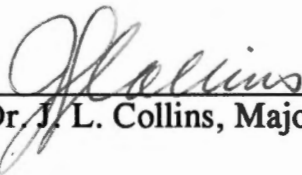
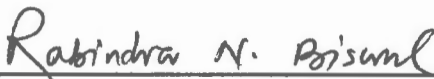


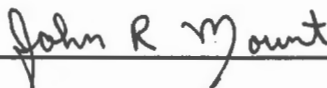
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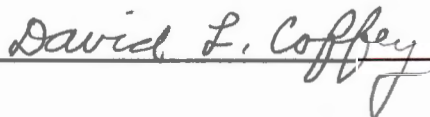
I am submitting herewith a thesis written by Dharia Renate entitled "Osmotic Concentration of Italian Tomato." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Technology and Science.


Dr. J. L. Collins, Major Professor

We have read this thesis and
recommend its acceptance:







Accepted for the Council:


Associate Vice Chancellor
and Dean of The Graduate School

**OSMOTIC CONCENTRATION
OF ITALIAN TOMATO**

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Dharia Renate

August 1991

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THESIS

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DEDICATION

This thesis is dedicated to my parents Hi. Damiri Barmawie and Hj. Ronimah Damiri, my husband Edison and my little daughter Editha Renesteen for their support and love.

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ABSTRACT

The objectives of this research were to determine the concentrating effect of different concentrations of sucrose or salt on tomato flesh and to measure/evaluate chemical, physical and sensory quality properties after dehydration.

Fresh tomatoes of Roma and Milano cultivars were prepared and concentrated partially in solutions of sucrose (50, 60, 70%) or salt (10, 15, 20%). Times for holding in solution were extended up to 2 hr in sucrose solution and 1.5 hr in salt solution. Moisture loss, solids weight gain and net weight loss were measured at designated times during these periods. Following these determinations, the tomato flesh was dehydrated at 57 °C for 14 hr. Color was measured on the dehydrated tomato.

Tomato samples were prepared for sensory evaluation, using sucrose solution (60%, 1.5 hr) and salt solution (15%, 1 hr). The dehydrated tomato was stored 2 and 4 months in sealed glass containers after flushing with nitrogen gas.

The longer the time of holding tomato flesh in either solution and the greater the concentration of solute, resulted in the greater the loss of moisture, gain in solids content and loss of net weight. Cultivar exhibited limited effect on these measurements.

Hunter color values of dehydrated tomato from the sucrose treatment were greater after 1 hr but no changes occurred with longer times. Sucrose concentration and cultivar had no effect on color. For salt-treated tomato, Hunter values increased with time of treatment, but the greatest increase occurred for L and 'b' values. Salt concentration and cultivar exhibited minor color changes.

Panel scores for sucrose-treated tomato of both cultivars ranged between means 5.7 and 6.6 ("like slightly" and "like very much"). Scores for salt-treated tomato in pasta sauce were highest at 6.0 ("like moderately") for color; for fresh tomato in pasta sauce, scores were highest at 5.2 and 5.0 ("like slightly") for flavor and overall acceptability, respectively. Female panelists give the higher scores for flavor and overall acceptability. Storage time had no effect on sensory scores.

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CHAPTER I

INTRODUCTION

Freshly harvested food crops are composed mainly of water. By removing a portion of the water, the high cost of shipping, packaging and storing the product may be reduced. One method for removing a portion of the moisture is by osmotic dehydration. Pieces of the fresh material (vegetable or fruit) are placed into a hypertonic solution. Water then diffuses from the tissues into the solution.

Different aspects of osmotic dehydration have been studied, including the concentration of the osmotic solution, the influence of process variables on the drying behavior and the practice of combining osmotic dehydration with hot air dehydration to finish the drying process (Biswal et al., 1991; Bolin et al., 1983; Hawkes and Flink, 1978; Islam and Flink, 1982; Lenart and Flink 1984a,b; Lerici et al., 1985; Ponting et al., 1966; Torreggiani et al., 1987). Intermediate moisture products have been produced by immersing the fruit into a 70° Brix sucrose solution to reduce the weight by 50% (Ponting et al., 1966). The products were further dried to about 4% moisture, using vacuum or hot air dehydration.

Another osmotic agent that has been used is sodium chloride in aqueous solution. However, the use of elevated concentrations of salt is limited because

a salty taste is imparted to the food. Biswal et al. (1991) stated that green beans lost as much as 22% moisture when contacted with 17% NaCl-water solution at room temperature for 1 hr.

No research has been conducted on the osmotic dehydration of tomato tissue. Tomato cultivars Milano and Roma might possess qualities for osmotic dehydration since the fruits have thick and firm flesh, excellent red color and attractive appearance. Thus, the purpose of this investigation was to determine the concentrating effect of different concentrations of sucrose or salt on tomato flesh and to measure/evaluate chemical, physical and sensory quality properties after dehydration.

CHAPTER II

LITERATURE REVIEW

A. Osmotic Concentration

1. Osmosis

Where pure water and sugar solution are separated by a semi-permeable membrane, the chemical potential of water on the side with pure water is higher than that on the other side. Sugar cannot diffuse across the membrane as water can. Thus, water will diffuse from the area of higher potential (pure water) to the area of lower potential (sugar solution). This diffusion of water across a differentially permeable membrane is called osmosis (Bidwell, 1974).

An increase in water potential within cellular protoplasm can be produced by an increase either in imbibitional pressure or in osmotic pressure of the protoplasmic contents (Goss, 1973). This phenomenon may result from water moving out of the cell or by accumulation of solutes such as mineral elements and sugars. Osmosis will cease when the water potential within the protoplasm becomes equal to the water potential outside the protoplasm. The water potential within the protoplasm can be reduced either by diluting the internal solution or by

increasing the turgor pressure. Since turgor pressure is the actual pressure produced within the cell as water moves into the cell (osmosis occurs), turgor pressure increases more than the osmotic pressure decreases until eventually the water potential within the protoplasm is equal to that outside the cell. At this point osmosis ceases with water moving across the cell membranes at constant rates.

2. Definition

Osmotic concentration of food plant tissue is a water removal process which is based on placing materials, such as pieces of fruits or vegetables, into a hypertonic solution (Lerici et al., 1985). Since this solution has higher osmotic pressure and, hence, lower water potential than the plant tissue, a driving force for water removal arises between the solution and food with the natural cell wall acting as a "semi-permeable" membrane. As the membrane is only partially selective, there is always some leakage of solutes from the solution into the food and passage from the food into the solution. Direct osmotic concentration is, therefore, a simultaneous water and solute diffusion process (Biswal and Le Maguer, 1989).

3. Advantages of Osmotic Concentration

Advantages of osmotic concentration were described by Ponting et al. (1966) and Contreras and Smyrl (1981) as follows. 1) Fruit concentrated by osmosis has not been subjected to a high temperature over an extended time; therefore, heat damage to color and flavor is minimized. 2) Use of sugar or syrup as the osmotic agent prevents much of the loss of fresh fruit flavor commonly found with ordinary air or vacuum drying methods. 3) A high concentration of sugar surrounding fruit pieces prevents enzymatic oxidative reactions that lead to discoloration of the fruit. Therefore, excellent color may be retained in the dried product without treatment with chemicals such as sulfur dioxide. 4) As water is removed by osmosis, some of the fruit acid is removed. Lower acid content combined with the small amount of sugar added to the fruit by the osmotic bath produces a blander and sweeter product than ordinary dried fruit.

4. Disadvantages of Osmotic Dehydration

Ponting et al. (1966) presented some disadvantages of using osmotic concentration for removal of water from fruit tissues. The disadvantages include the following: 1) The decrease in acidity mentioned above may be disadvantageous in certain products. Lower acidity removes natural fruit flavor and may make the fruit more susceptible to microbiological spoilage. The acidity can be increased

by adding a fruit acid to the syrup. 2) A residue of sugar is left in the fruit after drying. The surface coating of sugar can be reduced by a quick rinse in water after the osmotic dehydration step. 3) Sugar or syrup-treated fruit when dried to a very low moisture content tends to become rancid after several weeks of storage at room temperature.

B. Factors Affecting Osmotic Concentration

1. Types of Osmotic Agents

A solution used for osmotic concentration should possess pleasant flavor and be harmless. Commonly used solutes are sugars such as concentrated sucrose solution (50-70 °Brix) or corn syrup solids. Ponting et al. (1966) stated that sucrose was the best all around dry substance because of its effectiveness, convenience and desirable flavor. The rate of withdrawal of water from fruit by dry sucrose is extremely fast at first. It can reduce the weight of fruit by as much as 50%. Lenart and Flink (1984b) stated that after 2 hr of osmotic concentration the penetration depth increases from 1 to 6 mm as sucrose concentration increases from 0 to 60%. Contreras and Smyrl (1981) used corn syrup solids as the osmotic solute to concentrate apple rings.

Sodium chloride is also used as an osmotic agent for vegetables, but its use in concentrating fruit pieces is limited because of the salty flavor imparted. With 15% salt solution for 2 hr, a slight penetration occurred, but for 8 hr the penetration was much greater (Lenart and Flink, 1984b).

2. Effects of Temperature

Temperature affects the rate of osmosis. As temperature increases, percentage of weight loss increases. Research by Ponting et al. (1966) showed that the rate of osmosis increased with increasing temperatures. However, there was a limit of 49 °C, above which enzymic browning and flavor deterioration began to occur.

The sucrose solubility increases with increasing temperature; therefore, osmotic pressure of saturated sucrose solution will be higher at higher temperatures, resulting in greater dehydration of the food (Camirand et al., 1968). In addition, penetration depth increases with increasing temperature (Lenart and Flink, 1984b).

3. Effects of Time

Different times of osmotic concentration affect the importance of some physical, chemical, and technological parameters to obtain products of satisfactory

quality and shelf-life at ambient temperature. Increasing time of osmotic concentration increases penetration depth and moisture loss of the fruit (Lenart and Flink, 1984b). However, water loss and penetration of sugar and ascorbic acid into fruit occurred mainly during the first 2 hr of processing (Torreggiani et al., 1987).

4. Effects of Agitation

Osmotic concentration occurs more rapidly with agitation. Percentage weight loss of apple chips in stirred sucrose syrup was higher than that in unstirred sucrose syrup (Hawkes and Flink, 1978). Agitation or circulation of syrup reduces the time of osmosis (Bongirwar and Sreenivasan, 1977).

C. Factors Contributing To Tomato Color

Color in the tomato fruit is produced by the presence of carotenes and carotenols (Gould, 1983). The carotenoid pigments derive their names from carotene and are, for the most part, polyene compounds of a yellow to red color. Many different pigments have been isolated in the tomato fruit, but of major importance to overall color are: (1) alpha-carotene, (2) beta-carotene, (3) gamma carotene, (4) delta-carotene, (5) lycopene, and (6) 22 xanthophylls (carotenols).

The most abundant carotenoid of the tomato is lycopene which comprises approximately 83 % of those pigments present.

Carotenoids are chemically more stable compared to other plant and animal pigments such as chlorophyll, anthocyanin, hemoglobin, and myoglobin. However, carotenoids of tomato products may be destroyed at partially low percentage of water, heating, the presence of metallic ion (Cu^{2+} , Fe^{3+} , etc.) or the presence of oxygen.

The carotene content of the tomato fruit is influenced by various factors such as size, degree of ripeness, mineral nutrient supply of the product, soil conditions and variety.

D. Some Research Findings

Bongirwar and Sreenivasan (1977) reported on the effect of sugar concentration on rate of osmotic concentration of banana slices in syrup of 60, 70, 80 and 82 strength (W/W) and dipped up to 4 hr. They found that weight loss increased proportionally from 5 to 40% as the time increased from 1 to 4 hr.

Hawkes and Flink (1978) conducted research on osmotic concentration of apple slices with 25 to 60% sucrose solution. Results indicated that water loss increased from 0 to 40% as time increased from 0 to 4 hr. Solids gain increased

rapidly up to 0.5 hr of contact of fruit with the solution, and it remained the same up to 4 hr.

Moy et al. (1978) stated that the amount of water removed by the osmotic step increased with increasing sucrose concentration (0 to 60% weight) and contact time (up to 6 hr). The weight loss of mango was directly proportional to sucrose concentration while it was not linear for papaya.

Torreggiani et al. (1978) conducted research on 3 cultivars of cherries, using 70 °Brix corn syrup at 25 °C for 2, 4 and 6 hr. It was confirmed that the water loss and the penetration of sugars and ascorbic acid into the fruit occurred mainly during the first 2 hr of the process. From sensory evaluation tests, no significant differences were found among the different samples immediately after the osmotic treatment.

Islam and Flink (1982) stated that osmotic concentration with sucrose and NaCl showed a basic difference in osmotic behavior. For sucrose, increasing percentage of sucrose up to 60%, resulted primarily in water loss. The uptake of solids gain was fairly constant for all sucrose concentrations. On the other hand, increasing NaCl produced water loss and solids gain.

Bolin et al. (1983) presented results of osmotic concentration on apple from use of sucrose syrup and high fructose corn syrup (HFCS) of 70 °Brix for 6 hr. After 3 hr in the osmotic media apple in HFCS had absorbed 50% more solids

than apple held in the sucrose solution. After 5 hr, apple absorbed 70% more solids from HFCS than from sucrose solution.

Lenart and Flink (1984b) investigated the effect of osmotic concentration of potato in sucrose solutions of 0 to 60% for 8 hr and salt solutions for 6.5 to 15% for 8 hr. Increasing the concentration of solute in solution or increasing the osmotic time produced increasing penetration depth and a decrease of the relative moisture content at all locations in the sample.

Lerici et al. (1985) reported on the changes of some characteristics of apple pieces during direct contact with glucose solution (51 °Brix). After 12 hr, water loss was 45%, weight reduction was 35% and solids weight gain was 15%.

Giangiacomo et al. (1987) reported on investigations of osmotic concentration of cherry, apricot and peach in 50% corn syrup at ambient temperature 25 °C for 6 hr. The amount of solids that penetrated the fruits in 6 hr was different among the fruits; for apricot approximately 20% of total solids in solution entered the fruit compared to only approximately 5% in the two other fruits.

Biswal et al. (1991) investigated osmotic concentration of green beans prior to freezing. The beans were partially concentrated in a NaCl-water solution at room temperature for 1 hr. The beans lost up to 22% of their moisture content.

CHAPTER III

MATERIALS AND METHODS

A. Preliminary Research

Ripe tomatoes of Roma and Milano cultivars were heated in water at 100 °C for 10 seconds, peeled manually, cut into halves with the placental materials and seeds removed. The pieces were concentrated, using solutions of sodium chloride (10, 15, 20 and 25% and saturated salt); sucrose (30, 40, 50 and 60%) and combinations of sucrose and salt (20% sucrose +15% salt, 30% sucrose +15% salt, 40% sucrose +15% salt and 50% sucrose +15% salt). Concentration was accomplished by holding tomato pieces in solution for 0.5, 1, 1.5, 3 and 4 hr. Then, the tomato pieces were drained of the solution, blotted to remove excess solution and tested for loss of weight, loss of moisture, texture and appearance.

B. Main Research

1. Materials

Sucrose and sodium chloride were used to prepare osmotic solutions. Tomato fruits of 'Roma' and 'Milano' were grown at the Plateau Experiment Station, Crossville, TN. Fully ripened fruit of normal and uniform size were used.

2. Concentration (Dehydration) Procedure

The osmotic solutions were prepared by mixing the solutes in deionized water (W/V). The following concentrations were used: sucrose solution (50, 60 and 70%) and sodium chloride solutions (10, 15 and 20%). Osmotic concentration of tomato was conducted for periods between 1-24 hr in a stainless steel vessel which contained 2L of solution. The vessel was covered with aluminum foil to reduce evaporation.

Tomatoes were prepared in a manner similar to that presented for the preliminary research. The fruit halves were dipped into 0.1% calcium chloride solution for 20 min. Then, 210 g fruit were held in 1.5L osmotic solution under constant agitation with a magnetic stirrer. Concentration was conducted at ambient room temperature for 0, 1, 1.5 and 2 hr for each level of sucrose and 0, 0.5, 1

and 1.5 hr for each level of salt. When the process was completed, fruit was removed from the solution, blotted free of surface liquid and tested for moisture loss, solids weight gain, net weight loss and salt content. Dehydration of tissue was completed in a cabinet dehydrator under forced air at 57 °C for 14 hr. The diagram of procedure for osmotic concentration and dehydration of tomato is presented in Figure 1.

Dehydrated tomato was analyzed for color and moisture content. Dehydrated fruit halves from one of the sucrose treatments (60%, 1.5 hr) and one of the salt treatments (15%, 1 hr) were stored for 2 and 4 months for sensory evaluation. Samples of 100 g were stored in sealed glass jars of 1.2 L capacity. Jars were flushed with nitrogen gas, then covered tightly with a 2-piece dome lid. Jars with sample were placed into boxes and stored in the dark at ambient room temperature. Samples were tested after storage for sensory attributes.

3. Analysis of Samples

a. **Moisture**. Moisture content of tomato was determined by the AOAC Vacuum Oven Method (AOAC, 1984). Samples of 20 g were dried to constant weight in a vacuum oven at 70 °C overnight at 163 mm Hg. Percentage of moisture was calculated.

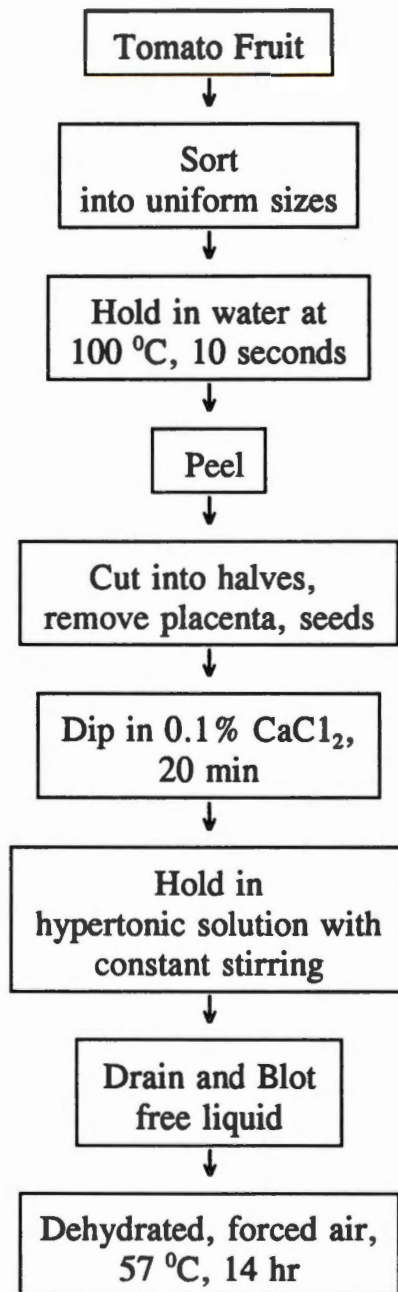


Figure 1. Diagram of Procedure for Osmotic Concentration and Dehydration of Tomato

b. Salt Content. Percentage of salt was determined with a standardized Dicromat Salt Analyzer, Model 1-10 & DSA. The analyzer was standardized by a 5%-sodium chloride solution. The dial was adjusted to establish a "set-point" of 5.00. Ten g sample of tomato were prepared by blending with an Osterizer Blender (kitchen type). The sample was blended 1 min at low range-blend in an 80-mL jar to which were added 40 mL deionized water. The slurry was poured into a graduated cylinder and added water to 100 mL. Samples were poured through the Whatman filter No. 4 paper and transferred the filtrate to the reservoir of the analyzer. The readout of the meter was recorded and used for calculation.

c. Color. Color of dehydrated tomato was measured with a Hunter Color Meter (model D25D2M). The meter was standardized with a white tile (Hunter C-2-21125; $L = 91.03$, $'a' = -1.3$, $'b' = 1.6$). Three pieces of tomato (1.5 fruit) were cut into pieces of approximately 5 mm square. The samples were placed into a cuvette constructed with an optical glass bottom and the L , $'a'$ and $'b'$ values were recorded.

4. Sensory Evaluation

Dehydrated tomato halves from the sucrose treatment were served and evaluated without further preparation. Tomatoes dehydrated with salt or solar-dried were prepared as a pasta sauce as follows. The following procedure was

used for making pasta sauce (Penfield, 1990). One-half cup dehydrated tomato was immersed in warm water for 5 min, then in hot water (100 °C) for 2 min. The tomato pieces were drained, covered with 125 mL water and a mixture of spices (0.4 g garlic, 0.18 g black pepper, 0.35 g basil, 0.1 g oregano and 1 teaspoon corn syrup). The mixture was blended in an Osterizer Blender (kitchen-type) in a jar (943 mL capacity) at low range-blend. The sauce was placed in a small saucepan, brought to the boiling point and allowed to simmer 5 to 8 min. To compare the experimental samples with commercial products, fresh and commercial, solar-dried tomatoes were purchased at a local market. The dried tomatoes were prepared as a sauce as described above. Fresh tomatoes were peeled after holding in boiling water for 30 seconds and cut into small pieces. One and one-half cups of fresh tomatoes were blended with spices (0.6 g garlic, 0.28 g black pepper, 0.48 g basil, 0.16 g oregano, 1 g salt and 1 teaspoon corn syrup). The sauce was placed in a small saucepan, brought to boil and simmered 5 to 8 min.

A piece of tomato equal to one-fourth size of the fruit from the sucrose treatment was served to each panelist. On the following day, 15 mL pasta sauce was served to each panelist. Samples were prepared in random order and evaluated from 9:00 AM to 2:00 PM under cool-white fluorescent light in an air conditioned laboratory. A "consumer" panel of 50 panelists, consisting of

students, staff and faculty of Food Technology and Science and Animal Science Departments, evaluated the sucrose-treated samples for color, texture, flavor, sweetness and overall acceptability and the sauces for color, flavor and overall acceptability. An 8-point hedonic scale was used: 8=like extremely, 7=like very much, 6=like moderately, 5=like slightly, 4=dislike slightly, 3=dislike moderately, 2=dislike very much and 1=dislike extremely (Larmond, 1977; Penfield, 1990).

5. Experimental Design

The experiment was conducted as factorials of a completely randomized design (Steel and Torrie, 1980). Treatments for samples of both solutes were concentration of solute and time: 3 x 4 (solute strength x time) replicated 3 times.

6. Data Analyses

All data were analyzed by analysis of variance. The Tukey test (Steel and Torrie, 1980) was used to determine significance among the means at the 0.05 probability level. All data were analyzed, using The Statistical Analysis System (SAS, 1985) at The University of Tennessee Computing Center.

CHAPTER IV

RESULTS AND DISCUSSION

Preliminary research indicated that osmotic concentration of tomato flesh coupled with dehydration in a forced hot air oven to the final moisture level was plausible. Experiments were conducted to determine the effect of sucrose in solution at 30, 40, 50 and 60% and salt in solution at 10, 15, 20 and 25% and at saturation at times of 0.5 to 4 hr with 0.5 hr intervals on osmotic concentration as determined by measuring moisture loss, net weight loss, texture and appearance.

Based on preliminary experiments, sucrose solution at 60% for 1.5 hr and salt solution at 15% for 1 hr used to concentrate tomato fruit tissue were found to produce satisfactory products and were selected for further experiments with dehydrated tomato.

A. Changes in tomato flesh held in hypertonic sucrose solutions

The procedure for calculation of moisture loss, solids weight gain and net weight loss is outlined in Appendix A.

1. Moisture Loss

The sum of squares from the analysis of variance of moisture loss from tomato after holding in hypertonic sucrose solutions are presented in Table I. Sucrose concentration and time had significant ($p < 0.01$) effects and cultivar had a significant ($p < 0.05$) effect on moisture loss, while the interactions except sucrose x time ($p < 0.05$), had no effect ($p > 0.05$).

The mean values for moisture loss of tomato flesh as affected by the main sources of variability are presented in Table II. The original moisture of tomato for both cultivar was 95% and moisture loss into the solution continued with time, losing 41.5% of available moisture after 2 hr. The greater the concentration of sugar in the solutions, the greater the loss of moisture. Sugar at 60% removed 4.1% more moisture than sugar at 50%, and sugar at 70% removed 3% more than sugar at 60%. Overall, 'Milano' lost 2.1% more moisture than 'Roma.'

Significance of the sucrose x time interaction meant that rate of moisture loss with time increased as the concentration of sucrose increased. Conditions for maximum loss of moisture were not attained. At 2 hr the loss was greater than at 1.5 hr, and the loss at 70% was greater than that at 60%.

Table I - Sum of squares from the analysis of variance of moisture loss (%) of tomato flesh after holding in hypertonic sucrose solutions for up to 2 hr^a

Source	df	Sum of Squares
Cultivar (C)	1	75.46*
Sucrose level (S)	2	609.71**
Time (T)	3	16163.93**
Replication	2	36.03 ^{ns}
C x S	2	28.70 ^{ns}
C x T	3	37.72 ^{ns}
S x T	6	229.74*
C x S x T	6	38.87 ^{ns}
Error	46	682.85

^a Cultivar: Roma and Milano;
 Sucrose solution: 50, 60 and 70%; and
 Time: 0, 1, 1.5 and 2 hr.

* Significant at $p < 0.05$.

** Significant at $p < 0.01$.

^{ns} Not significant at $p > 0.05$.

Table II - Moisture loss of tomato flesh after holding in hypertonic sucrose solutions for up to 2 hr

Hr	Time		Sucrose		Tomato	
	Mean ^a		%	Mean ^b	Cultivar	Mean ^c
	Per cent			Per cent		Per cent
0	2.52 ^g		50	23.94 ^f	Roma	26.64 ^e
1	30.99 ^f		60	28.01 ^e	Milano	28.69 ^d
1.5	35.70 ^e		70	31.04 ^d		
2	41.45 ^d					

^a N = 18.

^b N = 24.

^c N = 36.

^{d-f} Means within a column are significantly different ($P < 0.05$) when followed by different superscripts.

2. Solids weight gain

The sum of squares from the analysis of variance of solids weight gain of tomato flesh held in hypertonic sucrose solutions are presented in Table III. Cultivar and time affected the solids gain, but sucrose concentration had no effect ($p > 0.05$). Only the cultivar x time interaction was significant ($p < 0.01$). The rate of weight gain with time was greater for 'Milano.'

The mean values for solids weight gain of tomato flesh as affected by the main sources of variability are presented in Table IV. The solids content of the tomato flesh increased as time increased. After 2 hr, solids increased by 24.6%, 'Milano' gained more solids than 'Roma.' The solids gained may be attributed primarily to uptake of sucrose from the solutions.

3. Net weight loss

The sum of squares from the analysis of variance of net weight loss of tomato after holding in hypertonic sucrose solutions are presented in Table V. Sucrose concentration and time had significant effects on weight loss, but cultivar and the interactions had no effect ($p > 0.05$).

The mean values for net weight loss of tomato flesh as affected by the main sources of variability are presented in Table VI. Net weight loss increased as time and percentage of sucrose in the solutions increased. After 2 hr, net weight loss

Table III - Sum of squares from the analysis of variance of solids weight gain (%) of tomato flesh after holding in hypertonic sucrose solutions for up to 2 hr^a

Source	df	Sum of Squares
Cultivar (C)	1	639.27**
Sucrose level (S)	2	15.65 ^{ns}
Time (T)	3	5845.30**
Replication	2	73.19 ^{ns}
C x S	2	8.39 ^{ns}
C x T	3	386.69**
S x T	6	201.27 ^{ns}
C x S x T	6	52.26 ^{ns}
Error	46	854.06

^a Cultivar: Roma and Milano;
 Sucrose solution: 50, 60 and 70%; and
 Time: 0, 1, 1.5 and 2 hr.

** Significant at $p < 0.01$.

^{ns} Not significant at $p > 0.05$.

Table IV - Solids weight gain of tomato flesh after holding in hypertonic sucrose solutions for up to 2 hr

Time		Sucrose		Tomato	
Hr	Mean ^a	%	Mean ^b	Cultivar	Mean ^c
	Per cent		Per cent		Per cent
0	1.65 ^f	50	17.57 ^d	Roma	13.95 ^e
1	19.39 ^e	60	16.47 ^d	Milano	19.91 ^d
1.5	22.08 ^{de}	70	1.74 ^d		
2	24.59 ^d				

^a N = 18.

^b N = 24.

^c N = 36.

^{d-f} Means within a column are significantly different ($P < 0.05$) when followed by different superscripts.

Table V - Sum of squares from the analysis of variance of net weight loss (%) of tomato flesh after holding in hypertonic sucrose solutions for up to 2 hr^a

Source	df	Sum of Squares
Cultivar (C)	1	3.74 ^{ns}
Sucrose level (S)	2	388.20 ^{**}
Time (T)	3	7768.01 ^{**}
Replication	2	60.31 [*]
C x S	2	20.52 ^{ns}
C x T	3	23.76 ^{ns}
S x T	6	84.89 ^{ns}
C x S x T	6	26.74 ^{ns}
Error	46	286.94

^a Cultivar: Roma and Milano;
 Sucrose solution: 50, 60 and 70%; and
 Time: 0, 1, 1.5 and 2 hr.

^{*} Significant at $p < 0.05$.

^{**} Significant at $p < 0.01$.

^{ns} Not significant at $p > 0.05$.

Table VI - Net weight loss of tomato flesh after holding in hypertonic sucrose solutions for up to 2 hr

Hr	Time		Sucrose		Cultivar	Tomato Mean ^c
	Mean ^a	Per cent	%	Mean ^b		
0	2.64 ^g	Per cent	50	16.58 ^f	Roma	19.89 ^d
1	20.60 ^f		60	20.24 ^e	Milano	19.44 ^d
1.5	25.31 ^e		70	22.18 ^d		
2	30.11 ^d					

^a N = 18.

^b N = 24.

^c N = 36.

^{d-g} Means within a column are significantly different ($P < 0.05$) when followed by different superscripts.

was 30.1%. The small loss of weight at 0 time suggests that weight loss was caused by loss of tomato solutes by leaching and by moisture loss during the short-time dip in the solution. No weight loss difference occurred between cultivars.

At least 3 major changes occurred in the tomato flesh held in hypertonic sucrose solutions. The measured changes were loss of moisture, gain in solids contents and net loss of weight. Not measured was the apparent loss by leaching of tomato solutes into the solution. Loss of solutes may reduce the tomato flavor intensity while the gain in solids (or sucrose) will, no doubt, increase sweetness.

4. Color

The sum of squares from the analysis of variance of Hunter color measurements of tomato flesh after holding in hypertonic sucrose solutions and dehydrating are presented in Table VII. Time affected ($p < 0.01$) the three Hunter color measurements; however, cultivar, sugar concentration and the interactions had no effect on color.

Color measurements of tomato flesh as affected by time, sucrose concentration and cultivar are presented in Table VIII. Holding times of 1 hr or longer caused the tomato flesh to exhibit greater luminosity (except at 1.5 hr), redness and yellowness when compared to 0 time as evidenced by the greater

Table VII - Sum of squares from the analysis of variance of Hunter color measurements of tomato flesh after holding in hypertonic sucrose solutions for up to 2 hr and dehydrating^a

Source	df	Sum of Squares		
		L	'a'	'b'
Cultivar (C)	1	10.43 ^{ns}	4.80 ^{ns}	2.03 ^{ns}
Sucrose level (S)2	1	3.86 ^{ns}	8.53 ^{ns}	6.33 ^{ns}
Time (T)	3	198.17 ^{**}	470.66 ^{**}	101.21 ^{**}
Replication	2	13.15 ^{ns}	22.89 ^{ns}	0.39 ^{ns}
C x S	2	13.37 ^{ns}	3.54 ^{ns}	5.26 ^{ns}
C x T	3	36.87 ^{ns}	11.80 ^{ns}	18.29 ^{ns}
S x T	6	13.14 ^{ns}	6.79 ^{ns}	8.31 ^{ns}
C x S x T	6	21.07 ^{ns}	38.14 ^{ns}	7.31 ^{ns}
Error	46	408.43	240.06	199.92

^a Cultivar: Roma and Milano;
 Sucrose solution: 50, 60 and 70%; and
 Time: 0, 1, 1.5 and 2 hr.

^{**} Significant at $p < 0.01$.

^{ns} Not significant at $p > 0.05$.

Table VIII - Hunter color measurements of tomato flesh after holding in hypertonic sucrose solutions for up to 2 hr and dehydrating^a

Time		Sucrose				Tomato			
Hr	L	Mean		%		Mean		Cultivar	Mean
		'a'	'b'			L	'a'		'b'
0	21.0 ^e	13.1 ^e	7.1 ^e	50		23.4 ^d	17.8 ^d	Roma	23.9 ^d 17.2 ^d 8.8 ^d
1	24.5 ^d	18.6 ^d	9.5 ^d	60		23.1 ^d	17.0 ^d	Milano	23.2 ^d 17.8 ^d 9.2 ^d
1.5	23.3 ^d	19.4 ^d	9.0 ^d	70		24.2 ^d	17.7 ^d		9.4 ^d
2	25.4 ^d	18.9 ^d	10.4 ^d						

^a N = 18.

^b N = 24.

^c N = 36.

^{d-e} Means within a column are significantly different ($P < 0.05$) when followed by different superscripts.

Hunter measurements. Sucrose concentration and cultivar had no significant effect on color.

In the presence of hot air as in dehydration, sucrose solution gradually develops an amber color that can lead to a brighter color of tomato flesh. Lycopene, the major pigment of tomato is highly unsaturated and, therefore, susceptible to oxidation. Some loss of color is possible due to isomerization of the trans-form of lycopene to the cis-form. MacKinney and Little (1962) stated that isomerization is promoted in the presence of light and by heat and acid. Lycopene may be partially destroyed under the conditions of the low water percentage of tomato products and heating (Gould, 1983). The presence of sucrose in/on the tomato flesh may have prevented pigment breakdown and did intensify the color as evidenced by an increase in the Hunter values with time up to 1 hr (Table VIII).

B. Changes in tomato flesh held in hypertonic salt solutions

1. Moisture Loss

The sum of squares from the analysis of variance of moisture loss of tomato flesh after holding in hypertonic salt solutions are presented in Table IX. Cultivar, salt concentration and time had significant ($p < 0.01$) effects on moisture loss. All

Table IX - Sum of squares from the analysis of variance of moisture loss (%) of tomato flesh after holding in hypertonic salt solutions for up to 1.5 hr^a

Source	df	Sum of Squares
Cultivar (C)	1	194.50**
Salt level (S)	2	293.07**
Time (T)	3	2222.66**
Replication	2	60.29*
C x S	2	16.22 ^{ns}
C x T	3	85.16*
S x T	6	54.74 ^{ns}
C x S x T	6	49.97 ^{ns}
Error	46	317.98

^a Cultivar: Roma and Milano;
Salt solution: 10, 15 and 20%; and
Time: 0, 0.5, 1, and 1.5 hr.

* Significant at $p < 0.05$.

** Significant at $p < 0.01$.

^{ns} Not significant at $p > 0.05$.

interactions except cultivar x time ($p < 0.05$), had no ($p > 0.05$) effect. The rate of moisture loss with time was greater for 'Roma.'

The mean values for moisture loss of tomato flesh as affected by the main sources of variability are presented in Table X. Moisture losses increased as time increased; however, at 0.5 hr and longer the losses between adjacent times were not significant ($p > 0.05$). Salt at 15 and 20% produced similar losses which were greater than the loss from 10% salt. 'Roma' lost the greater percentage of moisture, reflecting the effect of a thinner flesh.

Conditions for maximum removal of moisture were 15% salt solution and either 0.5 or 1.5 hr. The time depends upon ones point of view. Loss at 0.5 hr was significant over loss at 0 hr. Loss at 1 hr was not greater than loss at 0.5 hr. However, moisture loss at 1.5 hr was greater than the loss at 0.5 hr.

2. Solids weight gain

The sum of squares from the analysis of variance of solids weight gain of tomato flesh after holding in hypertonic salt solutions are presented in Table XI. Cultivar, salt concentration and time had significant ($p < 0.01$) effects on the solids weight gain, but the interactions had no effect ($p > 0.05$).

Mean values for solids weight gain of the tomato flesh are presented in Table XII. Percentage gain at time periods between 0.5 and 1.5 hr were similar

Table X - Moisture loss of tomato flesh after holding in hypertonic salt solutions for up to 1.5 hr

Hr	Time		Salt		Tomato	
	Mean ^a		%	Mean ^b	Cultivar	Mean ^c
	Per cent			Per cent		Per cent
0	2.56 ^f	10		9.13 ^e	Roma	13.62 ^d
0.5	13.31 ^e	15		13.09 ^d	Milano	10.62 ^e
1	15.36 ^d	20		13.67 ^d		
1.5	16.62 ^d					

^a N = 18.

^b N = 24.

^c N = 36.

^{d-f} Means within a column are significantly different ($P < 0.05$) when followed by different superscripts.

Table XI - Sum of squares from the analysis of variance of solids weight gain (%) of tomato flesh after holding in hypertonic salt solutions for up to 1.5 hr^a

Source	df	Sum of Squares
Cultivar (C)	1	135.71 ^{**}
Salt level (S)	2	181.81 ^{**}
Time (T)	3	402.17 ^{**}
Replication	2	6.52 ^{ns}
C x S	2	9.47 ^{ns}
C x T	3	100.00 ^{ns}
S x T	6	57.68 ^{ns}
C x S x T	6	74.69 ^{ns}
Error	46	602.10

^a Cultivar: Roma and Milano;
Salt solution: 10, 15 and 20%; and
Time: 0, 0.5, 1 and 1.5 hr.

^{**} Significant at $p < 0.01$.

^{ns} Not significant at $p > 0.05$.

Table XII - Solids weight gain of tomato flesh after holding in hypertonic salt solutions for up to 1.5 hr

Hr	Time		Salt		Tomato	
	Mean ^a		%	Mean ^b	Cultivar	Mean ^c
	Per cent			Per cent		Per cent
0	2.98 ^e		10	4.81 ^e	Roma	5.68 ^e
0.5	8.31 ^d		15	8.09 ^d	Milano	8.43 ^d
1	8.74 ^d		20	8.26 ^d		
1.5	8.19 ^d					

^a N = 18.

^b N = 24.

^c N = 36.

^{d-f} Means within a column are significantly different ($P < 0.05$) when followed by different superscripts.

but 2.8 times greater than the gain at 0 min. Salt at 15 and 20% caused similar weight gains which were 1.8 times greater than the gain at 10% salt. 'Milano' gained 1.5 times the weight gained by 'Roma.' The reason for this difference is not apparent; however, the thicker flesh of 'Milano' may be related to the increased weight gain.

The gain in weight was due to salt uptake. The salt content of the tomato samples is found in Appendix C-1. It should be stated that a portion of the salt in the tomato tissue, probably a small portion, was retained when the sample was prepared for analysis. Such retention would underestimate the actual salt content.

3. Net weight loss

The sum of squares from the analysis of variance of net weight loss of tomato flesh after holding in hypertonic salt solutions are presented in Table XIII. Cultivar, salt concentration and time had significant ($p < 0.01$) effects on weight loss. All interactions, except cultivar x time ($p < 0.01$), had no effect ($p > 0.05$) on weight loss. The rate of net weight loss with time was greater for 'Roma.'

The mean weight loss values are presented in Table XIV. Weight loss increased as concentration of salt was increased. The loss at 1.5 hr, however, was not greater ($p > 0.05$) than the loss at 1 hr. Tomato held in 15 and 20% salt solutions lost similar weights, but both losses were greater than that at 10% salt.

Table XIII - Sum of squares from the analysis of variance of net weight loss (%) of tomato flesh after holding in hypertonic salt solutions for up to 1.5 hr^a

Source	df	Sum of Squares
Cultivar (C)	1	209.47**
Salt level (S)	2	73.59**
Time (T)	3	892.19**
Replication	2	6.32 ^{ns}
C x S	2	27.45 ^{ns}
C x T	3	81.92**
S x T	6	31.20 ^{ns}
C x S x T	6	18.84 ^{ns}
Error	46	278.03

^a Cultivar: Roma and Milano;
Salt solution: 10, 15 and 20%; and
Time: 0, 0.5, 1 and 1.5 hr.

** Significant at $p < 0.01$.

^{ns} Not significant at $p > 0.05$.

Table XIV - Net weight loss of tomato flesh after holding in hypertonic salt solutions for up to 1.5 hr

Hr	Time		Salt		Tomato	
	Mean ^a		%	Mean ^b	Cultivar	Mean ^c
	Per cent			Per cent		Per cent
0	3.25 ^f	10		7.56 ^e	Roma	10.69 ^d
0.5	9.08 ^e	15		9.66 ^d	Milano	7.28 ^e
1	11.24 ^{de}	20		9.74 ^d		
1.5	12.38 ^d					

^a N = 18.

^b N = 24.

^c N = 36.

^{d,f} Means within a column are significantly different ($P < 0.05$) when followed by different superscripts.

'Roma' lost the greater percentage of net weight, reflecting the effect of a thinner flesh.

4. Color

The sum of squares from the analysis of variance of Hunter color measurements of tomato flesh after holding in hypertonic salt solutions and dehydrating are presented in Table XV. Cultivar, salt concentration and time affected ($p < 0.01$) luminosity (L) and cultivar and time affected yellowness ('b') at $p < 0.01$. Salt affected yellowness at $p < 0.05$. Only time affected ($p < 0.05$) redness ('a'). All interactions had no effect ($p > 0.05$) except that cultivar x time affected luminosity ($p < 0.05$). The rate of change in luminosity with time was greater for 'Milano.'

The Hunter color measurements are presented in Table XVI. As the time of holding tomato flesh in the hypertonic solutions increased, luminosity (L), redness ('a') and yellowness ('b') increased also. Salt at 20% increased luminosity and yellowness of tomato flesh compared to at 10% salt. Dehydrated 'Milano' had the greater luminosity and yellowness and similar redness. Thus, salt, as sucrose, caused an enhancement of the color. Observations indicated that salt solution increased the brightness and produced a white appearance on the surface of the tomato flesh.

Table XV - Sum of squares from the analysis of variance of Hunter color measurements of tomato flesh after holding in hypertonic salt solutions for up to 1.5 hr and dehydrating^a

Source	df	Sum of Squares		
		L	'a'	'b'
Cultivar (C)	1	488.80 ^{**}	5.44 ^{ns}	110.76 ^{**}
Salt level (S)	2	365.06 ^{**}	3.37 ^{ns}	35.85 [*]
Time (T)	3	1520.32 ^{**}	70.67 [*]	147.62 ^{**}
Replication	2	24.28 ^{ns}	17.02 ^{ns}	3.52 ^{ns}
C x S	2	26.13 ^{ns}	26.22 ^{ns}	0.27 ^{ns}
C x T	3	130.40 [*]	46.23 ^{ns}	19.98 ^{ns}
S x T	6	88.62 ^{ns}	82.11 ^{ns}	16.59 ^{ns}
C x S x T	6	28.38 ^{ns}	28.89 ^{ns}	3.48 ^{ns}
Error	46	496.73	360.18	171.15

^a Cultivar: Roma and Milano;
Salt solution: 10, 15 and 20%; and
Time: 0, 0.5, 1 and 1.5 hr.

^{*} Significant at $p < 0.05$.

^{**} Significant at $p < 0.01$.

^{ns} Not significant at $p > 0.05$.

Table XVI - Hunter color measurements of tomato flesh after holding in hypertonic salt solutions for up to 1.5 hr and dehydrating^a

Time			Salt			Tomato		
Hr	Mean		%	Mean		Cultivar	Mean	
	L	'a' 'b'		L	'a' 'b'		L	'a' 'b'
0	21.0 ^f	12.2 ^{de} 7.2 ^f	10	25.3 ^e	11.3 ^d 8.2 ^e	Roma	25.3 ^e	11.3 ^d 7.9 ^e
0.5	27.4 ^e	10.9 ^{de} 8.4 ^{ef}	15	27.5 ^e	11.9 ^d 9.3 ^{de}	Milano	30.5 ^d	11.9 ^d 10.4 ^d
1	29.3 ^e	12.9 ^d 10.0 ^{de}	20	30.8 ^d	11.5 ^d 9.9 ^d			
1.5	33.8 ^d	10.4 ^e 10.9 ^d						

^a N = 18.

^b N = 24.

^c N = 36.

^{d-f} Means within a column are significantly different ($P < 0.05$) when followed by different superscripts.

As evidenced in this osmotic process, significant changes of moisture loss, solids weight gain and net weight loss in the tomato flesh occurred. These changes depended on a number of factors in the osmotic process, such as solute type, solution concentration and time. It was noted that changes differed between the hypertonic sucrose solution and the hypertonic salt solution. According to Lenart and Flink (1984b), plant cells when concentrated in sucrose solution become compressed with cellular membrane breakdown. Immersion in salt, on the other hand, seems to act to destroy membrane function, thus changing solute permeability of the cells (Towill and Mazur, 1976). The eventual effect of cellular dehydration on transport properties will depend partly on tissue properties, especially the intercellular space present in the tissue and the amount of insoluble solids present (Lenart and Flink, 1984b). The tomato may have high intercellular space and low insoluble solids, so water will be easy to remove when hypertonic solutions force it. However, for both solutions, the general statement can be made that increasing the concentration of solute and times of the osmotic process gives rise to an increasing percentage of moisture and net weight losses.

C. Sensory Evaluation

1. Sucrose-treated, dehydrated tomato flesh

The sum of squares from the analysis of variance of sensory scores of tomato flesh treated in sucrose solution and dehydrated are presented in Table XVII. Cultivar affected ($p < 0.05$) texture scores but not color, flavor, sweetness and overall acceptability. Panelist affected ($p < 0.05$) color, sweetness and overall acceptability scores but not texture and flavor scores. Storage and cultivar x storage interaction had no effect ($p > 0.05$) on any of the measurements. Age of panelists affected all attributes ($p < 0.05$) except sweetness. Gender of panelists affected ($p < 0.05$) only sweetness.

Least-squares means for the effect of cultivar on the 5 sensory measurements of sucrose-treated tomato are presented in Table XVIII. For all the attributes measured, the scores ranged between means 5.5 and 6.6. Thus, the panel considered the attributes to be between "like moderately" and "like very much." Texture of 'Milano' was higher than 'Roma.' Color of both cultivars was "liked very much" while the other attributes were "liked moderately."

For all attributes except sweetness, panelists of the oldest group (ages 40-49) gave higher ($p < 0.05$) scores than panelists of the two younger (ages 17-29, 30-39) groups, among which no difference was found. Scores of the oldest

Table XVII - Sum of squares from the analysis of variance of sensory scores of tomato flesh held in hypertonic sucrose solution, dehydrated and stored for up to 4 months^a

Source	df	Sum of squares				Overall Acceptability
		Color	Texture	Flavor	Sweetness	
Cultivar (C)	1	0.68 ^{ns}	19.21*	1.23 ^{ns}	2.33 ^{ns}	6.71 ^{ns}
Storage (S)	1	2.46 ^{ns}	1.75 ^{ns}	3.69 ^{ns}	2.22 ^{ns}	5.59 ^{ns}
C X S	1	0.90 ^{ns}	1.74 ^{ns}	0.12 ^{ns}	6.76 ^{ns}	0.03 ^{ns}
Panelist (storage)	98	236.49*	398.02 ^{ns}	392.88 ^{ns}	419.60*	402.85*
Age	2	10.97*	19.34*	23.69*	13.58 ^{ns}	18.84*
Gender	1	1.14 ^{ns}	0.03 ^{ns}	5.78 ^{ns}	12.31*	3.73 ^{ns}
Error	95	157.95	276.14	275.99	275.49	267.74

^a Panelists: N = 50;

Cultivars: Roma and Milano;

Sucrose solution: 60%, 1.5 hr and

Storage: 2 and 4 months

* Significant at $p < 0.05$.

^{ns} Not significant at $p > 0.05$.

Table XVIII - Least squares means for scores of selected attributes of tomato flesh of 2 cultivars held in hypertonic sucrose solution, dehydrated and stored for up to 4 months^a

Selected sensory attributes	Cultivar	
	Roma	Milano
Color	6.6 ± 0.22 ^b	6.5 ± 0.22 ^b
Texture	5.5 ± 0.29 ^c	6.3 ± 0.29 ^b
Flavor	6.0 ± 0.29 ^b	6.2 ± 0.29 ^b
Sweetness	5.8 ± 0.29 ^b	6.0 ± 0.29 ^b
Overall acceptability	5.7 ± 0.28 ^b	6.2 ± 0.29 ^b

^a Panelists: N = 50,
 Sucrose solution: 60%, 1.5 hr, and
 Storage: 2 and 4 months.

^{b-c} Means within a row are significantly different ($p < 0.05$) when followed by different superscripts.
 Scoring systems: 1=Dislike extremely; 4=Dislike slightly; 5=Like slightly; 6=Like moderately; 7=Like very much and 8=Like extremely.

groups fell between the categories "like very much" and "like extremely." Scores of the younger groups fell between "like slightly" and "like moderately." Scores for sweetness of all age groups were not different ($p > 0.05$).

Female panelists gave a mean score of 6.4 ("like moderately") and male panelists gave a mean score of 5.3 ("like slightly") for sweetness. Scores for the remaining attributes were similar for the 2 gender. Means scores 6.5 for color, 5.9 for texture, 6.1 for flavor and 5.9 for overall acceptability.

2. Pasta Sauce

The sum of squares from the analysis of variance of sensory scores of sauces prepared with 3 types of 'Roma' tomato (fresh, solar-dried and salt-treated) are presented in Table XIX. Type of tomato affected ($p < 0.01$) color, flavor and between ($p < 0.05$) flavor but not color and overall acceptability. None of the other factors affected the scores.

Table XX presents least-squares means for the sauces as affected by 3 types of tomato. Sauce with salt-treated, dehydrated tomato received the highest score for color. This sauce, however, received lower scores for flavor and overall acceptability than sauce prepared with fresh tomato. Sauce with salt-treated, dehydrated tomato scored the same for flavor as sauce with commercially dried tomatoes but higher for overall acceptability. Sauce with salt-treated, dehydrated tomato was "liked moderately" for color, but flavor and overall acceptability were

Table XIX - Sum of squares from the analysis of variance of sensory scores of tomato sauce prepared with fresh, solar-dried and salt treated, dehydrated tomato^a

Sources	df	Sum of Squares		
		Color	Flavor	Overall Acceptability
Type of tomato sauce (T)	2	299.57**	60.84**	84.61**
Storage (S)	1	1.41 ^{ns}	1.05 ^{ns}	0.06 ^{ns}
T X S	2	4.44 ^{ns}	5.79 ^{ns}	6.88 ^{ns}
Panelist (storage)	98	300.97*	401.87**	348.58*
Age	2	1.40 ^{ns}	0.20 ^{ns}	1.44 ^{ns}
Gender	1	0.39 ^{ns}	10.61*	6.66 ^{ns}
Error	193	415.86	522.64	462.65

^a All tomatoes were 'Roma';
Panelists: N = 50.

* Significant at $p < 0.05$.

** Significant at $p < 0.01$.

Table XX - Least square means for score of selected attributes of sauces prepared with 3 types of tomato^a

Type of tomato	Color	Flavor	Overall Acceptability
Fresh	5.4 ± 0.21 ^c	5.2 ± 0.24 ^b	5.0 ± 0.22 ^b
Commercial, solar dried	3.4 ± 0.20 ^d	4.0 ± 0.23 ^c	3.6 ± 0.22 ^d
Salt - treated	6.0 ± 0.21 ^b	4.4 ± 0.24 ^c	4.5 ± 0.22 ^c

^a All tomatoes were 'Roma';
Panelists: N = 50.

^{b-d} Means within a column are significantly different ($p < 0.05$)
when followed by different superscripts.
Scoring system: refer to footnote, Table XVIII.

placed between "dislike slightly" and "like slightly." The commercially, solar-dried tomatoes were brown and exhibited a strong straw-like odor.

Table XXI presents least-squares means for the sauces as affected by gender of panelists. For all the attributes measured, female panelists gave higher scores than male panelists. Scores ranged between 4.0 and 5.0. Thus, the female panelists considered the samples to be "liked slightly" while the male panelists considered the samples to be "disliked slightly."

Table XXI Least - squares means for scores of selected attributes of sauces prepared with 3 types of tomato as affected by gender of panelists^a

Gender	Color	Flavor	Overall Acceptability
Male	4.9 ± 0.27 ^b	4.1 ± 0.30 ^c	4.0 ± 0.28 ^c
Female	5.0 ± 0.24 ^b	5.0 ± 0.27 ^b	4.7 ± 0.26 ^b

^a For type of tomato, refer to Table XX;
Panelists: N = 50, male = 24; female = 26.

^{b-c} Means within a column are significantly different ($p < 0.05$) when followed by different superscripts.

Scoring system: refer to footnote, Table XVIII.

CHAPTER V

SUMMARY AND CONCLUSION

The objectives of this research were to determine the concentrating effect of different concentrations of sucrose or salt on tomato flesh and to measure/evaluate chemical, physical and sensory quality properties after dehydration.

Fresh fruit of Roma and Milano cultivars of tomato were used. The tomatoes were peeled and the seed and placental material were removed, leaving the flesh for use. Solutions for concentrating the flesh were prepared from sucrose (50, 60, 70% w/v) and salt (10, 15, 20% w/v). Flesh was held in sucrose for 0, 1, 1.5 and 2 hr and in salt, for 0 0.5 1 and 1.5 hr. After concentrating in solution, the flesh was blotted free of surface liquid and measured for moisture loss, solids weight gain, net weight loss and salt content. Following these measurements, the tomato flesh was dehydrated at 57 °C for 14 hr. Upon dehydration, the tomato material was measured for color.

Samples of tomato were prepared for sensory evaluation, using 60% sucrose at 1.5 hr and 15% salt at 1 hr. The samples were stored for 2 and 4 months in sealed glass containers after nitrogen gas flushing. Tomato treated with sucrose

was evaluated without additional preparation, and tomato treated with salt was evaluated as an ingredient in pasta sauce. For purpose of comparison, sauces were prepared also with fresh and commercially, solar dried tomato. Fifty panelists evaluated each treatment.

Tomato held in both sucrose or salt lost moisture, gained in solids content and lost net weight.

From this study the following conclusions may be made:

1. The longer the time of holding tomato in solution, the greater the amount of moisture loss, gain in solids content and loss of net weight. After 2 hr of holding tomato in sucrose solution, there was a loss of 41.5% moisture, gain of 24.6% solids and loss of 30.1% net weight. After 1.5 hr in salt solution, tomato lost 16.6% moisture, gained 8.2% solids and lost 12.4% net weight.
2. The greater the concentration of solutes in solution, the greater the amount of moisture loss, gain in solids content and loss of net weight. At 70% sucrose, tomato lost a mean 31.0% moisture, gained 16.7% solids and lost 22.2% net weight. At 20% salt, tomato lost a mean 13.7% moisture, gained 8.3% solids and lost 9.7% net weight.
3. Cultivar exhibited some effects on the measurements. When held in sucrose, 'Milano' had the greater loss of moisture and gain in solids with

- no difference between cultivar for net weight loss. When held in salt solution, 'Roma' had the greater moisture loss and net weight gain, but 'Milano' had the greater gain in solids.
4. Color of dehydrated tomato was affected by holding tomato flesh in sucrose or salt solutions. After 1 hr in sucrose, the L, 'a' and 'b' values increased significantly with no significant change up to 2 hr. Generally, salt produced a significant increase in the color values up to 1.5 hr. Concentration of sucrose had no effect on color, and concentration of salt exhibited only minor increases in the color values. Color of the tomato of the 2 cultivars was not different when held in sucrose solution, and only minor color changes were determined when tomato was held in salt solution.
 5. The sensory panel evaluated tomato from the sucrose treatment for color, texture, flavor, sweetness and overall acceptability. Cultivar affected texture only, and this finding occurred with 'Roma'. On a score of 1-8, the mean scores ranged from 5.7 to 6.6; these values fell between "like slightly" and "like very much." Storage time did not affect the scores.
 6. Tomato from the salt solution and prepared as pasta sauces were evaluated for color, flavor and overall acceptability. Type of tomato affected all the attributes. The experimentally salt-treated tomato in sauce received the

highest mean score (6.0 "like moderately") for color while fresh tomato in sauce received the highest score for flavor and overall acceptability (5.2 and 5.0, respectively, "like slightly"). Female panelists scored the sauces higher for flavor and overall acceptability than males. Storage time had no effect on the attributes.

REFERENCES

REFERENCES

1. AOAC. 1984. Official Methods of Analysis. 14th. ed. Association of Analytical Chemists, Washington, DC.
2. Bidwell, R.G.S. 1974. Plant Physiology. MacMillan Publishing Co., Inc. New York.
3. Biswal, R. N. Bozorgmehr, K., Liu, X. and Tompkin, F.D. 1991. Osmotic concentration of green beans prior to freezing. J. Food Sci. (in press).
4. Biswal, R.N. and LeMaguer, M. 1989. Mass transfer in plant materials in contact with aqueous solutions of ethanol and sodium chloride. J. Food Process Eng. 11:159-176.
5. Bolin, H.R., Huxsoll, C.C., and Jackson, R. 1983. Effect of osmotic agent and concentration on fruit quality. J. Food Sci. 48:202-205.
6. Bongirwar, D.R. and Sreenivasan, A. 1977. Studies on osmotic dehydration of banana. J. Food Sci. Technol. 14: 104-112.
7. Camirand, W.M., Forrey, R.R., Popper, K., Boyle, F.P. and Stanley, W.L. 1968. Dehydration of membrane-coated foods by osmosis. J. Sci. Fd Agric. 19: 472-474.
8. Contreras, J.E. and Smyrl, T.C. 1981. An evaluation of osmotic concentration of apple ring using corn syrup solid solutions. Can. Inst. Food Sci. Techn. 14:310.
9. Giangiacomo, R., Torreggiani, D. and Abbo, E. 1987. Osmotic dehydration of fruit: sugars exchange between fruit and extracting syrup. J. Food Process. Preserv. 11:183-195.
10. Goss, J.A. 1973. Physiology of Plants and Their Cells. Pergamon Press Inc., New York, N.Y.
11. Gould, W.A. 1983. Tomato Production, Processing and Quality Evaluation. 2nd. ed., The AVI Publishing Co., Westport, CT.

12. Hawkes, J. and Flink, J.M. 1978. Osmotic concentration of fruit slices prior to freeze dehydration. *J. Food Process. Preserv.* 2:265-284.
13. Islam, M.N. and Flink, J.N. 1982. Dehydration of potato: Osmotic concentration and its effect on air drying behavior. *J. Food Technol.* 17:387-403.
14. Larmond, E. 1977. *Methods for Sensory Evaluation of Food.* Publ. 1284. Canada Dept. of Agriculture, Ottawa, Canada.
15. Lenart, A. and Flink, J.M. 1984a. Osmotic concentration of potato: I criteria for the end-point of the osmosis process. *J. Food Technol.* 19:45-63.
16. Lenart, A. and Flink, J.M. 1984b. Osmotic concentration of potato: II spatial distribution of the osmotic effect. *J. Food Technol.* 19:65-89.
17. Lerici, C.R., Pinnavala, G., Rosa, M.D., and Bartolucci, L. 1985. Osmotic dehydration of fruit: Influence of osmotic agents on drying behavior and product quality. *J. Food Sci.* 50:1217.
18. MacKinney, G. and Little, A.C. 1962. Color of Food. The AVI Publishing Co., Westport, CT.
19. Moy, J.H., Lau, N.B.H. and Dollar, A.M. 1978. Effects of sucrose and acids on osmovac-dehydration of tropical fruits. *J. Food Process. Preserv.* 2:131-135.
20. Penfield, M.P. 1990. Personal Communication, The University of Tennessee, Knoxville, TN.
21. Ponting, J.D., Watters, G.G., Forrey, R.R., Jackson, R., and Stanley, W.L. 1966. Osmotic dehydration of fruit. *Food Technol.* 20:125.
22. SAS. 1985. SAS Users Guide: Statistics. Statistical Analysis System Institute Inc., Cary, NC.
23. Steel, R.G. and Torrie, J.H. 1980. Principles and Procedures of Statistics. MacGraw-Hill Inc., New York, N.Y.

24. Torreggiani, D., Forni, E., and Rizzolo, A. 1987. Osmotic dehydration of fruit: Influence of the osmosis time on the stability of precessed cherries. *J. Food Process. Preserv.* 12:27-44.
25. Towill, L.E. and Maxur, P. (1976). Osmotic shrinkage as a factor in freezing injury in plant tissue cultures. *Plant Physiology*, 57: 290-296.

APPENDICES

APPENDIX A
CALCULATIONS

1. Net weight loss (%) = $\frac{(M_o - M_\theta)}{M_o} \times 100$
 2. Moisture loss, % of Original moisture loss = $\frac{[M_o W_{H_2O(o)} - M_\theta W_{H_2O(\theta)}]}{M_o W_{H_2O(o)}} \times 100$
 3. Solids weight gain (%) = $\frac{(M_{s\theta} - M_{so})}{M_{so}} \times 100$
- $$\frac{M_{s\theta}}{M_{so}} = \frac{M_\theta [(1 - W_{H_2O(\theta)})]}{M_o [(1 - W_{H_2O(o)})]}$$

List of Symbols

M_o	=	mass of original tomato
M_θ	=	mass of tomato after osmotic concentrations
$W_{H_2O(o)}$	=	moisture of original tomato (mass fraction)
$W_{H_2O(\theta)}$	=	moisture of tomato after osmotic concentration (mass fraction)
$M_{s\theta}$	=	mass of solids after osmotic concentration
M_{so}	=	mass of original solids.

APPENDIX B

SENSORY EVALUATION SCORE CARDS

Panelist Number _____

Sample Number _____

You have TWO samples of dried tomato. Please taste each sample and indicate how well you like the COLOR, the TEXTURE (chewiness), the TOMATO FLAVOR, and the SWEETNESS of the samples on the scales below. Also indicate your overall impression of the samples on the scale provided. Take a sip of water between samples to rinse your mouth.

COLOR

____ Like extremely
____ Like very much
____ Like moderately
____ Like slightly
____ Dislike slightly
____ Dislike moderately
____ Dislike very much
____ Dislike extremely

**TEXTURE
(CHEWINESS)**

____ Like extremely
____ Like very much
____ Like moderately
____ Like slightly
____ Dislike slightly
____ Dislike moderately
____ Dislike very much
____ Dislike extremely

TOMATO FLAVOR

____ Like extremely
____ Like very much
____ Like moderately
____ Like slightly
____ Dislike slightly
____ Dislike moderately
____ Dislike very much
____ Dislike extremely

SWEETNESS

____ Like extremely
____ Like very much
____ Like moderately
____ Like slightly
____ Dislike slightly
____ Dislike moderately
____ Dislike very much
____ Dislike extremely

OVERALL ACCEPTABILITY

____ Like extremely
____ Like very much
____ Like moderately
____ Like slightly
____ Dislike slightly
____ Dislike moderately
____ Dislike very much
____ Dislike extremely

COMMENTS:

Card for evaluating sucrose-treated, dehydrated tomato.

Card (continued)

Panelist Number _____

Male _____ Female _____

Age _____ 17 - 29

_____ 30 - 39

_____ 40 - 49

_____ 50 - 59

_____ 60 - 69

_____ 70 and over

Have you ever consumed a fruit leather or fruit roll-up?

_____ yes _____ no

Did you like the commercially prepared product?

_____ yes _____ no

Would you purchase this type of dried tomato if available on the market?

_____ yes _____ no

Panelist Number _____

Sample Number _____

You will receive **THREE** samples of tomato sauce. Please taste each sample and indicate how well you like the COLOR and the FLAVOR of the samples of the scales below. Also indicate your overall impression of the samples on the scale provided. Take a sip of water between samples to rinse your mouth.

COLOR	FLAVOR	OVERALL ACCEPTABILITY
_____ Like extremely	_____ Like extremely	_____ Like extremely
_____ Like very much	_____ Like very much	_____ Like very much
_____ Like moderately	_____ Like moderately	_____ Like moderately
_____ Like slightly	_____ Like slightly	_____ Like slightly
_____ Dislike slightly	_____ Dislike slightly	_____ Dislike slightly
_____ Dislike moderately	_____ Dislike moderately	_____ Dislike moderately
_____ Dislike very much	_____ Dislike very much	_____ Dislike very much
_____ Dislike extremely	_____ Dislike extremely	_____ Dislike extremely

COMMENTS:

Panelist Number _____

Male _____ Female _____

Age _____ 17 - 29
_____ 30 - 39
_____ 40 - 49
_____ 50 - 59
_____ 60 - 69
_____ 70 and over

Card for evaluating tomato pasta sauce.

APPENDIX C

SALT CONTENT AND MEAN VALUES FOR SPECIFIED DATA

Table C-1 - Salt content of tomato after held in hypertonic salt solutions for up to 2 hr^a

Salt, %	Time, Hr	Roma	Milano
		-----Per cent-----	
10	0	3.40 ± 0.05	1.27 ± 0.15
	0.5	3.23 ± 1.95	5.10 ± 0.50
	1	5.77 ± 0.05	6.27 ± 0.50
	1.5	6.97 ± 0.15	7.97 ± 0.15
15	0	1.40 ± 0.20	1.87 ± 0.55
	0.5	6.37 ± 0.20	6.43 ± 0.40
	1	9.10 ± 0.41	9.03 ± 0.25
	1.5	11.37 ± 0.30	10.60 ± 0.45
20	0	1.23 ± 0.40	2.77 ± 0.58
	0.5	7.10 ± 1.55	9.10 ± 0.45
	1	11.33 ± 0.85	11.17 ± 0.45
	1.5	12.76 ± 1.34	14.37 ± 0.28

^a 3 replications.

Table C-2 Mean values for moisture loss of tomato held in hypertonic sucrose solutions for up to 2 hr

Sucrose, %	Cultivar	Time, Hr			
		0	1	1.5	2
		-----Percent-----			
50	Roma	1.35 ± 0.96	25.89 ± 2.03	30.34 ± 2.01	30.51 ± 2.87
	Milano	2.24 ± 1.44	29.26 ± 1.60	34.05 ± 3.74	37.87 ± 0.67
60	Roma	2.00 ± 0.74	30.41 ± 2.12	35.31 ± 0.96	41.94 ± 0.74
	Milano	3.16 ± 0.46	30.88 ± 2.53	34.52 ± 5.27	45.88 ± 5.28
70	Roma	2.36 ± 1.36	32.85 ± 2.71	41.04 ± 1.21	45.69 ± 3.93
	Milano	4.01 ± 1.15	36.65 ± 5.74	38.97 ± 0.84	46.78 ± 5.93

N = 3.

Table C-3 Mean values for solids weight gain of tomato held in hypertonic sucrose solutions for up to 2 hr

Sucrose, %	Cultivar	Time, Hr			
		0	1	1.5	2
-----Percent-----					
50	Roma	1.68 ± 0.06	13.62 ± 3.97	16.39 ± 4.43	24.74 ± 1.01
	Milano	1.24 ± 1.33	22.30 ± 3.77	30.91 ± 7.58	29.65 ± 5.19
60	Roma	1.72 ± 0.09	19.06 ± 2.12	14.63 ± 3.38	19.69 ± 4.93
	Milano	1.69 ± 0.41	25.26 ± 9.52	23.36 ± 3.69	24.35 ± 4.58
70	Roma	3.01 ± 1.01	16.30 ± 4.80	17.10 ± 5.57	19.43 ± 3.75
	Milano	0.55 ± 0.31	19.80 ± 5.25	30.08 ± 6.72	27.69 ± 4.29

N = 3.

Table C-4 Mean values for net weight loss of tomato held in hypertonic sucrose solutions for up to 2 hr

Sucrose, %	Cultivar	Time, Hr			
		0	1	1.5	2
-----Percent-----					
50	Roma	2.23 ± 0.82	16.53 ± 2.23	20.98 ± 0.89	26.43 ± 1.38
	Milano	1.69 ± 1.70	18.09 ± 0.39	21.96 ± 2.06	24.71 ± 1.13
60	Roma	3.07 ± 1.23	19.78 ± 2.97	26.61 ± 1.31	30.50 ± 2.84
	Milano	2.11 ± 1.89	21.57 ± 2.03	26.00 ± 2.45	32.31 ± 3.15
70	Roma	4.12 ± 0.57	23.40 ± 4.75	30.87 ± 3.10	34.21 ± 4.73
	Milano	2.64 ± 1.50	24.26 ± 2.16	25.44 ± 5.85	32.48 ± 4.05
N = 3					

Table C-5 Mean values for Hunter color L-value of tomato held in hypertonic sucrose solution for up to 2 hr and dehydrated

Sucrose, %	Cultivar	Time, Hr		
		0	1	2
50	Roma	21.1 ± 2.01	24.7 ± 3.57	23.4 ± 4.54
	Milano	20.2 ± 2.16	22.9 ± 0.87	23.9 ± 1.55
60	Roma	20.6 ± 0.96	27.5 ± 3.05	22.7 ± 5.60
	Milano	19.8 ± 1.59	21.2 ± 1.25	22.7 ± 3.37
70	Roma	22.4 ± 3.14	26.1 ± 2.50	23.2 ± 1.24
	Milano	22.2 ± 3.17	24.9 ± 0.90	23.9 ± 3.52

N = 3.

Table C-6 Mean values for Hunter color 'a'-values of tomato held in hypertonic sucrose solution for up to 2 hr and dehydrated

Sucrose, %	Cultivar	Time, Hr			
		0	1	1.5	2
50	Roma	13.6 ± 1.68	18.2 ± 2.19	20.8 ± 0.43	17.2 ± 2.02
	Milano	13.6 ± 3.35	19.5 ± 3.55	19.1 ± 2.98	20.6 ± 1.21
60	Roma	13.6 ± 0.10	17.3 ± 1.35	18.2 ± 2.05	19.8 ± 1.45
	Milano	11.6 ± 1.78	19.1 ± 1.30	18.8 ± 4.19	18.4 ± 1.66
70	Roma	13.5 ± 0.35	19.2 ± 1.52	19.0 ± 1.91	17.2 ± 2.98
	Milano	13.4 ± 5.11	18.0 ± 2.04	20.7 ± 2.40	20.5 ± 0.76

N = 3.

Table C-7 Mean values for Hunter color 'b'-values of tomato held in hypertonic sucrose solution for up to 2 hr and dehydrated

Sucrose, %	Cultivar	Time, Hr			
		0	1	1.5	2
50	Roma	6.3 ± 1.91	9.3 ± 2.90	8.9 ± 1.73	9.3 ± 2.54
	Milano	8.2 ± 1.78	8.7 ± 1.32	9.1 ± 1.42	12.2 ± 3.20
60	Roma	6.5 ± 0.47	10.5 ± 2.73	8.7 ± 2.69	9.5 ± 0.66
	Milano	6.2 ± 1.16	8.0 ± 0.77	9.1 ± 3.02	10.9 ± 1.93
70	Roma	7.4 ± 1.85	10.5 ± 2.42	9.2 ± 1.68	10.1 ± 0.51
	Milano	8.4 ± 3.09	10.1 ± 1.09	9.2 ± 0.65	10.3 ± 2.72

N = 3.

Table C-8 Mean values for moisture loss of tomato held in hypertonic salt solutions for up to 1.5 hr

	Sucrose, %	Cultivar	Time, Hr			
			0	0.5	1	1.5
			-----Percent-----			
10		Roma	1.06 ± 0.94	10.63 ± 1.88	11.78 ± 1.19	16.98 ± 4.86
		Milano	1.97 ± 0.70	9.91 ± 0.67	10.24 ± 2.74	10.47 ± 4.29
15		Roma	3.30 ± 1.44	16.06 ± 4.56	20.71 ± 5.94	19.78 ± 2.34
		Milano	2.37 ± 2.20	12.10 ± 2.24	13.82 ± 2.29	16.59 ± 2.05
20		Roma	4.07 ± 1.32	16.04 ± 0.96	22.24 ± 4.84	20.63 ± 4.21
		Milano	2.58 ± 0.56	15.15 ± 1.25	13.40 ± 1.70	15.24 ± 0.91

N = 3.

Table C-9 Mean values for solids weight gain of tomato held in hypertonic salt solutions for up to 1.5 hr

Salt, %	Cultivar	Time, Hr			
		0	0.5	1	1.5
10	Roma	2.15 ± 1.66	2.88 ± 2.15	4.28 ± 3.93	6.27 ± 1.07
	Milano	2.79 ± 2.20	8.50 ± 0.43	9.06 ± 4.40	2.54 ± 1.93
15	Roma	2.53 ± 1.89	7.20 ± 4.25	6.46 ± 1.99	8.99 ± 2.83
	Milano	4.12 ± 0.27	10.55 ± 4.25	13.69 ± 0.96	11.23 ± 10.13
20	Roma	2.58 ± 0.99	6.17 ± 2.97	9.19 ± 5.03	9.49 ± 1.30
	Milano	3.70 ± 0.75	14.58 ± 5.93	9.76 ± 4.75	10.61 ± 1.04

N = 3.

Table C-10 Mean values for net weight loss of tomato held in hypertonic salt solutions for up to 1.5 hr

Salt, %	Cultivar	Time, Hr			
		0	0.5	1	1.5
-----Percent-----					
10	Roma	1.92 ± 0.26	9.16 ± 1.77	9.35 ± 1.67	13.21 ± 4.50
	Milano	2.97 ± 0.70	6.30 ± 1.60	7.34 ± 1.09	10.20 ± 2.44
15	Roma	3.72 ± 1.37	11.67 ± 2.52	16.60 ± 6.39	14.55 ± 1.22
	Milano	3.38 ± 1.03	7.11 ± 0.75	8.71 ± 0.80	11.58 ± 1.34
20	Roma	4.23 ± 1.35	12.19 ± 0.74	16.84 ± 5.34	14.87 ± 3.34
	Milano	3.24 ± 2.32	8.05 ± 1.68	8.60 ± 0.45	9.89 ± 0.48
N = 3.					

Table C-11 Mean values for Hunter color L. values of tomato held in hypertonic salt solutions for up to 1.5 hr and dehydrated

Salt, %	Cultivar	Time, Hr			
		0	0.5	1	1.5
10	Roma	19.2 ± 3.06	20.5 ± 2.05	22.9 ± 0.87	24.8 ± 1.15
	Milano	20.3 ± 1.56	28.6 ± 5.22	31.7 ± 3.57	34.4 ± 1.92
15	Roma	20.6 ± 1.51	25.1 ± 0.72	25.6 ± 5.55	30.8 ± 4.79
	Milano	22.5 ± 5.00	27.3 ± 0.35	30.4 ± 2.16	38.2 ± 4.20
20	Roma	21.2 ± 0.81	29.7 ± 1.56	30.6 ± 1.95	32.4 ± 2.66
	Milano	22.4 ± 3.20	33.3 ± 3.30	34.6 ± 5.06	42.2 ± 5.78

N = 3.

Table C-12 Mean values for Hunter color 'a' -values of tomato held in hypertonic salt solutions for up to 1.5 and dehydrated

Salt, %	Cultivar	Time, Hr			
		0	0.5	1	1.5
10	Roma	12.8 ± 1.09	10.0 ± 1.55	11.7 ± 3.61	13.2 ± 1.68
	Milano	12.0 ± 3.79	8.7 ± 2.61	11.2 ± 2.46	11.3 ± 3.17
15	Roma	13.0 ± 1.40	11.1 ± 2.30	11.2 ± 0.36	9.8 ± 2.19
	Milano	12.3 ± 4.36	11.4 ± 4.50	17.4 ± 3.88	8.9 ± 3.93
20	Roma	12.0 ± 1.27	11.9 ± 3.46	10.9 ± 1.32	8.4 ± 1.62
	Milano	11.0 ± 3.32	12.0 ± 3.47	15.0 ± 2.27	10.8 ± 1.75

N = 3.

Table C-13 Mean values for Hunter color 'b'-values of tomato held in hypertonic salt solutions for up to 1.5 hr and dehydrated

Salt, %	Cultivar	Time, Hr			
		0	0.5	1	1.5
10	Roma	6.8 ± 1.50	6.0 ± 0.98	7.2 ± 0.50	8.3 ± 1.33
	Milano	7.2 ± 1.60	7.9 ± 1.10	10.9 ± 1.45	11.9 ± 1.68
15	Roma	6.8 ± 0.15	7.5 ± 1.40	8.3 ± 2.22	9.3 ± 2.09
	Milano	8.7 ± 2.37	9.0 ± 2.00	11.8 ± 1.36	13.0 ± 4.08
20	Roma	6.2 ± 0.81	9.6 ± 1.61	9.8 ± 1.85	9.7 ± 2.20
	Milano	7.9 ± 2.13	10.6 ± 1.25	12.4 ± 2.71	13.7 ± 2.95

N = 3.

VITA

Dharia Renate was born November 10, 1961, in Tanjungkarang, Lampung, Indonesia to Hi. Damiri Barmawie and Hj. Ronimah Damiri. In May 1979, she received her senior high school diploma from S.M.A. Negeri II Tanjungkarang in Lampung, Indonesia. In the same year, she attended the University of Lampung and graduated in 1984 with a minor in Food Technology and Science.

In 1985, she served as teaching assistant at the University of Lampung. The next year, she joined the University of Lampung as an instructor. In January 1989, she began her studies toward a Master of Science degree at the University of Tennessee and received the degree in August 1991 in the College of Agricultural Sciences and Natural Resources with a major in Food Technology and Science. She is a member of the Institute of Food Technologists.

Presently, she is an Assistant Professor at the University of Lampung, Lampung, Indonesia, where she has been working since 1986.

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