{-1.328}{0.095} = 13.979$$

$$t_2 = \frac{b_2}{S_b} = \frac{-1.253}{0.095} = -13.189$$

$$t_{12} = \frac{b_{12}}{Sb} = \frac{-0.048}{0.095} = -0.505$$

The summary of the estimated effects, the confidence intervals and the calculated t- values are presented in Table 4.8.

TABLE 4.8 THE ESTIMATED EFFECTS CONFIDENCE INTERVALS AND CALCULATED T- VALUES

REGRESSION COEFFICIENT	ESTIMATED EFFECT	CONFIDENCE INTERVAL	t-VALUES OBSERVED	t VALUES REQUIRED 5% 1%
b_0	5.858	±0.177	61.658	1.86 2.90
b_i	- 1.328	±0.177	-13 .979	
b_2	- 1. 253	±0.177	- 0. 505	
* b_{12}	- 0.048	±0.177	- 0.505*	

* Insignificant at 5 percent level and 1 percent level

Comparing the calculated t-values with the appropriate critical table value $t_{(0.05,8)} = 1.860$

reveals that regression coefficients b_{12} is statistically insignificant. Using only the statistically significant regression coefficients, the fitted or predicted model could be defined as

$$\hat{Y} = b_o + b_1 X_1 + b_2 X_2 \quad \text{.......... 4.5}$$

$$\hat{Y} = 5.858 - 1.328\, X_1 - 1.253\, X_2 \quad \text{.......... 4.6}$$

The calculation of equation (4.6) at the levels of the independent variable, provide the fitted values. Using the fitted model, the predicted values of Y at the four points in the design could be generated as

$$\bar{Y}_1 = 5.858 - 1.\ 328\ (+1) - 1.253\ (-1)$$
$$= 5.858 - 1.328 + 1.253$$
$$= 5.78$$

$$\bar{Y}_2 = 5.858 - 1.328\ (-1) - 1.253\ (-1)$$
$$= 5.\ 858 + 1.328 + 1.253$$
$$= 8.44$$

$$\bar{Y}_3 = 5.858 - 1.328\ (+1) - 1.253\ (+1)$$
$$= 5.858 - 1.328 - 1.253$$
$$= 3.28.$$

$$\bar{Y}_4 = 5.858 - 1.328\ (-1) - 1.253\ (+1)$$
$$= 5.858 + 1.328 - 1.253$$
$$= 5.93.$$

The mean experimental observations Y_u, the fitted value (Y_i), the residuals e = ($Y_u - Y_i$) and the squares of the residuals $e^2_I = (Y_y - Y_i)^2$ are summarized in Table 4.9. the residuals are the deviations of the measured values Y_u from their predicted counter parts Y_i.

TABLE 4.9:- THE MEAN EXPERIMENTAL OBSERVATIONS, THE FITTED VALUES, THE RESIDUALS ARE THE SQUARES OF THE RESIDUALS AT 5% LEVEL

RUN NO	Y_u	Y_i	$e_i = Y_u - Y_i$	$e^2_i = (Y_u - Y_i)^2$
1	5.83	5.78	0.05	0.0025
2	8.39	8.44	-0.05	0.0025
3	3.23	3.28	-0.05	0.0025
4	5.98	5.93	0.05	0.0025

The adequacy of the fitted model equation (4.6) could be evaluated by testing hypothesis on the individual regression coefficients. Applying equations (3.25) through (3.27) the sum of squares for the effects are

$$Ss_{b1} = \frac{r}{N} \sum_{u=1}^{N} (X_i Y_u)^2$$

$$Ss_{bij} = \frac{r}{N} \sum_{U=1}^{N} (X_{ij} Y_u)^2$$

The sum of squares for the effects are

$$Ss_{bi} = \tfrac{3}{4}(\text{contrast})^2 = \tfrac{3}{4}(-5.31)^2$$
$$= 21.147$$

$$SS_{b2} = \tfrac{3}{4}(\text{contrast})^2 = \tfrac{3}{4}(-5.01)^2 = 18.858$$

$$SS_{b12} = \tfrac{3}{4}(\text{contrast})^2 = \tfrac{3}{4}(-0.19)^2 = 0.027$$

The total sum of squares is calculated using equation (3.28), that is

$$SS_T = \sum_{u=1}^{N.r} Y_{uv} - \frac{(\sum_{u=1}^{N.r} Y_{uy})}{N.r}$$

Where $\sum_{u=1}^{12} Y^2_{uy}$ = $+ (5.67)^2 + (9)^2 + (3.35)^2 + (6.14)^2$

$+ (6.14)^2 + (8.09)^2 + (3.17)2 + (5.67)^2$

$+ (5.67)^2 + (8.09)^2 + (3.17)^2 + (6.14)^2$

$= 452. 764$

and

$(\sum_{u=1}^{12} Y_{uy})^2$ = $\{ 5.67 + 9 + 3.35 + 6.14 + 6.14 + 8.09 + 3.17 + 5.67$

$+ 5.67 + 8.09 + 3.17 + 6.14\}^2$

$= (70.3)^2$

$= 4942.09$

Therefore the total sum of squares

$$SS_T = 452.764 - \frac{4942.09}{4x3} = 40.923$$

From equations (3.29) and (3.30), the error sum of squares

$$SS_E = SS_T - \sum SS_R$$

$$SS_E = SS_T - (Ss_{b1} + SS_{b2} + SS_{b12})$$

$= 40.923 - 39.999$

$= 0.924$

The F – ratios are calculated using equation (3.31)

$$F_{calculated} = \frac{MS_R}{MS_E} = \frac{SS_R/df_R}{SS_E/N(r-1)}$$

Since the degree of freedom regression = 1

F – ratios are therefore calculated as:

$$F_{b1} = \frac{21.147}{0.116} = 182.302$$

$$F_{b2} = \frac{18.825}{0.116} = 162.284$$

$$F_{b12} = \frac{0.027}{0.116} = 0.233$$

The complete analysis of variance is summarised in table 4.10

TABLE 4.10 ANALYSIS OF VARIANCE FOR REPLICATED 2^2 FACTORIAL EXPERIMENT FOR DRIED OKRO

SOURCE OF VARIATION	EFFECT	SUM OF SQUARES (SS)	DEGRESS OF FREEDOM (df_R)	MEAN SQUARES (MS)	F-RATIOS OBSERVED	F-RATIOS REQUIRED 5%	1%
b_l	-1.328	21.147	1	21.147	182.302	5.32	11.26
b_2	-1.253	18.825	1	18.825	162.284		
* b_{12}	-0.048	0.027	1	0.027	0.233 *		
ERROR		0.924	8	0.116			
TOTAL		410.923	11				

* Insignificant at 5 percent level and 1 percent levels

Comparing the calculated F-ratio individually, with the appropriate critical table value

$F_{(\propto, dfR, N(r-l))} = F_{(0.05, 1,8)} = 5.32$ reveals that only coefficient b_{12} are insignificant. However this coefficient has earlier been found statistically insignificant.

The adequacy of the overall regression model could be further checked, by calculating the dispersion of adequacy for the replicate experiment and compare the magnitude with the variance estimate given by the mean squared error.

Applying equation (3.33), the dispersion of adequacy for the replicate experiment is.

$$SS^2_{(ad)} = \frac{r}{N-\Lambda} \sum_{u=1} (Y_u - Y_u)^2 = \frac{r}{df_{(ad)}} \sum_{u=1}^{N} (Y_u - Y_u)^2$$

$$\text{From Table 4.8} \quad \sum_{U=1}^{4} e^2_u = \sum_{u=1}^{4} (Y_u = Y_u)^2 = 0.01$$

The number of in adequate coefficients $\Lambda = 1$

The degree of freedom of adequate experiment

$F_{ad} = 4 - 1 = 3$

$$S^2_{(ad)} = 3/3\ (0.01) = 0.01$$

Applying the Fisher's criteria (equation 3.34)

$$F_{cal} = \frac{S^2_{ad}}{S^2_{(y)}} = \frac{0.01}{0.109} = 0.092$$

From statistical table, $F_{(0.05,3,8)} = 4.07$

As $F_{cal} < F_{(0.05,3,8)}$, the fitted regression model can be regarded adequate. That is the fitted model is;

$$\hat{Y}_u = 5.858 - 1.328 X_1 - 1.253 X_2 \quad \ldots\ldots 4.6$$

Comparing the calculated t – values in table 4.8 with the approximate critical table value at 10% level

$t_{(0.01,8)} = 2.900$ reveals that the regression b_{12} is insignificant at 1% level

Using only the statistically significant regression coefficients, to define the fitted or predicted model.

$$\hat{Y} = b_o + b_1 X_i + b_2 X_2 \quad \ldots\ldots 4.7$$

$$\hat{Y} = 5.858 - 1.328 X_1 - 1.253 X_2 \quad \ldots\ldots 4.8.$$

The calculation of equation (4.8) at the levels of the independent variable provide the fitted values. Using the fitted model, the predicted values of Y at the four points in the design could be generated as:-

$$\bar{Y}_1 = 5.858 - 1.328 (+1) - 1.253 (-1)$$
$$= 5.858 - 1.325 + 1.253$$
$$= 5.783$$

$$\bar{Y}_2 = 5.858 - 1.328 (-1) - 1.253 (-1)$$
$$= 5.858 + 1.328 + 1.253$$
$$= 8.439$$

$$\bar{Y}_3 = 5.858 - 1.328 (+1) - 1.253 (+1)$$
$$= 5.858 - 1.328 - 1.253$$
$$= 3.277$$

$\overline{Y}_4$ = 5. 858 – 1.328 (-1) –1.253 (+1)

= 5.858 +1.328 – 1.253

= 5.933

The mean experimental observations Y_u the fitted value (Y_1) the residuals e_l =(Y_u – Y_i)

And the squares of the residuals e^2_l = $(Y_u - Y_i)^2$ are summarised in Table 4.11 the residuals are the deviations of the measured values Y_u from their predicted counter parts Y_i

Table 4.11 the mean experimental observations, the fitted values the residuals and the squares of the residuals at 1% level

RUN NO	Y_u	Y_l	$e_l = (Y_u - Y_u)$	$e_2 = (Y_u - Y_u)^2$
1	5.830	5.783	0.047	0.00221
2	8.390	8.439	-0.049	0.00240
3	3.230	3.277	-0.047	0.00221
4	5.980	5.933	0.047	0.00221

The adequacy of the fitted model equation (4.7) could be evaluated by testing hypothesis on the individual regression coefficient.

Applying equations (3.25) through (3.27) the sum of squares for the effects are:

SS_{b1} = 21.147

SS_{b2} = 18.825

SS_{b12} = 0.027

The total sum of squares as found in equation (3.28) = 40.923

The error sum of squares = 0.924

The F – ratios as calculated using equation (3.31) are:

F_{b1} = 182. 302

F_{b2} = 162.284

F_{b12} = 0.233

Using table 4.10, comparing the calculated F-ratio individually, with the appropriate critical table value of $F_{(0.01,18)}$ = 11.26

Reveals that coefficient b_{12} is insignificant at 1% level. However this coefficient b_{12} has earlier been found statistically insignificant.

The adequacy of the overall regression model could be checked further, by calculating the dispersion of adequacy for the replicate experiment and compare the magnitude, with the variance estimate given by the mean squared error.

Applying equation (3.33) the dispersion of adequacy for the replicate experiment is

$$SS_{(ad)} = \frac{r}{N-\Lambda} \sum_{u=1}^{N} (\bar{Y}_u - \bar{Y}_i)^2 = \frac{r}{df_{(ad)}} \sum_{u=1}^{N} (\tilde{Y}_u - \bar{Y}_i)^2$$

From table 4.11 $\sum_{U=1}^{4} (\bar{Y}_u - \hat{Y}_u)^2$ = 0.00903

Λ = Number of inadequate coefficient = 1

degree of freedom of adequate experiment,

$df_{(ad)}$ = 4-1 =3

S^2_{ad} = 3/3 (0.00903) = 0.00903

Applying the fisher's criteria (equation 3.34)

$$F_{cal} = \frac{S^2_{ad}}{S^2_y} = \frac{0.00903}{0.109} = 0.083$$

From statistical table $F_{(0.01,3,8)} = 7.59$

Since $F_{cal} < F(0.01, 3, 8)$

0.083 < 7.59 the fitted regression model could be regarded adequate that is the fitted model at 1% level is $Y_u = 5\text{-}858 - 1.328 X_1 - 1.253 X_2$..........................4.8

4.1.3 QUALITY APPRASIAL FOR DRIED SWEET PEPPER

For dried sweet pepper with data shown in table 4.12

Applying equation (3.3) through (3.5) the various mean and dispersion are as shown in table 4.10.

$$S^2_1 = \frac{(6.14 . 5.83)^2 + (5.67-5.83)^2 + (5.67 - 5.83)^2}{3.1}$$

$$= 0.074$$

$$S^2_2 = \frac{(9 - 8.39)^2 + (8.09-8.39)^2 + (8.09-8.39)^2}{3-1}$$

$$= 0.276$$

$$S^2_3 = \frac{(3.17 - 3.11)^2 + (3-3.11)^2 + (3.17-3.11)^2}{3-1}$$

$$= 0.010$$

$$S^2_4 = \frac{(7.33-6.90)^2 + (6.69 - 6.90)^2 + (6.69-6.90)^2}{3-1}$$

$$= 0.137$$

The maximum dispersion is 0.276

Applying equation (3.6) to the dried sweet pepper data yields

$$\sum_{u=1}^{4} S^2_u = 0.497$$

To ascertain the possibility of carrying out regression analysis, using the G-criteria, we have

$$G_{cal} = \frac{S^2_u \, Max}{\sum^4 S^2_u} = \frac{0.276}{0.497} = 0.555$$

This calculated G- value is compared with an appropriate table value

$$G_{(N,\, r-1,\, \propto - 0.05)} = G_{(4,\, 2,\, 0.05)}$$

Homogeneity condition: $G_{cal} < G_{(N,\, r-1,\, \propto 0.05)}$

Since G_{cal} < G table 0.555 < 0768 Thus fulfilling

Homogeneity condition, the analysis is then proceeded to regression analysis, to determine the experimental error.

Applying equations (3.10) through (3.12), the average sample variance and the experimental error are:-

$$S^2_{(y)} = \frac{1}{4} \sum_{u=1}^{4} S^2_u = \frac{1}{4}\,(0.497) = 0.124$$

$$S_{(y)} = \sqrt{S2(y)} = \sqrt{0.124} = 0.352$$

Since the experimental design is orthogonal, the regression coefficients are estimated using Table 3.2 and equations (3.13) through (3.18)

$$b_o = ¼ \sum_{u=1}^{4} X_o Y_u = 24.23 = 6.058$$

$$b_1 = 1/N \sum_{u=1} X1 \ Y = ¼ \ (+5.83 - 8.39 + 3.11 - 6.90)$$

$$= ¼ (-6.35) = -1.588$$

$$b_2 = 1/N \sum_{u=1}^{4} X^2 Y = ¼ \ (+5.83 - 8.39 + 3.11 - 6.90)$$

$$= ¼ (-4.21) = -1.053$$

$$b_{12} = 1/N \sum_{u=1}^{4} X_{12} Y = ¼ \ (+5.83 - 8.39 + 3.11 - 6.90)$$

$$= ¼ (-4.21) = -0.308$$

to assess the statistical significance of the regression coefficients estimated above, the confidence interval is constructed and test hypothesis on individual regression coefficient is carried out. Confidence intervals for the regression coefficients are of the general form given in equation (3.19) that is

$$b_i \pm \Delta \ b_I$$

Where $\Delta \ b_i = t_{(\alpha, N(r-1)} \ Sb$

From statistical table, $t_{(0.05,8)} = 1.860$

Applying equation (3.20), the error in each regression coefficient is

$$S_b = \frac{S_{(y)}}{\sqrt{N.r}} = \frac{0.352}{\sqrt{12}} = 0.102$$

$$\Delta b_s = 1.860 \times 0.102 = 0.190$$

Applying equation (3.21) the calculated t – values for testing the significance of each regression coefficients are:

$$t_o = \frac{(b_o)}{S_b} = \frac{6.058}{0.102} = 59.392$$

$$t_1 = \frac{(b_1)}{S_b} = \frac{-1.588}{0.102} = 15.569$$

$$t_2 = \frac{(b_2)}{S_b} = \frac{-1.053}{0.102} = 10.324$$

$$t_{12} = \frac{(b_{12})}{S_b} = \frac{-0.308}{0.102} = 3.02$$

the summary of the estimated effects, the confidence intervals and the calculated t – values are presented in Table 4.14

TABLE 4.14 THE ESTIMATED EFFECTS CONFIDENCE INTERVALS AND CALCULATED T VALUES

REGRESSION COEFFICIENT	ESTIMATE EFFECT	CONFIDENCE INTERVAL	t – VALUES OBSERVED	t-VALUES REQUIRED 5%	1%
b_o	6.058	+ 0.190	59.392	1.86	2.90
b_1	-1.588	+0.190	15.569		
b_2	-1.053	+ 0.190	10.324		
b_{12}	-0.308	+ 0.190	3.02		

Comparing the calculated t – values, with the appropriate critical table value

$t_{(0.05,8)}$ = 1.860 reveals that an the

Regression coefficients are all statistically significant using these statistically significant regression coefficients, to define the fitted or predicted model.

$\hat{Y}_u = b_o + b_1 X_1 + b_2 X_2 + b_{12} X_{12}$ 4.5

$\hat{Y}_u = 6.058 - 1.588 X_1 \; 1.053 X_2 - 0.308 X_{12}$..4.6

The calculation of equation (4.6) at the levels of the independent variables provide the fitted values. Using the fitted model, the predicted values of Y at the for points in the design, could be generated as:-

$\bar{Y}_1$ = 6.058 – 1.588 (+1) – 1.053 (-1) – 0.308 (-1)

= 6.058 – 1.588 + 1.053 + 0.308

= 5.831

$\bar{Y}_2$ = 6.058 – 1.588 (-1) – 1.053 (-1) – 0.308 (+1)

= 6.058 + 1.588 + 1.053 – 0.308

= 8.391

$\acute{Y}_3$ = 6.058 – 1.588 (+1) – 1.053 (+1) – 0.308 (+1)

= 6.058 – 1.588 – 1.053 – 0.308

= 3.109

$\acute{Y}_4$ = 6.058 – 1.588 (-1) – 1.053 (+1) – 0.308 (-1)

= 6.058 + 1.588 – 1.053 + 0.308

= 6.901

The mean experimental observations $\acute{Y}_u$, the fitted value ($\acute{Y}_i$) the residuals e_i = ($\acute{Y}_u - \acute{Y}_i$) and the squares of the residuals e_2 = ($\acute{Y}_u$ – $Y_u)^2$ are summarised in table 4.15. the residuals are the deviations of the measured values $\acute{Y}_u$ from their predicted counterparts $\acute{Y}_i$

Table 4.15:- The mean experimental observations, the fitted values, the residuals are the squares of the residuals.

RUN NO.	$\acute{Y}_U$	$\acute{Y}_I$	e^2_i = Ýu Ýi	$e'_2 = (\acute{Y}_U - \acute{Y}_I)^2$
1.	5.830	5.831	-0.001	0.000001
2.	8.3390	8.391	-0.001	0.000001
3.	3.110	3.109	0.001	0.000001
4.	6.90	6.901	-0.001	0.000001

The adequacy of the fitted model (that is equation 4.6 could be evaluated by testing hypothesis on the individual regression coefficients. Applying equation (3.25) through (3.27) the sum of squares for the effects are.

$$SS_{bi} = \frac{r}{N} \sum_{u=1}^{N} (X_i\ Y_u)^2$$

Ss_{b1} = ¾ (contrast)^2 = ¾ (-6.35)^2 = 30242

SS_{b2} = ¾ (contrast)^2 = ¾ (-4.21)^2 = 13.293

SS_{b12} = ¾ (contrast)^2 = ¾ (-1.23)^2 = 1.135

The total sum of squares is calculated using equation (3.28) that is

$$SS_T = \sum_{u=1}^{N\cdot r} Y_{uv} - \frac{(\sum_{u=1}^{N.r} Y_{uv})^2}{N.r}$$

Where $\sum_{U=1}^{12} Y^2_{uv}$ =

+ (b.14)^2 + (9^2) + (3.17)^2+ (7.33)^2
+ (5.67)^2+ (8.09)^2 +(3)3 + (6.69)^2
+ (5.67)^2 + (8.09)^2 + (3.17)2 + (6.69)^2
= 486 .233

$(\sum_{u=1}^{12} Yuv)^2$ =

(6.14 + 9 + 3.17 + 7.33
+ 5.67 + 8.09 +3 + 6.69
+ 5.67 + 8.09 + 3.17 + 6.69)^2

= (72.71)^2
= 5286.744

Therefore, the total sum of squares

$$SS_T = \frac{486.233 - 5286.744}{12} = 45.671$$

From equations (3.29) and (3.30), the error sum of squares

SS_E = SS_T - (Ss_{b1} + SS_{b2} + SS_{b12})
= 45.671 – 44.67
= 1.001

The F – ratios are calculated using equation (3.31)

$$F \text{ calculated} = \frac{MS_R}{MS_E} = \frac{SS_R/df_R}{SS_E/N(r-1)}$$

Since the degree of freedom regression = 1

F – ratios are therefore calculated as

$$F_{b1} = \frac{30.242}{0.125} = 241.936$$

$$F_{b2} = \frac{13.293}{0.125} = 106.344$$

$$F_{b12} \quad \frac{1.135}{0.125} = 9.08$$

The complete analysis of variance is summarised in Table 4.16

Table 4.16 Analysis of variance for replicated 22 factorial Experiment for dried sweet pepper.

SOURCE OF VARIATION	EFFECT	SUM OF SQUARES (SS)	DEGREE OF FREEDOM (df_R)	MEAN SQUARES (MS)	F-RATIOS OBSERVED	F-RATIOS REQUIRED 5%	1%
b1	-1.588	30.242	1	30.242	241.936	5.32	11.26
b2	-1.053	13.293	1	13.293	106.344		
b12	-0.308	1.135	1	1.135	9.08		
error		1.001	8	0.125			
total		45.671	11				

Comparing the calculated F – ratio individually, with the appropriate critical table value

$F_{(X1\ dfR,\ N(r-1)} = F_{(0.05,\ 1,8)} = 5.32$

Reveals that all the coefficients are significant.

The adequacy of the overall regression model could be checked further, by calculating the dispersion of adequacy for the replicate experiment and compare the magnitude, with the variance estimate given by the mean squared error

Applying equation (3.33), the dispersion of adequacy for the replicate experiment is

$$SS^2_{(ad)} = \frac{r}{N-\lambda} \sum_{u=1}^{N} (\acute{Y}_u - \dot{Y}_u)^2 = \frac{r}{df_{(ad)}} \sum_{u=1}^{N} (\acute{Y}_u - \dot{Y}_u)^2$$

From table 4.12 $\sum_{U=1}^{4} e^2_u = \sum_{u=1}^{u} (\acute{Y}_u - \acute{Y}_u)^2 = 0.000004$

λ = number of in adequate coefficient = 0

degree of freedom of adequate experiment = 4

$SS^2_{(ad)} = \frac{3}{4}(0.000004) = 0.000003$

Applying the fisher's critical (equation 3.34)

$$F_{cal} = \frac{S^2_{ad}}{S^2_{(Y)}} = \frac{0.000003}{0.124} = 0.0000024$$

From Statistical table $F_{(0.05,3,8)}$ = 5.32

As $F_{cal} < F_{(0.05,3,8)}$, the fitted regression

Model could be regarded adequate. That is the fitted model is

$$\hat{Y} = 6.058 - 1.588\ X_1 - 1.053\ X_2 - 0.308\ X_{12}$$

Comparing the calculated t values in table 4.14 with the appropriate critical table value at 1% level

t (0.01,8) = 2.900 reveals that all the regressions are statistically significant even at 1% level.

Using this statistically significant regression coefficients to define the fitted or predicted model.

$$\hat{Y}_u = b_0 + b_1 X_1 + b_2 X_2 + b_{12} X_{12} \qquad \text{.......... 4.9}$$

$$\hat{Y}_u = 6.058 - 1.588 X_1 - 1\ 053 X_2 - 0.308 X_{12} \qquad \text{.......... 4.10}$$

The calculation of equation (4.10) at the levels of the independent variables provides the fitted values. Using the fitted model, the predicted values of Y at the four points in the design, could be generated as

$$\bar{Y}_1 = 6.058 - 1.588\ (+1) - 1.053\ (-1) - 0.308\ (-1)$$
$$= 6.058 - 1.588 + 1 - 1.053 + 0.308$$
$$= 5.831$$

$$\bar{Y}_2 = 6.058 - 1.588\ (-1) - 1.053\ (-1) - 0.308\ (+1)$$
$$= 6.058 - 1.588 + 1 - 1.053 + 0.308$$
$$= 8.391$$

$$\bar{Y}_3 = 6.058 - 1.588\ (+1) - 1.053\ (+1) - 0.308\ (+1)$$
$$= 6.058 - 1.588 - 1 - 1.053 + 0.308$$
$$= 3.109$$

$\bar{Y}_4$ = 6.058 – 1.588 (-1) – 1.053 (+1) –0.308 (-1)

= 6.058 – 1.588 +1 – 1.053 + 0.308

= 6.901

the mean experimental observations Ý are fitted value ($Ý_i$) the residuals e_i = ($Ý_u – Y_i$) and the squares of the residuals e^2_I = $(Ý_u – Ý_i)^2$ are summarised in table 4. 17. The residuals are the deviations of the measured values Y_u from their predicted counterpart $Ý_i$.

Table 4.17: The mean experimental observations, the fitted values, the residuals and the squares of the residuals.

RUN NO	$Ý_u$	$Ý_I$	$e_i = Ý_u – Ý_I$	$e^2_I = (Ý^u – Ý_I)_2$
1	5.830	5.831	-0.001	0.000001
2	8.390	8.391	-0.001	0.000001
3	3.110	3,109	0.001	0.000001
4	6.900	6.901	-0.001	0.000001

The adequacy of the fitted model equation (4.10) could be evaluated by testing hypothesis on the individual regression coefficient applying equations (3.25) through (3.27) the sum of squares for the effects are

Ss_{b1} = 30.242

SS_{b2} = 13.293

SS_{b12} = 1.135

The total sum of squares as found in equation (3.28)

The error sum of squares = 1.001

The F – ratios as calculated using equation (3.31) are;

F_{b1} = 241.936

F_{b2} = 106.344

F_{b12} = 9.08

Using table 4.16, comparing the calculated F – ratio individually, with the appropriate critical table value = F (0.01,1,8) = 11.26 reveals that coefficient b_{12} is not significant at 1evel.

The adequacy of the over all regression model could be checked further by calculating the dispersion of adequacy for the replicate experiment and compare the magnitude, with the variance estimated given by the mean squared error.

Apply equation (3.33) the dispersion of adequacy for the replicate experiment

$$\text{Is } Ss_{ad} = \frac{r}{N-\lambda} \sum_{U=1}^{N} (\acute{Y}_u - \acute{Y}_i)^2 = \frac{r}{df_{ad}} \sum_{u=1}^{N} (\acute{Y}_u - \acute{Y}_u)^2$$

From table 4.17 $\sum_{U=1}^{4} (\acute{Y}_u - \acute{Y}_u)^2$ = 0.000004

λ = number of inadequate coefficient = 1

degree of freedom of adequate experiment,

df_{ad} = 4 – 1 = 3

S^2_{ad} = 3/3 (0.000004) = 0.000004

Applying the fisher's criteria (equation 3.34)

$$F_{cal} = \frac{S^2_{ad}}{S^2_y} = \frac{0.000004}{0.124} = 0.00000323$$

From statistical table

$F_{(0.01, 3,8)}$ = 7.59

Since $F_{cal} < F_{(0.01,3,8)}$

0.0000032 < 7.59 the fitted regression model could be regarded adequate that is the fitted model of 1% level is

$\acute{Y}_u = 6.058 - 1.588 X_1 - 1.053 X_2 - 0.308 X_{12}$ 4.10

4.2 COLOUR SENSORY EVALUATION OF THE DRIED VEGETABLES

At the end of the drying period of each vegetable products, the dried vegetables are evaluated for change in physical quality parameters by the use of questionnaires as shown in apendix 1-6.

The results of the observed panelist's scores for the various sample treatments are as shown in Tables 4.18 through 4.20

4.2.1 COLOUR EVALUATION OF THE DRIED TOMATOES

To determine whether the observed colour scores differ significantly from the expected or original colour of the tomatoes, observed panellist's score for the samples at the various drying condition are analysed statistically. For dried tomatoes, with data shown in Table 4.18,

A statistical hypothesis is then set up about the sample population. It is hypothesized that there is no significant difference between the colour quality of the fresh and the dried tomatoes.

Ho: μ = 8

Hi: $\mu <$ 8

TABLE 4.18. RESULT OF COLOUR SENSORY EVALUATION OF DRIED TOMATOES

PANELISTS	Y_1 REPLICATIONS			Y_2 REPLICATIONS			Y_3 REPLICATIONS			Y_4 REPLICATIONS		
	Y_{11}	Y_{12}	Y_{13}	Y_{21}	Y_{22}	Y_{23}	Y_{31}	Y_{32}	Y_{33}	Y_{41}	Y_{42}	Y_{43}
1	6	6	6	7	7	7	5	6	6	7	7	6
2	6	7	7	7	7	8	6	6	6	7	7	7
3	6	7	7	7	7	7	6	7	6	6	7	6
4	6	7	6	7	7	7	5	6	6	6	6	6
5	7	7	7	8	7	7	6	7	6	7	7	7
6	6	6	6	7	7	7	6	6	6	6	6	6
7	6	7	7	8	7	8	6	6	6	7	6	7
8	6	7	6	7	8	8	5	6	6	7	7	7
9	6	7	7	8	7	8	6	7	6	6	7	7
10	6	7	6	7	8	8	6	7	6	6	7	6
MEAN	6.1	6.8	6.5	7.3	7.2	7.5	5.7	6.4	6.0	6.5	6.7	6.5

Where:

Y_1 = sample dried at 65°c for 3 hours (coded A_1 in the questionnaire).

Y_2 = Sample dried at 35°c for 3 hours (coded A_2 in the questionnaire)

Y_3 = Sample dried at 65°c for 5 hours (code A_3 in the questionnaire)

Y_4 = Sample dried at 35°c for 5 hours (coded A_4 in the questionnaire)

To determine whether the observed frequencies (obtained from Table 4.18) differ significantly from the expected frequencies, a measure of the discrepancy existing between the observed and expected frequencies is supplied by the statistic chi – square.

Given + by

$$X^2 = \frac{(0_1 - E_1)^2}{E_1} + \frac{(0^2 - E_2)^2}{E_2} + \ldots\ldots + \frac{(0_k - E_k)^2}{E_k}$$

$$= \sum_{j=1} k \quad \frac{(0_j - E_j)^2}{E_j}$$

using the mean values obtained in Table 4.18 to calculate the Chi- square value as shown in Table 4.19

TABLE 4.19

TREAMENTS	**REPLICATIONS**						
	1		**2**		**3**		
	0	**E**	**0**	**E**	**0**	**E**	**TOTAL**
1	6.1	(8)	6.8	(8)	6.5	(8)	19.4
2	7.3	(8)	7.2	(8)	7.5	(8)	18.1
3	5.7	(8)	6.4	(8)	6.0	(8)	18.1
4	6.5	(8)	6.7	(8)	6.5	(8)	19.7
TOTAL	25.6		27.1		26.5		79.2

$$\chi^2 = \frac{\sum (0 - E)^2}{E}$$

$$= \frac{(6.1 - 8)^2}{8} + \frac{(6.9 - 8)^2}{8} + \frac{(6.5 - 8)^2}{8} + \frac{(6.5 - 8)^2}{8}$$

$$= 3.31$$

Degree of freedom = 1

Checking the calculated value of 3.31, opposite degree of freedom 1 shows that the probability of obtaining the results observed by chance alone is about 5% since the observed chi-square is close to 3.841 found at 5% point since the calculated chi-square value is less the chi-square table.

Applying the results to the discrete data to determine its goodness of fit using Yates correction factor, to further check the discrepancy and the validity of the previous result obtained.

$$\chi^2 \text{ (corrected)} = \frac{(0_1 - E_1) - 0.5)^2}{E_1} + \frac{(0_2 - E_2) - 0.5)^2}{E_2} + \ldots\ldots$$

$$+ \frac{(0_k - E_k) - 0.5)^2}{E_k}$$

$$\chi^2 \text{ (corrected)} =$$

$$= \frac{(6.1 - 8) - 0.5)^2}{8} + \ldots\ldots\ldots + \frac{(6.5 - 8) - 0.5)^2}{8}$$

$$= 5.815$$

referring to the chi-square table under I degree of freedom, we would expect a value of not greater than 3.841 at 5% level and not greater than 6.635 at 1% level since the calculated chi-square is less than 6.635 the hypothesis is confirmed to be accepted with 1% level of error.

4.2.2. COLOUR EVALUATION OF THE DRIED OKRO

For dried Okro, with data shown in table 4.20

TABLE 4.20 RESULT OF COLOUR SENSORY EVALUATION OF DRIED OKRO

PANELISTS	Y_1 REPLICATIONS			Y_2 REPLICATIONS			Y_3 REPLICATIONS			Y_4 REPLICATIONS		
	Y_{11}	Y_{12}	Y_{13}	Y_{21}	Y_{22}	Y_{23}	Y_{31}	Y_{32}	Y_{33}	Y_{41}	Y_{42}	Y_{43}
1	6	6	6	7	7	7	6	6	6	6	6	7
2	6	5	6	7	7	8	6	6	5	7	6	7
3	6	6	6	7	7	7	5	7	5	6	7	7
4	6	5	6	7	7	7	5	5	6	7	6	6
5	6	6	7	8	7	7	6	5	6	6	7	7
6	6	6	6	7	7	7	5	6	5	7	6	6
7	6	6	6	7	7	8	6	5	6	7	7	7
8	5	6	6	7	7	8	6	6	5	7	6	6
9	6	6	6	8	7	7	6	6	6	7	6	6
10	5	6	6	7	7	7	5	6	6	6	7	7
MEAN	5.8	5.8	6.1	7.2	7.0	7.3	5.6	5.7	5.6	6.6	6.4	6.6

Where:

Y_1 = sample dried at 65°c for 3 hours (coded B_1 in the questionnaire).

Y_2 = Sample dried at 65°c for 5 hours (coded A_2 in the questionnaire)

Y_3 = Sample dried at 65°c for 5 hours (code A_3 in the questionnaire)

Y_4 = Sample dried at 35°c for 5 hours (coded A_4 in the questionnaire)

To determine whether the observed frequencies (obtained from Table 4.20) differ significantly from the expected frequencies, a measure of the discrepancy existing between the observed and the expected frequencies is supplied by the statistic chi-square.

$$\chi^2 = \frac{\sum (0 - E)^2}{E}$$

$$= \frac{(5.8-8)^2}{8} + \frac{(5.8\text{-}8)2}{8} + \frac{(6.1-8)^2}{8} + \ldots\ldots\ldots\ldots + \frac{(6.6-8)^2}{8}$$

$$= 4.86$$

Degree of freedom = 1

Checking the calculated value of 4.86 opposite I degree of freedom shows that the probability of obtaining the result by chance also is less than 5% but slight higher than 1% since the observed chi-square vales is slightly higher than 3.841 at point 5%, but less than 6,635 at point 1%.

Applying the results to the discrete data, to determine its goodness of fit, using Yates' correction factors, to further check the discrepancy and the validity of the previous chi-square result obtained.

$$\chi^2_{(corrected)} = \sum \frac{\{(0_1 - E_1)\text{-}0.5\}^2}{E_1} \frac{\{(0_2 - E_2)\ 0.5\}^2}{E_2} + \ldots\ldots\ldots + \frac{\{(0_k - E_k)\text{-}0.5\}^2}{E_k}$$

$$\chi^2_{cor} = \frac{\{(5.8-8)-0.5\}^2}{8} + \frac{\{(5.8-8)\text{-}0.5\}^2}{8} + \ldots + \frac{\{(6.6-8)-0.5\}^2}{8}$$

$$= 7.74$$

We see that we would expect a value of 6.6 35 at % of the occurrence by chance alone and 10.827 only 0.1% of the time. Therefore we can say that the probability of obtaining chi-square value as large as 7.74 is only slightly more than I in a 1000 so we reject the hypothesis.

4.2.3 COLOUR EVALUATION OF THE DRIED SWEET PEPER

For dried sweet pepper, with data shown in Table 4:22

TABLE 4.22: RESULT OF COLOUR SENSORY EVALUATION OF DRIED SWEET PEPPER

PANELISTS	Y_1 REPLICATIONS			Y_2 REPLICATIONS			Y_3 REPLICATIONS			Y_4 REPLICATIONS		
	Y_{11}	Y_{12}	Y_{13}	Y_{21}	Y_{22}	Y_{23}	Y_{31}	Y_{32}	Y_{33}	Y_{41}	Y_{42}	Y_{43}
1	7	6	6	8	7	7	7	6	6	7	7	7
2	7	7	7	7	7	7	7	6	6	7	7	7
3	7	6	7	8	8	7	7	6	7	8	7	7
4	6	7	7	8	8	7	6	6	6	8	7	8
5	7	7	7	8	8	8	7	6	7	6	7	7
6	7	6	7	7	7	7	6	7	6	7	7	7
7	7	7	6	8	8	8	6	7	7	8	7	7
8	7	7	7	7	7	7	7	7	7	7	8	7
9	6	7	6	8	8	8	6	7	7	7	7	8
10	7	6	6	7	7	8	6	7	6	7	8	7
MEAN	6.8	6.6	6.6	7.6	7.5	7.4	6.5	6.5	6.5	7.3	7.3	7.2

Where:

Y_1 = sample dried at 65°c for 3 hours (coded C_1 in the questionnaire).

Y_2 = Sample dried at 65°c for 5 hours (coded C_2 in the questionnaire)

Y_3 = Sample dried at 65°c for 5 hours (code C_3 in the questionnaire)

Y_4 = Sample dried at 35°c for 5 hours (coded C_4 in the questionnaire)

To determine whether the observed frequencies (obtained from table 4.22 differ significantly from the expected frequencies, a measure of the discrepancy existing between the observed and expected frequencies is supplied by the statistic chi-square.

TABLE 4.23

TREAMENTS	**REPLICATIONS**						
	1		**2**		**3**		
	O	**E**	**O**	**E**	**O**	**E**	**TOTAL**
1	6.8	(8)	6.6	(8)	6.6	(8)	20
2	7.6	(8)	7.5	(8)	7.4	(8)	22.5
3	6.5	(8)	6.5	(8)	6.5	(8)	19.8
4.	7.3	(8)	7.2	(8)	7.2	(8)	21.8
TOTALS	28.2		27.9		27.7		

$$\chi^2 = \sum \frac{(0 - E)^2}{E}$$

$$= \frac{(6.8-8)^2}{8} + \frac{(6.6-8)^2}{8} + \frac{(6.6-8)^2}{8} + \ldots\ldots + \frac{(7.2-8)^2}{8}$$

$$= 1.812$$

Degree of freedom = 1

Checking the calculated value of 1.82, opposite I degree of freedom shows that alone is about 10% since the observed chi-square value is slightly less than 2.706 at point. 10%

Applying the results to the discrete data, to determine its goodness of fit using Yates correction factor, to further check the discrepancy and the validity of previous chi-square result obtained.

$$\chi^2 = \frac{\{(0_1 - E_1)\text{-}0.5\}^2}{E_1} + \frac{\{02 - E_2) - 0.5\}^2}{E_2} + \ldots\ldots \frac{\{0k - Ek)\text{-}0.5)^2}{E_k}$$

$$= \frac{\{(6.8 - 8)\text{-}0.5\}^2}{8} + \frac{\{(6.6 - 8)\text{-}0.5\}^2}{8} + \ldots\ldots \frac{\{(7.2 - 8)\text{-}0.5\}^2}{8}$$

$$= 3.71$$

referring to the chi-square table under 1 degree of freedom, we would expect a value of not greater than 3.841 at 5% level and not greater than 6.635 at 1% level since the chi – square (corrected) calculated is less than 6.635 and less than 3.841 the hypothesis is accepted with 1% level of error.

4.3 TEXTURE EVALUATION OF THE DRIED VEGETABLES

4.3.1 TEXTURE EVALUATION OF THE DRIED TOMATOES

To determine whether the observed texture of the dried tomatoes differ significantly from the expected texture (Fresh tomatoes).

The observed panellist's score for the samples at the various drying conditions (Table 4.24) are analysed statistically.

TABLE 4.24: TEXTURE EVALUATION SCORES FOR DRIED TOMATOES

PANELLISTS	Y_1 REPLICATIONS			Y_2 REPLICATIONS			Y_3 REPLICATIONS			Y_4 REPLICATIONS		
	Y_{11}	Y_{12}	Y_{13}	Y_{21}	Y_{22}	Y_{23}	Y_{31}	Y_{32}	Y_{33}	Y_{41}	Y_{42}	Y_{43}
1	7	7	7	6	6	6	7	7	7	6	7	7
2	7	7	7	6	6	6	7	7	7	7	6	6
3	6	7	7	6	6	6	7	7	7	6	7	7
4	7	7	7	6	6	6	7	7	7	6	6	6
5	6	6	6	6	6	6	7	7	7	7	7	7
6	7	7	7	6	6	6	7	7	7	7	7	7
7	7	7	7	6	6	6	7	7	7	6	6	7
8	7	7	7	5	6	6	7	7	7	7	7	7
9	7	7	7	5	6	6	7	7	7	7	7	6
10	7	7	7	6	6	6	7	7	7	7	7	7
MEAN	6.8	6.9	6.9	5.8	5.9	5.9	7.0	7.0	7.0	6.6	6.7	6.7

Where:

Y_1 = Sample dried at 65^0c for 3 hours (coded A_1 in the questionnaire)
Y_2 = Sample dried at 35^0c for 3 hours (coded A_2 in the questionnaire)
Y_3 = Sample dried at 65^0c for 5 hours (coded A_3 in the questionnaire)
Y_4 = Sample dried at 35^0c for 5 hours (coded A_4 in the questionnaire)

A measure of the discrepancy of the observed from the expected values is supplied by the statistic chi-square, using table 4.25

Table 4.25

TREATMENTS	REPLICATIONS						
	1		2		3		
	0	E	O	E	O	E	TOTAL
1	6.8 8	6.9	8	6.9	8	20.6	
2	5.8 8	5.9	8	5.9	8	17.6	
3	7.0 8	7.0	8	7.0	8	21.0	
4	6.6 8	6.7	8	6.7	8	20.0	
TOTALS	**26.2**		**26.5**		**26.5**		

$$X^2 = \Sigma \frac{(0-E)^2}{E}$$

$$= \frac{(6.8-8)^2}{8} + \frac{(6.9-8)^2}{8} + \frac{(6.9-8)^2}{8} + \ldots + \frac{(6.7-8)^2}{8}$$

$$= 3.12$$

Degree of freedom = 1

Checking the calculated value of 3.12, opposite 1 degree of freedom shows that the probability is about 5%. Since the observed chi-square value is close to 3.841 found at 5% point.

Using Yate's correction factor, to further check the result,

$$X^2_{\text{Corrected}} = \frac{\{0_1 - E_1) - 0.5\}^2}{E_1} + \frac{\{(0_2 - E_2) - 0.5\}^2}{E_2} + \ldots + \frac{\{(0_k\ E_k) - 0.5\}^2}{E_k}$$

$$= \frac{\{(6.8-8)-0.5\}^2}{8} + \frac{\{(6.9-8)-0.5\}^2}{8} + \ldots \frac{\{(6.7-8)-0.5\}^2}{8}$$

$$= 5.72$$

Referring to the chi-square table under 1 degree of freedom, we would expect a value not greater than 3.841 at 5% level and not greater than 6.635 at 1% level. Since the calculated chi-square is less than 6.635 the hypothesis is confirmed to be accepted.

4.3.2 TEXTURE EVALUATION OF THE DRIED OKRO

To determine water the observed texture of the dried okro differ significantly from the expected texture (fresh okro), the panellists, score for the samples at various drying conditions (Table 4.26) are analysed statistically.

TABLE 4.26: TEXTURE EVALUATION SCORES FOR DRIED OKRO

ANELISTS	Y_1 REPLICATIONS			Y_2 REPLICATIONS			Y_3 REPLICATIONS			Y_4 REPLICATIONS		
	Y_{11}	Y_{12}	Y_{13}	Y_{21}	Y_{22}	Y_{23}	Y_{31}	Y_{32}	Y_{33}	Y_{41}	Y_{42}	Y_{43}
1	6	7	7	5	5	6	7	7	7	7	6	7
2	7	7	7	6	6	5	7	7	7	6	7	6
3	7	6	6	5	6	6	7	7	7	6	7	6
4	7	7	7	6	5	6	7	7	7	6	6	6
5	7	6	7	6	6	5	7	7	7	7	7	7
6	7	7	7	6	6	6	6	7	7	6	7	6
7	6	7	6	6	5	6	7	7	7	6	6	6
8	7	6	7	6	6	6	7	7	7	6	7	7
9	7	7	7	6	6	5	7	7	7	7	6	7
10	7	6	7	6	6	6	7	7	7	6	7	7
MEAN	**6.8**	**6.6**	**6.8**	**5.8**	**5.7**	**5.7**	**6.9**	**7.0**	**7.0**	**6.3**	**6.6**	**6.6**

Where:

Y_1 = Sample dried at 65^0c for 3 hours (coded B_1 in the questionnaire)
Y_2 = Sample dried at 35^0c for 3 hours (coded B_2 in the questionnaire)
Y_3 = Sample dried at 65^0c for 5 hours (coded B_3 in the questionnaire)
Y_4 = Sample dried at 35^0c for 5 hours (coded B_4 in the questionnaire)

A measure of the discrepancy of the observed from the expected values is supplied by the statistic chi-square, using table 4.27

Table 4.27

TREATMENTS	REPLICATIONS 1		2		3		
	0	E	O	E	O	E	TOTAL
1	6.8 8	6.6	8	6.8	8	20.2	
2	5.8 8	5.7	8	5.7	8	17.2	
3	6.9 8	7.0	8	7.0	8	20.9	
4	6.3 8	6.6	8	6.6	8	19.5	
TOTALS	**25.8**		**25.9**		**26.1**		

$$X^2 = \Sigma \frac{(0 - E)^2}{E}$$

$$= \frac{(6.8-8)^2}{8} + \frac{(6.6-8)^2}{8} + \frac{(6.6-8)^2}{8} + \ldots + \frac{(6.6-8)^2}{8}$$

$$= 3.81$$

Checking the calculated value of 3.81, opposite 1 degree of freedom shows that the probability of obtaining the result by chance alone is about 5% since the observed value is close to 3.841 found at 5% point.

Since the calculated chi-square value is less than the critical chi-square table value at 5% level. It could be said that the observed frequencies do not differ significantly from the expected frequencies.

Using Yate's correction factor, to further check the discrepancy,

$$X^2_{\text{Corrected}} = \frac{\{(6.8-8)-0.5\}^2}{8} + \frac{\{(6.6-8)-0.5\}^2}{8} + \ldots + \frac{\{(6.6-8)-0.5\}^2}{8}$$

$$= 6.43$$

Comprising the calculated chi-square value with that obtained at the 1% level which is 6.635, it is noted that since the calculated value is less than the critical table value. The hypothesis is confirmed to be accepted at 1% level of error.

4.3.2 TEXTURE EVALUATION OF DRIED SWEET PEPPER

TABLE 4.28: PANELIST'S TEXTURE EVALUATION SCORES FOR SWEET PEPPER

PANELISTS	Y_1 REPLICATIONS			Y_2 REPLICATIONS			Y_3 REPLICATIONS			Y_4 REPLICATIONS		
	Y_{11}	Y_{12}	Y_{13}	Y_{21}	Y_{22}	Y_{23}	Y_{31}	Y_{32}	Y_{33}	Y_{41}	Y_{42}	Y_{43}
1	7	7	7	6	6	6	7	7	7	7	7	7
2	6	6	7	6	5	6	7	7	7	6	6	7
3	7	7	7	6	6	6	7	7	7	7	7	7
4	7	7	7	6	6	6	7	7	7	6	7	7
5	7	7	7	6	6	6	7	7	7	7	7	7
6	7	7	6	6	6	6	7	7	7	7	7	6
7	7	7	7	5	6	6	7	7	7	6	6	7
8	7	7	7	6	6	6	7	7	7	7	7	6
9	7	7	7	5	6	6	7	7	7	7	6	7
10	7	7	7	6	6	6	7	7	7	7	7	7
MEAN	**6.9**	**6.9**	**6.9**	**5.9**	**5.9**	**6.0**	**7.0**	**7.0**	**7.0**	**6.7**	**6.7**	**6.8**

Where:

Y_1 = Sample dried at 65^0c for 3 hours (coded C_1 in the questionnaire)

Y_2 = Sample dried at 35^0c for 3 hours (coded C_2 in the questionnaire)

Y_3 = Sample dried at 65^0c for 5 hours (coded C_3 in the questionnaire)

Y_4 = Sample dried at 35^0c for 5 hours (coded C_4 in the questionnaire)

A measure of the discrepancy of the observed from the expected values is supplied by the statistic chi-square, using table 4.29

Table 4.29

TREATMENTS	REPLICATIONS 1		2		3		
	0	**E**	**O**	**E**	**O**	**E**	**TOTAL**
1	6.9	8	6.9	8	6.9	8	20.7
2	5.9	8	5.9	8	5.9	8	17.8
3	7.0	8	7.0	8	7.0	8	21.0
4	6.7	8	6.7	8	6.8	8	20.2
TOTALS	**26.5**		**26.5**		**26.7**		

$$X^2 = \Sigma \frac{(0 - E)^2}{E}$$

$$= \frac{(6.9-8)^2}{8} + \frac{(6.9-8)^2}{8} + \frac{(6.6-8)^2}{8} + \ldots + \frac{(6.8-8)^2}{8}$$

$$= 3.04$$

Checking the calculated chi-square value of 3.04, opposite 1 degree of freedom shows that the probability of obtaining the result by chance alone is about 5% since the observed value is close to 3.841 found at 5% point.

Since the calculated chi-square value is less than the critical chi-square table value at 5% level, it could be said that the observed frequencies do not differ significantly from the expected frequencies.

Using Yate's correction factor, to further check the result obtained above,

$$X^2_{\text{Corrected}} = \frac{\{(6.9 - 8) - 0.5\}^2}{8} + \frac{\{(6.9 - 8) - 0.5\}^2}{8} + \ldots + \frac{\{(6.8 - 8) - 0.5\}^2}{8}$$

$$= 5.58$$

Referring to the chi-square table under I degree of freedom, we would expect a value not greater than 6.635 at 1% level.

Since the calculated value is less than 6.635 the hypothesis is confirmed to be accepted at 1% level of error.

4.4 SIZE AND SHAPE EVALUATTION OF FRESH/DRIED VEGETABLES

4.4.1 SIZE AND SHAPE EVALUATION OF TOMATOES

TABLE 4.3O ROUNDNESS EVALUATION OF TOMATOES

TREAMENTS	SIZE AND SHAPE (ROUNDNESS) REPLICATIONS					
	1		2		3	
	a	b	a	b	a	b
65°c for 3 hours	0.56	0.69	0.68	0.56	0.14	0.60
35°c for 3 hours	0.16	0.14	0.49	0.51	0.44	0.40
65°c for 5 hours	0.65	0.63	0.42	0.44	0.61	0.39
35°c for 5 hours	0.40	0.62	0.56	0.44	0.48	0.74

TABLE 4.31 SPHERICITY EVALUATION OF TOMATOES

TREAMENTS	SIZE AND SHAPE (SPHERICITY) REPLICATIONS					
	1		2		3	
	a	b	a	b	a	b
65°c for 3 hours	0.75	0.83	0.82	0.75	0.75	0.78
35°c for 3 hours	0.4	0.38	0.71	0.72	0.67	0.63
65°c for 5 hours	0.81	0.80	0.65	0.67	0.78	0.63
35°c for 5 hours	0.63	0.79	0.75	0.67	0.69	0.86

4.4.2 SIZE AND SHAPE EVALUATTION OF OKRO

TABLE 4.32 ROUNDNESS EVALUATION OF OKRO

TREAMENTS	SIZE AND SHAPE (ROUNDNESS) REPLICATIONS					
	1		2		3	
	a	b	a	b	a	b
65°c for 3 hours	0.51	0.43	0.67	0.48	0.42	0.43
35°c for 3 hours	0.51	0.53	0.62	0.42	0.36	0.54
65°c for 5 hours	0.69	0.60	0.64	0.63	0.75	0.82
35°c for 5 hours	0.40	0.61	0.34	0.32	0.35	0.32

TABLE 4.33 SPHERICITY EVALUATION OFOKORO

TREAMENTS	SIZE AND SHAPE (SPHERICITY) REPLICATIONS					
	1		2		3	
	a	b	a	b	a	b
65°c for 3 hours	0.71	0.65	0.81	0.70	0.65	0.65
35°c for 3 hours	0.71	0.76	0.79	0.65	0.60	0.74
65°c for 5 hours	0.69	0.63	0.67	0.67	0.75	0.86
35°c for 5 hours	0.63	0.78	0.59	0.57	0.59	0.56

.4.3 SIZE AND SHAPE EVALUATION OF SWEET PEPPER

'ABLE 4.34 ROUNDMESS EVALUATION OF SWEET PEPPER

TREAMENTS	SIZE AND SHAPE (ROUNDNESS) REPLICATIONS					
	1		2		3	
	a	b	a	b	a	b
65°c for 3 hours	0.16	0.08	0.46	0.32	0.41	0.31
35°c for 3 hours	0.27	0.38	0.17	0.44	0.54	0.51
65°c for 5 hours	0.17	0.09	0.31	0.31	0.27	0.01
35°c for 5 hours	0.42	0.12	0.29	0.09	0.41	0.64

\BLE 4.35 SPHERICITY EVALUATION OF SWEET PEPPER

TREAMENTS	SIZE AND SHAPE (SPHERICITY) REPLICATIONS					
	1		2		3	
	a	b	a	b	a	b
65°c for 3 hours	0.41	0.29	0.68	0.57	0.64	0.56
35°c for 3 hours	0.52	0.61	0.61	0.67	0.74	0.72
65°c for 5 hours	0.41	0.30	0.55	0.46	0.52	0.11
35°c for 5 hours	0.65	0.50	0.54	0.31	0.63	0.40

CHAPTER FIVE

5.0 DISCUSSION AND INTERPRETATION OF RESULT

5.1.0 INTERPRETATION OF MODELS

The effects of two factors, drying temperature and drying time on the moisture content of some selected vegetables (Tomatoes, Okro and sweet pepper) are investigated simultaneously at two levels each, to obtain the results as shown in (4.1.1), (4.1.2) and (4.1.3).

The effect of a factor is said to be the change in the factor, usually called a main effect. The main effects could be said to be the difference between the average response at the low level and the average response at the high level of the factor. This difference is proportional to the regression co-efficient.

As shown in equation (4.2) for instance

$Y_U = 8.526 - 2.485 X_1 - 1.995 X_2 - 0.355 X_{12}$ 1..... 4.2

regression b_1 = -2.485 and b_2 = 1.995 indicates that moving 2.485 units in the X_1 (drying temperature) direction (from its base level along the steepest descent) for every 1.995 units in the X_2 (drying time) direction (from its based level along the steepest decent).

Interactions usually occur between the various factors, in an experiment. When the effect of an interaction is larger than the corresponding main effects, the interaction is said to mask the significance of these main effects, hence has more practical importance (Douglas, 1991).

5.1.1 TOMATOES DRYING MODEL

$Y_U = 8.526 - 2.485 X_1 - 1.995X_2 - 0.355 X_{12}$ ... 4.2

Equation (4.2) expresses the fitted model for a suitable drying temperature- time relationship for drying tomatoes, with 5% level of error.

Where:

X_1 = drying temperature in degree centigrade (^{0}C)

X_2 = drying time in hour

For better clarity the plots of the two main effects are presented in figure 5.1

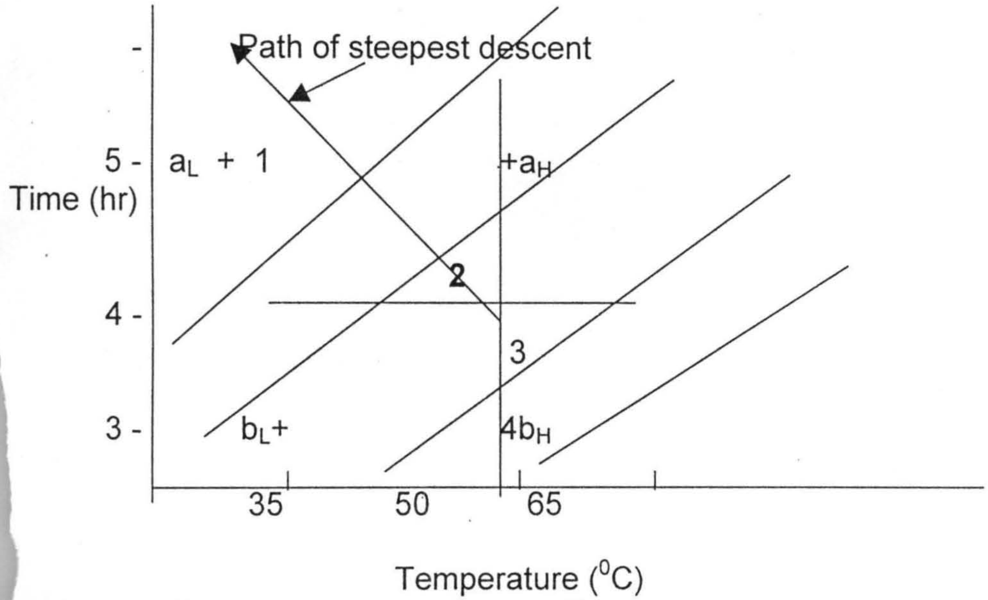

Figure 5.1 Plots for response of main effects

a_L = experiment 1 and a_H = experiment 3

b_L = experiment 2 and a_H = experiment 4

That is from Tables 3.2, 4.4 and 4.6

1(a) Experiment 2 puts temperature at low level, while time factor was at high level and at this condition, the fitted values Y_2 = 12.651% moisture content achievable at 95% confidence level or at 5% level of error. At the 99% confidence level or at 1% level of error, the values about 13.006% moisture content. Which indicates that the probability that drying conducted under this temperature–time relationship, would reduce the moisture content of the fresh tomatoes from its original value (about 16% on dry basis as observed in this particular experimental sample. It has been noted by Mardkordylas, (1990) that ripe tomatoes contain about 94% moisture content which correspond to 15% on dry basis) to about 12.651% or 13.006% moisture content is 95% and 99% probable respectively.

1 (b) Experiment 1 puts temperature at high level while time factor was at low level and the fitted values

$\bar{Y}_1$ = 8.391% moisture content (95% confidence level)

= 8.036% moisture content (99% confidence level)

2 (a) Experiment 4 puts time at high level while temperature was at low level and the fitted values Y_4 = 9.371% moisture content (95% confidence level)

= 9.016% moisture content (99% confidence level)

(b) In experiment 3, raising the temperature level, from its low level to a high level of 65^0C and at the high level of time of 5 hours, helps on drying the tomatoes to a fitted level of

$\bar{Y}_3$ = 3.691% moisture content (at 95% confidence level)

= 4.046% moisture content (at 99% confidence level)

5.1.2 OKRO DRYING MODEL

$$Y_U = 5.858 - 1.3228\, X_1 - 1.253\, X_2 \quad \ldots 4.6$$

Equation (4.6) expresses the fitted model for a suitable drying temperature time relationship for drying Okro both at 5% and 1% level of error.

From Table 4.9 and 4.11

1 (a) Experiment 2 puts temperature at low level, while time factor was at high level and at this condition, the fitted value is Y_2 = about 8.44% moisture content of the fresh okro from its initial value (about 10.11% as observed in this particular experimental sample. It has been noted by Maudkordylas (1990) that fresh okro contains about 86% water which is equivalent to about 6.14% on dry basis) to about 8.44% moisture content is 99%.

(b) Experiment I puts temperature at high level while time factor was at low level and the fitted value Y_1 = about 5.78% moisture content both at 5% and 1% level of error.

2 (a) Experiment 4 puts time at high level while temperature was at low level and the fitted values Y_4 = 5.93% moisture content both at 5% and 1% level of error.

(b) In experiment 3, raising the temperature level from its low level to a high level of 65^0C and at a high level of time of 5 hours, help in the drying okro to a fitted value of Y_3 = 3.28% moisture content both at 5% and 1% level of error.

5.1.3 DRYING MODEL FOR SWEET PEPPER

$Y_U = 6.058 - 1.588 X_1 - 1.053 X_2 - 0.308 X_{12}$ ... 4.10

Equation (4.10) expresses the fitted model for a suitable drying temperature – time relationship for drying okro both at 5% level and 1% level of error.

From table 4.15 and 4.17

1 (a) Experiment 2 puts temperature at low level, while time factor was at high level and at this condition, the factor which indicates that this temperature – time relationship would reduce the moisture content of the fresh ripe sweet pepper from its initial value (about 10.71% as observed in this experimental sample. It has been noted by Maudkordylas

(1990) that unripe sweet pepper contains about 83% moisture which is equivalent to about 4.88% moisture content) to about 8.39%.

(b) Experiment 1 puts temperature at high level, while time factor was at low level and the fitted value Y_1 = 5.83 moisture content both at 5% and 1% level of error.

2 (a) Experiment 4 puts time at high level while temperature was at low level and the fitted values $\dot{Y}_4$ = 6.901% moisture content both at 5% and 1% level of error.

(b) In experiment 3, raising the temperature level from its low level of a high level of 65^{0}C and at a high level of time and 5 hours, helps in the drying of sweet pepper to a fitted value of Y_3 = 3.109 moisture content both at 5% and 1% level of error.

5.2 INTERPRETATION OF CHI-SQUARE VALUES FOR COLOUR

TABLE 5.1

PRODUCT	χ^2 Calculated	χ^2 Corrected	χ^2 table 5%	χ^2 table 1%
Tomatoes	3.31	5.815	3.841	6.635
Okro	4.86	7.74		
Sweet pepper	1.82	3.71		

5.2.1 CHI-SQUARE VALUE FOR TOMATO COLOUR

Referring to table 5.1 being the summary of Chi-squares obtained. Since the calculated Chi-square value for tomatoes is less than the chi-square table both at 5% and 1% level, we could therefore say that the observed colour frequencies for tomatoes, do not differ significantly from the expected frequencies, therefore the hypothesis is accepted at 5% level of error. This indicates that the resultant colour of tomatoes at the end of drying under the given fitted model could be said to be of no significant difference from the original colour of the fresh tomatoes, hence would give a well acceptable colour.

Since the value obtained by the chi-square corrected is less that that of table over at the 1% level is a confirmation that there is no significant difference in the colour of the dried tomatoes and that of the fresh tomatoes prior to drying.

5.2.2 CHI-SQUARE VALUE FOR OKRO COLOUR

Referring to table 5.1, since the calculated chi-square value for okro is higher than the critical value at point 5% level, but less than 6.635 at point 1% level, the hypothesis could be rejected at 5% level under the use of Yates' correction factor, since the calculated chi-square value is equally higher than table value at 1% level, the hypothesis is rejected at 5% level. This indicates that there is a significant difference in the resultant colour of the dried okro from that of the fresh okro prior to drying under the fitted model by equation (4.6).

5.2.3 CHI-SQUARE VALUE FOR SWEET PEPPER COLOUR

Referring to table 5.1, since the calculated chi-square value for sweet pepper is less than the chi-square table value both at 5% and 1% level, it could be said that the observed colour frequencies for sweet pepper, do not differ significantly from the expected frequencies. Therefore the hypothesis is accepted at 5% level. Since the chi-square corrected value obtained is less than that of the critical table value at 5% point. The hypothesis is confirmed accepted at 5% level of error which indicates that the resultant colour of sweet pepper at the end of the drying, under the given fitted model (equation 4.10) could be said to be of no significant difference from that of the fresh sweet pepper, prior to drying.

5.3 INTERPRETATION OF CHI-SQUARE FOR TEXTURE

TABLE 5.2

PRODUCT	χ^2 Calculated	χ^2 Corrected	χ^2 table 5%	1%
Tomatoes	3.12	5.72	3.841	6.635
Okro	3,81	6.43		
Sweet pepper	3.04	5.58		

5.3.1 CHI-SQUARE VALUE FOR TOMATO TEXTURE

Referring to table 5.2, since the calculated Chi-square value for tomatoes is less than the chi-square table at 5% and 1% level and the chi-square corrected value is also less than table value at 1% level, it could be said that there is no significance difference in the frequencies of the observed texture and that of the expected frequencies, therefore, the hypothesis is accepted at 5% level of which indicates that there is no significant difference in the resultant texture of the dried tomatoes from that gotten from the fresh tomatoes.

5.3.2 CHI-SQUARE VALUE FOR OKRO TEXTURE

Referring to table 5.2, since the calculated Chi-square value is less than that of table value at 5% and 1% level points, since the value is close to that obtained in point 5% level, the hypothesis is accepted at 5% level of error since the value obtained at 1% level point, It could be said that it is confirmed that the hypothesis could be accepted at 5% level of error. This indicates that there is no significant difference in the texture obtained from okro dried from and that obtained from the fresh okro, prior to drying under the fitted model given by equation (4.6).

5.3.3 CHI-SQUARE VALUE FOR SWEET PEPPER TEXTURE

Referring to Table 5.2, the calculated chi-square value is less than that of table value at 5% and 1% level points, since the value is close to that obtained in point 5% level, the hypothesis is accepted at 5% level of error. Since the value obtained at chi-square corrected is less than that obtained at 1% level point, it could be said that it is confirmed that the hypothesis could be accepted at 5% level of error. This indicates that there is no significant difference in the texture obtained from dried sweet pepper and that obtained from fresh ones prior to drying under the fitted model given by equation (4.10).

5.4 SIZE AND SHAPE EVALUATION

From table 4.30, 4.31 and 4.32 shrinkage is generally observed since there is a reduction in the size of the dried vegetables from the original size when fresh.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The results obtained from 2^2 full factorial design technique employed have shown that:

1. A suitable temperature-time relationship for drying tomatoes, okro and sweet pepper could be said to be 65^0C for 5 hours, with the following fitted models, for predicting amount of water loss by drying at 95% confidence limits.

$\hat{Y}$ = $8.526 - 2.485 X_1 - 1.995 X_2 - 0.355 X_{12}$ ... 4.2

$\hat{Y}$ = $5.858 - 1.328 X_1 - 1.253 X_2$ ... 4.6

$\hat{Y}$ = $6.058 - 1.588 X_1 - 1.053 X_2 - 0.308 X_{12}$ ... 4.10

For tomatoes, okro and sweet pepper respectively

Where:

X_1 = drying temperature in ^{0}C

X_2 = drying time in hours

2. The estimation of the effects of temperature, time as well as their interaction on the moisture content of the tomatoes, okro and sweet pepper is also suggested by the fitted models 4.2, 4.6 and 4.10 respectively.
3. The statistical analysis of the evaluation of the dried vegetables indicate that under these given fitted models
   (a) There is no significant difference in the colour and texture obtained from the dried tomatoes and sweet pepper and that obtained from them when fresh (prior to drying), except for okro that shows a significant difference in colour quality.
   (b) Evidence of shrinkage is observed for size and shape which indicates a reduction in space to be occupied for packaging and storage of the dried vegetables.
   (c) The final moisture content observed with the temperature-time relationship of 65^0C for 5 hours employed are 3.69%, 3.2% and 3.1% for tomatoes, okro and sweet pepper respectively, which indicates an appropriate moisture content for good storage since it has been observed by Hall et al. (1986) that the level

of moisture required, to prevent microbial growth is less than 10% and that for prevention of biochemical deterioration is less than 5%. It has also been noted that for safekeeping and storage of vegetables in particular, about 90% of the present water is required to be removed (Maudkordylas, 1990).

6.2 RECOMMENDATIONS

Statistical analysis of the evaluation of the colour quality of okro shows that there is a significant loss of the green colour (chlorophyll) pigment during drying at the fitted model given. To prevent enzymatic browning and to retain the good colour and texture of okro.

The following are recommended:

1. Chemical dips such as 0.5 percent potassium bicarbonate, and 1.0 percent sodium bicarbonate solution.
2. Use of solution dip of 2 percent salt + 0.5 percent potassium metabisulphite (Maudkordylas, 1990).

Indication of any improved treatment given would be necessary on the label of such dried vegetables for proper information to the consumers in case of individuals that might be sensitive to any of such chemicals.

Air tight containers, such as polythene bags or glass jars re recommended for storage of dried vegetables, to avoid moisture being picked up.

It is highly recommended that the developed models are valid only for values of X_i that fall within the intervals of values used in producing them. user who employs the models for values outside these intervals is guilty of extrapolations. The models are purely for dying using tray-dryer however, the general rule is:

The higher the drying temperature, the lower the drying time; the lower the final moisture content, the higher the shelf life.

REFERENCES

Adgidzi,D and Olorunsogo S.T. (1998). Optimisation of Ascorbic Acid content in Pineapple Juice. Proc. Of the Nigerian institute of Food Science and Technology, Abeokuta.

Ali, H.M. and Sakr I.A (1981). Drying of vegetables in Egypt. Food drying Proc. of a workshop held at Edmentoh Alberta 6-9 July 1981 Pp 15 – 19

Anita, Tull (1999). Food and Nutrition Pp 112 –120.

Brennan, J.N. Butters N.D. (1976) Food Engineering Operations second Edition Applied Science Publication Limited London Pp 313 – 329

Carl W. Hall et al. (1986) Encyclopedia of Food Engineering AV1 Publishing Connecticut Pp 229 –410.

Charles R. Hicks (1973) Fundamental Concepts in the Design of Experiments Holt, Rinchart and Winston Inc, U.S.A. Pp 108 – 141

Clayton Dalal (1981). Black Agricultural Dictonary 2nd Edition Published by Wheaton and Coltd Exter Devon Pp, 166, 392.

Derek, Joy and E.J. Wibberley (1979). Tropical Agricultural Hand Book Pp 108 –112

Desrosier, N.W and Desrosier J.N. (1977) The Technology of Food preservation Fourth Edition Avi Duplication Co. INC. West port Connecticut Pp 312, 343 – 347

Douglas, C. Montgomery (1991). Design and Analysis of Experiments (Third Edition) John Wiley and sons, New York. Pp. 197 – 208, 230 – 235, 270-309, 498 – 513, 541 – 543.

Earle, R.L (1988). Unit Operation in Food Processing second Edition Pergamon press Limited Oxford England Pp 126 –164.

Eke, A.B. (1995).Tomato drying (A paper presented at The Nigeria Society of Agricultural Engineers conference.

Fields, M.L (1977). Laboratory Manual in Food preservation AV1 publishing co inco. West port Connecticut Pp 49-73.

Henkel, C.E. (1960). Effects of drying and dehydration on Food nutrients Nutritional evaluation of Food processing 1st Edition Pp 148 – 157.

Hill, Popp Grove (1982).I MH second Edition published by Tata Mc Grew-Hill publishing company Ltd; New Delh1 Pp 259 – 260.

Holds, Worth S.D (1971). Dehydration of Food product. A review Journal of Food Technology vol. No 4. Pp 331 – 370.

In he koronye A.I, and Ngoddy P.O. (1985). Integrated Food Science and Technology for theTropics Mac Millon Publishers London Pp 183 – 189, 220.

Irwin Guttmen et al. (1982). Introductory Engineering Statistics. Third Edition, Published by John Wiley and son U.S.A. Pp 445 – 481.

Jackson, T.H., Mohammed B.B. (1985). Sundrying of Fruits and vegetables Agricultural Services Bulletin No 5 (Rome FAO). Pp 8 – 10.

Kwanchai, A. Gomez and Arturo, A Gomez (1984). Agricultural Research 2nd Edition published by John wiley and Sons Pp. 458 – 477.

Mahmood, B.A, Shah W.H (1980). National Seminar on Dehydration, preservation of vegetables and Fruits Pp 18-24.

Maudkcordylas, (1990). Processing and preservation of Tropical and sub Tropical Foods. ELBS with Macmillan Education Ltd, Hond Mills Basing atoke, Hemsphire Pp 187 – 190, 240 –245.

Mayhew, Y.R. and Rogers G.F.C. (1977). Thermodynamics and Transport properties of Fluids second Edition published by Oxford Basil Blackwell Pp 2 –3.

Mc Carthy D. (1986) Concentration and Drying of Foods. Applied Science publishers Limited England Pp. 1 – 10.

Michael, J.I (1990). Physical properties of Foods and Food processing systems Ellis Horwood Ltd. West suss ex Pp 32 –45.

Normen, W. Desrosier (19977). Elements of Food Technology AV1 publishing company INC. West Port, Connecticut Pp. 7 – 20, 219-246.

Nur I., N. Moh Senin (1986). Physical properties of plant and Animal Materials (Second Revised and updated Edition). Pp 1 – 3, 15 – 16, 79 – 92, 383 – 454.

Nigeria Stored products Research (1990). No 4 Pp 7.

Ogazi Jones, M.C (1990). Food Journal Nigerian Institute of Food Science and Technology Vol. 8 Pp - 85.

Oscar, A. Lorenz, Donald, N. Maynard (1980). Knott's Hand book for Vegetable Growers Pp 2-4, 29, 294-305.

Owen, R. Fennema (1976). Principles of Food Science Marcel Dekker Inc. Newyord Pp 35 6-381, 770 –775.

Oyeniran, J.O. (1988) Reports of Activities of the Nationally co-ordinated Research proc. of the National Workshop on improved packaging and storage systems for Fruits and Vegetables in Nigeria, Ilorin Kwara State.

Peggi, oti – Boateng (1993). Drying Food Cycle Technology source Book 6 United Nations Development fund for women Pp 8 – 25.

Rao, S.S (1977). Optimisation: Theory and application. Wiley eastern Ltd. New Delti Bangalone Bombcy Calcutta Pp. 1 – 3, 9.

Rice R. P. et al. (1993). Fruit and vegetable production in Africa Pp 231 – 239

Samprit, Chatter jec, Bertram price (1991). Regression Analysis by example second Edition John Willey and Son inc. New York Pp 3-10, 59, 62 – 65, 74.

Solanke, Richard (1998). Drying Characteristics of Selected Fruits and vegetables Abstract of a project report in the department of Food Technology Kaduna Polytechnic.

Spiers, C.I, Coote H.C (1986). Solar drying practical methods of Food preservation, international labour organisation, Geneva Switzerland Pp. 79-105.

Thomas, M. Little, F. Jackson Hills (1978). Agricultural Experimentation Design and analysis published by John wiley and Sons Newyork. Pp 42 – 60, 185-186 29-250, 258 –266.

Tindall, H.D. (1988). Vegetables in the Tropics. Third Edition published by Mac Millan Education Limited London Pp 5 27 – 533.

Williams, A.A. (1981) Quality in stored and processed vegetables and Fruit Academic press incorporation Limited London. Pp 17.

Williams, A.A. (1982). Scoring methods in the sensory analysis of Foods and beverages at Long Aston Research station Journal of Food Technology 17, 163 – 175.

Yaciuk, G. (1981) Food Drying Proc. of a Workshop held or Edmonton Alberta 6 – 9 July ottowa International Development Research Centre Pp 15 – 19, 31 – 33.

COLOUR SCORING QUESTIONNAIRE

Name: ____________________________

Date: ____________________________

Please evaluate these samples of dried vegetables for colour (Appearance)

Check the point on the scale that best describes your evaluation of the samples as compaired with the original, standard (Fresh) sample R

Sample code colour numerical scoring scale

CODE	R	1	2	3	4	5	6	7	8
CODE	A_{11}	1	2	3	4	5	6	7	8
CODE	A_{12}	1	2	3	4	5	6	7	8
CODE	A_{13}	1	2	3	4	5	6	7	8
CODE	A_{21}	1	2	3	4	5	6	7	8
CODE	A_{22}	1	2	3	4	5	6	7	8
CODE	A_{23}	1	2	3	4	5	6	7	8
CODE	A_{31}	1	2	3	4	5	6	7	8
CODE	A_{32}	1	2	3	4	5	6	7	8
CODE	A_{33}	1	2	3	4	5	6	7	8
CODE	A_{41}	1	2	3	4	5	6	7	8
CODE	A_{42}	1	2	3	4	5	6	7	8
CODE	A_{43}	1	2	3	4	5	6	7	8

SCORING RATING

Extremely dull Red	=	1
Very dull Red	=	2
Moderately dull Red	=	3
Slightly dull Red	=	4
Slightly bright Red	=	5
Moderately bright Red	=	6
Very bright Red	=	7
Extremely bright Red	=	8

Comments:

COLOUR SCORING QUESTIONNAIRE

Name: ______________________________

Date: ______________________________

Please evaluate these samples of dried vegetables for colour (Appearance)

Check the point on the scale that best describes your evaluation of the samples as compaired with the original, standard (Fresh) sample R

Sample code colour numerical scoring scale

CODE	R	1	2	3	4	5	6	7	8
CODE	B_{11}	1	2	3	4	5	6	7	8
CODE	B_{12}	1	2	3	4	5	6	7	8
CODE	B_{13}	1	2	3	4	5	6	7	8
CODE	B_{21}	1	2	3	4	5	6	7	8
CODE	B_{22}	1	2	3	4	5	6	7	8
CODE	B_{23}	1	2	3	4	5	6	7	8
CODE	B_{31}	1	2	3	4	5	6	7	8
CODE	B_{32}	1	2	3	4	5	6	7	8
CODE	B_{33}	1	2	3	4	5	6	7	8
CODE	B_{41}	1	2	3	4	5	6	7	8
CODE	B_{42}	1	2	3	4	5	6	7	8
CODE	B_{43}	1	2	3	4	5	6	7	8

SCORING RATING

Extremely dull Green	=	1
Very dull Green	=	2
Moderately dull Green	=	3
Slightly dull Green	=	4
Slightly bright Green	=	5
Moderately bright Green	=	6
Very bright Green	=	7
Extremely bright Green	=	8

Comments:

COLOUR SCORING QUESTIONNAIRE

Name: ______________________________

Date: ______________________________

Please evaluate these samples of dried vegetables for colour (Appearance)

Check the point on the scale that best describes your evaluation of the samples as compaired with the original, standard (Fresh) sample R

Sample code colour numerical scoring scale

CODE	R	1	2	3	4	5	6	7	8
CODE	C_{11}	1	2	3	4	5	6	7	8
CODE	C_{12}	1	2	3	4	5	6	7	8
CODE	C_{13}	1	2	3	4	5	6	7	8
CODE	C_{21}	1	2	3	4	5	6	7	8
CODE	C_{22}	1	2	3	4	5	6	7	8
CODE	C_{23}	1	2	3	4	5	6	7	8
CODE	C_{31}	1	2	3	4	5	6	7	8
CODE	C_{32}	1	2	3	4	5	6	7	8
CODE	C_{33}	1	2	3	4	5	6	7	8
CODE	C_{41}	1	2	3	4	5	6	7	8
CODE	C_{42}	1	2	3	4	5	6	7	8
CODE	C_{43}	1	2	3	4	5	6	7	8

SCORING RATING

Extremely dull Red	=	1
Very dull Red	=	2
Moderately dull	=	3
Slightly dull Red	=	4
Slightly bright Red	=	5
Moderately bright Red	=	6
Very bright Red	=	7
Extremely bright Red	=	8

Comments:

TEXTURE SCORING QUESTIONNAIRE

Name: ______________________________

Date: ______________________________

Please evaluate these samples of dried vegetables for colour (Appearance)

Check the point on the scale that best describes your evaluation of the samples as compaired with the original, standard (Fresh) sample R

Sample code colour numerical scoring scale

CODE	R	1	2	3	4	5	6	7	8
CODE	A_{11}	1	2	3	4	5	6	7	8
CODE	A_{12}	1	2	3	4	5	6	7	8
CODE	A_{13}	1	2	3	4	5	6	7	8
CODE	A_{21}	1	2	3	4	5	6	7	8
CODE	A_{22}	1	2	3	4	5	6	7	8
CODE	A_{23}	1	2	3	4	5	6	7	8
CODE	A_{31}	1	2	3	4	5	6	7	8
CODE	A_{32}	1	2	3	4	5	6	7	8
CODE	A_{33}	1	2	3	4	5	6	7	8
CODE	A_{41}	1	2	3	4	5	6	7	8
CODE	A_{42}	1	2	3	4	5	6	7	8
CODE	A_{43}	1	2	3	4	5	6	7	8

SCORING RATING

Extremely dull rough	=	1
Very dull rough	=	2
Moderately dull rough	=	3
Slightly dull rough	=	4
Slightly bright smooth	=	5
Moderately bright smooth	=	6
Very bright smooth	=	7
Extremely bright smooth	=	8

Comments:

TEXTURE SCORING QUESTIONNAIRE

Name: ______________________________

Date: ______________________________

Please evaluate these samples of dried vegetables for colour (Appearance)

Check the point on the scale that best describes your evaluation of the samples as compaired with the original, standard (Fresh) sample R

Sample code colour numerical scoring scale

CODE	R	1	2	3	4	5	6	7	8
CODE	B_{11}	1	2	3	4	5	6	7	8
CODE	B_{12}	1	2	3	4	5	6	7	8
CODE	B_{13}	1	2	3	4	5	6	7	8
CODE	B_{21}	1	2	3	4	5	6	7	8
CODE	B_{22}	1	2	3	4	5	6	7	8
CODE	B_{23}	1	2	3	4	5	6	7	8
CODE	B_{31}	1	2	3	4	5	6	7	8
CODE	B_{32}	1	2	3	4	5	6	7	8
CODE	B_{33}	1	2	3	4	5	6	7	8
CODE	B_{41}	1	2	3	4	5	6	7	8
CODE	B_{42}	1	2	3	4	5	6	7	8
CODE	B_{43}	1	2	3	4	5	6	7	8

SCORING RATING

Extremely dull rough	=	1
Very dull rough	=	2
Moderately dull rough	=	3
Slightly dull rough	=	4
Slightly bright smooth	=	5
Moderately bright smooth	=	6
Very bright smooth	=	7
Extremely bright smooth	=	8

Comments:

TEXTURE SCORING QUESTIONNAIRE

Name: ______________________________

Date: ______________________________

Please evaluate these samples of dried vegetables for colour (Appearance)

Check the point on the scale that best describes your evaluation of the samples as compaired with the original, standard (Fresh) sample R

Sample code colour numerical scoring scale

CODE	R	1	2	3	4	5	6	7	8
CODE	C_{11}	1	2	3	4	5	6	7	8
CODE	C_{12}	1	2	3	4	5	6	7	8
CODE	C_{13}	1	2	3	4	5	6	7	8
CODE	C_{21}	1	2	3	4	5	6	7	8
CODE	C_{22}	1	2	3	4	5	6	7	8
CODE	C_{23}	1	2	3	4	5	6	7	8
CODE	C_{31}	1	2	3	4	5	6	7	8
CODE	C_{32}	1	2	3	4	5	6	7	8
CODE	C_{33}	1	2	3	4	5	6	7	8
CODE	C_{41}	1	2	3	4	5	6	7	8
CODE	C_{42}	1	2	3	4	5	6	7	8
CODE	C_{43}	1	2	3	4	5	6	7	8

SCORING RATING

Extremely dull rough	=	1
Very dull rough	=	2
Moderately dull rough	=	3
Slightly dull rough	=	4
Slightly bright smooth	=	5
Moderately bright smooth	=	6
Very bright smooth	=	7
Extremely bright smooth	=	8

Comments:

APPENDIX 7

TABLE 3.4 EXPERIMENTAL DATA

EXP NO	toc X_1	td(hr) X_2	X_0	X_1	X_2	X_{12}	Y_{U1} Y_{U2} Y_{U3}	TOTAL Y_u	MEAN Y_u	$Y_U - \overline{Y_U}$	$(Y_U - \overline{Y_U})^2$	$Y_{U2} - \overline{Y_U}$	$(Y_{Us} - \overline{Y_U})^2$	$Y_{U3} - \overline{Y_U}$	$(Y_{U2} - \overline{Y_U})^2$	S^2_U
Y_1	65	3	+	+	–	–										
Y_2	35	3	+	–	–	+										
Y_3	65	5	+	+	+	+										
Y_4	35	5	+	–	+	–										

$Y_{uj} = u + 6_u + 6_j + \sum_{uj}$ 3.3

Where:- (Irwin et al, 1982)

Y_{uj} are the observed moisture content values.

U = 1 -- 3
J = 1 -- 4

6_u are the batch or sample effects

6_j are the treatment effects

APPENDIX 8

TABLE 4.2 OBSERVED MOISTURE CONTENT AND STATISTICAL ANALYSIS OF DRIED TOMATOES (Lycopersicum esculentum)

EXP NO	t°c X_1	Td(hr) X_2	X_0	X_1	X_2	X_{12}	Y_{U1}	Y_{U2}	Y_{U3}	TOTAL Y_u	MEAN Y_u	$Y_U - \bar{Y}_U$	$(Y_U - \bar{Y}_U)^2$	$Y_{U2} - \bar{Y}_U$	$(Y_{US} - \bar{Y}_U)^2$	$Y_{U3} - \bar{Y}_U$	$(Y_{U2} - \bar{Y}_U)^2$	S^2_U
Y_1	65	3	+	+	–	–	9	8.09	8.09	25.18	8.39	-0.61	0.3721	-0.3	0.09	-0.3	0.09	0.276
Y_2	35	3	+	–	–	+	13.29	12.33	12.33	37.95	12.65	0.64	0.4096	-0.32	0.1024	-032	0.1024	0.307
Y_3	65	5	+	+	+	+	3.76	3.76	3.55	11.07	3..69	0.07	0.0049	0.07	0.0049	-0.14	0.0196	0.015
Y_4	35	5	+	–	+	–	10.11	9	9	28.11	9.37	0.74	0.5476	-0.37	0.1369	-0.37	0.1369	0.411
											$\sum$ 34.1							

APPENDIX 9

TABLE 4.7 OBSERVED MOISTURE CONTENT AND STATISTICAL ANALYSIS OF DRIED OKRO (Hibiscus esculentus)

EXP NO	t°c X_1	Td(hr) X_2	X_0	X_1	X_2	X_{12}	Y_{U1}	Y_{U2}	Y_{U3}	TOTAL Y_u	MEAN Y_u	$Y_U - \overline{Y_U}$	$(Y_U - \overline{Y_U})^2$	$Y_{U2} - \overline{Y_U}$	$(Y_{US} - \overline{Y_U})^2$	$Y_{U3} - \overline{Y_U}$	$(Y_{U2} - \overline{Y_U})^2$	S^2_U
Y_1	65	3	+	+	–	–	5.67.	6.14	5.67	17.48	5.83	-0.16	0.0256	0.13	0.0961	-0.16	0.0256	0.074
Y_2	35	3	+	–	–	+	9	8.09	8.09	25-18	8.39	0.61	0.3721	-0.3	0.09	-0.3	0.09	0.276
Y_3	65	5	+	+	+	+	3.35	3.17	3.17	9.69	3.23	0.12	0.0144	-0.06	0.0036	-0.06	0.0036	0.011
Y_4	35	5	+	–	+	–	6.14	5.67	6.14	17.95	5.98	0.16	0.0256	-0.31	0.0961	0.16	0.0256	0.074
											$\sum$ 23.43							

APPENDIX 10

TABLE 4.12 OBSERVED MOISTURE CONTENT AND STATISTICAL ANALYSIS OF DRIED SWEET PEPPER (Capsicum annuum)

EXP NO	t°c X_1	Td(hr) X_2	X_0	X_1	X_2	X_{12}	Y_{U1}	Y_{U2}	Y_{U3}	TOTAL Y_u	MEAN Y_u	$Y_U - \bar{Y}_U$	$(Y_U - \bar{Y}_U)^2$	$Y_{U2} - \bar{Y}_U$	$(Y_{US} - \bar{Y}_U)^2$	$Y_{U3} - \bar{Y}_U$	$(Y_{U2} - \bar{Y}_U)^2$	S^2_U
Y_1	65	3	+	+	–	–	6.14	5.67	5.67	17.48	5.83	0.31	0.096	-0.16	0.0256	0.16	0.0256	0.074
Y_2	35	3	+	–	–	+	9	8.09	8.09	25.18	8.39	0.61	0.3721	-0.3	0.09	-0..3	0.09	0.276
Y_3	65	5	+	+	+	+	3.17	3	3.17	9.34	3.11	0.06	0.0036	0.11	0.012	-0.06	0.0036	0.010
Y_4	35	5	+	–	+	–	7.33	6.69	6.69	20.71	6.90	0.43	0.185	-0.21	0.044	-0.21	0.044	0.137
											∑ 24.23							∑ 0.497

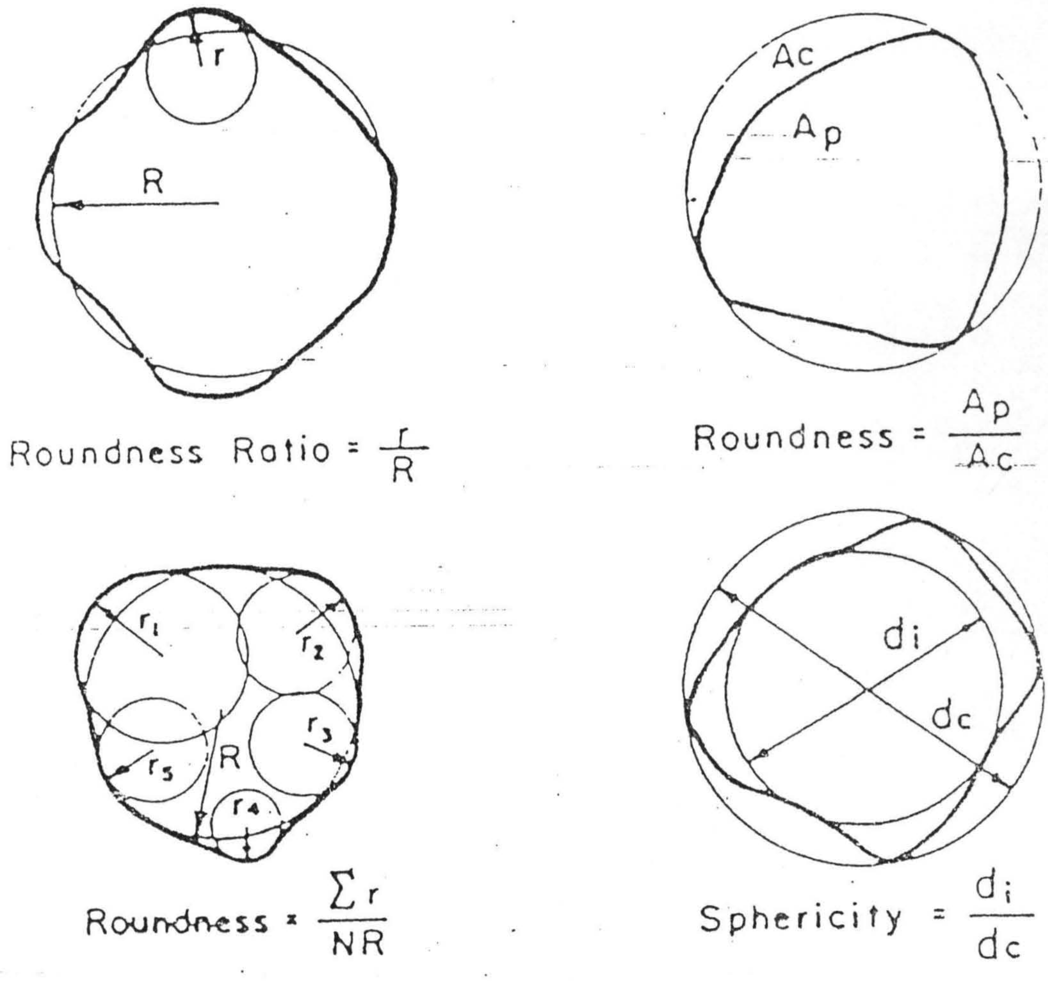

Fig. 3.24 Roundness and sphericity as defined by geologists to describe shape of grains and pebbles (Mohsenin, 1986)

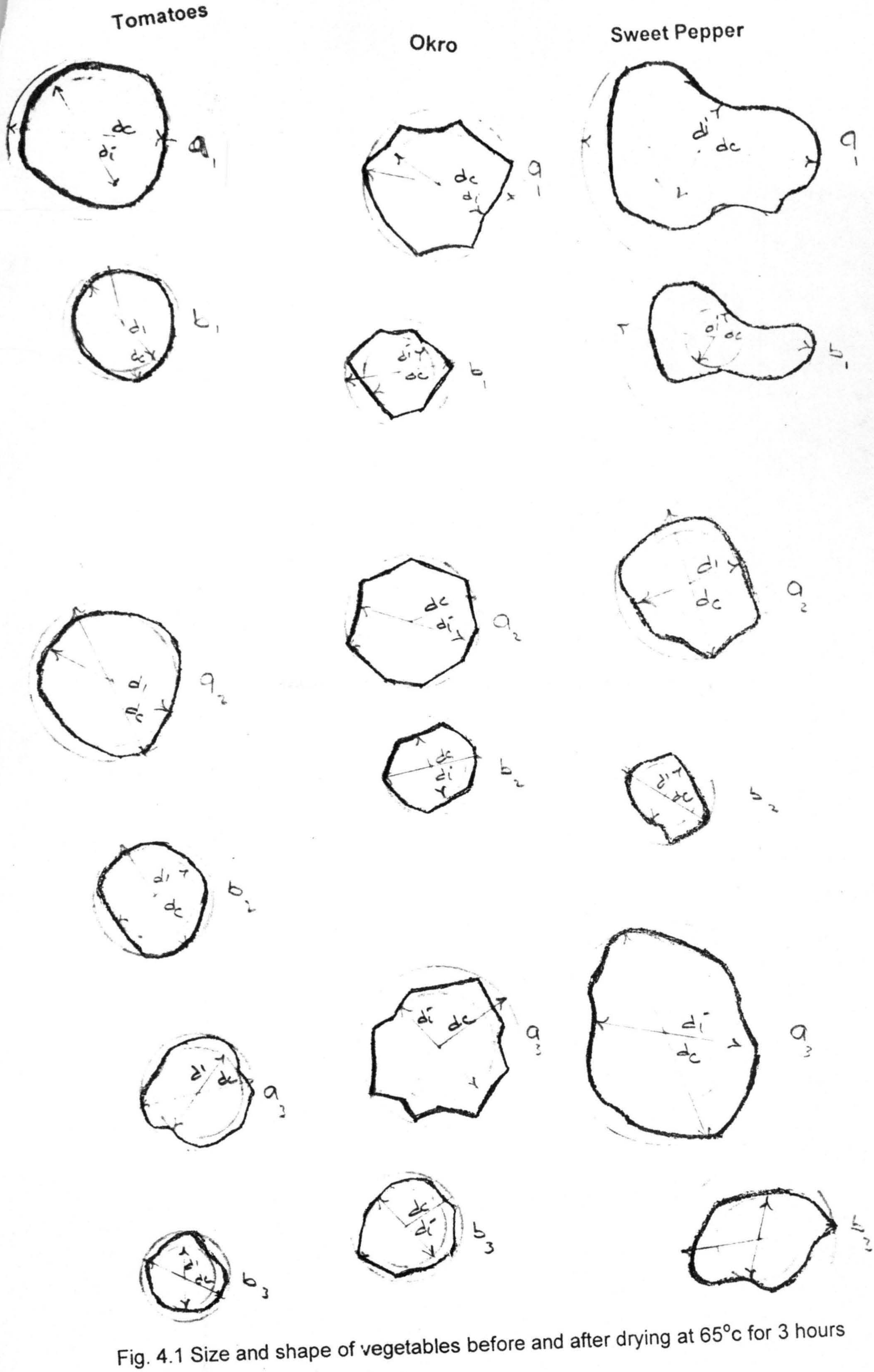

Fig. 4.1 Size and shape of vegetables before and after drying at 65°c for 3 hours

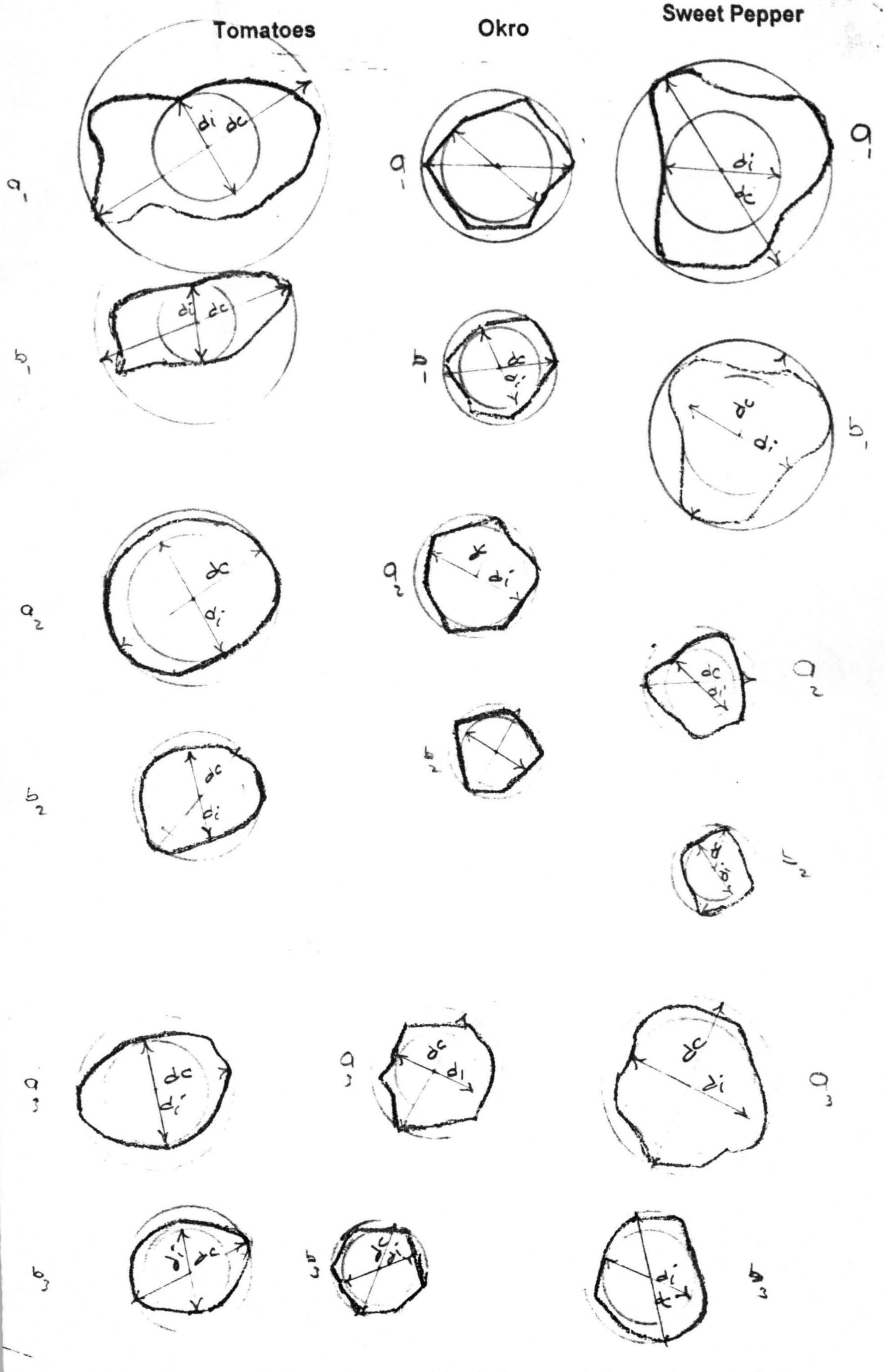

Fig. 4.2 Size and shape of vegetables before and after drying at 35°c for 3 hours

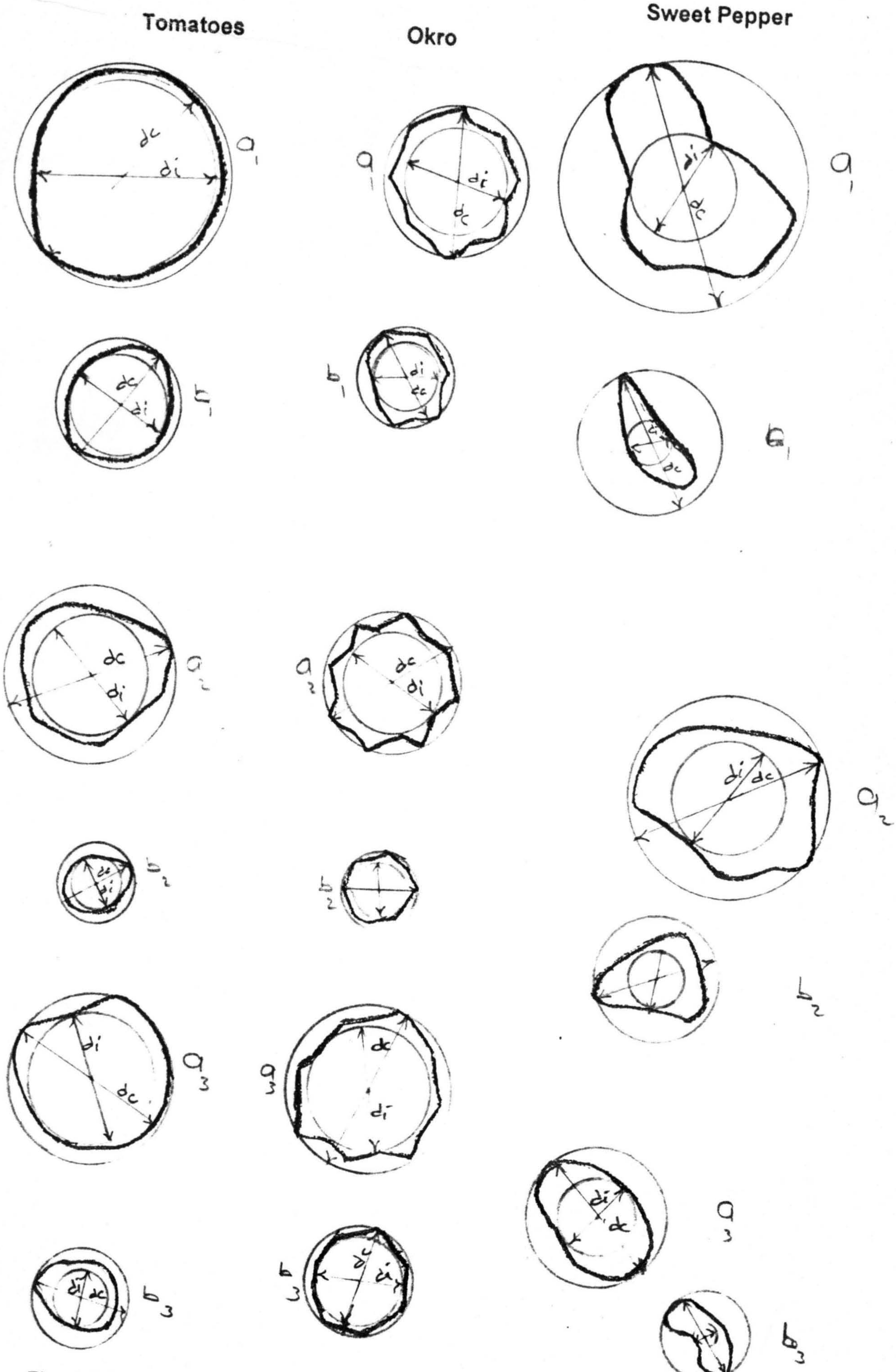

Fig. 4.3 Size and shape of vegetables before and after drying at 65°c for 5 hours

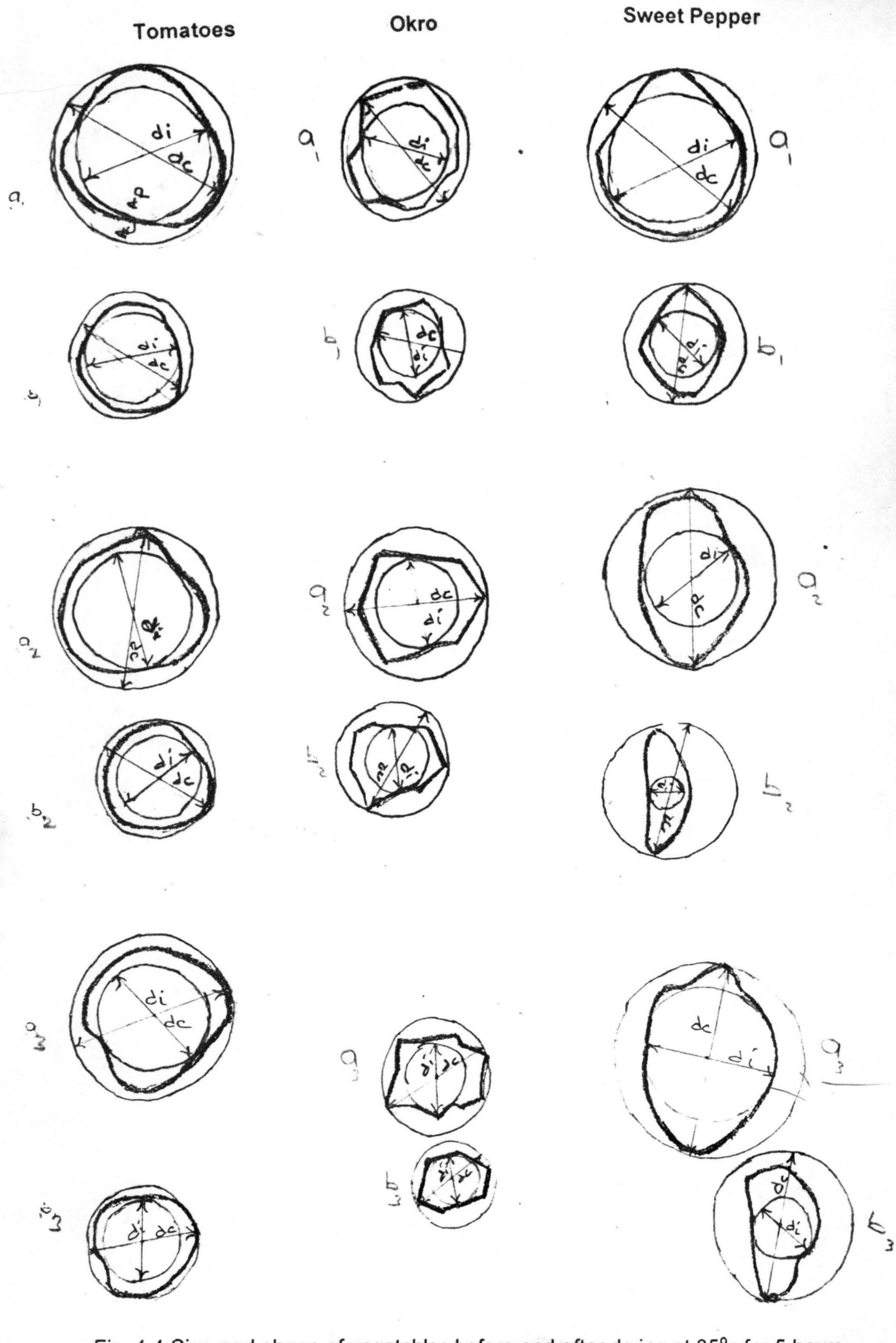

Fig. 4.4 Size and shape of vegetables before and after drying at 35°c for 5 hours