12-1999

Development and storage stability of a dried tomato product produced by osmotic concentration and dehydration

Harjeet Singh Sidhu

To the Graduate Council:

I am submitting herewith a thesis written by Harjeet Singh Sidhu entitled "Development and storage stability of a dried tomato product produced by osmotic concentration and dehydration." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Science and Technology.

J. L. Collins, Major Professor

We have read this thesis and recommend its acceptance:

J. R. Mount, M. P. Penfield

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

To the Graduate Council:

I am submitting herewith a thesis written by Harjeet Singh Sidhu entitled "Development and Storage Stability of a Dried Tomato Product Produced by Osmotic Concentration and Dehydration. I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science with a major in Food Science and Technology.

Dr. J. L. Collins, Major Professor

We have read this thesis
and recommend its acceptance:

Marjorie P. Penfield

John R Mount

Accepted for the council:

Associate Vice Chancellor and
Dean of The Graduate School

Development and Storage Stability of a Dried Tomato Product Produced by Osmotic Concentration and Dehydration

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Harjeet Singh Sidhu

December 1999

DEDICATION

This thesis is dedicated to my parents

Late Mr. Nihal Singh Sidhu

and

Late Mrs. Bhagwan Kaur Sidhu

who provided me invaluable life experiences

and educational opportunities.

ACKNOWLEDGMENT

It is my proud privilege to express my deepest gratitude to Dr. J. L. Collins, Professor of Food Science and Technology, for suggesting to me the present research topic. I acknowledge, hereby, my great indebtedness to him for his unstinted advice, incessant encouragement and ebullient inspiration and for his making many invaluable suggestions and constructive criticisms during the course of the present investigation. To my great expectations, not only did he take great pains, even after his retirement, but also gave dexterous guidance throughout the tenure of this study.

It is my pleasant duty to express my most sincere thanks to Dr. C. J. Brekke, Head of the Department, and Dr. H. O. Jaynes, former Head of the Department, who provided monetary support and gladly assisted me when I approached them.

I feel honored and obliged to Dr. J. R. Mount and Dr. M. P. Penfield for their valuable suggestions and constructive criticism, apart from agreeing to serve on my committee.

My thanks are due also to Dr. William Sanders and Mr. John Schneider for their assistance in experimental design and analysis of data.

The paucity of space does not permit me to mention the names of all those colleagues, friends and well-wishers who helped me more than they

probably realized. Words cannot express my full gratitude in particular to Ms. Annie Ruth Hill for her assisting me in the aforesaid endeavor.

The author feels profound pleasure in expressing his cordial thanks to Dr. Terry Walker, Ms. Emayet Spenser, Ms. Kay Trigiano and Dr. Yobouet Dje for their help, especially during testing of samples.

The author also expresses his cordial thanks to Laura Basilio, Lou Ann Carden, Cary Baird, Bob Baron, Kim Johnson, Tina Perry, Amy Burns and Keneko Claybon for their assistance in conducting sensory panels and collection and processing of sensory panel data. He is also thankful to Dr. M.P. Penfield and Ms. Annie Ruth Hill for their contribution. The thanks are also due for all the members of faculty, staff and students of the Institute of Agriculture who served on the sensory panels.

The author feels profound pleasure in expressing his cordial thanks to Mr. Timothy L. Davis, Manager, Cereal Mix Division, J.W. Allen & Company, Morristown, Tennessee for his support and encouragement and for much needed time off from work to complete this thesis.

Last, but not least, my sincerest thanks go to my affectionate wife, Prabhjot and my son Harmanjeet and daughter Harmaneek who neither objected to my long working hours nor minded my indisposition to give them all the attention they deserved. In spite of this, their enthusiastic inspiration made me courageous to pursue and complete the present course of study.

ABSTRACT

An acceptable dried tomato product (18% moisture) was developed by osmotic concentration and dehydration. In the first experiment, ripe Roma tomatoes were prepared and processed in 0.6% acidified 40 or 50 °Brix sucrose solutions held at 30, 40 or 50°C for 2, 3 or 4 hr. Measurements included moisture loss (ML), net weight loss (NWL) and solids weight gain (SWG), Hunter color (L and hue-angle), lycopene, pH, titratable acidity, soluble solids, water activity and sensory acceptability. The experimental variables affected the measurements variously. Osmotic concentration followed by dehydration produced an acceptable product with potential uses such as an ingredient in bakery items or as snacks.

In a second experiment, storage stability of two selected treatments was determined with respect to moisture content, color stability, lycopene concentration, firmness, microbiological presence and sensory acceptability. Ripe Roma tomatoes were prepared and processed in 40 or 50 °Brix, both at 40°C and 3 hr. Samples were packaged under air, partial vacuum or nitrogen gas flush and stored for up to 5 mo. The experimental variables and their interactions affected the measurements variously, also. The process treatments produced two dried tomato products which were acceptable and shelf stable when stored for at least 5 mo.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER IV

PART I

INTRODUCTION

This research was conducted to develop an osmotically/dehydrated product of approximately 18% moisture from red-ripe, thick-walled tomato fruit. Chapter III presents that part which deals with development of the product and measurement of selected quality attributes. Chapter IV presents that part of the research which deals with determining the effects of storage conditions, at ambient temperature, on selected quality attributes. Overall, the results indicated that the process used to reduce the moisture content produced a dried product of tomato fruit which may be used as an ingredient in formulations of other food items or as a dried fruit for eating-out-of-hand.

PART II

REVIEW OF LITERATURE

THE TOMATO

The tomato (*Lycopersicon esculentum* Mill.), a member of *Solanaceae* family, is believed to have originated in tropical America, Peru or Mexico (Gould, 1983; Smith, 1994). Until the nineteenth century, the tomato was grown chiefly as an ornamental plant for its colorful fruit, but as a food, it was considered to be toxic (Villareal, 1980). Since its production increased in the United States of America (USA) during the early nineteenth century, it has become a major, popular fruit (or vegetable) not only in the USA but all over the world (Smith, 1994). The popularity of tomato exploded because of its processibility by which it could be transformed into various products, subsequently utilized in different foods. It has gained an indispensable position as a valuable ingredient, not only in the kitchen, but also in the food manufacturing industry.

NUTRITIONAL AND HEALTHFUL BENEFITS

Tomatoes contribute a significant amount of vitamins A and C to the human diet. In addition, tomatoes provide small amounts of B-complex vitamins and minerals such as iron and potassium (Gould, 1983). Many people in rural Philippines feed red, ripe tomatoes to mothers-to-be with the perception that the babies will have fair complexions and rosy cheeks (Villareal, 1980).

Lycopene is a powerful antioxidant and is found abundantly in tomatoes. This carotenoid is credited with possessing significant health benefits such as reducing the risk of several forms of cancer and strengthening the cardiovascular system. The heat-treated concentrated tomato products rather than fresh tomatoes have been reported to be the more effective form. The heat treatment during processing of tomatoes releases lycopene from its matrix, making it readily available for absorption during digestion (Broihier, 1997; Otto, 1997).

DRYING METHODS

The production of shelf-stable foods by drying is one of the oldest known methods of food preservation. Dehydration offers various advantages such as reduced storage space and transportation costs by reducing the bulk of the product, storage at ambient temperatures, and convenience of packaging. However, there are some disadvantages attributed to drying which includes shrinkage of product, loss of flavor and nutrients, deterioration of color and appearance and development of a tough-to-chew texture. Several methods of drying are now available which can be employed to achieve dried products with specific characteristics aimed at the development of new products or ingredients to be used as ingredients in other products. Specific objectives aimed at the development of a low-moisture sweet-tasting dried tomato product with a soft and supple texture, longer shelf-life without added preservatives could only be obtained through air-drying preceded by osmotic concentration. Therefore, the literature review has only been presented here for air-dehydration, osmotic concentration and osmo-air dehydration.

Air dehydration

Air-dehydration is a process in which the water is removed from the food stuff by heat treatment which ultimately results in restricting microbial growth and retarding certain chemical and enzymatic reactions. Although

simple in concept, air-drying is a complex process in which heat is applied to the water contained in fruits to such an extent that it migrates to the surfaces and evaporates. The surface water is subsequently lost by evaporation and immediately replaced by water from within the fruit by diffusion and convection. The success of this process depends upon the continuous application of heat to the surface until the moisture content of fruit reached to the desirable level without sacrificing the quality. The driving force behind this moisture transfer is the difference in vapor pressure on and/or around the evaporating fruit surface. However, during the drying process some heat damage may occur, depending upon the amount and duration of heat applied (Anderson, 1991; Desrosier and Desrosier, 1977; Karel, 1973; Toledo, 1991).

Some of the important factors affecting the rate of dehydration are shape, size and arrangement of fruits as well as temperature, relative humidity and velocity of the heated air (Karel, 1973; Toledo, 1991; Troller and Christian, 1978).

Some of the disadvantages of air-drying include browning, denaturation of proteins, loss of solubility, development of textural toughness and loss of nutrient, color and organoleptic quality (Talburt et al., 1987; Troller and Christian, 1978).

Mechanical drying of tomato alone is a costly process because most fruits contain about 85-95% water and require excessive amounts of energy

to produce a dried product (Gupta and Nath, 1984; Hawlader et al., 1991). Energy consumption during convection drying of apple and carrot slices was 2-3 times greater than that consumed when drying was preceded by osmotic concentration (Lenart and Lewicki, 1988). Collignan et al. (1992) found that the total energy consumption was 2.4-7.1 times greater for air-dried as compared to osmo-air dried samples. For the same amount of moisture removal, osmotic treatment required much less energy than was required during air dehydration alone.

Olorunda et al. (1990) dehydrated tomatoes in a pilot-scale dryer at 60, 70 and 80°C with air velocity of 1.75 m/sec and found that the rate of moisture removal increased with an increase in temperature, particularly during the first 2 hr of drying. Irrespective of temperature, oven-dried tomatoes had an unattractive dark color due to the browning reaction or degradation of pigments. They were judged inferior in appearance, taste and aroma when made into tomato sauce.

Osmotic concentration

Osmotic concentration is a method of moisture removal from the fruits by osmosis while the fruit is submerged in a concentrated sucrose solution. The fruits are submerged in and contacted by a concentrated sucrose solution having a water activity lower and osmotic pressure higher than that of the fruit. Osmotic removal of water from fruit tissue is possible because the cell membranes of fruits are semi-permeable which allows the

outflow of water but restricts the in-flow of sugar into the fruit. The flow of water from the fruit to the osmotic solution is caused by the water and solute activity gradient across the semi-permeable cell membrane. Osmotic concentration is a dynamic process, creating two simultaneous counter current flows. First, outflow of water from the fruit to sucrose solution which occurs in the absence of oxygen and at low temperatures within the first few hours of osmosis. Second, the solute impregnation from the osmotic solution into the fruit tissue which modifies the functional, nutritional and organoleptic quality of the fruit as desired in the resultant product. The diffusion of solutes into the tissues causes the outflow of water which in turn prevents the inflow of the solutes (Hough et al., 1993; Islam and Flink, 1982; Jayaraman and Das Gupta, 1992; Karathanos and Kostarpoulos, 1995; Kim and Toledo, 1987; Lerici et al., 1985, 1988; Maltini et al., 1993; Ponting, 1973; Ponting et al., 1966; Raoult-Wack et al., 1994; Torreggiani, 1993; Yao and Maguer, 1994).

Combined process: Osmo-air dehydration

Osmotic concentration has been used successfully to produce many dried fruit products in the recent past (Biswal and Bozorgmehr, 1990, 1992; Bolin et al., 1983; Hawkes and Flink, 1978; Hough et al., 1993; Jayaraman and Das Gupta, 1992; Karathanos and Kostarpoulos, 1995; Kim and Toledo, 1987). Since the osmotic concentration alone does not reduce the moisture content to the desirable level, this process must be followed by the hot air-

dehydration (Lenart and Lewicki, 1988). Removal of a portion of water from fruit slices by osmotic concentration as an intermediate drying step has been used by several researchersprior to subjecting the slices to air-drying (Biswal and Bozorgmehr, 1992; Giroux et al., 1994; Karathanos and Kostarpoulos, 1995; Kim and Toledo, 1987; Lenart and Lewicki, 1988; Ponting, 1973; Ponting et al., 1966; Rahman and Lamb, 1991; Silveira et al., 1996; Uzuegbu and Ukeka, 1987). As much as 50% of the water from the fruits can be removed through osmosis (Ponting et al., 1966). Karathanos and Kostarpoulos (1995) concluded that osmotically dehydrated apple slices required a much shorter air-dehydration time to reach final moisture content than untreated apples required because the untreated apples took a longer air-drying time to change from an initial high moisture to the moisture content of osmotically treated samples. Maltini et al. (1993) indicated that osmotic dehydration followed by air-dehydration may produce a finished dried fruit product with a moisture level safe enough from microbiological contamination to ensure storage for relatively long periods of time.

Apart from reducing air-dehydration time, osmotic concentration also improves product quality (Karathanos and Kostarpoulos, 1995). Compared to air dehydration alone, osmotic concentration offers many advantages such as color retention without using preservatives, modification of nutritional and functional properties of foodstuff, limited heat damage to

fruit tissues, improved textural quality, greater vitamin retention, flavor enhancement and extended shelf-life through reduced water activity (Baristain et al., 1990; Karathanos and Kostarpoulos, 1995; Lerici et al., 1985; Maltini et al., 1993; Ponting, 1973; Ponting et al., 1966; Torreggiani, 1993). Osmotic dehydration was found to increase nutrient retention even during subsequent air-drying (Kim and Toledo, 1987). Color and flavor were observed to have escaped heat damage because of removal of acids from the fruit during osmotic dehydration (Conway et al., 1983). The acidic taste of dried fruits is reduced because as sugar moves into fruit tissues during osmosis, the sugar to acid ratio is increased (Conway et al., 1983; Giangiacomo et al., 1987; Lerici et al., 1985; Ponting, 1973; Ponting et al., 1966). Energy consumption for dehydration was greatly reduced when air-dehydration of apple and carrot slices were preceded by osmotic treatment (Lenart and Lewicki, 1988). Silveira et al. (1996) found no significant differences between osmo-air dried and osmo-vacuum dried pineapple products. They further indicated that the product was fairly acceptable in terms of color, flavor and texture.

Kim and Toledo (1987) reported that because sugar coats fruit pieces during osmotic treatment, the rate of moisture loss is reduced and pieces adhered to the drying tray as well as to each other.

PROCESS VARIABLES OF OSMOTIC CONCENTRATION

The amount of moisture removed from fruit tissue by osmotic concentration depends largely upon several process variables which contribute to the success of the mass transfer processes. Some of the major process variables are temperature, nature, agitation and concentration of osmotic solution; fruit submersion time in osmotic solution; size of fruit slices; peeling or no peeling; and solution/fruit ratio.

Farkas and Lazar (1969) concluded that the rate of osmotic dehydration of apple slices and rings was a function of process temperature, syrup concentration and size of fruit slices. A longer time of osmotic concentration in a sucrose solution resulted in a sweeter product. They also observed that the pieces of apple fruit had to be kept submerged in the osmotic solution by force due to the difference in the specific gravity between apples and sucrose solution. Similar observations were confirmed in several fruits by Holdsworth (1985) who further concluded that the addition of acids to sucrose solution boosted the effects of osmotic concentration on mass transfer. Lerici et al. (1988) concluded that concentration and temperature of osmotic solution and fruit/solution weight ratio in a recirculating solution greatly influenced the rate of mass transfer. However, the rate was dependant upon the initial chemical composition of the fruit, physical structure and surface area contacted by the solution.

Silveira et al. (1996) indicated that both the water reduction and solids gain increased with an increase in the syrup temperature and concentration during osmotic dehydration of pineapple wedges.

Bolin et al. (1983) conducted sensory evaluation of fruits produced by osmotic concentration, using sugar and corn syrup as solutes. They concluded that the fruits treated in sucrose solution were highly acceptable by the panelists as compared to those treated in the corn syrup solutions. They noted further that the sucrose solution could be recycled a maximum of 5 times without affecting the fruit quality. The sucrose was absorbed less by the fruits than high fructose corn syrup due to the difference in the molar mass of the solutes.

Yang et al. (1987) produced an osmotically-dehydrated blueberry snack product which had an acceptable flavor, texture, overall quality and a longer shelf-life. A fruit:sugar ratio of 3:1 or 4:1 was utilized. They concluded that osmotic concentration changed or modified the nutritional and functional properties of a fruit product by manipulation of the solutes impregnated in the tissue. Torreggiani (1993) indicated that by controlling the process variables, the sweetness of the fruit product could be modified. The increased level of solute preserves the product, eliminating the need for added preservatives to prolong shelf-stability.

Karel (1976) reports that circulating syrup around stationary apple slices resulted in maximum solute uptake after 30 min and remained

constant thereafter. Hawkes and Flink (1978) observed an increase in mass transfer coefficient with increased sucrose concentration specially when concentration exceeded 50% during osmotic concentration of apple slices. When apple slices were kept submerged in a circulating 70% sucrose solution held at 51°C for 4 hr, Dixon et al. (1976) found that the fruit slices gained 45% solids and contained 55% moisture. As a result of this osmotic treatment, a sweeter product with pleasing taste and flavor was obtained. Lerici et al. (1985) found that after 2 hr of osmotic concentration of apple pieces in a concentrated sucrose solution, appreciable amounts of organic acids, reducing sugars, minerals and nitrogenous compounds diffused from the fruit pieces even though sucrose impregnation continued but only slowly. Vial et al. (1991) reported that processing kiwi fruit in sucrose solutions held at or below 40°C produced a satisfactory finished product with attractive color and enhanced retention of ascorbic acid.

Lazarides et al. (1995) studied the mass transfer kinetics of osmotic concentration in apple slices and found that an increase in process temperature increased both water loss and solids gain but favored a more rapid water loss. On the other hand, increased sucrose solution concentration also increased both water loss and solids gain but favored a more rapid solids gain. They further indicated that the amount of moisture removed from the fruits was always greater than the amount of solid gain. However, sucrose concentration and temperature at various levels can be

used to the advantage of obtaining desired product characteristics. Yao and Maguer (1994) studied the mass transfer mechanism in red beet tissue during the osmotic processes. They observed that the water removal was maximum and solute impregnation was minimum in the early stages of osmosis. They further indicated that the solutes were confined within a thin layer near the surface during the first hour of osmosis.

Rahman and Lamb (1991) concluded that the sucrose (solids) gain imbibed by pineapple during osmotic treatment caused the fruit slices to dry at a slower rate during subsequent air-drying. This may have occurred because the sugar acted as the water binding agent which increased internal resistance to moisture movement, and, therefore, water removal resistance increased from within the fruit.

Giroux et al. (1994) studied the effects of agitation on the rate of water removal from the apple slices and concluded that high agitation (2500 L/sec, pump flowrate) increased the rate of moisture reduction up to 25% compared to low agitation (800 L/sec, pump flowrate) during the first hour of osmosis. Thus, higher rate of agitation out performed the lower rate of agitation. Also, on a time basis, renewal of syrup every 1.5 sec around the boundary layer of apple slices was sufficient to develop an effective osmotic rate.

MOISTURE LOSS, WEIGHT REDUCTION AND SOLIDS GAIN

Tissue compactness (Giangiacomo et al., 1987), original solids content of both soluble and insoluble (Lenart and Flink, 1984a, b), amount of gas in intercellular spaces (Forni et al., 1986) and enzymatic activity of various fruits are some of the main factors which control of water loss, weight reduction and solids gain realized during osmotic dehydration. Torreggiani (1993) observed that a weight reduction of more than 50% was not practical because of considerable decrease in the osmosis rate as time was extended beyond certain lengths of contact time. Also, fruit shrinkage resulting from moisture and weight loss may modify the appearance of the fruit product, rendering it unacceptable. During osmotic concentration of fruits, maximum water loss and solids gain occur during the first 2 hr and first one-half hr, respectively (Conway et al., 1983; Giangiacomo et al., 1987; Torreggiani, 1993). Lazarides et al. (1995) indicated that 25% of the initial moisture was removed within the first hour, while the process required 3 hr to remove 40% of initial moisture due to drastic drop in water loss rate. Vial et al. (1991) observed that solutions of higher sucrose concentration held at high temperatures increased the water removal rate but not solute impregnation. Raoult-Wack et al. (1994) indicated that lower concentrations of sucrose solution (10-30% w/w) favored the solids gain; whereas, higher concentrations (40-60% w/w) favored the water loss.

However, the intermediate concentrations (30-40% w/w) equally favored both water loss and solids gains. Yang and Laguer (1992) reported that osmotic solution temperature exerted a significant effect on the amount of moisture loss and solids gain in strawberries by controlling the rates exchange of sugar and water between the strawberries and sucrose solution. They obtained a 40% reduction in moisture and only a 0.1% sugar gain in strawberries surrounded by a 63% sucrose solution and held at 25°C for 2 hr. Solids gain has been observed to accelerate when osmotic solution temperature exceeded 60°C by Farkas and Lazar (1969); Bongirwir and Sreenivasan (1977); and Lenart and Lewicki (1990a, b). Blanching the fruits prior to osmotic concentration has been reported to favor solids gain over water loss due to increased tissue permeability which enhanced solute uptake (Islam and Flink, 1982; Karel, 1975; Ponting, 1973). Low molar mass of solutes in corn syrup favored the solids gain and results in reduced moisture loss; whereas, high molar mass of solutes in concentrated sucrose solution favors the effects opposite those of corn syrup (Bolin et al., 1983; Contreras and Smyrl, 1981; Islam and Flink, 1982; Lerici et al., 1985). High molecular weight of solutes in sucrose solution exert less osmotic pressure than low molecular weight of solutes in corn syrup. Therefore, corn syrup caused greater solids gain while sucrose accelerates water loss (Karathanos and Kostaropoulos, 1995).

WATER ACTIVITY

All fruits contain high amounts of water which lead to rapid deterioration due to biological and chemical changes, ultimately affecting the quality, processing and storage. The amount of water present in the fruits determines the water activity (a_w) which may be defined as the ratio of the vapor pressure of water of a food material to the vapor pressure of pure water at a given temperature. Removal of water contributes to the lowering of a_w which aides in protecting the fruit against microbiological spoilage and reduces enzymatic and chemical activities. Such is the principle of food dehydration. Reduction of a_w plays an important part in determining shelf stability of a food product (Anderson, 1991; Gould, 1983; Karel, 1973).

An acceptable quality of dry fruits can be determined by sensory evaluation, but their shelf stability is a function of water a_w. Osmotic concentration has been shown to reduce the a_w of fruits, enabling them to become more shelf-stable (and with pH control helps save energy and subsequently cost of preservation) (Alzamora et al., 1989; Levi et al., 1983; Maltini et al., 1993; Torreggiani et al., 1988). A specific or targeted a_w can be achieved through a combined process of air dehydration preceded by osmotic concentration in a sucrose syrup (Torreggiani et al., 1988). The reduction of a_w by osmosis results from impregnation of soluble solids such as sucrose gain (Maltini et al., 1993; Torreggiani et al., 1988). Spoilage of

most fruit products with a_w of 0.65 or lower is unlikely to occur for up to 2 yr. However, degradation may occur due to oxidative rancidity or nonenzymatic browning (Robertson, 1993). Bacterial spoilage in tomatoes is greatly reduced when a_w is lowered to 0.91 or below; whereas, some yeasts or molds may continue to grow at a_w as low as 0.60 (Gould, 1983).

COLOR

Consumers are most likely to choose a fruit product due to its attractive color rather than to its nutritional value. Thus, color strongly influences the choices made by the consumer (Francis, 1980; Gould, 1983). The natural pigments present in the fruits are highly sensitive to chemical and physical effects during processing such as heat treatment (Gross, 1991). Long drying times for fruits at relatively high temperatures are responsible for altering the pigments (Dosrosier and Dosrosier, 1977).

The red color of ripe tomato fruit is due to the presence of the predominant carotenoid, lycopene. Lycopene is an acyclic carotene with a symmetrical carbon skeleton and possesses 11 conjugated double bond which absorbs and reflects light selectively. In nature, lycopene is found almost exclusively in all-*trans* form (Davies, 1976). In tomato fruit, lycopene is found at levels ranging of 83-90% of the total carotenoids. β-carotene is only about a tenth that of lycopene (Gross, 1991).

Silveira et al. (1996) developed osmo-air dried pineapple wedges and observed that the product became darker due to browning, possibly resulting from air dehydration. However, Hunter a values (redness) increased and Hunter b values (yellowness) decreased after storage of the product in plastic bags for 3 mo at 25°C. Cole and Kapur (1957) concluded that the presence of oxygen triggered the loss of lycopene when heating

tomato pulp at 100°C for 2 hr. However, the loss of lycopene was greatly reduced when heating occurred in the presence of carbon dioxide. Sharma and Maguer (1996) studied the degradation of lycopene in tomato pulp during heating at 100°C and found that the degradation rate increased due to an increase in lycopene concentration, acids, sugars and overall pulp total solids as a result of heating. They further concluded that high intensity of temperature, air and light had significant effects on lycopene degradation. Also, in oven- dried samples stored between 25 and 75°C, loss of lycopene increased with the exposure of tomato pulp to air, light and increase in storage temperature.

STORAGE

Sugaring has long been the standard method for protecting the color and flavor of fruits during storage, becoming the basis for osmotic concentration. Adesina and Aina (1990) stored peeled apples in 20% sugar solution in closed containers under ambient conditions and found that texture, color and flavor were preserved even after 16 wk of storage.

Uzuegbu and Ukeka (1987) reported that osmotically concentrated bananas, mangoes and papayas retained excellent flavor, with no added preservatives, when stored in sealed cellophane bags for up to 12 mo. Forni et al. (1993) found that osmotic concentration caused the color in cherries to lighten. The color of cherries was fairly acceptable to panelists in spite of some loss of anthocyanin pigments during thermal processing and storage at ambient temperature. Silveira et al. (1996) developed an osmo-air dried pineapple product and found the product fairly acceptable in terms of color, flavor and texture even after 3 mo of storage in plastic bags at 25°C. The panel scores, based on hedonic scales of 1 to 9 (1 = extremely disliked; 9 = extremely liked) for color, flavor and texture, where 6.8, 7.3 and 7.1, respectively.

Torreggiani et al. (1987) studied the stability of osmodehydrated cherries over 6 mo of storage and concluded that the pH values did not change; whereas, a decrease was observed in total titratable acidity. They

further indicated that lightening of product color occurred during the first 2 mo of storage. A decrease in chroma and shifting of hue from red to yellow occurred over the entire period of storage.

Shelf-stable dried fruit products developed by osmotic dehydration have been successfully packaged in flexible films for storage without added preservatives have and without added been packaged successfully in flexible films for storage (Jayaraman and Das Gupta, 1992).

REFERENCES

Adesina, A.A. and Aina, J.O. 1990. Preservation of African star apple fruits (*Chrysophyllum albidum*) by osmotic dehydration. Tropical Sci. 30: 249-253.

Alzamora, S.M., Gerschenson, L.N., Cerrutti, P, and Rojas, A.M. 1989. Shelfstable pineapple for long-term non-refrigerated storage. Lebensm. -Wiss. u. -Technol. 22: 233-236.

Anderson, K. 1991. Other preservation methods. Ch. 7, In: Vegetable Processing, D. Arthey and C. Dennis (Ed.), p. 154-162. VCH Publishers, New York.

Baristain, C., Azuara, E., Cortes, R, and Garcia, H.S. 1990. Mass transfer during osmotic dehydration of pineapple rings. Intl. J. Food Sci. Technol. 25: 576-582.

Biswal, R.N. and Bozorgmehr, K. 1990. A model for osmotic dehydration with mixed agents. Paper presented at the 1990 International Winter Meeting, American Society of Agricultural Engineers, Hyatt Regency Chicago, IL. Dec. 18-21, 1990.

Biswal, R.N. and Bozorgmehr, K. 1992. Mass transfer in mixed solute osmotic dehydration of apple rings. Trans. Am. Soc. Agric. Eng. 35: 257-262.

Bolin, H.R., Huxsoll, C.C., Jackson, R., and Ng, K.C. 1983. Effect of osmotic agents on drying behavior and product quality. J. Food Sci. 48: 202-205.

Bongirwir, D. R. and Sreenivasan, A. 1977. Studies on osmotic dehydration of bananas. J. Food Sci. Technol. India 14: 104-112.

Broihier, K. 1997. Tomato tales: sauce, paste are potent sources of a little-known phytochemical: lycopene. Food Processing 58: 40.

Cole, E.R. and Kapur, N.S. 1957. The stability of lycopene. II. Oxidation during heating of tomato pulps. J. Sci. Food Agric. 8: 366-368.

Collignan, A., Raoult-Wack, A.L., and Themelin, A. 1992. Energy study of

food processing by osmotic dehydration and air-drying. Agric. Eng. J. 1: 125-135.

Contreras, J. M. and Smyrl. T. G. 1981. An evaluation of osmotic concentration of apple rings using corn syrup solids solutions. Can. Inst. Food Sci. Technol. J. 14: 301-14.

Conway, J., Castaigne, F., and Voran, P.G. 1983. Mass transfer consideration in the osmotic dehydration of apples. Can. Inst. Food Sci. Technol. 16: 25-34.

Davies, B.H. 1976. Carotenoids. In: Chemistry and Bio-Chemistry of Plant Pigments. T.W. Goodwin (Ed.). p. 38-165. Academic Press, London.

Desrosier, N.W. and Desrosier, J.N. 1977. The Technology of Food Preservation. 4th Edition. AVI Publishing Co., Inc., Westport, CT.

Dixon, G.M., Jen, J. J., and Paynter, V.A. 1976. Tasty apple slices results from combined osmotic dehydration and vacuum-drying process. Food Prod. Dev. 10(7): 60.

Farkas, D.F. and Lazar, M.G. 1969. Osmotic dehydration of apple pieces. Food Technol. 23: 688-690.

Forni, E., Torreggiani, D., Battison, P., and Polesello, A. (1986). Research into changes of pectic substances in apricots and peaches processed by osmotic dehydration. Carbohydrate Polymers 6: 379-93.

Forni, E., Polesello, A., and Torreggiani, D. 1993. Changes in anthocyanins in cherries (*Prunus avium*) during osmodehydration, pasteurization and storage. Food Chem. 48: 295-299.

Francis, F.J. 1980. Color quality evaluation of horticultural crops. HortScience 15: 58-59.

Giangiacomo, R., Torreggiani, D., and Abbo, E. 1987. Osmotic dehydration of fruit. Part I. Sugar exchange between fruit and extracting syrups. J. Food Proc. Preserv. 11: 183-195.

Giroux, F., Guilbert, S., and Trystram, G. 1994. Dynamic modeling of fruit dehydration. In: Developments In Food Engineering. T. Toshimasa, P.R. Matsuno, and P.K. Nakamura (Ed.). Blackie Academic & Professional Press, New York.

Gould, W.A. 1983. Tomato Production, Processing and Quality Evaluation. 2nd Ed. AVI Publishing Co., Inc., Westport, CT.

Gross, J. 1991. Pigments in Vegetables: Chlorophyll and Carotenoids. AVI Publishing Co., Inc., Westport, CT.

Gupta, R.G. and Nath, N. 1984. Drying of tomatoes. J. Food Sci. Technol. India 21: 372-376.

Hawkes, J. and Flink, J.M. 1978. Osmotic concentration of fruit slices prior to freeze dehydration. J. Food Proc. Preserv. 2: 265-284.

Hawlader, M.N.A., Uddin, M.S., Ho, J.C., and Teng, A.B.W. 1991. Drying characteristics of tomatoes. J. Food Eng. 14: 259-268.

Holdsworth, S. D. 1985. Advances in the dehydration of fruits and vegetables. In: Concentration and Drying of Foods, D. MacCarthy (Ed). Elsevier Applied Science Publishers, London.

Hough, G., Chirife, J., and Marini, C. 1993. A simple model for osmotic dehydration of apples. Lebensm. -Wiss. U. -Technol. 26: 151-156.

Islam, M.N. and Flink, J. M. 1982. Dehydration of potato II. Osmotic concentration and its effect on air drying behavior. J. Food Technol. 17: 669-678.

Jayaraman, K.S. and Das Gupta, D.K. 1992. Dehydration of fruits and vegetables - Recent developments in principles and techniques. Drying Technol. 10: 1-50.

Karathanos, V.T. and Kostaropoulos, A.E. 1995. Air-drying kinetics of osmotically dehydrated fruits. Drying Technol. 13: 1503-1521.

Karel, M. 1973. Dehydration of foods. Ch. 10. In: Principles Of Food Science: Part II. Physical Principles Of Food Preservation, M. Karel, O.R. Fennema, and D.B. Lund. Vol. 4, p. 309-357. Marcel Dekker, Inc., New York.

Karel, M. 1975. Osmotic drying. In: Principles of Food Science-Part II. O. R. Fennema, (Ed.), p. 348-357. Marcel Dekker, Inc., New York.

Karel, M. 1976. Technology and application of new intermediate moisture foods. In: Intermediate Moisture Foods. R. Davies, G.G. Birch and

K.J. Parker (Eds.). p18. Applied Science Publishers Ltd., London, England.

Kim, M.H. and Toledo, R.T. 1987. Effect of osmotic dehydration and high temperature fluidized bed drying on properties of dehydrated rabbiteye blueberries. J. Food Sci. 52: 980-984, 989.

Lazarides, H.N., Katsanidis, E., and Nickolaidis, A. 1995. Mass transfer kinetics during osmotic concentration aiming at minimal solid uptake. J. Food Eng. 25: 151-166.

Lenart, A. and Flink, J. M. 1984a. Osmotic concentration of potato. Part I- Criteria for the end point of the osmotic process. J. Food Technol. 19: 45-63.

Lenart, A. and Flink, J. M. 1984b. Osmotic concentration of potato. Part II- Spatial distribution of the osmotic process. J. Food Technol. 19: 65-89.

Lenart, A. and Lewicki, P.P. 1988. Energy consumption during osmotic and convective drying of plant tissue. Acta Alimentaria Polonica 14: 65-72.

Lenart, A. and Lewicki, P.P. 1990a. Osmotic dehydration of apples at high temperature. In: Drying '89, Mujumdar, A. S. (Ed.). p. 7-14 Hemisphere Publishing Corp, Bristol, PA.

Lenart, A. and Lewicki, P.P. 1990b. Osmotic dehydration of carrots at high temperature. In: Engineering and Food, Preservation Process and related techniques, Vol. 2, W.E.L. Spiess and H. Schubert (Ed.), p. 731-740. Elsevier Science Publishers, London.

Lerici, C.R., Mastrocola, D., Sensidoni, A., and Dalla Rosa, M. 1988. Osmotic concentration in food processing. In: Concentration and Drying of Food Materials, S. Bruin (Ed.), p. 123-134. Elsevier Science Publication, B.V., Amsterdam, The Netherlands.

Lerici, C.R., Pinnavaia, G., Dalla Rosa, M., and Bartolucci, L. 1985. Osmotic dehydration of fruit: Influence of osmotic agents on drying behavior and product quality. J. Food Sci. 50: 1217-1219, 1226.

Levi, A.,Gagel. S., and Juven, B.J. 1983. Intermediate moisture tropical fruit products for developing countries. Part I- Technological data on

papaya. J. Food Technol. 18: 667-85.

Maltini, E., Torreggiani, D., Brovetto, B.R., and Bertolo, G. 1993. Functional properties of reduced moisture fruits as ingredients in food systems. Food Res. Intl. 26: 413-419.

Olorunda, A.O., Aworh, O.C., and Onuoha, C.N. 1990. Upgrading quality of dried tomato: Effects of drying methods, conditions and pre-drying treatments. J. Sci. Food Agric. 52: 447-545.

Otto, P.E. 1997. Survey offers full plate of food product ideas: Tomatoes - weapon against heart attack. Food Prod. Design 7: 20.

Ponting, J.D. 1973. Osmotic dehydration of fruits. Recent modifications and applications. Process Biochem. 8: 18-20.

Ponting, J.D., Waters, G.G., Forrey, R.R., Jackson, R., and Stanley, W.L. 1966. Osmotic dehydration of fruits. Food Technol. 20: 125-128.

Rahman, M.S. and Lamb, J. 1991. Air drying behavior of fresh and osmotically dehydrated pineapple. J. Food Process Eng. 14: 163-171.

Raoult-Wack, A.L., Saurel, R., Rios, G.M., and Guilbert, S. 1994. Recent advances in dewatering and impregnation soaking processes. In: Developments In Food Engineering. T. Toshimasa, P.R. Matsuno, and P.K. Nakamura (Ed.). Blackie Academic & Professional Press, New York.

Robertson, G.L. 1993. Food Packaging. Marcel Dekker, Inc., New York.

Sharma, S.K. and Maguer, M.L. 1996. Kinetics of lycopene degradation in tomato pulp solids under different processing and storage conditions. Food Res Intl. 29: 309-315.

Silveira, E.T.F., Rahman, M.S., and Buckle, K.A. 1996. Osmotic dehydration of pineapple: kinetics and product quality. Food Res. Intl. 29: 227-233.

Smith, A.F. (1994). The Tomato In America: Early History, Culture and Cookery. p. 1-51. University of South Carolina Press, Columbia, SC.

Talburt, W.F., Schwimmer, S., and Burr, H.K. 1987. Structure and chemical composition of potato tuber. In: Potato Processing, 4th

edition, Talburt, W.F. and Smith,O. (Ed), AVI Publishing Co., Inc. Wesport, CT.

Toledo, R.T. 1991. Fundamentals of Food Process Engineering. 2nd Edition. Van Nostrand Reinhold, New York.

Torreggiani, D. 1993. Osmotic dehydration in fruit and vegetable processing. Food Res. Intl. 26: 59-68.

Torreggiani, D., Forni, F., and Rizzolo, A. 1987. Osmosis dehydration of fruit. Part II. Influence of the osmosis time on the stability of processed cherries. J. Food Proc. Pres. 12: 21-44.

Torreggiani, D., Maltini, E., Bertolo, G., and Mingardo, F. 1988. Frozen intermediate moisture foods: Studies on techniques and product properties. Proc. Intl. Symposium 'Progress in Food Preservation Processes'. CERIA, Bruxelles, Belgium. Vol 1, p. 71-78.

Troller, J. and Christian, J. 1978. Water Activity and Food. Academic Press, New York.

Uzuegbu, J.O. and and Ukeka, C. 1987. Osmotic dehydration as a method of preserving fruits to minimize ascorbic acid loss. J. Food Agric. 1: 187-188.

Vial, C., Guilbert, S., and Cup, J.L. 1991. Osmotic dehydration of kiwi fruit: influence of process variables on the color and ascorbic acid content. Sci. Des Aliments 11: 63-84.

Villareal, R.L. 1980. Tomatoes In The Tropics. Westview Press, Boulder, CO. p. 55.

Yang, D.C. and Laguer, M. 1992. Osmotic dehydration of strawberries in a batch recirculating system. J. Food Qual. 15: 387-397.

Yang, A.P., Willis C., and Yang, T.C. 1987. Use of a combination process of osmotic dehydration and freeze drying to produce a raisin-type lowbush blueberry product. J. Food. Sci. 52: 1651-1653, 1664.

Yao, Z. and Maguer, M.L. 1994. Mass transfer in osmotic processes. In: Developments In Food Engineering. T. Toshimasa, P.R. Matsuno, and P.K. Nakamura (Ed.). Blackie Academic & Professional Press, New York.

PART III

DEVELOPMENT OF A DRIED TOMATO PRODUCT UTILIZING OSMOTIC CONCENTRATION AND AIR-DRYING

ABSTRACT

An acceptable dried tomato product was developed by osmotic concentration followed by dehydration. Ripe 'Roma' tomatoes were peeled, cut into halves, separated from the placenta and seeds, held 20 min in 1% $CaCl_2$ solution, submerged in 0.6% acidified 40 or 50 °Brix sucrose solutions and held at 30, 40 or 50°C for 2, 3 or 4 hr. The moisture content was measured and used for calculations of moisture loss (ML), net weight loss (NWL), and solids weight gain (SWG). Osmotically concentrated tomato was dehydrated to approximately 18% moisture and measured for Hunter color (L and hue-angle), lycopene, pH, titratable acidity, soluble solids, water activity and sensory acceptability, using 8-point hedonic scales.

As temperature and contact times increased, ML, NWL and SWG increased likewise. Sucrose concentration and temperature had no effect on Hunter L and contact time had only a limited effect. However, samples treated in 40° Brix solution had a lower hue-angle and thus were redder then samples treated in 50 °Brix solution. Samples treated at 30°C had the lowest hue-angle and were reddest with no difference between 40 and 50°C. Contact time had no effect on hue angle. Lycopene, pH and titratable acidity decreased and water activity increased with an increase in

sucrose concentration. Titratable acidity and pH decreased with an increase temperature and contact time. For sensory evaluation of each attribute, average panel scores among treatments were not different.

Osmotic concentration followed by dehydration produced an acceptable tomato product for use as an ingredient in bakery products, snacks and tomato based sauces.

INTRODUCTION

Fruits serve to enrich the human diet with necessary vitamins, minerals and dietary fiber (Haytowitz and Matthews, 1984). They also offer energy and desirable colors, flavors and variety when eaten.

The tomato, one of our most popular fruits, finds innumerable uses in both fresh and processed forms. Traditionally, processed products include the ketchups, salsas, sauces, pastes, purees, juices and canned tomatoes. More recently, dried tomatoes, especially those that are sun-dried, have become commercially available and popular with consumers.

The drying process produces distinct changes in the tomato. The fruit tissue darkens upon drying and develops a strong characteristic flavor (Gupta and Nath, 1984). Even with these changes, dried tomato is finding many culinary uses - preparation of various reconstitution tomato products, pizza toppings, pestos and other savory dishes.

While solar drying is relatively inexpensive, additional methods for drying with greater control over quality are needed. The shelf life of the product is relatively short as undesirable color and flavor changes increase with time. Mechanical dehydration may be an alternative to solar drying, but the costs are excessive because tomato contains 93-94% moisture (Haytowitz and Matthews, 1984). The greater the moisture content, the

greater the cost of drying. Also, dehydrated tomato darkens and develops flavors similar to tomato dried in the sun.

Osmotic concentration, followed by dehydration, has been proposed as an intermediate drying step for fruits (Lenart and Lewicki, 1988; Ponting, 1973). In this process, raw fruit pieces are submerged in a solution of sugar for specified periods of time (Jayaraman and Das Gupta, 1992). Following the osmotic treatment, the fruit pieces are mechanically dehydrated to a desirable moisture level suitable for producing an acceptable and safe product with satisfactory self stability.

The concentrating process creates changes in the fruit pieces that lead to development of a product similar to dried fruits. During the osmotic process, 30% or more of the moisture may be removed (Hawkes and Flink, 1978; Ponting, 1973; Ponting et al., 1966). Concurrent with moisture loss is an uptake of sugar into the fruit. The increased concentration of sugar increases the sugar:acid ratio, causing the fruit taste to become less tart and sweeter. The increased sugar also provides protection to the pigments and other components against oxidation, thereby enhancing quality stability of the dried fruit.

A number of traditional fruits has been dehydrated with application of osmotic concentration to remove a portion of the moisture of the fresh fruit. Fruits concentrated by osmotic treatment include apples (Biswal and Bozorgmehr, 1992; Conway et al., 1983; Garrote et al., 1992; Hough et al.,

1993), cherries, apricot and peaches (Giangiacomo et al. 1987), blueberries (Kim and Toledo, 1987), pineapple (Baristain et al., 1990; Rahman and Lamb, 1991), and strawberries (Garrote et al., 1992). Osmotic concentration has been applied to vegetables, but to lesser extent (Biswal and Bozorgmehr, 1992; DeSimone, 1992; Torreggiani, 1993).

Osmotically concentrated, dehydrated tomato has many potential uses. Being similar to dried fruits, the tomato product may be used as traditional dried fruits. Some uses include adding it to various bakery items, salads and to the different fruit, nut and snack mixes as an ingredient. The tomato product may be eaten out-of-hand. Thus, to increase knowledge of the osmotically concentrated, dehydrated tomato fruit product, research was conducted to produce such a product under selected experimental parameters and to measure selected physical changes that occurred in the tomato fruit during drying.

The objectives of this research project were to develop a concentrated and dehydrated dried tomato fruit product of natural red tomato color with desirable sweetness, flavor and texture by osmo-air dehydration; to determine the effects of process variables on selected chemical, physical and sensory attributes on the dried tomato fruit product during storage.

MATERIALS AND METHODS

Source and type of tomatoes

Tomatoes of 'Roma' cultivar were bought from the local market and sorted for uniform size and maturity. This cultivar was selected because the fruits have relatively thick walls and high solids content. The tomatoes were held for approximately 3 da at 21-22°C to allow further development of the red color. Following this period, the fruits with uniform red color were selected for use.

Preparation of tomatoes

The tomatoes were rinsed in tap water and placed into boiling water and held 30 sec to facilitate removal of peel. The peeled tomatoes were cut along the longitude axis into halves. The placenta and seeds were removed and discarded. All slices were placed into a 1% calcium chloride ($CaCl_2$) solution and held 20 min to promote retention of flesh integrity.

Experimental set-up

The sucrose solution and tomato halves were subjected to osmotic treatment in a large cylindrical glass vessel. These containers were placed in a custom-made temperature-controlled water bath with water circulation to maintain temperature control within approximately 1°C. The water bath was of sufficient size to hold four glass beakers filled with syrup and

samples. The syrup was circulated with a small submersible, electric pump (kind used in small garden fountains). It was necessary to agitate syrup in order to prevent the formation of a dilute solution film and to maintain a uniform temperature around the samples. A stainless steel perforated grip-cage was used to submerge the tomato pieces in the syrup for the duration of the contact time. Tomato halves weighing 0.91 kg were held in 3.64 kg of syrup.

Osmotic concentration of tomato halves

Samples of tomato halves were held in sucrose solution to concentrate the tomato solids. The solutions were prepared to contain 40 or 50 °Brix. Citric acid at 0.4% and malic acid at 0.2%, of the sucrose solution weight, were added to the osmotic solution to maintain an acidic taste in dehydrated product. To concentrate the solids, the pieces were submerged in the sucrose solution [1 part tomato: 4 parts solution (w/w)] at 30, 40 or 50°C. At each temperature, the tomato pieces were submerged in the solution under agitation for 2, 3 or 4 hr. After treatment, the pieces were removed from the solution, rinsed briefly in water to remove surface sugar solution and blotted to remove excess water.

Air-dehydration of concentrated tomato pieces

The osmotically concentrated tomato pieces were placed in a single layer on a standard drier tray. Temperature of a forced hot-air dehydrator was maintained at 60°C and drying was carried out to a moisture content of

approximately 18%. This value was predetermined indirectly by measuring the moisture content of the concentrated pieces and calculating the final weight that each batch of tomato pieces must reach to contain 18% moisture, thereby, producing a dehydrated product. Fig. 1 shows the flow diagram of procedure adapted for the osmotic concentration and dehydration to produce the dried tomato product.

Measurements conducted on the tomato halves

1. Tests to follow osmotic treatment

The following measurements were made on the osmotically concentrated tomato samples from all treatments.

(i). Moisture. Measurement of moisture content was determined by AOAC method 934.1 for vacuum oven drying. To facilitate drying, the tomato flesh was cut into squares of about 4 mm. Moisture was determined on fresh and osmotically dehydrated tomato tissues.

Calculations of changes in fresh tomato produced by osmotic concentration are presented below.

(a). Moisture loss (ML). The ML (%) of original moisture was calculated by the following equation:

$$ML\ (\%) = [(Mo\ W_{H_2O(o)} - M\Theta\ W_{H_2O(\Theta)})/Mo\ W_{H_2O(o)}] * 100$$

where $Mo\ W_{H_2O(o)}$ = moisture of original tomato (mass fraction)

$M\Theta\ W_{H_2O(\Theta)}$ = moisture of tomato after osmotic concentration, (mass fraction)

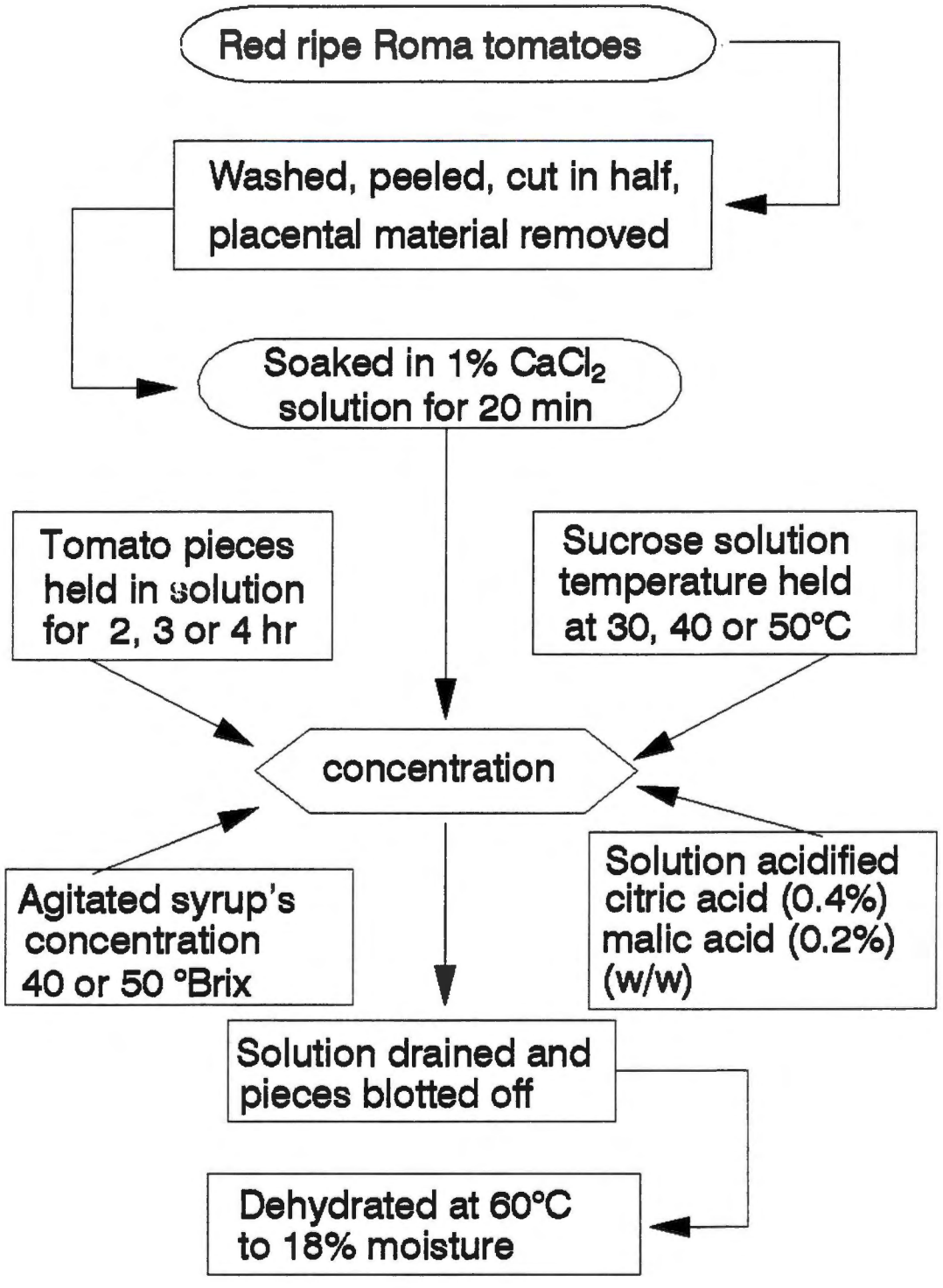

Fig. 1-Flow diagram of the procedure for the osmotic concentration and dehydration process to produce a dried tomatoes.

(b). Net weight loss (NWL). The NWL (%) was determined from loss of moisture and gain of solids and calculated by the following equation:

$$NWL\ (\%) = [(Mo - M\Theta)/ Mo]*100$$

where Mo = mass of original tomato

$M\Theta$ = mass of tomato after osmotic concentration,

(c). Solids weight gain (SWG). The SWG (%) resulted from the net gain of solids, primarily sugar. For calculation, the following equation was applied:

$$SWG\ (\%) = [(Ms\Theta - Mso)/ Mso] * 100$$

$$Ms\Theta = M\Theta\ [(1 - W_{H_2O(\ )}]$$

$$Mso = Mo\ [(1 - W_{H_2O(o)}]$$

where $Ms\Theta$ = mass of solids after osmotic concentration

Mso = mass of original solids,

2. Tests to follow after hot-air dehydration

The following measurements were made on the osmo-air dehydrated product.

(i). Moisture content as stated above.

(ii). Color. A Minolta Spectrophotometer, model CM-508D, (Minolta, 1994) was used to measure color of tomato pieces after dehydration. Hue-angle ($\tan^{-1}$ b/a) was calculated by using Hunter a (redness) and b (yellowness) values. Hunter L (lightness) was recorded. The meter was calibrated on illuminant C (6774K) with a white standard (Minolta calibration

white plate) before each use.

(iii). Lycopene. The lycopene was measured by the rapid spectrophotometric method developed by Adsule and Dan (1979) for lycopene estimation in tomato fruit. The lycopene was extracted by shaking 1g of homogenized tomato sample with 20 mL of acetone for 30 min on an electric shaker having a speed of 135 cycles/min. A 125 mL stoppered conical flask was used for shaking the samples. The flask was covered with aluminum foil to prevent light-induced lycopene oxidation. The contents of the flask were transferred to a centrifuge tube and centrifuged at 12,000 X g for 10 min. The supernatant was decanted and adjusted to 20 mL with acetone. The absorbency of the extract at 503 nm (wavelength of maximal absorption) was measured with a Shimadzu UV160U UV-Visible Recording Spectrophotometer (Shimadzu Scientific Instruments, Inc., 1993). The quantitative determination of lycopene was calculated using a molecular extinction coefficient of 17.2×10^4 $mol \cdot cm^{-1}$ (Beer and Siddappa, 1959) and expressed as $\mu g/g$ and calculated on the dry weight (Gross, 1991).

(iv). Water activity (a_w) was measured by the AquaLab CX2 Water Activity Measuring System (AquaLab, 1992). A tomato piece weighing 5 g was placed in the calibrated apparatus and reading was recorded directly from the readout.

(v). Total acidity was measured by dissolving 10 g of homogenized tomato sample in 40 mL deionized water. The resulting mixture was titrated with

0.1N NaOH solution to pH 8.1 by using a Fisher Accumet pH meter (Model 600, Fisher Scientific Co., Pittsburgh, PA). The results were reported as percentage of citric acid. The pH of tomatoes was measured on the above mixture by using the pH meter (AOAC, 1990).

(vi). Soluble solids were measured by dissolving 10 g of homogenized dried tomato sample in 40 mL deionized water. The filtrate obtained from the resulting mixture was used to determined soluble solids with an Abbé Refractometer at 20°C and reported as °Brix. The results were multiplied with proper dilution factor.

Procedure for sample selection by sensory evaluation

Sensory evaluation using 8-point hedonic scales (1 = dislike extremely; 8 = like extremely) was conducted in order to select a treatment of highest consumer acceptability. A 40-member consumer sensory panel (Larmond, 1987), consisting of faculty, students and staff of the College of Agriculture and Natural Sciences of The University of Tennessee, Knoxville, evaluated the dried tomato product. The majority of panel members had participated in sensory panels previously, but none was trained specifically for this test. The sensory attributes of sweetness, color, flavor, texture and overall acceptability were evaluated and used as the basis for sample selection in the storage test. The sensory evaluation was conducted after 5 da of storage in air-tight glass jars in order to equilibrate the moisture content of dried tomato product. Sensory evaluation was conducted under cool-white

fluorescent light in the air conditioned sensory laboratory of the Food Science and Technology Department. One piece (one-half of a tomato half) of dried tomato fruit product, without additional preparation, was served to a panelist. Sensory evaluation was conducted over a 5-da period. On a given day, individual panelists received one sample from each of four treatments. Some individuals may not have served for all five days. Samples were prepared on five different days and same pattern was followed for sensory evaluation. Using a balanced randomized order of presentations, each panelist was served the four samples, numbered with three-digit random numbers, one at a time. Forty responses were obtained per treatment.

Experimental design and statistical analysis

The experiment consisted of 18 treatment combinations: two sucrose concentrations, three temperatures and three contact times with two replications. Statistical analysis of the data was performed using SAS Software (SAS Institute, 1988) at The University of Tennessee Computing Center. The experimental design was a factorial of complete block design (Little and Hills, 1978). The effects of osmotic solution concentration, process temperature, piece contact time and their interactions were determined on all dependent variables (except sensory evaluation) by General Linear Model (GLM). Significant differences among treatments were determined at the 5% level of significance by the PDiff option (Steele and

Torrie, 1980).

Statistical analysis on the sensory data was performed differently. The goal of sensory evaluation was to select a treatment combination of highest consumer acceptability rather than the effects of process variables. Twenty treatment combinations were selected, using E4 (Evolutionary Software, Inc., 1991), a computer program which generates fractional factorial experimental designs. Significant differences among treatments were determined at the 5% level of significance by the PDiff option (Steele and Torrie, 1980).

RESULTS AND DISCUSSION

Moisture loss

Moisture loss was affected by sucrose concentration (40 and 50 °Brix), temperature (30, 40 and 50°C), time (2, 3 and 4 hr) and the temperature x time interaction. Analysis of variance table and means for the three-way interaction may be found in Appendix B, Table 1. Appendix A, Table 1 presents the raw data.

Fig. 2 presents the moisture loss as affected by the temperature x time interaction. Loss at each temperature over time is fairly linear. At each temperature, loss of moisture increased significantly with each additional hour of contact, except at 50°C between 3 and 4 hr. For the first two hours of contact time, moisture loss ranged from ~49 to 64.5%, depending upon the temperature. With an additional 2 hr of contact, there was a 1.28 fold increased moisture loss at 30°C; 1.16, at 40°C and 1.08, at 50°C. Higher temperatures and longer contact time favored the ML. These results are in agreement with those reported in apple (Conwey et al., 1983), banana (Pokharkar et al., 1997), pineapple (Silveira et al., 1996) and strawberry halves (Garrote et al., 1992).

Net weight loss

Net weight loss (NWL) was affected by sucrose concentration, temperature, time and the temperature x time and the sucrose concentration

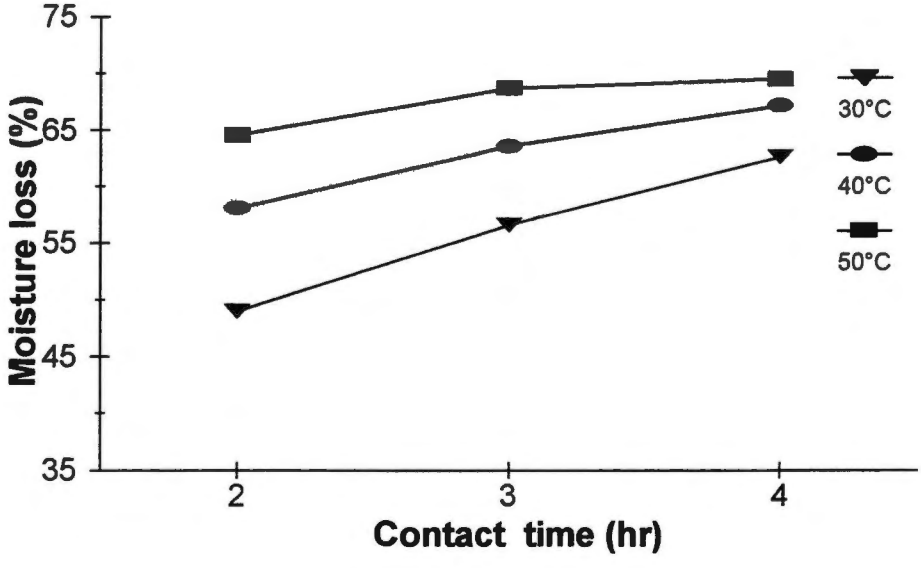

Fig. 2-The effects of the interaction of temperature x time on the moisture loss of peeled tomato halves during the osmotic concentration.

x temperature x time interactions. Analysis of variance table and means for the three-way interaction may be found in Appendix B, Table 2. Appendix A, Table 1 presents the raw data.

Overall, samples treated in the 50 °Brix solution exhibited the greater NWL (Fig. 3). As temperature of the solutions increased, there was a tendency for the NWL to increase from both sucrose treatments. Within each sucrose treatment, the NWL increased as the contact time was extended. The lowest NWL was observed from the 40 °Brix solution, 30°C and 2 hr treatment. The highest NWL was observed from the 50 °Brix solution, 50°C and 3 hr treatment. NWL was the result of loss of moisture from the tomato tissue countered by the uptake of solutes.

Solids weight gain

Solids weight gain was affected by sucrose concentration, temperature, time and the sucrose concentration x time and sucrose concentration x temperature interactions. Analysis of variance table and means for the three-way interaction may be found in Appendix B, Table 3. Appendix A, Table 1 presents the raw data. Fig. 4 and 5 presents solids weight gain.

Means of solids weight gain for the sucrose concentration x time interaction are found in Fig.4. At 40 °Brix, the solids weight gain was was not significant between 2 and 3 hr, but at 4 hr, there was a significant gain. At 2 and 3 hr, the solids weight gain at both concentrations of

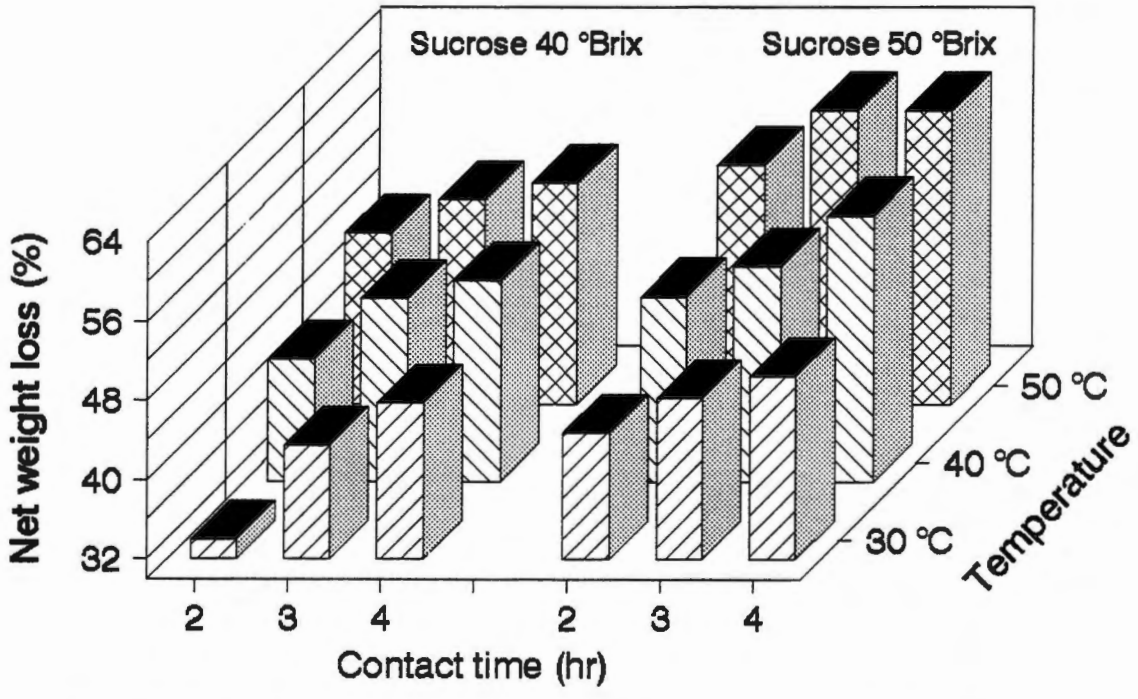

Fig. 3 —The effects of the interaction of sucrose concentration x temperature x time on the net weight loss of peeled tomato halves during the osmotic concentration.

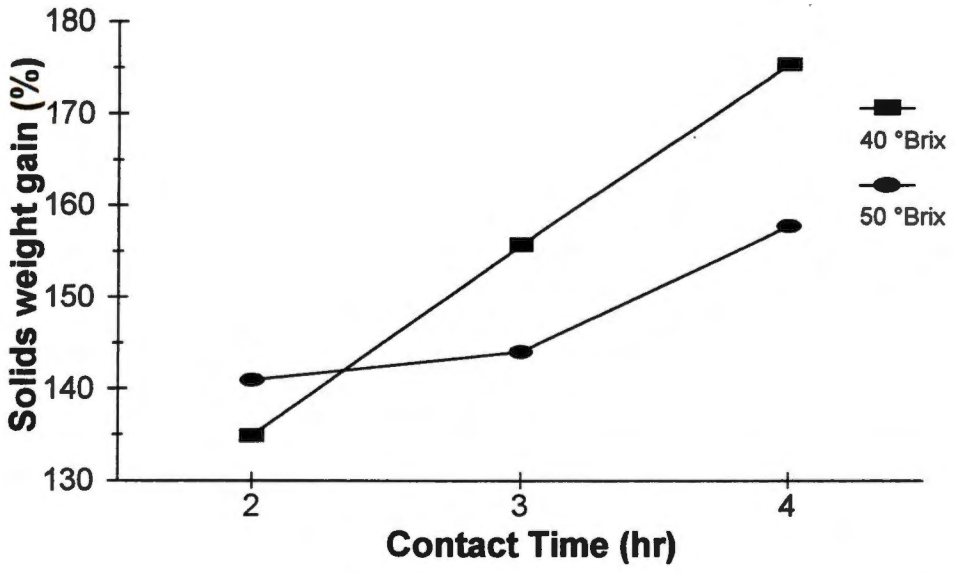

Fig. 4-The effects of the interaction of sucrose concentration x time on the solids weight gain of peeled tomato halves during the osmotic concentration.

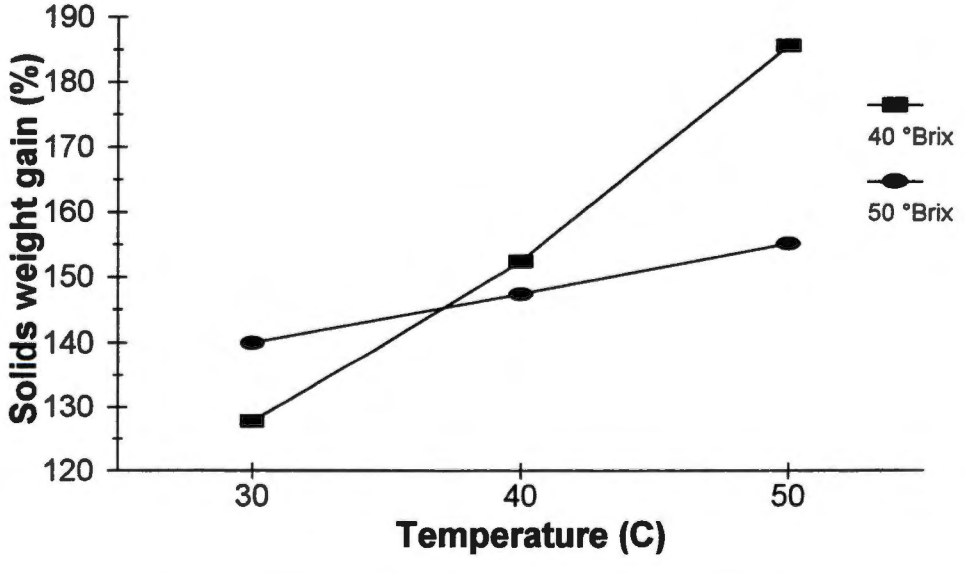

Fig. 5-The effects of the interaction of sucrose concentration x temperature on the solids weight gain of peeled tomato halves during the osmotic concentration.

sucrose were not different, but at 4 hr there was a significant difference, with 40 °Brix producing the greater gain. Lower sucrose concentration was observed to produce sweeter apple rings because of higher solid (sucrose) gains with extended contact time (Farkas and Lazar, 1969).

Fig. 5 presents the solids weight gain of the treated tomato halves as affected by the sucrose concentration x temperature interaction. As temperature increased, the solids weight gain increased also. The increase was linear for both sucrose concentrations. At 30°C, the solids weight gain was greater from the 50 °Brix solution. However, at 40 and 50°C, the weight gain was greater from the 40 °Brix solution. At 40°C, the gain was 1.03 times greater and at 50°C, the gain was 1.2 times greater.

Color--Hunter L

The Hunter L was affected by time and the sucrose concentration x temperature, sucrose concentration x time, temperature x time and sucrose concentration x temperature x time interactions. Analysis of variance table and means for the three-way interaction may be found in Appendix B, Table 4. Appendix A, Table 2 presents the raw data.

The tomato samples treated in the 40 and 50 °Brix solutions at 30°C exhibited similar Hunter L values and, thus, were similar in lightness (Fig.6). As the temperature was increased, differences between the sucrose concentrations became evident. Samples from the 40 °Brix-40°C treatment, had lower Hunter L values (darker) than samples from the 50

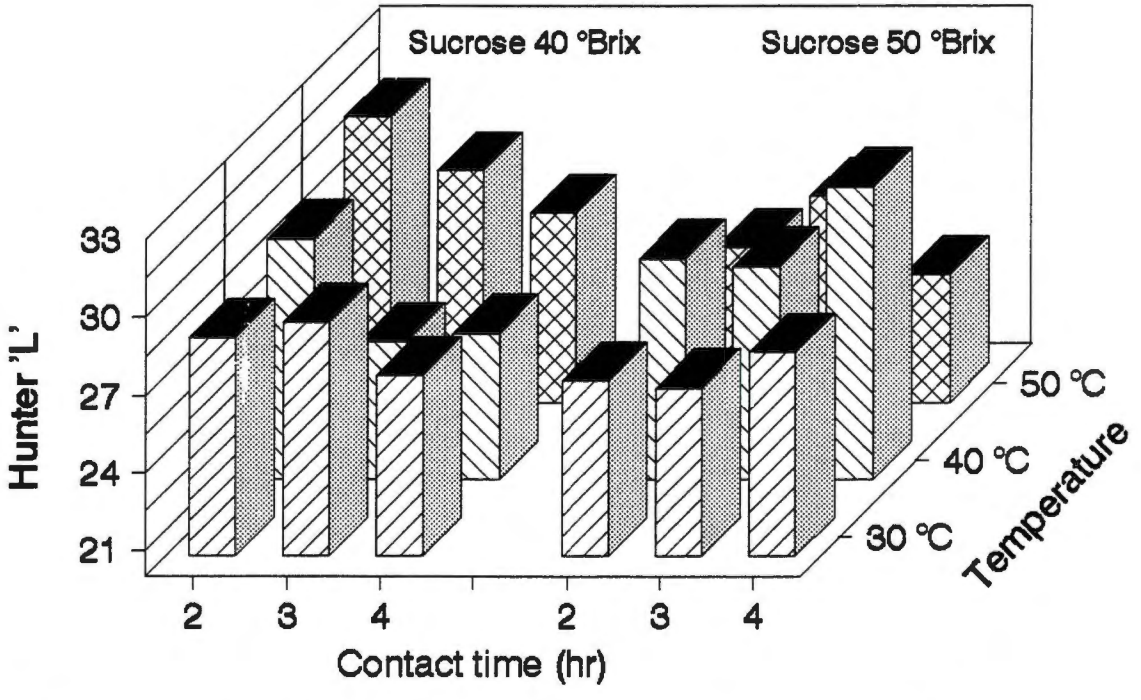

Fig. 6 —The effects of the interaction of sucrose concentration x temperature x time on the Hunter 'L' values of final dried tomato product produced by the osmotic concentration and dehydration.

°Brix-40°C treatment. At the highest temperature, the situation that occurred at 40°C was reversed. There was no consistent trends in Hunter L values among the contact times as the temperature was increased. Samples from the 40 °Brix solution tended to darken as contact time was extended from 2 to 4 hr. However, samples became lighter with time for the samples treated in the 50 °Brix solution.

Color--hue angle

Hue-angle was affected by sucrose concentration, temperature and the sucrose concentration x temperature, sucrose concentration x time and sucrose concentration x temperature x time interactions. Analysis of variance table and the means for the three-way interaction may be found in Appendix B, Table 5. Appendix A, Table 2 presents the raw data.

On average, the hue-angle of samples from the 40 °Brix treatment was lower (redder) than that from samples of the 50 °Brix treatment (Fig 7). The retention of the red color in the 40 °Brix treatment may have been influenced by the greater uptake of solute, expressed as SWG (Fig. 4 and 5). This is supported by the work of Ponting et al. (1966) who reported that the sugar uptake during osmotic concentration helped protect color against oxidation and subsequent loss during further dehydration. As the temperature of the solutions increased, hue-angle tended to increase also, resulting in samples becoming more yellow. The manifestation of greater yellow color from the higher temperatures most likely resulted from

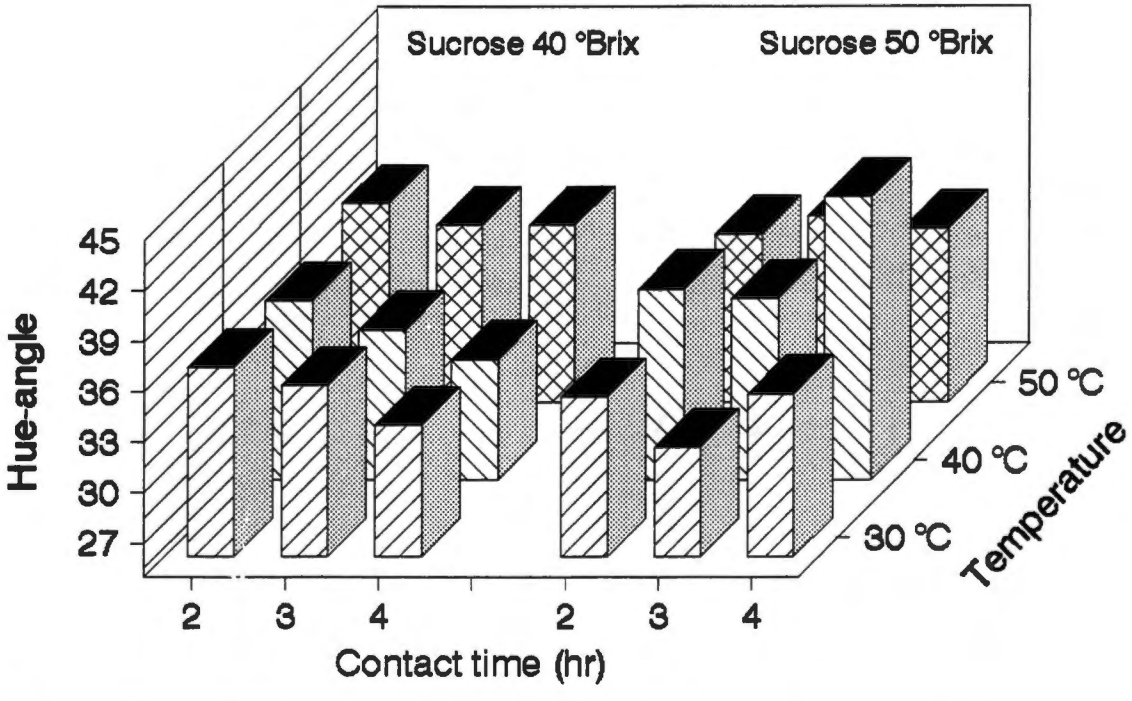

Fig. 7 —The effects of the interaction of sucrose concentration x temperature x time on the hue-angle values of final dried tomato product produced by the osmotic concentration and dehydration.

degradative reactions on lycopene and, thus, reduced it intensity. Contact time had no effect on hue-angle.

Lycopene

Lycopene concentration was affected by sucrose, temperature, time and all the related interactions. Analysis of variance table and means for the three-way interaction may be found in Appendix B, Table 6. Appendix A, Table 2 presents the raw data.

On average, the lycopene concentration of samples from the 50 °Brix treatment was lower (Fig. 8). Across sucrose concentrations, samples treated at 40°C contained a greater concentration of lycopene than samples treated at 50°C. The lycopene concentration from samples treated at 30°C, however, did not differ from samples held at the higher temperatures. There are no uniform trends across contact time as affecting lycopene concentration.

pH

pH was affected by sucrose, temperature, time and the sucrose concentration x temperature, temperature x time and sucrose concentration x temperature x time interactions. Analysis of variance table and means for the three-way interaction may be found in Appendix B, Table 7. Appendix A, Table 3 presents the raw data.

pH of the samples between sucrose concentration treatments appear similar; however, on average, pH of the 40 °Brix treatment was slightly

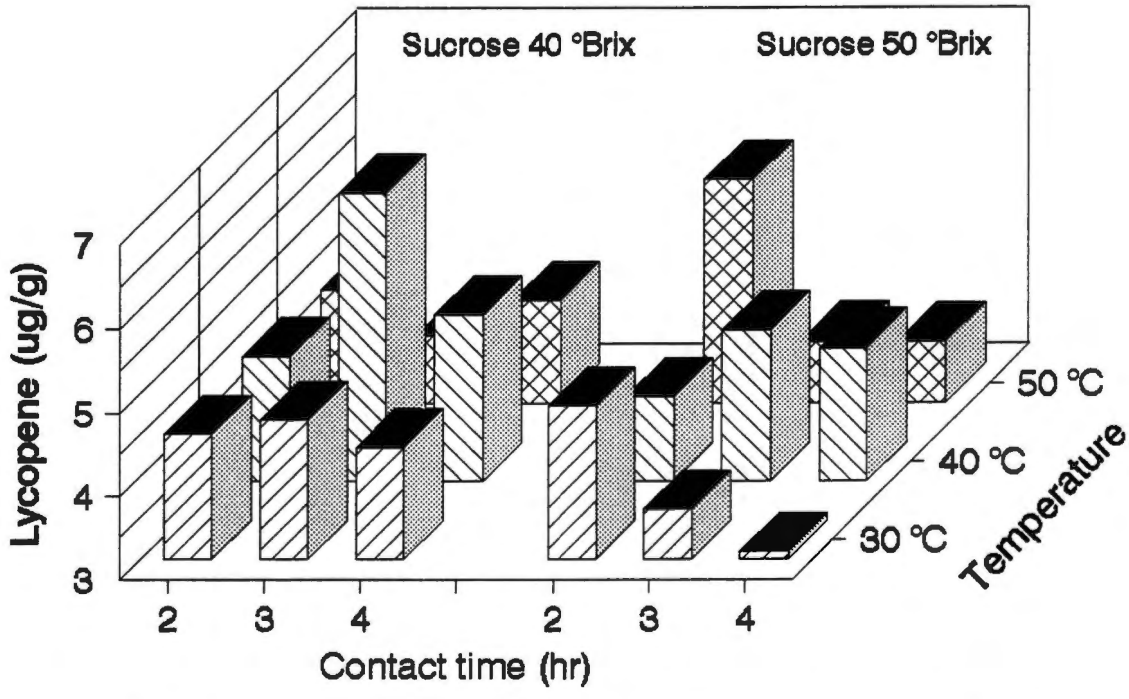

Fig. 8 —The effects of the interaction of sucrose concentration x temperature x time on the lycopene content of final dried tomato product produced by the osmotic concentration and dehydration.

lower (Fig. 9). Overall, as temperature increased and as time was extended, pH decreased. Both conditions, as they were increased, lead to a greater uptake of the acids from the acidified sucrose solutions.

Titratable acidity

Titratable acidity was affected by sucrose, temperature and time and sucrose concentration x temperature, temperature x time and sucrose concentration x temperature x time interactions. Analysis of variance table and means for the three-way interaction may be found in Appendix B, Table 8. Appendix A, Table 3 presents the raw data.

The samples from the 40 °Brix solution had the higher titratable acidity, but only by a small concentration (Fig. 10). On average, as temperature increased and contact time was extended, titratable acidity showed small decreases. A decrease in titratable acidity with extended contact time was also reported by Forni et al., 1997 in aprocot. Overall, the findings show that the highest titratable acidity resulted from the treatment of 30°C for 2 hr, and the lowest titratable acidity resulted from the treatment of 50°C at 4 hr. These findings seem to be in contradiction with those for pH, where the overall results showed that the highest pH was found for samples treated at 30°C for 2 hr and the lowest pH was found for samples treated at 50°C at 4 hr. This author is unable to explain this apparent contradiction.

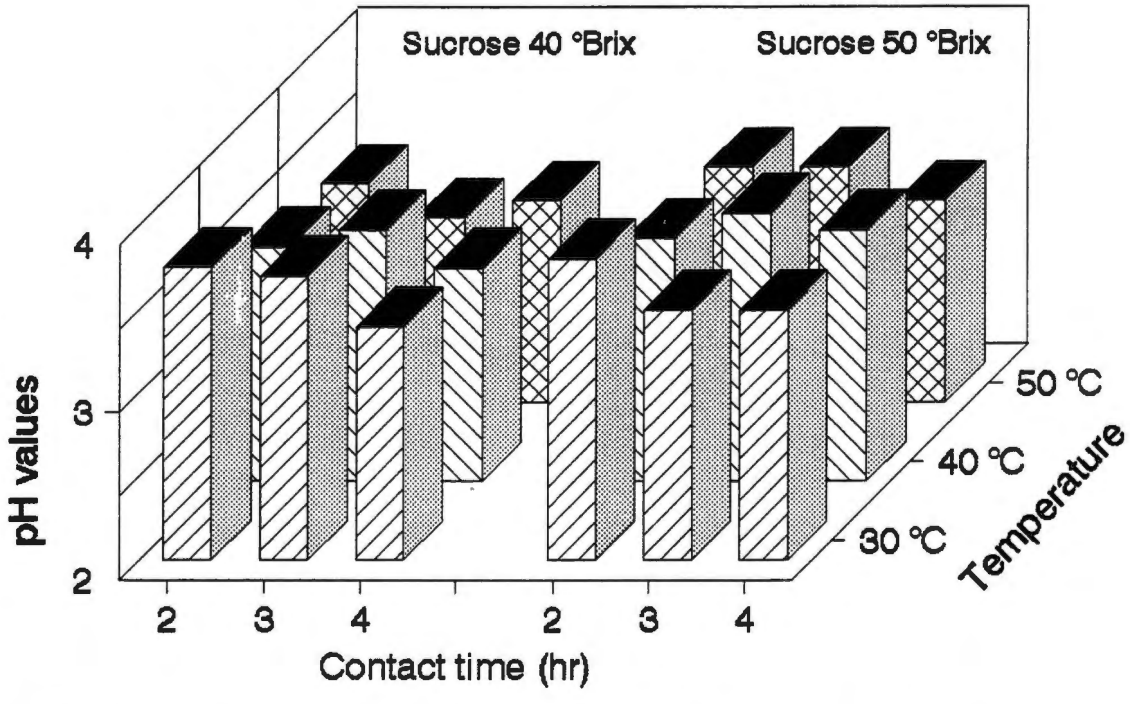

Fig. 9 —The effects of the interaction of sucrose concentration x temperature x time on the pH values of final dried tomato product produced by the osmotic concentration and dehydration.

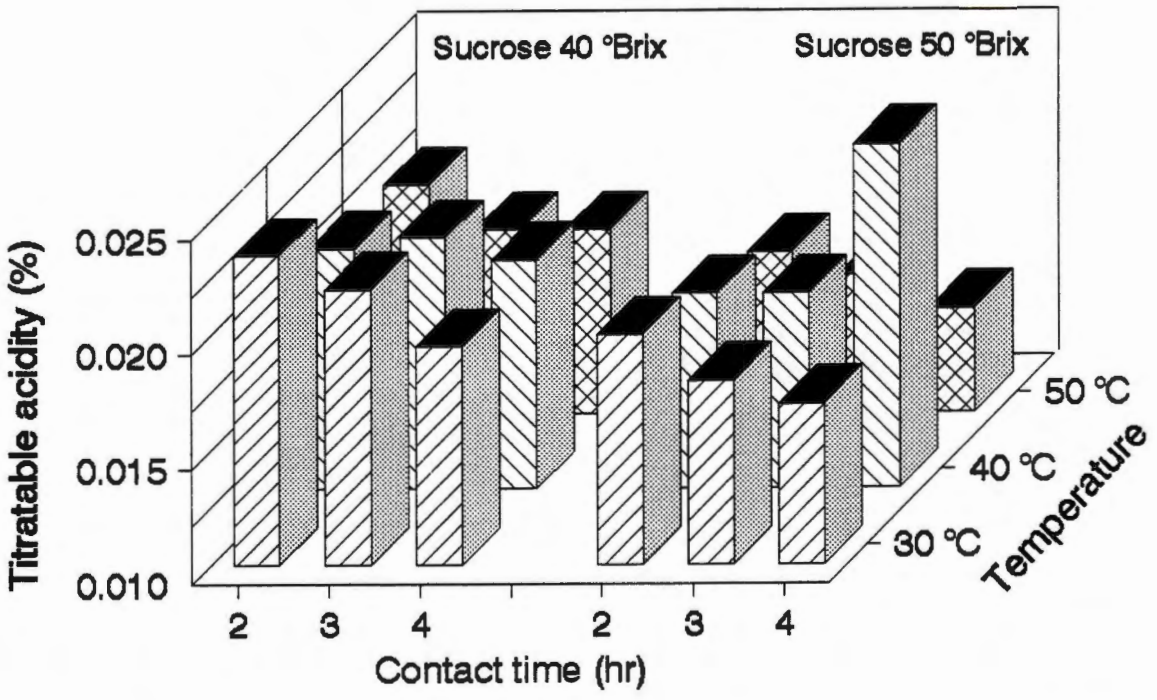

Fig. 10 — The effects of the interaction of sucrose concentration x temperature x time on the titratable acidity (as % citric acid) of final dried tomato product produced by the osmotic concentration and dehydration.

Soluble solids

The soluble solids of the samples was affected by the sucrose concentration x temperature, sucrose concentration x time and sucrose concentration x temperature x time interactions. The individual variables had no effect. Analysis of variance table and means for the three-way interaction may be found in Appendix B, Table 9. Appendix A, Table 3 presents the raw data.

While the three-way interaction was significant, it is not so clear as to the trends that occurred (Fig. 11). Also, the individual variables, being nonsignificant, do not offer guidance. There are, however, some general trends that seem evident. Samples from the 40 °Brix treatments which were held for 4 hr at 50°C tended to contain greater soluble solids. Those samples held at 40°C contained the lowest levels. For the samples from the 50 °Brix treatments, those held for 3 hr tended to contain the greatest concentration of soluble solids. The SWG previously reported should show some relationship to the soluble solids since the sucrose that was absorbed in the SWG measurement is the substance being reported here as soluble solids. But that seems to be remote. All the individual variables affected SWG measurements, but the third-level interaction was non-significant.

Water activity

Water activity was affected by sucrose concentration, temperature, time, sucrose concentration x temperature, sucrose concentration x time,

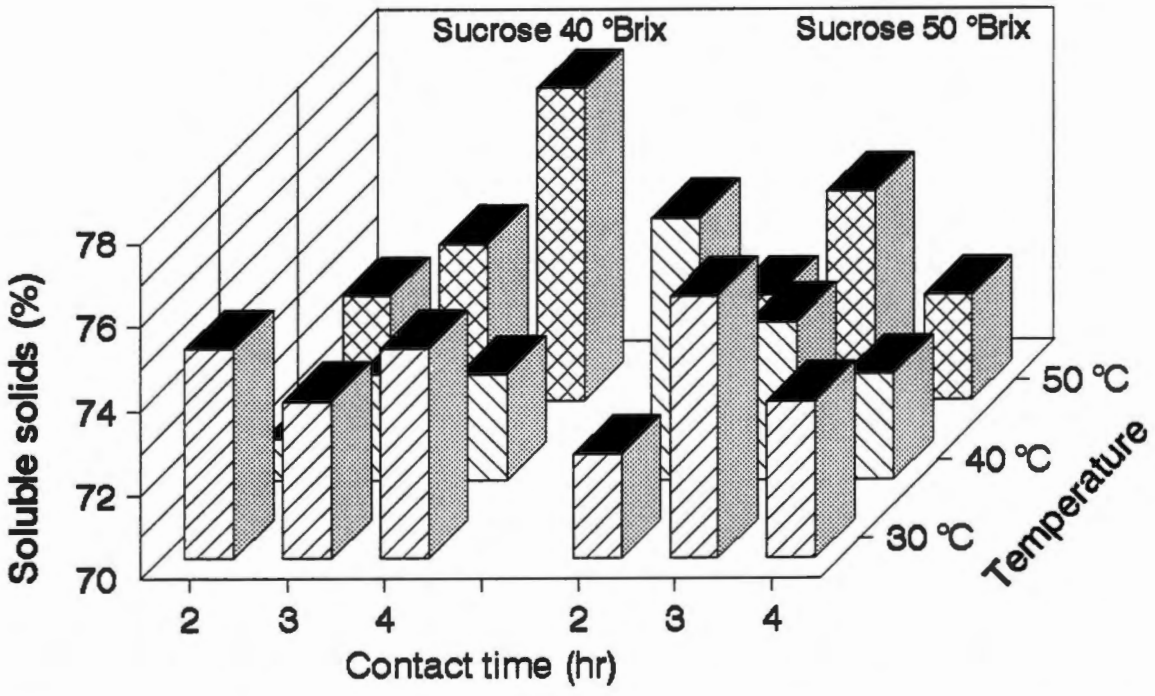

Fig. 11 — The effects of the interaction of sucrose concentration x temperature x time on the soluble solids of final dried tomato product produced by the osmotic concentration and dehydration.

temperature x time and sucrose concentration x temperature x time interactions. Analysis of variance table and means for the three-way interaction may be found in Appendix B, Table 10. Appendix A, Table 3 presents the raw data.

The effects of the interaction of sucrose concentration x temperature x time interaction on water activity is presented in Fig 12. Small differences among water activity means were significant. The higher sucrose concentration treatment yielded the higher water activity (0.64 vs. 0.63). The greatest effect occurred among contact times with water activity decreasing as time was extended. However, Fig. 12 does not indicate that the lower water activity was supported by lower concentrations of soluble solids. Samples held at 50°C possessed the lowest water activity, whereas, the samples held at 30°C possessed the highest. These results indicated that those process variables contributed to maximum solids gain during the osmosis also helped to lower the water activity because water activity is composition dependant (Torreggiani et al., 1987).

Sensory evaluation

No significant differences were found among the means of consumer-type panel scores of the dried tomato product for color, sweetness, flavor, texture and overall acceptability. The means ranged between 5 and 6 (like slightly and like moderately, respectively) and indicated that the panelists liked the dried tomato product. The percentages of panelists who liked the

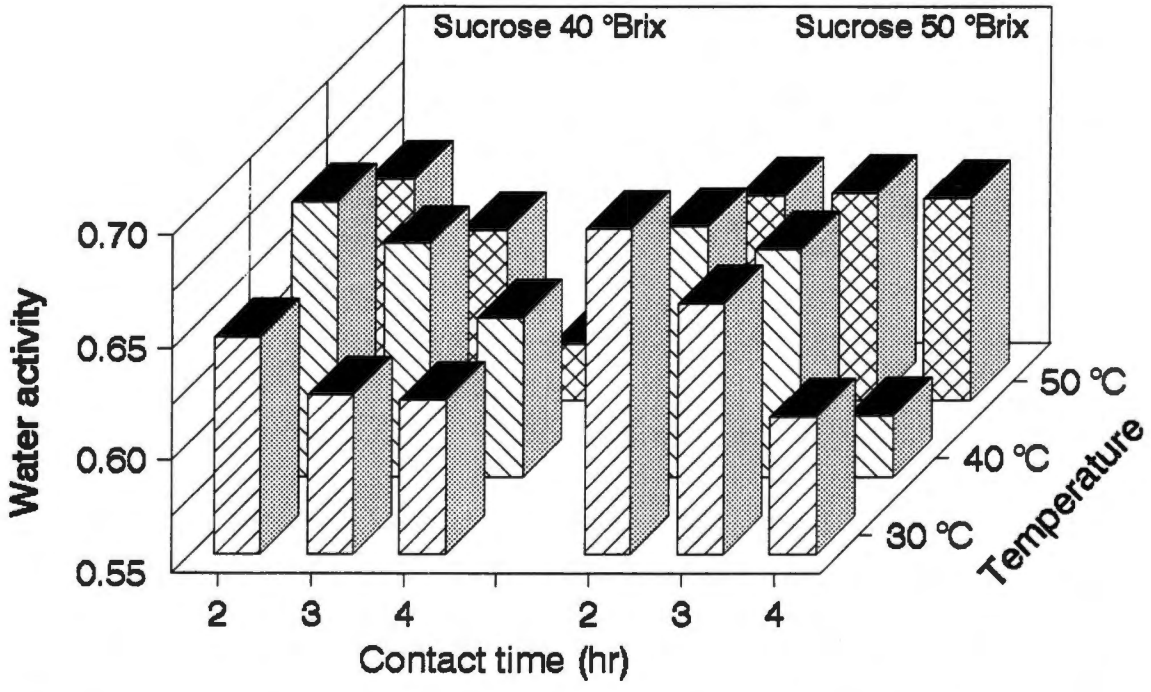

Fig. 12 — The effects of the interaction of sucrose concentration x temperature x time on the water activity of final dried tomato product produced by the osmotic concentration and dehydration.

color, sweetness, flavor and texture of the product were 87.9, 84.1, 83.4 and 84.4, respectively. Overall, the product was liked by 82.7% of the panelists. These results indicated that an acceptable dried tomato product was produced by using osmotic concentration in sucrose solutions, followed by dehydration.

In summary, this experiment showed that ripe, thick-walled tomatoes can be processed to produce a product similar to dried fruits. The process retained the natural red color, increasing the utility of the product. The sensory evaluations showed that the dried product was acceptable. This process adds value to the fresh tomato fruit by converting it to a dried product, similar to traditional dried fruits. Successful development of such a dried product could boost tomato production and utilization; therefore, farm income could be increased. Subsequently, both processors and retailers could enjoy financial gains and consumers could enjoy a new, dried, sweet-tasting dried tomato product. This product has many potential uses: ingredient in tomato-based sauces, in a variety of bakery products and in mixed fruit snacks. It could be eaten out-of-hand as any dried fruit.

REFERENCES

Adsule, P.G. and Dan, A. 1979. Simplified extraction procedure in the rapid spectrophotometric method for lycopene estimation in tomato. J. Food Sci. Technol. 16: 216.

AOAC. 1990. Official Methods of Analysis. 15th ed. Assoc. of Analytical Chemists, Washington, DC.

AquaLab. 1992. Operator's Manual For AquaLab Cx2 Water Activity Measuring System. Dacagon Devices, Inc., Pullman, WA.

Baristain, C.I., Azuara, E., Cortes, R., and Garcia, H.S. 1990. Mass transfer during osrnotic dehydration of pineapple rings. Intl. J. Food Sci. Technol. 25: 576-582.

Beer, O.P. and G.S. Siddapa. 1959. A rapid spectrophotometric method for the detection and estimation of adulterants in tomato ketchup. Food Technol. 13: 414-418.

Biswal, R.N. and Bozorgmehr, K. 1992. Mass transfer in mixed solute osmotic dehydration of apple rings. Trans. Am. Soc. Agric. Eng. 35: 257-262.

Conway, J., Castaigne, F., and Voran, P.G. 1983. Mass transfer consideration in the osmotic dehydration of apples. Can. Inst. Food Sci. Technol. 16: 25-34.

DeSimone, J. 1992. Sweet potato (*Ipomoea batatas* Lam.) dehydration by osmotic concentration and tray drying. M.S. thesis. The University of Tennessee, Knoxville.

Evolutionary Software, Inc. 1991. E4 Users Guide, Version 91.1. Evolutionary Software, Inc., Knoxville, TN.

Farkas, D.F. and Lazar, M.G. (1969). Osmotic dehydration of apple pieces. Food Technol. 23: 688-690.

Forni, E., Sormani, A, Scalise, S., and Torreggiani, D. 1997. The influence of sugar composition on the colour stability of osmodehydrofrozen intermediate moisture apricots. Food Res. Intl. 30: 87-94.

Garrote, R.L., Silva E.R., and Bertone, R.A. 1992. Osmotic concentration at 5°C and 25°C of pear and apple cubes and strawberry halves. Lebensm.-Wiss. u.-Technol. 25: 133-138.

Giangiacomo, R., Torreggiani, D., and Abbo, E. 1987. Osmotic dehydration of fruit. Part I. Sugar exchange between fruit and extracting syrups. J. Food Proc. Preserv. 11: 183-195.

Gross, J. 1991. Pigments in Vegetables: Chlorophyll and Carotenoids. AVI Publishing Co., Inc., Westport, CT.

Gupta, R.G. and Nath, N. 1984. Drying of tomatoes. J. Food Sci. Technol. India 21: 372-376.

Hawkes, J. and Flink, J.M. 1978. Osmotic concentration of fruit slices prior to freeze dehydration. J. Food Proc. Preserv. 2: 265-284.

Haytowitz, D.B. and Matthews, R.H. 1984. Composition of foods: Vegetables and vegetable products. Agricultural Handbook 8-11, U.S. Department of Agriculture, Washington, DC.

Hough, G., Chirife, J., and Marini, C. 1993. A simple model for osmotic dehydration of apples. Lebensm. -Wiss. U. -Technol. 26: 151-156.

Jayaraman, K.S. and Das Gupta, D.K. 1992. Dehydration of fruits and vegetables - Recent developments in principles and techniques. Drying Technol. 10: 1-50.

Kim, M.H. and Toledo, R.T. 1987. Effect of osmotic dehydration and high temperature fluidized bed drying on properties of dehydrated rabbiteye blueberries. J. Food Sci. 52: 980-984, 989.

Larmond, E. 1987. Laboratory methods for sensory evaluation of food. Publication #1637/E. Can. Dept. of Agric., Ottawa, Ontario, Canada.

Lenart, A. and Lewicki, P.P. 1988. Energy consumption during osmotic and convective drying of plant tissue. Acta Alimentaria Polonica 14: 65-72.

Little, T.M. and Hills, F.J. 1978. Agricultural Experimentation: Design and Analysis. John Wiley and Sons, New York.

Minolta. 1994. Operator's manual for Minolta CM-508D Spectrometer. Minolta Corp., Ramsey, NJ.

Pokharkar, S.M., Prasad, S., and Das, H. (1997). A model for osmotic concentration of bananas slices. J. Food Sci. Technol. 34: 230-232.

Ponting, J.D. 1973. Osmotic dehydration of fruits. Recent modifications and applications. Process Biochem. 8: 18-20.

Ponting, J.D., Waters, G.G., Forrey, R.R., Jackson, R., and Stanley, W.L. 1966. Osmotic dehydration of fruits. Food Technol. 20: 125-128.

Rahman, M.S. and Lamb, J. 1991. Air drying behavior of fresh and osmotically dehydrated pineapple. J. Food Process Eng. 14: 163-171.

SAS Institute. 1988. SAS Procedure Guide, Release 6.03 ed. SAS Institute Inc., Cary, NC.

Shimadzu Scientific Instrumentals. 1993. Instruction Manual for Shimadzu UV160U UV-Visible Recording Spectrophotometer. Shimadzu Scientific Instrumentals Inc., Columbia, MD.

Silveira, E.T.F., Rahman, M.S., and Buckle, K.A. 1996. Osmotic dehydration of pineapple: kinetics and product quality. Food Res. Intl. 29: 227-233.

Steele, R.G. and Torrie, J.H. 1980. Principles and Procedures of Statistics. McGraw-Hill Inc., New York.

Torreggiani, D. 1993. Osmotic dehydration in fruit and vegetable processing. Food Res. Intl. 26: 59-68.

Torreggiani, D., Forni, F., and Rizzolo, A. 1987. Osmosis dehydration of fruit. Part II. Influence of the osmosis time on the stability of processed cherries. J. Food Proc. Pres. 12: 21-44.

PART IV

STORAGE STABILITY OF A TOMATO PRODUCT DRIED BY OSMOTIC CONCENTRATION AND DEHYDRATION

ABSTRACT

Storage stability of two selected treatments of dried tomato product stored for up to 5 mo was determined with respect to moisture, color stability, lycopene concentration, firmness and microbiological presence. Sensory evaluations, using 8-point hedonic scales, were conducted on samples stored for 2.5, 5.0, 7.5 mo. Treatments were: 40 and 50 °Brix (sucrose), both at 40°C and 3 hr contact time. Samples were packaged in glass containers under air, partial vacuum or nitrogen gas flush and stored for up to 5 or 7.5 mo.

The moisture content decreased as the storage period was extended. Samples treated in 50 °Brix sucrose solution had a higher Hunter L value than samples treated in the 40 °Brix solution. Dried tomato halves tended to become darker after 2.5 mo of storage. Hue-angle increased from 0 to 2.5 mo of storage and remained unchanged thereafter. Thus, samples were reddest in the beginning but became less red and more yellow after 2.5 mo of storage. Hue-angle of tomato material held in partial vacuum or nitrogen-flush packages did not change during storage. Lycopene concentration remained unchanged for the first 2.5 mo of storage, but increased after 5 mo in air-flushed packages. Tomato tissue treated in 50 °Brix solution was softer than tissue treated in 40 °Brix solution. The samples became firmer as the storage period was extended to 5 mo. All samples were essentially

free of microbiological contamination. Only air-flushed samples supported growth. Samples of all treatments recieved similar panel scores for the attributes evaluated except color which was affected by storage. Osmotic concentration with dehydration produced an acceptable and shelf-stable dried tomato product which can be stored for up to 5 mo with acceptable quality attributes.

INTRODUCTION

Many seasonal fruits are dried to prolong their availability throughout the year. Nowadays, most of the dried fruits are used as a snack food or as an ingredient in the formulation of another food product. Any shelf-stable dried fruit or ingredient which does not require special storage conditions is considered to be cost-effective. Among different drying techniques, osmotic concentration followed by dehydration has gained considerable attention in the recent past due to its potential applications in food process industry (Biswal and Bozorgmehr, 1990, 1992; Hawkes and Flink, 1978; Hough et al., 1993; Jayaraman and Das Gupta, 1992; Karathanos and Kostarpoulos, 1995; Ponting, 1973; Ponting et al., 1966). The dried fruit products obtained through this process not only are microbiological safe and shelf-stable but also retain their color, flavor and texture which are highly acceptable to the consumers (Baristain et al., 1990; Karathanos and Kostarpoulos, 1995; Lerici et al., 1985; Maltini et al., 1993; Ponting, 1973; Ponting et al., 1966; Torreggiani, 1993). A shelf-stable product can be produced, packaged and distributed at a relatively lower cost.

The overall goal in the development of a shelf-stable dried fruit product is to prolong its storage stability during which it should maintain its attractive color, flavor, texture and overall appearance (Stafford and Guadagni, 1977). Sugaring has long been the standard method for

protecting the color and flavor of fruits during storage and has become the basis for osmotic dehydration (Adesina and Aina, 1990). Osmotically dehydrated bananas, mangoes and papayas retained much better flavor with no added preservatives when stored in sealed cellophane bags for more than 12 mo of storage (Uzuegbu and Ukeka, 1987). An osmo-air dried pineapple product was fairly acceptable in terms of color, flavor and texture even after 3 mo of storage filled in plastic bags at 25° C (Silveira et al. 1996). The color of osmotically dehydrated cherries was fairly acceptable to panelists in spite of some loss of anthocyanin pigments which caused a lightening of color during storage at ambient temperatures (Forni et al., 1993; Torreggiani et al., 1987). A decrease in chroma and modification of hue from red to yellow were observed in osmodehydrated cherries over the entire 6 mo of storage (Torreggiani et al., 1987). Shelf-stable dried fruit products developed by osmotic dehydration were packaged successfully in flexible films instead of cans, for storage without added preservatives. The use of films served to keep the cost down, enhanced natural taste and conserved energy consumption low for drying (Jayaraman and Das Gupta, 1992).

Water activity (a_w) of dried fruit products is a major factor determining their keeping quality (Anderson, 1991; Gould, 1983; Karel, 1973). A reduced a_w of 0.65 or lower will prevent the microbial spoilage of most dried fruit products for up to 2 yr (Robertson, 1993). The shelf life of dried fruit

products is also influenced by their pH values. A pH below 4.5 is critical in preventing microbial spoilage (Gould, 1983).

The objectives of this investigation were to determine the effects of packaging atmospheres, sugar strength and length of storage on selected chemical, physical and sensory attributes of the dried tomato fruit product and to determine shelf-life stability during an extended period of storage.

MATERIALS AND METHODS

Selection of sample treatments

Based upon the results obtained in the first experiment (Part III), the treatment of 40 °Brix, 40°C and 3 hr contact time was selected for producing a dried tomato product for use in the storage experiment. Maximum benefits of moisture loss and solids weight gain coupled with maximum retention of lycopene pigment had resulted from this treatment. A similar treatment, but of 50 °Brix sucrose solution, was selected to evaluate the effects of sucrose concentration during the storage period.

Preparation of samples

Dried tomato samples of two treatments: 40 °Brix sucrose solution held at 40°C for 3 hr; and 50 °Brix sucrose solution held at 40°C for 3 hr were prepared as described in Part III, Methods and Materials. The experiment was replicated two times.

Packaging of samples for storage

Samples of dried tomato product were packaged in glass jars (473 mL) equipped with two-piece, air-tight lids. The samples were packaged under three atmospheres: air, nitrogen and partial vacuum. As the samples were being filled in the jars, a constant flow of either air or nitrogen or partial vacuum were maintained. Immediately after dried tomato halves

were filled in the jars, the lids were secured and tightened. The glass jars were labeled for the proper treatments, atmosphere gases, months of storage and replication numbers. The glass jars were then arranged in styrofoam boxes and stored at ambient temperature (air-conditioned room) for 0, 2.5 and 5 mo.

Measurements conducted on the dried tomato product during storage

The following measurements were made on the dried tomato product samples from all treatments after 0, 2.5 and 5 mo of storage.

Moisture. Measurement of moisture content was determined by AOAC Method 934.1 for vacuum oven drying (AOAC, 1990). To facilitate drying, the tomato pieces were cut into squares of about 4 mm.

Color. A Minolta Spectrophotometer, model CM-508D, (Minolta, 1994) was used to measure color of tomato pieces after dehydration. Hue-angle ($\tan^{-1}$ b/a) was calculated by using Hunter a (redness) and b (yellowness) values. Hunter L (lightness) was recorded. The meter was calibrated on illuminant C (6774K) with a white standard (Minolta calibration white plate) before each use.

Lycopene. The lycopene concentration was measured by the rapid spectrophotometric method of Adsule and Dan (1979) for lycopene estimation in tomato fruit. The lycopene was extracted by shaking 1 g of homogenized tomato sample with 20 mL of acetone for 30 min on an electric shaker having a speed of 135 cycles/min. A 125-mL stoppered

conical flask was used for shaking the samples. The flask was covered with aluminum foil to prevent light-induced lycopene oxidation. The contents of the flask were transferred to a centrifuge tube and centrifuged at 12,000 X g for 10 min. The supernatant was decanted and adjusted to 20 mL with acetone. The absorbency of the extract at 503 nm (wavelength of maximal absorption) was measured with a Shimadzu UV160U UV-Visible Recording Spectrophotometer (Shimadzu Scientific Instruments, Inc., 1993). The quantitative determination of lycopene was calculated using a molecular extinction coefficient of 17.2×10^4 $mol \cdot cm^{-1}$ (Beer and Siddappa, 1959) and expressed as $\mu g/g$ and calculated on the dry weight basis (Gross, 1991).

Microbiological determinations. The dried tomato fruit samples were evaluated for microbial growth. After removal from storage, 25 g of each sample were placed in a sterile plastic bag and 225 mL of peptone water (0.1%) was poured into the bag. Each bag was then shaken in a Stomacher blender for 60 sec to rinse the sample completely. A sterile pipette was used to draw 0.1 mL of diluted sample which was placed in the middle of a pre-poured media (Table 1) petri dish (dried overnight). The sample was then carefully and quickly spread over the surface of the media using a sterile bent glass rod. The petri dish was then quickly covered to prevent cross contamination and placed in an incubator (Table 1). A Leica Quebec Darkfield colony counter (Lieca Inc., Buffalo, NY) was used to enumerate colony count and reported as log CFU/g of dried tomato product. When the

Table 1-Methods for microbial analysis used to determine the storage stability of dried tomato product

Test	Method	Culture Media	Incubation Time (days)	Incubation Temperature
Aerobic Plate Count	Spread Plate	Standard Methods Agar	2	32°C
Yeasts & Molds	Spread Plate	Rose bengal Agar with Chloramphenicol	5	21°C
Lactics	Spread Plate	Modified MRS*	2	32°C

(Speck, 1984)

colony count was <25, the colony count was reported as less than log 2 CFU/g (Busta et al., 1984). The details of the tests conducted are outlined in Table 1.

Firmness. Texture Analyzer TA-XT2 (Texture Technologies Corp., Scarsdale, NY) equipped with attached computer loaded with XTRAD software was used to measure the force required to cut through individual 1 cmwide dried tomato halves. Firmness was measured using a square-ended blade of 3 mm thickness. The parameters were: test speed at 1.7 mm/s; trigger force at 20 g; contact area at 1 mm^2; contact force at 5 g. The sample was placed on the test platform directly under the cutting blade.

The test was run and the results were recorded by the instrument and sent to the attached computer. Using the XTRAD software, area under the curve was calculated which was used to measure the differences among various treatments. The results obtained were the averages of three samples per replication. The experiment was replicated two times.

Sensory evaluation. Sensory evaluation using eight point hedonic scale (1 = dislike extremely; 8 = like extremely) was conducted to evaluate the effects of length of storage on the consumer panel acceptability. A 30-member consumer sensory panel (Larmond, 1987) consisting of faculty, students and staff of the College of Agriculture and Natural Sciences of The University of Tennessee, Knoxville, evaluated the dried tomato product. A majority of panel members had participated in other sensory panels, but none was trained specifically for this test. The sensory attributes of sweetness, color, flavor, texture and overall acceptability were evaluated. The sensory evaluation was conducted after 2.5, 5 and 7.5 mo of storage. Sensory evaluation was conducted under cool-white fluorescent light in the air conditioned sensory laboratory of the Food Science and Technology Department. Using a balanced order of presentations, each panelist was served two samples numbered with three-digit random numbers, one at a time. Sensory evaluation was conducted over 3 da period. Thirty responses per treatment were obtained.

Experimental design and statistical analysis

The experiment consisted of 18 treatment combinations: two sucrose concentrations (40 and 50 °Brix), three package atmospheres (air, nitrogen and partial vacuum) and three storage times (0, 2.5 and 5 mo) with two replications. However, statistical analysis on sensory evaluation data was performed after 2.5, 5 and 7.5 mo of storage. Statistical analysis on the data was performed by the SAS Software (SAS Institute, 1988) at The University of Tennessee Computing Center. The experimental design was a factorial of complete block design (Little and Hills, 1978). The effects of sucrose concentration, package atmosphere and storage times and their interactions were determined on the shelf-life of dried tomato product by General Linear Model (GLM). Significant differences among means were determined at the 5% level of significance by Pdiff option (Steele and Torrie, 1980).

RESULTS AND DISCUSSION

Moisture

Moisture was affected by storage period and the sucrose concentration x storage period interaction. Analysis of variance table and means for the three-way interaction may be found in Appendix D, Table 1. Appendix C, Table 2 presents the raw data.

Fig. 1 presents the moisture content of the samples as affected by the sucrose concentration x storage period interaction. Moisture decreased in the 50 °Brix-treated samples linearly as storage was extended from 0 to 5.0 mo. Samples of the 40 °Brix-treated samples decreased during the 2.5 mo storage but did not change during storage to 5 mo. At the 0 and 2.5 mo storage periods, no differences in moisture content were found between samples of the two sucrose solutions. At 5-mo storage, the moisture content of samples treated in 40 °Brix was higher than that in samples of the 50 °Brix treatment. This finding resulted from the higher soluble solids content of the samples treated in the 40 °Brix solution. It is not possible, at this time, to explain why no differences occurred between the two treatments at 0 and 2.5 mo storage.

Color--Hunter L

Hunter L values of the tomato samples was affected by sucrose concentration and storage period only. Analysis of variance table may be

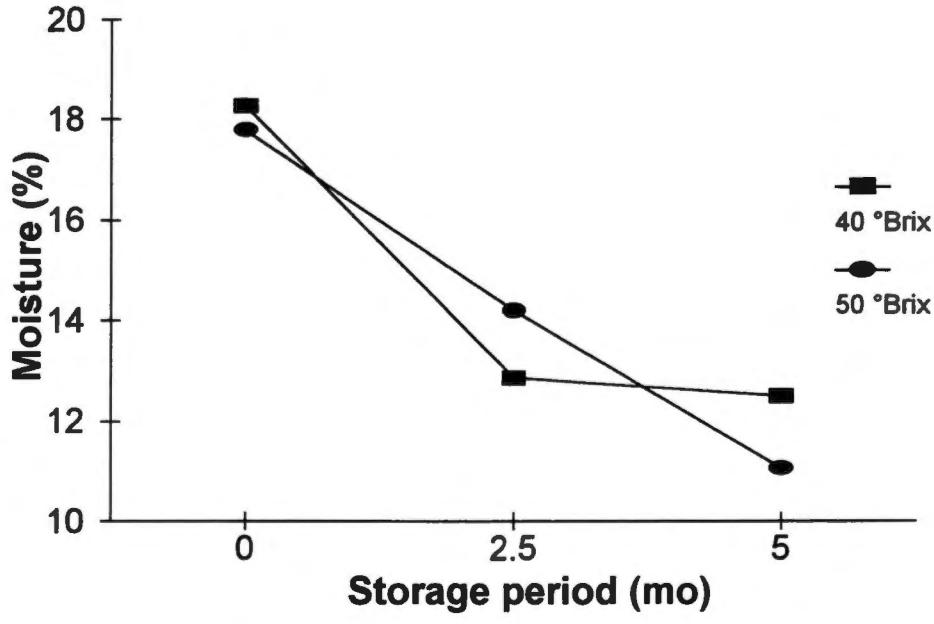

Fig 1 - The effects of the interaction of sucrose concentration x storage period on the moisture content of dried tomato product during the storage.

found in Appendix D, Table 2. Appendix C, Table 1 presents the raw data.

Samples treated in the 50 °Brix solution had a higher Hunter L (lighter) than samples treated in the 40 °Brix solution. During storage, samples tended to become lighter. However, only the sample storage 2.5 mo was significantly lighter (higher Hunter L).

Color--hue-angle

Hue-angle of the samples was affected by the storage period only. Analysis of variance table may be found in Appendix D, Table 3. Appendix C, Table 1 presents the raw data.

The values show that the samples were reddest at the beginning of the storage period. As time advanced, the samples became less red and more yellow with no difference between 2.5 and 5 mo.

Lycopene

Lycopene concentration of the samples was affected by the storage periods x package atmosphere, sucrose concentration x storage period and sucrose concentration x storage period x package atmosphere interactions. None of the main variables had a significant effect. Analysis of variance table and means for the three-way interaction may be found in Appendix D, Table 4. Appendix C, Table 1 presents the raw data.

The three-way interaction for the effects on lycopene is presented in Fig. 2. The major differences appear to exist between samples of the two sucrose treatments. At 40 °Brix, lycopene shows a slight increase as

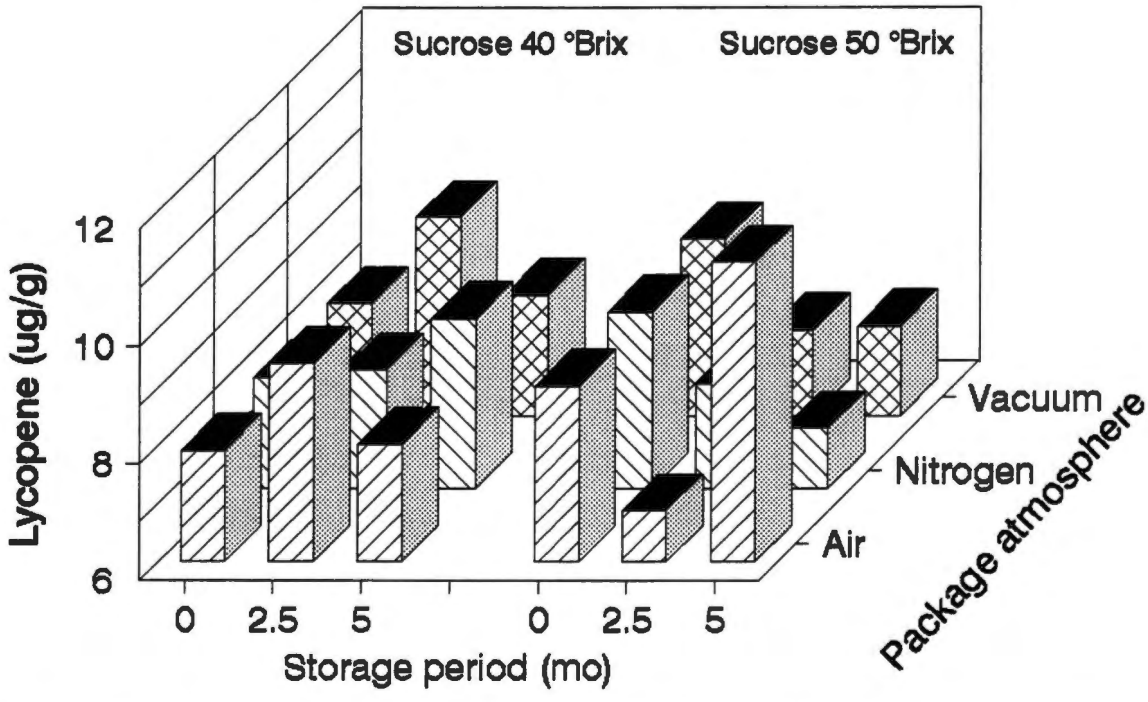

Fig. 2 —The effects of the interaction of sucrose concentration x storage period x package atmosphere on the lycopene content of dried tomato product during 5 mo of storage.

storage period was extended, but at 50 °Brix, lycopene, in general, decreased as time was extended. The package atmosphere seemed to exert no definite effects on the lycopene content.

Firmness

Firmness was affected by sucrose, storage period and the storage period x package atmosphere and sucrose concentration x storage period interactions. Analysis of variance table and means for the three-way interaction may be found in Appendix D, Table 5. Appendix C, Table 2 presents the raw data.

Fig. 3A presents the firmness of samples as affected by the sucrose concentration x storage period interaction. Samples treated in 40 °Brix sucrose solution exhibited a linear increase in firmness during the 5 mo storage. Samples treated in 50 °Brix sucrose solution exhibited a decrease in firmness at 2.5 mo storage and then an increase at 5 mo to show a net increase in firmness across storage. At each storage period, firmness values were difference between samples of the two sucrose treatments.

Fig. 3B presents the firmness of samples as affected by the package atmosphere x storage period interaction. During the 2.5 mo storage, firmness of all samples did not change. However, with an additional 2.5 mo period, firmness increased sharply with the air-flushed packages yielding the softer sample while the nitrogen-flushed and partial vacuumed packages yielded firmer samples, with no differences between the two.

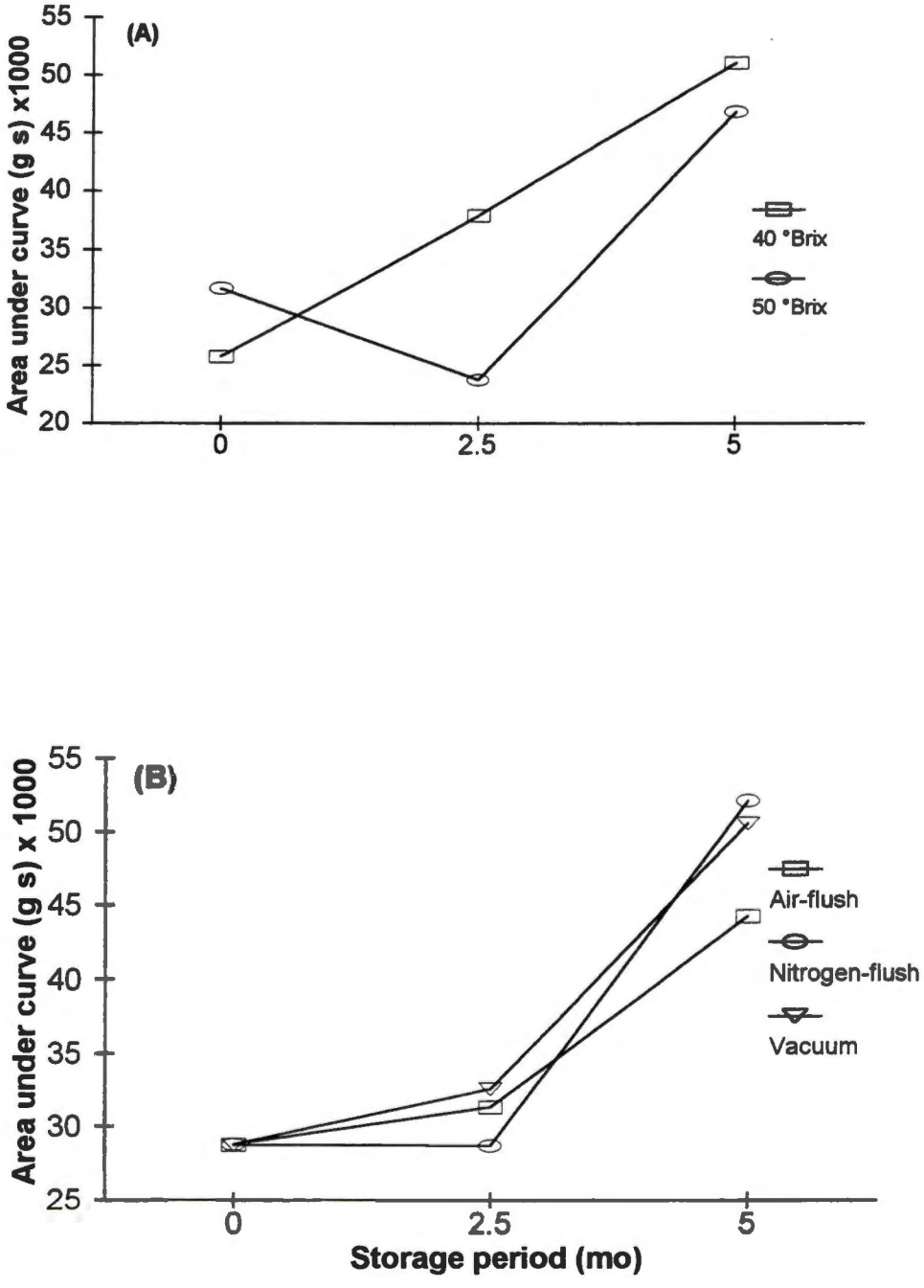

Fig. 3–The effects of the interactions of (A) sucrose concentration x storage period and (B) package atmosphere x storage period on the firmness of dried tomato product during the storage.

Microbiological presence

The aerobic plate count (APC) of the samples was affected by storage period, package atmosphere and the storage period x package atmosphere interaction. Analysis of variance table and means for the three-way interaction may be found in Appendix D, Table 6. Appendix C, Table 2 presents the raw data.

Fig. 4 presents the APC (log CFU/g) of the samples as affected by the storage period x packaging atmosphere interaction. The APC increased significantly on the air-packaged samples, and the increase occurred between 0 and 2.5 mo storage. No change occurred after 2.5 mo. No counts were found for the partial vacuumed and nitrogen-flushed samples. No detectable colonies were observed for yeasts/molds and lactic acid forming bacteria.

Sensory evaluation

Of the five attributes--color, texture, flavor, sweetness and overall acceptability--evaluated by the sensory panel, only hedonic score color was affected by storage period. No difference was found in the panel scores for color between 2.5 and 5.0 mo storage (mean 6.1; liked moderately). After 7.5 mo, the scores for color dropped to a mean 5.6 (midway between liked slightly and liked moderately). Color of the product was liked by an average 92.3% of the panelists during the first 5 mo of storage, but the percentage dropped to 77.1% after 7.5 mo. On average, the percentages of panelists

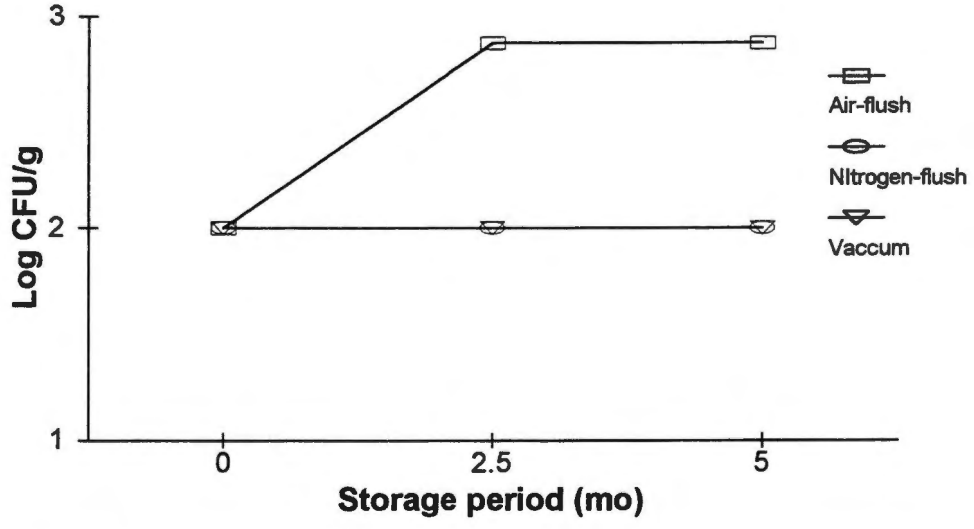

Fig. 4-The effects of the interaction of package atmosphere x storage period on the aerobic plate count of dried tomato product during the storage.

who liked the sweetness, flavor, texture and overall acceptability of the product were 79.4, 77.8, 84.5 and 80.8, respectively. Storage time had no effect on the scores for these attributes. These results indicated that an acceptable and shelf-stable dried tomato product was prepared and stored for up to 5 mo with acceptable quality attributes.

The panel consisted of 41.1% male and 58.6% female members. Among the three storage periods in which samples were evaluated, 88.9% of the panelists were of the age 18 to 44 years. Responses from the panelists indicated that 52.5% ate dried fruit products several times a year; 22.3%, several times a month; 10.8%, several times a week and 2.2%, every day. Those who never ate dried fruit products totaled 12.2%.

In summary, this experiment showed that the dried product could be stored for up to 5 mo. This means that an acceptable product from the stand point of sensory quality and low microbiological contamination can be made available for consumer use.

REFERENCES

Adesina, A.A. and Aina, J.O. 1990. Preservation of African star apple fruits (*Chrysophyllum albidum*) by osmotic dehydration. Tropical Sci. 30: 249-253.

Adsule, P.G. and Dan A. 1979. Simplified extraction procedure in the rapid spectrophotometric method for lycopene estimation in tomato. J. Food Sci. Technol. 16: 216.

Anderson, K. 1991. Other preservation methods. Ch. 7, In: Vegetable Processing, D. Arthey and C. Dennis (Ed.), p. 154-162. VCH Publishers, New York.

AOAC. 1990. Official Methods of Analysis. 15th ed. Assoc. Analytical Chemists, Washington, DC.

Baristain, C.I., Azuara, E., Cortes, R., and Garcia, H.S. 1990. Mass transfer during osmotic dehydration of pineapple rings. Intl. J. Food Sci. Technol. 25: 576-582.

Beer, O.P. and G.S. Siddapa. 1959. A rapid spectrophotometric method for the detection and estimation of adulterants in tomato ketchup. Food Technol. 13: 414-418.

Biswal, R.N. and Bozorgmehr, K. 1990. A model for osmotic dehydration with mixed agents. Paper presented at the 1990 International Winter Meeting, American Society of Agricultural Engineers, Hyatt Regency Chicago, IL. Dec. 18-21, 1990.

Biswal, R.N. and Bozorgmehr, K. 1992. Mass transfer in mixed solute osmotic dehydration of apple rings. Trans. Am. Soc. Agric. Eng. 35: 257-262.

Busta, F.F., Peterson, E.H., Adams, D.M., and Johnson, M.G. 1984. Colony Count Methods. In: Compendium of Methods for the Microbiological Examinations of Foods. M.L. Speck (Ed.), American Public Health Association, Washington, DC.

Forni, E., Polesello, A., and Torreggiani, D. 1993. Changes in anthocyanins in cherries (*Prunus avium*) during osmodehydration, pasteurization and

storage. Food Chem. 48: 295-299.

Gould, W.A. 1983. Tomato Production, Processing and Quality Evaluation. 2nd Ed. AVI Publishing Company, Inc., Westport, CT.

Gross, J. 1991. Pigments in Vegetables: Chlorophyll and Carotenoids. AVI Publishing Co., Inc., Westport, CT.

Hawkes, J. and Flink, J.M. 1978. Osmotic concentration of fruit slices prior to freeze dehydration. J. Food Proc. Preserv. 2: 265-284.

Hough, G., Chirife, J., and Marini, C. 1993. A simple model for osmotic dehydration of apples. Lebensm. -Wiss. U. -Technol. 26: 151-156.

Jayaraman, K.S. and Das Gupta, D.K. 1992. Dehydration of fruits and vegetables - Recent developments in principles and techniques. Drying Technol. 10: 1-50.

Karathanos, V.T. and Kostaropoulos, A.E. 1995. Air-drying kinetics of osmotically dehydrated fruits. Drying Technol. 13: 1503-1521.

Karel, M. 1973. Dehydration of foods. Ch. 10. In: Principles Of Food Science: Part II. Physical Principles Of Food Preservation, M. Karel, O.R. Fennema and D.B. Lund (Ed.), p. 309-357. Marcel Dekker, Inc., New York.

Larmond, E. 1987. Laboratory methods for sensory evaluation of food. Publication #1637/E. Can. Dept. of Agric., Ottawa, Ontario, Canada.

Lerici, C.R., Pinnavaia, G., Dalla Rosa, M., and Bartolucci, L. 1985. Osmotic dehydration of fruit: Influence of osmotic agents on drying behavior and product quality. J. Food Sci. 50: 1217-1219, 1226.

Little, T.M. and Hills, F.J. 1978. Agricultural Experimentation: Design and Analysis. John Wiley and Sons, New York.

Maltini, E., Torreggiani, D., Brovetto, B.R., and Bertolo, G. 1993. Functional properties of reduced moisture fruits as ingredients in food systems. Food Res. Intl. 26: 413-419.

Minolta. 1994. Operator's manual for Minolta CM-508D Spectrometer. Minolta Corp., Ramsey, NJ.

Ponting, J.D. 1973. Osmotic dehydration of fruits. Recent modifications and applications. Process Biochem. 8: 18-20.

Ponting, J.D., Waters, G.G., Forrey, R.R., Jackson, R., and Stanley, W.L. 1966. Osmotic dehydration of fruits. Food Technol. 20: 125-128.

Robertson, G.L. 1993. Food Packaging. Marcel Dekker, Inc. New York.

SAS Institute. 1988. SAS Procedure Guide, Release 6.03 ed. SAS Institute Inc., Cary, NC.

Shimadzu Scientific Instrumentals. 1993. Instruction Manual for Shimadzu UV160U UV-Visible Recording Spectrophotometer. Shimadzu Scientific Instrumentals Inc., Columbia, MD.

Silveira, E.T.F., Rahman, M.S., and Buckle, K.A. 1996. Osmotic dehydration of pineapple: kinetics and product quality. Food Res. Intl. 29: 227-233.

Speck, M.L. 1984. Compendium of Methods for the Microbiological Examinations of Foods. American Public Health Association, Washington, DC.

Stafford A. E. and Guadagni, D. E. 1977. Storage stability of raisins dried by different procedures. J. Food Sci. 42: 547-548.

Steele, R.G. and Torrie, J.H. 1980. Principles and Procedures of Statistics. McGraw-Hill Inc., New York.

Torreggiani, D. 1993. Osmotic dehydration in fruit and vegetable processing. Food Res. Intl. 26: 59-68.

Torreggiani, D., Forni, F., and Rizzolo, A. 1987. Osmosis dehydration of fruit. Part II. Influence of the osmosis time on the stability of processed cherries. J. Food Proc. Pres. 12: 21-44.

Uzuegbu, J.O. and and Ukeka, C. 1987. Osmotic dehydration as a method of preserving fruits to minimize ascorbic acid loss. J. Food Agric. 1: 187-188.

APPENDICES

APPENDIX A

PART III: RAW DATA AND MEANS

Table 1- Net weight loss, moisture loss and solids weight gain data with means obtained during the osmotic concentration of peeled tomato flesh

Treatment[1]	Net weight loss (%)		Moisture loss (%)		Solids weight loss (%)	
	Data	Mean	Data	Mean	Data	Mean
40-30-2-1	31.21		43.42		94.04	
40-30-2-2	32.72	31.97	46.45	44.94	103.02	98.53
40-30-3-1	40.87		51.53		129.85	
40-30-3-2	42.06	41.47	51.60	51.57	136.23	133.04
40-30-4-1	45.89		59.64		155.62	
40-30-4-2	45.64	45.77	61.25	60.45	147.87	151.75
40-40-2-1	41.62		54.42		134.48	
40-40-2-2	43.05	42.34	56.75	55.59	127.48	130.98
40-40-3-1	48.38		60.81		142.93	
40-40-3-2	48.46	48.42	61.38	61.10	143.32	143.13
40-40-4-1	51.27		64.49		169.81	
40-40-4-2	49.23	50.25	62.85	63.67	196.44	183.13
40-50-2-1	46.39		59.82		186.37	
40-50-2-2	48.10	47.25	61.44	60.63	163.86	175.12
40-50-3-1	52.50		65.32		178.59	
40-50-3-2	48.74	50.62	61.49	63.41	203.36	190.98
40-50-4-1	51.88		64.55		180.76	
40-50-4-2	52.78	52.33	66.08	65.32	201.41	191.09
50-30-2-1	43.31		54.30		120.10	
50-30-2-2	42.36	42.84	51.66	52.98	158.56	139.33
50-30-3-1	46.38		62.81		132.15	
50-30-3-2	46.22	46.30	60.32	61.57	137.56	134.86
50-30-4-1	48.60		64.94		151.34	
50-30-4-2	48.44	48.52	64.68	64.81	140.53	145.94
50-40-2-1	48.82		62.20		137.99	
50-40-2-2	48.49	48.66	58.88	60.54	132.70	135.35
50-40-3-1	52.77		65.61		139.73	
50-40-3-2	50.60	51.69	66.51	66.06	142.35	141.04
50-40-4-1	56.70		70.48		164.21	
50-40-4-2	56.99	56.85	70.84	70.66	167.64	165.93
50-50-2-1	53.56		68.00		145.15	
50-50-2-2	54.60	54.08	68.91	68.46	150.96	148.06
50-50-3-1	59 24		74.73		149.00	
50-50-3-2	59.99	59.62	73.23	73.98	163.15	156.08
50-50-4-1	57.18		71.92		160.70	
50-50-4-2	61.98	59.58	75.38	73.65	161.85	161.28

[1]Treatments notation indicates sucrose concentration - solution temperature - contact time - replication.

Table 2- Hunter L, a, b, hue-angle and lycopene of dried tomato product data with means

	HUNTER L		HUNTER a		HUNTER b		Hue-angle		Lycopene	
Treatment[1]	Data	Mean	Data	Mean	Data	Mean	Data	Mean	Data	Mean
40-30-2-1	28.88		24.07		9.60		38.00		4.81	
40-30-2-2	28.88	28.88	24.07	24.07	9.60	9.60	38.00	38.00	4.94	4.88
40-30-3-1	29.06		27.54		10.13		35.20		4.48	
40-30-3-2	29.06	29.06	27.54	27.54	10.13	10.13	35.20	35.20	4.88	4.68
40-30-4-1	27.03		25.00		8.50		32.80		4.41	
40-30-4-2	27.03	27.03	25.00	25.00	8.50	8.50	32.80	32.80	4.28	4.35
40-40-2-1	29.27		26.45		9.84		35.60		4.41	
40-40-2-2	29.27	29.27	26.45	26.45	9.84	9.84	35.60	35.60	4.57	4.49
40-40-3-1	25.33		22.89		8.08		33.90		6.50	
40-40-3-2	25.33	25.33	22.89	22.89	8.08	8.08	33.90	33.90	6.39	6.44
40-40-4-1	25.92		22.87		7.82		32.90		5.06	
40-40-4-2	25.92	25.92	22.87	22.87	7.82	7.82	32.90	32.90	5.21	5.14
40-50-2-1	31.00		25.98		10.01		36.80		4.81	
40-50-2-2	31.00	31.00	25.98	25.98	10.01	10.01	36.80	36.80	3.88	4.34
40-50-3-1	29.55		26.20		9.98		36.40		3.65	
40-50-3-2	28.33	28.94	20.03	23.12	7.25	8.62	34.70	35.55	3.95	3.80
40-50-4-1	27.30		23.12		8.56		35.50		4.30	
40-50-4-2	27.30	27.30	23.12	23.12	8.56	8.56	35.50	35.50	4.13	4.22
50-30-2-1	26.81		23.68		8.51		34.50		4.80	
50-30-2-2	26.81	26.81	23.68	23.68	8.51	8.51	34.50	34.50	4.90	4.85
50-30-3-1	26.55		24.77		8.07		31.50		3.59	
50-30-3-2	26.55	26.55	24.77	24.77	8.07	8.07	31.50	31.50	3.61	3.60
50-30-4-1	27.91		24.21		8.76		34.70		3.05	
50-30-4-2	27.91	27.91	24.21	24.21	8.76	8.76	34.70	34.70	3.13	3.09
50-40-2-1	26.95		28.56		10.78		36.10		3.95	
50-40-2-2	30.09	28.52	27.38	27.97	10.48	10.63	36.60	36.35	4.08	4.02
50-40-3-1	28.22		25.41		9.51		35.80		4.56	
50-40-3-2	28.22	28.22	25.41	25.41	9.51	9.51	35.80	35.80	5.05	4.80
50-40-4-1	31.31		25.06		11.12		41.80		4.63	
50-40-4-2	31.31	31.31	25.06	25.06	11.12	11.12	41.80	41.80	4.55	4.59
50-50-2-1	25.96		22.66		8.27		35.00		5.83	
50-50-2-2	25.96	25.96	22.66	22.66	8.27	8.27	35.00	35.00	5.50	5.66
50-50-3-1	27.94		25.43		9.59		36.10		3.68	
50-50-3-2	27.94	27.94	25.43	25.43	9.59	9.59	36.10	36.10	3.78	3.73
50-50-4-1	23.78		21.23		8.32		37.40		3.83	
50-50-4-2	26.03	24.90	21.95	21.59	7.56	7.94	33.20	35.30	3.61	3.72

[1]Treatments notation indicates sucrose concentration - solution temperature - contact time - replication.

Table 3- Data with means of pH, titratable acidity, soluble solids and water activity of dried tomato product

	pH		Titratable acidity		Soluble Solids		Water Activity	
Treatment[1]	Data	Mean	Data	Mean	Data	Mean	Data	Mean
40-30-2-1	3.8		0.023		77.50		0.65	
40-30-2-2	3.8	3.8	0.024	0.024	75.00	76.25	0.65	0.65
40-30-3-1	3.7		0.022		72.50		0.62	
40-30-3-2	3.7	3.7	0.022	0.022	75.00	73.75	0.62	0.62
40-30-4-1	3.4		0.019		75.00		0.62	
40-30-4-2	3.4	3.4	0.020	0.020	75.00	75.00	0.62	0.62
40-40-2-1	3.4		0.021		72.00		0.67	
40-40-2-2	3.4	3.4	0.020	0.020	70.00	71.00	0.67	0.67
40-40-3-1	3.5		0.021		72.50		0.66	
40-40-3-2	3.5	3.5	0.021	0.021	72.50	72.50	0.65	0.65
40-40-4-1	3.2		0.021		75.00		0.62	
40-40-4-2	3.2	3.2	0.020	0.020	70.00	72.50	0.62	0.62
40-50-2-1	3.3		0.020		72.50		0.65	
40-50-2-2	3.3	3.3	0.020	0.020	72.50	72.50	0.64	0.65
40-50-3-1	3.1		0.018		72.50		0.63	
40-50-3-2	3.1	3.1	0.018	0.018	75.00	73.75	0.62	0.62
40-50-4-1	3.2		0.018		77.50		0.57	
40-50-4-2	3.2	3.2	0.018	0.018	77.50	77.50	0.58	0.57
50-30-2-1	3.8		0.020		72.50		0.70	
50-30-2-2	3.8	3.8	0.020	0.020	72.50	72.50	0.69	0.69
50-30-3-1	3.5		0.018		77.50		0.66	
50-30-3-2	3.5	3.5	0.018	0.018	75.00	76.25	0.66	0.66
50-30-4-1	3.5		0.017		75.00		0.61	
50-30-4-2	3.5	3.5	0.017	0.017	72.50	73.75	0.61	0.61
50-40-2-1	3.45		0.019		77.50		0.66	
50-40-2-2	3.45	3.45	0.018	0.018	75.00	76.25	0.66	0.66
50-40-3-1	3.6		0.018		75.00		0.64	
50-40-3-2	3.6	3.6	0.019	0.018	72.50	73.75	0.66	0.65
50-40-4-1	3.5		0.019		72.50		0.58	
50-40-4-2	3.5	3.5	0.019	0.019	72.50	72.50	0.57	0.58
50-50-2-1	3.4		0.017		72.50		0.64	
50-50-2-2	3.4	3.4	0.017	0.017	72.50	72.50	0.64	0.64
50-50-3-1	3.4		0.016		75.00		0.64	
50-50-3-2	3.4	3.4	0.016	0.016	75.00	75.00	0.64	0.64
50-50-4-1	3.2		0.015		72.50		0.65	
50-50-4-2	3.2	3.2	0.014	0.014	72.50	72.50	0.63	0.64

[1]Treatments notation indicates sucrose concentration - solution temperature - contact time - replication.

APPENDIX B

PART III: OUTPUT OF ANALYSIS OF VARIANCE TABLE AND MEAN SEPARATION WITH LSD METHOD

Table 1-Analysis of variance and LSD for mean separation of moisture loss of fresh tomato tissue during osmotic concentration

A. Analysis of variance table of moisture loss

Source[1]	DF	Type III SS	Mean Square	F Value	Pr > F
SUCROSE	1	484.80700	484.80700	205.85	0.0001
TEMP	2	806.71055	403.35527	171.26	0.0001
SUCROSE*TEMP	2	16.16514	8.08257	3.43	0.0560
TIME	2	522.36245	261.18122	110.90	0.0001
SUCROSE*TIME	2	6.41577	3.20789	1.36	0.2827
TEMP*TIME	4	77.48815	19.37204	8.23	0.0007
SUCROSE*TEMP*TIME	4	16.98416	4.24604	1.80	0.1748

[1]Sucrose = Sucrose concentration of osmotic solution (°Brix),
Temperature = osmotic solution temperature (°C),
Time = Pieces held in heated osmotic solution (hr)

B. LSD for means separation of dependent variable:moisture loss

SUCROSE (°Brix)	TEMP (°C)	TIME (hr)	ML LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	LSMEAN LetGrp
40	30	2	44.9350000	1.0851707	0.0001	
40	30	3	51.5650000	1.0851707	0.0001	
40	30	4	60.4450000	1.0851707	0.0001	
40	40	2	55.5850000	1.0851707	0.0001	
40	40	3	61.0950000	1.0851707	0.0001	
40	40	4	63.6700000	1.0851707	0.0001	
40	50	2	60.6300000	1.0851707	0.0001	
40	50	3	63.4050000	1.0851707	0.0001	
40	50	4	65.3150000	1.0851707	0.0001	
50	30	2	52.9800000	1.0851707	0.0001	
50	30	3	61.5650000	1.0851707	0.0001	
50	30	4	64.8100000	1.0851707	0.0001	
50	40	2	60.5400000	1.0851707	0.0001	
50	40	3	66.0600000	1.0851707	0.0001	
50	40	4	70.6600000	1.0851707	0.0001	
50	50	2	68.4550000	1.0851707	0.0001	
50	50	3	73.9800000	1.0851707	0.0001	
50	50	4	73.6500000	1.0851707	0.0001	

Table 2-Analysis of variance and LSD for mean separation of net weight loss of fresh tomato tissue during osmotic concentration

A. Analysis of variance table of net weight loss

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SUCROSE	1	370.17760	370.17760	218.71	0.0001
TEMP	2	754.03316	377.01658	222.75	0.0001
SUCROSE*TEMP	2	8.23920	4.11960	2.43	0.1176
TIME	2	369.23277	184.61639	109.08	0.0001
SUCROSE*TIME	2	11.48895	5.74447	3.39	0.0575
TEMP*TIME	4	22.70628	5.67657	3.35	0.0338
SUCROSE*TEMP*TIME	4	33.50480	8.37620	4.95	0.0079

[1]Sucrose = Sucrose concentration of osmotic solution (°Brix),
Temperature = osmotic solution temperature (°C),
Time = Pieces held in heated osmotic solution (hr)

B. LSD for means separation of dependent variable:net weight loss

SUCROSE (°Brix)	TEMP (°C)	TIME (hr)	NWL LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	LSMEAN LetGrp
40	30	2	31.9650000	0.9199316	0.0001	H
40	30	3	41.4650000	0.9199316	0.0001	G
40	30	4	45.7650000	0.9199316	0.0001	F
40	40	2	42.3350000	0.9199316	0.0001	G
40	40	3	48.4200000	0.9199316	0.0001	E
40	40	4	50.2500000	0.9199316	0.0001	DE
40	50	2	47.2450000	0.9199316	0.0001	E
40	50	3	50.6200000	0.9199316	0.0001	D
40	50	4	52.3300000	0.9199316	0.0001	C
50	30	2	42.8350000	0.9199316	0.0001	G
50	30	3	46.3000000	0.9199316	0.0001	EF
50	30	4	48.5200000	0.9199316	0.0001	E
50	40	2	48.6550000	0.9199316	0.0001	E
50	40	3	51.6850000	0.9199316	0.0001	CD
50	40	4	56.8450000	0.9199316	0.0001	B
50	50	2	54.0800000	0.9199316	0.0001	C
50	50	3	59.6150000	0.9199316	0.0001	A
50	50	4	59.5800000	0.9199316	0.0001	AB

Table 3-Analysis of variance and LSD for mean separation of solids weight gain of fresh tomato tissue during osmotic concentration

A. Analysis of variance table of solids weight gain

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SUCROSE	1	542.6570	542.6570	4.89	0.0411
TEMP	2	8044.3937	4022.1969	36.22	0.0001
SUCROSE*TEMP	2	2790.3254	1395.1627	12.56	0.0004
TIME	2	4959.7434	2479.8717	22.33	0.0001
SUCROSE*TIME	2	908.9004	454.4502	4.09	0.0354
TEMP*TIME	4	1103.5702	275.8926	2.48	0.0827
SUCROSE*TEMP*TIME	4	617.9376	154.4844	1.39	0.2789

[1]Sucrose = Sucrose concentration of osmotic solution (°Brix),
Temperature = osmotic solution temperature (°C),
Time = Pieces held in heated osmotic solution (hr)

B. LSD for means separation of dependent variable:solids weight gain

SUCROSE (°Brix)	TEMP (°C)	TIME (hr)	SWG LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	LSMEAN LetGrp
40	30	2	98.530000	7.451418	0.0001	
40	30	3	133.040000	7.451418	0.0001	
40	30	4	151.745000	7.451418	0.0001	
40	40	2	130.980000	7.451418	0.0001	
40	40	3	143.125000	7.451418	0.0001	
40	40	4	183.125000	7.451418	0.0001	
40	50	2	175.115000	7.451418	0.0001	
40	50	3	190.975000	7.451418	0.0001	
40	50	4	191.085000	7.451418	0.0001	
50	30	2	139.330000	7.451418	0.0001	
50	30	3	134.855000	7.451418	0.0001	
50	30	4	145.935000	7.451418	0.0001	
50	40	2	135.345000	7.451418	0.0001	
50	40	3	141.040000	7.451418	0.0001	
50	40	4	165.925000	7.451418	0.0001	
50	50	2	148.055000	7.451418	0.0001	
50	50	3	156.075000	7.451418	0.0001	
50	50	4	161.275000	7.451418	0.0001	

Table 4-Analysis of variance and LSD for mean separation of Hunter L of dried tomato product

A. Analysis of variance table of Hunter L

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SUCROSE	1	1.805507	1.805507	4.16	0.0541
TEMP	2	1.338589	0.669294	1.54	0.2369
SUCROSE*TEMP	2	48.530309	24.265154	55.97	0.0001
TIME	2	6.638568	3.319284	7.66	0.0032
SUCROSE*TIME	2	24.717904	12.358952	28.51	0.0001
TEMP*TIME	4	20.184405	5.046101	11.64	0.0001
SUCROSE*TEMP*TIME	4	13.777796	3.444449	7.94	0.0005

[1]Sucrose = Sucrose concentration of osmotic solution (°Brix),
Temperature = osmotic solution temperature (°C),
Time = Pieces held in heated osmotic solution (hr)

B. LSD for means separation of dependent variable: Hunter L

SUCROSE (°Brix)	TEMP (°C)	TIME (hr)	HUNTER L LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	LSMEAN LetGrp
40	30	2	28.4700000	0.3292265	0.0001	B
40	30	3	29.0600000	0.4655965	0.0001	C
40	30	4	27.0300000	0.4655965	0.0001	C
40	40	2	29.2700000	0.4655965	0.0001	B
40	40	3	25.3300000	0.4655965	0.0001	D
40	40	4	25.6425000	0.3292265	0.0001	D
40	50	2	31.0000000	0.4655965	0.0001	A
40	50	3	28.9400000	0.4655965	0.0001	B
40	50	4	27.3000000	0.4655965	0.0001	C
50	30	2	26.8100000	0.4655965	0.0001	C
50	30	3	26.5500000	0.4655965	0.0001	C
50	30	4	27.9100000	0.4655965	0.0001	BC
50	40	2	28.5200000	0.4655965	0.0001	B
50	40	3	28.2200000	0.4655965	0.0001	B
50	40	4	31.3100000	0.4655965	0.0001	A
50	50	2	25.9600000	0.4655965	0.0001	CD
50	50	3	27.9400000	0.4655965	0.0001	B
50	50	4	24.9050000	0.4655965	0.0001	D

Table 5-Analysis of variance and LSD for mean separation of hue-angle of dried tomato product

A. Analysis of variance table of hue-angle

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SUCROSE	1	6.183824	6.183824	4.55	0.0449
TEMP	2	23.995377	11.997688	8.82	0.0017
SUCROSE*TEMP	2	53.654597	26.827299	19.73	0.0001
TIME	2	7.504104	3.752052	2.76	0.0863
SUCROSE*TIME	2	43.576104	21.788052	16.02	0.0001
TEMP*TIME	4	13.487713	3.371928	2.48	0.0752
SUCROSE*TEMP*TIME	4	27.928661	6.982165	5.13	0.0048

[1]Sucrose = Sucrose concentration of osmotic solution (°Brix),
Temperature = osmotic solution temperature (°C),
Time = Pieces held in heated osmotic solution (hr)

B. LSD for means separation of dependent variable: hue-angle

SUCROSE (°Brix)	TEMP (°C)	TIME (hr)	HUE-ANGLE LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	LSMEAN LetGrp
40	30	2	36.3000000	0.5830544	0.0001	B
40	30	3	35.2000000	0.8245634	0.0001	B
40	30	4	32.8000000	0.8245634	0.0001	C
40	40	2	35.6000000	0.8245634	0.0001	B
40	40	3	33.9000000	0.8245634	0.0001	C
40	40	4	32.1500000	0.5830544	0.0001	C
40	50	2	36.8000000	0.8245634	0.0001	B
40	50	3	35.5500000	0.8245634	0.0001	B
40	50	4	35.5000000	0.8245634	0.0001	B
50	30	2	34.5000000	0.8245634	0.0001	BC
50	30	3	31.5000000	0.8245634	0.0001	C
50	30	4	34.7000000	0.8245634	0.0001	B
50	40	2	36.3500000	0.8245634	0.0001	B
50	40	3	35.8000000	0.8245634	0.0001	B
50	40	4	41.8000000	0.8245634	0.0001	A
50	50	2	35.0000000	0.8245634	0.0001	B
50	50	3	36.1000000	0.8245634	0.0001	B
50	50	4	35.3000000	0.8245634	0.0001	B

Table 6-Analysis of variance and LSD for mean separation of lycopene content of dried tomato product

A. Analysis of variance table of lycopene

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SUCROSE	1	1.6544118	1.6544118	23.22	0.0001
TEMP	2	3.9739384	1.9869692	27.89	0.0001
SUCROSE*TEMP	2	2.1156642	1.0578321	14.85	0.0001
TIME	2	1.6574623	0.8287312	11.63	0.0004
SUCROSE*TIME	2	3.2358436	1.6179218	22.71	0.0001
TEMP*TIME	4	7.8423308	1.9605827	27.52	0.0001
SUCROSE*TEMP*TIME	4	1.4371365	0.3592841	5.04	0.0052

[1]Sucrose = Sucrose concentration of osmotic solution (°Brix),
Temperature = osmotic solution temperature (°C),
Time = Pieces held in heated osmotic solution (hr)

B. LSD for means separation of dependent variable: lycopene

SUCROSE (°Brix)	TEMP (°C)	TIME (hr)	LYCOPENE LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	LSMEAN LetGrp
40	30	2	4.51000000	0.13345801	0.0001	C
40	30	3	4.68000000	0.18873813	0.0001	C
40	30	4	4.34500000	0.18873813	0.0001	C
40	40	2	4.49000000	0.18873813	0.0001	C
40	40	3	6.44500000	0.18873813	0.0001	A
40	40	4	4.98500000	0.13345801	0.0001	C
40	50	2	4.34500000	0.18873813	0.0001	C
40	50	3	3.80000000	0.18873813	0.0001	D
40	50	4	4.21500000	0.18873813	0.0001	CD
50	30	2	4.85000000	0.18873813	0.0001	C
50	30	3	3.60000000	0.18873813	0.0001	D
50	30	4	3.09000000	0.18873813	0.0001	E
50	40	2	4.01500000	0.18873813	0.0001	D
50	40	3	4.80500000	0.18873813	0.0001	C
50	40	4	4.59000000	0.18873813	0.0001	C
50	50	2	5.66500000	0.18873813	0.0001	B
50	50	3	3.73000000	0.18873813	0.0001	D
50	50	4	3.72000000	0.18873813	0.0001	D

Table 7-Analysis of variance and LSD for mean separation of pH of dried tomato product

A. Analysis of variance table of pH

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SUCROSE	1	0.0618382	0.0618382	39.96	0.0001
TEMP	2	0.7316039	0.3658019	236.36	0.0001
SUCROSE*TEMP	2	0.0457338	0.0228669	14.78	0.0001
TIME	2	0.2013442	0.1006721	65.05	0.0001
SUCROSE*TIME	2	0.0037338	0.0018669	1.21	0.3192
TEMP*TIME	4	0.1421139	0.0355285	22.96	0.0001
SUCROSE*TEMP*TIME	4	0.1145088	0.0286272	18.50	0.0001

[1]Sucrose = Sucrose concentration of osmotic solution (°Brix),
Temperature = osmotic solution temperature (°C),
Time = Pieces held in heated osmotic solution (hr)

B. LSD for means separation of dependent variable:pH

SUCROSE (°Brix)	TEMP (°C)	TIME (hr)	pH LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	LSMEAN LetGrp
40	30	2	3.75000000	0.01966989	0.0001	AB
40	30	3	3.70000000	0.02781743	0.0001	B
40	30	4	3.40000000	0.02781743	0.0001	E
40	40	2	3.40000000	0.02781743	0.0001	E
40	40	3	3.50000000	0.02781743	0.0001	D
40	40	4	3.27500000	0.01966989	0.0001	F
40	50	2	3.30000000	0.02781743	0.0001	E
40	50	3	3.10000000	0.02781743	0.0001	H
40	50	4	3.20000000	0.02781743	0.0001	G
50	30	2	3.80000000	0.02781743	0.0001	A
50	30	3	3.50000000	0.02781743	0.0001	D
50	30	4	3.50000000	0.02781743	0.0001	D
50	40	2	3.45000000	0.02781743	0.0001	D
50	40	3	3.60000000	0.02781743	0.0001	C
50	40	4	3.50000000	0.02781743	0.0001	D
50	50	2	3.40000000	0.02781743	0.0001	E
50	50	3	3.40000000	0.02781743	0.0001	E
50	50	4	3.20000000	0.02781743	0.0001	F

Table 8-Analysis of variance and LSD for mean separation of titratable acidity of dried tomato product

A. Analysis of variance table of titratable acidity

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SUCROSE	1	0.0000678	0.0000678	269.77	0.0001
TEMP	2	0.0000543	0.0000271	108.07	0.0001
SUCROSE*TEMP	2	0.0000038	0.0000019	7.58	0.0033
TIME	2	0.0000241	0.0000120	47.89	0.0001
SUCROSE*TIME	2	0.0000005	0.0000003	1.07	0.3609
TEMP*TIME	4	0.0000147	0.0000037	14.60	0.0001
SUCROSE*TEMP*TIME	4	0.0000031	0.0000008	3.06	0.0394

[1]Sucrose = Sucrose concentration of osmotic solution (°Brix),
Temperature = osmotic solution temperature (°C),
Time = Pieces held in heated osmotic solution (hr)

B. LSD for means separation of dependent variable:titratable acidity

SUCROSE (°Brix)	TEMP (°C)	TIME (hr)	TA LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	LSMEAN LetGrp
40	30	2	0.02350000	0.00025059	0.0001	A
40	30	3	0.02200000	0.00035439	0.0001	B
40	30	4	0.01950000	0.00035439	0.0001	C
40	40	2	0.02050000	0.00035439	0.0001	C
40	40	3	0.02100000	0.00035439	0.0001	BC
40	40	4	0.02000000	0.00025059	0.0001	C
40	50	2	0.02000000	0.00035439	0.0001	C
40	50	3	0.01800000	0.00035439	0.0001	D
40	50	4	0.01800000	0.00035439	0.0001	D
50	30	2	0.02000000	0.00035439	0.0001	C
50	30	3	0.01800000	0.00035439	0.0001	D
50	30	4	0.01700000	0.00035439	0.0001	E
50	40	2	0.01850000	0.00035439	0.0001	D
50	40	3	0.01850000	0.00035439	0.0001	D
50	40	4	0.01900000	0.00035439	0.0001	CD
50	50	2	0.01700000	0.00035439	0.0001	E
50	50	3	0.01600000	0.00035439	0.0001	E
50	50	4	0.01450000	0.00035439	0.0001	F

Table 9-Analysis of variance and LSD for mean separation of soluble solids of dried tomato product

A. Analysis of variance table of soluble solids

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SUCROSE	1	0.264706	0.264706	0.13	0.7201
TEMP	2	11.352597	5.676299	2.83	0.0817
SUCROSE*TEMP	2	20.209740	10.104870	5.03	0.0164
TIME	2	5.323377	2.661688	1.33	0.2868
SUCROSE*TIME	2	25.141558	12.570779	6.26	0.0074
TEMP*TIME	4	14.824291	3.706073	1.85	0.1576
SUCROSE*TEMP*TIME	4	29.091153	7.272788	3.62	0.0214

[1]Sucrose = Sucrose concentration of osmotic solution (°Brix),
Temperature = osmotic solution temperature (°C),
Time = Pieces held in heated osmotic solution (hr)

B. LSD for means separation of dependent variable:soluble solids

SUCROSE (°Brix)	TEMP (°C)	TIME (hr)	SOLIDS LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	LSMEAN LetGrp
40	30	2	75.0000000	0.7083683	0.0001	A
40	30	3	73.7500000	1.0017841	0.0001	B
40	30	4	75.0000000	1.0017841	0.0001	AB
40	40	2	71.0000000	1.0017841	0.0001	B
40	40	3	72.5000000	1.0017841	0.0001	B
40	40	4	72.5000000	0.7083683	0.0001	B
40	50	2	72.5000000	1.0017841	0.0001	B
40	50	3	73.7500000	1.0017841	0.0001	B
40	50	4	77.5000000	1.0017841	0.0001	A
50	30	2	72.5000000	1.0017841	0.0001	B
50	30	3	76.2500000	1.0017841	0.0001	A
50	30	4	73.7500000	1.0017841	0.0001	B
50	40	2	76.2500000	1.0017841	0.0001	A
50	40	3	73.7500000	1.0017841	0.0001	B
50	40	4	72.5000000	1.0017841	0.0001	B
50	50	2	72.5000000	1.0017841	0.0001	B
50	50	3	75.0000000	1.0017841	0.0001	A
50	50	4	72.5000000	1.0017841	0.0001	B

Table 10-Analysis of variance and LSD for mean separation of water activity of dried tomato product

A. Analysis of variance table of water activity

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SUCROSE	1	0.0010780	0.0010780	58.32	0.0001
TEMP	2	0.0012597	0.0006299	34.07	0.0001
SUCROSE*TEMP	2	0.0040444	0.0020222	109.39	0.0001
TIME	2	0.0177629	0.0088814	480.46	0.0001
SUCROSE*TIME	2	0.0002996	0.0001498	8.10	0.0034
TEMP*TIME	4	0.0015656	0.0003914	21.17	0.0001
SUCROSE*TEMP*TIME	4	0.0051443	0.0012861	69.57	0.0001

[1]Sucrose = Sucrose concentration of osmotic solution (°Brix),
Temperature = osmotic solution temperature (°C),
Time = Pieces held in heated osmotic solution (hr)

B. LSD for means separation of dependent variable:water activity

SUCROSE (°Brix)	TEMP (°C)	TIME (hr)	aW LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	LSMEAN LetGrp
40	30	2	0.64650000	0.00304017	0.0001	D
40	30	3	0.62050000	0.00304017	0.0001	F
40	30	4	0.61850000	0.00304017	0.0001	F
40	40	2	0.67200000	0.00304017	0.0001	B
40	40	3	0.65350000	0.00304017	0.0001	C
40	40	4	0.62050000	0.00304017	0.0001	F
40	50	2	0.64800000	0.00304017	0.0001	D
40	50	3	0.62500000	0.00304017	0.0001	F
40	50	4	0.57500000	0.00304017	0.0001	H
50	30	2	0.69450000	0.00304017	0.0001	A
50	30	3	0.66150000	0.00304017	0.0001	C
50	30	4	0.61100000	0.00304017	0.0001	G
50	40	2	0.66100000	0.00304017	0.0001	C
50	40	3	0.65100000	0.00304017	0.0001	D
50	40	4	0.57700000	0.00304017	0.0001	H
50	50	2	0.64050000	0.00304017	0.0001	E
50	50	3	0.64200000	0.00304017	0.0001	D
50	50	4	0.63950000	0.00304017	0.0001	E

Table 11-Analysis of variance of color of dried tomato product sensory data

Source	DF	Type III SS	Mean Square	F Value	Pr > F
JUDGE	40	162.83023	4.07076	2.73	0.0001
TRT[1]	17	30.61736	1.80102	1.21	0.2509
REP	1	0.32001	0.32001	0.21	0.6432
REP*TRT	1	0.16578	0.16578	0.11	0.7388

[1]Treatments: 40 or 50°Brix sucrose solution held at 30, 40 or 50°C for 2, 3 or 4 hr.

Table 12-Analysis of variance of texture of dried tomato product sensory data

Source	DF	Type III SS	Mean Square	F Value	Pr > F
JUDGE	40	178.04768	4.45119	2.29	0.0001
TRT	17	42.88432	2.52261	1.30	0.1877
REP	1	3.79772	3.79772	1.95	0.1630
REP*TRT	1	0.04197	0.04197	0.02	0.8833

[1]Treatments: 40 or 50°Brix sucrose solution held at 30, 40 or 50°C for 2, 3 or 4 hr.

Table 13-Analysis of variance of flavor of dried tomato product sensory data

Source	DF	Type III SS	Mean Square	F Value	Pr > F
JUDGE	40	235.57516	5.88938	2.90	0.0001
TRT	17	35.68792	2.09929	1.03	0.4170
REP	1	0.00631	0.00631	0.00	0.9555
REP*TRT	1	0.50873	0.50873	0.25	0.6167

[1]Treatments: 40 or 50°Brix sucrose solution held at 30, 40 or 50°C for 2, 3 or 4 hr.

Table 14-Analysis of variance of sweetness of dried tomato product sensory data

Source	DF	Type III SS	Mean Square	F Value	Pr > F
JUDGE	40	215.31553	5.38289	3.16	0.0001
TRT	17	25.27199	1.48659	0.87	0.6079
REP	1	0.47498	0.47498	0.28	0.5977
REP*TRT	1	0.28159	0.28159	0.17	0.6845

[1]Treatments: 40 or 50°Brix sucrose solution held at 30, 40 or 50°C for 2, 3 or 4 hr.

Table 15-Analysis of variance of overall acceptability of dried tomato product sensory data

Source	DF	Type III SS	Mean Square	F Value	Pr > F
JUDGE	40	199.87818	4.99695	2.76	0.0001
TRT	17	23.48339	1.38138	0.76	0.7375
REP	1	1.19626	1.19626	0.66	0.4167
REP*TRT	1	0.38563	0.38563	0.21	0.6447

[1]Treatments: 40 or 50°Brix sucrose solution held at 30, 40 or 50°C for 2, 3 or 4 hr.

APPENDIX C

PART IV: RAW DATA AND THEIR MEANS

Table 1- Data and means of Hunter L, hue-angle and lycopene obtained during the storage of dried tomato product

Treatment[1]	Hunter L		Hue-angle		Lycopene	
	Data	Mean	Data	Mean	Data	Mean
N-40-0.0-1	26.03		27.07		7.41	
N-40-0.0-2	27.55	26.79	28.95	28.01	8.40	7.90
A-40-0.0-1	26.03		27.07		7.41	
A-40-0.0-2	27.55	26.79	28.95	28.01	8.40	7.90
V-40-0.0-1	26.03		27.07		7.41	
V-40-0.0-2	27.55	26.79	28.95	28.01	8.40	7.90
N-50-0.0-1	27.07		28.26		8.99	
N-50-0.0-2	27.22	27.14	28.91	28.58	9.03	9.01
A-50-0.0-1	27.07		28.26		8.99	
A-50-0.0-2	27.22	27.14	28.91	28.58	9.03	9.01
V-50-0.0-1	27.07		28.26		8.99	
V-50-0.0-2	27.22	27.14	28.91	28.58	9.03	9.01
N-40-2.5-1	27.09		31.13		8.12	
N-40-2.5-2	28.87	27.98	37.13	34.13	7.93	8.02
A-40-2.5-1	26.04		32.00		9.42	
A-40-2.5-2	30.61	28.32	34.79	33.39	9.37	9.40
V-40-2.5-1	29.87		32.68		8.91	
V-40-2.5-2	26.53	28.20	31.27	31.98	9.85	9.38
N-50-2.5-1	26.11		30.67		8.73	
N-50-2.5-2	29.11	27.61	32.11	31.39	6.86	7.80
A-50-2.5-1	27.30		30.42		7.70	
A-50-2.5-2	29.24	28.27	33.23	31.82	6.07	6.88
V-50-2.5-1	32.60		35.69		7.95	
V-50-2.5-2	33.47	33.03	37.51	36.60	6.95	7.45
N-40-5.0-1	25.94		34.09		9.02	
N-40-5.0-2	23.91	24.92	33.86	33.98	8.77	8.90
A-40-5.0-1	26.22		34.09		8.12	
A-40-5.0-2	26.64	26.43	33.17	33.63	7.91	8.02
V-40-5.0-1	28.50		36.76		7.39	
V-40-5.0-2	25.63	27.06	32.70	34.73	8.71	8.05
N-50-5.0-1	27.75		33.82		7.50	
N-50-5.0-2	28.27	28.01	35.01	34.42	6.57	7.04
A-50-5.0-1	27.49		34.86		11.06	
A-50-5.0-2	30.85	29.17	38.56	36.71	11.16	11.11
V-50-5.0-1	31.13		36.59		7.94	
V-50-5.0-2	27.61	29.37	33.53	35.06	7.09	7.52

[1]Treatments notation indicates package atmosphere (A=Air-flush; N=Nitrogen-flush; V=Partial vacuum) - sucrose concentration - storage period - replication.

Table 2- Data and means of moisture content, firmness and microbiological presence obtained during the storage of dried tomato product

Treatment[1]	Moisture (%) Data	Means	Firmness Area/Curve Data	Means	APC Log CFU/g Data	Means	Yeast Molds Log CFU/g	Lactics
N-40-0.0-1	18.48		26473		<2		<2	<2
N-40-0.0-2	18.06	18.27	25052	25762.5	<2	<2	<2	<2
A-40-0.0-1	18.48		26473		<2		<2	<2
A-40-0.0-2	18.06	18.27	25052	25762.5	<2	<2	<2	<2
V-40-0.0-1	18.48		26473		<2		<2	<2
V-40-0.0-2	18.06	18.27	25052	25762.5	<2	<2	<2	<2
N-50-0.0-1	17.90		31178		<2		<2	<2
N-50-0.0-2	17.68	17.79	32275	31726.5	<2	<2	<2	<2
A-50-0.0-1	17.90		31178		<2		<2	<2
A-50-0.0-2	17.68	17.79	32275	31726.5	<2	<2	<2	<2
V-50-0.0-1	17.90		31178		<2		<2	<2
V-50-0.0-2	17.68	17.79	32275	31726.5	<2	<2	<2	<2
N-40-2.5-1	13.17		36043		<2		<2	<2
N-40-2.5-2	13.75	13.46	35296	35669.5	<2	<2	<2	<2
A-40-2.5-1	12.96		43635		<2		<2	<2
A-40-2.5-2	13.18	13.07	31457	37546	3	2.7	<2	<2
V-40-2.5-1	12.36		39865		<2		<2	<2
V-40-2.5-2	11.74	12.05	41219	40542	<2	<2	<2	<2
N-50-2.5-1	14.64		23697		<2		<2	<2
N-50-2.5-2	13.45	14.04	19557	21627	<2	<2	<2	<2
A-50-2.5-1	13.28		21513		3		<2	<2
A-50-2.5-2	14.77	14.02	28651	25082	<2	2.7	<2	<2
V-50-2.5-1	14.93		25061		<2		<2	<2
V-50-2.5-2	14.19	14.56	24078	24569.5	<2	<2	<2	<2
N-40-5.0-1	10.39		53359		<2		<2	<2
N-40-5.0-2	10.61	10.5	52792	53075.5	<2	<2	<2	<2
A-40-5.0-1	12.10		49173		3		<2	<2
A-40-5.0-2	12.89	12.49	48097	48635	<2	2.7	<2	<2
V-40-5.0-1	12.09		52303		3		<2	<2
V-40-5.0-2	16.97	14.53	50844	51573.5	<2	2.7	<2	<2
N-50-5.0-1	11.93		55486		<2		<2	<2
N-50-5.0-2	8.46	10.19	46763	51124.5	<2	<2	<2	<2
A-50-5.0-1	11.72		43493		3		<2	<2
A-50-5.0-2	12.51	12.11	36268	39880.5	3	3	<2	<2
V-50-5.0-1	11.72		48446		<2		<2	<2
V-50-5.0-2	10.05	10.88	50663	49554.5	<2	<2	<2	<2

[1]Treatments notation indicates package atmosphere (A=Air-flush; N=Nitrogen-flush; V=Partial vacuum)- sucrose concentration - storage period - replication.

APPENDIX D

PART IV: OUTPUT OF ANALYSIS OF VARIANCE TABLES AND MEAN SEPARATION WITH LSD METHOD

Table 1-Analysis of variance and LSD for mean separation of moisture content of dried tomato product during 5 mo of storage

A. Analysis of variance table of moisture content

Source[1]	DF	Type III SS	Mean Square	F Value	Pr > F
ATM	2	3.00201	1.50100	1.12	0.3490
Store	2	248.96362	124.48181	92.93	0.0001
ATM*Store	4	10.15066	2.53767	1.89	0.1578
SUGAR	1	0.32871	0.32871	0.25	0.6267
ATM*SUGAR	2	0.55704	0.27852	0.21	0.8143
STORE*SUGAR	2	12.07962	6.03981	4.51	0.0269
ATM*STORE*SUGAR	4	8.80363	2.20091	1.64	0.2094

[1]ATM = Package atmospheres (air-flush; nitrogen-flush; partial vacuum), STORE = Storage period (mo), Sugar = Sucrose concentration of osmotic solution (°Brix)

B. LSD for means separation of dependent variable:moisture content

ATM	STORE (mo)	SUGAR (°Brix)	MOISTURE LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	LSMEAN LetGrp
Air	0.0	40	18.2700000	0.8184045	0.0001	
Air	0.0	50	17.7900000	0.8184045	0.0001	
Air	2.5	40	13.0700000	0.8184045	0.0001	
Air	2.5	50	14.0250000	0.8184045	0.0001	
Air	5.0	40	12.4950000	0.8184045	0.0001	
Air	5.0	50	12.1150000	0.8184045	0.0001	
Nitrogen	0.0	40	18.2700000	0.8184045	0.0001	
Nitrogen	0.0	50	17.7900000	0.8184045	0.0001	
Nitrogen	2.5	40	13.4600000	0.8184045	0.0001	
Nitrogen	2.5	50	14.0450000	0.8184045	0.0001	
Nitrogen	5.0	40	10.5000000	0.8184045	0.0001	
Nitrogen	5.0	50	10.1950000	0.8184045	0.0001	
Vacuum	0.0	40	18.2700000	0.8184045	0.0001	
Vacuum	0.0	50	17.7900000	0.8184045	0.0001	
Vacuum	2.5	40	12.0500000	0.8184045	0.0001	
Vacuum	2.5	50	14.5600000	0.8184045	0.0001	
Vacuum	5.0	40	14.5300000	0.8184045	0.0001	
Vacuum	5.0	50	10.8850000	0.8184045	0.0001	

Table 2-Analysis of variance and LSD for mean separation of Hunter L of dried tomato product during 5 mo of storage

A. Analysis of variance table of Hunter L

Source	DF	Type III SS	Mean Square	F Value	Pr > F
ATM	2	14.119506	7.059753	2.76	0.0916
STORE	2	24.036439	12.018219	4.70	0.0238
ATM*STORE	4	10.698861	2.674715	1.05	0.4129
SUGAR	1	20.566225	20.566225	8.04	0.0114
ATM*SUGAR	2	4.380950	2.190475	0.86	0.4423
STORE*SUGAR	2	8.326850	4.163425	1.63	0.2256
ATM*STORE*SUGAR	4	12.959050	3.239762	1.27	0.3215

[1]ATM = Package atmospheres (air-flush; nitrogen-flush; partial vacuum), STORE = Storage period (mo), Sugar = Sucrose concentration of osmotic solution (°Brix)

B. LSD for means separation of dependent variable:Hunter L

ATM	STORE (mo)	SUGAR (°Brix)	Hunter L LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	LSMEAN LetGrp
Air	0.0	40	26.7900000	1.1309463	0.0001	
Air	0.0	50	27.1450000	1.1309463	0.0001	
Air	2.5	40	28.3250000	1.1309463	0.0001	
Air	2.5	50	28.2700000	1.1309463	0.0001	
Air	5.0	40	26.4300000	1.1309463	0.0001	
Air	5.0	50	29.1700000	1.1309463	0.0001	
Nitrogen	0.0	40	26.7900000	1.1309463	0.0001	
Nitrogen	0.0	50	27.1450000	1.1309463	0.0001	
Nitrogen	2.5	40	27.9800000	1.1309463	0.0001	
Nitrogen	2.5	50	27.6100000	1.1309463	0.0001	
Nitrogen	5.0	40	24.9250000	1.1309463	0.0001	
Nitrogen	5.0	50	28.0100000	1.1309463	0.0001	
Vacuum	0.0	40	26.7900000	1.1309463	0.0001	
Vacuum	0.0	50	27.1450000	1.1309463	0.0001	
Vacuum	2.5	40	28.2000000	1.1309463	0.0001	
Vacuum	2.5	50	33.0350000	1.1309463	0.0001	
Vacuum	5.0	40	27.0650000	1.1309463	0.0001	
Vacuum	5.0	50	29.3700000	1.1309463	0.0001	

Table 3-Analysis of variance and LSD for mean separation of Hue-angle of dried tomato product during 5 mo of storage

A. Analysis of variance table of Hue-angle

Source	DF	Type III SS	Mean Square	F Value	Pr > F
ATM	2	3.38195	1.69097	0.60	0.5588
STORE	2	273.01702	136.50851	48.62	0.0001
ATM*STORE	4	5.53273	1.38318	0.49	0.7412
SUGAR	1	3.85468	3.85468	1.37	0.2575
ATM*SUGAR	2	8.77991	4.38995	1.56	0.2380
STORE*SUGAR	2	2.11111	1.05555	0.38	0.6922
ATM*STORE*SUGAR	4	27.39821	6.84955	2.44	0.0867

[1]ATM = Package atmospheres (air-flush; nitrogen-flush; partial vacuum), STORE = Storage period (mo), Sugar = Sucrose concentration of osmotic solution (°Brix)

B. LSD for means separation of dependent variable:Hue-angle

ATM	STORE (mo)	SUGAR (°Brix)	HUE-ANGLE LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	LSMEAN LetGrp
Air	0	40	28.0100000	1.1847758	0.0001	
Air	0	50	28.5850000	1.1847758	0.0001	
Air	2.5	40	33.3950000	1.1847758	0.0001	
Air	2.5	50	31.8250000	1.1847758	0.0001	
Air	5	40	33.6300000	1.1847758	0.0001	
Air	5	50	36.7100000	1.1847758	0.0001	
Nitrogen	0	40	28.0100000	1.1847758	0.0001	
Nitrogen	0	50	28.5850000	1.1847758	0.0001	
Nitrogen	2.5	40	34.1300000	1.1847758	0.0001	
Nitrogen	5	40	33.9750000	1.1847758	0.0001	
Nitrogen	5	50	34.4150000	1.1847758	0.0001	
Nitrogen	2.5	50	31.3900000	1.1847758	0.0001	
Vacuum	0	40	28.0100000	1.1847758	0.0001	
Vacuum	0	50	28.5850000	1.1847758	0.0001	
Vacuum	2.5	40	31.9750000	1.1847758	0.0001	
Vacuum	2.5	50	36.6000000	1.1847758	0.0001	
Vacuum	5	40	34.7300000	1.1847758	0.0001	
Vacuum	5	50	35.0600000	1.1847758	0.0001	

Table 4-Analysis of variance and LSD for mean separation of lycopene of dried tomato product during 5 mo of storage

A. Analysis of variance table of lycopene

Source	DF	Type III SS	Mean Square	F Value	Pr > F
ATM	2	2.537239	1.268619	3.01	0.0761
STORE	2	0.685106	0.342553	0.81	0.4603
ATM*STORE	4	5.645778	1.411444	3.35	0.0340
SUGAR	1	0.047669	0.047669	0.11	0.7408
ATM*SUGAR	2	1.844306	0.922153	2.19	0.1428
STORE*SUGAR	2	11.048372	5.524186	13.10	0.0004
ATM*STORE*SUGAR	4	14.125478	3.531369	8.37	0.0006

[1]ATM = Package atmospheres (air-flush; nitrogen-flush; partial vacuum), STORE = Storage period (mo), Sugar = Sucrose concentration of osmotic solution (°Brix)

B. LSD for means separation of dependent variable:lycopene

ATM	STORE (mo)	SUGAR (°Brix)	LYCOPENE LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	LSMEAN LetGrp
Air	0.0	40	7.9050000	0.4591785	0.0001	C
Air	0.0	50	9.0100000	0.4591785	0.0001	B
Air	2.5	40	9.3950000	0.4591785	0.0001	B
Air	2.5	50	6.8850000	0.4591785	0.0001	C
Air	5.0	40	8.0150000	0.4591785	0.0001	C
Air	5.0	50	11.1100000	0.4591785	0.0001	A
Nitrogen	0.0	40	7.9050000	0.4591785	0.0001	C
Nitrogen	0.0	50	9.0100000	0.4591785	0.0001	B
Nitrogen	2.5	40	8.0250000	0.4591785	0.0001	C
Nitrogen	2.5	50	7.7950000	0.4591785	0.0001	C
Nitrogen	5.0	40	8.8950000	0.4591785	0.0001	B
Nitrogen	5.0	50	7.0350000	0.4591785	0.0001	C
Vacuum	0.0	40	7.9050000	0.4591785	0.0001	C
Vacuum	0.0	50	9.0100000	0.4591785	0.0001	B
Vacuum	2.5	40	9.3800000	0.4591785	0.0001	B
Vacuum	2.5	50	7.4500000	0.4591785	0.0001	C
Vacuum	5.0	40	8.0500000	0.4591785	0.0001	B
Vacuum	5.0	50	7.5150000	0.4591785	0.0001	C

Table 5-Analysis of variance and LSD for mean separation of firmness of dried tomato product during 5 mo of storage

A. Analysis of variance table of firmness

Source	DF	Type III SS	Mean Square	F Value	Pr > F
ATM	2	3.973E+07	1.986E+07	2.08	0.1555
SUGAR	1	1.547E+08	1.547E+08	16.20	0.0009
ATM*SUGAR	2	4.634E+06	2.317E+06	0.24	0.7872
STORE	2	2.970E+09	1.485E+09	155.52	0.0001
ATM*STORE	4	1.303E+08	3.258E+07	3.41	0.0319
SUGAR*STORE	2	6.075E+08	3.037E+08	31.81	0.0001
ATM*SUGAR*STORE	4	3.209E+07	8.024E+06	0.84	0.5185

[1]ATM = Package atmospheres (air-flush; nitrogen-flush; partial vacuum), STORE = Storage period (mo), Sugar = Sucrose concentration of osmotic solution (°Brix)

B. LSD for means separation of dependent variable:firmness

ATM	SUGAR (°Brix)	STORE (mo)	FIRMNESS LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	LSMEAN LetGrp
Air	40	0.0	25762.5000	2184.9890	0.0001	
Air	40	2.5	37546.0000	2184.9890	0.0001	
Air	40	5 0	48635.0000	2184.9890	0.0001	
Air	50	0.0	31726.5000	2184.9890	0.0001	
Air	50	2.5	25082.0000	2184.9890	0.0001	
Air	50	5.0	39880.5000	2184.9890	0.0001	
Nitrogen	40	0.0	25762.5000	2184.9890	0.0001	
Nitrogen	40	2.5	35669.5000	2184.9890	0.0001	
Nitrogen	40	5.0	53075.5000	2184.9890	0.0001	
Nitrogen	50	0.0	31726.5000	2184.9890	0.0001	
Nitrogen	50	5.0	51124.5000	2184.9890	0.0001	
Nitrogen	50	2.5	21627.0000	2184.9890	0.0001	
Vacuum	40	0.0	25762.5000	2184.9890	0.0001	
Vacuum	40	2.5	40542.0000	2184.9890	0.0001	
Vacuum	40	5.0	51573.5000	2184.9890	0.0001	
Vacuum	50	0.0	31726.5000	2184.9890	0.0001	
Vacuum	50	2.5	24569.5000	2184.9890	0.0001	
Vacuum	50	5.0	49554.5000	2184.9890	0.0001	

Table 6-Analysis of variance and LSD for mean separation of aerobic plate count (microbial invasion) of dried tomato product during 5 mo of storage

A. Analysis of variance table of aerobic plate count

Source	DF	Type III SS	Mean Square	F Value	Pr > F
ATM	2	20000.000	10000.000	17.00	0.0001
SUGAR	1	1111.111	1111.111	1.89	0.1872
ATM*SUGAR	2	2222.222	1111.111	1.89	0.1816
STORE	2	5000.000	2500.000	4.25	0.0319
ATM*STORE	4	10000.000	2500.000	4.25	0.0145
SUGAR*STORE	2	555.556	277.778	0.47	0.6316
ATM*SUGAR*STORE	4	1111.111	277.778	0.47	0.7555

[1]ATM = Package atmospheres (air-flush; nitrogen-flush; partial vacuum), STORE = Storage period (mo), Sugar = Sucrose concentration of osmotic solution (°Brix)

B. LSD for means separation of dependent variable:aerobic plate count

ATM	SUGAR (°Brix)	STORE (mo)	APC LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	LSMEAN LetGrp
Air	40	0	-0.0000000	17.1498585	1.0000	
Air	40	2.5	50.0000000	17.1498585	0.0096	
Air	40	5	50.0000000	17.1498585	0.0096	
Air	50	0	-0.0000000	17.1498585	1.0000	
Air	50	2.5	100.0000000	17.1498585	0.0001	
Air	50	5	100.0000000	17.1498585	0.0001	
Nitrogen	40	0	-0.0000000	17.1498585	1.0000	
Nitrogen	40	2.5	0.0000000	17.1498585	1.0000	
Nitrogen	40	5	-0.0000000	17.1498585	1.0000	
Nitrogen	50	0	-0.0000000	17.1498585	1.0000	
Nitrogen	50	2.5	0.0000000	17.1498585	1.0000	
Nitrogen	50	5	0.0000000	17.1498585	1.0000	
Vacuum	40	0	0.0000000	17.1498585	1.0000	
Vacuum	40	5	0.0000000	17.1498585	1.0000	
Vacuum	40	2.5	-0.0000000	17.1498585	1.0000	
Vacuum	50	0	0.0000000	17.1498585	1.0000	
Vacuum	50	2.5	-0.0000000	17.1498585	1.0000	
Vacuum	50	5	0.0000000	17.1498585	1.0000	

Table 7-Analysis of variance of overall acceptability of dried tomato product sensory data

Source	DF	Type III SS	F Value	Pr > F
SUGAR	1	2.76116951	1.21	0.2708
STORE	2	2.60764863	0.57	0.5638
REP	2	0.37757622	0.08	0.9203
SUGAR*STORE	2	0.60405641	0.13	0.8756
SUGAR*REP	2	1.52640378	0.34	0.7149
STORE*REP	4	6.40330815	0.70	0.5892

Table 8-Analysis of variance of color of dried tomato product sensory data

Source	DF	Type III SS	F Value	Pr > F
SUGAR	1	1.14804177	0.63	0.4273
STORE	2	33.74285822	9.27	0.0001
REP	2	3.25392706	0.89	0.4095
SUGAR*STORE	2	4.38354210	1.20	0.3005
SUGAR*REP	2	3.79584233	1.04	0.3530
STORE*REP	4	2.56141578	0.35	0.8427

Table 9-Analysis of variance of sweetness of dried tomato product sensory data

Source	DF	Type III SS	F Value	Pr > F
SUGAR	1	1.22120077	0.47	0.4926
STORE	2	2.42458298	0.47	0.6265
REP	2	1.17809633	0.23	0.7967
SUGAR*STORE	2	3.75463625	0.72	0.4849
SUGAR*REP	2	2.37542679	0.46	0.6324
STORE*REP	4	9.44460400	0.91	0.4568

Table 10-Analysis of variance of flavor of dried tomato product sensory data

Source	DF	Type III SS	F Value	Pr > F
SUGAR	1	2.18765344	0.82	0.3668
STORE	2	1.64610999	0.31	0.7358
REP	2	0.27958884	0.05	0.9492
SUGAR*STORE	2	0.19678913	0.04	0.9640
SUGAR*REP	2	0.73536913	0.14	0.8719
STORE*REP	4	4.99008228	0.47	0.7612

Table 11-Analysis of variance of texture of dried tomato product sensory data

Source	DF	Type III SS	F Value	Pr > F
SUGAR	1	1.74439518	0.78	0.3783
STORE	2	10.92460217	2.43	0.0886
REP	2	0.52598032	0.12	0.8894
SUGAR*STORE	2	2.31294531	0.52	0.5975
SUGAR*REP	2	0.80317558	0.18	0.8362
STORE*REP	4	2.02485274	0.23	0.9241

VITA

Harjeet Singh Sidhu was born April 22, 1951, at Bathinda (Punjab), India. He received his Bachelor of Science degree in Agriculture in March, 1973, from Punjab Agricultural University, Ludhiana, India. He received the Master of Science degree in Horticulture and graduated second in the class from Agra University, Agra, India. He received his Master of Philosophy degree (post M.S. and pre-Ph.D. Advanced Training) in Horticulture, received a merit scholarship and graduated first in the class from Meerut University, Meerut, India.

He served as Lecturer in Horticulture at Khalsa College, Amritsar, India for two academic years from 1982 to 1984. He moved to United States of America February, 1984 and lived at Virginia Beach, Virginia.

In May 1989, he began graduate studies in the Department of Agricultural Engineering of The University of Tennessee, Knoxville. He became a citizen of the United States of America in March, 1990 and became a Graduate Research Assistant in May, 1990. He is a member of Gamma Sigma Delta, the Honor Society of Agriculture, and the Institute of Food Technologists. He received the Master of Science degree with a major in Agricultural Engineering Technology and a minor in Food Science and Technology in December, 1992.

He was accepted in M.S. program in Food Science and Technology

Department of The University of Tennessee, Knoxville, and was also awarded a Graduate Research Assistantship. He plans to receive the Master of Science degree with a major in Food Science and Technology in December, 1999.

Currently, he is working as the Cereal Mix Supervisor with J.W. Allen & Company, Morristown, Tennessee.

He is married to the former Prabhjot Kaur Mann. They have a son Harmanjeet, 17 and a daughter Harmaneek, 12.