MODELLING THE EFFECTS OF STEAM BLANCHING AND SULPHITING ON THE RETENTION OF β–CAROTENE IN DRIED TOMATO (*Lycopesicum esculentum*)

BY

MUSA-MAKAMA, ADEYINKA LARABA (MRS)
(M.ENG./SEET/98/276)

A THESIS SUBMITTED TO THE POST-GRADUATE SCHOOL IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTERS IN ENGINEERING DEGREE IN AGRICULTURAL ENGINEERING
(CROP PROCESSING AND STORAGE OPTION)

FEDERAL UNIVERSITY OF TECHNOLOGY
MINNA, NIGERIA

JUNE, 2005

CERTIFICATION

This thesis "Modelling the Effect of Steam Blanching and Sulphiting On the Retention of β Carotene in Dried Tomato" (***Lycopesicum esculentum***) by MUSA-MAKAMA, ADEYINKA LARABA (MRS.) (M.ENG/SEET/98/276) meets the regulations governing the award of Masters in Engineering (M.ENG) Degree in Agricultural Engineering of the Federal University of Technology, Minna, and is approved based on its contributions to scientific knowledge and literary presentation.

..... 20-06-05

Engr, Dr D. Adgidzi — DATE

Supervisor

..... 20/06/05

Dr E.O. Ogbadoyi — DATE

Co- Supervisor

..... 20.06.05

Engr. Dr. D. Adgidzi — DATE

Head of Department/Chief Internal Examiner

Dr S.I. Oluka 5/05/2005

External Examiner — DATE

..... 19/08/05

Professor E. O. Akinbode — DATE

Dean, SEET

....

Professor J. A. Abalaka — DATE

Dean, Postgraduate School.

DEDICATION

This work is dedicated to **ELSHADDAI**

And

To my darling daughter **JOY**

A gift from God to the generation of womanhood

ACKNOWLEDGEMENT

I give God praise and thanks for His grace and divine enablement to do this work; I couldn't have been able to do it without his help. I appreciate my project supervisor who is also the Head of department of Agricultural Engineering, FUT Minna, Engr. Dr D. Adgidzi for every effort rendered to make this research work successful. I am also grateful to my co- supervisor Dr Ogbadoyi of Biochemistry department FUT. Minna who went through this report. My sincere thanks go to all the staff of Agricultural Engineering Department, FUT Minna who in a God fearing manner imparted knowledge into me. Particular appreciation goes to Engr. Dr. (Mrs). Z.D Osunde who encouraged me all through. God bless you.

I deeply appreciate my dear son Rhema who stayed beside me at all times with patience and love, and cared so greatly. I give God praise for my little daughter Joy who endured my absence most nights and days. God bless you both for being there. I also appreciate my parents, brothers and sisters who never left me alone especially Oriyomi Anthony who loved, cared and supported my children and I.

I am indebted to the following people who worked hard with me to bring out the results presented herein. Dr Evans Egwim, Miss Caroline Akpu, Pastor Dan Adinoyi, and Mr. Samuel Olorunsogo (ADP, Bida).

I am sincerely grateful to the following persons; Deacon Philip Obasohan, Mr. Uwala (NCRI), Dr Abiodun Ojenuwah (F.M.C, Bida), my beloved sister and friend Mrs. Fumilayo Falusi, and my 'son' Philip Odekunle, whose love, care, and prayers kept me all through particularly when I was ill.

"Silver and Gold, I have not", but all of you and several others not mentioned here who have been a blessing to me shall ever remain blessed.

ABSTRACT

A series of experiments were conducted to determine the drying rates of pre-treated tomato as well as the effect of the pre-treatments (Steam blanching and Sulphiting) on the retention of β-carotene in the dried tomato. The experiments were conducted using a 2^2 full factorial design. Two factors, steam blanching time (X_1) and sulphite concentration (X_2) at two levels (coded as - and +) were investigated under different drying conditions. Pre-treatments resulted in lose of moisture in samples before drying in the range of 0.078% -- 3.78% db. All samples were dried using tray dryer at air temperatures of 65°c and 50°C and velocity of 2.0m/s, as well as sun drying to 4 ± 0.1% (wb) (i.e. 0.042 ± 0.001% db). Total drying time was reduced by 17 – 47.09%, 8.3 – 33.3% and 9.03 – 54.54% in 65°C, 50°C and sun drying experiments respectively. The model developed showed that steam blanching and sulphiting have higher significance difference in retention of β-carotene than interactions of these factors at 5% and 1% levels of significance. This showed percentage retention of 48.41 – 87.82%, 43.17 – 76.7%, and 27.8 – 57.45% in 65°C, 50°C and sun drying conditions respectively. Sulphiting showed a higher significant effect than steam blanching. Both constant rate and falling rate periods in the drying process were affected by pre-treatment. A constant rate of water removal values of 42.90 gH_2O/ hr, 12.76 gH_2O/hr and 4.11 gH_2O/hr for 65°C, 50°C tray drying and sun drying conditions respectively were highest and obtained in the 3-minutes steam blanched samples. The diffusion model fitted experimental data with coefficient of determination R in the ranges of 0.83 – 0.986 in 65°C, 0.98 – 0.99 in 50°C tray drying and 0.85 – 0.98 in sun drying conditions. Values of drying constant k were obtained for all samples. Samples sulphited at 2000 ppm had highest value of k, 2.05 $^{-}$1, 1.57 hr $^{-}$1 and 1.45 hr $^{-}$1 for 65°C, 50°C and sun drying conditions respectively. The non-linearity of tomato drying process over a longer period of drying may be attributed to the nature of the material. The obtained k – values can be used to describe an average drying behavior of tomato over the range of moisture content of samples investigated.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF NOTATIONS

ρ	=	Bulk density
a	=	Constant in drying equation
a	=	Air
b	=	Regression coefficient
c	=	constant, critical point
D	=	Diffusion coefficient
d	=	Depth or thickness of bed
db	=	Dry basis
D_f	=	Dilution factor
D_m	=	Dry matter content
dM/dt	=	Drying rate
e	=	Equilibrium
f	=	Final Moisture
w	=	Water
G	=	Mass flow rate
h_c	=	Convective heat transfer coefficient
h_t	=	Total heat transfer coefficient
i	=	Initial Moisture
k	=	Drying rate constant
Kg	=	Mass transfer coefficient
M	=	Moisture content %db or %wb
MR	=	Moisture ratio
n	=	Constant
p	=	Vapour pressure
S	=	Surface
t	=	Time
T	=	Temperature

V	=	Volume
v	=	Velocity
W	=	Weight
wb	=	Wet basis
X_1	=	Steam blanching time
X_2	=	Sulphiting concentration
Y_u	=	Response variable
λ	=	latent heat of evaporation
β	=	Beta Carotene

CHAPTER ONE

1.0 INTRODUCTION

1.1 NATURE AND CLASSIFICATION OF VEGETABLES

Vegetables are essential crop for a nutritionally balanced diet. They are major source of vitamins A and C and minerals such as iron, calcium and potassium. Most vegetables contain 60 to 90 percent biologically active water, low protein and fat, and have high digestible and indigestible cellulose (Mircea, 1995). Vitamin A precursor (carotenoids) is found in leafy-green, yellow and orange colored vegetables. Vegetable classification falls into groups such as leafy, stem, roots, tubers as well as fruity vegetables. Common vegetables include those in the leafy and fruit classes. Those in the fruit class include tomato, okra, sweet and hot pepper, and garden eggs. The high water content in vegetables is a primary factor in their deterioration and post harvest losses. Their susceptibility to spoilage makes them have short shelf life. Loses due to spoilage, do not only represents an economic loss, but tragically represents nutritional loses apart from shortage in all-year-round supply.

Preservation is the process or method of preventing losses due to deterioration thus extending the storage life of a produce. The principles of preservation are based on manipulation of the environmental and product conditions that aid enzymic and microbial agents of spoilage. Drying is probably the oldest method of preservation practiced by mankind and according to Ihekoronye and Ngoddy (1985), seems the most adequate method under most conditions in developing economies. It tends to extend the shelf life of vegetables beyond the few weeks they are in season. Traditionally, in developing countries natural sun drying is the method of drying vegetables.

Vegetables are heat sensitive and therefore present special problems in drying because the major nutrients are easily destroyed by heat. Prolong heat treatment such as in sun drying result into loss of flavour, decrease in nutritional quality (vitamin losses) and a marked decline in colour and taste, thus poor acceptability of dried products by consumers. New drying technologies that give more attention to drying conditions and food quality during drying have been developed, (McCarthy, 1986). Such techniques include heated air-drying, (tray and spray), vacuum drying, freeze-drying, solar drying etc. However, the economic involvement of

these systems has been a major barrier to their use by rural farmers, thus leaving direct sun drying as the only alternative.

Vegetables, which are commonly dried for storage, include tomato, okra, pepper etc. Tomato has been reported to rank 1st both in production and consumption among others in Nigeria (Adedipe et al. 1995). This makes it a vital source of vitamin A and C and minerals such as iron and calcium. β - Carotene is an important vitamin A precursor

1.2 STATEMENT OF THE PROBLEM

According to Igene (1996), World Bank reported a high level of micronutrient deficiency especially vitamin A and iron among Nigerians. This situation is partly attributed to high post- harvest losses in vegetables, poor processing, preservation and storage methods. High water content, favourable temperature, high P^H and other environmental conditions are factors favourable to enzymes and microbial activities. These conditions are prevalent in hot-humid tropical climate found in Nigeria (Franklin et al. 1978). Under such conditions, fresh tomatoes have an extremely low level of natural protection against climate, pest, biochemical and physiological deterioration. Thus less than half of the quantity produced reaches the consumers in good quality. The high rate of spoilage between harvest and consumption does not only pose an economic loss but also tragically, nutritional losses.

Several storage systems are being employed for preservation of vegetables, but are inadequate in the maintenance of good quality on a long-term basis. For example, in okra, freezing causes loss of firmness, damage to tissues resulting into excessive softness (Taiwo, 1995; Ihekoronye and Ngoddy, 1985). Rural farmers adopt sun drying predominantly as a form of preservation. Quantitatively this method seems to help regulate the balance between demand and supply but the nutritional value, taste, colour, and odour of dried vegetables found in the local market stalls are poor and not satisfactory (Musa- Makama, 1999). Farmers spread products on open space, roofs, roadside and woven mats during The drying process, vegetables are not protected against dust, moisture, rodents or birds (Mottran, 1991) and (Abe and Basunia, 2001). Poor nutritional quality due to contamination with partly pathogenic microorganisms and incomplete or uneven drying characterize natural sun-dried vegetables.

One of the problems of conventional sun drying of vegetables is the slow drying rate and incomplete drying due to the low temperature of natural air. The accumulated effects of long direct contact with light, oxygen, and solar heat also result into vitamin A degradation,

discoloration and enzymic activities during and after sun drying. Studies have also shown oxidative damage to tomato after drying and also during storage. (Zanoni et al., 2000), (Eke, 1999) and (Solanke 1998). While the use of high temperature air increases drying rate, uneven drying due to surface case hardening is often inevitable, especially when cells are impermeable sufficiently enough for free moisture transport from within the product to the surface for removal.

Vegetables, which are commonly dried for storage, include tomato, okra, pepper etc. Tomato has been reported to rank 1st both in production and consumption among others in Nigeria (Adedipe et al. 1995). This makes it a vital source of vitamin A and C and mineral such as iron and calcium. β - Carotene, an important vitamin A precursor is found in yellow and orange colored vegetables such as potato, tomato, carrot etc. In view of it's high nutritional status and 100 percent bioactivity, the World Bank reiterates that this nutrient in diets cannot be substituted by supplements (World Bank, (2001). Generally, carotene will break down easily into its cis-form during sun drying and dehydration except there is an anti -oxidation protective treatment. Farmers who sundry tomato do not treat it prior to drying and this account to about 56-73 percent loss in carotene (Musa - Makama, 1999). A lot of people in the world are becoming increasingly aware of vitamin rich foods especially those in vitamin A and in the absence of good drying techniques, the price of fresh tomato fluctuates many fold during the year.

1.3 JUSTIFICATION OF THE RESEARCH

The retention of β - carotene during drying of tomato in view of its nutritional value as reported by Simmonne et al. (1997) and WHO (1995), becomes an imperative problem to be solved if the nutritional deficiency reported by the World Bank (Igene, 1996) is to be reduced. Processing this vegetable for adequate preservation during drying and in store is required to improve the intake of beta-carotene from dried tomato in order to meet vitamin A daily requirement. Drying and storage of dried vegetables can have detrimental effect on β-carotene if the effects of heat, oxygen and compounds that affect carotene degradation are not controlled by operations preceding drying.

Primary causes of carotene degradation during drying need to be controlled by manipulation of spoilage conditions as well as control of drying rate. Processing methods must

of necessity, include methods of reducing photo-oxidation and enzymic activities associated with carotene degradation as exhibited by discoloration seen in dried tomato in Nigerian markets, a condition which results from lack of pretreatment by local farmers. The rate of drying which is a function of the nature of drying air and the product also affect β- carotene retention. This vitamin is labile to heat and susceptible to oxidation. It is therefore important to find a relationship between pre-processing, and β- carotene degradation during drying under different conditions.

Preservation problems resulting from traditional sun drying which is a major way of preserving tomato are elaborate. These ranges from poor physical qualities to low nutritional values especially carotene, during drying and in storage. However, it is always possible to improve drying techniques to better respond to the demand of high quality dried product. While there is high demand for high vitamin foods, dried product can still meet this demand if quality is improved by improved processing techniques and conditions. In addition, the balance between supply and demand of fresh tomato can be regulated by drying when there is an over abundance during full production season. If properly processed and nutrients are retained to a high extent, dried tomato can be a good substitute for fresh one.

Since drying is used mostly to preserves tomato in developing countries including Nigeria, the factors that influence carotene retention during drying must be integrated in finding solution to its loss during drying. Through this integration, it is expected that a model for maximizing carotene retention during drying can be obtained. It would therefore be useful to examine an approach required to provide a suitable model of pre-drying treatments that are sensitive to carotene retention. This approach can be used to predict pretreatments that best retain carotene. The result of this work would contribute to knowledge in this area of drying which can be extended to rural farmers.

With a large tonnage of tomato being produced annually (9.646×10^3 metric tones, Adedipe et al. 1996) as well as tomato being a viable source of carotene, it is justified that techniques and methods capable of reducing loss in nutritional value during drying be developed. Increasing consumer market for properly processed tomato prompts this research into investigation of pre-drying treatments as a preservation technique. In view of increasing food requirement of the growing population, and to provide high quality product capable of meeting export standard, it is necessary to develop suitable methods beneficial to final quality.

In recent years the commercial importance of dried tomato slices have increased since they can be used as a component of several foods.

1.4 OBJECTIVE OF THE RESEARCH.

In view of the possibility of minimizing the loss of β- carotene by adequate pretreatments and drying conditions, the objectives of this research are:

- To determine the effect of pretreatments (steam blanching and sulphiting) and different drying conditions on the drying rates of tomato.
- To evaluate the quantity of β-carotene retained in pretreated tomato dried under different conditions using the open-column chromatography.
- To derive models that best describe the effect of different pretreatments (blanching, sulphiting) on β-carotene retention in tomato under different conditions.
- To obtain a way of pretreating and drying tomato in order to get maximum retention of β-carotene

1.5 SCOPE OF THE RESEARCH

This research work covers the cropping of fresh tomato, drying and biochemical analysis of dried samples. It is limited to tomato being the most widely grown and consumed vegetable in Nigeria and the world. The studies of the effect of blanching and sulphiting will be limited to β - carotene retention under tray and sun drying conditions.

CHAPTER TWO

2.0 REVIEW OF LITERATURE

2.1 VEGETABLE PRODUCTION TREND

Fruits and vegetables are either annual, biannual crops on multiple cropping systems. World estimates reveal that in developing countries, production of vegetables is about 80 percent of cereal production, which is above world average of 70 percent (FAO, 1989). In Nigeria vegetables are grown in large quantities across all ecological zones. It is therefore common to see large quantities of these crops in the rural and urban markets in Nigeria. However, unlike most developed economies, production estimates are rarely reliable. Production estimates of some selected vegetables are shown in table 2.1a in appendix 2. The high production has further been established by the upsurge in development of irrigation facilities and high yielding cultivars during the last decade of the 20^{th} century. Although seasonal productions are high, there are basic problems of spoilage and storage which makes supply of these seasonal crops fall short of demand nationally. Though reliable statistics of post-harvest losses are few, Oyeniran (1988) puts estimates as 35-50 percent in Nigeria.

Tomato (*Lycopersicum esculentum*) belongs to the economically important family of vegetables, the solanacea family. It is cultivated for its fleshy fruits. Tomato originated from Peru and Ecuador and today it is widely grown throughout the tropical and subtropical regions of the world including Nigeria. Tomato has been reported as ranking 2^{nd} in production among other vegetables of the world (Macrea et al. 1993) In Nigeria, tomato is one of the most important cultivated vegetables and an important component of the daily diet of most Nigerians, it is ranked 1^{st} both in production and consumption with annual production estimated at about 9.646×10^3 metric – tonnes, (Adedipe et al. 1996). Tomato is cultivated across most ecological zones during the wet season but predominantly in the northern zones during the dry season under irrigation (Swarup and Denton, 1988). Akinbolu et- al. (1991), reported that tomato production in the semi -arid ecological zones the peak harvest period is between January and March.

Description and Nutritional Importance of Tomato

Tindal (1983), and Villarreal (1980)discussed the botany of tomato. The domesticated tomato is described as a weak stemmed, trailing-multi-branch crop. It is a short-lived perennial

grown as annuals. The tomato plant has an extensive fibrous stem with small glistering yellow glandular hairs. The roots are vigorous while the leaves are spirally arranged with toothed pineas. The tomato fruit (literarily called tomato) is a fleshy berry with 2-9 loculi and shiny smooth skin when ripe. The shape and colour of tomato fruit is reported to vary according to cultivars (NIHORT, 1990) and (Grubben, 1977). The fruit's colour ranges from pink, orange, to red with carotene and lycopene as predominant pigment. According to Salunke and Dessai (1984b), pigment distribution varies with maturity and ripening, (Table 2.1b Appendix 2). The commercial and processing cultivars have elongated to square-shape fruits. Most of the local varieties are also reported as not suitable for processing due to variation in shape and size, and also fail to withstand processing requirement such as cutting, Mircea (1995). Varieties such as Roma VF, Ronita, Piacanza 0164, and Mazinina are processable cultivars and suitable for both wet and dry season cropping. Roma VF and Ronita are predominantly grown in the northern ecological zones (Quin, 1980).

Tomato though have low level of vitamin A and C, Macrea et al. (1993) reported that with its high level of consumption worldwide, it contributes significantly to Vitamin A, C, thiamin and niacin in human diet as well as minerals such as potassium, calcium and iron. Tomato seed contains twenty four percent (24%) semi- drying oil used in manufacture of margarine and soaps. Cake gotten after oil extraction is used as fertilizers and stock feed due to its protein content (Tindal 1983). The nutritional value of tomato is given in table 2.2 (Appendix 2).

2.2 VEGETABLE SPOILAGE, PROCESSING AND PRESERVATION

Spoilage in vegetables is due to two distinctive processes: (1) Autolysis: - the digestion of food by enzymes present within the tissues of the plant which are released when cell membranes lose there turgidity due to death and (2) Microbial attack: - this is the invasion by bacteria and fungi. The nature of these processes is what dictates the method of protecting the food in order to preserve the quality. High water content, favorable temperature, high P^H and other environmental conditions are factors favourable to enzymes and microbial activities. These conditions are prevalent in hot-humid tropical climate found in Nigeria (Franklin et al. 1978). Under such conditions, fresh vegetables have an extremely low level of natural protection against climate, pest, biochemical and physiological deterioration. Loses due to spoilage, do not only represents an economic loss, but tragically represent nutritional loses apart from shortage in all-year-round supply.

Preservation is the process or method of preventing losses due to deterioration thus extending the storage life of a produce. The principles of preservation are based on manipulation of the environmental and product conditions that aid enzymic and microbial agents of spoilage. The process of preserving fresh produce successfully must therefore ensure that the spoilage agents are destroyed or inhabited without destroying the nutritional value and palatability of the produce. The knowledge of deteriorating factors and the ways they act, including rate of deterioration in a specific food type give possible ways of limiting their action and obtaining product preservation. Various methods of preservation include:

- Physical methods: heating, cooling, lowering water content (drying), sterilization, filtration and pasteurization, Irradiation.
- Chemical methods: salting, smoking, addition of sugar, artificial acidification.
- Biochemical methods: lactic acid fermentation (natural acidification) alcoholic fermentation.

In order to maintain nutritional and organoleptic properties, not all identified methods have practical application to vegetable preservation. The methods that have found practical applications are those majorly used in preservation of fruits and vegetables. These techniques are directed at properties that aid food spoilage such as enzyme, active water content, hydrogen ion concentration, and nucleic acidity, which aids metabolic action. These preservation techniques include:

- Moisture removal- drying, dehydration and concentration
- Heat treatment- blanching, sterilization, and pasteurization.
- Low temperature preservation –freezing, refrigeration
- Chemical preservation- sulphuring and sulphiting.
- Acidity control- lactic fermentation.
- Irradiation.

According to Mircea (1995), if microbial and biochemical deteriorations are to be avoided, no single technique can be applied alone. A combination of two or three is required if the food value is to be preserved, for example, blanching (heat treatment) cannot completely inactivate enzymic activities without inducing non-desirable modification in produce. Also, while drying ensures microbial stability, undesirable modification such as vitamin losses, and

oxidation phenomena occurring during processing and storage are setbacks. Hence, vegetable preservation will often require the application of combined techniques.

The choice of preservation method depends on the product, the desired properties in storage, storage facilities, availability of energy and cost involved. Low temperature preservation is a relatively harmless method of preserving fruits and vegetables widely used in developed countries. However, the required sophisticated equipment, high cost and unavailability of electricity and fossil fuel put a limitation on its use in developing countries, (Abe and Basunia, 2001). In Nigeria, electricity supply is unsteady in urban areas and unavailable in most rural areas. The high cost and frequent scarcity of fossil fuel (i.e. petroleum products) makes this method unaffordable and unavailable to rural farmers

2.3 PRESERVATION BY DRYING

Drying involves deliberate removal of water from food product with the end product being in a solid form. It accomplishes preservation by removing the water required for enzyme activities and creating unfavorable environment for microbial growth. Vegetables are highly perishable due to high moisture content, however when this moisture is reduced to very low level, they can be preserved over a long period with minimal microbial attack.

Drying is probably the oldest method of preservation practiced by mankind and according to Ihekoronye and Ngoddy (1985), seems the most adequate method under most conditions in developing economies It tends to extend the shelf life of vegetables beyond the few weeks they are in season. Traditionally, in developing countries natural sun drying is the method of drying vegetables. Normally farmers spread products on open space, roofs, roadside and woven mats. While this method can remove water from products at low cost, the intermittent non-absolute periodic nature of radiations results into slow drying process and uncontrollable drying conditions. Also during the drying process, vegetables are not protected against dust, moisture, rodents or birds; which eventually lead to incomplete drying and quality degradation. (Mottran, 1991) and (Abe and Basunia, 2001).

Vegetables are heat sensitive and therefore present special problems in drying because the major nutrients are easily destroyed by heat. Therefore the drying of vegetables has to be carried out under carefully controlled conditions. Prolong heat treatment such as in sun drying result into loss of flavour, decrease in nutritional quality (vitamin losses) and a marked decline

in colour and taste, thus poor acceptability of dried products by consumers. New drying technologies that give more attention to drying conditions and food quality during drying have been developed, (McCarthy, 1986). Such techniques include heated air-drying, (tray, and spray), vacuum drying, freeze-drying, solar drying, etc. However, the economic involvement of these systems has been a major barrier to their use by rural farmers, thus making direct sun drying the only alternative.

2.4 QUALITY OF DRIED VEGETABLE.

During drying, the mineral components of vegetables are stable in heated and natural air-drying, but the heat sensitivity of the vitamins present a special problem. Vitamin C and Pro- vitamin A are highly labile to heat and are also destroyed through enzymic, oxidative and photo-degradative mechanism, (Zanoni et al. 1999). The extent of this destruction depends on the drying technique and is manifested in form of brown coloration, off- flavour, vitamin losses and odor when in store.

Carotenoids are susceptible to free- radical oxidation mechanism when exposed to air, as in drying; this results into slow decomposition as their conjugated double bond oxidizes. Under the influence of heat and radiation, carotene isomerizes to a more labile cis - form. The exposure of vegetable to direct solar radiation during sun drying causes isomerization of carotene pigment
(Bluestein and Labuza, 1988). The slow drying associated with this method also aid chemical reactions, which result into physical quality deterioration.

Drying using heated air tend to increase the drying rate by elevating temperature and lowering humidity. It has been noted that low temperature air improves retention of product quality and vitamins; such temperatures are often insufficient to inactivate microbials and enzymes. High temperature air, which is capable of destroying enzymes and microbials, may be too high for drying vegetable and this could result into case hardness of surface thus alleviating internal mould and fungi infestation. Hence while drying tends to reduce enzymic activities, it does not completely prevent it. The rate of carotene loss is dependent on the presence of air, heat and light during drying.

2.5 FRESH PRODUCT QUALITY.

The quality of fresh product is a major factor that affects the quality of final dried tomato. Quality of fresh or raw material is defined as it's value accessed from the relative characteristics that determine acceptability for processing. These include shape, colour, flavour, texture and nutritional value. Since processing is aimed at keeping product near original (fresh) quality, it is necessary to give attention to the fresh tomato quality. According to FAO (1989), nutrient value in vegetables is a function of genetics of plant, fertility of farmland and degree of maturity. Cultivars and the degree of maturity are two important factors in potential quality of product from the field. Tomato cultivars for processing in Nigeria have been reported to have better flavour, shape, colour, vitamin C and β-carotene content compared with local cultivars (Quin, 1974). The stage of ripeness is affected by the degree of maturity, which in turn influence the β –carotene content, and suitability of tomato for pre-drying and drying operations. Salunke and Dessai (1984b) and FAO (1990) reported that tomato meant for drying should be picked up at a stage of disappearance of green colour, this is the first sign of maturity.

Other factors, which affect fresh tomato quality according to Quin (1980), include weather, and fertilizer application. Low temperature - low humidity characteristics of the dry season best suit tomato for best quality and good yield without disease. Vareeke et al. (1979) reported that application of NPK fertilizer improved β-carotene content of orange pigment vegetables while potassium and phosphorous are indispensable for good fruit and seed development in tomato (FAO, 1989).

2.6 VITAMIN A AND ITS PRECURSORS

Vitamin A is a generic term referring to compounds other than carotenoids that exhibits the biological activity of the retinol. Dietary vitamin A exists as preformed (i.e. retinol) in animals and as proformed (i.e. carotenoids) in plants (Guthrie, 1979). Carotenoids are large pigments associated with chlorophyll in the chloroplast; they range in colour from yellow through orange to red and are soluble in fat. Among naturally occurring carotenoids only ten (10) have potential of being converted to vitamin A. Out of these ten (10), only β - carotene can be converted to vitamin A in the intestine and other tissues (Guthrie, 1979).

β-Carotene is importantly related to vitamin A, one molecule of orange β-carotene is converted into two (2) molecules of colourless vitamin A in the animal body when plants are consumed.

2.6.1 Nutritional Importance and Stability Of Beta Carotene

The importance of dietary vitamin A has been extensively discussed by Fisher and Bende (1985), and Brownsell and Griffith (1989), among several authors. Deficiency in vitamin A leads to night blindness, poor bone and tooth development in children, epithelial cell, nose, throat and eye diseases, all these also holds for beta (β) carotene. According to Edes et al. (1989), epidemiological studies correlated the intake of β-carotene rather than vitamin A to reduce cancer as cancer protective properties are higher in β-carotene than retinol.

WHO (1995) also reported that an average intake of β-carotene lowers the risk of coronary heart diseases. β-Carotene has also been found to help participate in defense against anti-oxidative stress, its deficiency is reported to be significant in children's morbidity, poor health and death (Esterbair et al. (1989). Anderson et al. (1994) similarly reported that the World Health Organization (WHO) is against its supplement because of its effective protection against the development of cancer and heart diseases.

The principal responsibility in food preservation is to maintain nutrient status throughout the phase of food acquisition and processing. It is thus important to know the specific sensitivity and stability of nutrients, particularly vitamins. β-Carotene is sensitive to acid medium, air, light and heat table 2.3 (Appendix 2). It is subject to isomerization and oxidation during drying when exposed to air and light in the presence of acid. Its oxidation rate depends on the rate of oxidation of fat or lipid in the presence of perioxidaze and free radicals in fat; it is promoted by light, temperature and air, though stable to P^H less than 4.5. During tomato ripening (i.e. yellow- pink colour point), β-carotene synthesis is predominant, while lycopene formation is recessive. In the red (ripe) state, lycopene pigment is predominant (Salunke and Dessai, 1984b).

2.7 DRYING.

Drying has been the oldest method used by man to prevent foodstuff from natural spoilage. This method still prevails in most parts of the world and seems the most adequate and well adapted method under most developing economies including Nigeria especially for fruit and vegetable preservation.

2.7.1 Theory Of Drying.

Drying is a process of removing large quantity of moisture contained in a product in order to prevent growth and activities of microorganisms causing decay. Less than 10% of moisture is required to prevent microbial activities and less than 5% for biochemical degradation (Hall, 1986). Drying involves simultaneously heat and mass transfers. The transfer or removal of moisture requires heat (i.e. latent heat) to convert liquid to vapor from within and the surface of product. The heat required for moisture vaporization can be supplied either by conduction, radiation or as sensible heat of drying air. Air is the most versatile drying medium for agricultural products. Sensible heat of air is used to vaporize moisture and move vapour through product tissues away from surface after separation from the tissues. The temperature difference between the air and the material maintains a flow of heat to the material and evaporating water mainly at the surface. Simultaneously, moisture or water vapor migrates from the core of the materials to its surface to replace the moisture evaporated.

The success of the drying process is a function of (i) the nature and composition of the product and (2) the medium of heat and mass transfer, (Hall 1986 and Mircea 1995). The nature of the material affects the migration of moisture to the surface either by diffusion, capillary flow caused by gravity, or shrinkage. The product parameters, which affect moisture removal, include the moisture content, cellular structure and the form of moisture in the product. Generally vegetables contains large amount of water along with vitamins, carbohydrates and dry matter. The available water that can be removed easily is held in the cells and the ease of removal depends on the pore structure and the porosity of the material. Tomato, contain relatively low dry matter (4-6.5%) and high moisture (93-96%), and the major part of water in tomato is the free water, this needs to be lowered to the monomolecular layer (0%< Mc <5%) where available moisture is closely bonded to dry matter such that microorganism cannot develop (Mircea, 1995).

In agricultural product drying, air current is the conventional medium of water removal. The characteristics of the air, which affects the rate of drying, include; air temperature, air humidity ratio and relative humidity and velocity. Low humid air has better ability to absorb and hold moisture from the surface of product. The potential for holding water vapor (i.e. low relative humidity) increases as air temperature is increased. High air temperature will also increase the rate of heat transfer to the surface water and material,

resulting into higher evaporation rate and increasing the flow of moisture to the surface. The rate of evaporation of water from product surface also depends on the rate of vapor diffusion through laminar layer to moist surface and the rate of heat flow. According to (Dryden 1982), a relatively high velocity air steam will reduce the laminar layer and increase both heat transfer and evaporation rate

2.7.2 Drying Mechanism

When hot air is blown over the surface of wet food, latent heat is transferred to the surface and water is caused to evaporate. The water vapor diffuses through the film of air around the surface and is carried away by the moving air. As moisture is removed continuously from the surface, the water vapor pressure is lowered causing a vapor gradient between the moist interior of the food and the surface. The mechanism of moisture removal from the surface of product is governed majorly by the nature of the drying air. The moisture transfer from interior to the surface is however governed by internal mechanism of liquid flow. Internal liquid or vapor transfer may occur by several mechanisms depending on the nature and structure of the solid. Some possible mechanisms are: (1) diffusion (liquid or vapor) (2) capillary flow (3) flow due to shrinkage and pressure (4) flow caused by gravity. Generally one mechanism predominates at any given time during drying of solids (Perry and Chilton 1975). Air-drying of most agricultural material is fundamentally vapor diffusion-like process, with the external driving force being the vapor pressure gradient. The water vapor gradient created allows the water within to diffuse to the product surface (Mircea, 1995).

To ensure evaporation of moisture from surface of product the particle size, geometry, and the extent to which the surface is exposed to air are critical factors. The complex physiological nature of vegetables has been noted to restrict moisture migration from within to the surface from where it can evaporate, (Anderson et al. 1994). It has also been noted that rapid removal of moisture from outer layers can cause a hard permeable outer crust which act as a barrier to diffusion and causing inadequate drying in the center of the product.

2.8 DRYING PROCESS.

Several investigators have described the drying process as involving two broad regimes. However, Rozis (1997) and Charms (1971) noted that an initial short- term period called setting phase exist. During this period, the material is said to advance in temperature

until it attains equilibrium with wet-bulb temperature of drying air, this period is short and unnoticeable. Vegetables when dried in single layer under constant experimental conditions exhibit an initial constant moisture loss. The detailed study of the drying process of biological materials with moisture content above 75% such as vegetable can be zoned into three; (1) Short heat-up period, (2) Constant rate drying period (3) Falling rate drying period. The two broad stages are constant-rate and falling rate drying periods Sitkie (1986).

2.8.1 Constant-Rate Drying Period

Fruits and vegetables have been reported to display initially a constant rate drying behavior when dehydrated under constant ambient conditions (Brooker et al. 1992). When heated air passes over the wet surface of a product, the surface heats up to wet-bulb temperature of the air and drying commences. During this period the surface of the product is covered by a thin-film or layer of water identical to a free water surface. Drying proceeds by diffusion of vapor from the saturated surface across a stagnant air film into the environment. The free water is removed at a constant mass rate. The rate of moisture migration from interior to the surface is higher than from surface by evaporation, and evaporation rate remains constant as long as moisture movement within the material is rapid enough to maintain the free water surface. This stage in drying process is essentially dependent on the nature of the drying air (i.e. external drying parameters) such as the temperature, relative humidly and velocity (Battey and Folkman, 1983).

According to Bluestin and Labuza (1988), where nutrient retention is critical, low temperature air should be used to extend the constant rate period. However the critical moisture content would still be above the maximum level for chemical reaction (which is about 4 - 5% in vegetables), while the product temperature is still independent of dry-bulb temperature, which is low. Thus, to avoid reactions that change colour and flavour which are highest during this stage, Bluestin and Labuza (1988), suggested that the period of constant rate drying be made shorter. Increasing cell permeability and or using low temperature -low humidity air at high velocity can achieve this. Charms (1971) and Earle (1988) noted that for a successful constant rate drying, drying air should have moderately high dry-bulb temperature (50-65% for vegetables), low relative humidity (15-25%), and high air velocity (2-3 m/s). Constant rate drying will proceed until free moisture disappears from the surface then the

moisture migration becomes less progressive. The moisture content at which drying rate ceases to be constant is known as the critical moisture content. Below the critical moisture level the drying mechanism is controlled by internal factors.

2.8.2 Falling Rate Drying Period

The falling rate period begins at the point of critical moisture content when the amount of free water at the surface becomes progressively scarce. During this period, Rozis (1997), reports that the product surface in contact with drying air reaches the hygroscopic moisture (i.e. bound water) threshold. The drying front shifts from the external surface to inside the product, where the available moisture is removed by an internal mechanism. The migration of moisture from internal to external surface becomes less than the rate of evaporation from the surface; this is due to increased internal resistance to moisture transfer. As drying rate decreases, the product surface temperature also increases above wet-bulb, and approaches dry bulb value.

Ihekoronye and Ngoddy (1985) noted that practically, all agricultural product drying takes place in the falling rate period and that more than 20% of total moisture removable from vegetable during drying takes place in the falling rate period, this account for a large proportion of drying time and energy. The falling rate period is controlled by internal mechanism of moisture diffusion and can be divided into two stages; (1) unsaturated surface drying zone and (2) zone where rate of moisture diffusion within the product is slow and is the controlling factor. Hall (1980), noted that carefully controlled research indicates more than two falling rate periods, depending on the number of molecular layers of water in the product. When final moisture content is low, the second falling rate period usually predominates and determines overall drying time. The falling rate-drying period ends when exposed surface of the product reaches the equilibrium moisture content with the drying air.

2.9 DETERMINATION OF DRYING RATES

Vegetables when dried in single layer or as single particles under constant external conditions have been reported to exhibit a constant moisture loss during the initial drying period, followed by a falling rate drying phase Patil et al. (1992), suggested that high moisture produce are best dried in single layer than deep bed drying. The determination of rates and

periods of drying require kinetics or drying curves for the drying experiment. For a thin-layer of product fully exposed to the drying air stream, the drying curves is obtained by plotting decrease in moisture content over time (in hours) for a constant temperature of drying medium (Hall, 1980). When a solid is dried experimentally, data, which relates moisture content to time, are usually obtained. These data are processed then plotted as moisture content (db) versus time. For a constant drying temperature, this curve is not smooth, which indicates that drying is not controlled all through by a single mechanism (Perry and Chilton, 1975).

2.9.1 Moisture Content

This refers to the amount of moisture or water in a given product, and usually expressed in percentage of either the wet or dry weight of the product. According to Perry and Chilton (1975), when solids are dried experimentally, the decrease in moisture content can be expressed either on wet basis and dry basis. The wet basis expresses moisture content as either absolute or percentage of wet solid.

$$\% \text{ Mc (wb)} = \frac{\text{weight of sample before drying} - \text{weight of sample after drying}}{\text{Weight of sample before drying}} \times 100$$

$$= \frac{W_w}{W_W + W_d} x100 \qquad (2.1)$$

The dry basis expresses moisture content in absolute terms (kilogram moisture per kilogram dry substance) or as a percentage of dry solid by weight.

$$\% \text{ Mc (db)} = \frac{\text{Weight of water in material}}{\text{Weight of dry matter}} \times 100$$

$$\% \text{ Mc (db)} = \frac{W_w}{W_d} \times 100 \qquad (2.2)$$

Where Mc (wb) and Mc (db) are Moisture content wet basis and dry basis (at time t) respectively

W_W = Weight of water in material (at time t)

W_d = Weight of dry mat

Hall (1980), noted that wet basis moisture content is used for commercial designation by standard organizations, while the dry basis moisture content is used mainly for research and in equations dealing with moisture variation, and more likely to be in drying equations. Field (1977) also noted that moisture content wet basis gives an incorrect impression when applied to drying; a better way to express moisture content is the dry basis. Moisture content of some tropical fruits and vegetables are given in table 2.4 (Appendix 2). The weight of dry matter in a given weight of product is given as (Rozis, 1997),

$$W_d = (1 - M_{wb})W_i \tag{2.3}$$

Where W_i is initial weight of product before drying.

Desired moisture content in agricultural products often depends on its use or purpose. Where preservation as food is the objective, final moisture contents are such that must inhibit both enzymic and microbial activities, hence, deterioration in storage. The final moisture content for fruits and vegetables are given in table 2.4.0. In practical drying works, the amount of moisture to be removed and the final weight to be attained by a known weight of wet product is expressed as below (Rozis, 1997).

$$W_{out} = \left[\frac{M_f - M_i}{100 - M_i}\right]W_i \tag{2.4}$$

and

$$W_f = \left[\frac{100 - M_i}{100 - M_f}\right]W_i \tag{2.5}$$

Where M_i and M_f are initial and final moisture content of product respectively (%)

W_i = initial weight of material (kg)

W_f = Final weight of material required to obtain final moisture content (kg)

W_{out} = weight of water required to be removed to attain required final moisture content.

2.9.2. Constant Rate

When hot air is the medium of heat for evaporation, in the constant rate period, a dynamic equilibrium is established between the rate of heat transfer to material and the rate of vapour removal from the surface. The moisture loss in biological material during constant rate drying in thin layer according to Brooker et al; (1992) is expressed as;

$$\frac{dW}{dt} = \frac{h_c A(T_a - T_s)}{\lambda} = K_g A(P_s - P_a) \qquad (2.6)$$

Where, $\frac{dW}{dt}$ = drying rate, kg Water / hr

h_c = Total heat transfer coefficient KW/m^2 °C

T_a and T_s = air dry bulb temperature and product's surface temperature respectively, °C

A = Area of total heat transfer (m^2)

λ = Latent heat of evaporation at T_s

k'_g = Mass transfer coefficient kg / hr / m^2

P_s and P_a are Vapor pressures of water at surface temperature and partial pressure of water vapor in the air.

For drying calculations, equation 2.6 above has been expressed in terms of moisture decrease rather than quantity of water removed and where convective heat transfer is predominant:

$$\frac{dW}{dt} = \frac{h_c A(T_a - T_s)}{dp\lambda} \qquad (2.7)$$

Where h_c = convective heat transfer coefficient KW / m^2 °C (conduction and radiation effects are negligible) ρ= Bulk density of dry material and d = Depth or thickness of the bed.

Perry and Chilton (1975) reported that in estimating drying rates using equations 2.7 and 2.8, the use of convective heat transfer coefficients is preferred as they are more reliable than mass transfer coefficients. Brooker et al. (1992), also noted that owing to the anomalous shapes of biological materials, it is difficult to obtain the value of h_c and k'_g experimentally. However, Brennan and Butter (1976), relates h_c to the mass flow rate of drying air as;

$h_c = 14.3\ G^{0.8}$ for parallel flow of air and $h_c = 24.2\ G^{0.37}$ for perpendicular air flow.

Where G = Mass flow rate of air, kg / m^2 /s

G = Vρ. V = Velocity of air m/s and

ρ = density of air, kg/m^2 (at the drying air temperature).

The drying time in the constant rate period is found using;

$$t_c = \frac{\rho\lambda d\left(Mc_i - Mc_c\right)}{h_c\left(T_a - T_s\right)} \qquad (2.8)$$

Where t_c = constant rate drying time.

Mc_i and Mc_c = initial moisture and critical moisture contents of solid respectively (Brennan and Butters, 1976).

According to Charms (1971), the critical moisture content and constant rate of drying are better determined using experimental moisture decrease data than empirical equations. Charms and Saravacos (1962) suggested that the curve of moisture content at various drying time be plotted against drying time. The straight-line portion of the graph corresponds to the drying period controlled by surface evaporation.

Henderson and Perry (1976) showed that the constant rate of water removal could be computed using the slope of the straight-line portion of the drying curve, giving the expression.

$$C_{RD} = \frac{dM}{dt} x W_d \qquad (2.9)$$

Where $\frac{dM}{dt}$ = Slope of straight portion of drying curve, Kg H_2O / kg dry matter

W_d = dry matter content kg dry matter; C_{RD} = Constant rate of drying kg H_2O / hr

2.9.3 Falling Rate

The prediction of drying rate of biological materials during the falling rate period has been described as more complicated than the constant rate period. Brooker et al. (1992) noted that this is due to the involvement of both heat and mass transfer and diffusion within the product in the analysis of drying rate. The method of estimating drying rates in the falling period depend on whether the material is porous or non-porous. In non-porous materials such as agricultural crops, beyond the superficial water threshold, further drying can only occur at a rate governed by diffusion (McCabe et al; 1986).

During thin – layer drying of agricultural materials, the physical mechanisms that describe moisture movement according to Brennan and Butter (1976), and Brooker et al. (1992) include:

(i) Liquid movement due to surface forces

(ii) Liquid or Vapor diffusion concentration gradient.

(iii) Surface diffusion due to surface pores

(iv) Thermal diffusion due to temperature difference

(v) Thermodynamic flow of moisture due to total pressure difference

Liquid or Vapor diffusion is reported to be the primary mass transfer mechanism in drying fruits and vegetables (Teslime et al, 1996).

2.10. MATHEMATICAL MODELS FOR DRYING

Mathematical models for describing drying based on the factors mentioned above have been developed for drying of agricultural crops. Some of these model equations are described below.

2.10.1 The Luikov's Equation

Luikov (1966), developed a mathematical model for describing the drying of products such as grains following a system of partial differential equations

$$\frac{\delta M}{\delta t} = \nabla^2 K_{11} M + \nabla^2 K_{12}\theta + \nabla^2 K_{13} P \qquad 2.10a$$

$$\frac{\delta \theta}{\delta t} = \nabla^2 K_{21} M + \nabla^2 K_{22}\theta + \nabla^2 K_{23} P \qquad .2.10b$$

$$\frac{\delta p}{\delta t} = \nabla^2 K_{31} M + \nabla^2 K_{32}\theta + \nabla^2 K_{33} P \qquad 2.10c$$

Where M = moisture content, θ =temperature, P = pressure K_{11}, K_{22}, and K_{33} are phenomenological coefficients (e.g. K_{11} =D, K_{22} = $1/\alpha$) while other K values represents coupling coefficients (Sahay and Singh, 2003). Equations 2.10a – 2.10b has been further simplified as pressure and temperature gradients are negligible. This results into a generalized drying equation

$$\frac{dM}{dt} = \nabla^2 K_{11} M \qquad (2.11)$$

.2.10.2 Diffusion Model Equation

The most widely investigated theoretical model in thin layer drying of foods is given by Fick's second law. This law follows the simplified Luikov equation (Teslime et al, 1996).

$$\frac{dM}{dt} = \nabla^2 K_{11} M = \nabla(D\nabla M) \qquad (2.12a)$$

$$\Rightarrow \frac{dM}{dt} = \nabla^2 DM \qquad .(2.12b)$$

Where D = diffusion coefficient and M = moisture content.

Sun and Wood (1994), reported that where moisture is distributed within product, the Fick's law governs mass transfer. According to Hutchinson and Otten (1983) and Diamante and Munro (1993) these equations (2.12a and 2.12b) assume the following.

- That temperature within material is constant
- The drying force for moisture movement is internal gradient
- Liquid or Vapor diffusion predominates

Considering initial boundary conditions:

i.e. M (r, o) = M_o for r < R M (r_o , t) = M_e for t > 0

r = radius of materials, M_o = initial moisture content and M_e = equilibrium moisture content, the solution for equation 2.12b is given below, (Sahay and Singh2003)

$$\frac{(M_t - M_e)}{(M_i - M_e)} = MR = \frac{6}{\pi^2}\sum_{n=1}^{\infty}\frac{1}{n} exp\left[\frac{n^2\pi^2 X^2}{9}\right] \qquad (2.13)$$

M_t= Moisture content at time t.

M_i = Initial moisture content

M_e= Equilibrium moisture content

X = Dimensionless quantity expressing time= $\frac{A}{V}(Dt)^{\frac{1}{2}}$

A = Surface area of material, m^2

V = Volume of the body, m^3; for a spherical body A/V = 3/radian, D =diffusion coefficient; (Brooker et al. 1992).

Considering the spherical coordinates, the solution to equation 2.12a and 2.12b for a constant diffusion coefficients, after considering boundary condition can be written as (Sahay and Singh 2003)

$$\left(\frac{M - M_E}{M_0 - M_E}\right) = MR = \frac{6}{\pi^2}\sum_{n=1}^{\infty}\frac{1}{n}\exp\left[\frac{n^2\pi^2}{9}\frac{Dt}{R^2}\right] \qquad (2.14)$$

R = radius of the sphere, (m).

The value of equilibrium moisture content has been expressed by Nellist and O' Callaghan (1971) as

$$M_e = \frac{M_i + M_f - (M_m)^2}{M_i + M_f - 2M_m} \qquad (2.15)$$

Where M_i = initial moisture content at time zero, %db

M_f = final moisture content, %db

M_m = moisture content at half-time, %db

However Teslime et al. (1996), noted that the equilibrium moisture content attained during drying of fruits and vegetables is relatively small compared to M_t and M_I, hence equation 2.14 can be written as

$$\frac{M_{ti}}{M_0} = MR = \frac{6}{\pi^2}\sum_{n=1}^{\infty}\frac{1}{n}\exp\left[n^2\pi^2\frac{Dt}{R^2}\right] \qquad (.2.16)$$

Where D = diffusion coefficient.

Brooker et al. (1992) noted that since the value of D depends on temperature and moisture content, analytical solutions differ from predicted values. As drying progresses with drying time, beyond the first term of equation 2.16, other terms approaches zero.

Restricting the development of the equation 2.16 to the first term, the solution to the diffusion equation in the spherical coordinates is simplified and the evolution of moisture as a function of time is given as (Sahay and Singh 2003).

$$\frac{M_t}{M_i} = MR = \frac{6}{\pi^2}exp[kt] \qquad (2.17)$$

Equation 2.17 can be simplified to a simpler form such as

$$\frac{M_t}{M_i} = a\exp(kt) \qquad (2.18)$$

$$k = \frac{\pi^2 Dt}{R^2} \quad , \quad \text{and } a = 6/\pi^2$$

k = drying constant, 1/hr and t = drying time , hr.

Equation 2.18 is termed the diffusion equation. If the value of the logarithm of M/M_i is plotted against time, a straight line should be obtained whose slope gives the value of K from which diffusion coefficient D can be calculated. The simplified diffusion equation in the spherical coordinates has been used to describe thin – layer drying in Carrots, Grapes and Basil leaves

(Rocha et al. 1993), Apricot fruit, (Teslime et al. 1996). Balikson and Sankel (1994) reports that the simplified diffusion equation may be used analyzing the falling rate period only during fruits and vegetable drying. Empirical equations governing moisture diffusions have been found to be analogous to heat and mass transfer in transient conditions. In order to obtain the liquid diffusivity D of a material, an experimental curve must be established (Charms, 1971). On a plot of moisture content % (db) versus drying time (hrs), the straight-line portion of the graph shows the constant rate regime and from the corresponding slope, the drying rate can be calculated using equation 2.19. Charms (1971) suggested that the moisture ratio be expressed as a proportion of the critical moisture content Mc, such that:

$$MR = \frac{M_t}{M_c}$$ (i.e. M_c becomes the initial moisture content at t = zero at Mc).

In order to determine if a simple relationship exist in the falling rate period, Perry and Chilton (1975) and Charms (1971) noted that if the moisture ratio is plotted on a semi logarithmic paper, a straight line is obtained for moisture ratio range when diffusion controls drying. The constants 'a' and ' k' in equation 2.18 can be evaluated by linear regression after logarithmic transformation to the form $\ln \frac{M}{M_0} = \ln a - kt$ (2.19)

M_c = Critical moisture content, subscript f = falling rate

M_e = equilibrium moisture content

2.10.3 Exponential Or Logarithm Model Equation

A relationship similar to the diffusion equation 2.19 and analogues to Newton's law of cooling has been developed and given as (Brooker et al. 1992).

$$\frac{dM}{dt} = -k(M_0 - M_e)$$ (2.20)

This is referred to as the exponential or logarithmic equation. It is assumed that the rate of moisture loss in a material surrounded by air is proportional to the difference between product moisture content and equilibrium moisture content. Separating variables and integrating between proper limits with initial and boundary conditions as in equation 2.13

$$\frac{M_t}{M_i} = MR = exp[-kt]$$ (2.21)

Brooker et al. (1992), Mustapha and Abdala (1989) and Sun and Wood (1994) all reported that the exponential equation is widely used in predicting thin – layer drying curves for grains. However, the prediction of drying curves using this equation is poor.

2.10.4 Page Model Equation

A modified empirical thin – layer equation that describes the drying of several agricultural product is the page equation and is given as

$$\frac{M_t - M_e}{M_i - M_e} = MR = exp\left[-k't^c\right] \qquad (2.22)$$

Where c = constant, k' is the modified drying constant and t = drying time.

Ajibola et al. (1988) used the Page equation in prediction of drying rate of pre-jelled yam.

The constant c and k are evaluated by linear regression after logarithmic transformation to the form

$$\ln (MR) = \ln k + C \ln t \qquad (2.23)$$

2.11 DRYING METHODS.

Drying has been classified into various ways by several authors, predominantly as natural and artificial drying, (Seravan, 1999).

2.11.1 Natural Drying.

This method of drying utilizes natural air and heat conditions to remove water from product surface. It includes sun drying and shade drying. These methods have been reported to be traditionally aged long and are still been used especially in drying of fruits and vegetables. (Seravan, 1999).

Sun drying utilizes natural radiation and environmental air. It involves simple exposure of product to natural air and radiant heat energy. Traditionally, vegetables are spread on bare ground or rooftops and regularly turned for even drying, (Seravan, 1999). To avoid contamination, Taiwo (1995) as well as Spiers and Coote (1986), reported that it is preferable to raise vegetables off the ground by using tray. Such trays should be made from bamboo or wood with nylon mesh base to permit adequate airflow around the drying product. Vegetables should be spread in thin even layer (single layer) and stirred every hour during the constant

drying period, (Petil et al. 1992). According to Peggy- Otti (1993), the product surface temperature will depend on the surrounding air temperature and humidity. Direct exposure of vegetables to sunrays has been noticed to affect their physical and nutritional qualities, Taiwo (1995), suggested that drying vegetables under shade will reduce the photo degradation.

Shade drying follows the same technique as sun drying except that product is placed in shade away from sun light. Spier and Coote (1986) noted that this method of natural drying though takes a little longer time than sun drying, it is better when it is necessary to prevent discoloration or retain nutrient. In dry air conditions, it has been noted that shade drying can be accomplished as quickly as sun drying with ample air circulation.

2.11.2 Artificial Drying

In artificial drying the drying medium characteristics are altered from natural state, usually the heat being generated by technical means. The required heat is supplied to the product by either conduction (drum drying) convection (air drying) or by infrared rays. Salunke et al. (1974) described the development of artificial drying (dehydration) techniques. This includes vacuum, freeze, and heated air-drying systems. Systems common in heated air-drying include tray, cabinet, spray, solar drying etc. The techniques of vacuum and freeze-drying according to Salunke et al (1974) have been widely employed in developed countries.

Trays or cabinet drying: In tray or cabinet drying systems, product are spread thinly on set of trays and placed in an insulated cabinet containing an air circulating fan, a heater and adjustable baffles, which direct air across and through the trays and food. Air velocities 2-5m/s are obtainable in cross flow systems; tray dryers are flexible and are mainly for fruits and vegetable drying (Earle, 1988). Heated air passing through or across product on trays pick up moisture and flow out through a plenum. A typical tray dryer used is shown in Fig A5.2 in appendix 5. It consists of an air duct mounted on a floor standing frame and an axial flow motor-driven fan with varying speed up to a maximum of 2.0 m/sec in the duct.

The air passes over an electrically heated element, which is controlled by a power regulator in order to provide heated air up to a maximum of 80°C. Heated air passes into the drying section where trays holding materials to be dried are set. The trays are designed for thin

layer drying. Air passing through the product is discharged into atmosphere through an outlet duct section where a vane anemometer with resolution counter for measurement of air velocity is positioned. When product weight is being taken, the airflow is reduced and returned to set value as soon as product is returned into the dryer. Wet and dry bulb temperatures of the air entering and leaving the drying section are measured by aspirated psychrometer mounted on the dryer by placing it into the duct at the upstream and downstream of the drying chamber.

Solar Drying: In solar drying, radiant energy is trapped and used to heat up air within a chamber; this can be done directly or indirectly. In the direct solar drying, solar radiation trapping and product drying are carried out with the same chamber. The product and other part of the cabinet act as radiant heat collectors. The convective air affects only removal of vapour usually through perforations in the chamber. In the indirect drying, the radiant heat is collected in a separate cabinet and air is allowed to pass over heated absorber surface. The heated air is carried into another cabinet where the product to be dried is kept. Energy supply to product and removal of water vapor from the product is affected by convective airflow.

Freeze-Drying: During freeze-drying, moisture is removed from pre-frozen food under vacuum by sublimation. Pressure is reduced to below triple point of water (i.e. 4.6mmHg), then heat is supplied to frozen product resulting into sublimation of water. According to King (1971), the heating plate temperature is highest when product temperature is lowest. As drying proceeds both plate and product temperature attains equilibrium. Freeze drying has been reported to give minimal nutrient destruction, enhance reconstitution characteristics of vegetables; as well as reduces oxidation process and thermal reaction.

2.12 FACTORS THAT AFFECT BETA CAROTENE RETENTION DURING DRYING OF VEGETABLES.

Beta- carotene (β-carotene) is generally lost during air-drying of vegetables with the highest loses occurring during sun drying. Labuza (1973) showed that high temperature, drying time; oxygen availability and light are critical to β-carotene loss in natural and heated air-drying.

2.12.1 Light

Ultraviolet rays from sunlight have been reported to cause oxidation of fat and lipids in fruits and vegetables, thus increase in degradation of carotene during sun drying (Spier and Coote, 1986). In open-air drying solar radiation is not controlled, drying under shade can only reduce the direct effect. This has resulted in high losses of vitamins C and carotene.

2.12.2 Temperature And Time

Vegetables are generally heat sensitive, prolong exposure to heat often results into loss of vitamins. Macrea (1995) reported that heat causes isomerization and reduce potency of β-carotene. According to Wierzchoroski (1956), artificial drying at high temperature resulted into 60-90% loss in β-carotene with variation in time. Losses recorded were lower at 50-60 °C and highest at 105°C Rapid drying during constant rate period at temperature not exceeding permissible values for vegetables will help preserve β-carotene. During the falling rate period, it is suggested that temperature below critical value to avoid enzymic browning (Rozis, 1997).

Sweeney and Marsh (1971) reported higher losses of β-carotene in carrots at higher temperature-short time processes due to thermal reactions. This has a tendency of causing case hardening. Dallas and Mac Dowel (1956) showed that tray drying at 93°C. -2hrs and 60°C. -6hrs temperature time combination resulted into 74% and 81% retention of β- carotene respectively. Salunke et al. (1984) suggested that drying equipment operating at short time and low temperature such as vacuum dryers are best in improving carotene retention. Ihekoronye and Ngoddy (1985) reported that this type of equipment is expensive for rural farmers in developing countries. In sun drying, temperature is uncontrollable, the variation in temperature with time affects drying rate and allows longer exposure to light and oxygen, thus

greater loss in carotenes. Taiwo (1995) noted that for vegetable such as tomato, the low temperature- low humidity air condition during the harmattern season in Nigeria would reduce these effects.

2.12.3 Oxygen

Carotene may be auto - oxidized when exposed to atmospheric oxygen. The rate of oxidation depends on light, heat and the presence of antioxidant. Natural and Artificial air-drying provide the best environments for interaction of free radicals during oxidation of lipids, this results into loss of β-carotene. According to Sweeney and Marsh (1971), the presence of oxygen has also been attributed to accelerated enzymic browning especially under long drying period. Oxygen was also reported to reduce sulphur dioxide concentration under light and temperature conditions.

2.12.4 Enzymes

Enzymes are biological catalysts that promote biochemical reactions in food cells. Perioxidaze, which are lytic enzymes, have been shown to be active and widely distributed in many vegetables. Though drying tends to inhibit enzymic activity by reducing water activity, it does not entirely prevent it. Perioxidaze has been used as an indicator enzyme in vegetables because it is the most heat resistant and easy to measure. According to Adams (1981), the complete inactivation of perioxidaze has been well correlated with achievement of best quality. While other enzymes rather than perioxidaze may directly cause change, Fields (1977) reported that the presence of perioxidaze in vegetable is indicated as a major cause of loses of β-carotene during drying and in storage.

Macrea (1995) and Fields (1977), both reported that elimination of perioxidaze can be achieved by blanching. Adams (1981), suggested that the test to indicate that a predetermined activity of perioxidaze has been reached is required after blanching. Under blanching and over blanching will cause more loss of carotene pigment. Adequacy of enzyme inactivation is determined by perioxidaze test as described by Fields (1977). Selman (1987), suggest that a visual test would be useful and the relationship between visual assessed perioxidaze activity and a time perioxidaze activity as determined by a spectrophotometer be compared.

2.13 PRE-DRYING OPERATION

Taiwo (1995) reported that during traditional sun drying of vegetables, Nigerian farmers do not thoroughly wash the vegetables, and do not carryout physical and or chemical pretreatments.

2.13.1 Washing, Sorting And Cutting

Washing is done immediately after harvesting in order to remove dirty leaves and limit the development of microorganisms. According to Feaster (1971), vegetables should be washed carefully in order to avoid bruises, which could activate enzymic activity and thus accelerate oxidation of β-carotene. Washing of vegetables under cold running tap is preferable. It is important to sort unripe, premature and damaged products from the lot of washed vegetables before drying. This is important in fruit and vegetables such as tomato, pepper in order to enhance uniformity of shape and colour of samples.

Vegetables to be dried can be cut into various shapes: halves, cubes, slices and stripes. It is necessary that sizes are uniform and as thin as possible; the thinner the pieces are, the quicker they dry. According to Kodylas (1991), uniformity in size and shape allow uniform application of chemical pretreatment as well as drying. Cutting can be done either manually using sharp edge knives or mechanically using cutting or slicing machines.

2.13.2 Pre-Treatments

Pre- treatment of vegetables before drying have been reported to affect structural changes that ensure easy heat and moisture transfer thus faster drying rates, as well as keeping them from microbial attack during drying. The major pretreatments are blanching, and sulphuring or sulphiting, for vegetables.

2.13.3 Blanching

Blanching according to Selman (1987) is a process of subjecting food to short-time heat treatment using either steam or water. According to Rozis (1997), blanching helps inactivate enzymes, which will otherwise catalyze degradation of vitamins. It also renders cell structures permeable to moisture transfer, thus reducing drying time and eliminates inter-

cellular air responsible for oxidation. It also limits discoloration and decrease bacterial load. According to Selman (1994), blanching enables almost - complete inactivation of perioxidaze in vegetables. Blanching also affect vegetables in various ways such as; loss in weight, soluble nutrient up to 40% for vitamins, and can also act as heat process to reduce microbial load. Selman (1987), reported that 3minute blanching of soybeans in boiling water reduces total bacterial load to below 14000/g. 3min. blanching in water at 60°C gave 81% reduction of anthio in cucumbers, tomato and pumpkins.

Blanching can be done by water or steam, however during water blanching, there is the tendency of leaching of soluble vitamins. This does not affect β-carotene, rather the anti-oxidation effect of ascorbic acid, which can be preserved by the addition of 1-2 % sodium chloride into blanching water. Typical blanching process utilizes temperature about 75-95°C for times of about 1-10min. depending on the food material (Selman 1994). Table 2.5 (Appendix 2) shows various blanching time for vegetables. In Steam blanching it takes longer for heat to penetrate to center of food, fewer nutrients are leaked out and the food do not get discolored. Blanching has significant effect on drying rate due to the break down of cell membrane by heat. According to Brandoffer et al. (1985) the following factors affect the length of blanching time, particle size, depth of loading, blanching medium and temperature.

Gomez (1981) reported higher carotene retention in blanched Jews mallow and okra than unblanched samples. Etchetema (1991) also reported 72% carotene retention in blanched solar dried okra. According to Salunke et al. (1974), up to 80% of carotene will be lost if vegetables were processed without enzyme inactivation. Blanching treatment, which is used to inactivate, enzyme is therefore necessary if loss in carotene due to enzymic activities is to be avoided (Handel, 1971).

2.13.4 Sulphiting

Sulphiting involves impregnating sulphur-dioxide into vegetables by the use of salts such as sodium metabisulphite, sodium sulphate or potassium metabisulphite. Sulphur dioxide (SO_2) has been reported to possess anti-oxidant and reducing properties to prevent non-enzymic browning, as well as carry out antiseptic action on bacterial, yeast and mould (Rozis, 1997). Sulphiting can be done either by adding the salt to blanching water or spraying of

sulphite solution on the material. Where steam blanching is employed the method of spraying sulphite is used. The addition of sulphite salt to water used in blanching has been found to have deeper of penetration of sulphur dioxide thus better retention of ascorbic acid as well as improvement of carotene stability during dehydration, (Salunke et al. 1974).

2.14 RELATED RESEARCH

Teslime et al. (1996) reported that oxygen has a scavenging effect on sulphur dioxide, which help stabilize carotene during drying and in storage. Increase in drying rate particularly the constant rate drying period, has also been reported in sulphited parsley (Pointing and Macbean, 1970). Rocha et al. (1995), reported that the influence of temperature during falling rate period is negligible in sulphited vegetable hence making low temperature drying during this period possible. According to Bolin and Strafford (1974), and Gomez (1981), there are higher losses in β-carotene in unsulphited dried vegetable samples than sulphited dried samples. Salunke et al. (1974), equally showed that sulphur dioxide protect oxygen sensitive vitamin such as vitamin A and C and minimizes their loss during processing. Similarly Abainum (1999) showed that sulphited dehydrated tomato slices had higher rate of moisture loss than unsulphited or blanched sample over the same drying period.

Sodium metabisulphite has been reported to have greater stability than other sulphite salts and it is the main compound used in food preservation to generate sulphur dioxide and its corresponding anions (Teslime et al. 1996). Application concentration and duration differ with product. Table 2.5. The addition of sodium chloride to sulphiting solution has been reported to enhance the inhibition of oxidation by other antioxidants, and usually more effective (Brandoeffer et al. 1985).

Various researchers have studied different drying techniques in drying of pre-treated vegetables. Pre-treatments and drying methods have influence on carotenoids retained during drying and in shortage of vegetables.

Badifu et al. (1995) reported that losses were higher in all pretreated samples of sun dried fluted pumpkin leaves than oven dried ones.Unbalanced samples were reported to exhibit highest loss, while steam-blanched sample retained most. According to Macrea et al (1993),

5 and 25% loss in β-carotene were recorded in freeze-dried and air-dried carrots respectively.

Gomez (1981) studied the effect of pretreatment and drying methods on nutrient retention in different dried vegetables. The result showed that carotene loss was lower in shaded-ambient dried samples than direct open dried samples. Light protected solar drying resulted in high retention of carotene than exposed samples, with steam-blanched samples having the highest value. Bolin and Strafford (1974), studied the effect of processing on vitamin A and C and provitamin A in dried apricot using sun, shade and drum drying methods. The result showed that drying method influence carotenoids retention than pretreatment. Sun-dried sulphited samples recorded 20% less than drum - dried sulphited samples and the same trend was recorded for unsulphited samples.

Teslime et al. (1996) studied the effect of concentration of Sulphur- dioxide (using sodium metabisulphite) on the drying rate and storage ability of pretreated apricot dried using shade, sun and solar drying techniques. It was reported that solar drying and higher concentration of sodium metabisulphite solution increased drying rate. Sulphiting was reported to cause permeability of membranes thus increasing evaporation rate.

Wiezchoroski (1956) studied the influence of temperature, oxygen and light on the carotene content of green foliage during drying. The crops were dried in the field, in the shade, under a roof, artificially in an air oven at 50-60°C with ventilation, in a vacuum oven at 50°C and an air oven at 105-200°C. Field dried samples showed 95-100% loss in carotene; samples dried in shade had 90% losses while artificially dried samples at high temperature showed 60-69% loss. Loss in carotene was low at 50-60°C temperatures while vacuum drying recorded the lowest loss of 0.2-3%. Low air-drying temperature has therefore been suggested as necessary for non-pretreated samples.

Processing reduces vitamin A potency during isomerization of β-carotene by 15-20% in green and 30-35% in yellow vegetables having only β-carotene and α-carotene respectively. Higher temperatures and lower blanching times increases loss of carotene. Drying of untreated fruits and vegetables can cause considerable losses of carotene ranging from almost complete destruction in the local open air-drying to 10-20% loss in controlled vacuum conditions (Sweeney and Marsh 1971).

Baras et al. (1971) studied the effect of drying methods on all trans- β-carotene in dried carrots. It was reported that loss in a range of 40-50% of all trans β-carotene resulted when dried in air, and 20% in vacuum dried samples. Koh et al. (1987) have also reported that long-time sun drying causes deterioration of quality in dried capsicum.

Zanoni et al. (2000) reported that optimization of tomato drying in terms of maximizing drying rate and minimizing oxidative damage require low temperature for short times. This may be achieved by drying tomato in the slices or small pieces. A reduction in thickness is reported to correspond to an increase in moisture diffusion, thus resulting into faster removal of water. Traditional drying of tomato to low moisture content results into oxidative heat damage due to longer drying time and higher surface temperature.

Rocha et al. (1993) studied the effects of steam blanching and surfactant and different drying conditions on the drying rate and chlorophyll retention in air-dried Basil. It was shown that pretreatments increased drying rate by a factor of 10 for steam blanching and 14 for surfactants respectively.

Taiwo et al. (2001) also reported that blanching increases drying rate. Moisture content was also reported to decrease after pretreatments. In another work by Ali and Sakr (1981), vegetables air-dried at 60°C showed higher constant rate drying than falling rate and that heat damage was inevitable at high moisture content due to longer exposure to air. It was suggested that rather than traditional spreading of product on floors, stainless steel trays be used to hasten drying. It was also reported that blanching, apart from increasing drying rate will help retain carotene better during drying. However, Charms (1971) recommended that trays made from nylon mesh be used to avoid the catalytic action of iron in carotene degradation. Eke (1995) observed that intense heat from direct exposure of vegetables to sun ray for a long time resulted into loss of carotene exhibited by loss of orange-red pigment of tomato slices.

Bhaskarachary et al. (1995) analyzed total carotene in several vegetables using the spectrophotometer. Provitamin (carotenoids) was separated on HPLC, β-carotene was found predominant in all foods investigated. Table 2.6 (in appendix 2) shows the value of total and β- carotene content of common vegetables in Nigeria. Bhaskarachary et al. (1995), reported that β-carotene amounted to 20.8% of total carotene in tomato.

2.14 METHODS OF BIOCHEMICAL ANALYSIS OF BETA (β) CAROTENE

Biochemical analysis of carotenoids can be grouped into biological (bioassays) and physiochemical methods. The bioassay method determines the actual retinol activity of food while the physiochemical method measures the amount of various carotenoid without indicating the biological potency in terms of vitamin owing to the tediousness, time consumption, high errors and variations in results, this method has been replaced by the physiochemical methods (Ball, 1994).

The physiochemical method involves extraction, saponification and physical separation of pigments. The quantification of pigments is based on their light absorbance properties at 450nm. Physiochemical analysis methods include:

2.14.1 Gas – Liquid Chromatography (GLC)

The GLC method has been reported unsuitable for carotenes separation due to their high melting points and thermal instability. However, it has been reported that xanthophylls separation can be better done using the GLC method (Taylor and Ikawa, 1980).

2.14.2 Thin Layer Chromatography

In thin layer chromatography, extracts are streaked on absorption plate and developed in a nitrogen environment. The identified colors are extracted from the absorbent, spotted on glass or plastics plates and the spots are quantified by spectrophotometer. This technique has been reported as excellent for identification and purification of carotenoids; however, a single absorbent will not resolve all the carotenoids.

2.14.3 High Performance Liquid Chromatography (HPLC)

The HPLC is a rapid reproducible, sensitive and qualitative method of carotenoid analysis. According to Ball (1994), it uses detection limits under variable wavelength detector. Several column solvents are used to separate pigments, which are identified by their retention time, and quantified by peak area or light. This is done after an initial extraction and filtration. Simmonne et al. (1997), reported HPLC analysis in bell – shaped pepper under a yellow light to avoid oxidation. Bueno (1997) also reported a comparison of the Association Of Analytical Chemist (AOAC) column chromatography and the HPLC methods. The report showed marked variation. Zakari et al. (1979) reported the analysis of carotene in tomato using the

reversed- phased HPLC method. The result also showed better reliability in evaluation than the AOAC method. The predominant hindrance to the use of HPLC method in most developing nations is the high cost of the equipment (Ball, 1996). This has led to the modification of the AOAC column separation along with spectrophotometric quantification.

2.14.4 Column Chromatography

The column method is used to isolate individual carotenoid pigment. It adopts the principle of varying affinity of pigments towards absorbents for the formation of bands or fractions of the absorbents. The pigment in each fraction is eluted from the column and quantified by spectral analysis. The Association Of Analytical Chemist (AOAC) adopts this method. It is widely used due to its low cost of operation and visual monitoring of separation (AOAC, 1980).

However, the AOAC values given in food composition tables have been reported to be rather total carotenoids than β-carotene especially in products like tomato, (Bhaskarachary et al. 1995). Lycopene, which is inactive carotenoids, is present in large amount in tomato fruits. The AOAC method include this carotenoids along with others thus giving high value. According to Chang (1977), simple modifications that reflect the saponification have been developed. . Bhaskarachary et al. (1995) reported that the column chromatography is time consuming and suffers incomplete resolution of activities of carotenoids. However for tissues containing only β-carotene, the AOAC have been reported to be good method of estimation. Table 2.7 in appendix 2 shows comparative value of carotene using the AOAC and HPLC methods.

2.14.5 Open Column Chromatography

This method involves the use of open columns to isolate and individually separate carotenoids. The principle involves extraction of pigment by a suitable process and purifying the extract by saponification. According to Martins (1983), the extraction is aimed at breaking fat – protein bands to release carotenoids from any combined form in which they may exist. Lento (1984) noted that some natural vitamins contained in food are bounded up with lipo protein and it is necessary to break the fat/protein band in order to release and isolate the vitamin fraction by extraction. Ball (1994) reports that digestion and extraction produces a concentrated extract for saponification.

Saponification process helps separate sterol carotenoids, which are unsaponifiable matters from diluted saponifiable matter in the extract. This is achieved by a liquid – liquid extraction using a water immiscible organic solvent. Saponification helps to break down a large number of pigments and other matters that might otherwise interfere with vitamin measurement. During saponification, it has been noted that vitamins are protected against degradation by addition of antioxidants (Sodium Chloride and Ascorbic acid) (Martins, 1983).

Conventional saponification by refluxing at high boiling temperature causes loss of xanthophylls; this is reported as an added advantage in determination of carotenes, (Martin, 1983). Where xanthophylls and carotenes are required to be determined, cold saponification has been suggested. Ball (1994) noted that the use of amber colored glasswares and deoxygenating by nitrogen flushing are percussions that should be taken during saponification.

According to De-Ritter and Purcell (1985,) saponification of already extracted pigment by refluxing with potassium hydroxide (KOH) and antioxidant such as sodium chloride removes the need for a nitrogen flow into the saponification flask. The saturated vapor of the alcohol prevents aerial oxidation during boiling. Ben–Azis et al (1973) noted that in ripe tomato samples, expoxides are formed and in the presence of florescent or mercury light causes photo-oxidation of β – carotene in fatty acids. While it may be completely impossible to avoid light, it was suggested that prolong exposure to light should be avoided, antioxidants such as ascorbic acid and sulphite salts should be used to protect carotene while the solvent for extraction must not be solely acetone.

Chromatographic separation of carotene pigments from saponified samples involves the packing of columns and elution of pigments using suitable eluting solvents. Magnesium oxide or aluminium oxide mixed with silica gel or diatomaceous earth and spherised are common absorbent used in columns packing. Quackenbush and Small-Ridge(1986) noted that magnesium oxide and diatomaceous earth mixture helps remove interfering pigments such as residual chlorophyll and xanthophylls (from unsaponifiable fractions) obtained from tomato extract. The method of spectrophometric measurement is either by use of standard caliberation curve of β– Carotene or desired pigment or by direct calculation with valid extinction of the pigment in n-hexane as eluting solvent. The value of extinction of 91% β- Carotene in solution

of n – hexane using 1cm cuvette at maximum wavelength of 450nm is given as $E^{\%}_{1cm}$ = 2590 – 2592. Lento (1984) expresses the value of total Carotene eluted using 35% acetone – n – hexane as

$$\text{Carotene (mg/100g)} = \frac{A \times V \times D_f \times 1000}{E^{\%}_{1cm} \times W} \qquad (2.27)$$

Where A = absorbance, V = volume of test solution, $E^{\%}_{1cm}$ = extinction of coefficient of carotene in n – hexane and W = weight of dried sample (g).

2.15 CONCEPT OF EXPERIMENTAL DESIGN

2.15.1 The Experimental Design

Experimental designs differ depending on whether they are single or multiple factor experiment and in the way the treatments (i.e. factors) are being applied. Experiments are designed to: -

* Provide an estimate of variation, which may be present in the response value among experimental units.
* To reduce experimental errors in the data collected
* To help facilitate randomization (Hicks,1977)

Randomization is an important part of experimental design because it creates precaution against uncontrollable effects that may or may not occur. It ensures also that every unit of the experiment is equally likely to receive any treatment.

2.15.2 Factorial Experiment

In agricultural and biological research, two or more factors or treatments are often involved, with each treatment having different quantitative values. Such an experiment is called a factorial experiment. The experimental unit is said to receive a combination of treatments and not just a treatment. When considering a factorial design, the 2^K full factorial experiments have been found to be most efficient. The 2^K full factorial experiments (FFE) consist of k main factors interacting at two (2) levels. In a 2^K factorial experiment, a designed matrix plan, which shows the run-by-run order, is required (Douglas, 1991). For example, for a 2^2 factorial experiment a total of four (2x2) runs are obtained as shown in table 2.1. In adopting the above design plan, according to Cochran and Cox (1957) it is assumed that: -

(a) The two factors should be independent and their levels are quantitative and preset

(b) A first order multiple linear model is adoptable

(c) All measurements or treatment levels must be equally replicated to ensure acceptable approximation of the functional relationship.

(d) The factorial design must be completely randomized and the response is assumed normally distributed at each value of treatment.

Factorial designs have been used and shown to be important in finding out what factors are important and at what levels, as well as the effects of one factor's dependence on the level of the other. It increases the scope of inference and precision by reducing experimental errors of the treatment means. In a factorial experiment, the main effect of a factor is said to be the change in response produced by a change in the level of the factor involved. This can also be described as the difference between the mean response at the lower levels and the mean response at the upper levels of the factors. The difference is proportional to the regression coefficient. In factorial experiment, interaction exist between factors, the interaction effect is said to have a higher importance than the main effect if it is larger.

Zanoni et al. (2000) employed a 2^3 full factorial experiment using surface response method to determine the optimal condition of the phenomenon studied. A response surface model was developed to describe the change in the response as a function of variables being studied. Jackson et al. (1996) used a 2^6 factorial design to model banana drying. Main and interaction effects were analyzed and the adequacy of the model and optimum conditions were reported. Similarly, Olorunsogo and Adgidzi (1998) used a 2^5 full factorial design in modeling ascorbic acid retention in orange juice. Factors and their interaction that affect the shell life of non-refrigerated storage of orange juice were determined.

Table 2.1 Matrix Plan For 2^2 Factorial Experiments

No. OF	FACTORS				RESPONSE
RUNS	X_O	X_1	X_2	X_{12}	Y_β
1	+	-	-	+	
2	+	+	-	-	
3	+	-	+	-	
4	+	+	+	+	

X_o = Dummy variable

X_1 = Steam blanching time (min)

X_2=Sulphite concentration (ppm)

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 MATERIALS

The materials and equipment used during this research work are classified according to the activity chain shown in figure 3.1 and the flow chart shown in figure A5.1 (in appendix 5)

Tomato seeds (Roma V_F variety)

Experimental plot of land

Farming tools (Hoe, Cutlass, Watering Can)

Cartons.

EQUIPMENT FOR DRYING EXPERIMENT

Tomato fruits (fresh) Roma V_F variety

Distilled water

Plastic bowls

Plastic colanders (2)

Pair of plastic tongs

Digital weighing Balance (TM 2000,Capacity 2400g,precision ±0.1)

Stop watch

Chopping board (plastics)

Stainless Steel Tomato Slicer

Petri dishes (12 No)

Vacuum Oven (Gallenkamp OV- 440)

Thermometers (100 ^{O}C, 4 No.)

Water bath (with circulators; Grant CC15)

Drying trays (Aluminum mesh 20 cm x 20 cm, Nylon mesh 20 cm x 20cm).

Anemometer (Airflow LCA 6000: Javac (UK) Limited)

Wet and dry bulb thermometers

Desiccators (3 large)

Hygrometer

Graduated Cylinders ([Pyrex glass500 ml, 250 ml, 100ml, 50 ml and 10 ml)

Tray drier (armfield Engineering Teaching and Research Equipment BI.CH.UO.08)

Spatula

Polythene and foil paper

Sealing machine

Masking tape

UV Spectrophotometer (SHIMADZU, UV2100)

Test-tubes

Centrifuge (eppendorf 5810)

REAGENTS*

Guaicol 1% solution

Hydrogen perioxide

2% sodium chloride solution

Acetate buffer solution

Sodium metabisulphite salt (GPR)

Sodium chloride salt (GPR)

EQUIPMENT FOR BIOCHEMICAL ANALYSIS

Dried Tomato samples

Macerating porcelain mortar and pestle

Filter Flask

Separating Spherical funnels (Pyrex glass with stopper 500ml capacity 3 no.)

Fritted glass funnel (2)

Beakers (Pyrex glass250, 50 and 100m/s)

Graduated measuring cylinder (10, 50, and 500ml)

Pipettes (1, 5, 10, and 50ml)

Burettes (18 x 175mm)

Rotary Vacuum Evaporator (CAMPTON 28122)

Filter paper (Watt man number 110)

Thermostatic water bath (with circulators; Grant CC15)

UV Spectrophotometer (SHIMADZU, UV2100)

Centrifuge (eppendorf 5810)

REAGENTS*

Methanol absolute

Acetone (dried AnalaR 99.5%)

Anhydrous sodium sulphite (fine powder)

n-Hexane (99%)

Potassium hydroxide 40% w/v in methanol

Magnesium Oxide (Sea Sorbs 43)

L-Ascorbic acid (Vitamin C) AnalaR

Diatomaceous Earth, hyflo super Cel

*All reagents are BDH AnalaR grades purchased from Katchey Company Limited (KCL) 20A Odanye Close, off Adeniyi Jones Avenue Ikeja, Lagos.

3.2 SOURCE OF EXPERIMENTAL SAMPLE

Tomato fruits used in this research were obtained from an experimental farm raised in Zamfara village kilometre 2 along Bida -Minna Road, where local farmers farm tomato. The location ensured that production activities and conditions are similar to those carried out by local farmers, except that nursery soil was sterilized prior to planting to destroy micro organisms and avoid diseased fruits.

The experimental farm ensured that samples were uniform in terms of variety, source, production conditions, physical characteristics (shape size and colour) as well as maturity and time of harvest. Fresh tomato fruits were harvested at orange-pink point from the farm early in the morning. Fig 3.2 shows freshly harvested fruits

3.2 FRESH PRODUCT PREPARATION

3.3.1 Sorting, Washing and Cutting

The selection or sorting of fresh tomato fruits was carried out manually. Fruits with physical and pathological damages, non-uniform colour and small size were sorted out from the entire sample. Foreign materials, and stalks were also removed from the product. Fruits that were good, and of diameter 50 ± 1mm were separated.

Plate 1: Freshly harvested tomato fruits

Plate 2: Sorted, Washed and sliced tomato sample

3.4 PRE-DRYING EXPERIMENTS

3.4.1 Blanching Adequacy Test

Prior to blanching pre-treatment, the blanching adequacy test was carried out to determine the blanching time adequate for total inactivation of enzymes. The peroxides test was used as this enzyme has been reported to be the most difficult to inactivate (Selman 1985).

Procedure

Tomato samples were blanched using steam over a range of time from 0 to 4 minutes at 30-seconds intervals and allowed to cool in a desiccator. Cooled sample was then macerated in petri dish and properly labelled T_1, T_2, and T_3. 25g of each macerated sample are put inside a test tube. To each sample in test tubes, 0.5ml of distilled water, 1.0ml each of 1% guaicol and 0.5% hydrogen peroxide were added. The test tube was properly agitated in a rotary evaporator and allowed to stand for 5 minutes. After 5 minutes, the reaction in each test tube was checked for colour change. The colour changes observed indicated the presence of peroxides either as positive, negative, trace or slightly positive. According to Fields (1977), both negative and trace reactions can be taken for effective blanching. The texture of the material is also observed.

3.4.2 Moisture Content Determination

The moisture content of fresh and pre-treated samples was determined using the gravimetric method involving the use of oven drying at 100°C

Procedure

Clean dry petri dish was weighed and the weight was recorded as W_1. 20 ± 0.1g of sample was added into the petri dish, the weight of dish and sample was taken and recorded as W_2. The material was chopped in the dish. Each sample was replicated three times. The dishes and samples were then put into a pre-heated oven at 100°C. Samples were withdrawn from oven and cooled in a desiccator every 30 minutes, then weighed. This was continued until a constant weight W_4 ± 0.1g was recorded.

The sample initial weight was recorded as $W_3 = (W_2 - W_1)$

The final weight sample is recorded as $W_5 = (W_4 - W_1)$

Moisture content on wet basis was calculated as using equation 2.1. The amount of water to be extracted from the tomato to attain the final moisture content of 4.0 ± 1% wet basis was calculated using equation 2.4. The product final weight to final moisture content (W_f) is calculated for each sample using equation 2.5.

3.5 PRE-DRYING TREATMENTS

3.5.1 Steam Blanching

Steam blanching was carried out using steam from a water bath at 100 ± 1°C for a period of 2 and 3 minutes selected based on the result of blanching adequacy test. Tomato samples were arranged on drying trays, placed on water bath and covered. They were left for the selected blanching time, on expiration of time; trays were removed and placed in desiccator for samples to cool.

3.5.2 Sulphiting

Sulphiting was carried out by spraying sodium metabisulphite +1% sodium chloride solution. Sulphite solution was prepared according to the selected concentrations. 1.5g and 3.0g sodium metabisulphite were weighed and dissolved in 1000mls of distilled water to which to which 10g of sodium chloride salt had been added. This constitutes solutions of 1000ppm and 2000ppm respectively. Blanched tomato samples were placed in plastic colanders and sprayed with sulphite solution such that all slices were adequately covered and dripping. This was done for 3 minutes and then allowed to drain. The sulphite solution was applied to blanched sample according to the experimental plan (designed matrix shown in table 2.8).

In the first experimental run, samples blanched for 2 minutes were sprayed with 1000ppm sulphite solution and for 3 minutes, then allowed to drain. In the second experimental run, samples blanched for 2 minutes were sprayed with 2000ppm solution for 3 minutes, and then allowed to drain. In the third experimental run, samples blanched for 3 minutes were sprayed with 1000ppm solution for 3 minutes, and then allowed to drain. In the forth-experimental run, samples blanched for 3 minutes were sprayed with 2000ppm solution for 3minutes and then allowed to drain. All samples were pre-treated in three (3) replications.

3.6 DRYING OPERATIONS

Drying of pre-treated and untreated samples were carried out using sun drying, and tray drying at 65°C and 50°C.

3.6.1 Tray Drying

Tray drying was carried out at two selected temperatures 65°C and 50°C. The air for drying was first conditioned to the selected temperature using the temperature controlled knob and psychrometer in the dryer unit. The selected dry bulb and the wet bulb temperatures of the drying air were monitored through the holes at the upstream and downstream ends of the drying chamber to ensure constant drying conditions. The fan speed was also regulated to supply air at velocity of 2.0 m/s, (Rocha et al. 1993) and (Kodylas 1991).

Prior to loading of tomato samples, the dryer was allowed to run for 15 minutes, during which temperatures were checked to ensure constant value. Upon maintenance of constant required temperatures (wet and dry bulb), samples of 80 ± 0.5g were arranged on trays in three (3) replicates and placed in the plenum (i.e. drying chamber). The stopwatch was turned on as drying begins. The samples on trays before loading into dryer are shown in fig. 3.5 while samples in the drier is shown in fig. 3.6. During drying, samples were weighed every 5 minutes for the first 1 hour and 20 minutes thereafter. To minimize loss or gain of moisture outside dryer; the weighing balance was situated close to the plenum chamber, and samples when withdrawn from drier were placed in desiccators to cool, then weighed and returned into dryer immediately after weighing. Other measurements, which were monitored at weighing time intervals, include plenum entry and exit air temperatures and relative humidity using a digital hygrometer. Drying was discontinued as soon as sample attained calculated final weight ± 0.05g.Samples were placed in the desiccators and allowed to cool before packaging. Cooled samples are wrapped in foil paper and sealed in polythene. Fig 3.8a.

Plate 3: Pre-treated tomato samples before loading into dryer

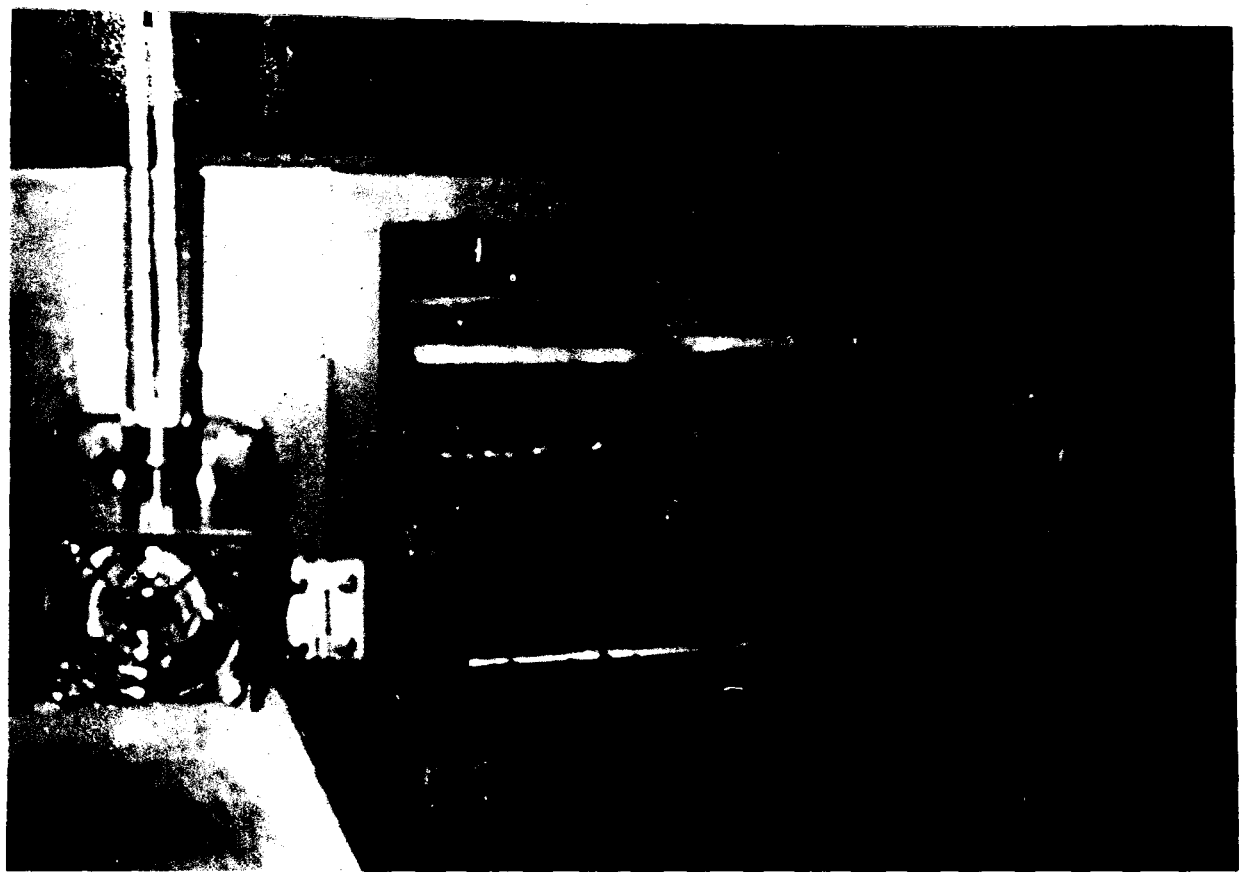


Plate 4: Tray drying of pre-treated Tomato at 50 ° C

3.6.2 Sun Drying

Sun drying was carried out on a concrete floor in the open. Drying commenced at 9.00 a.m in the morning. Prior to drying, environmental conditions were recorded. Wind speed and relative humidity were measured using the digital vane anemometer and hygrometer. A wet and dry bulb thermometer was stationed near the drying platform to read corresponding temperatures.

Prior to commencement of drying, 80 ± 0.5g of each pre-treated sample was weighed in the tray (in three (3) replications) and placed outside in the sun; drying time was recorded as zero. Samples were weighed at 20min intervals for the first three (3) hours of drying then every hour until moisture content of 4 ± 0.1% (wb) was attained. Samples were withdrawn at sunset and kept in desiccators. The desiccators were wrapped in black polythene and kept in a refrigerator until the following day. On the day two of sun drying, samples were weighed and put out in the sun; weights were taken until at one-hour intervals until final moisture content was attained. Environmental conditions were also measured each time sample weights were taken. At the end of drying, sample were packed as in tray drying. Fig. 3.7a and 3.7b show samples of sun dried tomato on days I and II respectively, while Fig. 3.8b showed packaged sundried tomato samples.

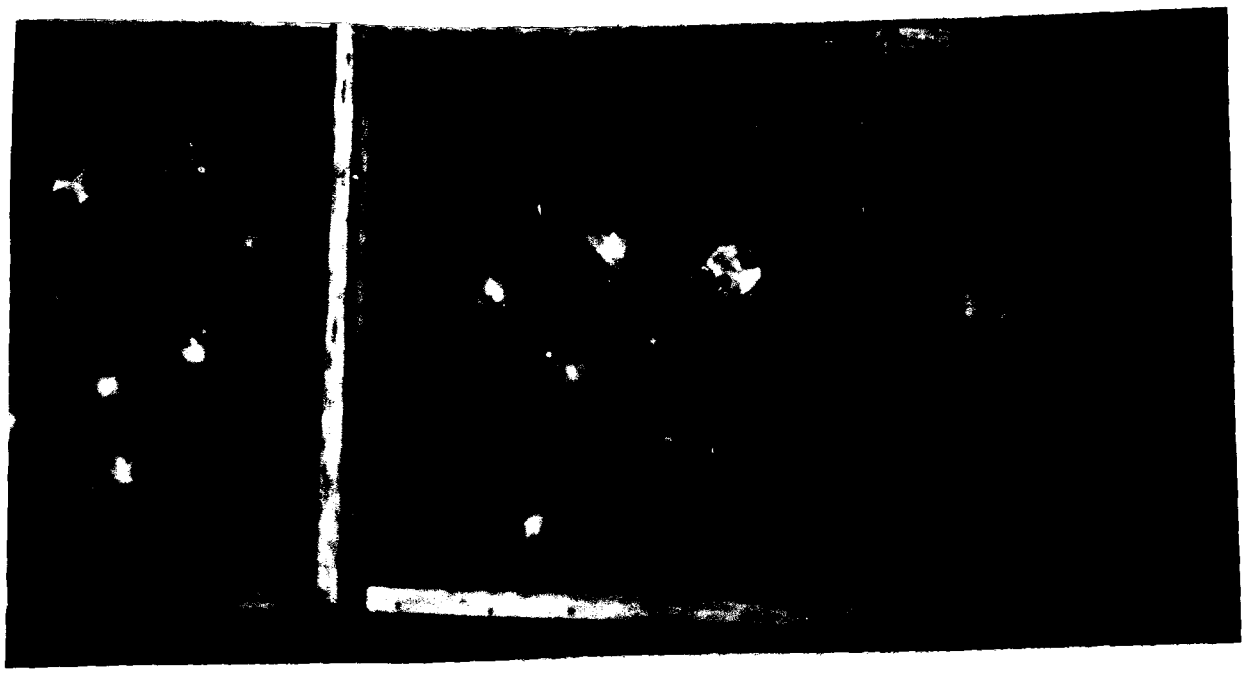
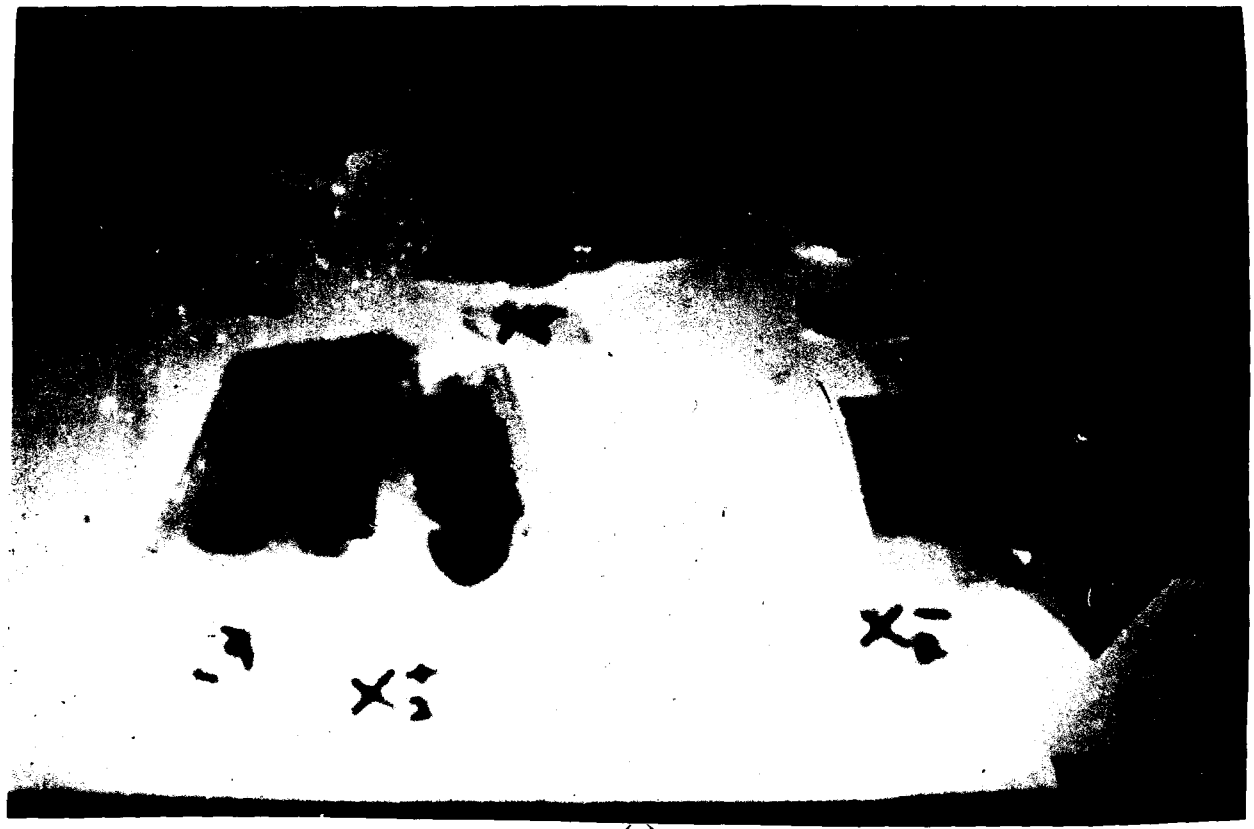
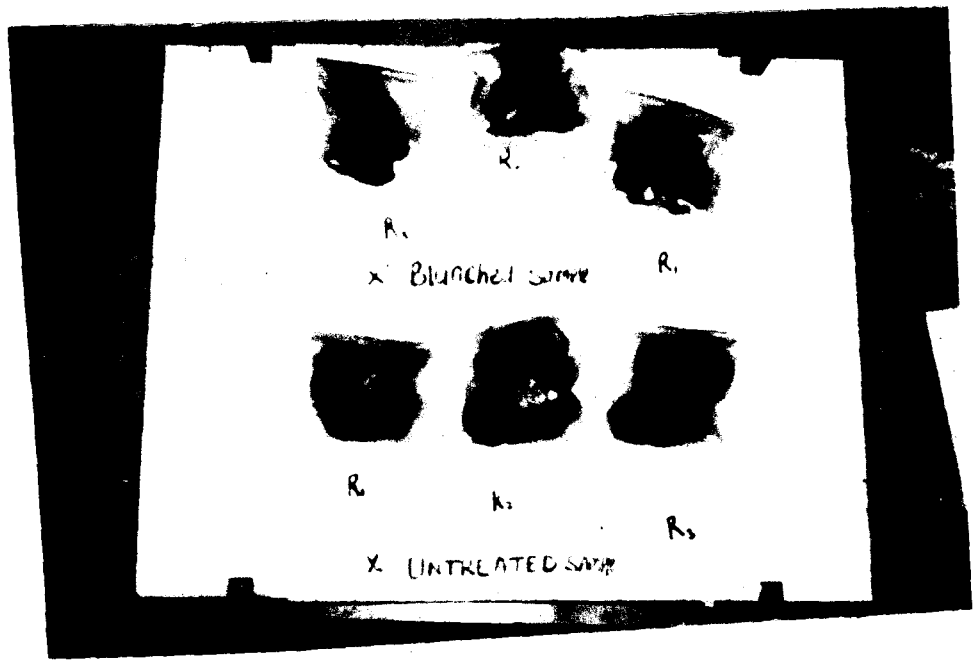


Plate5a: Sun drying of tomato Day-I

Plate 5b: Sun drying of tomato Day-II



(a)



(b)

Fig 3.8: Packaged dried tomato (a) tray dried (b) Sun dried

3.7 DETERMINATION OF β-CAROTENE

3.7.1 Open Column Chromatography

The simple modified A.O.A.C.(1980) method according to Lenton (1984) and DeRitter and Purcell (1981) as described was adopted. The principle involved extraction of carotenoids pigment by a suitable process, purification of extract by saponification, separation of pigments on a magnesium- oxide (MgO)– diatomaceous earth column, and spectrophotometry quantification at 450nm wavelength.

3.7.2 Samples Preparation And Extraction Of Carotenoids Pigments

Procedure

2.0g of pre-treated dried tomato sample and 33.1g of fresh samples were weighed in three (3) replications using the mettler weighing balance. Fresh sample was sourced directly from farm. The extraction solvent, n-hexane-acetone 1:1 ($^{v}/_{v}$) mixture was first prepared by mixing equal volumes of n-hexane and acetone into a graduated cylinder.2.0g of dried sample was macerated in methanol into finer particles using porcelain mortar. The sample was then homogenized and extracted with 30mls of n-hexane-acetone mixture (i.e. extraction solvent). The homogenate was transferred into a fritted glass funnel placed over a filter flask and filtered. The residue was re-homogenised with 10mls of the extraction solvent successively until the upper layer became colourless. The extract was then transferred into a seperatory flask and covered with the Teflon stop cork. 10mls portion of distilled water and 6mls portion of n-hexane were measured and added into the flask. The flask and content were shaken gently for 1 minute and the layers of pigments were allowed to separate, this was repeated, then 6mls of n-hexane only was added into the flask and left without shaking.

5mls of already prepared 5% anhydrous sodium sulphate aqueous solution was gradually added down the side of the seperatory flask. This was to allow the transfer of pigment in the lower water acetone layer into the n-hexane layer and prevent likely emulsion. The water-acetone layer was then drawn into another seperatory flask through the drain; the layer was rewashed using 6mls n-hexane portion two times. The extract was again transferred into another seperatory flask I, and 40mls of distilled water was added to the n-hexane extract and allowed to separate without shaking the flask, after which the aqueous lower phase was drained and discarded. This was repeated twice to remove every trace of acetone (polar solvent).

The n-hexane extract was filtered over anhydrous sodium sulphate in order to dry the extract. The dried extract termed "aliquot" was collected into an amber beaker and the volume measured (V_A). The n-hexane dried extract or aliquot was evaporated to dryness inside a rotating vacuum evaporator and re-dissolved in 10mls n-hexane.

3.7.3 Saponification Of Carotenoids Extract

Procedure

5% methanolic potassium hydroxide ($^{w}/_{v}$) was prepared by dissolving 5g potassium hydroxide (KOH) in 100mls of methanol. 10 ml of the extract concentrate was measured into a graduated beaker and 2mls of methanolic KOH added. 5g of ascorbic acid was added to the extract in the beaker, the mixture was shaken vigorously and placed in a steam bath for 30 minutes at 75°C and then rapidly cooled in cold water. The volume of the alkaline mixture was measured and transferred into a seperatory flask l; an equal volume of n-hexane was then added. 10mls of distilled water was added slowly (avoiding any shaking) to wash out the potassium hydroxide after which the aqueous phase was discard. The washing was repeated using 10mls of water until all potassium hydroxide have been removed. When the seperatory funnel showed no alkali phase, the saponified extract was poured into a graduated amber glass and 1gm of sodium chloride added.

The saponified extract was washed over anhydrous sodium sulphate and concentrated in a rotary vacuum evaporator. The residue was then dissolved in 25mls portion of n-hexane. Upon saponification, chlorophyll residue and xanthophylls were removed leaving only carotenes.

3.7.4 Chromatograph Separation

Separation of pigment of carotene from saponified extract involved packing of a column transferring the extract into column and elution of pigment.

Open Column Packing

A 18mm by 250mm glass tube was used in the packing of an open column. The tube was first attached to a fritted filter flask with a constricted end and stuffed with glass wool.

Vacuum of 4 -5 in Hg (using a vacuum pump) was applied to the fritted flask. The absorbent, a mixture of magnesium - oxide and diatomaceous earth 1: 2 by weight was poured into the column and vacuum applied until 20mm length of the tube was filled. With the aid of a glass-cork end plunger, the absorbent was pressed down firmly ensuring no crack along its length, this was repeated until 100mm length of the column was filled. A 10mm layer of anhydrous sodium sulphite was added to the top of the absorbent in the column to remove any moisture left in the extract. 50mls portion of n-hexane was poured gradually into the tube and allowed to drain under vacuum until 25mm length of the solvent was left above the sodium sulphite, and then the vacuum was turned off.

Elution Of Carotene

The saponified extract was completely transferred by means of pipette into the column. The extract was rinsed with 10mls portion of n-hexane and poured into the column, then the column was subjected to vacuum of 4 –5 in Hg. 50ml portion of 10% acetone – hexane ($^{v}/_{v}$) solvent was poured gradually down the neck of the column to elute the absorbed band of carotene. The eluate (i.e. carotene pigment) was collected in a graduated flask. The process was stopped when the last fraction of eluate became colourless. The carotene fraction was then concentrated to dryness in a rotary vacuum evaporator. The residue was dissolved in 10ml n-hexane. This gives the test solution, which is taken for spectrophotometric quantification.

3.7.6 Spectrophotometric Measurement and evaluation of carotene

The UV spectrophotometer was turned on and allowed to warm for 30 minutes. The wavelength of 450nm specified for carotene absorption in n-hexane according to Bhaskachary et al. (1975) was selected. n-hexane was poured into a 1cm corvette as blank solution and used to calibrate the absorption to zero. The test solution was poured into a 1cm corvette and the absorption of the solution read and recorded. The total carotene content in tomato samples is quantified using equation 2.27.

3.8 METHOD OF STATISTICAL ANALYSIS.

The 2^2 full factorial experiment forms the framework of this research. The experiment involved two (2) main factors, each at two levels. The coded X's and the interval of variations of factors are shown in table 3.1 below.

Table 3.1: Factors and levels of variation in 2^2 fractional experiment.

Factors		X_1	X_2
Level	Code	Steam blanching (min)	Sulphite Concentration (ppm)
Upper level	+	3	2000
Base	0	2 ½	1500
Lower level	-	2	1000
Level of Variation	Δxi	½	500

X_1 = Steam-blanching time (min).

X_2 = Sulphite concentration (ppm).

The experimental data generated consist of four (4) replicated observations of response.

From the Observed response mean and dispersion for 2^2 factorial experiment was calculated

$\bar{Y}_u$ = mean of response $= \frac{1}{r}\sum_{v=1}^{r} Y_{uv}$.

(3.1)

r = no. of replicates Y_{uv}.= observed response.

S_u^2 = Dispersion of the mean response from replicated values

$$S_u^2 = \frac{1}{r-1}\sum_{v=1}^{r}(Y_{uv} - \bar{Y}_u)^2 \qquad (3.2)$$

$$\text{The sum of dispersions} = \sum_{U=1}^{N} S_U^2 \qquad (3.3)$$

Where (N =1.... 4)

The maximum dispersion value from run 1 to 4 of the experiment is termed $S^2_{U\max}$. In analyzing the 2^2 factorial experiments in this research, the first order multiple linear relationships were used. It has been shown as an acceptable relationship between the independent variable x_i and the response Y. The ascribed functional relationship is expressed as;

$$Y = b_o x_o + b_1 x_1 + b_2 x_2 + b_{12} x_1 x_2 + e_i \qquad (3.4)$$

b_i are regression coefficients of the model., x_i = are coded variables.

e_i = Measure of error in relationship i.e. random error with zero mean and constant variable at each x_i point., Y = response variable.

3.8.1 The G-Test.

The G-test (Cochran G-criteria) was used to ascertain the possibility of carrying out regression analysis. The G-test helps to check the accuracy of the replication by verifying the homogeneity of the dispersion of the replicate experiments.

The G-value was calculated using the expression

$$G_{cal} = \frac{S^2_{u\max}}{\sum_{u=1}^{N} S_u^2} \qquad (3.5)$$

N = no of experimental runs and equal 4 for this work.

The value G_{cal} is compared with the values on an appropriate G-table. The condition for homogeneity is given as $G_{cal} < G$ (N, r-1, α = 0.05). (Douglas 1991)

N = number of experiment, = 4, r = number of replicates =3, α = level of significance. 0.05. the regression analysis is continued if this condition is satisfied.

3.8. Dispersion And Experimental Error.

The dispersion is given as $S^2_{(y)} = \frac{1}{N}\sum_{u=1}^{N} S^2_u$ (3.6)

This is also described as the average sample variance. The experimental error

$$S_{(y)} = \sqrt{S^2_{(y)}} = \sqrt{\Sigma \frac{S^2_u}{N}}$$

(3.7)

3.8.3 Estimating Model Regression Coefficient

In the four (4) replicated runs in the 2^2 factorial experiment, one mean effect, two main effects and one-two factor interactions can be estimated. According to Douglas (1991), this holds only for experiments with orthogonal design. The orthogonal relationship between the independent variables (factors) provides the method of estimating their effects on the response. In order to estimate an effect or the sum of squares of an effect, the contrast associated with that effect has to be determined. Using the contrast associated with an effect as given in the matrix design plan for the experiment, the regression coefficient was then estimated by computing the sum of squares for the effects. The mean effect was estimated using the expression;

$$b_o = \frac{1}{N}\sum_{u=1}^{N}\left(X_o . \overline{Y_u}\right) \quad (3.8)$$

u = 1,.2 , 3, 4; X_o are the coded signs in the X_o column on the matrix plan

Each of the 2-main effects was estimated by;

$$b_i = \frac{1}{N}\sum_{u=1}^{N}\left(X_i . \overline{Y_u}\right) \quad (3.9)$$

i = 1.2 and u = 1.2.....4, X_i are the coded signs in the X_i columns of the matrix plan.

The one-interaction effect was estimated thus;

$$b_{ij} = \frac{1}{N}\sum_{u=1}^{N}\left(X_{ij} . \overline{Y_U}\right) \quad (3.10)$$

Where b^s are the regression coefficients, X_{ij} is the coded sign in the columns of the design matrix, $\overline{Y_u}$ is the corresponding experimental mean result.

3.8.4 Statistical Significance Of Regression Coefficient

In trying to assess the statistical significance of each regression coefficient, it is required to construct confidence interval and test hypothesis about the individual coefficient (Samprint et al.1991). Generally, the form of confidence interval is given as

$$b_i \pm t\{\mu, N(r-1)\}S_{b_s} \qquad (3.11)$$

where α = level of significance, t (α, N (r – 1)) is the tabulated t criteria at N (r – 1) degree of freedom. b_i are the estimated regression coefficients S_{bs} = estimated standard error in the regression coefficient for a full factorial experimental design S_{bs} are the same; hence,

$$S_{b_o} = S_{b_1} = S_{b_2} = \frac{S_{(y)}}{\sqrt{N.r}}. \qquad (3.12)$$

Where $S_{(y)}$ is the experimental error.

The regression coefficients were tested by t-test. The t value for each estimated regression coefficient

$$t_i = \frac{|b_i|}{S_{b_i}} \qquad (3.13a)$$

i = 1,2.....k For this work, the values of t_o, t_1, t_2, t_{12} are calculated as ;

$$t_1 = \frac{|b_1|}{S_{b_1}} \qquad (3.13b)$$

$$t_2 = \frac{|b_2|}{S_{b_2}} \qquad (3.13c)$$

$$t_{12} = \frac{|b_{12}|}{S_{b_{12}}} \qquad (3.13d)$$

Where $|b|$ is absolute value of regression coefficient.

The coefficient of regression was tested by comparing the calculated t- values with values on a t- test table. The coefficient is significant if the absolute value of t_{cal} is greater than the table value of t at (α, N(r – 1). Where t_{cal} < t-table, the coefficient of regression is considered

not significant and dropped from the regression model (Gomez and Gomez, 1980 ; Douglas 1991). The predicted model equation can then be redefined using only the statistically significant regression coefficients.

$$\hat{Y} = b_o + b_1X_1 + b_2X_2 + b_{12}X_{12} \quad (3.14)$$

The value of $\hat{Y}$ is the fitted value of the response. The deviation of the measured value $\bar{Y}$ from the predicted value $\hat{Y}$ is called the residuals e_u

$$e_u = \bar{Y} - \hat{Y} \quad (3.15)$$

u = 1, 2, - - - 4

This residual helps to ascertain the adequacy of the least square principle used in calculating the regression coefficients.

3.8.6 Evaluation Of Model Adequacy

The adequacy of regression model was evaluated by carrying out a test of significance on the individual regression coefficient. It is useful in ascertaining the magnitude of each estimated effect. The analysis of variance is very useful in carrying out this test of significance. The analyses of variance show the regression of the response Y on X_i after ascertaining that the X_i is significant. It involved computing the sum of squares of each component in the model (i.e. X_i) and the associated degree of freedom. The expected mean square was computed in order to construct an appropriate test. The regression sum of squares for any effect in a 2^k full factorial experiment was given by:

$$SS_R = \frac{r}{N}\sum_{u=1}^{N}(contrast)^2 \quad (3.16a)$$

With a single degree of freedom for, any main effect,

$$SS_{b_i} = \frac{r}{N}\sum_{u=1}^{N}\left(X_i.\bar{Y}_u\right)^2 \quad (3.16b)$$

Where X_i are the coded signs on the X_i columns of the matrix plan. For 2- factor interaction,

$$SS_{b_{ij}} = \frac{r}{N}\sum_{u=1}^{N}\left(X_{ij}.\bar{Y}_u\right)^2 \quad (3.16c)$$

X_{ij} is the coded sign in the X_{ij} column of the matrix plan. For a 2^K experiment with interaction between all k-factors then there are 2^K two-factor interactions. Hence for the 2^2 experiment there are 4-two-factor interactions.

Total sum of the squares for each factor was given by

$$SS_T = \sum_{u=1}^{N.r} Y_{uv}^{\ 2} - \frac{\Sigma(Y_{uv})^2}{N.r} \tag{3.17}$$

The error sum of squares was computed as

$$SS_E = SS_T - SS_R$$

$$SS_E = SS_T - (SS_{b_i} + SS_{b_j} + SS_{b_{ij}}) \tag{3.18}$$

In testing the significance of individual coefficient, the F-test was thus applied. This involved calculating the mean squares of each effect and the mean square of the error. The means squares are given as;

$$MS_{b_{ij}} = \frac{SS_{b_{ij}}}{df_{b_{ij}}} \tag{3.19}$$

$df_{b_{ij}}$ = Degree of freedom of regression = 1

$$MS_E = \frac{SS_E}{N(r-1)} \tag{3.20}$$

The F = criteria for the test was computed as,

$$F_{cal} = \frac{MS_R}{MS_E} \tag{3.21}$$

The null hypothesis will be rejected if $F_{cal} \rangle F_{\{\alpha, df_R N(r-1)\}}$ for all coefficient of regression.

This means that the coefficients contribute significantly to the regression (Fred and Elazar (1982). In checking further the adequacy of the model, the dispersion of adequacy for the replicated experiment was computed and by the mean squared error MS_E. This was given as

$$SS^2_{adj}\, SS^2_{adj} = \frac{r}{(N-\lambda)} \sum_{u=1}^{N} \left(Y_u^2 - \hat{Y}_u\right)^2 = \frac{r}{df_{adj}} \sum_{u=1}^{N} \left(\bar{Y}_u - \hat{Y}_u\right)^2 \tag{3.22}$$

Where $\bar{Y}_u$ is the mean value of observed response, $\hat{Y}_u$ is the predicted value.

$(\bar{Y}_u - \hat{Y}_u)$ = Residual (3.23)

df_{adq} = The degree of freedom of adequacy

λ = No. of inadequate coefficients.

F-test estimation of adequacy is determined as

$$F_{cal} = \frac{S_{adj}}{S^2_{(y)}} \quad (3.24)$$

$S^2_{(y)}$ = the variance of the mean squared error. The condition of adequacy when the F value calculated was compared with table value was given as

$$F_{cal} \leq F_{\{\alpha, df_R N(r-1)\}}$$

If this condition is satisfied, then it can be said that the predicted model is adequate. Based on the significant regression coefficient only, the final fitted or predicted model can be expressed as $\hat{Y} = (b_o \pm - - - - - - - - - - - b_K X_K)$ (Douglas (1991).

CHAPTER FOUR

4.0 RESULTS OF ANALYSIS OF EXPERIMENTAL DATA

The Two variable, two-level factorial experiments were conducted in a randomized order in three (3) replications using three different drying methods. The experiments were conducted according to the designed experimental plan (matrix) given in table 2.8. The results from the analysis of the collected data are presented in two segments, the first one is on β-carotene retained while the second is on the drying rates.

4.1 RESULT OF EXPERIMENT ON β – CAROTENE RETENTION IN PRETREATED DRIED TOMATO

The results of β- carotene retained in pretreated dried tomato and the statistical analysis are presented according to the drying methods used. The value of β carotene in fresh sample is 0.574mg/100g. Detailed calculations of statistical analysis are given in appendix 1A to 1C

4.2 STATISTICAL ANALYSIS OF β CAROTENE IN PRE-TREATED TOMATO TRAY DRIED AT 65°C

4.2.1 The values of β carotene obtained in this experiment are shown in table 4.1 below. The mean value of β-carotene in untreated sample tray dried at 65°C is 0.0982mg/100g

Table 4.1: β Carotene Retained In Pretreated (65°C) Tray Dried Tomato

EXP.	CODED	β CAROTENE (mg/100g)			
No	SAMPLE	R_1	R_2	R_3	Mean
1	$X_1^- X_2^-$	*0.2788*	*0.2733*	*0.2816*	*0.2778*
2	$X_1^+ X_2^-$	*0.3702*	*0.3661*	*0.4222*	*0.3861*
3	$X_1^- X_2^+$	*0.4326*	*0.4747*	*0.4672*	*0.4581*
4	$X_1^+ X_2^+$	*0.4950*	*0.5040*	*0.5133*	*0.5041*

In order to ascertain the possibility of carrying out regression analysis on this data, the G-criteria value calculated using equations 3.1 –3.5 as shown in the appendix was compared with the table value of $G_{(4,2,0.05)} = 0.768$. The result shows that the value of $G_{cal} < G_{tab}$

(i.e. $0.6185 < 0.768$). This indicates homogeneity of the data and that regression analysis can be carried out.

4.2.2 Model Regression Coefficients

For the orthogonal 2^2 factorial design, using equations 3.8, 3.9 and 3.10, the model regression coefficients were estimated as shown in appendix. The statistical significance of each estimated regression coefficient was tested by t – test using equations 3.11 and 3.12, to determine which coefficient contributed significantly to the model. The estimated effects, the confidence intervals and the calculated t – value are summarized and presented in table 4.2

Table 4.2: Estimated effect, confidence internal and calculated t-value for pretreated tomato tray dried at 65 C.

Regression Coefficient	Estimated Effect	Confidence Interval	t-value	Table t-value	
				5%	%1
			Calculated	1.860	3.355
b_o	*0.4066*	*±0.0107*	*70.98*		
b_1	*0.0386*	*±0.0107*	*6.715*		
b_2	*0.0745*	*±0.0107*	*12.981*		
b_{12}	*-0.0156*	*±0.0107*	*2.712*		

4.2.3 The Predicted Model

From table 4.2 above calculated t –values are greater than table values for all regression terms. This shows that all the regression coefficients are seen to be statistically significant at 5% and 1% significance levels. The predicted equation using the calculated regression coefficient is thus given as

$$\hat{Y} = 0.4066 + 0.0386X_1 + 0.0745X_2 - 0.0156X_{12} \qquad (4.1)$$

The calculations of the fitted values of Y at the levels of the independent variables (i.e. four points of the design) were carried out using the predicted model given in equation 4.1 The mean experimental observation, the fitted value, the residuals and the squares of the residuals are shown in table 4.3

Table 4.3: Mean Experimental Observations, Fitted Values, Residuals and Squares of Residuals for 65°C Tray Drying Experiment.

Exp Run	Mean Value $\bar{Y}_u$	Fitted Value $\hat{Y}$	Residual $\ell = (Y_n - \hat{Y})$	Square Of Residual $\ell^2 = (Y_n - \hat{Y})^2$	$\sum \ell_u^2$
1	*0.2778*	*0.27782*	*0.00002*	*4×10^{-9}*	*5.929 x*
2	*0.3861*	*0.386113*	*0.000013*	*1.69×10^{-10}*	*10^{-9}*
3	*0.4581*	*0.458142*	*0.000042*	*1.76×10^{-9}*	
4	*0.5041*	*0.5041*	*0*	*0*	

4.2.4 Model Adequacy

The adequacy of the predicted model was evaluated by carrying out the F-test on each regression coefficient by analysis of variance using equations 3.13 –3.21.. Comparing the F-value associated with each regression term with $F_{(0.05;\ 1,\ 8)} = 5.32$, the result shows that all the regression coefficients are significant at 5 % and 1 % levels of error . The analysis of variance is summarized in table 4.4

Table 4.4: Analysis of Variance (ANOVA) For Replicated 2^2 Factorial Experiment For Tray-Dried (65°C) Tomato

Source Of Variation	Effect	df	Sum Of Squares	Mean Sum Of Squares	F-ratio		
					Observed Value	Table Value 5%	1%
						5.32	11.26
b_1	*0.0386*	*1*	*0.01785*	*0.0178*	*45.078***		
b_2	*0.07455*	*1*	*0.0669*	*0.0669*	*168.41***		
b_{12}	*1.0158*	*1*	*0.00291*	*0.0029*	*7.358**		
Error		*8*	*0.0032*	*0.00040*			
Total		*11*	*0.0906*				

** Highly significant *significant

From the F-test estimation of adequacy using equations 3.22 – 3.24 as given in the appendix, the value for F_{adj} obtained when compared $F_{(0.05, 1, 8)}$ showed that $F_{adj} < F_{(0.05, 1, 8)}$ hence the predicted model is considered adequate. The fitted model equation for pretreated tomato tray dried at 65°C is thus

$$\hat{Y} = 0.4066 + 0.0386X_1 + 0.0745X_2 + 0.0156X_{12} \qquad (4.2.)$$

4.3 STATISTICAL ANALYSIS OF β CAROTENE IN PRE-TREATED TOMATO TRAY DRIED AT 50 C

4.3.1 The values of β–carotene obtained in this experiment are shown in table 4.5 below. The mean value of β–carotene in untreated sample tray dried at 50°C is 0.0721mg/100g. The detailed calculations of the result presented here are given in appendix 1B.

Table 4.5: β- Carotene content in pretreated tomato tray dried at 50°C

EXP.	CODED	β CAROTENE (mg/100g)			
No	SAMPLE	R_1	R_2	R_3	Mean
1	$X_1^- X_2^-$	*0.2601*	*0.2292*	*0.2535*	*0.2478*
2	$X_1^+ X_2^-$	*0.2868*	*0.2933*	*0. 2953*	*0.2918*
3	$X_1^- X_2^+$	*0.3120*	*0.3026*	*0.3178*	*0.3108*
4	$X_1^+ X_2^+$	*0.4181*	*0.4389*	*0.4636*	*0.4401*

The possibility of carrying out regression analysis on this data was determined by calculating G-criteria using equation 3.1 –3.5 as shown in the appendix. Comparing the table value of $G_{(4,2,0.05)}$ with the calculated values (G_{cal}), The result shows that the value of $G_{cal} < G_{tab}$ (i.e 0.5979 < 0.768).This shows homogeneity of the data and that it can be regressed.

4.3.2 Model Regression Coefficients

For the orthogonal 2^2 factorial design, the model regression coefficients for pretreated tomato tray dried at 50 °C were estimated using equations 3.8, - 3.10 as given in the appendix. The statistical significance of each estimated regression coefficient was tested by t – test using equations 3.11 and 3.12, to determine which coefficient contributed significantly to the model. The values of the estimated effects, the confidence intervals and the calculated t – value are presented in table 4.6

Table 4.6: Estimated effect, confidence internal and calculated t-value for pretreated tomato tray dried at 50°C.

Regression coefficients	Estimated effect	Confidence interval	Calculated t – value	Table t- value 5%	1%
				1.860	3.355
b_o	*0.3226*	*± 0.0079*	*75.8*		
b_1	*0.0433*	*± 0.0079*	*10.183*		
b_2	*0.0525*	*± 0.0079*	*12.416*		
b_{12}	*0.0214*	*± 0.0079*	*5.013*		

4.3.3 The Predicted Model

From table 4.6 above all the regression coefficients are seen to be statistically significant at 5% and 1% significance levels. The predicted equation using the calculated regression coefficients is thus given for pretreated tomato tray dried at 50°C as

$$\overline{Y} = 0.3226 + 0.0433X_1 + 0.0528X_2 + 0.0213X_{12} \qquad (4.3)$$

The calculations of the fitted values of Y at the levels of the independent variables (i.e four points of the design) was carried out using the predicted model given in equation 4.3. The mean experimental observation, the fitted value, the residuals and the squares of the residuals are shown in table 4.7

Table 4. 7: Mean Experimental Observations, Fitted Values, Residuals and Squares of Residuals for 50°C Tray Drying Experiment.

Exp Run	Mean Value $\bar{Y}_u$	Fitted Value $\hat{Y}$	Residual $\ell = (Y_n - \hat{Y})$	Square Of Residual $\ell^2 = (Y_n - \hat{Y})^2$	$\sum \ell_u^2$
1	*0.2478*	*0.247797*	*-3×10^{-6}*	*9×10^{-12}*	*5.59×10^{-10}*
2	*0.2818*	*0.29181*	*-1×10^{-5}*	*1×10^{-10}*	
3	*0.2108*	*0.310821*	*-2.1×10^{-5}*	*4.41×10^{-10}*	
4	*0.4402*	*0.440197*	*-2×10^{-6}*	*9×10^{-12}*	

4.3.4 Model Adequacy

The adequacy of the fitted model was evaluated by carrying out the F- test on each regression coefficient using analysis of variance as computed using equations3.13 –3.22. Comparing the F-value associated with each regression term with $F_{(0.05;\ 1,\ 8)} = 5.32$, the result shows that the regression coefficients are highly significant. The result of the analysis of variance as calculated in the appendix is summarized in the table 4.8

Table 4.8: Analysis Of Variance {ANOVA} 2^2 Factorial Experiment of Pretreated Tomato Tray dried At 50°C.

Source Of Variation	Effect	df	Sum Of Square	Mean Sum of Square	F-ratio Observed Value	F-ratio Table value 5%	F-ratio Table value 1%
b_1	*0.0433*	*1*	*0.0225*	*0.02255*	*103.90***	*5.32*	*11.26*
b_2	*0.0433*	*1*	*0.0335.*	*0.0335*	*154.47***		
b_{12}	*0.02134*	*1*	*0.0055*	*0.0055*	*25.185***		
Error		*9*	*0.0174*	*0.000217*			
Total		*11*	*0.0633*				

** Highly Significant

The model adequacy was further checked using equations 3.22 -3.24 as given in the appendix. The value for F_{adj} obtained is compared with F- value from statistical table, $F_{(0.05,\ 1,\ 8)} = 5.32$. Since the value of $F_{adj} < F(0.05, 1,8)$ (i.e $2.842 \times 10^{-8} < 5.32$), the predicted model given in equation 4.3. is considered adequate, hence for tomato pretreated and dried at 50°C, the final fitted model is given as

$$\hat{Y} = 0.3227 + 0.0433X_1 + 0.0528X_2 + 0.0213X_{12} \qquad (4.4).$$

4.4 STATISTICAL ANALYSIS OF BETA (β)-CAROTENE CONTENT PRETREATED SUN DRIED TOMA

4.4.1 The data in table 4.9 below show the values of β- Carotene retained when pretreated tomato slices were sun dried at a mean daily temperature of 37 C. Untreated (control) sample retained 0.045mg/100g. Detailed calculations of the results presented here are given in appendix 1C

Table 4.9: β -Carotene Retained In Pretreated Sun Dried Tomato

Exp Run	Sample (Coded)	β -CAROTENE (mg/100g)			
		$\bar{R}_1$	$\bar{R}_2$	$\bar{R}_3$	Mean
1	$X_1^- X_2^-$	*0.1645*	*0.1479*	*0.1662*	*0.1595*
2	$X_1^+ X_2^-$	*0.1866*	*0.1699*	*0.1733*	*0.1766*
3	$X_1^- X_2^+$	*0.2159*	*0.2226*	*0.2213*	*0.2199*
4	$X_1^+ X_2^+$	*0.2696*	*0.3026*	*0.3139*	*0.2954*

In order to ascertain the possibility of carrying out regression analysis on this data, the G-criteria value calculated using equations 3.1 –3.5 as shown in the appendix was compared with the table value of $G_{(4,2,0.05)} = 0.768$. The value of $G_{cal} < G_{tab}$ (i.e $0.7337 < 0.768$). This shows homogeneity condition and that the regression analysis could be carried out.

4.4.2 Model Regression Coefficients

For the orthogonal 2^2 factorial design, the model regression coefficients were estimated using equations 3.8 - 3.10 as given in the appendix. The statistical significance of each estimated regression coefficient was tested by t-test using equations 3.11 and 3.12. The summary of the estimated effects, the confidence intervals and the calculated t – value are presented in table 4.10

Table 4.10: Estimated Effect, Confidence Internal and Calculated t–Value For Pretreated Sun Dried Tomato

Regression coefficients	Estimated effect	Confidence internal	Calculated t – value	Table t value 5%	Table t value 1%
				1.860	*3.355*
b_o	*0.2128*	± *0.00722*	*54.846*		
b_1	*0.0231*	± *0.00722*	*5.958*		
b_2	*0.0448*	± *0.00722*	*11.540*		
b_{12}	*0.0146*	± *0.00722*	*3.760*		

4.4.3 The Predicted Model

From table 4.10 above all the regression coefficients are seen to be statistically significant at 5% and 1% significance levels. The predicted equation using the calculated regression coefficient is thus given as

$$\overline{Y} = 0.2128 + 0.0231X_1 + 0.04480X_2 + 0.0146X_{12} \qquad (4.5.)$$

The calculations the fitted values of Y at the levels of the independent variables (i.e four points of the design) was carried out using the predicted model given in equation 4.5. The mean experimental observation, the fitted value, the residuals and the squares of the residuals are shown in table 4.11.

Table 4.11:Mean Experimental Observations, Fitted Values Residuals and Square Of Residuals For Pretreated Sun Dried Tomato

Exp Run	Mean Value $\overline{Y_u}$	Fitted Value $\hat{Y}_u$	Residual $\ell_u = \overline{Y_u} - \hat{Y}_u$	Square of Residual $\ell_u^2 = (\overline{Y_u} - \hat{Y})^2$	$\sum \ell_u^2$
1	*0.1595*	*0.15954*	4×10^{-5}	1.6×10^{-9}	4.2×10^{-9}
2	*0.1766*	*0.17659*	1×10^{-5}	1×10^{-10}	
3	*0.2199*	*0.21993*	-3×10^{-5}	9×10^{-10}	
4	*1.2954*	*0.29536*	4×10^{-5}	1.6×10^{-9}	

4.4.4 Model Adequacy

The adequacy of the predicted model was evaluated by analysis of variance to test of significance on each regression coefficient using equations 3.13 - 3.21. The result of the analysis of variance as calculated in the appendix is summarized in the table 4.12

Table 4.12: Analysis Of Variance (ANOVA) For Replicated 2^2 {Full Factorial} Experiment For Pretreated Sun Dried Tomato .

Source Of Variation	Effect	df	Sum Of Square	Mean Sum of Square	F-ratio Observed Value	F-ratio Table value	
b_1	*0.02312*	*1*	*0.006416*	*0.006416*	*35.447***	*5.32*	*11.26*
b_2	*0.04479*	*1*	*0.02407*	*0.02407*	*133.0***		
b_{12}	*0.01460*	*1*	*0.002556*	*0.002556*	*14.12***		
Error		*9*	*0.001446*	*0.000181*			
Total		*11*	*0.034491*				

** Highly Significant

Comparing the F-value associated with each regression term with $F_{(0.05;\,1,\,8)} = 5.32$, the result shows that the regression coefficients are highly significant. The model adequacy was further checked by F-test estimation of adequacy. F-adjusted (F_{adj}) value obtained using equations 3.22 -3.24 was found to be less than $F_{(0.05,1,8)}$ ($F_{(adj)} < F_{(tab)}$), thus the predicted model fitted is considered adequate.

For pretreated sun dried tomato the fitted model equation is given as

$$Y = 0.2128 + 0.02312X_1 + 0.0448X_2 + 0.0146X_{12} \qquad (4.6)$$

4.5 RESULT OF EXPERIMENTS ON DRYING RATE

Three different experiments were carried out for all treatments; these were tray drying with heated air at 65^0 C and 50^0 Ć as well as sun drying. The observed data collected before and during drying include weight of samples before and after pretreatments, sample weights, inlet and exit air temperatures and relative humidity at predetermined time intervals during drying. The air velocity remained constant at 2.0m/s in tray drying experiments. Air velocity during sun drying was not constant.

4.5.1 Result Of Pre-Drying Experiments.

The colour after the reaction of perioxidaze in guaicol solution as well as the resultant texture of tomato for various drying time are shown in table 4.13 Both negative and trace reactions are regarded as satisfactory evidence of effective blanching (Fields 1997).

The moisture content of fresh untreated, and pretreated samples prior to drying as determined using vacuum oven drying method and equations 2.1 and 2.2 as well as The estimated amount of water to be extracted to bring samples to final moisture content of 4.0% (wb) using equations 2.4 and 2.5 are shown in table 4.14

4.5.2 Drying Air Conditions

Drying air was heated from ambient temperature of 27°C (wet bulb), and 37°C dry bulb to 65°C and 50°C dry bulb temperatures during tray drying. This reduced relative humidity from 38% to 15.2%and 20.5% respectively. Upon picking up moisture from the material in the dryer, the air temperature at exit within the first 1 hour of drying averaged 61±1 °C and 44°C (dry bulb) while the product surface temperature increased gradually from 30°C to 64°C and 48±1°C at the end of drying in the 65°C and 50°C experiments respectively. Average temperatures of 27°C wet bulb and 37°C dry bulb over drying period of 7hours per day and were recorded during sun drying. Relative humidity varied between 35% and 38%.

Table 4.13: Result of test showing adequate time to inactivate perioxidaze enzyme in tomato

Blanching Time (min)	Indicated colour	Indication	Texture
0	Reddish brown	Positive	Very strong
1	Reddish brown	Positive	Strong
1.5	Reddish brown specks	Positive	Strong
2.0	Scattered light brown marks	Negative	Strong
2.5	*Pinkish-red	Negative	Strong
3.0	Pinkish-red	Negative	Fairly strong
3.5	Pinkish-red	Negative	Soft
4.0	Pinkish-red	Negative	Very soft

* initial colour, no change in colour was observed

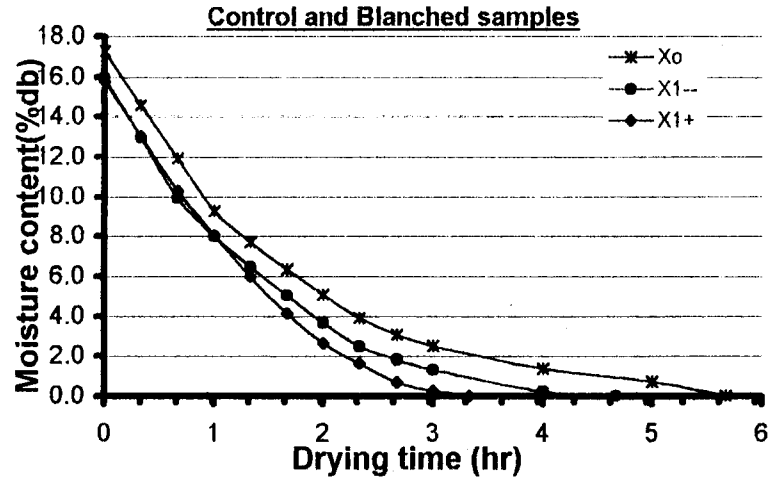
Table 4.14: Average moisture content of pre treated tomato samples before drying.

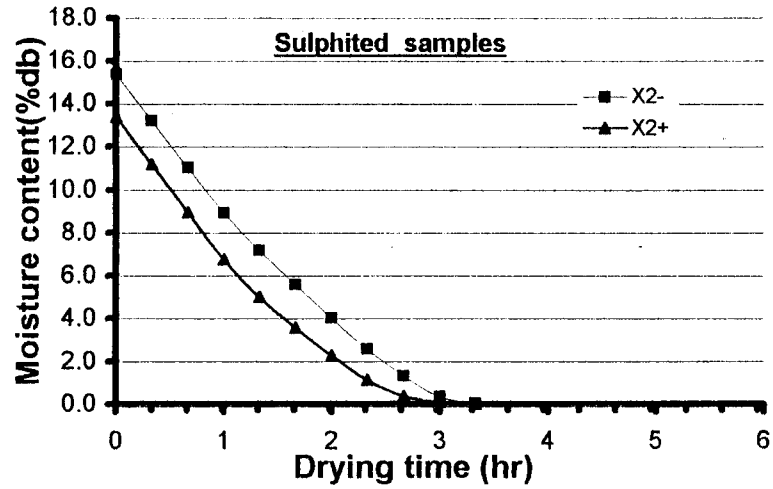
Samples	Sample weights (g)		Moisture content (%)		*Water content	
Treatments	Before drying	After drying	Wet basis	Dry basis	Total	To be removed
X_0	20.00	1.094	94.53	17.28	75.62	75.43
X_1^-	19.87	1.090	94.12	16.00	75.30	75.10
X_1^+	18.87	1.083	94.03	15.78	75.22	75.02
X_2^-	20.14	1.228	93.90	15.40	75.12	74.91
X_2^+	20.36	1.40	93.06	13.41	74.48	74.25
$X_1^- X_2^+$	20.04	1.142	94.30	.16.54	75.54	75.35
$X_1^+X_2^-$	20.00	1.20	94.02	15.77	75.22	74.86
$X_1^- X_2^+$	20.03	1.20	93.99	15.64	75.19	74.99
$X_1^+X_2^+$	19.77	1.30	93.39	14.13	74.71	74.49

* * Based on an average weight of 80±0.5g

4.6 RESULT OF DRYING EXPERIMENTS

Investigation of the drying rate of pretreated tomato slices involves analysis of the data collected to obtain the decrease in moisture content (dry basis) at given time intervals over the drying periods using equation 2.2. The visualization of the entire drying process is presented using the drying curves and the drying rate curves. The drying rate was determined by differentiating a first order polynomial resulting from the moisture content – time curve over the drying period. The drying rate curve is plotted as drying rate (gH_2O/gD_m/ hr) versus drying time (hr), while the drying curve is plotted as moisture content (%db) against drying time (hrs). The values of moisture contents and drying rates determined are shown in tables A4.1, A4.2 and A4.3 (in appendix 4) for 65°C and 50°C and sun drying experiments respectively. The drying and drying rate curves are shown in figures 4.1, 4.2, 4.3, and fig 4.4, 4. 5, 4.6 respectively for 65°C and 50°C and sun drying experiments. All drying curves showed prominently two major drying periods, the constant and the falling rate drying periods.





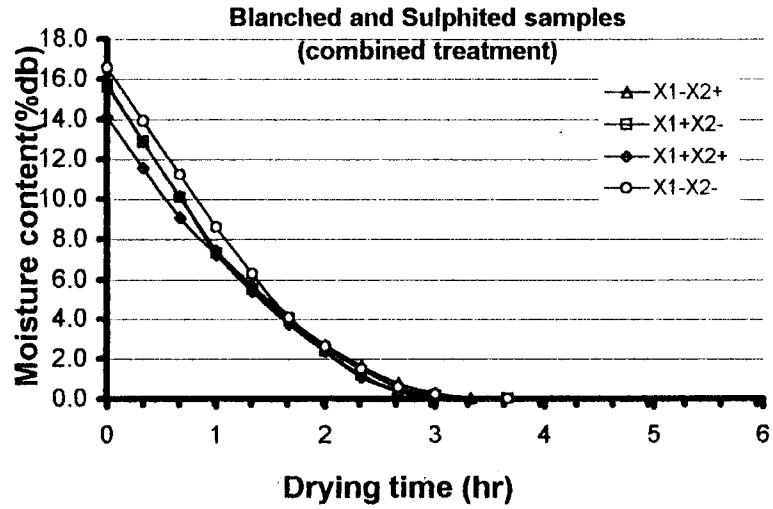


Fig 4.1: Drying curves for pretreated tomato traydried at 65°C

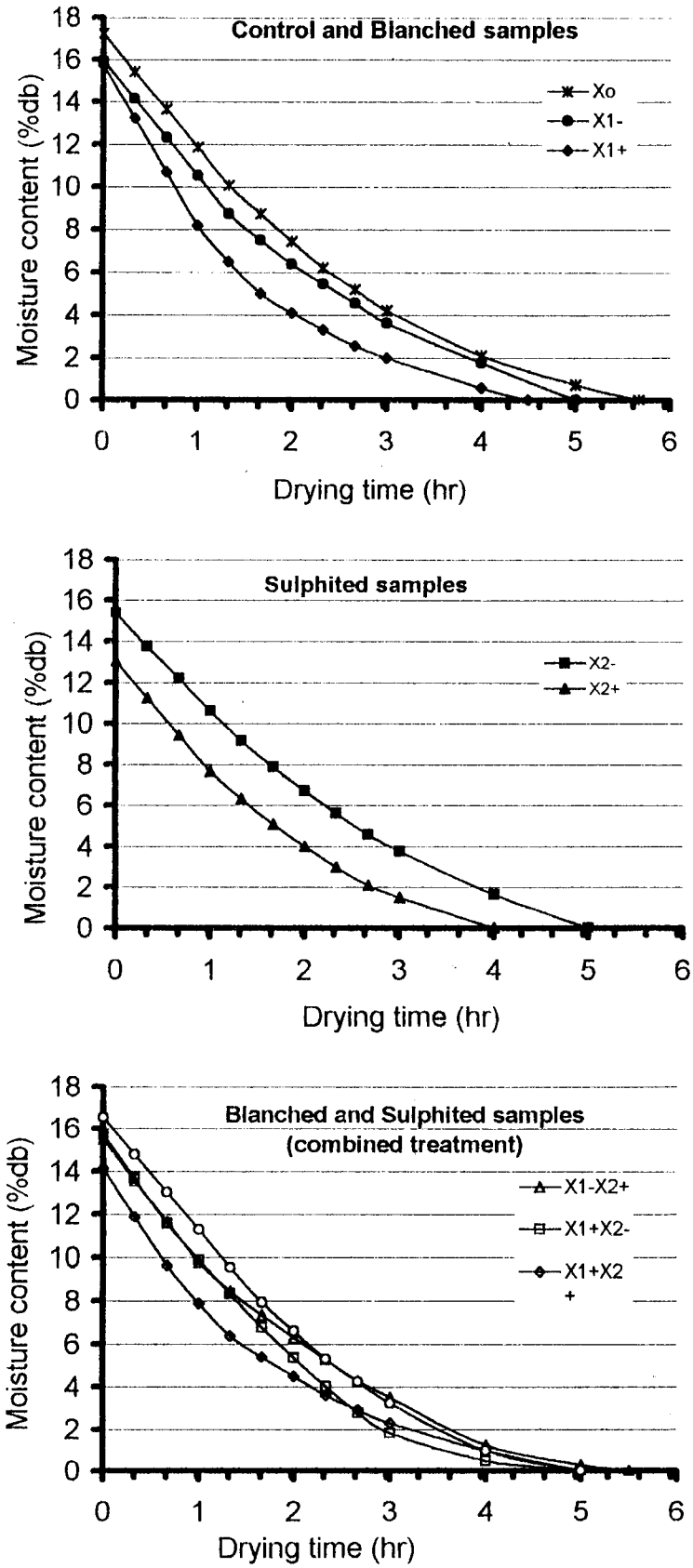
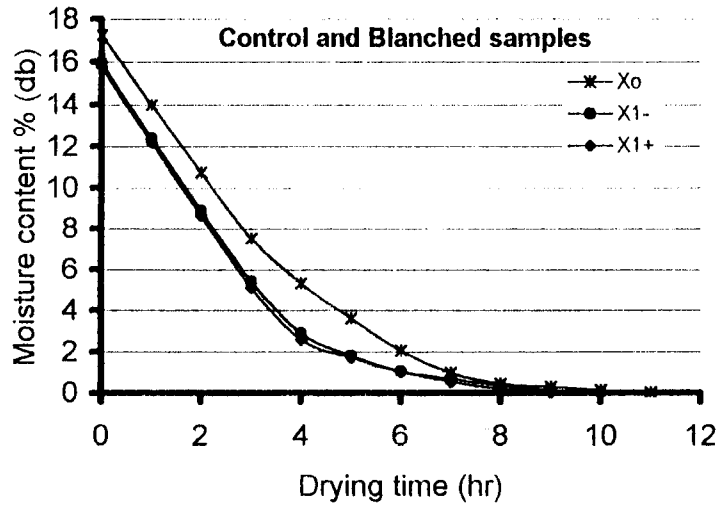
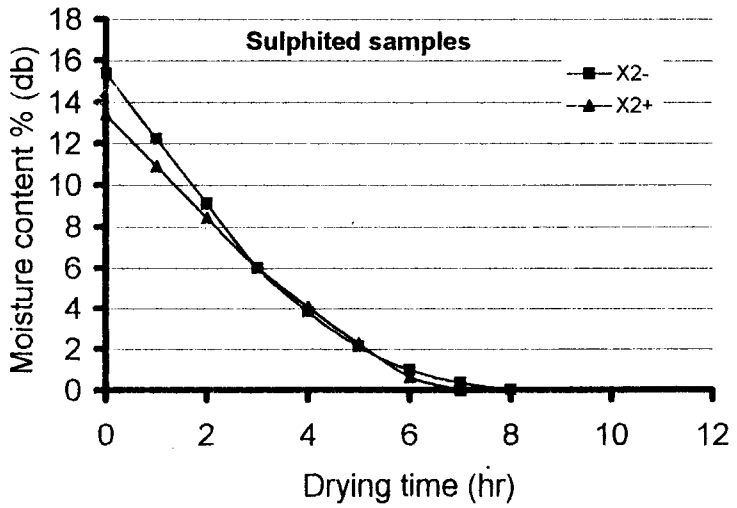


Fig 4.2: Drying curves for pretreated tomato traydried at 50°C





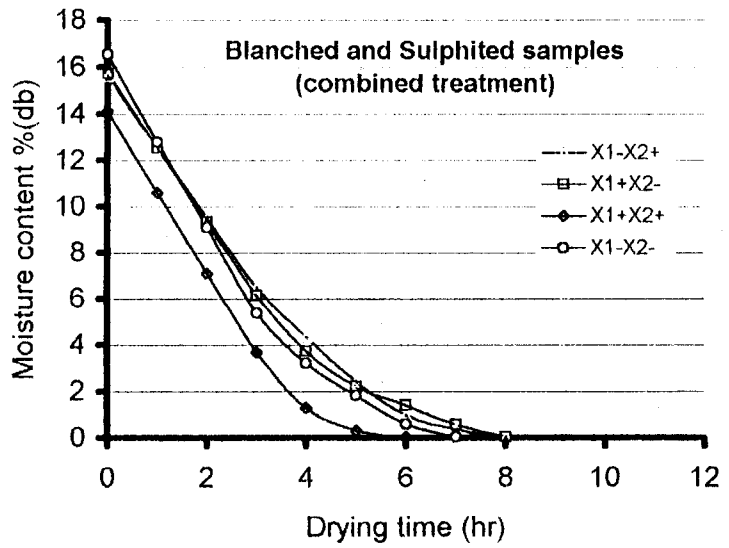
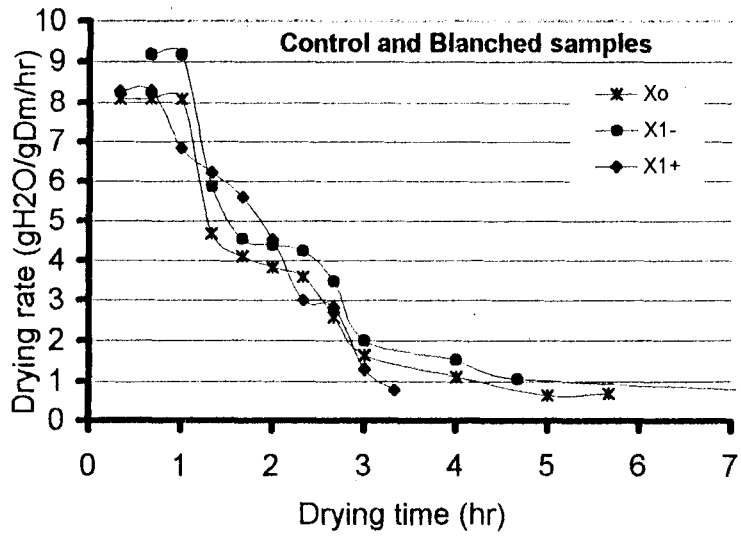
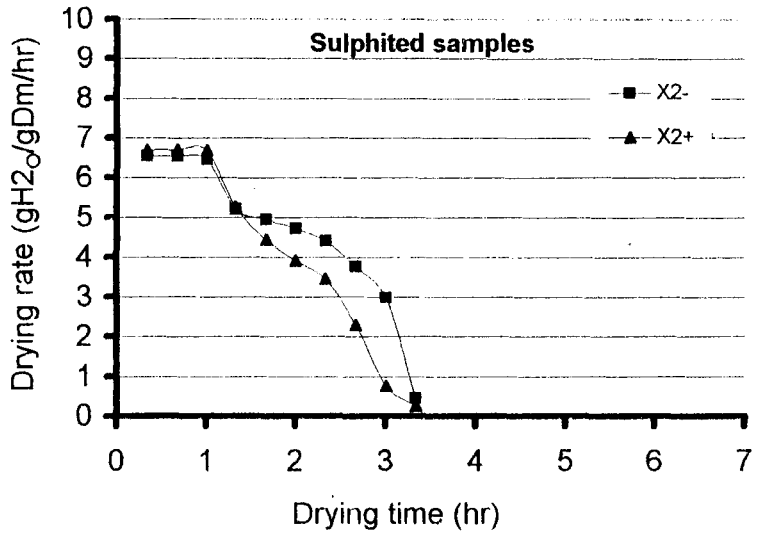


Fig 4.3: Drying curves for pretreated Sundried tomato





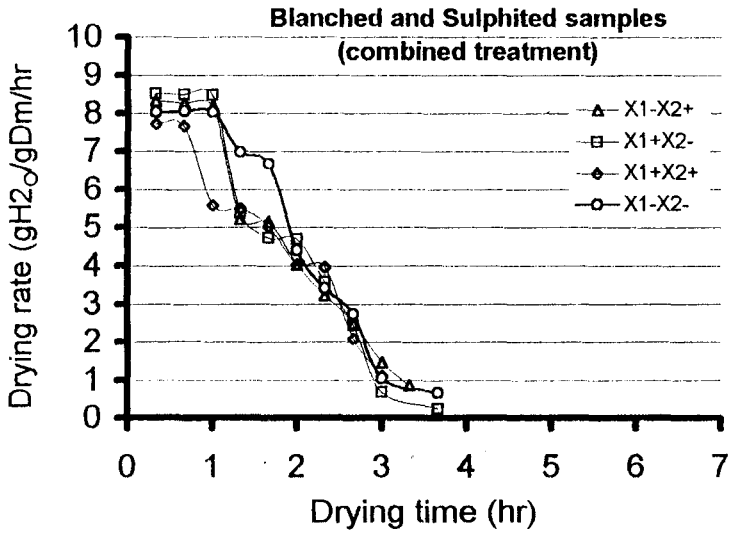
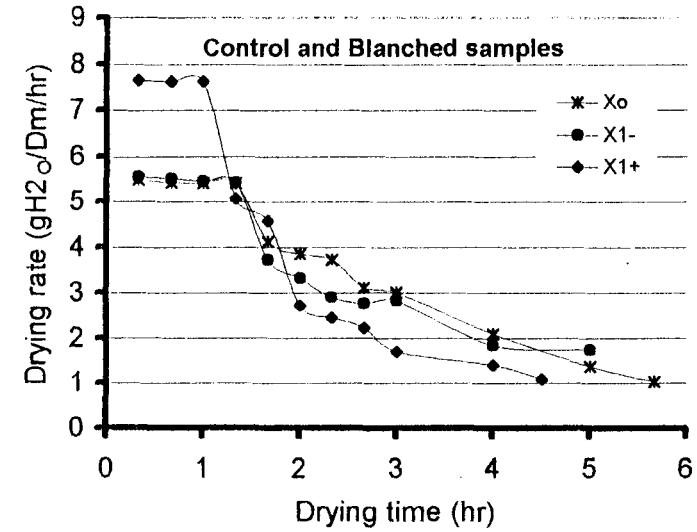
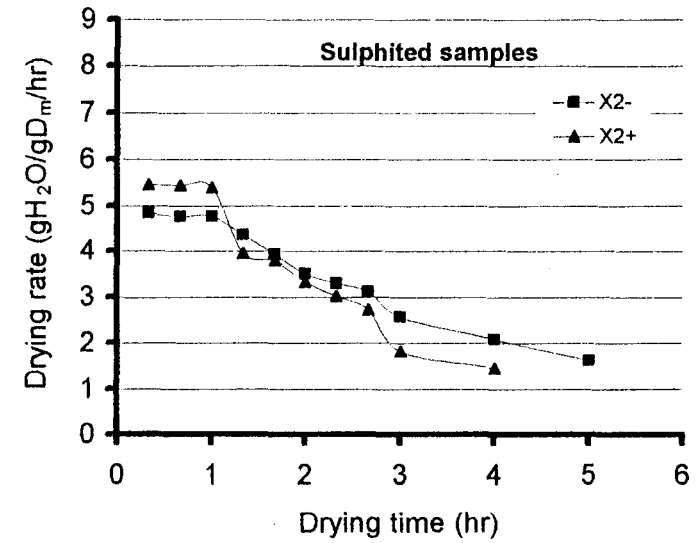


Fig 4.4: Drying rate vrs drying time curves for pretreated tomato traydried at 65°C





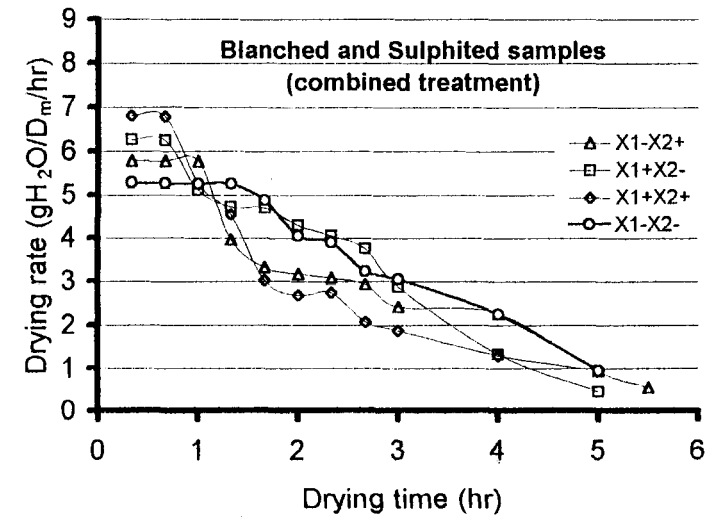
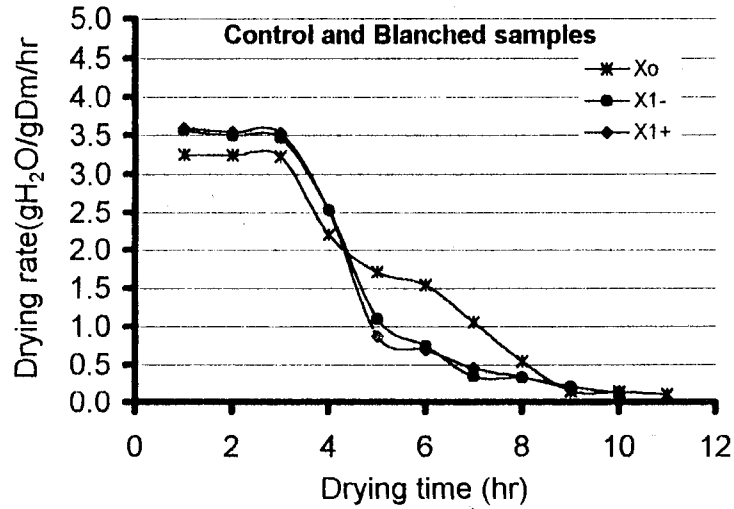
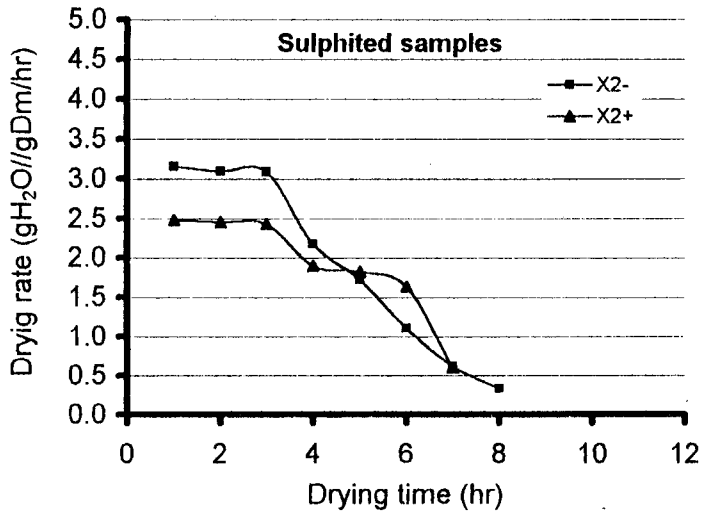


Fig 4.5:Drying rate vrs moisture content curve for pretreated tomato traydried at 50°C





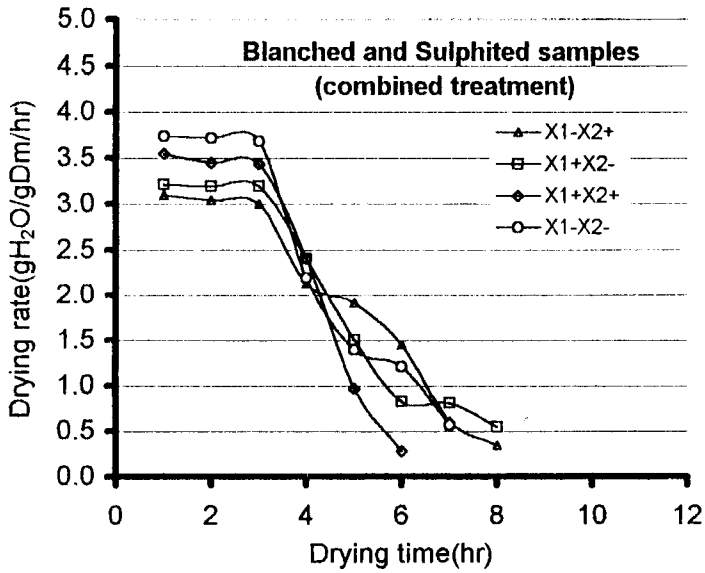


Fig 4.6: Drying rate vrs drying time curves for pretreated sundried tomato

4.7 RESULT OF CONSTANT RATE DRYING

The period of drying controlled by surface evaporation showed a straight line on the drying curves and drying rate curves and the point where the straight line deviates is the critical moisture content. The straight-line portion of the figures 4.7, 4.8 and 4.9 show the constant drying rate period for each drying experiment. The straight-line plotted points were regressed and from the corresponding linear equation generated, the slope of each curve was obtained. From the slope of each line and the dry matter in each sample, the constant rate of water removal over the corresponding period was calculated using equation 2.9. The values of constant drying rate of all samples in all drying experiments are given in table 4.15 for $65^{O}C$ and $50^{O}C$ tray drying and sun drying respectively.

Table 4.15: Constant rate drying and corresponding drying period of pretreated tomato for all drying experiments

		65°C tray drying			50°C traydrying			Sun drying		
Exp.Run	Sample (coded)	Drying rate (gH_2O/hr	Drying rate period (hr)	R^2	Drying rate (gH_2O/hr	Drying rate period (hr)	R^2	Drying rate (gH_2O/hr	Drying rate period (hr)	R^2
1	X_0	35.04	1	0.909	23.28	1.33	0.993	14	3	0.99
2	X_1^-	39.17	0.66	0.999	25.67	1.33	0.993	16.43	3	0.999
3	X_1^+	43.26	0.66	1	36.04	1	0.993	18.11	3	1
4	X_2^-	31.44	1	0.997	22.93	1	0.994	12	3	0.986
5	X_2^+	39.65	1	0.998	29.85	1	0.995	16.95	3	0.997
6	$X_1^-X_2^-$	36.1	1	0.996	23.39	1.33	0.983	14.25	3	0.984
7	$X_1^-X_2^+$	38.83	1	0.993	25.01	1.66	0.984	15.32	3	0.998
8	$X_1^+X_2^-$	39.13	1	0.996	25.09	1.33	0.995	15.66	3	0.997
9	$X_1^+X_2^+$	40.41	0.66	0.999	32.92	1	0.994	17.96	3	0.999

4.8 RESULT OF FALLING RATE DRYING

The period of moisture removal beyond the critical moisture content is seen on the drying curves to deviate from a straight line. In order to determine the relationship during this drying period, the moisture loss beyond the critical point was expressed as a proportion of the critical moisture content; i.e. moisture ratio as given in equation 2.19a. The obtained values were plotted over elapsed time with the time of critical moisture content t_c taken as zero (0). The values of the moisture ratio $\frac{M}{M_0}$ for all drying experiments are given in tables A4..4 – A4.6 (in appendix 4), while the falling rate-drying curves are shown in figures 4.7, 4.8, and 4.9, for 65°C and 50°C tray drying and sun drying respectively.

A non-linear relationship of the form $Y = ae^{Bx}$ was found to best relate the experimental data. In order to determine the slope of the curve, the data was regressed by first transforming the relationship into a linear form. The linear equation of the form $\ln Y = \ln a - Bx$, was obtained where $\ln Y = \ln\frac{M}{M_0}$. This describes the diffusion model equation, $\frac{M}{M_0} = a\ exp(-kt)$ where B = k = the slope of the line. The values of $\ln\frac{M}{M_0}$ were plotted against elapsed time (hrs), these are shown in figures 4.10, 4.11, and 4.12 for 65°, 50°C tray and sun drying experiments respectively. From the slopes of the straight lines obtained, the values of drying constant k, for the model for all samples in all drying conditions tested are given in table 4.16 with the coefficient of determination R^2 ranging from 0.836 – 0.968 in 65°C, 0.98 – 0.99 in 50°C and 0.85 – 0.98 in sun drying experiments. Coefficients of correlation R, ranged from 0.92 – 0.99. The effects of pre-treatments on both the constant and falling rates of drying are further shown in figures 4.13 and 4.14 respectively.

X_{12} = interaction of factors 1 and 2

The model expresses a suitable blanching time – sulphite concentration relationship in pretreating tomato before drying with 5% level of significance Considering the experimental design plan as shown in table 2.8;

Experiment 1 puts steam-blanching tomato for 2mins and sulphiting at1000ppm of Sodium-metabisulphite, the fitted value $\bar{Y}$ = 0.2779mg/100g of β –carotene was obtained at 5% level of error. This indicates that tray-drying tomato with air at 65°C with this treatment will retain about 51.59% of 0.574mg/100g β –carotene in fresh tomato sample and 34.5% above the control over a drying period of 3.66 hours.

Experiment 3 puts steam-blanching time at 2 minutes while sulphite concentration is at 2000ppm this gave a fitted value of $\bar{Y}$ = 0.4582mg/100g. This shows that about 79.82.3% of β - carotene in fresh tomato and 68.72% above the control is retained when dried at 65°C over a period of 3.33hours.

Experiment 2 puts steam-blanching time at 3minutes and sulphite concentration at 1000ppm, this resulted in a fitted value $\bar{Y}$ = 0.3862mg/100g β -carotene, indicating about 57 18 % retention of original content of 0.574 mg/100g and 67.28 % above the control when dried over a period of 3.66hrs.

Experiment 4 puts steam-blanching time at 3minutes and sulphite concentration of 2000ppm), a fitted value $\bar{Y}$ = 0.5041mg/100g was obtained. This shows that about 87.82% of original β –carotene content was retained and 76.72% above the control when dried out 65°C using the blanching time- sulphite concentration relationship over a period of 3.0hrs. Untreated sample retained 0.0982mg/100g of β –carotene, which is about 17.1% of fresh sample value over a period of 5.667hrs.

Considering the result from the fitted model within the range of levels of factors X_i (i = 1 and 2), the fitted model shows that when steam-blanching time was increased from 2min to 3min, β–carotene retention increased. This is explained by the positive coefficient b_1 (0.0386). Similarly increasing sulphite concentration from 1000ppm – 2000ppm of sodium metabisulphite caused a higher retention of β–carotene in tomato when dried at 65°C. This is further explained by positive coefficient b_2 (b_2 = 0.0745).

The interaction effect show that simultaneous increase in the level of blanching time and sulphite concentration will lead to lower retention of β –carotene when tray dried at

65°C, which is indicated by negative regression coefficient of interaction X_{12} (i.e. b_{12} = -0.0156). This could be attributed to high constant rate of drying than falling rate resulting into heat damage.

5.1.2 50°C Tray Drying Model

The fitted model for predicting the β- Carotene retained in pretreated tomato tray dried at 50°C is expressed by equation 4.4.

$$\hat{Y} = 0.3226 + 0.0433X_1 + 0.0528X_2 + 0.0213X_1$$

Considering the experimental plan given in table 2.8:

Experiment 1 put steam blanching time at 2 min and sulphite concentration at 1000ppm, the fitted value $\overline{Y}$ = 0.2478mg/100g at 5% level of error. This shows that about 43.17% of fresh value of β–carotene and about 30.61% above the control is retained; when dried at 50°C over a period of 5hrs.

Experiment 3 put steam-blanching time at 2min while sulphite concentration was increased from 1000ppm to 2000ppm and the fitted value $\overline{Y}$ = 0.3108gm/100g. This shows that about 54.14% of fresh value and 31.58 % above the control sample value was retained when dried at 50°C over a period of 5.5hrs.

Experiment 2 put steam blanching at 3min and sulphite concentration at 1000ppm, the fitted value $\overline{Y}$ = 0.2918mg/100g 5.0hrs. This shows that about 50.83% of fresh sample value and 38.27% above the control sample value was when dried at 50°C, over a period of.

Experiment 4 put steam blanching at 3min and sulphite concentration at 2000ppm, the fitted value $\overline{Y}$ = 0.4402mg/100g. This indicate that about 76.7% of fresh value is retained when dried at 50°C, over a period of 5hrs. This is about 54.14% above the control sample value.

The control (i.e. untreated) sample retained 0.0721 mg/100g, which is about 12.56% of fresh value over a period of 5.667hrs.

.Raising steam-blanching time from 2 minutes to 3 minutes improved carotene retention, this is shown by positive coefficient b_1 = 0.0433. Similarly, increasing sulphite concentration from1000ppm to 2000ppm improved retention, this is indicated further by the positive coefficient (b_2 = 0.0528). Simultaneous increase in the levels of both factors from their low to high levels also increased quantity of β-carotene retained. This is indicated by the positive coefficient of interaction factor b_{12} = 0.0213. However, the main

effects were higher than the interaction effects and are thus, more important. All main effects and the interaction effects show significant difference in retention of β-carotene in tomato when dried at 50°C. This also indicates that the factors do not act independently in producing the results obtained.

Comparing the predicted values for the four runs in this experiment, it can be seen that the values obtained at 50°C drying temperature were lower than that of 65°C. This is due to longer drying periods, which allowed for degradation of antioxidants. The treatment in experiment 4 retained the highest value of β-carotene $\bar{Y}$ = 0.4402mg/100g, being 76.7% of fresh value. Other treatments combining steam-blanching time and sulphite concentration condition as in experiments 1, 2, and 3 retained between 40% and 43% of fresh sample value. Under this drying condition, though lower quantities of β-carotene are retained, the treatment that gives optimum value is obtained in experiment 4, i.e. steam-blanching time of 3 minutes and sulphite concentration of 2000ppm.

5.1.3 Sun drying Model

Equation 4.6 expresses the fitted model for predicting β–carotene retention in pretreated sun dried tomato.

$$\hat{Y} = 0.2128 + 0.0231X_1 + 0.0448X_2 + 0.0146X_{12}$$

Considering the experimental plan given in table 2.8:

Experiment 1 put steam-blanching time at 2minutes and sulphite concentration at 1000ppm. , the fitted value of $\bar{Y}$ = 0.1595mg/100g. This shows that about 27.80% of fresh sample value and 28.2% above control is retained when sun dried over a period of 8hrs.

Experiment 3, put steam-blanching time at 2minute, while sulphite concentration was at 2000ppm. The fitted value $\bar{Y}$ = 0.2199mg/100g shows that about 38.31% of fresh sample value and 30.47% above the control is retained when sun dried over a period of 8hrs.

In experiment 2 the steam-blanching time was put at 3minutes while sulphite concentration was at 1000ppm. The fitted value for $\bar{Y}$ = 0.17659 mg/100g. This shows that about 30.76% of fresh sample value and 22.92% above the control is retained when sun dried over a period of 8hrs.

In experiment 4, the blanching time of 3minutes and sulphite concentration of 2000ppm was used. The fitted value $\bar{Y}$ =0.2953mg/100g. This value shows that 51.45% of fresh sample value and 43.61% above the control is retained when sun dried over a period of 8hrs.

The control (untreated) sample retained 0.045 mg/100g, which is about 7.84% of fresh value over a period of 11hrs.

Considering the experimental result and the predicted model for the sun drying, and within the intervals of the experimental factors, it is seen that, increasing the steam-blanching time from its low level (2minutes) to high level (3minutes), increases the amount of β–carotene retained. This is shown by positive coefficient of the factor X_1, (i.e. $b_1 = 0.02312$). Similarly, increasing the sulphite concentration from 1000ppm to 2000ppm (i.e. from lower to high level) improved retention; this is indicated further by the positive coefficient. $b_2 = 0.04479$. Simultaneously increasing the levels of factors from low to high levels will help improve β-carotene retained in sun dried tomato. This is indicated also by the positive coefficient of interacting factors $b_{12} = 0.01460$.

From the results of all the experiments, the regression coefficients are found to be significant at 5%level of error. This means that both factors (i.e. pretreatments) and their interactions contribute significantly to the fitted values and that there is a significant difference between the quantities of β –carotene retained in pretreated dried and the untreated dried tomato. Similarly, from the fitted model obtained in all the experiments, the main factors' effects are seen to be higher than the interaction effect, thus showing that main effects play more practical importance in β-carotene retention. Considering the values of the coefficients, it is evident that sulphite concentration has a higher significance and more practical importance than blanching. This higher effect of sulphite can be attributed to the anti-oxidant effect of Sulphur, which is further improved by the addition of sodium chloride. This reduces the rate of photo-oxidation of carotene pigments and inhibits Millard reaction during drying. Similarly oxidation and disintegration of fat soluble vitamins such as β–carotene during long drying period as in sun drying could also be seen to be reduced in pretreated samples when compared to untreated ones. Blanching on the other hand can be seen to have inhibited the activity of perioxidaze and minimized enzymic browning thus degradation of carotene pigments (Rozis, 1997).

The state of water relative to time during drying is significant on the loss of nutrient above the monolayer value. Since water acts as both reactant and catalyst, it's fast reduction (i.e. high constant rate drying while low moisture level is attained fast) which resulted from the pretreatments could also have helped to decreased the mobility of metals which catalyze free-radicals oxidation of carotenes, (Bluestein and Labuza, 1973).

Comparing experimental values for all the four runs in this experiment, it is seen that the values obtained in sun drying experiment are quite lower than those of tray drying experiments for each sample. This is owed likely to longer drying period and the photo-oxidation and degradation effects on β-carotene pigment. Experiments 1,2 and 3 retained less β-carotene (below 40% of fresh sample value) in sun drying as compared to those of tray dryings. It follows that under sun drying conditions very low amount of β-carotene is retained, however, the pretreatment with best result is that of experiment 4.The high retention of β-carotene is also a proof that Sulphur-dioxide as an anti- oxidant protects carotene during tomato drying.

Weirzchowsci (1956) reported similar result whereby sun dried Alfafa lost 95-100% β-carotene; rapid drying was also reported to help preserve carotenes. Sweeney and Marsh, (1971), also showed that high temperature - short time drying (as obtainable in the tray-drying experiments) reduced the loss of β-carotene. Badifu et al. (1995) in a similar work reported that after drying steam-blanched pumpkin leaves, 62.4% and 51.6% β-carotene were retained in dehydrated and sun dried sample respectively, indicating that steam-blanching and artificial drying improves β-carotene retention. Bolin and Strafford (1974) showed similar results, it was reported that sulphite dehydrated apricot showed little loss in carotene while sun dried halves showed 30% loss. Solanke (1985) also showed the trend of this result whereby dehydrated okra, pepper and carrot using tray drier have better carotene retention than sun drying at average temperature of 35^{O}C. The obtained results in this research are similar also to that of Gomez (1982), which evaluated the β-carotene content of steam-blanched and sulphited dried vegetables. β -carotene retention improved significantly in pretreated samples than untreated samples in all drying methods.

5.2 PRE-DRYING EXPERIMENTS

The adequate inactivation of perioxidaze (the predominant enzymes in tomato) was achieved by blanching tomato slices with steam at 95-100^{O}C over a time range of 2-3 minutes without destroying the texture of the material. Steam-blanching below 2 minutes though gave a strong texture; however, it is inadequate to inactivate the enzyme. Above 3 minutes of blanching complete inactivation can be obtained but (from table 4.13), the texture will be very soft and incapable of being handled during other processes.

Moisture content of all samples deviated from the initial value after pretreatment by 0.74 –3.85 % (db). Moisture loss was highest in samples sulphited at

2000ppm concentration (X^{+}_{2}), (i.e. 3.88± 0.02%(db)) and lowest in treatment at low levels of both factors ($X^{-}_{1}X^{-}_{2}$)), (i.e. 0.72 ±0.01%db). Blanching for 3 minutes only also recorded high moisture loss than for 2 minutes. Moisture losses resulting from combined treatments are however lower than those of single treatments. Moisture losses recorded in blanched samples before drying could be attributed to heat induced chemical reactions, which result into degradation of cell constituents and drying capacity of steam, (Taiwo et al, 2001). Sulphur dioxide from sulphiting treatments caused permeability of cell membrane causing loss of moisture. Similar observations have been reported for carrot and potato, (Edes 1989)

5.3 DRYING AND DRYING RATES

Generally for all samples in all drying experiments, the drying curves showed that moisture content fell steady as drying time increased in the drying processes and then a marked leveling or slow drying period until a final moisture content of 0.04 ± 0.001% db was attained. The drying processes shown in fig 4. 1, 4.2 and 4.3 reveal that there exist a period of constant drying rate which is evident within 1 to 1.66 hours in tray dryings and 3 hours in sun drying; a period when the materials still contain substantial amount of moisture. As moisture content reduces beyond the critical point there is a fall in the drying rate, this is the falling rate period. Total drying time for pretreated samples were lower than untreated sample in all drying experiments. Shortest time was recorded in 65°C tray drying and longest time in sun drying for corresponding samples. As drying temperature increased and drying time reduced, the drying curves became steeper showing that the rate of drying was higher.

5.3.1 Constant Rate Drying

The rate of drying when surface evaporation predominated the drying process as shown in table4.15 and Fig 4.7 - 4.9 for 65°C, 50°C tray drying and sun drying respectively demonstrate the effectiveness of pretreatments and drying conditions on the improvement of constant rate drying. Linear regressions of experimental data gave a coefficient of correlation within the range of 0.94 and 1.0.

In the 65°C tray drying, the fitted linear drying equations gave coefficients of determination in the range of 0.90 –1.0. The slope of the curves obtained and the corresponding amount of water removed per hour showed constant rate drying (in gH_2O/hr) for pretreated samples in the range of 31.44 – 42.90 gH_2O/hr, while the untreated (control sample) had drying rate of 35.04 gH_2O/hr. The 3mins steam-blanched sample gave

highest drying rate of 42.90 gH_2O/hr an increase of 7.86gH_2O/hr being about 22.43% above control. 2000-ppm sulphited sample gave an increase of 4.61 gH_2O/hr; being 13.15% while 2 min steam-blanched sample gave an increase of 4.13 gH_2O/hr, about 11.78% increase. Combining both treatments at these (high) levels also increased drying rate by about 15.32%. Other treatments showed lower increase in water removed per hour in the range 4.09 –1.06 gH_2O/hr, about 11.67-3.02%. 1000ppm sulphited sample showed lower drying rate than the control. This can be attributed to the (level) of sulphite salt concentration which may be inadequate.

Constant rate drying during 50°C tray drying showed similar trends with results obtained in 65°C drying except that the values are lower. This is expected since higher temperature increases water removal capacity of drying air. Correlation coefficient of fitted values was in the range of 0.998 –0.999. Untreated (control) sample recorded a drying rate of 23.28 gH_2O/hr. 3 minutes steam-blanching resulted in 12.76 gH_2O/hr (about 54.48%) increase above control, while 2000ppm sulphited sample gave 6.57 gH_2O/hr difference, an increase of 28.22% above untreated samples (control) drying rate. Combining both treatment showed significant increase in drying rate in the range of 41.4% - 0.472%. 2 min steam blanching increased drying rate by 2.39 gH_2O/hr, about 10.20%. Other pretreatments showed increase less than 10%. 2000ppm sulphited sample had lower drying rate than the control. This is unexpected as in 65°C drying and can be attributed to the same reason.

Sun dried samples showed the same trend but considerable lower drying rates than both tray-dried samples. Fitted values gave a correlation coefficient in the range of 0.991 – 1.00.From table 4.7.3, untreated tomato dried at the rate of 14 gH_2O/hr, 3 minutes steam-blanching increased drying rate by 4.11 gH_2O/hr, (about. 29.35% increase) above control while 2000ppm sulphited showed 21.10% increase. Steam blanching for 2 minutes showed about 17.35% increase. 1000ppm sulphiting resulted into lower drying rate than the control. Combined pretreatments showed increase in drying rate in the range o f0.25 - 3.96 gH_2O/hr, being 1.78% -28.28%. Combining pretreatments at high levels resulted into higher increase (28.28%) than any other combination. From the slope of the curves it is apparent that the initial drying rate of untreated samples are higher than some pretreated ones. For example samples sulphited at 2000ppm concentrations and dried at 65°C recorded 7.12 gH_2O/gD_m/hr, while the value for untreated samples are 8.0, gH_2O/gDm/hr. This is attributed to the higher initial moisture content of untreated

samples. However, the amount of water removed over the same drying period is higher in the sulphited as well as other pretreated samples.

Blanching removes air pores thus allow easy heat and moisture transfer during early drying period Sulphite pretreatments have been reported to increase drying rate during early period of drying apricots (Teslime et al. 1995), basil leaves (Rocha et al. 1995) and grape and waxy fruit (Saravacos and Charms 1962). There is little variation in constant rate drying period within samples in each drying experiment. For example, the periods' range differed by 1 - 0.66hs and 1 - 0.33hrs for 50 ^{O}C and 65^{O}C respectively. However, in sun drying this period are the same for all samples but the amount of water removed per hour differed with sample.

5.3.2 Falling Rate Drying

Considering table 4.16, the drying constant k obtained in all experiments conducted show that moisture movement from product's interior to surface is highest in 2000ppm sulphited pretreated sample (2.05 hr $^{-1}$, 1.51hr^{-1}1.45hr^{1-}) and the lowest values obtained in the untreated samples. Little variation is seen in k –values due to blanching only in each of the experiment conducted. The combined effect of both pretreatments at different interaction levels also show significant increase in k-values, however the effect of these treatments at their high levels showed a higher k-value than other treatments except for 2000ppm sulphiting. Coefficient of correlation of obtained was in the range of 0.836–0.973.

The moisture contents obtained in the falling rate data in these experiments are best fitted by the diffusion equation. The drying equation of the form dM/dt = exp (– kt) is seen to predict the behavior of the test pretreatments under different conditions with coefficient determination between 0.806 and 0.968. Drying of tomato is shown to takes place more practically in the falling rate period in all conditions investigated, however, more moisture will be lost over shorter period when tomato is pretreated. An examination of figures 4.10, 4.11 and 4.12 and tables 5.1 –5.3 (in appendix 5) shows that drying occurred majorly in the falling rate period with about 50% of moisture removed over a longer time than in the constant rate drying period. This is unexpected considering the high moisture nature of tomato. It is expected that the constant rate-drying period will dominate or prevail over a longer period and moisture level. This result shows that for all

samples, the rate at which moisture becomes available to the drying surface for evaporation falls with time. The drying rate is seen therefore as controlled by internal

moisture mechanism than surface evaporation, similar result has been reported by Balikson et al (1994).

The moisture content, and drying air condition have effect on the drying constant k with moisture content and drying time playing major roles. k reduces with lower moisture content and as drying time increases. The value of k obtained varied considerably amongst pre-treated samples and drying conditions, thus the rate of diffusion of moisture through tomato slices differs with pretreatments. The values of drying constant are an indication of diffusion rate. Moisture diffusion is seen to be higher with higher k – values and shorter drying time (k reduces as drying time increases). This shows that drying rate increases as k-values increases.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The results obtained from the 2^2 full factorial design techniques employed in this work have shown that a suitable steam blanching time – sulphite concentration relationship for retaining maximum b carotene in dried tomato could be said to be 3 min steam blanching – sulphiting at 2000ppm concentration with the following fitted models for predicting the amount of β –carotene retained at 5% level of error when using 65°C and 50°C tray drying conditions as well as sun drying.

$$\hat{Y} = 0.4066 + 0.0386\,X_1 + 0.07455X_2 - 0.01558X_{12} \qquad (4.2.)$$

$$\hat{Y} = 0.3226 + 0.0433X_1 + 0.05285X_2 + 0.02134X_{12} \qquad (4.3.)$$

$$\hat{Y} = 0.21285 + 0.02312X_1 + 0.04479X_2 + 0.0146X_{12} \qquad (4.4.)$$

Where

$\hat{Y}$ = Fitted response

X_1 = Main factor 1= Steam blanching time (min)

X_2 = Main factor 2 =Sulphite Concentration (ppm)

X_{12} = interaction of factors 1 and 2

The estimation of the effects of blanching - time sulphite concentration as well as their interactions on b – carotene retained in tomato dried at 65°C, and 50 °C tray drying is also suggested by the fitted model giving in equations 4.2, 4.4 and 4.6 respectively. The statistical analyses of the results of β carotene retained in dried tomato indicate that given the fitted models;

- There is a significant difference between the quantity of β– carotene retained in pretreated and untreated dried tomato under the different drying conditions investigated.
- A sulphite concentration has a higher significant effect and practical importance in retaining β –carotene during drying of tomato.
- The maximum β– carotene retained using be 3 min steam blanching – sulphiting at 2000ppm concentration are $\bar{Y}$ = 0.5041mg/100g, 0.4402mg/100g and 0.2953mg/100g indicating that between 51.45% and 87.82% of β–carotene in fresh tomato can be retained when tomato is given this treatment before drying. This amount to 76.72%, 54.14% and 43.61% above the values retained in untreated (i.e. control) samples for 65 °C, 50°C and

sun drying respectively. This treatment will as allow about 54.54% reduction in the total time required in sun drying if tomato is not pretreated. This treatment is thus important and vital particularly to local farmers.

Steam blanching and sulphiting within the levels used in this work are found to be important in reducing prolong exposure of tomato to the factors that destroy β – carotene as experienced in traditional sun drying (i.e. oxygen, light, radiant heat and enzymic activities). From the result in sun drying experiments, the direct heat of the sun and long period of exposure to light and air could have resulted into lower retention of β - carotene than in tray drying. Since atmospheric air in predominant production zones (i.e. Northern Zones) during peak production period when farmers dry is characterized by lower relative humidity and moderate temperature, the drying rate could be higher and better retention than results obtained in Bida could be achieved.

From the results obtained on drying rate, the loss of moisture in pretreated tomato prior to drying is indicative that steam blanching and sulphite treatments rendered cells more permeable to heat and moisture transfer. This is evident in the high rate of water removal during the constant rate drying period as well as faster diffusion of moisture in the falling rate period as compared to untreated samples. From the drying constants obtained in all investigations carried out it is conclusive that the rate of moisture diffusion differ with pretreatments and the more than 50% of moisture removal being in the falling rate period for a higher percentage of total drying time reveals that the drying rate of tomato is controlled more by internal mechanism of diffusion than surface evaporation

Since adverse heat effect on β – carotene is primarily in the constant rate drying period, a longer falling rate period revealed in this result (even though at high product's surface temperature) is not detrimental to β –carotene retention. The non-linear relationship resulting in the falling rate period of drying is attributed to the nature of tomato and that diffusion rate is not constant as assumed by diffusion equation but differs with the moisture content of the material The k values obtained in this work can therefore be used to describe an average drying behavior of pretreated tomato during thin-layer drying over the range of moisture content investigated The developed model is indicative that the main factors are important in improving nutrient quality of dried tomato. The predicted drying constants k can be used to simulate models for thin layer drying of pretreated tomato.

Brighter colors, which were observe in pretreated tomato relative to untreated ones are evidence of reduced photo oxidative effect on β – carotene pigment. Considering the importance of appearance in consumer's acceptability of products, these pre drying treatments could foster better consumers acceptance of dried tomato especially sun dried ones thus the improving the overall intake of β – carotene

6.2 RECOMMENDATIONS FOR FURTHER WORK

The traditional production of dried tomato at low moisture content result in oxidative, heat ad photo degradation of β-carotene due to longer drying time, and increases product surface temperature, with additional damage during storage. For optimization of β-carotene retention, farmers should be educated, advised and encouraged to steam-blanch and sulphite tomato to minimize oxidative damage and increase β-carotene retention, it is recommended that steam-blanching be carried out for 3 minutes and sulphiting at 2000ppm to allow fastest removal of moisture in early period of drying over an average temperature of 37 – 65°C thus allowing shorter drying time. For further work

- Assessment of the product quality in terms of organoleptic evaluation and shelf life should be carried out to ensure that product is acceptable to consumers.
- Local source of sulphite should be researched into and sourced to remove possible set back of cost of chemical sulphite salts to farmers.
- A simple steam-blancher should be developed using local materials to allow farmers adopt this processing techniques quite easily.

REFERENCES

Abainum S.A. (1999). Effect of Pre-treatment and Quality of Dehydrated Tomato Slices, Abstract of Unpublished HND Project Work Kaduna Polytechnic, Nigeria.

Abe T. and Basunia M.A. (2001). Design and Construction of Simple 3-Shelf Solar Rough Rice Dryer. Journal of Agric Mechanization in Asia, Africa and Latin America. Vol. 32 No. 3 Pp. 54.

Adams J.B.; (1981). Thermal Requirement for Blanching Fruits and Vegetables to be Frozen. Submission for Cost 91, Sub – Group Meeting November, Paris.Pp29

Adedipe N.O., Bakshi J.S, Odegbaro O.A. and Aliyu A. (1996). Evolving the Nigeria Agricultural Research Strategy Plan – Agro-ecological imputs in Integrated Production, Strategies and Mechanism for Food Security. National Agricultural Research Project Monograph No 5.

Ajibola O.O., Abonyi B.I., and Onayemi O. (1988). Effects of some Processing Variables on the Dehydration of Pregelled Yam Pieces. A Research Paper Journal of Food Science and Technology Vol. 25, No, 3, 117-120.

Akinbolu A.M., Ukoli U.U., Negbonebor C.A. and Igene J.O. (1991). Evaluation of Post Harvest Loses and Quality Changes in Tomato in Borno State. Journal of Tropical Science 31,235 - 242.

Ali , H.M. and Sakr, I.A.(1981) Drying of Vegetables in Egypt: Food Drying. A Proceeding of Workshop Held in Edmonton, Alberta, July 6-7 1981; Pp. 15 -19

Andales S.C. (1981). Drying of Cereal Grains in the Philippines– Food Drying Processing Workshop Held in Edmonton. Alberta 6 – 9 July 1981;Pp51 -60.

Anderson. A.S., David M., Mike L. and Ann F. (1994): Five a Day: - Factors Affecting Fruit and Vegetable Consumption in Scotland. Journal of Nutrition and Food Science (1978). Food Processing and Nutrition Academy Press, London pp 27-31.

Anold E.B. (1978). Food Processing and Nutrition. Academy Pren London Pp. 27 – 31.

A.O.A.C (1980). Association Of Official Analytical Chemist "Official Methods of Analysis Washington D.C13th Edn. [p 43: 006

Badifu G., Ar. Papunam A.M. and Gbemere V.M. (1995). The Face of β-Carotene in fluited Pumpkin. Journal of Plants Foods for Human Nutrition V 48 (2) 141-147.

Ball G.M.F. (1994). Fat-Soluble Vitamins Assay Vitamins – A Comprehensive Review. Elsever Applied Science. Chapman and Hall Publishers 2 –3 Boundary Row, London.Pp 428-435

Barras J., Trajkovic J. and Razarincevic (1971). Effect of the Method of Drying on all Trans β-Carotene in dried carrot Nutritional Abstract Review 41. No 23, Pp 11.

Battey J.C. and Folkman S.L. (1983). Food Engineering Fundamentals. John Wilsey Aid Sons U.S.A Pp 284 –287.

Balikson and Sankot (1994). Drying of Fresh and Candied Carambola - Canadian Agricultural Engineering Journal Vol. 36, No. 3, Pp 162-173.

Baraskarcharay,K., Sankarad,D.S.,Deosthale, Y.G. and Reddy,V.(1995). Carotene Content of Some Common and Less Familiar Foods of Plant Origin. Journal of Food Chemistry 54, Pp189-193

Ben-Aziz A.N., Brillour G. and Goodwill T.W. (1973). "Carotene exposide of Lycopersicum esculentum". Journal of Phyto Chemistry Vol. 12.

Benani M.B. (1991). Post Harvest and Processing Technologies of Africa Staple Foods Ed. Walson J.P. FAO Service Bulletin 89. Rome Italy. Pp 35

Bueno A.O. (1997). Collaborative Study; Determination of Retinol and Carotene by High-Performance Liquid Chromatography. Journal of Food Chemist. Vol. 59, No 1, Pp 65-170.

Bluestin P.M. Labuza T.P. (1988). Effect of Moisture Removal on Nutrients – In Nutritional Evaluation of Food Processing (Editors – Karmas E. and Harris R). AVI Publishers New York.Pp393 - 422

Bolin R.H. and Stratford A.E. (1974). Effect of Processing and Storage on Provitamin A and C in Apricot. Journal of Food Science 39, 1034 – 1036.

Brandorfer B., Kenedy L., Bateman C.O., Trim D.S. Werekobroby C. and Mrema G.C. (1985). Solar Dryer - Their Uses In Post Harvest Processing Commonwealth Science Council. Commonwealth Secretariat. London Pp. 8 – 18.

Brennan J.N. and Butter N.D. (1976). Food Engineering Operations, Second Ed.. Applied Science Publication Limited, London.Pp128

Brooker D.B., Balker-Arkema F.W. and Hall C.W. (1992). Drying Cereal Grains 2nd Ed.. A.V.I Publishing Coy, Westport Connecticut.Pp205 -217

Brown Sell V.L. and Griffith C.I. (1989). Applied Science in Food Studies. Longman Scientific and Technical Publishers U.K Excess C.M 202 JE, England.Pp192 -194

Chang U. (1977). Studies on the Carotenoids in Tomato and Corn. M.s. Thesis University of Rhodes Island Kingston.Pp102

Charms S.E. (1971). Fundamental of Food Engineering 2nd Ed.. AVI Publishing Coy International Westport, Connecticut.Pp300 -322

Charms S.E and Saravacos D.G.(1962) The Effects Of Surfactant Agents on The Dehydration O Fruits and Vegetables.Food Technology,16 Pp 91-95

Chriffe J. (1971). Diffussional Process in Drying Of Tapioca Roots. Journal of Food Science. Pp. 36:327 – 330.

Cochran W.G. and Cox G.M. (1957). Experimental Designs. John Wiley and Sons Inc. USA.Pp148 - 175

Dallas and Mac David (1960). Comparison of β – Carotene Content of Dried Carrots Prepared By Three Dehydration Processes. Journal of Food Technology 19, 141 – 143.

Diamante,L.M.and Munro,P,A.(1993). Mathematical Model Of Thin-Layer Solar Drying Of Sweet Potato Slices. Solar Energy,51,Pp 271-276

DeRiter E. and Purcell A.E. (1981); Carotenoids: Analytical Methods in Carotenoids as Colorant and Vitamin A Precursors. JC Bauernferd Ed. Technological and Nutritional Application, Academic Press, New York.Pp225-235

Douglas C.M. (1991). Design and Analysis of Experiments. 3rd Ed.. John Wiley and Sons Inc. New York. Pp. 197 – 208, 230 – 235, 270 – 309.

Dryden I.G.C. (1982). The Efficient Use of Energy. 2nd Ed.. Butterwoth & Co. Ltd. Pp281

Earle R.L. (1988). Unit Operations In Food Processing. 2nd Ed.. Pergamon Press, New York.Pp95-98

Edes T.B. Walliam I.- Jnr. and Jayendiah S. (1989). β – carotene and Aryl Hydrocarbon, Hydrolane in Rats – an Effect of β-Carotene Independent of Vitamin 'A' Activity. Journal of Nutrition Vol. 119 no 5 (1989) Pp 796 – 799.

Eke A.B. (1995). Tomato Drying: A Paper Presented at the Nigerian Society of Agricultural Engineering Conference.Pp1-5

Esterbaur H., Rotheneder M., Steiegh G., Waeg D., Ashy A.R., Scatter W. and Jurgen S.G. (1989). Vitamins and Other Lipothetic Antioxidant Protects LDL Against Oxidation. Journal of Food Science Technology (9) 316 - 323

Etehetema J.K., (1991). Development of Sun dried Okra Product Using the See-Saw Solar Drier. NIHORT Bulletin No. 15.

FAO (1989). Post-Harvest Loss of Perishable Crops: Fruits and Vegetables. Published by GTZ, Wageninger, The Netherlands.Pp21-31

FAO (1990). Rural Processing and Preservation Techniques for Fruits and Vegetables in Food and Nutrition. Journal of the FAO, Rome. 24/1 Pp14

Feaster (1971). Effects of Commercial Processing on Moisture of Fruits and Vegetable. In Nut Evaluation of Food Processing Ed. Harris and Vonheosecke. AVI Publishing Co. Westport.Pp109 -113

FGN/UNICEF(1994).The Nutritional Status of Women and Children in Nigeria. FGN/UNICEF, Lagos July 1994.

Field M.L. (1977). Laboratory Manual in Food Preservation. A.V.I. Publishing Company, Inc. Westport Connecticut.Pp71 - 72

Fisher P. and Bende A. (1995). The Value of Food 3rd Ed. Oxford University Press. Pp. 8

Franklin W., Martin I.R. and Rubert N. (1978). Editors. Vegetables for Hot Humid Tropics – A Newsletter and Annual Report Among Research Workers. Journal of Nayaguez Institute of Tropical Agriculture, Nayaguez, Puer to Rico No. 3, Pp81.

Fred N.K. and Elezar J.P. (1982). Multiple Regression in Behavioural Research. John Wiley and Sons Inc, New York Pp 29-77.

Gomez K.A. and Gomez A.A. (1985). Statistical Procedures for Agricultural Research. Pp. 375, 421. John Wiley and Sons Inc, USAPp31 –35.

Gomez M.I. (1981). Effect of Drying on Nutritive Value of Food in Kenya Food Drying; Proceeding of Workshop Held in Edmonton, Alberta, July 6-7 1981; Pp. 31-35

Grubben G.J.H. (1977). Tropical Vegetables and their Genetic Resources. International Board for Plant Genetic Resources Rome, Pp 25-37.

Guthrie H.A (1979). Introductory Nutrition 4th Ed.; C.V. Mosby Publishing Coy Missouri USA.Pp35

Hall C.W. (1986). Encyclopaedia of Food Engineering. A.V.I. Publishing Coy, Connecticut. Pp 229 – 410.

Hall C.W. (1980). Drying and Storage of Agricultural Crops. 2nd Ed. A.V.I. Publication Connecticut.Pp120 -128

Handel C.E. (1971). Effects of Drying and Dehydration on Food Nutrients In Nutritional Evaluation of Food Processing. Ed. Robert Hrris and Henry Leoseche. AVI Publishing Company Inc. Wesport Connecticut Pp 148-153.

Henderson and Perry (1976). Agricultural Process Engineering. A.V.I Publishing Company, Inc. Westport, Westport, Connecticut.Pp310 - 320

Hicks C.R. (1973). Fundamental Concept in the Design of Experiments. Holts Rinchart and Winson Inc. U.S.A. pp 108 – 141.

Hutchinson D. and Oten L. (1983). Thin Layer Air-Drying of Soybeans and White Beans. Journal of Food Technology, 18, 507 – 522.

Ihekoronye A.I. and Ngoddy P.O. (1985). Integrated Food Sciences and Technology for the Tropics. Macmillan Publishers London Pp 183 – 220.

Igene J.O. (1996). Food Production and Nutrition in Nigeria: - Integrated Agricultural Production Strategies and Mechanism for Food Security Monograph. No. 5 Agric Research project.

Jackson J. C., Malcolm C.B. and Barnard J. (1996). Optimization of Blanching for Crispness of Banana Chips Using Surface Response Method. Journal of Food Science Vol. 61. No. 1, 165 – 166.

Jackson T.H. and Mohammed B.B. (1985). Sundrying of Fruit and Vegetables. Agricultural Service Bulletin of Food and Agricultural Organization (FAO). No 5, Pp 8-70.

Karathanos, V.T., Villalobos, G., and Saravacos, G.D. (1990) Comparison Of Two Methods Of Estimation Of The Effective Moisture Diffusivity From Drying Data. Journal of Science 55: 218 -223

King C.J. (1971). Freeze Drying of Food CRC press Cleveland.Pp171

Kodylas J.M. (1991). Processing and Preservation of Tropical and Subtropical Foods. McMillan Education Limited, Handmills Basingatome Hemisphere. Pp. 187-190.

KOH, H., Young J. and Soepklee N. (1987). Effect of Variation in Drying Conditions on the Drying Rate and Quality During Red Pepper Drying. Journal of Agricultural Research 24 (2), 197-201.

Labuza T.P. (1973). Effect of Dehydration and Storage on Vegetables. Journal Food Technology 27 (1) 20, 51, 1973.

Lento H.J. (1984). Analytical Methods – Carotenoids in Chemistry and Biochemistry of Plant Pigment Ed. T.W. Goodwin 2nd Ed. Academy Pren, London.Pp222 –341

Luikov A.V. (1966). Heat and Mass Transfer In Capillary Porus Bodies. Pergamon Press, New York.

Macrea R., Robison R.K. and Sadlar M.J. (1993). Encyclopaedia of Food Technology and Nutrition. Academy Press Ltd London Pp 4579-4584

Martin W.F. (1983). Carotenoid Pigment in Whiteflesh Sweet Potatoes. Journal of Agriculture of University of Puerto - Rico Pp 67.

Mazza G. (1983). Dehydration of Carrot; Effect of Pre-Drying treatment on Moisture Transport and Product Quality. Journal of Food Technology. 18 , 113-123.

McCabe W.L., Smith J.C. and Harritott P. (1986). Unit Operation of Chemical Engineering 4th Ed. McGraw-Hill International Book Co, Singapore Pp 707-726.

McCarthy D. (1986). Concentration and Drying of Foods. Applied Science Publishers Limited England Pp 1-10.

Mircea (1995). Fruit and Vegetable Processing. Food and Agricultural Organization (FAO) Service Bulletin 119.

Mottran R.F. (1991). Human Nutrition 3rd Ed. Pergamont Press, UK Pp 106.

Musa Makama A.L. (1999). Assessment of Nutritional Changes in Locally Sundried Vegetables. Unpublished PGD Project Report. Federal University of Technology Minna, Nigeria Pp 14 - 18

Mustapha A.H. and Abdalla E.S. (1989). Determination of Drying Curves of Two Varieties of Peanuts. Journal of Agricultural Mechanization in Asia Africa and Latin America. Vol. 20, No. 4, Pp 47-51.

Nellist M.E. and Ochallagan J.R. (1971). "The Measurement of Drying Rates in Thin Layers of Ryegrass Seeds. Journal of Agricultural Engineering Research. 16, 192–212.

NIHORT (1990). Okra, tomato and sweet pepper cultivation, NIHORT production pamphlet No. 9.

Olorunsogo S.T. and A. Adgidzi D. (1998). Modelling Retention of Ascorbic Acid in Food Analysis. Proceeding 22nd Annual NIFST Conference 23rd – 26th Nov. 1998 Abeokuta, Nigeria. Pp. 76 – 78.

Oyeniran J.O. (1988). Report of Activities of the National Coordinated Research Proceeding of the National Workshop on Improved Packaging and Storage Systems for Fruits and Vegetables in Nigeria, Ilorin, Kwara State.Pp15

Paitil R.T., Sokhansanj S., Arinze E.A., and Schoenail G. (1992). Thin-Layer Drying of Components of Fresh Alfalfa J. Canadian Agricultural Engineering. Vol. 34 No. 4. 343-346.

Peggi-Oti B. (1993). Drying Food Cycle Technology. Source Book 6, United Nations Development Fund for Women. Pp 8 – 25 Rao. Ss (1977) Optimisation: Theory and Application Wiley Eastern Ltd. New Dehili Bombay Pp 1-9.

Perry,R.H. and Chilton,M. S.(1975).Chemical Engineer's Handbook 5th Edition. McGraw-Hill Intenational Book Co. Newyork. 21:10-20:15

Pointing J.O. and McBear D.M. (1970). Temperature and Dipping Treatments Effect on Drying Rate and Drying times of Grapes, Prices and Other Waxy Fruits. Food Technology 24, 85 – 88.

Quackenbush F.W. and Small-ridge R.L. (1986). Non Acqueous Reverse Phase Liquid Chromatography System for Separating and Quantitation of Provitamin A. Journal of Association of Analytical Chemist 69, 767 – 772.

Quin J.G. (1974). Environmental Establishment of an Industrial Tomato Crop in Nigeria. Process of Meeting of Tomato Workshop Group Held in Eucharpia International Centre for Advanced Mediterranean Agronomic Studies, Barri. Pp94

Quin J.G .(1980). Review of Tomato Cultivar Trial in Northern States of Nigeria. Pamphlet of the Institute of Agric Research, Ahmadu Bello University, Zaria, Nigeria.Pp9

Rocha Ta, Marlt, Audowin C. and Lerbeng I.A. (1995). Effect of Pre-Treatment and Drying Conditions on Drying Rate and Colour Retention Of Basic. Journal of Food Science and Technology 26, 446 – 463.

Rozis, Jean-Francois (1997). Drying Foodstuffs: Techniques, Processes, Equipment Technical Guidebook. Backhuys Publishers, Leinden. Pp29-50,65-91 .

Sahey,K.M. and Singh, K.K.(2003). Unit Operation In Agricultural Proceessing.2nd Edition.Vikas Publishing PVT Ltd. New Delhi.Pp125-130

Salunke D.K. and Dessai B.B. (1984a). Assessment of Post Harvest Loses and Loss Reduction Biotechnology - in Post Harvest Biotechnology of Vegetables. Vol 1 CRC Press Ohio USA. Pp 25 – 31.

Salunke D.K. and Dessai B.B. (1984b) The Effect of Agricultural Practices, Handling, Processing and Storage of Vegetables In Nutritional Evaluation of Food Processing. AVI Publication, New York Pp 25 – 67.

Salunke D.K. Do J.U. and Bolin R.H. (1974). Storage, Processing and Nutritional Qualities of Fruits and Vegetables. AVI Publishing Company Inc. Westport Connecticut Pp. 42–78.

Salunke D.K., Bolin R.H. and Do. J.U. (1971). Dehydrated Fruits and their Utilization. Utah Science 32(4) 123, Ppp 42 – 68.

Samprit, Chatter J. and Bertram P. (1991). Regression Analysis by example. Second Ed., John Wiley and Sons Inc. New York Pp 2 – 10.

Saravan, O.(1999). Preservation Of Food; Fruits and Vegetables. Agrodok Series 3, Aromesia, The NetherlandsPp 26-38

Selman J.D. (1987). Blanching Process in Development of Food Preservation – 4, Ed. S. Thorne, Elsevier Applied Science, London UK Pp 204 – 249.

Selman J.D. (1994). Vitamin Retention During Blanching of Vegetables. Journal of Food Chemistry 49, 137-149.

Simmonne A.H., Simmonne E.H., Eitenmiller R.R., Mills H.A. and Green N.R. (1997). Ascorbic Acid and Provitamin A content in Unusual Coloured. Ball Peppers (Capiscum, Annum L). Journal of Food Composition and Analysis 10, 299 – 311.

Sitkei .G. (1986). Mechanics of Agricultural Materials. Elsevier Science Publishers, Pp 80-96

Solanke R. (1998). Drying Characteristics of Selected Fruits and Vegetables. Abstract of a Project Report in the Department of Food Technology, Kaduna Polytechnic, Nigeria.

Spiers C.I. and Coote H.C. (1986). Drying Practical Methods of Food Preservation. United Nation Financing System on Science and Technology for Development (UNFSSD) K.O GenevaPp79 - 105.

Sun D. and Wood J.L. (1994). "Low Temperature Moisture Transfer Characteristics of Barley: Thin-Layer Models and Equilibrium Isotherms Journal of Agric Engineering Research. Pp. 59, 273 – 283.

Swarup V and. Denton O. (1988). Tomato Cultivation and its Potential in Nigeria. NIHORT Occasional Paper No.10 Pp 1-5

Sweeney and Marsh (1971). Effect of Processing on Provitamin A In Vegetable. Journal of Science and Agric Society Farmland 39, 99 – 106.

Taiwo A. T. (1995). Sundrying of Fruits, Vegetables, Grains, Legumes, Roots and Tubers. In Problems and Prospects Proceeding on Expert Contribution on Planning and Development of Sundrying Techniques in Africa.Pp22

Taiwo K.A., Angersbach A., Ade-Omowaye B.I.O., and Knorr D. (2001). Effects of Pretreatment on Diffusion Kinetics of some Quality Parameters of Osmotically Dehydrated Apple Slice. Journal of Food Chemistry 49. 2801-2811.

Taylor R.F. and Ikawa M. (1980). Gas Chromatography Mass - Spectroscopy and High-Pressure Liquid Chromatography of Carotenoids and Retinoil. Journal of Method in enzymology. Pp 67

Teslime M., Saygi Y.B., Borcakli M. and Ozay G. (1996). The Effects of Pretreatment – Drying Method Combination on the Drying Rate, Quality and Storage Stability of Apricot. Lebenson. Wis Technology 29, 418 – 424.

Tindal H.D. (1983). Vegetables in the Tropics 3rd Ed. Published by McMillan International College.Pp27-33

Vareeke M., Van Maercke D., Bosman I.G. and Coltence I.R. A. (1979). Subtractive Fertilization, Experiment in Carrot in Relation to Soil, Leaf Analysis and Yield Quality Journal of Acta Horticulture, (93) 197-203.

Vilareal R.L (1980). Tomato in the Tropics: Integrated Agricultural. Development services (IADS) literature series. West view press, 5500 central Av. Colorado.

WHO (1995). World Health Organization. Micronutrient Deficiency Information System. Global Prevalence of Vitamin A Defficiency, MOIS working Paper No. 2. WHO/NUT/95.3

Wierz Choroski (1956). Influence of Temperature Oxygen and Light on Carotene Content of Green Foliage During Drying – Nut Abstract Review 26, Pp. 351.

World Bank (1991). Nigerian Strategy for Food and Nutrition Security Report No 9040 UNL

World Bank Report (2001). Attacking Poverty. The World Bank,Washinton D.C.Pp1

Zakari M., Simpson K.L., Boron P.R. and Krstulove A. (1979). A Use of Reversed Phase During Shelf Life to Minimise Oxidative Damage.HPLC Analysis For Determination of Provitamin 'A' in Tomato. Journal of Chromatography, 176,Pp 109.

Zanoni B., Peri C., Nami R and Lovelli V.(1999).Oxidative Heat Damage Of Tomato Halves As Affected By Drying. Food Research International 31:Pp 395-41

Zanoni B., Pagliarin E. and Foschuro R.(2000). Study of The Stability of Dried Tomato Halves During Shelf Life to Minimize Oxidative Damage .Journal of Science Food and Agriculture.80: Pp2003-2008.

APPENDICES

APPENDIX 1A

STATISTICAL ANALYSIS OF β CAROTENE IN PRE-TREATED TOMATO TRAY DRIED AT 65°C

Using the data in tables 3.1 (in appendix 3) and 4.1, the maximum dispersion

$$S^2_{u_{max}} = 0.000979$$

Applying equation 3.2 to this data

$$\sum_{u=1}^{4} S_u^2 = 0.0015831$$

Calculating G-criteria from equation 3.5

$$G_{cal} = \frac{S^2_{umax}}{\sum_{u=1}^{4} S_u^2} = \frac{0.00052}{0.000870} = \frac{0.00098}{0.0016} = 0.61853$$

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

$G_{cal} < G_{tab}$ (0.61855 < 0.768), this shows that the data can be regressed.

Dispersion And Experimental Errors

Using equations 3.6 and 3.7, the average sample variance or dispersion and experimental error are calculated as

$$S^2_{(y)} = \frac{1}{4}\sum_{u=1}^{4} S_u^2 = \frac{0.0015831}{4} = 0.000396 \qquad \text{where } (N = 4)$$

$$S_y = \sqrt{S_y^2} = \sqrt{0.000396} = 0.0199$$

Estimation Of Model Regression Coefficient

Using equations 3.8, - 3.10, the model regression coefficients are estimated as

$$= b_0 = \frac{1}{4}(02778 + 0.3862 + 0.4581 + 0.5041) = 0.4066$$

$$bi = \frac{1}{4}(-0.2778 + 0.3861 - 0.4581 + 0.5041) = 0.0386$$

$$b_2 = \frac{1}{4}(-0.2778 - 0.3861 + 0.4581 + 0.5041) = 00745$$

$$b_{12} = \frac{1}{4}(0.2778 - .3861 - 0.4581 + 0.5401) = -0.0156$$

Statistical Significance of Regression Coefficients

The statistical significance of each estimated regression coefficient is tested using equations 3.11 and 3.12. The estimated standard error is given as

$$Sb's = \frac{S_{(y)}}{\sqrt{(N.r)}} = \frac{0.0199}{(4X3)} = 0.005744$$

From appropriate t – test table, $t_{(0.05,8)} = 1.860$.

$S_{bo} = S_{b1} = S_{b2} - - - - - - S_{bn}$

The confidence interval $\Delta bs = \pm(1.860 \times 0.005744) = 0.010685$

Using equations 3.13a –3.13d, the t – value for each coefficient is calculated as below

$$t_o = \frac{|b_o|}{Sb_o} = \frac{0.4066}{0.00574} = 70.7985$$

$$t_1 = \frac{|b_1|}{Sb_2} = \frac{0.3864}{0.00574} = 6.7156$$

$$t_2 = \frac{|b_2|}{Sb_2} = \frac{0.0745}{0.00574} = 12.981$$

$$t_{12} = |b_{12}| = \frac{0.0156}{0.00574} = 2.713$$

Table t – values at $t_{(0.05,8)}$ and $t_{(0.01,8)}$ are 1.860 and 3.355 respectively. The predicted equation for pretreated tomato tray-dried at 65°C:using the calculated regression coefficient is

$$\hat{Y} = 0.4066 + 0.0386X_1 + 0.0745X_2 - 0.0156X_{12}.. \qquad (1A.1)$$

Using equation A.1 the predicted values of Y at the levels of the independent variables are given below:

$$\hat{Y}_1 = (0.4066 + 0.0386(-) + 0.0745(-) - 0.0156 + (-)) = 0.27782$$

$$\hat{Y}_2 = .04066 + 0.0386(+) + 0.0745(-) - 0.0156(-) = 0.386113$$

$$\hat{Y}_3 = 0.4066 + 0.0386(-) + 0.0745(+) - 0.0156(-) = 0.458142$$

$$\hat{Y}_4 = 0.4066 + 0.0386(+) + 0.0745(-) - 0.0156(-) = 0.5041$$

The residual, *(e)* and the square of residual (e^2) are calculated below as $(\overline{Y_u} - \hat{Y_u})$ and $(\overline{Y_u} - \hat{Y_u})^2$ respectively.

1	*0.2778 –0.27782 = 0.00002:*	$e^2 = 4 \times 10^{-9}$
2	0.3861 – 0.386113 = 0.000013;	$e^2 = 1.69 \times 10^{-10}$
3	*0.4581 - 0.458142 = 0.000042;*	$e^2 = 1.76 \times 10^{-9}$
4	0.5041 - 0.5041 = 0	$e^2 = 0$

$\Sigma\ e^2 = 5.959 \times 10^{-9}$

Evaluation of Model's Adequacy by Analysis of Variance

The adequacy of the predicted model is evaluated by analysis of variance using equations 3.13 –3.21. The From equations 3.13b and 3.16c

$$SS_R = \frac{r}{N}\sum_{u=1}^{4}(X_y - \overline{Y_u})^2$$

$$SS_{b1} = \frac{r}{N}\sum_{u=1}^{N}\left(X_i\overline{Y_u}\right)^2 =$$

$$= \frac{3}{4}[-0.27759 + 0.3861 - 0.4581 + 0.5041] = \frac{3}{4}[0.154267]^2 = 0.0178$$

$$SS_{b_2} = \frac{3}{4}[-0.2778 - 0.3861 + 0.4581 + 0.5041]^2 = \frac{3}{4}[0.298203]^2 = 0.0669$$

$$SS_{b_{ij}} = \frac{r}{N}\sum_{u=1}^{N}\left(X_{ij}.\bar{Y}_u\right)^2$$

$$SS_{b_{12}} = \frac{3}{4}[0.2778 + 0.3861 + 0.4581 + 0.5041]^2 = \frac{3}{4}[-0.06233]^2 = 0.00291$$

SS_T is thus calculated from equation 3.17

$$SS_T = \sum_{u=1}^{(N-t)} Y_{uv}^2 - \sum_{u=1}^{N-t}(Y_{uv})^2 / N - \tau$$

$$\sum_{u=1}^{12} Y_{uv}^2 = (0.2787)^2 + (0.2816)^2 + (0.2733)^2 + (0.3707)^2$$
$$+(0.3661)^2 + (0.422)^2 + (0.4326)^2 + (0.4747)^2 + (0.4672)^2$$
$$+(0.5040)^2 + (0.5133)^2 + (0.4950)^2$$
$$= 2.7040$$

$$\sum_{u=1}^{N=t} (Y_{uv})^2 / N - \bar{t} \frac{(4.879056)^2}{12} = 1.9838$$

$$SS_T = 2.0744 - 1.9838 = 0.09062$$

$$SS_E = SS_T - \sum SS_R$$

Where $\sum SS_R = (SS_{b1} + SS_{b2} + SS_{b12})$

$$SS_R = (0.0178 + 0.0667 + 0.0029) = 0.08764$$

$$SS_E = 0.09062 - 0.08764 = 0.00316$$

Using equations 3.19 and 3.20, with degree of freedom of 1

$$MS_{b1} = \frac{0.0178}{1} = 0.0178$$

$$MS_{b2} = \frac{0.0667}{1} = 0.0667$$

$$MS_{b12} = \frac{0.0029178}{1} = 0.0029$$

where the degree of freedom df =

$$MS_E = \frac{SS_E}{N(t-1)} = \frac{0.00316}{(4X2)} = 0.00040$$

The F – criteria is calculated for each regression coefficient using equation 3.21:

$$Fb_1 = \frac{0.0178}{0.00040} = 45.07$$

$$Fb_2 = \frac{SS_{R_{b2}}}{MSE_{b_2}} = \frac{0.0669}{0.00040} = 168.41$$

$$Fb_{12} = \frac{SS_{R_{b12}}}{MSE_{b_{12}}} = \frac{0.0291}{0.00040} = 7.358$$

F ratio at $F_{(0.05, 1, 8)} = 5.32$

From equations 3.22 -3.24,

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

λ = number of insignificant term = 0 and $\Sigma\ (\overline{Y}_u - \hat{Y}_u) = 5.92\ x10^{-9}$

$$SS^2_{(adj)} = \frac{3}{4}(5.92' 10^{-9}) = 4.44 \times 10^{-9}$$

$$F_{cal} = \frac{SS^2_{adj}}{S^2_{(y)}} = \frac{1.5x10^{-9}}{0.1070} = 1.4\ X\ 10^{-8}$$

$F_{cal} < F_{(0.05, 1, 8)}$, the predicted model is adequate and the final fitted model for pretreated tomato tray dried at 65 °C is given as

$$\hat{Y} = 0.4066 + 0.386X_1 + 0.0745X_2 + 0.0156X_{12} \qquad (1A.2)$$

APPENDIX 1B

STATISTICAL ANALYSIS OF β CAROTENE IN PRE-TREATED TOMATO TRAY DRIED AT 50°C

Using the data in tables 3.2 (in appendix 3) and 4.5, the maximum dispersion

$$S^2_{U_{max}} = 0.00052$$

Applying equation 3.2,

$$\sum_{u=1}^{4} S_u^2 = 0.00870$$

G criteria is calculated using equation 3.5 as

$$\frac{S^2_{umax}}{\sum_{u=1}^{4} S_u^2} = \frac{0.00052}{0.000870} = 0.5979$$

$G_{(4,2,0.05)} = 0.7680$

$G_{cal} < G_{tab}$ $(0.5979 < 0.7680)$. This shows that the data can be regressed.

Dispersion And Experimental Errors

Using equations 3.6 and 3.7, The average sample variance or dispersion and experimental error are calculated as

$$S^2_{(y)} = \frac{1}{4}\sum_{u=1}^{4} S_u^2 = \frac{0.000870}{4} = 0.00022$$

$$S_{(y)} = \sqrt{S^2_{(y)}} = \sqrt{0.00022} = 0.01475$$

Estimation Of Model Regression Coefficient

Using equations 3.8 - 3.10, the model regression coefficients are estimated as

$$b_o = \frac{1}{4}[0.2478 + 0.2918 + 0.3108 + 0.4402] = 0.3226$$

$$b_1 = \frac{1}{4}[-0.02478 + 0.2918 - 0.3108 + 0.4402] = 0.04335$$

$$b_2 = \frac{1}{4}[-0.2478 - 0.2918 + 0.3108 + 0.4402] = 0.0528$$

$$b_{12} = \frac{1}{4}[0.2478 - 0.2918 - 0.3108 + 0.4402] = 0.0213$$

Statistical Significance of Regression Coefficients

The statistical significance of each estimated regression coefficient is tested using equations 3.11 and 3.13. The estimated standard error is given as

$$S_b = \frac{S_{(y)}}{\sqrt{N.r}} \quad \text{where N=4 and r = 3; } \Rightarrow S_b = \frac{0.01475}{\sqrt{12}} = 0.00426$$

From appropriate t – test table, $t_{(0.05,8)} = 1.860$

The confidence interval $= (1.860 x \pm 0.0426) = \pm 0.0079.$

For a full factorial experiment, $S_{bo} = S_{b1} = S_{b2} - - - - - - - S_{bn}$

Using equations 3.13a –3.13d, the t – value for each coefficient was calculated as

$$t_o = \frac{b_o}{Sb_o} = \frac{0.3226}{0.0079} = 75.79$$

$$t_1 = \frac{b_1}{S_{b_1}} = \frac{0.0433}{0.0079} = 10.18$$

$$t_2 = \frac{b_2}{S_{b_2}} = \frac{0.0528}{0.0079} = 12.41$$

$$t_{12} = \frac{b_{12}}{S_{b_{12}}} = \frac{0.0213}{0.0079} = 5.01$$

Table t – values at $t_{(0.05,8)}$ and $t_{(0.01,8)}$ are 1.860 and 3.355 respectively. The predicted equation using the calculated regression coefficient is thus

$$\overline{Y} = 0.3226 + 0.0433X_1 + 0.0528X_2 + 0.0213X_{12} \qquad (1B.1.)$$

Using equation 1B.1, the fitted values of Y at the levels of the independent variables are given below:

$\hat{Y} = (0.2478 + 0.0.2918(-) + 0.3108(-) + 0.4402(+)) = 0.24783$

$\hat{Y} = (0.2478 + 0.2918(-) + .03108(-) + 0.4402(+)) = 0.29181$

$\hat{Y} + (0.2478 + 0.2918(-) + 0.3108(+) + 0.4402(-)) = 0.31082$

$\hat{Y} = (0.2478 + 0.2918(+) + 0.3108(+) + 0.4402(+)) = 0.440197$

The residual, (e) and the square of residual (e^2) are calculated below as $(\overline{Y_u} - \hat{Y}_u)$ and $(\overline{Y_u} - \hat{Y}_u)^2$ respectively.

1.	$0.2478 - 0.247797$	$= 3 \times 10^{-6}$;	$e^2 = 9 \times 10^{-12}$
2.	$0.2918 - 0.298181$	$= -1 \times 10^{-5}$;	$e^2 = 1 \times 10^{-10}$
3.	$0.3108 - 031082$	$= -2.1 \times 10^{-5}$;	$e^2 = 4.41 \times 10^{-10}$
4.	$0.4402 - 0.44019$	$= -3 \times 10^{-6}$;	$e^2 = 9 \times 10^{-12}$
	$\Sigma e^2 = 5.59 \times 10^{-10}$		

Evaluation of Model's Adequacy by Analysis of Variance

The adequacy of the predicted model is evaluated by analysis of variance using equations 3.13 –3.21. The From equations 3.13b and 3.16c

$$SS_R = \frac{r}{N}\sum_{u=1}^{4}(X_y - \overline{Y_u})^2$$

$$SS_{b_1} = \frac{3}{4}[-0.2478 + 0.2918 - 0.3108 + 0.4402]^2 = \frac{3}{4}[0.1734]^2 = 0.0225$$

$$SS_{b_2} = \frac{3}{4}[-0.2478 - 02918 + 0.3108 + 0.4402]^2 = \frac{3}{4}[0.21141]^2 = 0.03352$$

$$SS_{b_{12}} = \frac{3}{4}[0.2478 - 0.2918 + 03108 + 0.4402]^2 = \frac{3}{4}(0.08536)^2 = 0.0055$$

$$\sum_{t=1}^{4} SS_{bi} = SS_R = (0.0225 + 00335 + 0.0055)$$

$SS_R = 0.0615$

The total sum of squares SS_T as given by equation 3.17.

$$SST = \sum_{u=1}^{(N,4)} \overline{Y_{uv}^2} - \frac{\sum_{u=1}^{(N,r)} (\overline{Y_{uv}})^2}{N.r}$$

$$SST = \sum_{u=1}^{(N,4)} \overline{Y_{uv}^2} = 1.3126$$

$$-\frac{\sum_{u=1}^{(N.r)}(\bar{Y}_{uv})^2}{N.r} = 1.2493$$

$SS_T = 1.3126 - 1.2493 = 0.0633$

$SS_E = SS_T - SS_R = 0.0633 - 0.0615 = 0.00174.$

Using equations 3.19 and 3.20, with degree of freedom of 1

$$MS_{b_{ij}} = \frac{SS_{b_{ij}}}{df}$$

$$MS_{b1} = \frac{0.0225}{1} = 0.0225$$

$$MS_{b2} = \frac{0.0335}{1} = 0.0335$$

$$MS_{b12} = \frac{0.0055}{1} = 0.0055$$

$$MS_E = \frac{SS_E}{N(r-1)} = \frac{0.00174}{4X3} = 0.00022$$

The F – criteria calculated for each regression coefficient using equation 3.21 is

$$F_{b1} = \frac{MSR_{bi}}{MSE} = \frac{0.0225574}{0.00022} = 103.90$$

$$F_{b2} = \frac{MS_{b2}}{MSE} = \frac{0.0335}{0.000217} = 154.47$$

$$F_{b12} = \frac{MS_{b12}}{MSE} = \frac{0.0055}{0.00022} = 25.85$$

Using equations 3.22 -3.24,

$$SS_{ad} = \frac{r}{N-\lambda}\sum(\bar{Y}_u - \hat{Y}_u)^2$$

where λ = member of insignificant coefficients = 0 and $\Sigma\ (\bar{Y}_u - \hat{Y}_u)^2 = 4.19x10^{-9}$

$$SS_{adj} = \frac{3}{4}\ (5.59x10^{-10}) = 4.19x10^{-10}$$

$$F_{ad} = \frac{SS_{aj}}{S_y^2} = \frac{4.1910^{-10}}{0.0147}$$

$F_{adj} = 2.842 \times 10^{-8}$

$F_{tab\,(0.05,\,1,\,8)} = 5.32.$

The predicted model given in equation A.3 is considered adequate hence for tomato pretreated and dried using tray dried at 50°C, the final fitted model is given as

$$\hat{Y} = 0.3227 + 0.0433X_1 + 0.0528X_2 + 0.0213X_{12} \qquad (1B.2)$$

APPENDIX 1C

STATISTICAL ANALYSIS OF BETA (β)-CAROTENE CONTENT IN PRETREATED SUN DRIED TOMATO

From the data in table 3.3 (appendix 3) and table 4.9, the maximum dispersion:

$$S^2_{u\,max} = 0.00053$$

Applying equations 3.2 and 3.5

$$\sum_{u=1}^{4} S_u^{\,2} = 0.000723$$

$$G_{cal} = \frac{S^2_{umax}}{\sum_{u=1}^{4} S_u^2} = \frac{0.00053}{0.000723} = 0.7337$$

$G_{(4,2,0.05)} = 0.768$, $G_{cal} < G_{tab}$ (i.e $0.7337 < 0.768$). .

Dispersion And Experimental Error

Using equations 3.12 and 3.13, the mean sample variance or dispersion and experimental errors are

$$S^2_{(y)} = \frac{1}{4}\sum_{u=1}^{4} S^2_u = \frac{0.000723}{4} = 0.000181$$

$$S_{(y)} = \sqrt{0.000181} = 0.013444$$

Estimated Model Regression Coefficient

Using equations 3.8, 3.9 and 3.10, the model regression coefficients are estimated as

$$b_o = \frac{1}{4}[0.1595 + 0.1766 + 0.2199 + 0.2954] = 0.21285$$

$$b_1 = \frac{1}{4}[-0.1591 + 0.1766 - 0.2199 + 0.2954] = 0.02312$$

$$b_2 = \frac{1}{4}[-0.1595 - 0.1766 + 0.2199 + 0.2945] = 0.04480$$

$$b_{12} = \frac{1}{4}[0.1595 - 0.1766 - 0.2199 + 0.2945] = 0.1460$$

Statistical Significance of Regression Coefficients

The statistical significance of each estimated regression coefficient is tested using equations 3.11 and 3.12. The estimated standard error is given as

$$S_{b'} = \frac{S_y}{\sqrt{N.r}} \qquad \text{where N} = 4 \quad \text{and r} = 3$$

$$S_{b'} = \frac{0.013444}{\sqrt{12}} = 0.0039 .$$

From appropriate t – test table, $t_{(0.05,\,8)} = 1.860$

The confidence interval $\Delta bs = (1.860\, x \pm 0.0039) = 0.00722$

Using equations 3.13a –3.13d, the t – value for each coefficient is calculated as:

$$t_o = \frac{b_o}{Sb_o} = \frac{0.2128}{0.0039} = 54.846$$

$$t_1 = \frac{b_1}{Sb_1} = \frac{0.2312}{0.0039} = 5.958$$

$$t_2 = \frac{b_2}{Sb_2} = \frac{0.0448}{0.0039} = 11.54$$

$$t_{12} = \frac{b_{12}}{Sb_{12}} = \frac{0.0146}{0.0039} = 3.760$$

Table t – values at $t_{(0.05,8)}$ and $t_{(0.01,8)}$ are 1.860 and 3.355 respectively. The predicted equation using the calculated regression coefficient is thus

$$\overline{Y} = 0.2128 + 0.0231X_1 + 0.04480X_2 + 0.0146X_{12} \qquad \text{(1C.1.)}$$

Using equation 1C.1, the fitted values of Y at the levels of the independent variables are given below:

$$\hat{Y}_1 = [0.02128 + 0.0231(-) + 0.0448(-) + 0.0146(+)] = 0.15954$$

$$\hat{Y}_2 = [0.2128 + 0.0231(+) + 0.0448(-) + 0.0146(-)] = 0.17659$$

$$\hat{Y}_3 = [0.2128 + 0.0231(-) + 0.0448(+) + 0.0146(-)] \qquad = 0.21993$$

$$\hat{Y}_4 = [0.2128 + 0.0231(+) + 0.0448(+) + 0.0146(+)] \qquad = 0.29536$$

The residual, (e) and the square of residual (e^2) are calculated below as $(\overline{Y_u} - \hat{Y_u})$ and $(\overline{Y_u} - \hat{Y_u})^2$ respectively.

1	$0.1595 - 0.15954 = 4 \times 10^{-5}$;	$e^2 = 1.6 \times 10^{-9}$
2	$0.1766 - 0.17659 = 1 \times 10^{-5}$;	$e^2 = 1 \times 10^{-10}$
3	$0.2199 - 0.21993 = -3 \times 10^{-5}$;	$e^2 = 9 \times 10^{-10}$
4	$0.2954 - 0.29536 = 4 \times 10^{-5}$;	$e^2 = 1.6 \times 10^{-9}$

$\Sigma\ e^2 = 4.2 \times 10^{-9}$

Evaluation of Model's Adequacy by Analysis of Variance

The adequacy of the predicted model is evaluated by analysis of variance using equations 3.13 –3.21. The From equations 3.13b and 3.16c

$$SS_{b_1} = \frac{3}{4}[-0.1595 + 0.1766 - 0.2199 + 0.2959]^2 = \frac{3}{4}[0.092491]^2 = 0.0064$$

$$SS_{b_2} = \frac{3}{4}[-0.1595 - 0.1760 + 0.2199 + 0.2954]^2 = \frac{3}{4}[0.17915]^2 = 0.024071$$

$$SS_{b_{12}} = \frac{3}{4}[0.1595 - 0.1766 + 0.2199 + 0.2954]^2 = \frac{3}{4}(0.05838)^2 = 0.00256$$

$$\sum_{t=1}^{4} SS_{bi} = SS_R = (0.00643 + 0.0240 + 0.00256)$$

$$SS_R = 0.0330$$

SS_T as given by equation 3.17.

$$SS_T = \sum_{u=1}^{(N,4)} Y_{uv}^2 - \frac{\sum_{u=1}^{(N,r)} (Y_{uv})^2}{N.r}$$

$$\sum_{uv}^{12} Y_{uv}^2 = [0.1645^2] + [0.1479^2] + [0.1662]^2$$

$$+ [0.18660]^2 + [0.1699]^2 + [0.1733]^2$$

$$+ [0.2159]^2 + [0.2226]^2 + [0.2213]^2$$

$$+ [0.2096]^2 + [0.3026]^2 + [0.3139]^2 \qquad = 0.54782$$

$$\sum \frac{(y_{uv})^2}{N.r} = \frac{(2.5542)^2}{4x3} = \frac{6.52414}{12} \qquad = 0.5437$$

$SS_T = 0.5478 - 0.5437 = 0.0345$

$SS_E = SS_T - SS_R = 0.0345 - 0.0330 = SS_E = 0.00145$

Using equations 3.19 and 3.20, with degree of freedom of 1 as:

$$MS_{b_{ij}} = \frac{SS_{b_{ij}}}{df}$$

$$MS_{b1} = \frac{0.00643}{1} = 0.00643$$

$$MS_{b2} = \frac{0.0240}{1} = 0.0240$$

$$MS_{b12} = \frac{0.00256}{1} = 0.00256$$

$$MS_E = \frac{SS_E}{N(r-1)} = \frac{0.001445}{4X3} = 0.000181$$

The F – criteria for each regression coefficient using equation 3.21 is calculated as below

$$F_{b_i} = \frac{MS_R bi}{MS_E} = \frac{0.00642}{0.000181} = 35.447$$

$$F_{b_2} = \frac{MS_{b2}}{MS_E} = \frac{0.024073}{0.000181} = 139.0$$

$$F_{b12} = \frac{MS_{b12}}{MSE} = \frac{0.002556}{0.000181} = 14.12$$

F – ratio at $F_{(0.05,\ 1,\ 8)} = 5.32$.

Using equations 3.22 -3.24, the dispersion of adequacy for the replicated experiment is

$$SS_{ad} = \frac{r}{N - \lambda}\sum(\bar{Y}_u - \hat{Y}_u)^2$$

λ = number of insignificant term = 0 ; $\Sigma\ (\bar{Y}_u - \hat{Y}_u)^2 = 1.7 \times 10^{-9}$

$$SS^2_{ad} = \frac{3}{4}(17 \times 10^{-9})^2 = 4.2 \times 10^{-9}$$

$$F_{ad} = \frac{SS_{ad}}{S^2_{(y)}} = \frac{4.2' 10^{-9}}{0.013444} = 3.124' 10^{-7}$$

$F_{xal\ (0.05,\ 1,\ 8)} = 5.32$

$F_{adj} < F_{tab}$ thus, the predicted model is adequate. For tomato pretreated and sun dried, the fitted model is given as

$$Y = 0.2128 + 0.02312X_1 + 0.0448X_2 + 0.0146X_{12} \qquad (1C.2)$$

APPENDIX 2

Table 2.1a: Estimated Productions of Selected Vegetables in Nigeria.

Crop	Estimated area under Production annually (Ha)	Average yield (Metric tons/ha)	Estimated Annual Production (1×10^3 Metric ton)
Sweet and Hot pepper	800	3 - 10	2.40 – 8.000
Tomato	646	15	9.694
Onion	200	25	2.500
Okra	100	12	1.2

Source: Adedipe et al. (1996)

Table 2.1b Changes in Pigment During Maturity and Ripening Of Tomato:

Degree of maturity	Carotene	Lycopene	Xanthophylls	Chlorophyll
Dark Green	1.27	0.00	0.194	2.867
Green White	0.166	0.00	0.214	2.055
ReddishTringe	1.431	0.195	0.979	1.701
Dark Red	428, 430.0	2,589,510.0	170,362.5	1.194

Pigment (mg\ 100g)	Stages of ripening				
	Large Green	Breaker	Pink-Orange	Red	Dark Red
Lycopene	80	124.0	230.0	3740	4.2
Chlorophyll	45.0	25.0	9.0	0.0	0.0
β-carotene	50.0	242	443	10.0	0.0

Source: Extracted from Salunke D.K and Dessai B.B. (1984).

Table 2.2: Nutritional Compositions Of Vegetables

Macronutrient	Energy	Moisture	Protein	Fat	CHO
Vegetable	(Kcal)	(%)	(g/100g)	(g/100g	(g/100g)
Tomato	22.56	94.7	1.0	0.1	1.9
Okra	35.0	89.6	1.9	0.4	6.4
Pepper	22.0	93.4	1.2	0.2	4.
Amaranth	45.0	85.7	4.0	0.5	6.1
Water spinach	28.0	90.3	2.9	0.4	2.1
Cucumber	13.0	06.3	0.4	0.1	2.5

Mineral	Ca	P	Fe	Mg
Vegetable	(mg/100g)	(mg/100g)	(mg/100g)	(mg/100g)
Tomato	8	27	0.5	10
Okra	66	56	1.5	
Pepper	9	22	0.7	
Amaranth	397	83	25.5	
Water spinach	110	46	3.9	
Cucumber	10	25	1.5	

	Vitamin				
Vegetable	A	Thiamin	Riboflavin	Niacin	Ascorbic Acid
	(IU)	(mg/100g)	(mg/100g)	(mg/100g)	(mg/100g)
Tomato	900	0.04	0.02	0.7	23
Okra	172	0.07	0.10	0.1	12
Pepper	900	0.06	0.06	0.5	128
Amaranth	18216	0.03	0.30	1.2	99
Spinach	6534	0.05	0.13	0.6	37
Cucumber	0	0.03	0	0.2	7
Carrot	8115	0.1	0.01	0.20	6

Source: Macrea et.al (1993)

Table 2.3: Specific Sensitivity Of Vitamins.

Nutrient	Neutral P^H=7.0	Acid P^H. < 7.0	Alkali P^H>7.0	Acid and Oxygen
Vitamin A	S	U	S	U
β-Carotene	S	U	S	U
Ascorbic acid	U	S	U	U
Biotin	S	S	S	S
Vitamin D	S	_	U	U

U= Unstable; S= Stable. Source: Rozis, 1975.

Table 2.4: Initial and Final (Safe Storage) Moisture Contents Of Fruits and Vegetable

Moisture Contents %(Wb)				Maximum Drying Temp. (°C)
Crop	Initial	Final		
		*	**	
Bananas	70%	12%	15%	70
Carrots	75%	5-7%	5%	75
Potatoes	75%	5%	13%	70
Onions	80%	5-7%	4%	55
Apricot	85%	18%	15-18%	65
Mangoes	80-85%	14%	12-15%	75
Cabbage	80%	4%	4%	55
Okra	87%	5%	4-5%	66
Tomatoes	95%	4-5%	10%	65
Pepper	85%	5-7%	5-6%	85

Source: *Saravan (1999). **Rozis (

Table 2.5:Blanching Time And Sulphite Application For Some Selected Vegetables

Vegetable	Blanching Time (Min)		Sulphite Concentration (Ppm)	
	Water	Steam	Concentration (ppm)	Soaking time (min)
Carrots	3	4-8	3000	1
Cabbage	4	5	2000	
Garden egg	3	4	-	
Spinach	3	3-4	-	
Tomato	1.5	3	1500	2-3
Amaranth	1.5, 1*	3	-	
Egg Plant	1.5-2		-	
Okra	2-6	4	2000	2-3
Sweet	3		5500	1
potatoes	4-2			
Pumpkin	2-3	3		
Leaves				
Bell pepper				

Source :Kodylas, (1991) *Taiwo, (1995)

Table 2.6 Total and β – Carotene Content Of Some Common Vegetables

Crop	Total Carotene (mg/100g)	β - Carotene (mg/100g)	Total(%) β - Carotene
Carrot	8.85	6.5	69.7
Sweet potato	2.23	1.87	84.1
Tomato	3.00	0.62	20.8
Bell pepper	0.69	0.11	15.8
Pawpaw	2.76	1.05	36.7
Guava	0.05	0.001	3.1
Orange	2.25	0.17	7.2
Mango	2.21	1.71	76-9
Amaranth	21.2	8.6	39.7
Fluted			
Pumpkin leaf	9.8	3.2	31.8
Okra	19.1	4.3	21.0
Lettuce	7.8	1.4	18-8

Source: Bhascharary et al. (1995)

Table 2.7: Comparative Values Of BCarotene In Vegetables Using AOAC And HPLC Methods

Crop	HPLC (mg /100g)	AOAC(mg/ 00g)
Orange	0.73	2.68
Pawpaw	0.44	0.99
Carrot	7.06	9.87
Spinach	2.62	3.35
Tomato	0.59	18.06*
Bell Pepper	1.87	2.5
Okra	2.34	3.23

Source: Ball,(1994) *Bolin and Strafford (1974)

APPENDIX 3

TABLE 3.1: OBSERVED β- CAROTENE RETAINED AND STATISTICAL ANALYSIS FOR PRETREATED TOMATO (Lycopersicum esculentum) TRAYDRIED AT 65°C

EXP.RUN	Y_1	Y_2	Y_3	$\bar{Y}_u$	$Y_1 - \bar{Y}_u$	$Y_2 - \bar{Y}_u$	$Y_3 - \bar{Y}_u$	$(Y_1 - \bar{Y}_u)^2$	$(Y_2 - \bar{Y}_u)^2$	$(Y_3 - \bar{Y}_u)^2$	S_u^2
1	0.27872	0.27331	0.28163	0.27789	0.000832	-0.0046	0.003744	6.9E-07	2.1E-05	1.4E-05	2E-05
2	0.37024	0.36608	0.42224	0.38619	-0.01595	-0.0201	0.036053	0.00025	0.0004	0.0013	0.001
3	0.43264	0.47466	0.46717	0.45815	-0.02551	0.0165	0.009013	0.00065	0.00027	8.1E-05	0.0005
4	0.49504	0.50398	0.51334	0.50412	-0.00908	-0.0001	0.009221	8.2E-05	1.9E-08	8.5E-05	8E-05

ΣS_u^2 = 0.001583

TABLE 3.2: OBSERVED β - CAROTENE RETAINED AND STATISTICAL ANALYSIS FOR PRETREATED TOMATO *(Lycopersicum esculentum)* TRAYDRIED AT 50°C

EXP.RUN	Y_1	Y_2	Y_3	$\bar{Y}_u$	$Y_1 - \bar{Y}_u$	$Y_2 - \bar{Y}_u$	$Y_3 - \bar{Y}_u$	$(Y_1 - \bar{Y}_u)^2$	$(Y_2 - \bar{Y}_u)^2$	$(Y_3 - \bar{Y}_u)^2$	S_u^2
1	0.26062	0.25355	0.22920	0.24779	0.01283	0.00576	-0.01859	0.00016	0.00003	0.00035	0.0003
2	0.28683	0.29532	0.29330	0.29182	-0.00498	0.00350	0.00148	0.00002	0.00001	0.00000	2E-05
3	0.31200	0.31782	0.30260	0.31081	0.00119	0.00702	-0.00821	0.00000	0.00005	0.00007	6E-05
4	0.41808	0.46363	0.43890	0.44020	-0.02212	0.02343	-0.00130	0.00049	0.00055	0.00000	0.0005
											0.0009

ΣS_u^2 = 0.00087

D STATISTICAL ANALYSIS FOR PRETREATED SUNDRIED

	Y_3	$\bar{Y}_u$	$Y_1 - \bar{Y}_u$	$Y_2 - \bar{Y}_u$	$Y_3 - \bar{Y}_u$	$(Y_1 - \bar{Y}_u)^2$	$(Y_2 - \bar{Y}_u)^2$	$(Y_3 - \bar{Y}_u)^2$
2	0.1479	0.1662	0.1595	0.00499	-0.01165	0.00666	0.00002	0.00014	0.00004
3	0.1866	0.1699	0.1733	0.1766	0.00998	-0.00666	-0.00333	0.00010	0.00004	0.00001
4	0.2159	0.2226	0.2213	0.2199	-0.00402	0.00263	0.00139	0.00002	0.00001	0.000002
	0.2696	0.3026	0.3139	0.2954	-0.02579	0.00728	0.01851	0.00067	0.00005	0.00034

ΣS_u^2

APPENDIX 4

TABLE A 4.1 : SUMMARY DATA OF ALL PRETREATED TOMATO SAMPLES TRAYDRIED AT 65°C

TREATMENT		X_0		X_1^-				X_1^+			
Drying Time(T)				Drying Time(T)				Drying Time(T)			
Minutes	Hours	%Mc(db)	dM/dT	Minutes	Hours	%Mc(db)	dM/dT	Minutes	Hours	%Mc(db)	dM/dT
0	0	17.28		0	0	16		0	0	15.78	
20	0.330	14.610	8.097	20	0.330	12.970	9.182	20	0.330	13.044	8.291
40	0.667	11.940	8.091	40	0.667	9.940	9.182	40	0.667	10.308	8.291
60	1.000	9.270	8.091	60	1.000	8.000	5.879	60	1.000	8.054	6.830
80	1.330	7.724	4.685	80	1.330	6.500	4.545	80	1.330	5.999	6.227
100	1.667	6.370	4.103	100	1.667	5.050	4.394	100	1.667	4.149	5.606
120	2.000	5.107	3.827	120	2.000	3.650	4.242	120	2.000	2.650	4.542
140	2.330	3.923	3.588	140	2.330	2.504	3.473	140	2.330	1.661	2.997
160	2.667	3.075	2.570	160	2.667	1.844	2.000	160	2.667	0.728	2.827
180	3.000	2.532	1.645	180	3.000	1.337	1.536	180	3.000	0.298	1.303
240	4.000	1.400	1.132	240	4.000	0.275	1.062	200	3.333	0.042	0.776
300	5.000	0.745	0.655	280	4.667	0.043	0.352				
340	5.667	0.042	0.703								

TREATMENT		X_2^-		X_2^+				$X_1^- X_2^-$			
Drying Time(T)				Drying Time(T)				Drying Time(T)			
Minutes	Hours	%Mc(db)	dM/dT	Minutes	Hours	%Mc(db)	dM/dT	Minutes	Hours	%Mc(db)	dM/dT
0	0	15.38		0	0	13.401		0	0	16.57	
20	0.330	13.220	6.545	20	0.330	11.192	6.694	20	0.330	13.920	8.030
40	0.667	11.060	6.545	40	0.667	8.982	6.697	40	0.667	11.260	8.061
60	1.000	8.926	6.467	60	1.000	6.773	6.694	60	1.000	8.613	8.021
80	1.330	7.209	5.203	80	1.330	5.037	5.261	80	1.330	6.306	6.991
100	1.667	5.585	4.921	100	1.667	3.573	4.436	100	1.667	4.100	6.685
120	2.000	4.029	4.715	120	2.000	2.281	3.915	120	2.000	2.644	4.412
140	2.330	2.575	4.406	140	2.330	1.138	3.464	140	2.330	1.518	3.412
160	2.667	1.330	3.773	160	2.667	0.379	2.300	160	2.667	0.615	2.736
180	3.000	0.347	2.979	180	3.000	0.126	0.767	180	3.000	0.266	1.058
220	3.330	0.042	0.457	200	3.330	0.042	0.255	220	3.667	0.043	0.676

APPENDIX 5

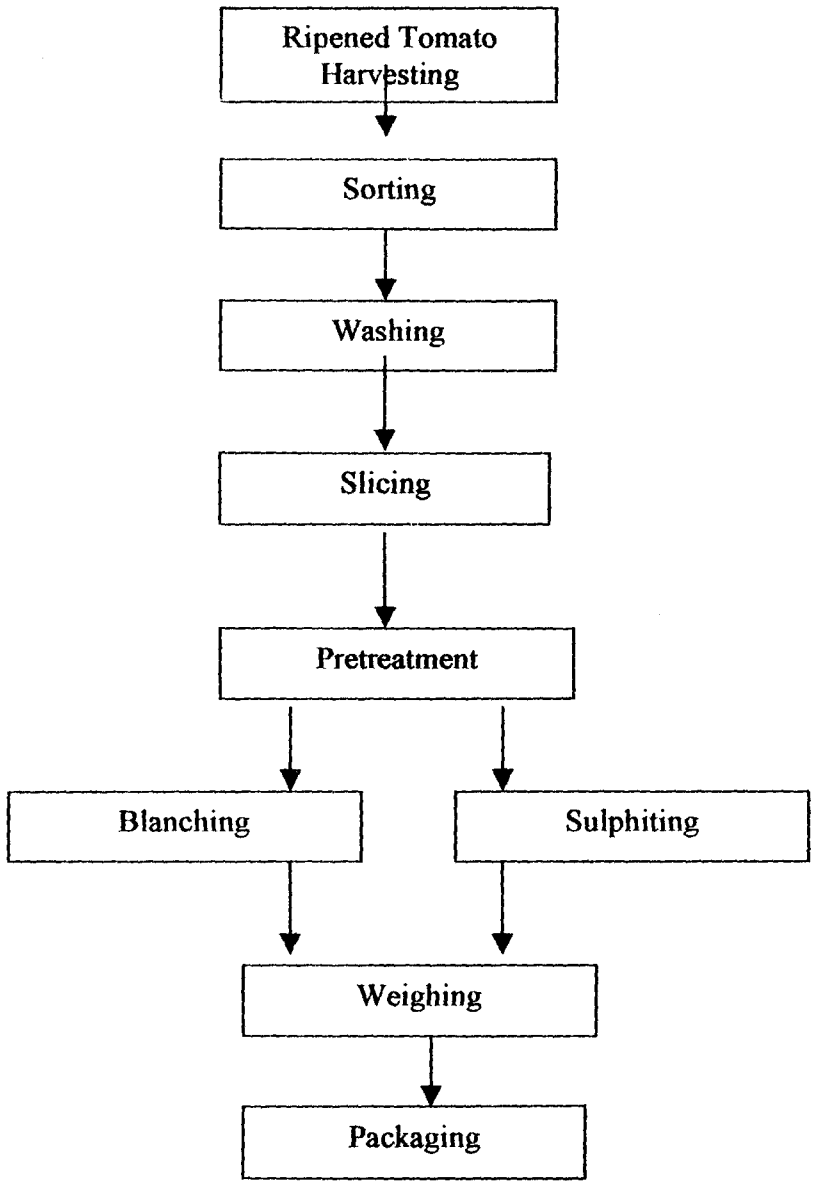


Fig A5.1: Flow Chart for Pretreatments and Drying Operations

TABLEA 4.1 : contd

TREATMENT		$X_1^- X_2^+$				$X_1^+ X_2^-$				$X_1^+ X_2^+$			
Drying Time(T)				Drying Time(T)				Drying Time(T)			
Minutes	Hours	%Mc(db)	dM/dT	Minutes	Hours	%Mc(db)	dM/dT	Minutes	Hours	%Mc(db)	dM/dT
0	0	15.64		0	0	15.722		0	0	14.13	
20	0.330	12.890	8.333	20	0.330	12.912	8.515	20	0.330	11.580	7.727
40	0.667	10.160	8.273	40	0.667	10.108	8.497	40	0.667	9.050	7.667
60	1.000	7.460	8.182	60	1.000	7.306	8.491	60	1.000	7.210	5.576
80	1.330	5.739	5.215	80	1.330	5.535	5.367	80	1.330	5.400	5.485
100	1.667	4.040	5.148	100	1.667	3.974	4.730	100	1.667	3.740	5.030
120	2.000	2.710	4.030	120	2.000	2.425	4.694	120	2.000	2.410	4.030
140	2.330	1.643	3.233	140	2.330	1.245	3.576	140	2.330	1.100	3.970
160	2.667	0.814	2.512	160	2.667	0.438	2.445	160	2.667	0.410	2.091
180	3.000	0.327	1.476	180	3.000	0.209	0.694	180	3.000	0.042	1.115
200	3.330	0.042	0.864	220	3.667	0.043	0.249				

TABLE A4.2:SUMMARY DATA OF ALL PRETREATED TOMATO SAMPLES TRAYDRIED AT 50°C

TREATMENT		X_o		TREATMENT		X_1^-		TREATMENT		X_1^+	
Drying Time(T)				Drying Time(T)				Drying Time(T)			
Minutes	Hours	%Mc(db)	dM/dT	Minutes	Hours	%Mc(db)	dM/dT	Minutes	Hours	%Mc(db)	dM/dT
0	0.00	17.26		0	0.00	15.99		0	0	15.760	
20	0.33	15.45	5.485	20	0.33	14.158	5.552	20	0.33	13.23	7.667
40	0.67	13.66	5.424	40	0.67	12.34	5.509	40	0.67	10.712	7.630
60	1.00	11.875	5.409	60	1.00	10.54	5.455	60	1.00	8.194	7.630
80	1.33	10.09	5.409	80	1.33	8.75	5.424	80	1.33	6.52	5.073
100	1.67	8.73	4.121	100	1.67	7.52	3.727	100	1.67	5.01	4.576
120	2.00	7.46	3.848	120	2.00	6.42	3.333	120	2.00	4.11	2.727
140	2.33	6.23	3.727	140	2.33	5.46	2.909	140	2.33	3.3	2.455
160	2.67	5.2	3.121	160	2.67	4.55	2.758	160	2.67	2.56	2.242
180	3.00	4.21	3.000	180	3.00	3.62	2.818	180	3.00	2	1.697
240	4.00	2.11	2.100	240	4.00	1.78	1.840	240	4.00	0.59	1.410
300	5.00	0.73	1.380	300	5.00	0.042	1.738	270	4.50	0.042	1.096
340	5.67	0.042	1.031								

TREATMENT		X_2^-		TREATMENT		X_2^+		TREATMENT		$X_1^-X_2^-$	
Drying Time(T)				Drying Time(T)				Drying Time(T)			
Minutes	Hours	%Mc(db)	dM/dT	Minutes	Hours	%Mc(db)	dM/dT	Minutes	Hours	%Mc(db)	dM/dT
0	0.000	15.370		0	0.00	13.040		0	0.00	16.530	
20	0.330	13.770	4.848	20	0.33	11.239	5.458	20	0.33	14.781	5.300
40	0.667	12.195	4.773	40	0.67	9.441	5.448	40	0.67	13.039	5.279
60	1.000	10.620	4.773	60	1.00	7.656	5.409	60	1.00	11.300	5.270
80	1.330	9.179	4.367	80	1.33	6.350	3.958	80	1.33	9.560	5.273
100	1.667	7.879	3.939	100	1.67	5.100	3.788	100	1.67	7.950	4.879
120	2.000	6.719	3.515	120	2.00	4.000	3.333	120	2.00	6.610	4.061
140	2.330	5.630	3.300	140	2.33	3.000	3.030	140	2.33	5.320	3.909
160	2.667	4.600	3.121	160	2.67	2.100	2.727	160	2.67	4.250	3.242
180	3.000	3.750	2.576	180	3.00	1.500	1.818	180	3.00	3.240	3.061
240	4.000	1.660	2.090	240	4.00	0.042	1.458	240	4.00	1.000	2.240
300	5.000	0.042	1.618					300	5.00	0.042	0.958

TABLE A4.2 contd

TREATMENT $X_1^- X_2^+$				TREATMENT $X_1^+ X_2^-$				TREATMENT $X_1^+ X_2^+$			
Drying Time(T)				Drying Time(T)				Drying Time(T)			
Minutes	Hours	%Mc(db)	dM/dT	Minutes	Hours	%Mc(db)	dM/dT	Minutes	Hours	%Mc(db)	dM/dT
100	1.67	7.490	3.388	0	0.000	15.720		0	0.000	14.130	
120	2.00	7.360	3.333	20	0.330	13.654	6.261	20	0.330	11.880	6.818
140	2.33	6.310	3.182	40	0.667	11.590	6.255	40	0.667	9.640	6.788
160	2.67	5.290	3.091	60	1.000	9.900	5.121	60	1.000	7.900	5.273
180	3.00	4.320	2.939	80	1.333	8.340	4.727	80	1.333	6.400	4.545
240	4.00	3.520	2.424	100	1.667	6.790	4.697	100	1.667	5.400	3.030
300	5.00	1.260	2.260	120	2.000	4.030	4.303	120	2.000	4.510	2.697
330	5.50	0.320	0.940	140	2.330	2.790	4.061	140	2.330	3.600	2.758
		0.042	0.556	160	2.667	1.840	3.758	160	2.667	2.920	2.061
				180	3.000	0.510	2.879	180	3.000	2.300	1.879
				240	4.000	0.042	1.330	240	4.000	1.000	1.300
				300	5.000		0.468	300	5.000	0.042	0.958

TABLE A4.3 :SUMMARY DATA OF ALL PRETREATED SUNDRIED TOMATO

TREATMENT		X_O				X_1^-				X_1^+	
Drying Time(T)				Drying Time(T)				Drying Time(T)			
Minutes	Hours	%Mc(db)	dM/dT	Minutes	Hours	%Mc(db)	dM/dT	Minutes	Hours	%Mc(db)	dM/dT
0	0	17.25		0	0	15.96		0	0	15.778	
60	1	14	3.25	60	1	12.405	3.555	60	1	12.188	3.590
120	2	10.759	3.241	120	2	8.905	3.500	120	2	8.648	3.540
180	3	7.533	3.226	180	3	5.441	3.464	180	3	5.120	3.528
240	4	5.33	2.203	240	4	2.909	2.532	240	4	2.596	2.524
300	5	3.616	1.714	300	5	1.809	1.100	300	5	1.720	0.876
360	6	2.074	1.542	360	6	1.063	0.746	360	6	1.020	0.700
420	7	1.012	1.062	420	7	0.713	0.350	420	7	0.560	0.460
480	8	0.459	0.553	480	8	0.383	0.330	480	8	0.221	0.339
540	9	0.302	0.157	540	9	0.168	0.215	540	9	0.043	0.178
600	10	0.155	0.147	600	10	0.042	0.126				
660	11	0.042	0.113								

TREATMENT		X_2^-				X_2^+				$X_1^- X_2^-$	
Drying Time(T)				Drying Time(T)				Drying Time(T)			
Minutes	Hours	%Mc(db)	dM/dT	Minutes	Hours	%Mc(db)	dM/dT	Minutes	Hours	%Mc(db)	dM/dT
0	0	15.377		0	0	13.389		0	0	16.548	
60	1	12.220	3.157	60	1	10.904	2.485	60	1	12.81	3.738
120	2	9.120	3.100	120	2	8.449	2.455	120	2	9.092	3.718
180	3	6.031	3.089	180	3	6.014	2.435	180	3	5.409	3.683
240	4	3.850	2.181	240	4	4.112	1.902	240	4	3.219	2.19
300	5	2.118	1.732	300	5	2.281	1.831	300	5	1.826	1.393
360	6	1.007	1.111	360	6	0.645	1.636	360	6	0.615	1.211
420	7	0.380	0.627	420	7	0.042	0.603	420	7	0.042	0.573
480	8	0.043	0.337								

TABLE A4.3 contd

TREATMENT $X_1^- X_2^+$				TREATMENT $X_1^+ X_2^-$				TREATMENT $X_1^+ X_2^+$			
Drying Time(T)				Drying Time(T)				Drying Time(T)			
Minutes	Hours	%Mc(db)	dM/dT	Minutes	Hours	%Mc(db)	dM/dT	Minutes	Hours	%Mc(db)	dM/dT
0	0	15.638		0	0	15.753		0	0	14.136	
60	1	12.541	3.097	60	1	12.535	3.218	60	1	10.586	3.550
120	2	9.503	3.038	120	2	9.340	3.195	120	2	7.136	3.450
180	3	6.503	3.000	180	3	6.145	3.195	180	3	3.700	3.436
240	4	4.372	2.131	240	4	3.743	2.402	240	4	1.299	2.401
300	5	2.453	1.919	300	5	2.234	1.509	300	5	0.327	0.972
360	6	1.005	1.448	360	6	1.410	0.824	360	6	0.042	0.285
420	7	0.393	0.612	420	7	0.596	0.814				
480	8	0.043	0.350	480	8	0.043	0.553				

...ding elapsed time for pretreated tomato traydried at 65°C

X_1^-

...ed(T) ...utes	Hours	%Mc(db)	M/Mo	LnM/Mo
60	0.000	9.261	1	0
80	0.330	7.724	0.8340	-0.1815
100	0.667	6.370	0.6878	-0.3742
120	1.000	5.107	0.5515	-0.5952
140	1.330	3.923	0.4236	-0.8590
160	1.667	3.075	0.3320	-1.1025
180	2.000	2.532	0.2734	-1.2968
240	3.000	1.400	0.1512	-1.8893
300	4.000	0.745	0.0804	-2.5202
340	5.667	0.042	0.0045	-5.3959

X_1^+

Elapsed Drying Time(T) Minutes	Hours	%Mc(db)	M/Mo	LnM/Mo
40	0.000	9.930	1	0
60	0.330	8.000	0.8056	-0.216119
80	0.667	6.500	0.6546	-0.423758
100	1.000	5.050	0.5086	-0.676172
120	1.330	3.650	0.3676	-1.000833
140	1.667	2.504	0.2522	-1.377671
160	2.000	1.844	0.1857	-1.683623
180	2.333	1.337	0.1346	-2.005132
240	3.333	0.275	0.0277	-3.586545
280	4.000	0.043	0.0043	-5.442116

Elapsed Drying Time(T) Minutes	Hours	%Mc(db)	M/Mo	LnM/Mo
40	0.000	10.200	1	0.000000
60	0.330	8.100	0.7941	-0.2305
80	0.667	6.050	0.5931	-0.5223
100	1.000	4.321	0.4236	-0.8589
120	1.330	2.950	0.2892	-1.2406
140	1.667	1.700	0.1667	-1.7918
160	2.000	0.700	0.0686	-2.6791
180	2.333	0.200	0.0196	-3.9318
200	2.667	0.042	0.0041	-5.4925

TREATMENT X_2^-

Elapsed Drying Time(T) Minutes	Hours	%Mc(db)	M/Mo	LnM/Mo
60	0.000	8.926	1.000	0
80	0.330	7.209	0.808	-0.2136
100	0.667	5.585	0.626	-0.4689
120	1.000	4.029	0.451	-0.7955
140	1.330	2.575	0.288	-1.2431
160	1.667	1.330	0.149	-1.9038
180	2.000	0.347	0.039	-3.2474
200	2.330	0.042	0.005	-5.3591

X_2^+

Elapsed Drying Time(T) Minutes	Hours	%Mc(db)	M/Mo	LnM/Mo
40	0.000	8.648	1.000	0
60	0.330	6.772	0.783	-0.2445
80	0.667	5.037	0.582	-0.5405
100	1.000	3.573	0.413	-0.8839
120	1.330	2.281	0.264	-1.3327
140	1.667	1.138	0.132	-2.0281
160	2.000	0.379	0.044	-3.1275
180	2.333	0.126	0.015	-4.2288
200	2.667	0.042	0.005	-5.3274

$X_1^- X_2^-$

Elapsed Drying Time(T) Minutes	Hours	%Mc(db)	M/Mo	LnM/Mo
60	0.000	8.624	1.000	0
80	0.330	6.306	0.731	-0.3130
100	0.667	4.100	0.475	-0.7436
120	1.000	2.644	0.307	-1.1823
140	1.330	1.518	0.176	-1.7372
160	1.667	0.615	0.071	-2.6407
180	2.000	0.266	0.031	-3.4788
220	2.667	0.043	0.005	-5.3011

Table A4.4 contd

TREATMENT		$X_1^- X_2^+$			$X_1^+ X_2^-$				$X_1^+ X_2^+$				
Elapsed Drying Time(T)					Elapsed Drying Time(T)				Elapsed Drying Time(T)				
Minutes	Hours	%Mc(db)	M/Mo	LnM/Mo	Minutes	Hours	%Mc(db)	M/Mo	LnM/Mo	Minutes	Hours	%Mc(db)	M/Mo	LnM/Mo
40	0.000	9.447	1	0	60	0.000	7.326	1	0	40	0.000	9.050	1	0
60	0.330	7.475	0.791256	-0.23413311	80	0.330	5.535	0.755528	-0.2803381	60	0.330	7.210	0.796685	-0.22729581
80	0.667	5.739	0.607494	-0.49841225	100	0.667	3.974	0.542452	-0.61165652	80	0.667	5.400	0.596685	-0.5163658
100	1.000	4.040	0.427649	-0.84945254	120	1.000	2.425	0.331013	-1.10559814	100	1.000	3.740	0.41326	-0.88367915
120	1.330	2.710	0.286864	-1.2487486	140	1.330	1.245	0.169943	-1.77229413	120	1.330	2.410	0.266298	-1.32313801
140	1.667	1.643	0.173918	-1.74917339	160	1.667	0.438	0.059787	-2.81696603	140	1.667	1.100	0.121547	-2.10745458
160	2.000	0.814	0.086165	-2.45149214	180	2.000	0.209	0.028529	-3.55685069	160	2.000	0.410	0.045304	-3.09436288
180	2.333	0.327	0.034614	-3.36349234	220	2.667	0.043	0.00587	-5.13798483	180	2.333	0.042	0.004641	-5.37285042
200	2.667	0.042	0.004446	-5.41578289										

Table A4.5: Moisture ratio and corresponding elapsed time for pretreated tomato traydried at 50°C

TREATMENT		X_o				X_1^-				X_1^+			
Elapsed Drying Time(T)					Elapsed Drying Time(T)					Elapsed Drying Time(T)			
Minutes	Hours	%Mc(db)	M/Mo	LnM/Mo	Minutes	Hours	%Mc(db)	M/Mo	LnM/Mo	Minutes	Hours	%Mc(db)	M/Mo	LnM/Mo
80	0.00	10.12	1	0	80	0.00	8.75	1	0	60	0.00	8.2	1	0
100	0.33	8.73	0.862648	-0.14775	100	0.33	7.52	0.859429	-0.15149	80	0.33	6.52	0.7951	-0.2293
120	0.67	7.46	0.737154	-0.30496	120	0.67	6.42	0.733714	-0.30964	100	0.67	5.01	0.6110	-0.4927
140	1.00	6.23	0.615613	-0.48514	140	1.00	5.46	0.624	-0.4716	120	1.00	4.11	0.5012	-0.6907
160	1.33	5.2	0.513834	-0.66586	160	1.33	4.55	0.52	-0.65393	140	1.33	3.3	0.4024	-0.9102
180	1.67	4.21	0.416008	-0.87705	180	1.67	3.62	0.413714	-0.88258	160	1.67	2.56	0.3122	-1.1641
240	2.00	2.11	0.208498	-1.56783	240	2.67	1.78	0.203429	-1.59244	180	2.00	2	0.2439	-1.4110
300	3.00	0.73	0.072134	-2.62922	300	3.67	0.042	0.0048	-5.33914	240	3.00	0.59	0.0720	-2.6318
340	4.00	0.042	0.00415	-5.4846						270	3.50	0.042	0.0051	-5.2742

TREATMENT		X_2^-				X_2^+				$X_1^- X_2^-$			
Elapsed Drying Time(T)					Elapsed Drying Time(T)					Elapsed Drying Time(T)			
Minutes	Hours	%Mc(db)	M/Mo	LnM/Mo	Minutes	Hours	%Mc(db)	M/Mo	LnM/Mo	Minutes	Hours	%Mc(db)	M/Mo	LnM/Mo
60	0.00	10.620	1	0	60	0.00	7.650	1	0	80	0.00	9.540	1	0
80	0.33	9.320	0.877589	-0.13058	80	0.33	6.350	0.830065	-0.18625	100	0.33	7.950	0.833333	-0.1823
100	0.67	8.100	0.762712	-0.27087	100	0.67	5.100	0.666667	-0.40547	120	0.67	6.610	0.692872	-0.3669
120	1.00	6.950	0.654426	-0.424	120	1.00	4.000	0.522876	-0.64841	140	1.00	5.320	0.557652	-0.5840
140	1.33	5.760	0.542373	-0.6118	140	1.33	3.000	0.392157	-0.93609	160	1.33	4.250	0.445493	-0.8086
160	1.67	4.600	0.433145	-0.83668	160	1.67	2.100	0.27451	-1.29277	180	1.67	3.240	0.339623	-1.0799
180	2.00	3.750	0.353107	-1.04098	180	2.00	1.500	0.196078	-1.62924	240	2.67	1.000	0.104822	-2.2555
240	3.00	1.660	0.156309	-1.85592	240	3.00	0.042	0.00549	-5.20479	300	3.67	0.042	0.004403	-5.4256
300	4.00	0.042	0.003955	-5.53282										

Table A4.5 contd

TREATMENT	X_1X_2				X_1X_2				X_1X_2				
Elapsed Drying Time(T)					Elapsed Drying Time(T)				Elapsed Drying Time(T)				
Minutes	Hours	%Mc(db)	M/Mo	LnM/Mo	Minutes	Hours	%Mc(db)	M/Mo	LnM/Mo	Minutes	Hours	%Mc(db)	M/Mo	LnM/Mo
100	0.00	7.360	1	0	80	0.00	8.340	1	0	60	0.00	7.900	1	0
120	0.33	6.310	0.857337	-0.15392	100	0.33	6.790	0.814149	-0.2056	80	0.33	6.400	0.8101	-0.2106
140	0.67	5.290	0.71875	-0.33024	120	0.67	5.370	0.643885	-0.4402	100	0.67	5.400	0.6835	-0.3805
160	1.00	4.320	0.586957	-0.5328	140	1.00	4.030	0.483213	-0.7273	120	1.00	4.510	0.5709	-0.5606
180	1.33	3.520	0.478261	-0.7376	160	1.33	2.790	0.334532	-1.0950	140	1.33	3.600	0.4557	-0.7859
240	2.33	1.260	0.171196	-1.76495	180	1.67	1.840	0.220624	-1.5113	160	1.67	2.920	0.3696	-0.9953
300	3.33	0.320	0.043478	-3.13549	240	2.67	0.510	0.061151	-2.7944	180	2.00	2.300	0.2911	-1.2340
330	3.83	0.042	0.005707	-5.16615	300	3.67	0.042	0.005036	-5.2911	240	3.00	1.000	0.1266	-2.0669
										300	4.000	0.042	0.0053	-5.2369

Table A4.6: Moisture ratio and corresponding elapsed time for pretreated Sundried tomato

TREATMENT		X_o			X_1^-					X_1^+				
Elapsed Drying Time(T)					Elapsed Drying Time(T)					Elapsed Drying Time(T)				
Minutes	Hours	%Mc(db)	M/Mo	LnM/Mo	Minutes	Hours	%Mc(db)	M/Mo	LnM/Mo	Minutes	Hours	%Mc(db)	M/Mo	LnM/Mo
240	4	5.33	1	0	180	3	5.446	1	0	120	2	8.2	1	0
300	5	3.616	0.678424	-0.387983	240	4	2.909	0.534154	-0.627072	180	3	5.12	0.62439	-0.47098
360	6	2.074	0.389118	-0.943872	300	5	1.809	0.33217	-1.102107	240	4	2.596	0.316585	-1.150162
420	7	1.012	0.189869	-1.661423	360	6	1.063	0.195189	-1.633786	300	5	1.72	0.209756	-1.56181
480	8	0.459	0.086116	-2.452056	420	7	0.0711	0.013055	-4.338549	360	6	1.02	0.12439	-2.084332
540	9	0.302	0.05666	-2.870679	480	8	0.383	0.070327	-2.654602	420	7	0.56	0.068293	-2.683953
600	10	0.155	0.029081	-3.537681	540	9	0.168	0.030848	-3.478673	480	8	0.221	0.026951	-3.613727
660	11	0.042	0.00788	-4.843437	600	10	0.042	0.007712	-4.864967	540	9	0.043	0.005244	-5.250689
660	11	0.042	0.00788	-4.843437										

TREATMENT		X_2^-			X_2^+					$X_1^- X_2^-$				
Elapsed Drying Time(T)					Elapsed Drying Time(T)					Elapsed Drying Time(T)				
Minutes	Hours	%Mc(db)	M/Mo	LnM/Mo	Minutes	Hours	%Mc(db)	M/Mo	LnM/Mo	Minutes	Hours	%Mc(db)	M/Mo	LnM/Mo
180	3	6.021	1	0	180	3	6.014	1	0	180	3	5.047	1	0
240	4	4.452	0.739412	-0.3019	240	4	4.112	0.683738	-0.380181	240	4	3.219	0.637805	-0.449723
300	5	3.118	0.517854	-0.658062	300	5	2.281	0.379282	-0.969476	300	5	1.826	0.361799	-1.016666
360	6	1.607	0.266899	-1.320884	360	6	0.645	0.10725	-2.232595	360	6	0.615	0.121855	-2.104927
420	7	0.38	0.063112	-2.762837	420	7	0.042	0.006984	-4.964176	420	7	0.042	0.008322	-4.78888
480	8	0.043	0.007142	-4.941809										

Table A4.6 contd

TREATMENT	$X_1^-X_2^+$				$X_1^+X_2^-$				$X_1^+X_2^+$				
Elapsed Drying Time(T)					Elapsed Drying Time(T)				Elapsed Drying Time(T)				
Minutes	Hours	%Mc(db)	M/Mo	LnM/Mo	Minutes	Hours	%Mc(db)	M/Mo	LnM/Mo	Minutes	Hours	%Mc(db)	M/Mo	LnM/Mo
180	3	6.523	1	0	180	3	6.163	1	0	180	3	3.37	1	0
240	4	4.372	0.670244	-0.400114	240	4	3.743	0.607334	-0.498676	240	4	1.299	0.38546	-0.953318
300	5	2.453	0.376054	-0.978023	300	5	2.234	0.362486	-1.01477	300	5	0.327	0.097033	-2.332708
360	6	1.005	0.15407	-1.870347	360	6	1.41	0.228765	-1.474974	360	6	0.042	0.012463	-4.384998
420	7	0.393	0.060248	-2.80928	420	7	0.596	0.096706	-2.336078					
480	8	0.043	0.006592	-5.02189	480	8	0.043	0.006977	-4.965119					

APPENDIX 5

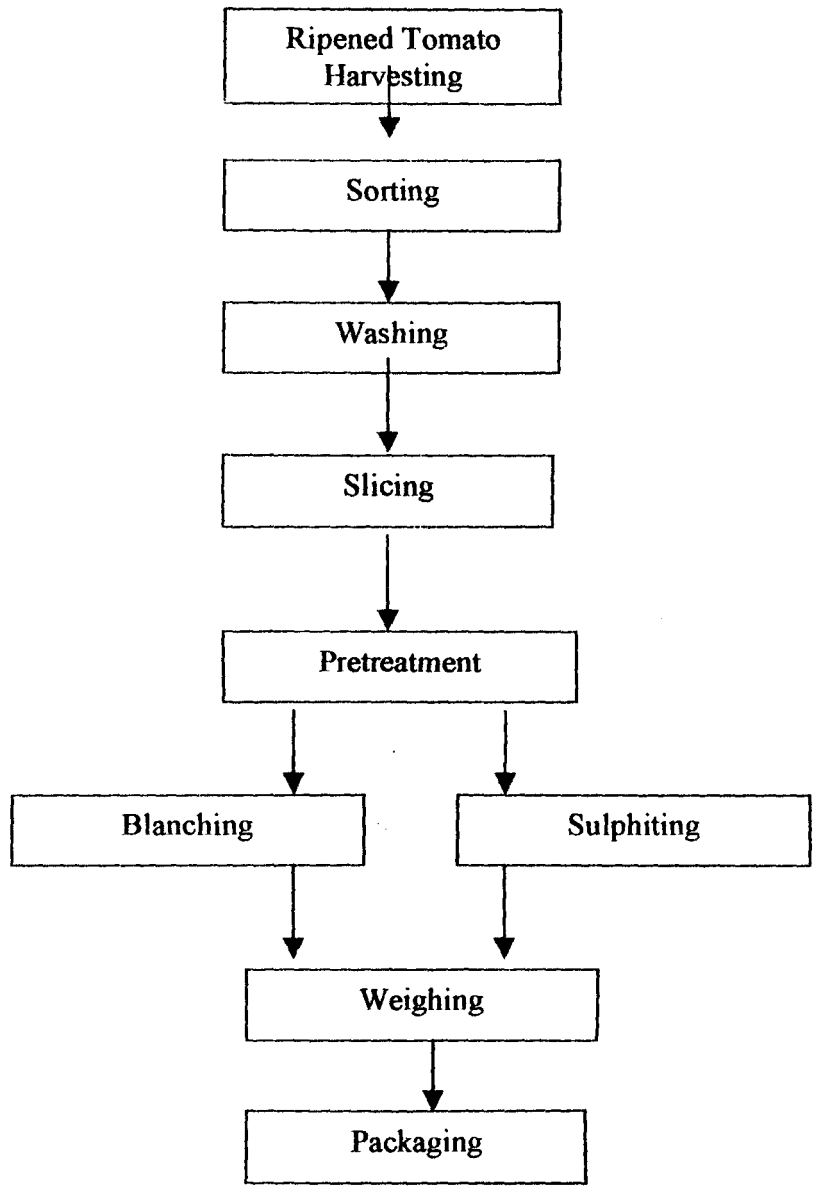


Fig A5.1: Flow Chart for Pretreatments and Drying Operations

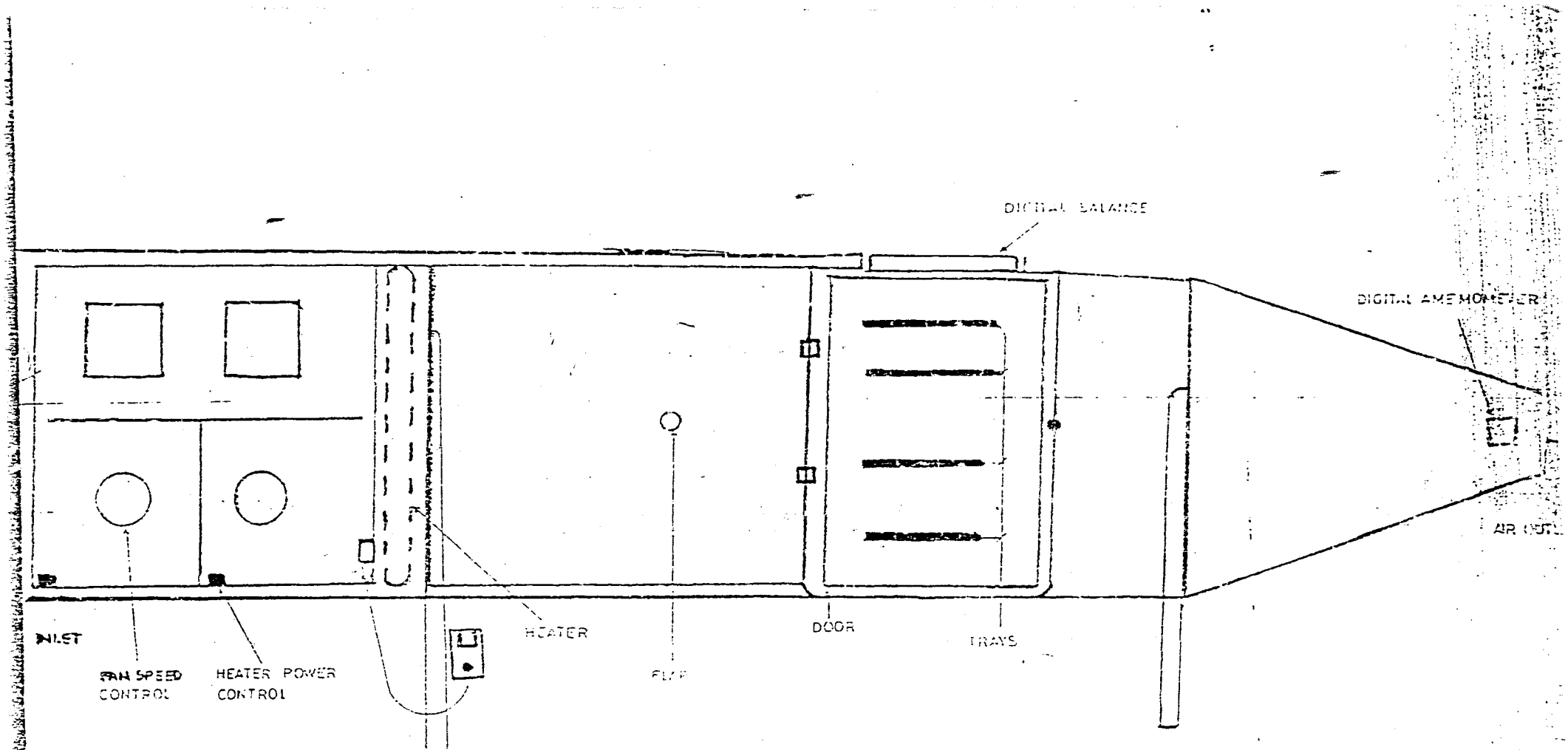


Fig A5.2: Line Diagram of the Tray Dryer Used