OSMOTIC DEHYDRATION OF WATERMELON

FLESH

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Bachelor of Science

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1998

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
July, 2005

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ACKNOWLEDGMENTS

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CHAPTER 1

INTRODUCTION

Since the nineteenth century when watermelon (*Citrullus lanatus*) was first

imported from Africa, it has attracted Americans because of its flavor and sweetness.

Mark Twain Wrote of watermelon: " when one has tasted it, he knows what angels eat".

Over the past twenty years, the production of watermelon has increased by 59 percent for

a total annual production of 3.9 billion pounds (NASS, National Agricultural Statistics

Service, 2002). In recent years, however, consumption of fresh watermelon has declined.

In 2003, the Economic Research Service of the United States Department of Agriculture

reported a 20% decrease in consumption of fresh watermelon, from 16.8 to 13.2 pounds

per capita annually. The decline in watermelon production also affects Oklahoma

agriculture. Oklahoma is ranked 12th in the United States for watermelon production, but

the number of acres planted in watermelon has decreased in recent years. Thus, new uses

and new products from watermelon are needed to increase watermelon consumption.

One variable affecting watermelon production is the seasonality of harvest. Late

harvested or second-class watermelons are often wasted or left in the field. Thus, a food

preservation process yielding an acceptable product is needed to capitalize on this

otherwise wasted commodity. Current efforts to increase consumption of watermelon

have focused on lycopene, watermelon juice, and roasted seeds, but none of these have been implemented at large scale to date. Another possibility is to produce a dried watermelon product, which would be shelf stable and allow it to be consumed all year.

One of the most widely used drying methods is osmotic dehydration. It is a traditional preservation process involving a soaking pretreatment of foods in order to prolong the shelf life. Osmotic dehydration has been developed to improve and maintain the quality of many food products, especially in drying fruits and vegetables such as dried apples, grapes, and bananas. Thus, the purpose of this study was to investigate the application of osmotic dehydration for creating a dehydrated watermelon product.

1.1 Objectives

The overall objective of this study is to determine the feasibility of using osmotic dehydration to create a dried watermelon fruit product from watermelon flesh. The specific objectives are:

1. To compare the use of various osmotic pre-treatment ingredients on the dried watermelon product.

   a. Compare the drying rate of watermelon under a greater sugar concentration (50° Brix) than exists in tissues (10° Brix).

   b. Describe the texture and color changes when pre-treated with various ingredients (sucrose, aluminum, and calcium)

2. To evaluate the effects of forced-air drying and vacuum drying.

   a. Compare drying rate of watermelon tissue at lower atmospheric pressure (15~20 in Hg) to standard (29.9 in Hg) .

b. Describe the physical property changes as a result of the use of two types of drying systems.

CHAPTER 2

REVIEW OF LITERATURE

2.1   Theory of Osmotic Dehydration

Osmotic dehydration is a drying technology which has been broadly used in food preservation. Osmotic dehydration is a pre-treatment used to remove water from samples prior to final drying. It applies the phenomenon of osmosis that involves the diffusion of water across a semi-permeable membrane. Under osmosis, the selective or semi-permeable membrane controls the migration of solutes or chemicals within the fruit matrix. In osmotic dehydration, samples are soaked in osmotic solutions and water molecules migrate to the areas of lower water concentration, out of the tissues. In today's dried fruits and vegetables, manufacturers commonly use osmotic dehydration as a pre-treatment before final drying. Commercial dried apples, grapes, and bananas are produced using an osmotic dehydration pre-treatment before drying (Fito, 2001). It has also been reported that the energy requirement of the drying process is decreased by osmotic dehydration (Raoult-Wack, 1994). Osmotic dehydration has been broadly used, not only for dried fruits and vegetables but also other food products such as meat and fish.

In food technology, research involving osmotic dehydration has been focus on two major issues: the use of food additives and drying system selection (Rao et al., 2001).

Various additives or solutes are used in combination with osmotic pre-treatment which either prolong the shelf life or enhance the physical and chemical properties of products. Much research has also been conducted involving the combination of osmotic dehydration with different drying systems or dryers. Grabowski et al., (2002) indicated that osmotically pre-treated samples with various drying systems are able to achieve a large range of desired food properties.

2.2   Food Additives in Osmotic Dehydration

It is unknown when our ancestors first used food additives to preserve foods. The use of additives originally was to prolong the shelf life of foods such as salted vegetables and sweetened dried fruits. Food additives are also used to modify sensory attributes such as color and texture. Many researchers have indicated that the use of a pre-treatment food additive in dried fruits and vegetables results in better quality products (Ponting, 1973; Raoult-Wack, 1994; Fito, 2001). In some case, the drying process may cause loss of pigment content, resulting from the effects of heat, presence of organic acids and exposure to oxygen, and additives have helped in color retention (Clooins and Marangoni, 2000). Additives have also been successfully used to preserve or improve food texture. For example, marine meat and pickling cucumbers are treated with additives to improve tenderness and crispness (Barrett and Caballero, 2003). In this study, three additives were studied to understand their potential for improvement of color and texture during the production of dried watermelon flesh: sugar (sucrose), potassium aluminum bisulphate [$AlK(SO_4)_2 \cdot 12H_2O$], and calcium chloride[$CaCl(OH)_2$].

2.2.1　Use of Sugar as a Food Additive

Sugar is one of the oldest additives used in preserving foods. Most preserved fruits and vegetables are treated with sugar in order to enhance or maintain their sweetness. Canned fruits are examples of both soaking and storage solutions not only to maintain the quality of products but also to enhance the sweetness (Camire, 2000). Dehydrated fruits such as dried apples, grapes, and peaches are also pre-treated with sugar to impact a sweet flavor (Caballero, 2003). Since watermelon is naturally sweet, the use of sugar is presumed to be more acceptable than salt.

In addition to the attribute of sweetness, sugar has other benefits regarding the physical and chemical properties of foods. Ponting (1973) suggested that sugar is an effective inhibitor of polyphenoloxidase (PPO) and prevents the loss of volatile compounds during dehydration. In physical properties, Fito (1994) and Raoult-Wack (1994) have indicated the usage of sugar decreases the compression of pore size in cellular matrix and improves texture and stability of pigments during the drying process of osmotic dehydration. In osmotic dehydration, the sugar soaking solution is able to strength cell walls, resulting in firmer fruits texture while the storage period (Camire, 2000).

However, there are some disadvantages to using sugar solutions in osmotic dehydration. One of most common disadvantages is that the highly concentrated sugar solutions affect the efficiency of osmotic dehydration, causing slower drying rates during the final drying process. During the final drying process, a surplus of sugar molecules forms crystals that retard the heat and mass transfer. Studies indicate that the ideal sugar concentration is dependent on the nature of the individual fruits and vegetables (Fito

(1994) and Raoult-Wack et al., (1994). Each individual commodity should be considered a different case. Nowakunda et al., (2004) indicated that banana slices soaked in 55 or 65 ºBrix sugar solutions are optimal concentrations microwave drying. Giraldo et al., (2003) suggested that mango leather was optimal with a 45 ºBrix sugar solution. In this study, 10 and 50 ºBrix solutions will be tested. The 10 ºBrix sugar solution corresponds to the original concentration of the watermelon, and the 50 ºBrix sugar solution is based on the range of previous experiments.

2.2.2   Use of Potassium Aluminum Bisulfate as a Food Additive

In addition to sugar, there were two other additives used in this study to improve dried watermelon flesh: potassium aluminum bisulphate [AlK $(SO_4)_2 \cdot 12H_2 0$] and calcium chloride hydroxide [CaCl $(OH)_2$]. In 2004, the Food and Drug Administration, FDA, has approved both of these substances as GRAS, generally recognized as safe. In food preservation, these types of additives have been applied to change pH value in handling or processing fruits and vegetables. In postharvest, aluminum and calcium solutions are used to kill or inhibit the growth of microbes and bacteria (Menzel and Caballero, 2003). In processing fruits and vegetables, they are added to maintain or improve physical properties of processed foods such as canned foods and pickles. In drying fruits and vegetables, these additives are applied to have desired sensory attributes or quality prior to the process of final drying.

Aluminum potassium sulphate [AlK$(SO_4)_2 \cdot 12H_2O$] is the most common additive in picking cucumbers. Pickled cucumber used the aluminum powders to prevent color loss and have crisp texture. Gordon and Klimek (2000) indicated that aluminum

potassium sulphate solutions are able to prevent discoloration and maintain firmness of pickles and relishes. In today's food manufacturing, applications of aluminum potassium sulphate have been developed by replacing compounds to have broader functions in drying fruits and vegetables. By replacing aluminum, potassium metabisulfates (KMS) can prevent the loss of β-Carotene, which is the isomer of Lycopene in dried tomato (Lewicki et al., 2002 & Negi and Roy, 2000). In osmotic dehydration, Igoe and Hui, (2001) suggested that osmotic pre-treated potato with KMS can prevent the discoloration. Menzel and Caballero (2003) also indicated that osmotic dehydrated fruit with the pre-treatment of KMS has better flavor and storage stability. Another form of aluminum potassium sulphate is aluminum sulfate (SAS), which replaces potassium with ammonium (NH_4) or sodium (Na). SAS forms of aluminum powder are used to preserve color deterioration and firm texture in processing fruits and vegetables (Lai and Lai, 1994).

2.2.3   Use of Calcium Chloride as a Food Additives

Calcium chloride hydroxide ($CaCl_2$) is one of most common food additives to modify texture in processing meat and fruits and vegetables. In preserving fruits and vegetables, $CaCl_2$ is used to minimize the enzymatic and non-enzymatic deteriorations and inhibit microbe growth (Lewicki et al., 2002). From pre-harvest to post-harvest, cultivars used $CaCl_2$ to maintain or improve the quality of fresh cut products with longer shelf life. One of the major reasons is that calcium ions regulate the texture of cell walls and membranes in both fresh or processed fruits and vegetables (Miller & Fennema, 1996). While fruits and vegetable were alive, Silva et al., (1991) indicated that calcium

binds proteins and polysaccharides to maintain the functions of cell membrane. Several studies researched the applications of calcium chloride in processing fruits and vegetables. In soaking fresh products, pickled fruits and vegetables used $CaCl_2$ soaking solutions to increase the firmness (Harrison and Andress, 2000). In canned foods, Miller and Fennema (1996) indicated that canned fruits soaked in the calcium ions solution had a firmer texture during storage than those without.

In food dehydration, osmotic dehydrated samples pre-treated with $CaCl_2$ solutions have been studied to have more stable products and better quality of foods in dried fruits and vegetables. Texture and color analysis are two popular evaluations to understand the effects of $CaCl_2$ in dried fruits and vegetables. In texture analysis, Valle et al., (1998) suggested that osmotic dehydrated apple tissues with $CaCl_2$ treatment have better texture with texture analyzer and microscopy. Lee and Howard (1999) indicated that dried banana peppers have the greater shear force with $CaCl_2$ treatment. Camire (2000) suggested that calcium ions (Ca+2) cross link pectin molecules are to imitating turgor pressure of cell walls in osmotic pre-treated plant tissues with calcium chloride ($CaCl_2$). In color measurement, Lewicki et al., (2001) indicated $CaCl_2$ treatment followed by osmotic dehydration is more efficient than single osmotic dehydration in drying tomatoes.

However, there is limited information on analyzing the effects of osmotic pre-treated fruits and vegetables with aluminum potassium sulphate and calcium chloride hydroxide. In previous experiments of this study, dried watermelon samples had better texture and color with the treatments of both additives. One of the possible explanations is that two additives are acidifications to modify pH value and prevent less deterioration

in processing food (Sancho-Madriz and Caballero, 2003). Hettiarachchy & Kalapthy (2000) has indicated that controlling pH value during processing food is important to stabilize and to maintain desirable properties of products. In this study, changes of physical properties of dried watermelon fleshes were evaluated to understand the effects of osmotic dehydration with or without the treatment of these two additives, aluminum potassium sulphate and calcium chloride hydroxide.

2.3   Drying Systems for Osmotic Dehydration

In today's food markets, most dried fruits and vegetables are produced using the pre-treatment of osmotic dehydration. After osmotic dehydration, samples are only partially dried and still contain a large amount of water. The partial drying process for raw materials is less efficient and stable than total drying for bacterial and microbial growth (Dauthy, 1995). These processed foods consisting of 15-40% moisture or 0.65-0.90 a_w are referred to as IMF, intermediate-moisture foods (Sych and Caballero, 2003). Under the IMF situation, although some microbial and enzymatic deterioration is controlled, a significant amount of water is still available and affects the stability of foods during storage. It is necessary to apply further drying processes to decrease water activity or moisture content to a shelf stable level.

Since 1966, when osmotic dehydration was shown to be beneficial for drying fruits and vegetables, food scientists have put much effort into developing drying systems for osmotically pre-dehydrated foods (Ponting, 1966). The selection of a proper drying system needs not only to inherit the benefits of osmotic dehydration but also to concern the nature of the commodity and its economic value. For example, freeze drying is

limited to fruits and vegetables with higher water content and causes structural damage.

Thus, a proper drying system is also the most relevant and challenging in unit operation

of food engineering (Vega-Mercado et al., 2001). Although the traditional sundrying

methods with osmotic dehydration are still available today for manufacturing dried

peaches and raisins, other drying systems such as forced air, vacuum, microwave, freeze,

and radiation processes are still developing (Raoult-Wack, 1991; Lewicki, 1998; Fito and

Chiralt, 2001; Vega-Mercado et al., 2001; Krokida et al., 1999). Among these drying

systems, forced-air and vacuum dryings are the most common methods in fruits and

vegetables and will be discussed later. Microwave and infrared radiation have lower

drying times by infusing energy to remove water within tissues (Fito and Chiralt, 2001).

In large scale production, microwave heating and radiation are limited to batch process

and textural damages. While the energy is accumulated within samples, the internal

pressure causes the explosion of solid food particles and results in poor texture (Brennan

and Caballero, 2003). Compared to microwave and irradiation, freeze drying has been

developed as a more feasible methods in commercial production for dried fruits and

vegetables. Several studies have indicated that freeze drying is an efficient drying method

for osmotically pre-treated samples. These studies, especially, have found better quality

of dried plant tissues; apples, bananas, and potatoes; and apples, kiwis, mangos, and

strawberries (Lewicki, 1998; Raoult-Wack, 1991; Fito and Chiralt, 2001). However,

compared to forced-air and vacuum drying, freeze dried fruits and vegetables resulted in

the loss of elasticity texture during rehydration in apples, bananas, carrots, and potatoes

(Krokida et al., (1999).

      In this study, vacuum and forced-air drying were both used to understand their

effects on drying watermelon. Forced-air drying and vacuum drying are the two most broadly used methods for drying fruits and vegetables today. Forced-air drying is the most common type of drying process which applies airflow to increase the drying ratio by removing the water from the surface of samples. Compared to traditional sundrying, forced-air drying of fruits and vegetables is more efficient and results in more uniform products. Dauthy (1995) indicated that drying processes with air circulation have better control and higher heat efficiency. Three critical factors have been identified during the drying of fruits and vegetables: heat, dry air, and air movement (Tim, 1998). In forced air systems, the heated air serves two functions: to remove water form the surface of samples and to provided energy needed for evaporation (Brennan and Caballero, 2003). In most current fruit and vegetable drying systems, forced-air drying is used in commercial-scale cabinet, belt, and bed dryers.

Vacuum drying is another drying system that improves water evaporation on the surface of samples. By lowering atmospheric pressure, the energy required for water evaporation is decreased, which results in a faster drying rate. Drouzas, A.E. and Schubert, H. (1995) indicated that drying fruits in vacuum drying systems resulted in faster drying rates by decreasing absolute pressure. Compared to forced-air drying, vacuum drying has also shown to produce higher quality of dried fruits and vegetables while the final drying process. In the final drying process, vacuum oven had some beneficial effects on color and physical properties (Litvin et al., 1998). Krokida et al., (1999) also indicated that vacuum drying results in less textural changes. By applying a vacuum, the texture changes seemed to be preserved within cell wall integrity and cellular turgor pressure for a high quality product (Gerschenson et al., 2001). In the

combination drying technologies for osmotic dehydration, osmotic pre-treated samples

have better quality while dried in a vacuum oven (Brennan and Caballero, 2003). Today,

manufactures apply vacuums to prevent physical changes and increase drying rate in

fruits and vegetables.

2.4   Theory of Texture Analysis

While consuming food, we receive the texture perception of foods through biting,

chewing, and swallowing. The texture perception provides information to indicate the

quality of food that we intake. In texture analysis, the texture perception is applied to

indicate physical characteristics of food products. Physical properties of food tissues can

be described in either quality or quantity. In the early days, sensory evolution in texture

analysis was conducted by panelists to describe the texture in quantity by scoring the

texture of food. However, the disadvantages of the texture analysis made by panelists are

limited to the basis of individual experiences and the training procedures. Thus, an

instrumental method for texture analysis has been developed to diminish the

disadvantages of panelist.

In today's texture analysis, a texture analyzer is commonly equipment used to

describe textural characteristics of products. There are two most widely used systems in

instrumental texture analysis: texture portfolio analysis (TPA) and Warner-Bratzler

Shearing (WBS). TPA test is an objective method by compressing a standard-size sample

twice to obtain food characteristics such as hardness, facturability, cohesiveness,

adhesives, ect. (Szczesniak and Torgenson, 1965). It has been applied to measure the

textural properties in processing cheese and baking goods. However, the textural

evaluation of osmotically pre-treated samples by texture portfolio analysis has some

limitations due to lack of uniform shape and size, especially, in fruits and vegetables.

Moreover, dried fruits and vegetables with sugar infused have much harder outside than

inside in geometry of samples. The TPA test compresses samples from the outside of

food tissues. It results the instrumental texture parameters are less sensitive than WBS,

which is cutting though samples (Veland and Torrissen, 1999).

      Another instrumental protocol for texture analysis, Warner-Bratzler Shearing

(WBS) test, has been developed by Bratzler (1949) and Warner (1952) to measure the

meat tenderness. In meat science, the WBS test is one of the most widely known

technologies to evaluate the quality of meat by measuring the maximum force, fracture

point. The Warner-Bratzler Shearing test translates the instrumental results (stress and

strain) to sensory evaluations (tenderness and toughness) (Szczesniak and Torgenson,

1965). By cutting through meat samples, WBS test has higher repeatability and more

consistence results than TPA test (Wheeler et al., 1997). For the instrumental

measurements, the repeatability and mean values needs to be standardized. In 1997,

Wheeler also suggested the results of the WBS test are affected by several factors: 1) the

orientation of the lattice and crystal structure, 2) temperature of sample and environment,

3) testing speed, 4) angle of the wedge, and 5) a sufficient number of sample. In addition,

the angle of the wedge affects the results in geometry of samples. The blade wedge with a

60º of V shape has a higher repeatability than 30º (Van Oeckel, et al., 1999). In this

study, dried watermelon samples were sheared with the 60º angle blade for the WBS test.

      In food dehydration, removal of water from food inevitably leads to the

precipitation of solutes and the aggregation of insoluble structural components (Horner,

2003). In drying fruits and vegetables, there are limited researches indicating the texture changes by the instrumental texture analysis. Although few studies have indicated that the treatment of additives and drying systems have the advantages of less texture change of dried products (Raoult-Wack, 1994 and Fito, 2001). What is needed is a standard protocol for texture analysis among researchers and institutions. By apply Warner-Bratzler Shearing test, more accurate and repeatable data on texture changes can be obtained in drying fruits and vegetables.

2.5   Theory of Color Measurement

Color is an attribute of food quality that determines the willing to purchase food products. At the point of purchase, color provides the first impression of food products in addition to other physical properties, flavor and texture. Compared to other measurements, the color measurement has less damage on physical and chemical properties. In harvesting fruits and vegetables, the color measurement is a convenience tool to examine the maturity of commodity (Kander, A.A. 2002). For example, in the fields, a mature watermelon has much clearer color presentations of green and white strips on the skin than an immature melon. Moreover, as watermelon is peeled, the more reddish color of watermelon fleshes has better quality or sweetness.

The Hunter Lab-value is the most widely used system to indicate the visual attributes in laboratory and industrial scale. Three qualitative color dimensions, L, a, and b, are essential to present the color differences of the objective: L=100 white, L=0 black, +a red, -a green, +b yellow, and -b blue. Hunt et al., (1991) indicated that the Hunter Lab-value in color measurement involves uneven color and variable discoloration of testing

samples. In processing foods, they also suggested that color measurement requires

standardized procedures that both repeatable and reproducible. Thus, the result of color

measurements is important to be described as a comparison limit and statistically analysis.

In drying fruits and vegetables, the Hunter Lab-value of color measurements has been

developed to examine the feasibility of drying systems and pre-treatments (Von Elbe and

Schwartz, 1996). Barreiro et al., (1997) indicated that the L, a, b scale providing better

color discrimination of thermal concentrated tomato (saturated colors) than CIE-X, Y, Z.

Wrolstad (2000) suggested that oxidation causes thermal dried fruits and vegetables and

results in color degradation. Thus, Krokida et al., (2001) examined the color degradations

in drying apples, bananas, carrots, and potatoes with five drying systems: conventional,

vacuum, microwave, freeze, and osmotic dehydration. Moreover, Ames (2003) indicated

that color degradation of processed foods related to the browning reaction such as

enzymatic or non-enzymatic browning. Thus, the Hunter Lab-value in color measurement

provides informations not only in sensory attributes but also in food quality.

      2.6   Theory of Moisture Content and Water Activity

      Moisture content in wet basis (MC_{wb}) and water activity (a_w) are two important

indicators to the amount of water in a food. Moisture content is defined as the mass of

water per unit mass of moist sample (Singh et al., 2001). In food production, it refers to

the moisture or humidity of products. In dried fruits and vegetables, moisture content

affects optimal postharvest handling and optimal drying process storage due to individual

commodities. Moreover, with a period of drying time, Singh et al., (2001) indicated the

moisture diffusion and movement of water at some locations within product. In osmotic

dehydration, moisture content indicates the efficiency of mass-transfer of water in drying foods.

Another indicator used to determine the amount of water in foods is water activity (a_w). Water activity is defined as the relative vapor pressure of water in samples to pure water vapor pressure (Chinachoti and Marangoni 2000). In food production, measurement of a_w is more widely used than moisture content. While the drying process, changes of water activity directly impact quality and safety of food such as color and texture and shelf life. In food safety, as sample with a_w lower than 0.6, most of the deterioration factors can be diminished and results shelf life stable food products (Roos and Caballero, 2003). In this study, both moisture content and water activity were applied to monitor or predict the changes of quality (texture and color) with various drying stages for dried watermelon samples.

2.7   The Brix Measurement for Watermelon Quality

Individual watermelon has a different quality even from the same provider. By measuring the degree of Brix for a raw watermelon is needed to assure the quality of watermelons. The U.S. Standards for Grades of Watermelons indicated watermelons have "good" quality with 8% total solids as determined in a random sample by an approved refractometer, and 10° Brix suggests a "very good " quality (Powers, 1978). Even though the degree of Brix is an indication of the sweetness, it provides a convenient task to minimize the seasonal variance of watermelons at the point of harvest. In addition, a 10° Brix soaking solution was selected as the control to model concentrations in exist tissues.

2.8   Application of Osmotic Dehydration to Watermelon

A similar drying process can be used to dehydrate watermelon products as well. Compared to most fruits and vegetables, watermelon contains more water, with an average of about 90~95 % moisture (wet basis). The high moisture content of watermelon creates more challenges or limits than other commodities currently dried to create shelf stable products. Chinachoti and Steinberg (1989) suggested that water molecules cause nutrient deterioration and changes in color, flavor, and texture. Another potential cause of the deterioration is the naturally occurring enzymes within the raw watermelon. The water molecule is a good medium for enzymatic oxidation, reactions which increase the spoilage. Thus, the osmotic technology could potentially be used for the production of dried watermelon to reduce the amount of water prior to the final drying process.

CHAPTER 3

METHODOLOGY

3.1   Experimental Design

In the development of a dried watermelon product, it was determined that the most important process factors to be studied were concentration of sugar soaking solution, use of calcium and aluminum additives, and type of drying systems used. Preliminary studies were used to determine optimal level for each variable.

The series of experiments conducted and four measurements are shown in Figure 1. The factors were two differing levels of sugar concentrations, with or without calcium and aluminum additives, and two types of drying systems. The four measured product outcomes involved moisture content (MC_{wb}) in web basis, water activity (a_w), color (L, a, b), and texture (shearing test). Experiments were conducted in series, so that the best results from the first study could be incorporated into the next set of treatments. For example, in the second study, both were pre-treated in the 50º Brix soaking solution for the experiment of calcium and aluminum additives. Similarly, in the third study, samples were both pre-treated by the 50º Brix sugar solution and the additives for the experiment of the two drying systems, forced-air and vacuum drying.

Experimental design was also limited by initial differences existing among individual watermelons. In order to thoroughly examine this difference, one single

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watermelon was used in one replicate in order to minimize the variability. For example, in the comparison of the 50º and 10º Brix sugar solutions, watermelon samples used for the two pre-treatments were prepared from one watermelon for one replicate. Thus, in one experiment, three individual watermelons were used as three replicates.
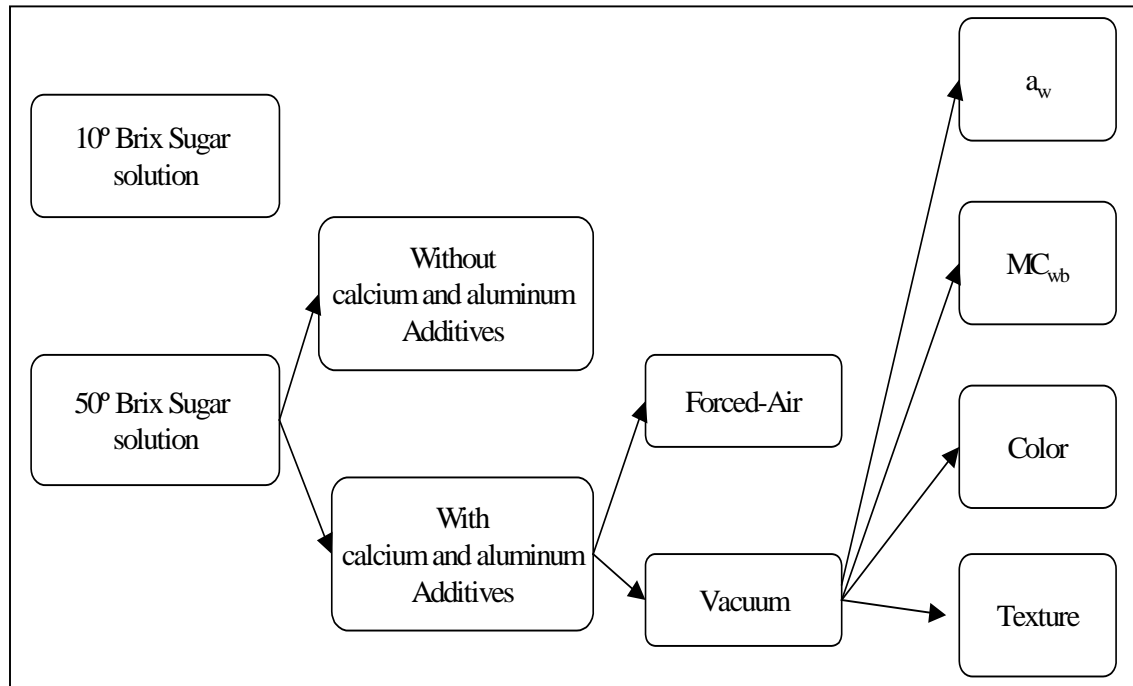
Figure 1. Series of three experiments conducted and four measurements

3.2   Sample Preparation

Locally purchased seedless watermelons (Borders, Sutton, and High-Lowe brands) were obtained from the Albertson's supermarket and stored in a refrigerator. The handling of the postharvest watermelon during the storage was recommended under the temperature range of 10~15º C to prevent chill injury (Kader, 2002 and Mayberry and Meister, 2003). In the sample preparation, the watermelon was rinsed with tap water and the rind removed. The flesh of watermelon was cut into 3x3x3 cm cubes. 100 cubes were

obtained from one watermelon for one replicate. Each pre-treatment would receive 50 cubes for either the control or the experimental group.

The sampling time depended on the time consumed for the selected treatments. Samples were collected at the pre-determined sampling times and temporarily stored in ziplock bags until testing (< 36 hrs). For each study, the sampling times were as follows:

1. In the 50º and 10º Brix experiment, the sampling times were: the 0 hour for raw watermelon fleshes, the 2nd hour after osmotic pre-treatment, the 7th hour for five hours oven drying, the 19th hour for 17 hours oven drying, and the 31st hour for 29 hours oven drying.

2. In the calcium and aluminum additional additives experiment, the pre-treatment with additives took place prior to the 50º Brix soaking. So, sampling times were the same as the first experiment.

3. In the forced-air and vacuum drying experiment, sampling times were: the 0 hour for raw watermelon, the 2nd hour after the two osmotic pre-treatments (soaking in the 50º Brix and calcium and aluminum additives), the 7th hour for five hours oven drying, the 13th hour for 11 hours oven drying, and the 31st hour for 29 hours oven drying.

3.3 Brix Measurement

The °Brix of purchased watermelons was measured using a digital refractometer (LEICA Auto brand). A laboratory blender was used to blend 50ml of the raw watermelon flesh for 30 seconds. The juice was filtered using a metal mesh and filled into 8 centrifuge tubes (1.5ml each). After centrifuging at 10,000 rpm for 10 min at 10° C, the °Brix reading of the watermelon juice measured was prepared for the Brix measurement. Watermelon which tested in the range of 7-10 °Brix was considered to be good quality (Powers, 1987). Melons with lower °Brix readings were not used for study.

3.4 The Osmotic Pre-treatment

During osmotic pre-treatment, watermelon samples were soaked in solutions of different solutes: sugar (sucrose), calcium [CaCl (OH)$_2$], and aluminum powder [AlK (SO$_4$)$_2$·12H$_2$0]. In the first experiment, sucrose (Albertson's sugar) was used to prepare two concentrations of the sugar soaking solutions, the 50° and 10° Brix. The sugar solutions were prepared by dissolving sugar in water to give a total volume of 1500ml. The sugar solution was then pre-heated to 120° C and covered with aluminum foil. Solutions were then poured onto watermelon samples in two metal containers with at least 2 liters volume. Samples were separated into two groups; one was soaked in the 10° Brix sugar solution and the other was soaked in the 50° Brix sugar solution. Continuous heating was applied in the forced-air drying oven (Cole Parmer AFCO Series #5200-55) for 15 min at 120° C. As the temperature of geographic center of cubes reached 60° C (temperature probe), the containers were removed and cooled down to room temperature (25°C) for the rest of the osmotic pre-treatment (105 min). 60° C was selected as the

blanching temperature for the watermelon samples. In the preliminary experiments of this study, it suggested that the blanching temperature over 60ºC would result a darker product.

Another osmotic pre-treatment involved the treatment of calcium and aluminum additives. In the second experiment, watermelon samples were treated with the additives before soaking in the 50 ºBrix sugar solution. For the treatment of the additives, samples were first soaked in the aluminum solution and then in the calcium solution, both at room temperature. The first soaking was in 1000 ml of a 0.75% (w/v) aluminum potassium sulfate [AlK $(SO_4)_2 \cdot 12H_20$] solution for 15 min. The second soaking was in 1000ml of a 1.5 % (w/v) calcium chloride hydroxide [CaCl $(OH)_2$] solution for 30min. For the treatment without additives, watermelon samples were soaked separately in two pure water solutions for 30 min and 15 minutes at room temperature.

3.5   Forced-air and Vacuum Drying

For the first two studies involving the osmotic pre-treatments, samples were dried in the forced-air drying oven (Cole Parmer AFCO Series #5200-55). The forced-air oven generates 112 units of air exchange/hour at 60º C. Osmotically pre-treated watermelon samples were evenly placed on a metal wire mesh within the oven. Prior to distributing samples, the metal mesh was covered with a thin layer of vegetable oil to prevent stickiness.

In the forced-air and vacuum drying comparison, all samples were pre-treated with the 50º Brix sugar solution and the calcium and aluminum additives. After the osmotic pre-treatments, samples were separated into two groups for the two drying

systems. One group was dried in the forced-air drying oven with the same conditions described previously. The other group was dried in the vacuum drying oven (VWR Scientific 1430D, Sheldon MFG., ING). A vacuum gauge on the oven was used to adjust the vacuum to a level of 15-20 in-Hg lower than the atmosphere pressure (29.9 in-Hg). Samples were distributed on similar metal meshes with vegetable oil and dried in the vacuum oven at 60º C.

3.6 MC_{wb} and a_w Measurements

The moisture content, MC_{wb}, was measured using a moisture analyzer (Computrac Max-2000 moisture analyzer). Watermelon samples were examined at a temperature of 120º C with a 95% relative prediction for the analyzer. Water activity was measured using an AquaLab CX2 water activity meter. In a_w analysis, samples were cut in smaller pieces (less than 0.5 cm) to increase the surface contact.

3.7 Texture Analysis

All texture measurements were performed using the TA.XT2 Texture Analyzer with the Warner-Bratzler Shearing (WBS) blade (Texture Technologies Corp, Scarsdale, NY/Stable Micro System, Godalming Surrey, UK) at room temperature. The analyzer was controlled by the Texture Expert software (Texture Technologies Crop). The WBS blade measured 1.5 mm wide x 10 mm long x 1.0 mm width and a 60º wedge angle.

Watermelon flesh samples were placed directly under the WBS blade in the base plate (provide by the Texture Analyzer). Sample was orientated was such that the blade had the maximum contact in length to the object. Before the Warner-Bratzler Shearing

searing test, sugar crystals at the edge of the sample were removed to minimize errors. During testing, the trigger force was set at 50 mg, so that when the compressive force reached 50mg, resistive force was recorded as the shearing force. The thickness of the watermelon sample was indicated by the testing distance or time. The shearing process continued until the WBS blade traveled a distance of 40 mm. It corresponds to the blade reaching the geometric center of raw watermelon cubes (3x3x3 cm). Although there was textural shrinkage of samples during drying, the 40 mm testing distance was fixed. Other settings of the Texture Expert software for the WBS test are listed below: Trigger force: 50 mg, Pretest rate: 5.00 mm/s, Testing rate: 1.00 mm/s, Posttest rate: 5.00 mm/s, and Testing distance: 40 mm. After the shearing test, the force-deformation plot was generated by the software. An ideal illustration of the plot was provided in Figure 2 (Stable Micro System).

Figure 2 shows the shearing force changes during the WBS blade cutting through a sample (Stable Micro System, 2000). In the illustration of the WBS test, Anchor 1 indicates the trigger force that starts the recording of the resistant force from the object. Anchor 2 (1f) is the maximum force or peak force. Anchor 3 is the end shearing force after the maximum force occurred and related to the testing distance. Anchor 4 is omitted in this study. In the deformation curve, a force area is calculated from the area under the curve between anchor 1 and anchor 3. The force area represents the deformation energy (Strain) of an object or the work done by the blade.
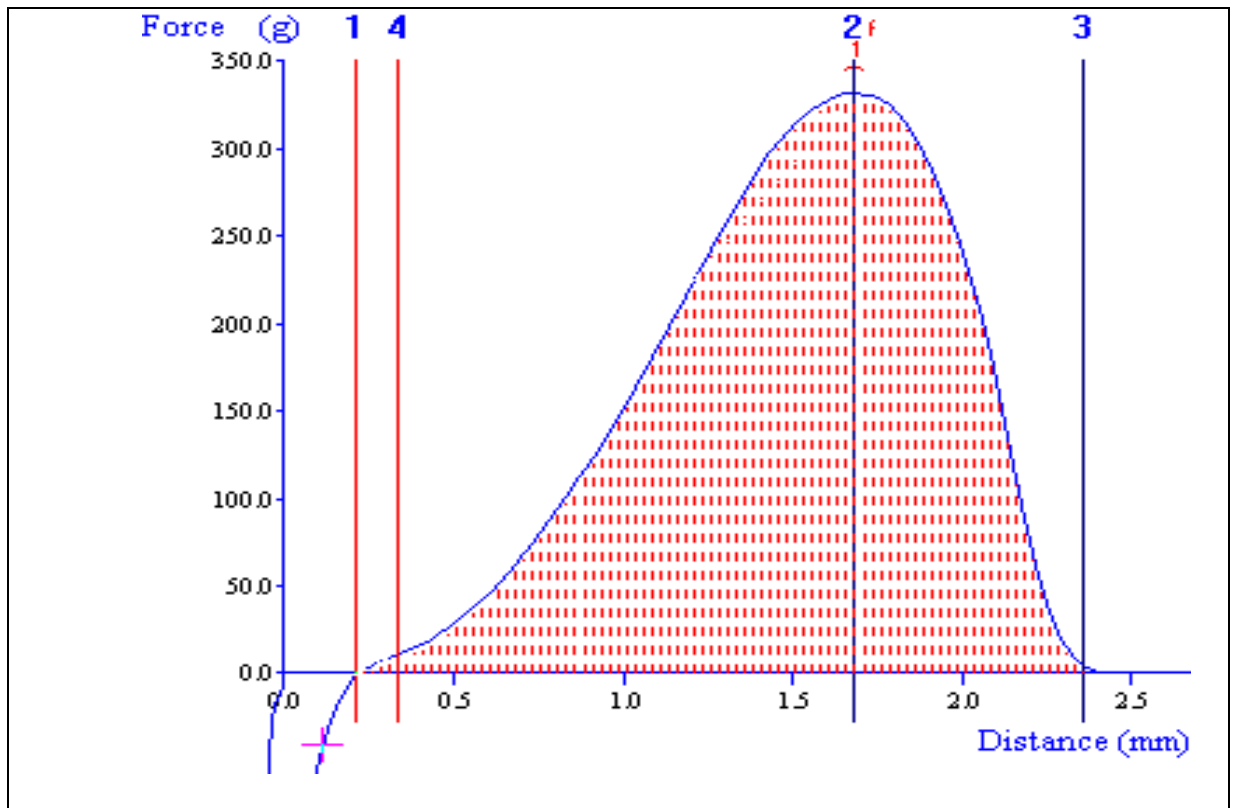
Figure 2. An ideal illustration of the force deformation plot for the Warner-Bratzler
Shearing test.

3.8   Color Measurement

The Hunter Lab-values of samples were measured using a hand-held colorimeter

(MiniScan XE Plus, Hunter Associates Lab. Inc. Reston, VA). Samples for color testing

had two types of watermelon flesh: raw watermelon flesh and dehydrated watermelon

flesh. For raw watermelon samples, color was measured before flesh was cut into cubes.

For dehydrated watermelon, samples were from the flesh after texture analysis. The

samples were processed by slicing and smashing into small pieces and constructing a

sphere shape of 5 cm diameter. Each side of the constructed sphere was measured at least

4 times by the colorimeter. A total of three mean values of the Hunter Lab values were

recorded.

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3.9 Statistical Analysis

Statistical analysis was performed using SAS (v 9.1). In each study, a p-value was used to indicate the likelihood that the populations of two different treatments were assumed the same. The percentage of P-value indicates the possibility that two populations are the same. By applying the t-test, when the P-value is less than 0.05, two populations are significantly different. In this study, the statistical analyses were used to compare the physical properties between two treatments. In color measurement, the P-value was used to compare three mean values (n=3) from each of two treatments. In the texture analysis, the P-value was used to compare 8 readings from each of two treatments. In addition, the results of moisture content and water activity were calculated by Microsoft Excel software. Moisture content, MC_{wb}, was reported in the mean values of individual replicate. Water activity, a_w, were reported in mean values of each three replicates, along with a trend line.

CHAPTER 4

RESULTS AND DISCUSSION

Because initial differences existed among individual watermelons used as samples in this study, the results presented compare the changes for the selected treatments that took place within a single watermelon. In each experiment, three replicates (three different watermelons) were used in order to demonstrate the repeatability of the changes. Therefore, three comparisons were made to examine the individual effects of each the three difference variables during osmotic dehydration: soaking in two different concentrations of sugar solutions, the addition or non-addition of additives, and the use of forced-air and vacuum oven drying.

4.1   Effect of Osmotic Pre-treatment by Sugar

Watermelon samples were soaked for 2 hours in sugar solutions of 50º and 10º Brix followed by force-air drying in order to determine the effects of sugar pre-treatment.

4.1.1 MC_{wb} and a_w Changes

Moisture content, web basis (MC_{wb}) and water activity (a_w) were used to monitor the rate of water loss and the change in water chemical activity. Figure 3 shows moisture content changes for three replicates of the two pre-treatments in 50 and 10º Brix solutions. All three replicates soaked in the 50 ºBrix sugar solution had a faster rate of water loss during the early drying stages (0, 2, and 7 hours). However, in the later stages of drying (19 and 31 hours), samples soaked in the 50 ºBrix sugar solutions had a slower rate of water loss than those soaked in 10º Brix sugar solutions. This suggests that the sugar holds water molecules and retards the mobility of water when the MC_{wb} is low in the fruit matrix.

Figure 3. MC_{wb} changes during drying of watermelon samples pre-treated with 50º and 10º Brix Solutions. 50B-1, 50B-2, and 50B-3 are three replicates of samples treated with

the 50º Brix solution. 10B-1, 10B-2, and 10B-3 are three replicates of samples treated with the 10º Brix solution.

Table I shows the mean values of moisture content (wb%) changes per hour in different drying periods for three replicates. In the earlier drying stages, all three replicates soaked in the 50º Brix had larger moisture changes than 10º Brix during the 0-2 hours drying period. In Table II, P-values indicate the differences of the moisture changes per hour between the two sugar concentrations. In the earlier drying stages, there is a significant difference between the two concentrations of sugar solution during the drying period of 0-2 hours ($P<0.05$).

Table I. Rate of change in moisture content (% per hour) for watermelon samples pre-treated with 50 and 10 ºBrix Solutions. 0-2, 2-7, 7-19, and 19-31 are drying time intervals.

Interval (hrs)	50 B-1	10 B-1	50-2	10 B-2	50 B-3	10 B-3
0-2	6.27	-0.27	6.61	-0.05	5.82	-0.99
2-7	5.60	2.86	0.45	1.30	4.29	3.00
7-19	3.01	4.56	4.77	5.62	3.61	5.16
19-31	0.48	0.91	0.88	0.91	0.56	0.74

Table II. P-values for drying rate differences between 50º and 10º Brix sugar solutions. Data used for P-value analysis was the mean value (n=3) of three replicates

Interval (hrs)	0-2	2-7	7-19	19-31
P value	0.00005	0.552616	0.092972	0.188672

Figure 4 shows the water activity for three replicates of the two osmotic pre-treatments in 50º and 10º Brix solutions. In the early drying stages, the samples treated with the 50º Brix solution had a faster rate of a_w decrease than those treated in the 10º Brix. In the later drying stages, samples soaked in the 50º Brix had a slower rate of a_w decrease.
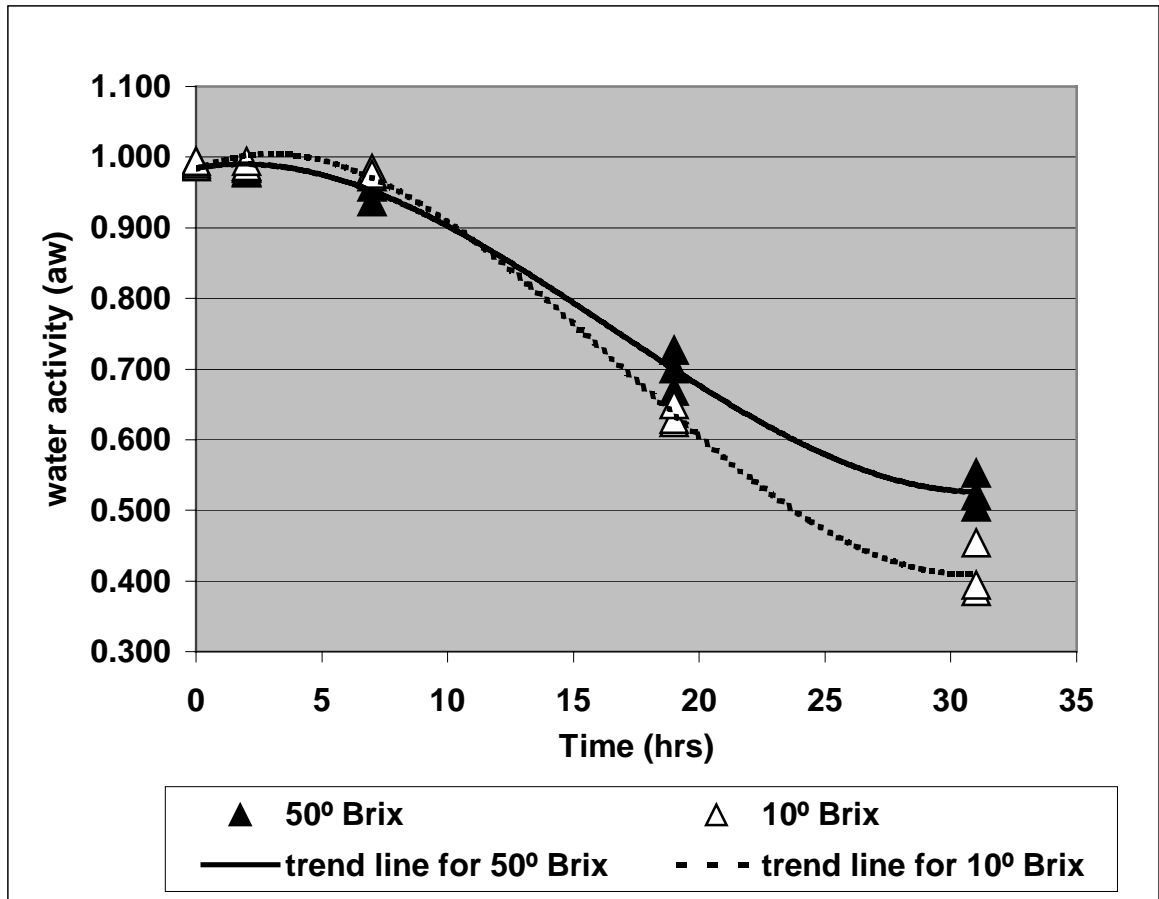
Figure 4. Changes in water activity (a_w) during drying of watermelon samples pre-treated with 50º and 10º Brix sugar solutions. Three replicates of each are shown, along with a trend line.

Table III shows the rate of change in water activity for different drying time intervals for three replicates. In the later drying stages, all three replicates soaked in 10º Brix treatments had larger a_w changes per hour than 50º Brix. In addition, during the earlier drying stages, watermelon samples pre-treated with 50º Brix sugar solutions had larger aw changes per hour than 10 ºBrix. In Table IV, P-values indicate the differences of a_w changes per hours between the two sugar concentrations. There are significant differences between the 50 ºBrix and 10 ºBrix soaking solutions in the drying periods of 0-2 and 7-19 hours (P<0.05).

Table III. Rate of change in water activity in different time intervals during the 50º and 10º Brix pre-treatments.

Interval (hrs)	50º Brix-1	10º Brix-1	50º Brix-2	10º Brix-2	50º Brix-3	10º Brix-3
0-2	0.50	0.05	0.55	0.15	0.50	0.00
2-7	0.80	0.28	0.06	0.06	0.52	0.36
7-19	2.23	2.90	2.08	2.96	2.15	2.72
19-31	0.97	1.42	1.72	2.03	1.63	2.13

Table VI. P-values for rate of change in water activity for the pre-treatments of 50º and 10º Brix sugar solutions. Data used for P-value analysis was the mean value (n=3) of three replicates

Interval (hrs)	0-2	2-7	7-19	19-31
P-value	0.000673	0.386868	0.001099	0.264908

It is instructive to compare the results of changes in water activity and moisture content during the later drying stages (19 and 31 hour). Figure 3 shows a similar final MC_{wb} for the two pre-treatments at 31 hrs while Figure 4 shows different a_w at 31 hrs. This observation reflects the difference in the definitions of moisture content and water

activity. MC_{wb} indicates the total amount of water remaining in the fruit matrix. Thus, the total amount of water was similar between the two osmotic pre-treatments. The water activity describes the chemical activity of water molecules, which indicates the readiness with free water molecules can associate with microorganisms and enzymes. After the 31 hours of drying, the samples soaked in 50 ºBrix solution had a higher a_w than those soaked in 10 ºBrix. These differences suggest that watermelon flesh soaked in a 10º Brix solution results in lower chemical activity of water for the same drying period and thus will have greater stability and shelf life than flesh soaked in the 50º Brix solution.

4.1.2 Color Analysis

Color changes were measured using a Hunter colorimeter for raw watermelon tissue and dehydrated watermelon flesh treated with the two osmotic pre-treatments (50º and 10º Brix solution). Table V shows the mean Hunter color values (L, a, b) for raw watermelon and dehydrated watermelon samples at the 19th and 31st drying hours. All three replicates indicate that samples soaked in the 50º Brix solution had less discoloration and resulted in a and b color values that were closer to those of the raw watermelons. The greater concentration (50º Brix) of the osmotic pre-treatment helped preserve the color of the watermelon flesh.

Table V. Hunter color values of raw watermelon and dehydrated watermelon flesh pre-treated in 50º and 10º Brix solutions. L=100 white, L=0 black, +a red, -a green, +b yellow, -b blue.

Replicate 1	Pre-treatment	L	a	b
Raw		48.5	26.1	24.6
19hr	50B	33.8	23.9	22.9
	10B	33.1	22.5	19.4
31hr	50B	34.8	23.4	22
	10B	35.6	19.8	16.1
Replicate 2				
Raw		48	25.6	26.5
19hr	50B	34.2	22.6	23.6
	10B	33.8	20.7	18
31hr	50B	36	22.9	23.2
	10B	35.1	21.5	19.9
Replicate 3				
Raw		43.6	30.6	27
19hr	50B	28.2	29.4	26.4
	10B	27.2	28.4	25
31hr	50B	28.3	27.9	25.1
	10B	30.8	22.2	16

Table VI shows P-values for color differences among raw watermelons used in each of the three replicates of the osmotic pre-treatment experiments. They indicate significant color differences between raw watermelon samples. The watermelon used in the third replicate showed a substantial difference in L and a color values compared to the other two replicates (P<0.05). There were no significant color differences between the two watermelons used in replicates 1 and 2 (P>0.05). The measurement demonstrated the inherent color difference that existed among watermelon samples. It also suggested the need to consider the relative color changes among replicates.

Table VII shows P-values for Hunter color values of samples pretreated with 50º and 10º Brix solutions. In the table, several significant differences in a and b values between the two osmotic pre-treatments can be observed, some at the 19th hour and some

at the 31st hour of drying (P<0.05). It suggested that the sugar additive has similar affects

on preventing color loss during drying watermelon in both 50 and 10 °Brix

concentrations. In addition, the L color value showed no significant differences between

two concentrations. It suggested that browning reaction is controlled by the sugar soaking

pre-treatment (Ames, 2003).

Table VI. P-values for color differences among raw watermelons used in each of the
three replicates of the 50 and 10 °Brix pre-treatments. Data used for P-value analysis was
the mean value of three readings (n=3). 1 vs 2 compares the two raw watermelons used in
replicates 1 and 2.

Replicates	Hunter Lab value	P value
1 vs 2	L	0.70
	a	0.84
	b	0.49
2 vs 3	L	0.02
	a	0.001
	b	0.61
1 vs 3	L	0.002
	a	0.001
	B	0.412

Table VII. P-values for L, a, b color values in dehydrated watermelon samples pre-treated
with 50° and 10° Brix solutions. Data used for P-value analysis was the mean value (n=3)
of three color measurement readings.

Replicate 1	L	a	b
50⁰ vs 10⁰ Brix at 19hr	0.63	0.13	0.13
50⁰ vs 10⁰ Brix at 31hr	0.84	0.04	0.10
Replicate 2			
50⁰ vs 10⁰ Brix at 19hr	0.49	0.11	0.01
50⁰ vs 10⁰ Brix at 31hr	0.47	0.14	0.06
Replicate 3			
50⁰ vs 10⁰ Brix at 19hr	0.42	0.32	0.47
50⁰ vs 10⁰ Brix at 31hr	0.04	0.01	0.01

4.1.3   Texture Analysis

Texture analysis was conducted using the TA.XT2 Texture Analyzer with a 60º wedge angle of the Warner-Bratzler shearing blade. Peak force and force area were determined in order to understand the textural changes in watermelon flesh between the 50º and 10º Brix osmotic pre-treatments. In one replicate, 8 samples from each pre-treatment were tested at each of the following sampling times: 0, 2, 7, 19,and 31 hours.

4.1.3.1 Peak Force

Figure 5 shows clearly the increase in the peak force as water activity is reduced for three replicates of each pre-treatment. In the early drying stages, there were minimal changes in peak force as the water activity decreased from 0.9 to 0.7. In the later drying stages, where samples had less than 0.7 a_w, the peak force increased rapidly. At the lower values of water activity, the samples soaked in the 50º Brix solutions had much lower peak force readings than those soaked in the 10º Brix solutions. The 50º Brix pre-treatment seems to result in a more tender or less hard texture due to higher water activity.
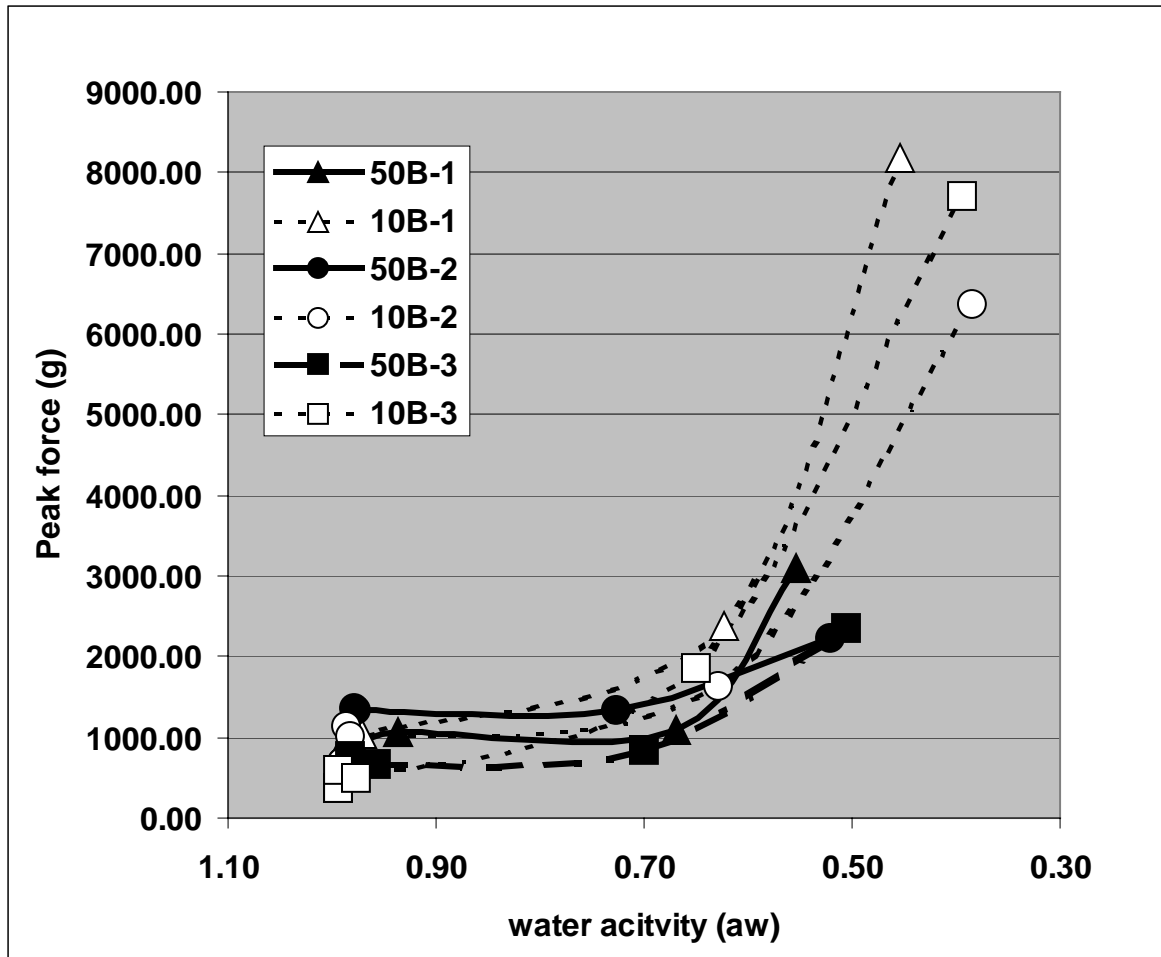
Figure 5. Texture peak force changes of watermelon samples pretreated with 50º and 10º Brix solutions. 50B-1, 50B-2, and 50B-3 are three replicates of samples treated with the 50º Brix solution. 10B-1, 10B-2, and 10B-3 are samples treated with the 10º Brix solution.

Table VIII shows the significant differences in peak force among the three raw watermelon samples ($P<0.05$). The fact that textural properties of the three raw watermelons are significantly different from each other confirms the need to make treatment comparisons within a single watermelon.

Table IX shows the significant differences in peak force between the two osmotic pre-treatments in each of three replicates. In the later drying stages, all three replicates showed a significant difference between pre-treated samples at the 19th and 31st hours

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(P<0.05). In addition, the smaller P-values at the 31st hour compared to those at the 19th hour indicate larger textural differences at longer drying times. As was evident in Figure 5, the a$_w$ decreased significantly from the 19th to the 31st hour. Thus causing significant changes in texture during that time period.

Table VIII. P-values of texture peak force between pairs of watermelons used in 50 and 10 ºBrix pre-treatment experiments. 1 vs 2 compares the raw watermelons used in replicates 1 and 2.

Replicates	P value
1 vs 2	0.005
2 vs 3	0.0000005
1 vs 3	0.001

Table IX. P-values of texture peak force in dehydrated watermelon samples pre-treated with 50º and 10º Brix solutions.

Drying Time (Hours)	2	7	19	31
50º vs 10º Brix in Replicate 1	0.412	0.826	0.021	0.000045
50º vs 10º Brix in Replicate 2	0.099	0.015	0.003	0.000000
50º vs 10º Brix in Replicate 3	0.012	0.063	0.014	0.000001

4.1.3.2 Force Area

Figure 6 shows the increase in the texture force area as water activity is reduced for three replicates of samples treated with 50 and 10 ºBrix solutions. In the early drying stages, there were minimal changes in force area as water activity decreased from 0.9 to 0.7. In the later drying stages, at less than 0.7 a$_w$, samples increased in force area more rapidly. At the lower values of water activity, samples soaked in the 50º Brix solutions had a lower force area than those soaked in the 10º Brix solutions. The 50º Brix pre-treatment seems to result in a less tough texture.

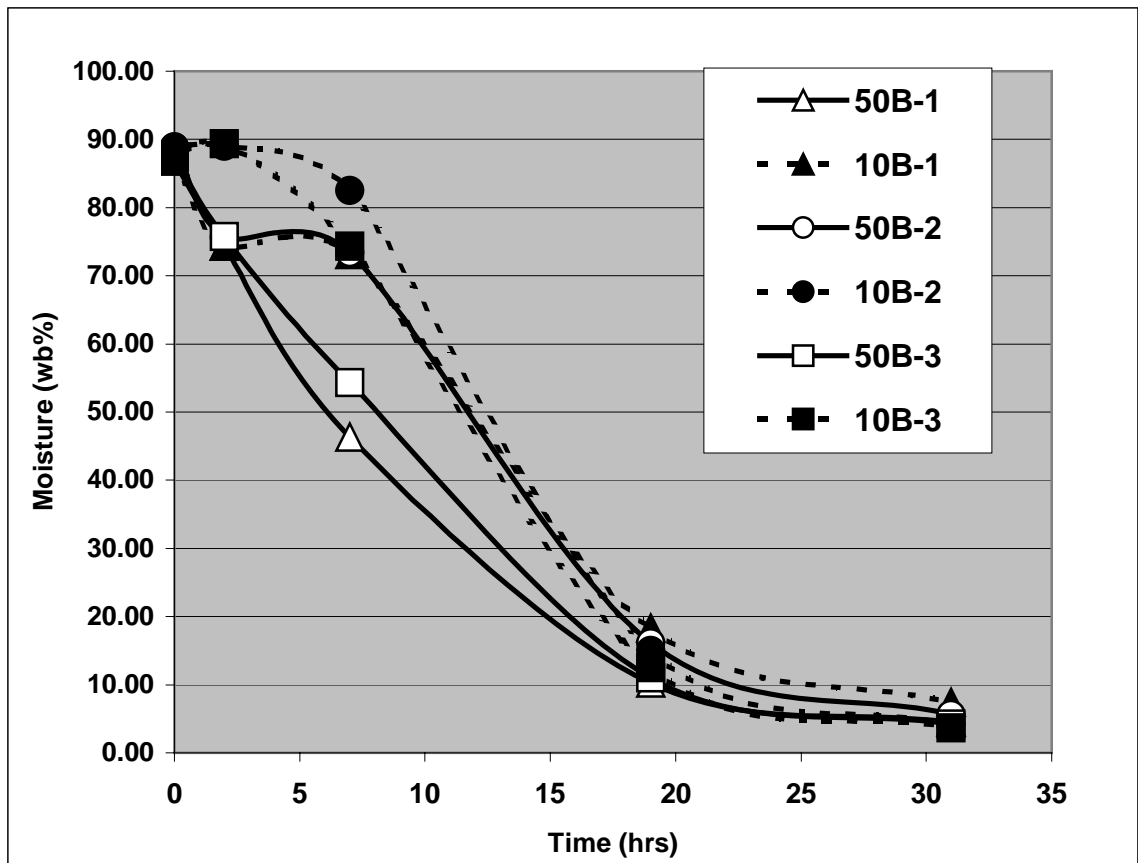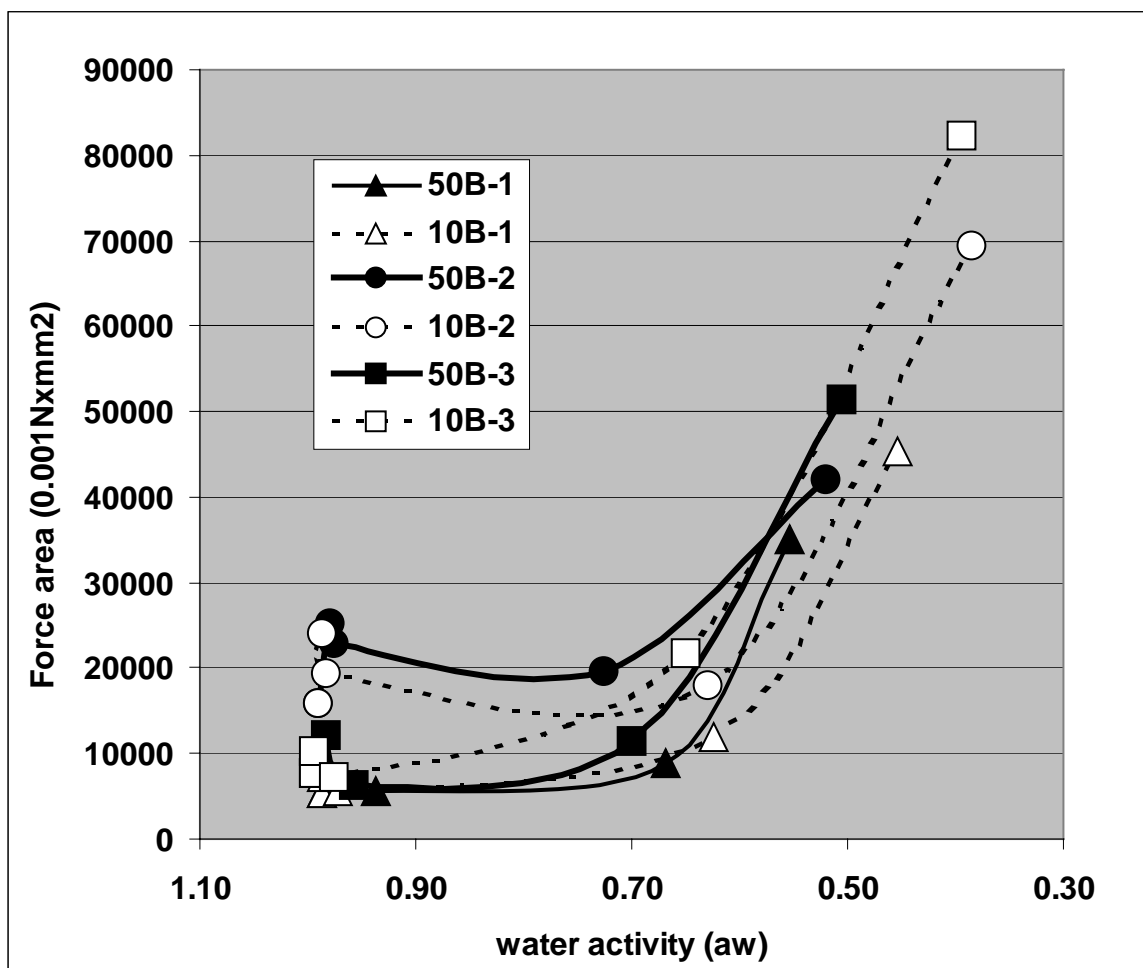Figure 6. Texture force area changes in watermelon samples pretreated with 50º and 10º Brix solutions. 50B-1, 50B-2, and 50B-3 are three replicates of samples treated with the 50º Brix solution. 10B-1, 10B-2, and 10B-3 are samples treated with the 10º Brix solution.

Table X shows the significant differences in texture force area among the three raw watermelon samples ($P>0.05$). Again, the three different melons tested show significant raw property differences. Table XI lists P-values for force area comparing the two osmotic pre-treatments. Replicates 2 and 3 show significant differences in force area between the two osmotic pre-treatments ($P<0.05$).

Table X. P-values of texture force area between pairs of raw watermelons used in 50 and 10 ºBrix pre-treatment experiments for three replicates. 1 vs 2 compares the raw watermelons used in replicates 1 and 2.

Replicates	P value
1 vs 2	0.0000000023
2 vs 3	0.00000004
1 vs 3	0.0005

Table XI. P-values of texture force area in dehydrated watermelon samples pre-treated with 50º and 10º Brix solutions.

Drying Time (Hours)	2	7	19	31
50º vs 10º Brix in Replicate-1	0.44	0.90	0.21	0.12
50º vs 10º Brix in Replicate-2	0.53	0.05	0.0002	0.0004
50º vs 10º Brix in Replicate-3	0.04	0.0001	0.02	0.0004

Results from this study show that while the 50 ºBrix solution improved the drying rates during the early drying stages, the sugar retarded the water movement in later drying stages. With retard to sample physical changes, pre-treatment with the 50 ºBrix solution significantly retard textural changes. The greater sugar concentration solution in the 50º Brix solution allowed the infusion of more sugar into watermelon samples than the 10 ºBrix, and it is presumed that the increase sugar helps to uphold the structure of the watermelon tissues and results in less textural change. It has been suggested by other researchers that a sufficient amount of sugar during the soaking process can prevent textural collapse and maintain the cell wall integrity for the drying process (Fito, 1994 and Raoult-Wack et al., 1994). In the osmotically dehydrated watermelon samples, the 50 ºBrix sugar soaking solution resulted in a better product than the 10 ºBrix.

4.2   Effect of Osmotic Pre-treatment with Additives: Calcium and Aluminum

Samples used to compare the effects of calcium and aluminum additives were pre-treated with 1.5 % (w/v) calcium hydroxide [CaCl (OH)$_2$] solution and 0.75 % (w/v) aluminum potassium sulfate [AlK (SO$_4$)$_2$·12H$_2$0] solutions followed by the 50º Brix sugar solution for osmotic dehydration. The 50 ºBrix solution was chosen as the better alternative between the 50 and 10 ºBrix pre-treatments in the first study.

4.2.1   MC$_{wb}$ and a$_w$ Changes

Figure 7 shows the MC$_{wb}$ changes for samples treated with and without calcium and aluminum additives. It can be seen that there were no MC$_{wb}$ differences between the samples pre-treated with additives and those without in all three replicates. It indicates that the treatment of calcium and aluminum additives didn't affect the rate of water loss under the 50º Brix sugar solution soaking.

Figure 8 shows the values of water activity for watermelon samples treated with calcium and aluminum additives and those without. Samples treated with the additives had a lower a$_w$ in the later drying stage than those without. It suggests that the treatment of calcium and aluminum additives resulted in a lower chemical reactivity of water in the fruit matrix. One of the possible explanations is that the calcium and aluminum are the chelating agents that form the complex structure within the watermelon samples (Gordon and Klimek, 2000). The calcium and aluminum additives bind with water molecules and result in a lower a$_w$.
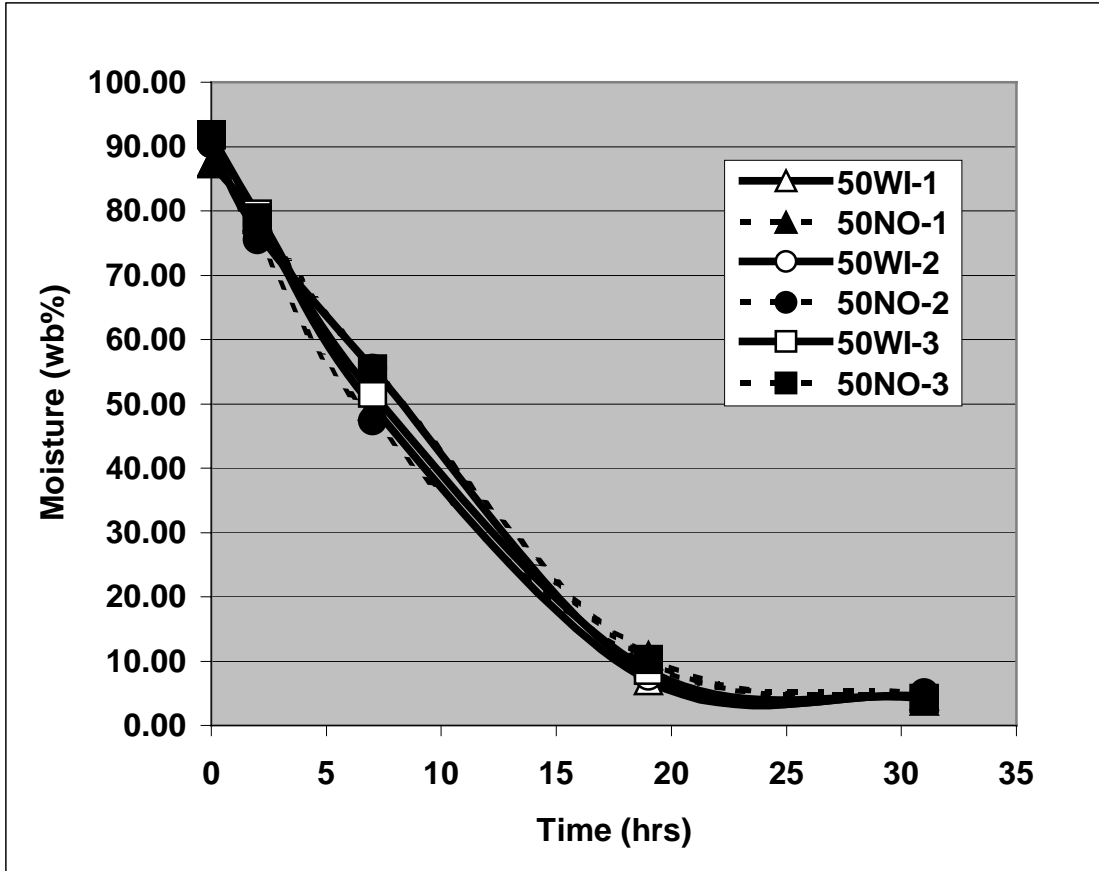
Figure 7. MC$_{wb}$ changes for watermelon samples treated with and without calcium and aluminum additives. Note: 50WI-1, 50WI-2, and 50WI-3 are three replicates of watermelon samples treated with additives under the 50º Brix sugar solution soaking. 50NO-1, 50NO-2, and 50NO-3 are three replicates of watermelon samples treated without additives before the 50º Brix solution soaking
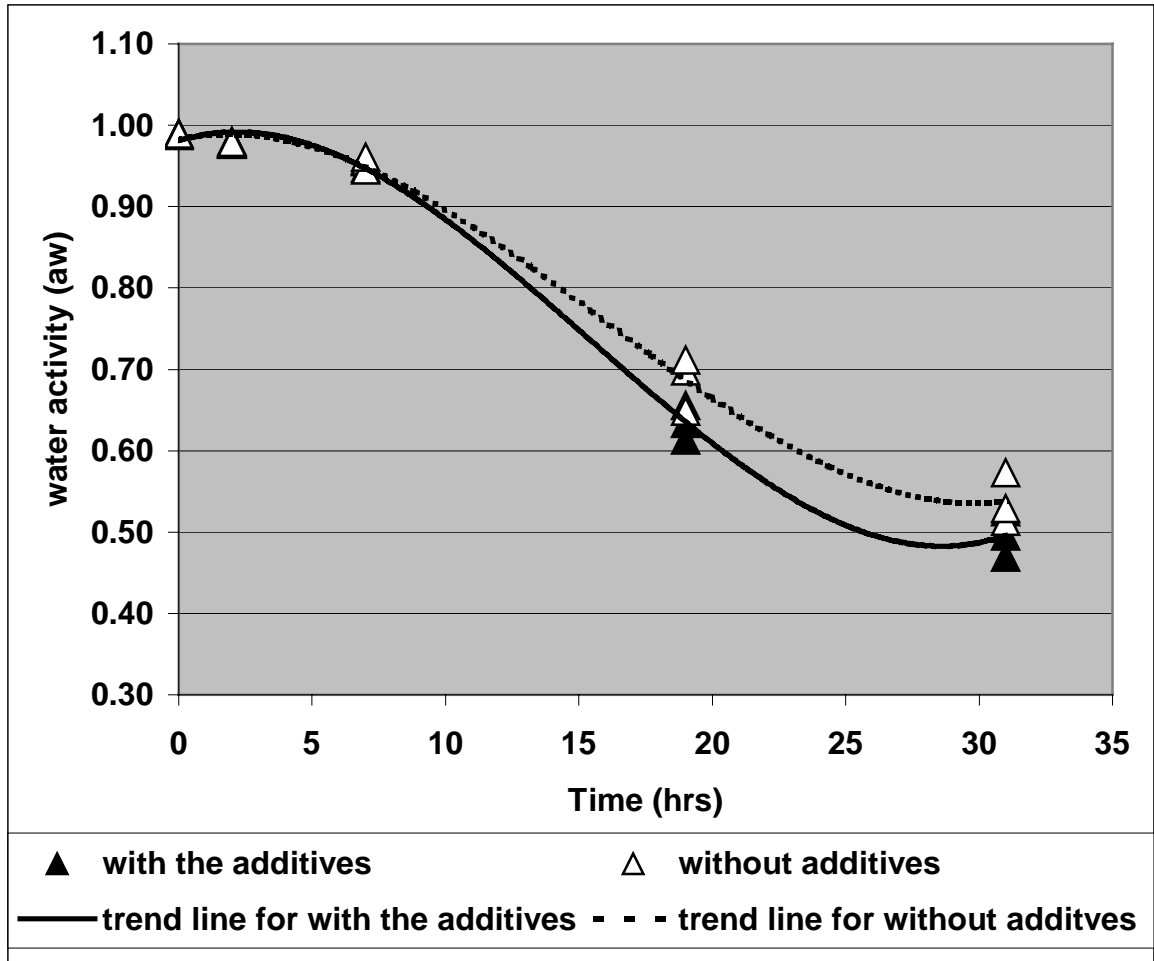
Figure 8. Changes in water activity (a_w) during drying watermelon samples treated with and without calcium and aluminum additives. Three replicates of each are shown, along with a trend line

4.2.2 Color Analysis

Color changes were measured using a Hunter colorimeter for raw watermelon tissue and dehydrated watermelon flesh with treatments of calcium and aluminum additives and those without. Table XII shows the mean Hunter color values (L, a, b) for raw watermelon and dehydrated watermelon treated with and without additives at the 19th and 31st drying hours. All three replicates indicate that samples treated with the additives

showed color change in the L, lightness value. It suggests that calcium and aluminum
additives appear to help preserve the lightness of the watermelon flesh.

Table XII. Hunter color values (L, a, b) of raw watermelon and dehydrated watermelon
samples treated with and without calcium and aluminum additives.

Replicate-1	Pre-treatment	L	a	b
Raw		41.1	31.5	30.0
19hr	with additives	28.0	29.6	26.0
	without additives	26.2	29.9	28.4
31hr	with additives	31.9	26.2	21.7
	without additives	28.3	26.0	25.4
Replicate-2				
Raw		42.8	31.6	27.8
19hr	with additives	32.1	25.8	18.3
	without additives	26.3	26.4	19.6
31hr	with additives	32.6	24.6	18.2
	without additives	31.3	24.0	18.3
Replicate-3				
Raw		38.5	32.1	36.0
19hr	with additives	34.7	27.0	24.8
	without additives	28.0	28.4	27.7
31hr	with additives	37.7	25.9	23.0
	without additives	31.4	26.9	25.0

Table XIII shows P-values for color differences among raw watermelons used in
each of three replicates in this experiment. They indicate significant color differences
between raw watermelon samples. The watermelon used in replicate 3 was significantly
different in L color value compared to the other two replicates ($P<0.05$). There was no
color difference between the two watermelons used in replicates 1 and 2 ($P>0.05$).

In Table XVI, several significant differences are shown between the treatments with additional additives and those without. It indicates that the L color values were significantly different between the two treatments in all three replicates.

Table XIII. P-values for color difference among raw watermelons used in each of the three replicates for the calcium and aluminum additives experiment. Data used for P-value analysis was the mean value of three readings (n=3). 1 vs 2 compares the two raw watermelons used in replicates 1 and 2.

Replicates	Hunter Lab Value	P value
1 vs 2	L	0.41
	a	0.98
	b	0.11
2 vs 3	L	0.98
	a	0.59
	b	0.007
1 vs 3	L	0.11
	a	0.72
	b	0.007

Table XVI. P-values for color differences among dehydrated watermelon samples treated with and without calcium and aluminum additives.

Replicate-1	L	a	b
with vs without additives at 19hr	0.03	0.39	0.18
with vs without additives at 31hr	0.003	0.92	0.07
Replicate-2			
with vs without additives at 19hr	0.01	0.73	0.56
with vs without additives at 31hr	0.06	0.0001	0.97
Replicate-3			
with vs without additives at 19hr	0.00	0.14	0.13
with vs without additives at 31hr	0.01	0.14	0.01

4.2.3   Texture Analysis

Texture peak force and force area were determined in order to understand the textural changes in watermelon samples treated with and without calcium and aluminum additives before the 50º Brix soaking.

4.2.3.1 Peak Force

Figure 9 shows the changes in texture peak force as water activity is reduced for three replicates of the treatment with and without calcium and aluminum additives. In the early drying stages, samples treated with the additives had a larger increase in texture peak force than those without. In the later drying stages, where samples had less than 0.7 a_w, all replicates showed a dramatic increase in peak force. However, samples treated with the additives showed less of an increase in peak force than those without. The pre-treatment with calcium and aluminum additives seems to help retain a softer texture.
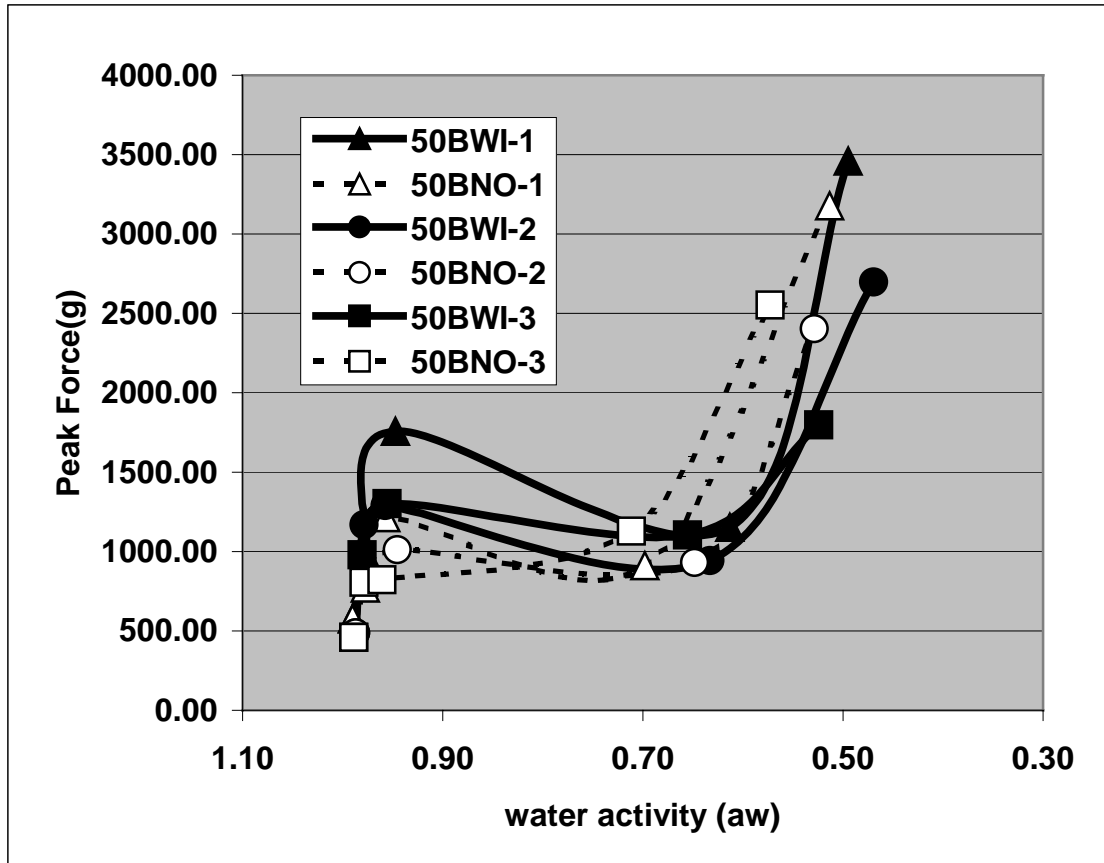
Figure 9. Texture peak force changes in watermelon samples pretreated with and without calcium and aluminum additives. Note: 50WI-1, 50WI-2, and 50WI-3 are three replicates of watermelon samples treated with additives under the 50º Brix sugar solution soaking. 50NO-1, 50NO-2, and 50NO-3 are three replicates of watermelon samples treated without additives before the 50º Brix solution soaking

Table XV shows the P-values for differences in texture peak force among the three raw watermelon samples. The watermelon used in replicate 1 had a significantly different compared to the other two replicates (P<0.05). There were no differences in peak force between the two watermelons used in replicates 2 and 3 (P>0.05).

Table XVI shows P-values for texture peak force in comparing the dehydrated watermelon samples treated with and without calcium and aluminum additives in each of three replicates. There were several significant peak force differences in the early stages (P<0.05). However, in the later drying stages, there was not enough evidence to suggest

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that a significant difference in texture peak force between the samples treated with and

without additives (P>0.05).

Table XV. P-values of texture peak force between pairs of raw watermelons used in the
calcium and aluminum additives treatment experiments.

Replicates	P value
1 vs 2	0.003
2 vs 3	0.320
1 vs 3	0.001

Table XVI. P-values of texture peak force in dehydrated watermelon samples treated with
and without calcium and aluminum additives.

Drying time (Hours)	2	7	19	31
with vs without additives in replicate-1	0.029	0.031	0.016	0.435
with vs without additives in replicate-2	0.0004	0.142	0.885	0.342
with vs without additives in replicate-3	0.054	0.010	0.353	0.002

4.2.3.2 Force area

Figure 10 shows the texture force area changes as a function of water activity of

for each of three replicates with treated with and without calcium and aluminum

additives. It can be seen again that forced area increases dramatically as aw gets below

0.7. In the earlier drying stages, there are minimal changes in force area. In the later

drying stages, samples treated with the additives showed less of and increase in force area

while the a_w was reduced to less than 0.7. It suggests that the calcium and aluminum

additives treatments resulted in a softer texture in the final drying process. The findings

of peak force and force area support the hypothesis that the calcium and aluminum

additives can help protect the color and texture of foods. The chelating agents, calcium

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and aluminum, likely form bridges within the watermelon samples and result in a softer

texture (Hettiarachchy and Kalapthy, 2000).
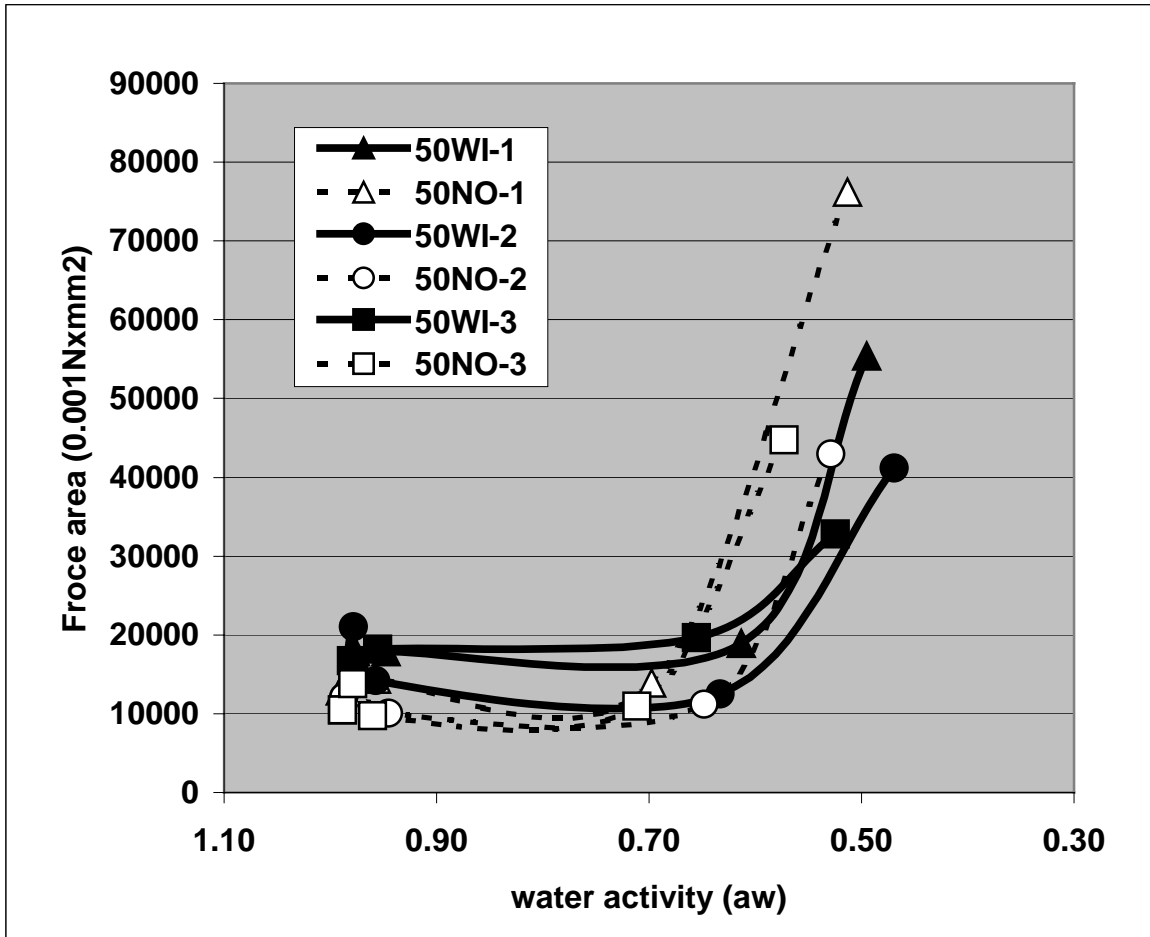
Figure 10. Texture force area changes in dehydrated watermelon samples treated with and without calcium and aluminum additives. Note: 50WI-1, 50WI-2, and 50WI-3 are three replicates of watermelon samples treated with additives under the 50º Brix sugar solution soaking. 50NO-1, 50NO-2, and 50NO-3 are three replicates of watermelon samples treated without additives before the 50º Brix solution soaking

Table XVII lists p-values for the differences in force area among the three raw

watermelon samples. The raw watermelon used in replicate 3 was different in force area

compared to other two replicates.

Table XVIII lists P-values for force area comparing the dehydrated watermelon samples in the treatments with and without calcium and aluminum additives. They indicate several significant differences in force area between the two treatments. At the 7th and 19th hours, all three replicates show significant differences in force area.

Table XVII. P-values of texture force area between pairs of raw watermelon used in the treatment of with and without calcium and aluminum additives experiments.

Replicates	P value
1 vs 2	0.11
2 vs 3	0.003
1 vs 3	0.00008

Table XVIII. P-values of texture force area in dehydrated watermelon samples treated with and without calcium and aluminum additives.

Drying time (Hours)	2	7	19	31
with vs without additives in replicate-1	0.092	0.010	0.001	0.100
with vs without additives in replicate-2	0.0001	0.004	0.00001	0.00001
with vs without additives in replcate-3	0.086	0.00005	0.0005	0.02

In this experiment, although the treatment of calcium and aluminum additives did not affect the moisture content, it did seem to result in a lower water activity. It has been hypothesized that the calcium and aluminum form complex structures within the watermelon and lower the water activity (Gordon and Klimek, 2000). In physical analysis, calcium and aluminum additives also decreased color and texture changes of osmotically dehydrated watermelon.

4.3   Effect of Osmotic Dehydration with Two Drying Systems: Forced-Air and

Vacuum Drying

Samples used to compare the effects of the two drying systems were both treated

with the 50º Brix sugar soaking solution and with calcium and aluminum additives. By

choosing the best results from previous experiments, the effects of the two drying systems,

forced-air and vacuum drying, will be evaluated while including the 50 ºBrix sugar

solution and the additives.

4.3.1 MC_{wb} & a_w Changes

Figure 11 shows MC_{wb} changes of watermelon samples treated with the $CaCl_2$ and

aluminum additives and the 50º Brix soaking and dried in the forced-air and vacuum

ovens. All three replicates dried in the forced-air oven had a faster rate of water loss during

the early drying stages (0, 2, and 7 hours). However, in the later drying stages (19 and 31

hours), samples dried in the forced-air oven had a slower rate of water loss than those

dried in the vacuum. One possible explanation is that the vacuum drying lacks the high

airflow rate and hence, the air convection is attained in forced air. In the early drying

stages, a huge amount of water molecules removed by the forced-air drying is more

efficient while watermelon samples consist of high MC_{wb}. In the later drying stages, the

vacuum environment decreases the vapor pressure and evaporation energy for the water

molecules on the surface of the watermelon samples. While samples consist of lower

MCwb, the vacuum drying is more efficient and benefits the drying process.
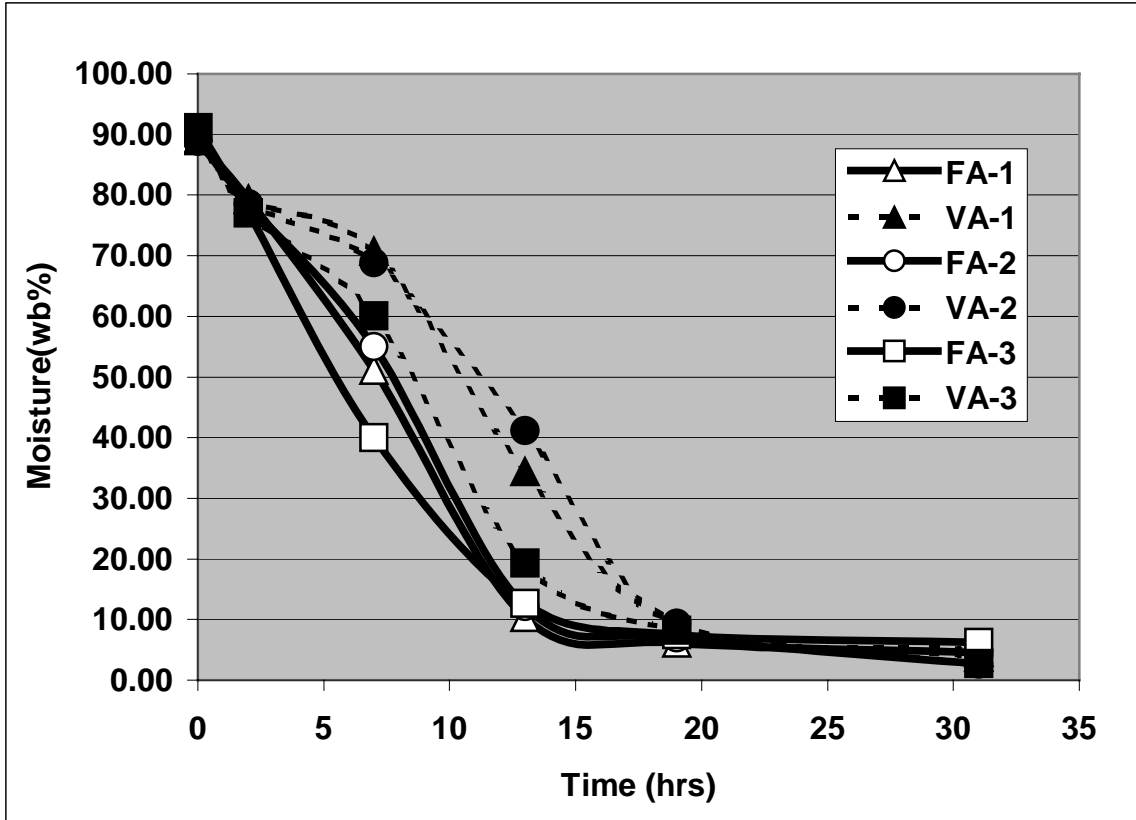
Figure 11. MC_{wb} changes for watermelon samples dried by two drying systems, forced-air and vacuum drying. FA-1, FA-2, and FA-3 are three replicates of samples dried in the forced-air drying oven. VA-1, VA-2, and VA-3 are three replicates of samples dried in the vacuum drying oven.

Table XIX shows the rate of change in moisture content (wb%) changes per hour for different drying periods. In the earlier drying stages, samples dried with the forced-air drying had larger MCwb changes per hour than vacuum drying. In Table XX, P-values indicate the differences of moisture changes per hour between the two drying systems. There are significant differences between the two drying systems in the 2-7 and 13-19 hour time intervals ($P<0.05$).

Table XIX. Rate of change in moisture content (% per hour) for watermelon samples dried using forced-air and vacuum drying. 0-2, 2-7, 7-13, 13-19, and 19-31 are drying time intervals.

Interval (hrs)	50FA-1	50VA-1	50FA-2	50VA-2	50FA-3	50VA-3
0-2	4.85	4.85	5.15	5.15	7.04	7.04
2-7	5.64	1.72	4.72	1.95	7.40	3.38
7-13	6.79	6.05	7.14	4.61	4.57	6.80
13-19	0.70	4.21	0.86	5.30	0.85	1.84
19-31	0.13	0.45	0.36	0.38	0.11	0.46

Table XX. P-values for drying rate differences between forced-air and vacuum drying. Data used for P-value analysis was the mean value (n=3) of three replicates.

Interval (hrs)	2-7	7-13	13-19	19-31
P value	0.019286	0.753308	0.043504	0.052118

Figure 12 shows the changes in the water activity for three replicates dried by each of two drying systems, forced-air and vacuum. In the early drying stages, samples dried in the forced-air oven had a faster rate of a_w decrease than those dried in the vacuum. In the later drying stages, the forced-air drying had a slower rate of a_w decrease. Differences were minimal, however.
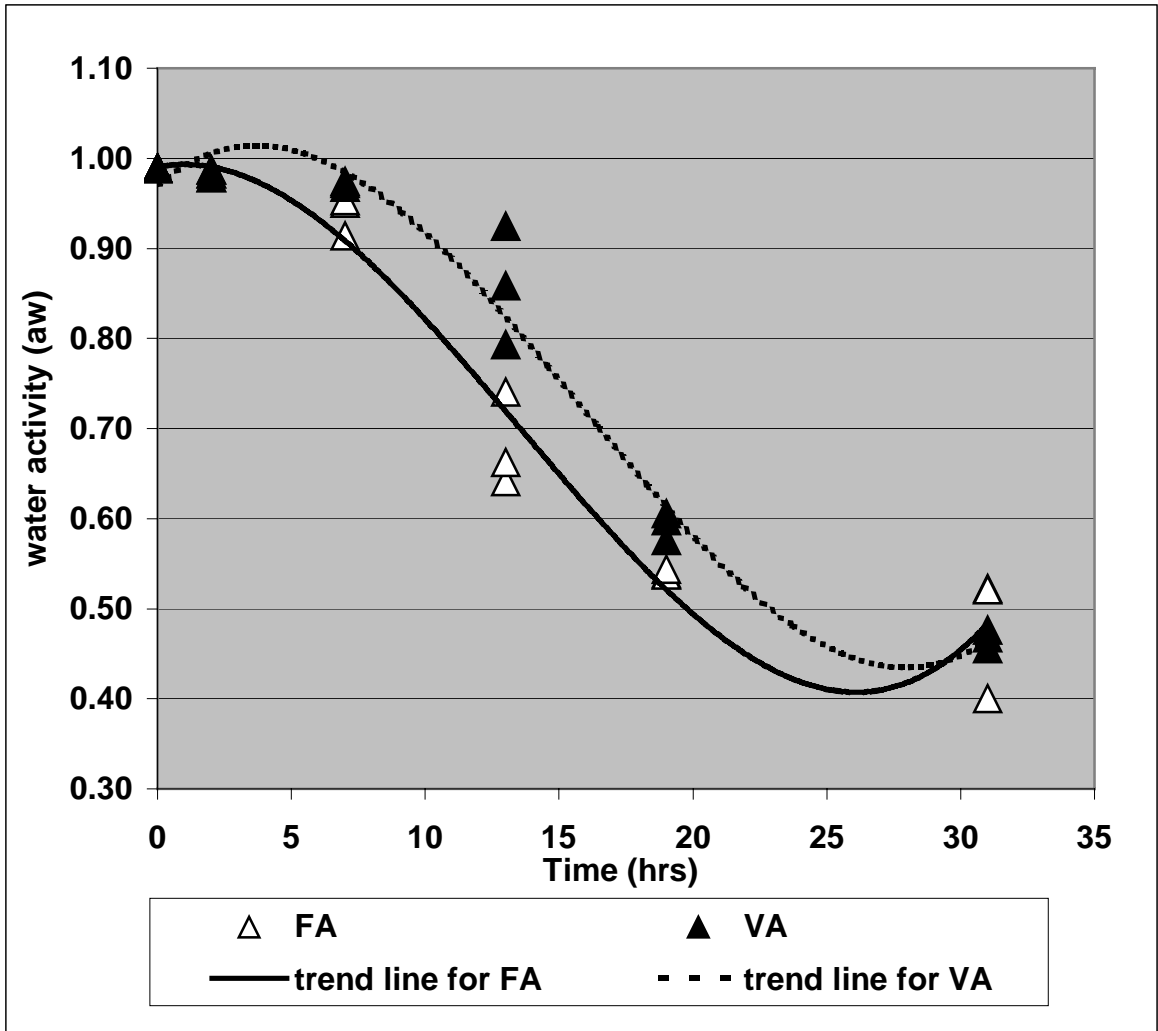
Figure 12. Changes in water activity (a_w) for watermelon samples dried by two drying systems: forced-air (FA) and vacuum drying (VA). Three replicates of each are shown, along with a trend line.

Table XXI shows the rate of change in water activity for different drying time intervals for three replicates. In the earlier drying stages, watermelon samples dried with forced-air had larger a_w changes per hour than vacuum. In addition, in the later drying stages, vacuum drying had lager a_w changes per hour than forced-air drying. Table XXII shows P-values for the rate of change in water activity between the two drying systems in each time interval. There are significant differences in the time intervals of 2-7, 7-13, and 13-19 hours (P<0.05), suggesting that the two drying systems significantly affected a_w changes in both earlier and later drying stages.

Table XXI. Rate of change in water activity in different time intervals during forced-air and vacuum drying

Time (hour)	50FA-1	50VA-1	50FA-2	50VA-2	50FA-3	50VA-3
0-2	0.33	0.33	0.11	0.11	0.47	0.47
2-7	0.65	0.16	0.68	0.30	1.29	0.22
7-13	5.15	1.94	3.55	0.80	4.20	2.91
13-19	1.70	4.22	3.38	5.45	1.97	3.63
19-31	0.14	1.15	1.14	1.01	0.19	1.00

Table XXII. P-values for rate of change in water activity for forced-air and vacuum drying. Data used for P-value analysis was the mean value (n=5) of three replicates.

Time (hour)	2-7	7-13	13-19	19-31
P value	0.038241	0.03443	0.049454	0.161917

4.3.2 Color Analysis

Color changes were measured using a Hunter colorimeter for raw watermelon tissue and watermelon dehydrated by two drying systems (forced-air and vacuum). Table XXIII shows the mean Hunter color values for raw watermelon and dehydrated watermelon samples at the 19th and 31st drying hours. At the 19th drying hour, all three replicates indicate that samples dried by vacuum drying showed less color change. At the 31st drying hour, replicates 1 and 2 indicated that samples dried by forced-air oven had less color changes in L, a, and b. Most differences were minimal, however..

Table XXIII. Hunter color values (L, a, b) of raw watermelon and dehydrated watermelon samples dried in the forced-air and vacuum ovens.

Replicate-1	Drying method	L	a	b
Raw		42.4	30.8	35.3
19hr	Forced-air	33.3	24.1	22.0
	Vacuum	37.0	24.8	24.8
31hr	Forced-air	38.8	23.2	25.5
	Vacuum	36.8	22.8	23.1
Replicate-2				
Raw		43.1	26.9	31.8
19hr	Forced-air	36.7	24.7	23.7
	Vacuum	39.1	26.2	26.1
31hr	Forced-air	37.8	24.3	23.9
	Vacuum	37.9	24.0	24.4
Replicate-3				
Raw		46.3	25.1	34.9
19hr	Forced-air	42.3	23.6	30.8
	Vacuum	43.8	23.9	33.2
31hr	Forced-air	45.7	20.8	34.3
	Vacuum	41.5	20.6	36.2

Table XXIV shows P-values of color differences among raw watermelons used in each of three replicates in the two drying methods experiments. There were few color differences between these raw watermelon samples. However, considering the

watermelons used in previous experiments, the results from color measurement indicate

that initial color differences typically do exist among watermelons.

Table XXV shows P-values for Hunter color values of samples dried with forced-

air and vacuum. There were very few significant differences in a and b color values, but

the L color value showed significant differences between the two drying methods in all

three replicates (P<0.05). In all cases expect one, the L-value for the vacuum dried sample

was closer to the forced-air dried.

Table XXIV. P-values for color differences among raw watermelons used in each of the
three replicates of the two drying methods. Data used for P-value analysis was the mean
value of three readings (n=3). 1 v 2 compares the two raw watermelons used in replicates1
and 2.

Replicates	Hunter Lab value	P value
1 vs 2	L	0.80
	A	0.06
	B	0.14
2 vs 3	L	0.42
	A	0.21
	B	0.07
1 v 3	L	0.38
	A	0.38
	B	0.85

Table XXV. P-values for L, a, b color values in dehydrated watermelon samples dried in
the forced-air and vacuum ovens. Data used for P value analysis was the mean value (n=3)
of three color measurement readings.

Replicate-1	L	a	b
Forced-air vs vacuum at 19hr	0.03	0.39	0.18
Forced-air vs vacuum at 31hr	0.003	0.92	0.07
Replicate-2			
Forced-air vs vacuum at 19hr	0.01	0.73	0.56
Forced-air vs vacuum at 31hr	0.06	0.0001	0.97
Replicate-3			
Forced-air vs vacuum at 19hr	0.00	0.14	0.13
Forced-air vs vacuum at 31hr	0.01	0.14	0.01

4.3.3 Texture Analysis

Texture peak force and force area were determined in order to understand the textural changes in watermelon samples dried with the two drying systems after the treatments of calcium and aluminum additives and the 50º Brix pre-treatments. In one replicate, 8 samples from each pre-treatment were tested at each of the following sampling times: 0, 2, 7, 13, 19,and 31 hours.

4.3.3.1 Peak force

Figure 13 shows the texture peak force changes as water activity is reduced for three replicates of the two drying methods. In the early drying stages, all three replicates showed changes in the texture peak force. In the later drying stages, where samples had less than 0.7 a_w, the peak force increased rapidly as the water activity was reduced. At the lower water activity, the peak force of samples dried were significant larger than samples dried with the forced-air. It suggests that vacuum drying in the final drying causes more severe textural changes than forced-air drying, which maintains the turgor pressure of cell matrix (Fito, 1994).
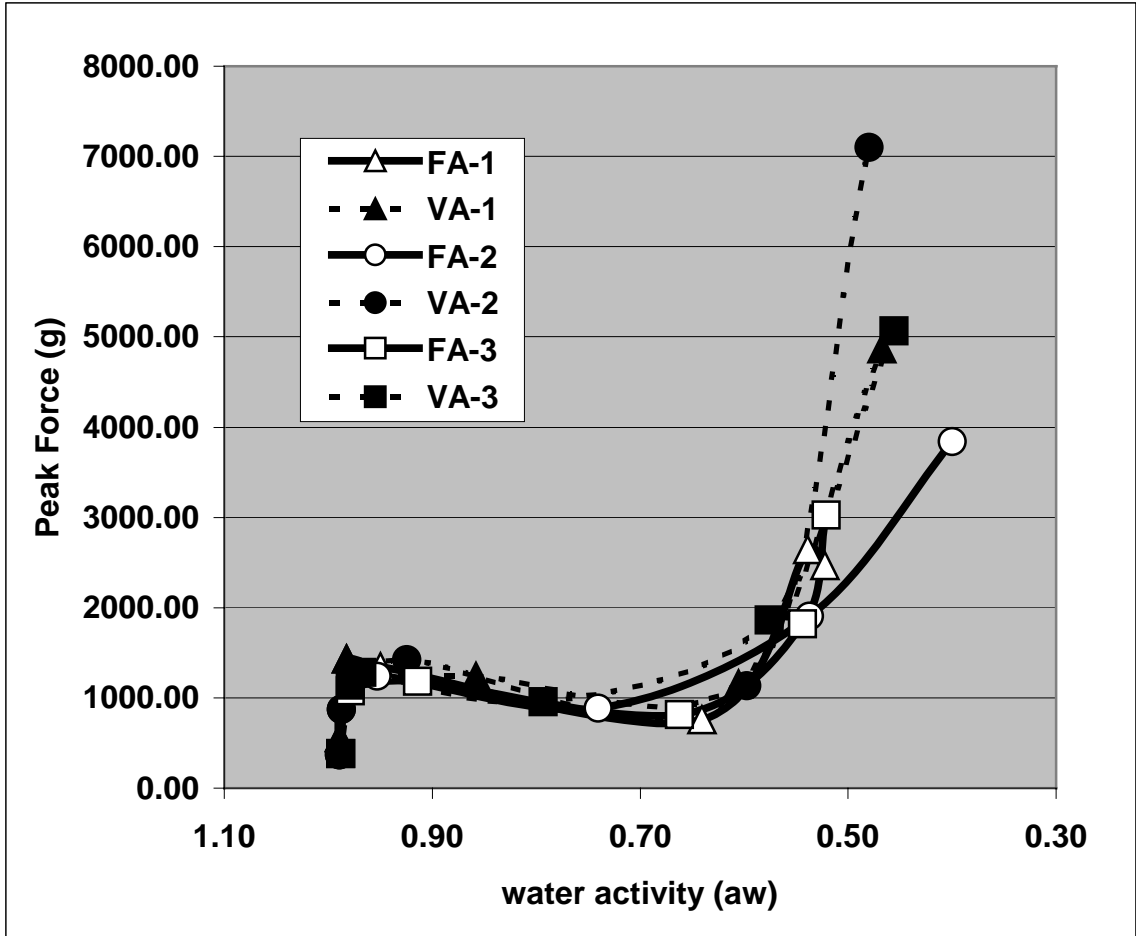
Figure 13. Texture peak force changes in watermelon samples dried with forced-air and vacuum. FA-1, FA-2, and FA-3 are three replicates of samples dried with forced-air under the osmotic pretreatments of the 50º Brix solution and with additives. VA-1, VA-2, and VA-3 area three replicates dried with vacuum after the osmotic pre-treatments of the 50º Brix solution and with additives.

Table XXVI shows P values of texture peak force changes among the three raw watermelons used in the drying method experiments. The watermelon used in replicate 1 was significantly different from the watermelon in replicates 2 and 3 (P<0.05). There were no significant differences in texture peak force between the watermelons used in replicates 2 and 3 (P>0.05).

Table XXVII shows P values of texture peak force differences between the two drying methods in each of three replicates. They indicate that there are differences in

texture peak force between forced air and vacuum drying (P<0.05). Replicates 1 and 2 showed significant differences in peak force between the two drying methods in the later drying stages (P<0.05). At the 31st hour, all three replicates indicate significant peak force differences between the two drying methods (P<0.05). It suggests that different drying method does affect texture peak force of dried watermelon samples.

Table XXVI. P-values of texture peak force between pairs of raw watermelons used in the drying method experiments. 1 vs 2 compares the raw watermelons used in replicates 1 and 2.

Replicates	P value
1 vs 2	0.000001
2 vs 3	0.521
1 vs 3	0.0001

Table XXVII. P-values of texture peak force in dehydrated watermelon samples between two drying methods, forced-air and vacuum drying.

Drying time (Hours)	2	7	19	31
Forced-air vs vacuum in replicate-1	0.692	0.000	0.001	0.001
Forced-air vs vacuum in replicate-2	0.814	0.030	0.014	0.001
Forced-air vs vacuum in replicate-3	0.684	0.175	0.918	0.039

4.3.3.2 Force area

Figure 14 shows texture force area changes as water activity is reduced for three replicates of the two drying method experiments. In the early drying stages, there were minimal changes in force area for all three replicates. In the later drying stages, where watermelon samples had a lower a_w, the force area increased rapidly. It suggests that vacuum dried watermelon samples treated with the osmotic dehydration results in a harder (peak force) and a tougher (force area) texture.
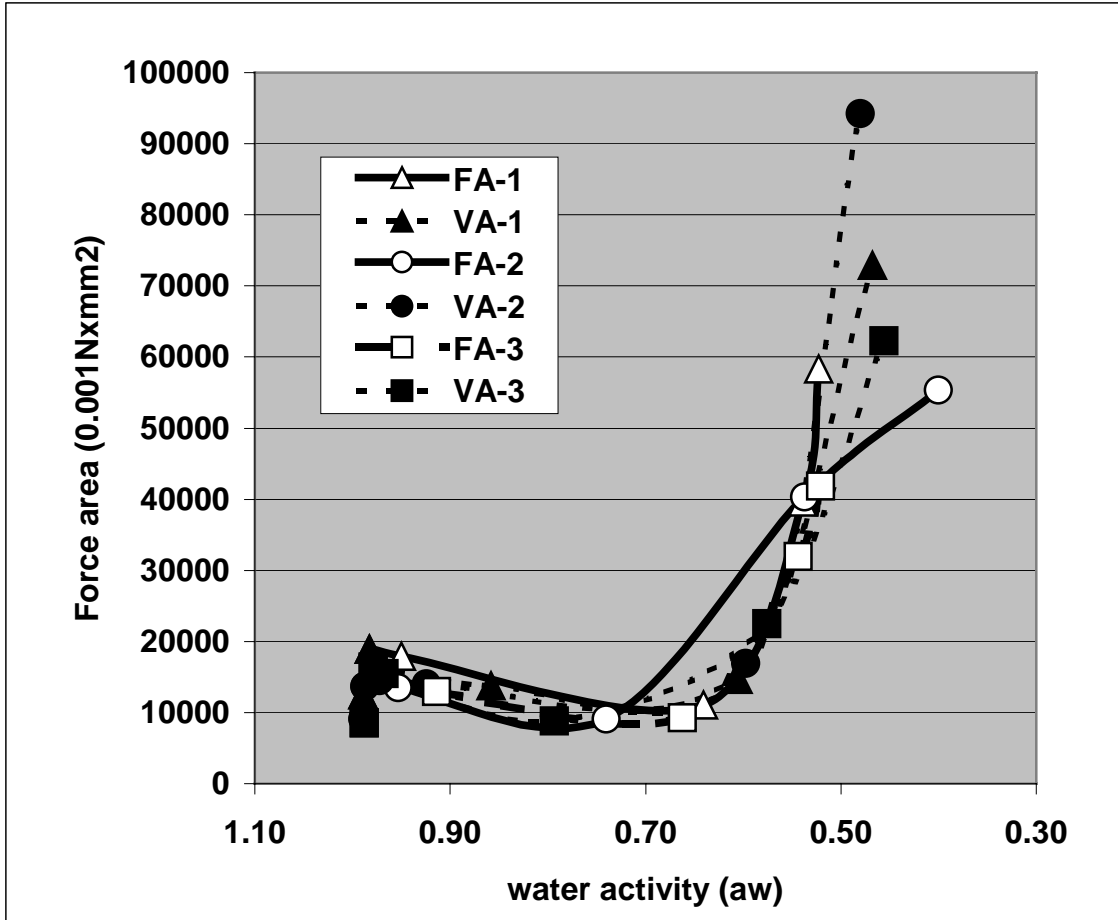
Figure 14. Texture force area changes in watermelon samples dried with forced-air and vacuum. NOTE: FA-1, FA-2, and FA-3 are three replicates of samples dried in the forced-air drying oven. VA-1, VA-2, and VA-3 are three replicates of samples dried in the vacuum drying oven.

Table XXVIII shows the P-values for texture force area among the three raw watermelon samples. The watermelon used in replicate 1 was significantly different from the other two replicates (P<0.05). In addition, the P values for the peak force differences in Table XVII have similar results to the force area, which confirming the earlier findings.

Table XXIX lists P-values for force area comparing the two drying systems. Replicates 1 and 2 show significant differences in force area between the two drying methods in the later drying stages (P<0.05).

Considering the combined results of peak force and force area, there were significant differences in texture between the two drying methods. Under the same osmotic pre-treatments, watermelon samples with vacuum drying resulted in a harder and a tougher texture than the forced-air drying.

Table XXVIII. P-values of texture force area between pairs of raw watermelons used in the drying method experiments.

Replicates	P value
1 vs 2	0.000001
2 vs 3	0.42
1 vs 3	0.0001

Table XXIX. P-values of texture force area in dehydrated watermelon samples between the two drying methods, forced-air and vacuum drying.

Drying time (Hours)	2	7	19	31
Forced-air vs vacuum in replicate-1	0.501	0.045	0.0001	0.004
Forced-air vs vacuum in replicate-2	0.457	0.002	0.001	0.001
Forced-air vs vacuum in replcate-3	0.177	0.642	0.115	0.095

In this experiment, both forced-air and vacuum drying systems resulted in a product with a water activity less than 19 hours of drying. Color results showed that vacuum dried samples were likely to have L-values closer to raw watermelon. Texture results favored the forced-air drying method. However, texture of samples dried with the vacuum was significantly harder and tougher than samples dried with the forced-air drying.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1   Conclusions

The goal of this study was to determine the feasibility of using osmotic dehydration

to develop a new product from watermelon flesh. The results indicate that the process is

feasible and may represent a new product for watermelon. Results show that an optimal

process may consist of soaking in a 50º Brix sugar solution, adding calcium and aluminum,

initial drying in a forced-air oven and followed by vacuum drying to create the final

product. These results are consistent with the following specific conclusions:

1.   Use of a 50º Brix pre-treatment solution compared to a 10º Brix resulted in:

   A.   Reduced drying rate in the early drying stages

   B.   Softer final product textures

   C.   Less color changes during processing

2.   Use of calcium and aluminum as additives with the 50º Brix pre-treatment

      resulted in:

   A.   No drying rate differences

   B.   Softer final product textures

C.   Less color changes in Lightness, L in Hunter color values.

3.   Use of vacuum drying compared to forced-air resulted in:

A.   The forced-air drying process resulted in faster drying rates during the early drying stages. The vacuum drying process resulted in faster drying rate during the later drying stages.

B.   A harder texture at low a_w was obtained in both drying systems.

4.   There are significant differences between the properties of individual watermelons, specifically color and texture. This highlights the need to make treatment comparisons within a single watermelon.

5.2   Recommendations for the Future Work

1.   Development of an optimal drying methods which utilize both forced-air and vacuum drying

2.   Sensory evaluation panel can be applied to express the preferred color and texture and to compare the changes made by experiments.

3.   Analysis of rehydration of dehydrated watermelon samples

4.   Evaluation of alternative concentrations of sugar solution and other additives.

5.   Use of over maturity or second class watermelons to evaluate the differences compared to the commercial watermelons used in this study.

Bibliography

Ames, J.M. 2003. Browning. <u>Encyclopedia of Food Science and Nutrition 2nd</u> . Elsevier Science Ltd. UK. pp 665-672

Barreiro J.A., Milano, M., Sandoval, A.J. 1997. Kinetics of colour change of double concentrated tomato paste during thermal treatment. Journal of Food Engineering, 33-359-371

Barrett, D.M. and Caballero, B. 2003. Pickling. <u>Encyclopedia of Food Science and Nutrition</u>. Elsevier Science Ltd. UK. pp 6089-6101

Barbosa-Canovas, G.V. and Vega-Mercado, H. 1996. <u>Dehydration of Foods</u>. Chapman and Hall, New York

Cai, T.D. and Chang, K.C. 1998. Characteristics of production-scale tofu as addected by soymilk coagulation method: propeller blade size, mixing time, and coagulant concentration. Food Research International. 31:4, 289-295

Chiralt, A., Behsnilian, D., Barata, J.M., Fito, P., Spiess, W.E.L. 2001. <u>Osmotic Dehydration & Vacuum Impregnation: Application of New Technology on Traditional Food</u>. Technomic Pub Co, Inc. Pennsylvania

Chiralt, A., Martínez-Navarrete, N., Martínez-Monzó, J., Talens, P., Moraga, G., Ayala, A., and Fito, P. 2001. Changes in mechanical properties throughout osmotic processes. Journal of Food Engineering, 49:2-3, 129-135

Chinachoti, P. and Steinberg, M.P. 1989. Correlation of protein T, with polymer and solute waters in starch-sucrose mixtures. Journal Food Science, 54: 691.

Chinachoti, P. and Marangoni, A.G. 2000. Water activity. <u>Food Chemistry: Principles and Applications</u>. Science Technology System [sTs], CA, 3, 21-34

Collins, J.L. and Marangoni, A.G. 2000. Vegetables. <u>Food Chemistry: Principles and Applications</u>. Science Technology System [sTs], CA, 21, 351-364

Dauthy, M.E. 1995. General procedures for fruit and vegetable preservation. <u>Fruit and Vegetable Processing.</u> Food and Agriculture Organization of United Nations. Rome.

Drouzas, A.E. and Schubert, H. 1995. Microwave application in vacuum drying of fruits. Journal of Food Engineering, 28, 203-209

Drouzas, A.E., Tsami, E., and Saravacos, G.D. 1998. Microwave/vacuum drying of model fruit gels. Journal of Food Engineering, 39, 117-122

Fennema, O.R. 1996. Food Chemistry 3rd Marcel Dekker, Inc. New York.

Fito, P., Chiralt, A., Barat, J. M., Andres, A., Martinez-Monzo, J. and Martinez-Navarrete, N. 2001. Vacuum impregnation for development of new dehydrated products. Journal of Food Engineering, 49, 297-302

Gerschenson, L.N., Rojas, A.M. and Marangoni, A.G. 2001. Effects of processing on kiwi fruit dynamic rheological behavior and tissue structure. Journal of Food Research International, 34-1, 1-6

Giraldo, G., Talens, T., Fito, P., and Chiralt, A. 2003. Influence of sucrose solution concentration on kinetics and yield during osmotic dehydration of mango. Journal of Food Engineering, 58, 33-43

Gordon, D.T. and Klimek, J.M. 2000. Minerals. Food Chemistry Principles and Applications. Science Technology System [sTs], CA, 167-181

Harrison, J.A. and Andress, E.L. 2000. Preserving food: pickled products. University of Georgia Cooperative Extension Service. GA

Hettiarachchy, N.S. and Kalapthy, U. 2000. Food additives. Food Chemistry: Principles and Applications. Science Technology System [sTs], CA, 16, 261-290

Kander, A.A. 2002. Postharvest biology and technology: An overview. Postharvest Technology of Horticulture Crops 2nd ch4

Horner, W.F.A. and Caballero, B, 2003 Drying: Physical and structural changes. Encyclopedia of Food Science and Nutrition 2nd . Elsevier Science Ltd. UK. pp 1942-1951

Hunt, M.C. 1991. Guidelines for meat color evaluation. Proceedings of the Reciprocal Meat Conference. 44

Igoe, R.S. and Hui, Y.H. 2001. Dictionary of Food Ingredients 4th . Aspen Publishers, Inc. Maryland. p 8

Krokida, M.K., Kiranoudis, C.T., and Marouli, Z.B. 1999. Viscoelastic behaviour of dehydrated products during rehydration. Journal of Food Engineering, 40:4, 269-277

Krokida, M.K., Maroulis, Z.B., and Saravocos, G.D. 2001. The effects of the methods of drying on the colour of dehydrated products. Journal of Food Engineering, 36, 53-59

Kander, A.A. 2002. Postharvest biology and technology: An overview. <u>Postharvest Technology of Horticulture</u> Crops 2nd ch4

Lai, Z.H. and Lai Y.C. 1994. <u>Food Technology Dictionary</u>. Fu-Lin. Taiwan.

Lee, Y. and Howard, L. 1999. Firmness and photochemical losses in pasteurized yellow banana peppers as affected by calcium chloride and storage. Journal of Agriculture Food Chemistry. 47:2, 700-703

Litvin, S., Mannhein, C.H. and Miltz, J. 1998 Dehydration of carrots by a combination of freeze drying, microwave heating, and air or vacuum drying. Journal of Food engineering, 36, 103-111

Lewicki, P. 1998 Effect of pre-drying treatment, dry and rehydration of plant tissue properties: a review. International Journal Food Properties. 1: 1-22

Lewicki, P.P., Le, H.V., and Pomaranska-Lazuka, W. 2002. Effect of pre-treatment on convective drying of tomatoes. Journal of Food Engineering. 54: 141-146

Mayberry, K.S. and Merister, H. 2003 UC Cooperative Extension-Imperial County Vegetable Crops Guidelines.

Menzel C.M. and Caballero, B. 2003. Fruits of tropical climates. <u>Encyclopedia of Food Science 2nd</u>. Elsevier Science Ltd. UK. pp 2795-2796

Negi, P.S. and Roy, S.K.2000. Effect of blanching and drying methods on *B*-carotene, ascorbic acid and chlorophyll retention of leafy vegetables. Lebensmittel-Wissenschaft und-Technology. Academic Press. 33, 295-298

Nowakunda, K., Andres, A., and Fito, P. 2004.Osomtic dehydration of banana slice as a pretreatment for drying processes. Drying 2004 – Proceedings of the 14th International Drying Symposium. Volume 4, pp. 2077-2083

Potter, N.N. 1986. <u>Food Science 4th</u>. Avi Publishing Company. CN.

Ponting, J.D. 1966 Osmotic dehydration of fruits. Food Technology. 1-10, 125-128

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

Powers, J.A. 1978. <u>United States Standards for Grades of Watermelon</u>. Washington, D.C.-U.S.D.A.-A.M.S.

Rao, V.H.P., Bangalore, D.V., Rao, K.H., and Singh, R.R.B. 2001. Developments & prospects of osmotic dehydration in food industry-A Review. Indian Dairyman. 53: 4, 55-66

Raoult-Wack, A.L., Rios, G., Sareul, R. and Guilbert, S. 1994. Recent advance in the osmotic dehydration of foods, Trends in Food Science & Technology. 5: 8, 255-260

Roos, T.H. and Caballero, B. 2003. Water activity: Effect on food stability. Encyclopedia of Food Science and Nutrition 2nd. Elsevier Science Ltd. UK. pp 6089-6101

Sancho-Madriz, M.F. and Caballero, B. 2003. Preservation of food. Encyclopedia of Food Science and Nutrition 2nd. Elsevier Science Ltd. UK. pp 4766-4772

Scott, W.J. (1953). Water relations of food spoilage microorganisms. Advance Food Science. 7: 83

Silva, D.A., Williams, R.J.P, and Williams, J.J.R.F. 1991. The Biological Chemistry of the Element: the Inorganic Chemistry of Life. Clarendon Press, pp 241-250

Singh, R.P. and Heldman, D.R. 2001. Food Science and Technology. 1, 557-561.

Spiess, W.E.L. and Behsnilian, D. 2001. Preface and introduction. Journal of Food Engineering, 49, 75-76

Stable Micro System, 2000. User Manual Texture Expert. Texture Technologies Crop, Scarsdale, New York and Stable Micro System, Godalming Surrey, UK.

Szczesniak, A.S. and Torgeson K.W. 1965. Methods of meat texture measurement viewed form the background of factors affection tenderness. Advance Food Resource 14, 33-165.

Tim, R. 1998. Food Preservation. Publication 348-597. Virginia Cooperative Extension, University of Virginia Tech.

Van Der Riet, W.B., Wight, A.W., Cilliers, J.J.L., and Datel, J.M. 1989. Food Chemical Investigation of Tofu and its byproduct Okara. Food Chemistry. 34,193-202

Van Oeckel, M.J., Warnants, N., and Boucqué, C.V. 1999. Modifications of the Warner-Bratzler shear force method to improve the relationship with pork tenderness. BSAS Winter Meeting. Scarborough (UK), p. 12. (RVV1084)

Vega-Mercado, H., Gongora-Neito, M.M. and Barbosa-Canvas, G.V. 2001. Advances in dehydration of foods. Journal of food Engineering. 49, 271-289

Veland, J.O. and Torrissen, O.J. 1999. The texture of Atlantic salmon (Salmo salar) muscle as measured instrumental using TPA and Warner-Bratzler shear test. Journal of the Science of Food and Agriculture. 79, 1737-1746

Von Elbe, J.H. and Schwartz, S.J. 1996. Colorants. <u>Food Chemistry</u> 3rd Marcel Dekker, Inc. New York. 10, 651-722

Wheeler, T.L., Shackelford, S.D., Johnson L.P., Miller M.F., Miller R.K., and Koohmaraie, M. 1997. A comparison of Warner-Bratzler shear force assessment within and among institution. Journal of Animal Science. 75, 2423-2432.

Wrolstad, R.E. 2000. Colorant. <u>Food Chemistry: Principles and Applications</u>. Science Technology System [sTs], CA, 14, 215-239

York, R. and Vaisey-Genser, M. 2003. Sensory evaluation. <u>Encyclopedia of Food Science and Nutrition 2nd</u>. Elsevier Science Ltd. UK. pp 5125-5172

APPENDIX

A.   Moisture Content of During Drying Watermelon Samples in Osmotic Pre-treated with 50º and 10º Brix Solutions Experiment

50º Brix Replicate-1					10º Brix Replicate-1				
Hour	Readings			Mean	Hour	Readings			Mean
0	84.643	87.192	89.238	86.86	0	84.643	87.192	89.238	86.86
2	73.029	75.625	NA	74.33	2	87.786	87.006	NA	87.40
7	48.109	44.581	NA	46.35	7	73.903	72.254	NA	73.08
19	10.18	9.35	11.149	10.23	19	13.086	18.348	15.717	18.35
31	4.749	4.319	NA	4.53	31	7.704	7.17	NA	7.44
50º Brix Replicate -2					10º Brix Replicate-2				
Hour	Readings			Mean	Hour	Readings			Mean
0	87.327	88.635	90.702	88.89	0	87.327	88.635	90.702	88.89
2	76.444	74.591	75.961	75.67	2	89.640	88.078	89.222	88.98
7	72.407	73.792	73.996	73.40	7	82.264	82.714	82.502	82.49
19	18.193	17.289	13.128	16.20	19	13.434	14.487	17.051	15.07
31	6.274	6.006	4.773	5.68	31	4.221	4.230	3.940	4.13
50º Brix Replicate -3					10º Brix Replicate-3				
Hour	Readings			Mean	Hour	Readings			Mean
0	87.81	88.127	86.266	87.40	0	87.81	88.127	86.266	87.40
2	75.57	76.249	75.494	75.77	2	89.093	88.436	90.598	89.38
7	55.35	53.812	53.827	54.33	7	74.349	74.26	74.548	74.39
19	10.235	11.244	11.546	11.01	19	12.118	12.507	12.819	12.48
31	3.83	3.979	4.989	4.27	31	3.392	4.25	3.35	3.66

B.   Water Activity During Drying of Watermelon Samples in Osmotic Pre-treated with 50º and 10º Brix Solutions Experiment

50º Brix Replicate -1				Mean	10º Brix Replicate -1				Mean
Hour	a_w			Mean	Hour	a_w			Mean
0	0.986	0.984	0.982	0.987	0	0.986	0.984	0.982	0.987
2	0.977	0.976	0.979	0.977	2	0.983	0.988	0.988	0.986
7	0.945	0.937	NA	0.937	7	0.971	0.973	NA	0.972
19	0.644	0.667	0.661	0.669	19	0.629	0.67	0.578	0.624
31	0.536	0.556	0.567	0.553	31	0.45	0.431	0.48	0.454
50º Brix Replicate -2					10º Brix Replicate -2				
Hour	a_w			Mean	Hour	a_w			Mean
0	0.989	0.99	0.99	0.990	0	0.989	0.99	0.99	0.990
2	0.978	0.98	0.978	0.979	2	0.987	0.985	0.987	0.987
7	0.975	0.975	0.976	0.976	7	0.983	0.983	0.985	0.984
19	0.696	0.719	0.774	0.727	19	0.626	0.643	0.617	0.629
31	0.524	0.521	0.528	0.521	31	0.375	0.378	0.399	0.385
50º Brix Replicate -3					10º Brix Replicate -3				
Hour	a_w			Mean	Hour	a_w			Mean
0	0.996	0.994	0.993	0.994	0	0.996	0.994	0.993	0.994
2	0.981	0.983	0.989	0.984	2	0.994	0.995	0.993	0.994
7	0.958	0.962	0.958	0.958	7	0.975	0.976	0.978	0.976
19	0.726	0.669	0.694	0.700	19	0.66	0.665	0.62	0.650
31	0.517	0.507	0.499	0.505	31	0.388	0.402	0.391	0.394

C. Hunter Color Values (L, a, b) of Raw watermelon and Dehydrated Watermelon Samples in the Osmotic Pre-treatment with 50º and 10º Brix Solutions Experiment

Replicate-1	Pretreatments	Hunter Lab Value	Readings			Mean
Raw		L	48.72	49.08	47.96	48.4
		a	25.44	26.01	26.79	25.8
		b	26.91	25.36	26.54	25.8
19hr	50º Brix	L	26.18	25.69	26.67	26.2
		a	27.15	24.87	25.66	25.9
		b	27.28	24.20	24.29	25.3
	10º Brix	L	31.27	29.83	30.30	30.5
		a	24.75	24.01	24.75	24.5
		b	21.43	20.75	22.68	21.6
31hr	50º Brix	L	30.75	31.97	33.05	31.9
		a	26.37	25.64	24.27	25.4
		b	25.23	22.68	23.65	23.9
	10º Brix	L	33.35	33.12	32.43	33.0
		a	22.29	22.87	20.85	22.0
		b	18.27	18.98	17.19	18.1
Replicate-2	Pretreatments	Hunter Lab Value	Readings			Mean
Raw		L	47.03	46.03	49.45	48.0
		a	26.22	24.67	26.72	25.7
		b	27.46	26.21	25.77	26.3
19hr	50º Brix	L	33.64	35.59	34.18	34.2
		a	24.19	19.91	23.20	22.6
		b	26.93	20.40	24.87	23.6
	10º Brix	L	33.34	33.78	34.21	33.8
		a	21.77	20.00	20.01	20.7
		b	19.30	17.23	18.12	18.0
31hr	50º Brix	L	33.65	34.68	38.22	36.0
		a	22.93	23.53	22.50	22.9

		b	21.46	20.65	25.76	23.2
	10º Brix	L	35.00	35.06	35.34	35.1
		a	22.57	23.00	19.89	21.5
		b	20.77	21.29	18.70	19.9
Replicate-3	Pretreatments	Hunter Lab Value	Readings			Mean
Raw		L	41.85	44.70	44.27	43.6
		a	31.66	30.71	29.46	30.6
		b	29.59	26.61	24.83	27.0
19hr	50º Brix	L	27.58	27.74	29.33	28.2
		a	30.11	29.83	28.11	29.4
		b	27.63	27.99	23.70	26.4
	10º Brix	L	29.20	25.88	26.39	27.2
		a	27.72	28.02	29.49	28.4
		b	23.55	24.27	27.23	25.0
31hr	50º Brix	L	27.84	29.25	27.88	28.3
		a	29.81	27.75	26.04	27.9
		b	28.99	24.70	21.54	25.1
	10º Brix	L	31.70	31.18	29.51	30.8
		a	22.01	22.74	21.80	22.2
		b	15.77	16.66	15.68	16.0

D. Texture Peak Force Readings of Raw Watermelon and Dehydrated Watermelon Samples in Osmotic Pre-treated with 50º and 10º Brix Solutions

50º Brix-1						10º Brix-1					
a_w	0.99	0.98	0.94	0.67	0.55	a_w	0.99	0.99	0.97	0.62	0.45
Hour	0	2	7	19	31	Hour	0	2	7	19	31
TEST01	365.13	801.52	1494.66	881.56	2533.71	TEST01	365.13	843.46	1216.21	2891.87	6357.22
TEST02	501.00	770.76	956.95	1092.85	5383.48	TEST02	501.00	1112.49	998.00	2885.99	8928.89
TEST03	565.82	1181.50	1383.15	899.00	1447.54	TEST03	565.82	708.68	1271.11	2384.94	5548.60
TEST04	602.97	783.43	851.71	1130.18	4860.91	TEST04	602.97	1091.37	762.73	2242.81	8401.10
TEST05	694.51	838.09	694.08	1154.55	2541.59	TEST05	694.51	811.32	927.21	4250.85	9047.89
TEST06	480.39	920.80	NA	1364.32	3092.97	TEST06	480.39	1090.69	NA	881.56	8591.58
TEST07	569.80	901.18	NA	NA	1782.47	TEST07	569.80	735.50	NA	1092.85	7390.09
TEST08	440.86	889.32	NA	NA	NA	TEST08	440.86	1292.54	NA	NA	11227.00
Mean	527.56	885.83	1076.11	1087.08	3091.81	Mean	527.56	960.76	1035.05	2375.84	8186.55
Stdev	102.57	132.02	346.40	179.40	1495.20	Stdev	102.57	212.94	209.59	1150.28	1760.15

50º Brix -2						10º Brix-2					
a_w	0.99	0.98	0.98	0.73	0.52	a_w	0.99	0.99	0.98	0.63	0.39
Hour	0	2	7	19	31	Hour	0	2	7	19	31
TEST01	577.09	1062.16	1529.01	1442.63	3005.37	TEST01	577.09	1172.74	1145.45	1881.10	7872.43
TEST02	649.56	1049.96	1492.27	1374.19	3115.81	TEST02	649.56	1259.17	728.14	1843.66	5991.89
TEST03	649.49	997.89	1182.48	1247.91	1684.85	TEST03	649.49	977.24	1254.92	1328.73	6113.84
TEST04	797.73	1613.19	1692.35	1344.71	1734.84	TEST04	797.73	926.95	1061.33	1705.85	6795.15
TEST05	575.48	1311.03	1091.75	1492.39	1659.58	TEST05	575.48	1248.46	1145.71	1545.94	5818.07
TEST06	722.10	1786.97	1437.44	1241.15	2822.49	TEST06	722.10	1025.89	1111.94	1581.05	6695.86
TEST07	850.22	1299.51	1367.25	1472.83	2097.63	TEST07	850.22	1352.09	779.71	1442.81	5726.77
TEST08	766.03	1796.95	875.23	1106.03	1691.33	TEST08	766.03	1144.66	858.12	1767.99	5917.04
Mean	698.46	1364.71	1333.47	1340.23	2226.49	Mean	698.46	1138.40	1010.67	1637.14	6366.38
Stdev	101.88	329.32	266.03	133.94	645.01	Stdev	101.88	149.72	194.69	195.80	724.69

50º Brix -3						10º Brix -3					
a_w	0.99	0.98	0.96	0.70	0.51	a_w	0.99	0.99	0.98	0.65	0.39
Hour	0	2	7	19	31	Hour	0	2	7	19	31
TEST01	392.68	530.20	839.21	750.04	2706.03	TEST01	392.68	665.54	486.20	1180.09	8650.23
TEST02	407.61	714.72	677.24	645.80	1726.84	TEST02	407.61	672.22	615.57	1203.90	5585.31
TEST03	329.44	982.42	461.86	981.18	2080.58	TEST03	329.44	525.81	384.82	2344.17	6703.61
TEST04	307.70	715.80	1101.45	832.86	2551.60	TEST04	307.70	493.08	598.81	3079.70	7540.84
TEST05	338.95	946.80	504.93	1133.30	2822.92	TEST05	338.95	610.94	383.03	1012.19	5905.35
TEST06	385.07	731.87	595.41	664.07	2384.05	TEST06	385.07	527.88	438.57	1049.01	8865.86
TEST07	394.72	808.79	676.53	1071.27	2139.93	TEST07	394.72	617.21	376.83	1468.84	7406.11
TEST08	336.01	652.52	475.44	722.30	2374.75	TEST08	336.01	630.48	651.27	3569.23	10997.73
Mean	361.52	760.39	666.51	850.10	2348.34	Mean	361.52	592.90	491.89	1863.39	7706.88
Stdev	37.49	149.24	216.72	188.71	358.14	Stdev	37.49	68.23	114.37	1004.68	1770.15

E. Texture Force Area Readings of Raw Watermelon and Dehydrated Watermelon Samples in Osmotic Pre-treated with 50º and 10º Brix Solutions

50º Brix-1						10º Brix-1					
a_w	0.99	0.98	0.94	0.67	0.55	a_w	0.99	0.99	0.97	0.62	0.45
Hour	0	2	7	19	31	Hour	0	2	7	19	31
TEST01	2906.23	3508.59	7755.98	3016.25	28640.17	TEST01	2906.23	7571.89	4945.84	13648.75	47609.27
TEST02	6512.11	9819.96	4271.64	11660.5	55992.82	TEST02	6512.11	7459.89	6011.25	13524.87	46903.87
TEST03	6056.58	7493.38	7605.17	7586.63	16675.32	TEST03	6056.58	4188.48	5857.21	9075.33	33776.41
TEST04	5588.56	4575.31	4852.4	9593.97	55230.18	TEST04	5588.56	9154.14	4552.19	14141.84	44980.07
TEST05	6062.06	6236.27	3887.17	9483.95	31143.53	TEST05	6062.06	6817.38	6407.33	18403.19	38099.12
TEST06	4207.98	7806.03	NA	11662.04	36083.77	TEST06	4207.98	6941.6	NA	3016.25	44919.64
TEST07	5006.7	4152.29	NA	NA	20967.33	TEST07	5006.7	5030.29	NA	11660.5	46767.64
TEST08	5888.95	7133.22	NA	NA	NA	TEST08	5888.95	9992.88	NA	NA	59014.17
Mean	5278.646	6340.631	5674.472	8833.89	34961.87	Mean	5278.646	7144.569	5554.764	11924.39	45258.77
Stdev	1198.66	2142.985	1864.032	3236.945	15487.37	Stdev	1198.66	1919.456	775.0266	4829.918	7397.073

50º Brix-2						10º Brix-2					
a_w	0.99	0.98	0.98	0.73	0.52	a_w	0.99	0.99	0.98	0.63	0.39
Hour	0	2	7	19	31	Hour	0	2	7	19	31
TEST01	14910.98	21311.06	20735.2	17643.55	59473.43	TEST01	14910.98	24691.72	19810.46	14872.22	60055.97
TEST02	13689.06	23333.23	23583.12	19508.08	57994.94	TEST02	13689.06	22024.92	15902.01	21813.33	52484.18
TEST03	15453.88	20691.4	21496.41	22595.27	24728.90	TEST03	15453.88	24460.66	24840.96	15830.66	67562.16
TEST04	16638.04	24310.58	29827.31	20750.35	40469.55	TEST04	16638.04	24343.93	18097.83	16231.92	71171.02
TEST05	13170.58	33065.86	23157.36	21026.26	28692.64	TEST05	13170.58	22519.57	20341.73	18502.23	75547.84
TEST06	16712.46	23707.13	23687.87	18929.38	54550.43	TEST06	16712.46	21438.16	21690.24	16633.47	84989.17
TEST07	18851.27	28281.00	22785.28	15528.94	35642.73	TEST07	18851.27	22144.93	19069.41	19166.14	74447.19
TEST08	16993.38	27963.56	17920.24	20933.59	34213.47	TEST08	16993.38	31448.58	16239.60	21781.22	68883.27
Mean	15802.46	25332.98	22899.1	19614.43	41970.76	Mean	15802.46	24134.06	19499.03	18103.90	69392.60
Stdev	1872.711	4154.447	3393.457	2234.96	13614.22	Stdev	1872.711	3212.553	2924.16	2668.53	9903.31

50º Brix-3						10º Brix-3					
a_w	0.99	0.98	0.96	0.70	0.51	a_w	0.99	0.99	0.98	0.65	0.39
Hour	0	2	7	19	31	Hour	0	2	7	19	31
TEST01	9010.19	13139.58	5149.9	8554.73	43575.57	TEST01	9010.19	9047.06	6425.72	13528.2	99372.47
TEST02	6287.27	14820.37	8657.34	9672.84	52526.71	TEST02	6287.27	12841.69	6174.89	25657.18	74456.19
TEST03	7293.42	11680.31	6077.94	13457.64	43360.41	TEST03	7293.42	9617.96	8063.41	37452.94	67896.88
TEST04	6879.53	13525.93	8302.17	10913.84	58971.29	TEST04	6879.53	9833.09	4645.41	34476.64	77622.9
TEST05	7070.48	12375.38	4225.17	13432.79	58991.64	TEST05	7070.48	11346.28	9920.61	10404.66	92180.3
TEST06	7988.87	10997.86	5180.07	9008.09	56006.11	TEST06	7988.87	9384.55	8266.81	11116.94	51352.95
TEST07	8904.04	12365.11	6546.83	14612.27	53431.3	TEST07	8904.04	10706.88	4550.84	16119.05	100898.7
TEST08	8526.42	8194.11	6277.17	11129.84	44544.35	TEST08	8526.42	8791.17	10089.54	24656.67	94909.41
Mean	7745.028	12137.33	6302.074	11347.76	51425.92	Mean	7745.028	10196.09	7267.154	21676.54	82336.23
Stdev	1010.452	1974.705	1538.011	2260.6	6702.032	Stdev	1010.452	1362.86	2164.419	10510.58	17495.14

F. Moisture Content During Drying Watermelon Samples in Treated with and without Additives Experiment

With additives-1					Without additives-1				
Hour	Readings			Mean	Hour	Readings			Mean
0	87.81	88.13	86.27	87.40	0	87.81	88.13	86.27	87.40
2	79.13	78.83	78.03	78.66	2	77.55	80.32	79.56	79.14
7	48.22	50.84	49.88	49.65	7	55.78	55.48	54.06	55.11
19	7.45	6.39	7.02	6.95	19	11.20	9.44	11.93	10.86
31	5.57	3.90	4.31	4.59	31	3.60	4.37	3.34	3.77
With additives-2					Without additives-2				
Hour	Readings			Mean	Hour	Readings			Mean
0	91.13	87.64	90.93	90.47	0	91.13	87.64	90.93	90.47
2	77.74	75.01	77.35	76.70	2	73.53	75.48	77.48	75.50
7	54.41	54.64	57.64	55.56	7	48.04	45.40	48.80	47.41
19	8.64	7.05	7.17	7.62	19	9.71	9.51	9.16	9.46
31	4.28	4.41	4.71	4.47	31	4.25	5.39	5.48	5.04
With additives-3					Without additives-3				
Hour	Readings			Mean	Hour	Readings			Mean
0	92.46	91.68	91.50	91.88	0	92.46	91.68	91.50	91.88
2	80.19	79.30	79.15	79.54	2	77.44	79.40	79.99	78.94
7	49.95	52.95	52.08	51.66	7	56.49	52.34	57.57	55.46
19	9.60	8.15	8.03	8.59	19	10.85	9.80	10.15	10.27
31	4.89	4.49	3.26	4.21	31	7.10	6.33	5.50	6.31

G.   Water Activity During Drying Watermelon Samples in Treated with and without Additives Experiment

With additives-1							Without additives-1						
Hour	a_w					Mean	Hour	a_w					Mean
0	1.00	1.00	0.99	0.99	0.98	0.99	0	1.00	1.00	0.99	0.99	0.98	0.99
2	0.98	0.98	0.97	0.98	0.98	0.98	2	0.98	0.98	0.98	0.98	0.97	0.98
7	0.95	0.95	0.95	0.95	0.95	0.95	7	0.96	0.96	0.95	0.95	0.95	0.96
19	0.61	0.59	0.62	0.63	0.61	0.61	19	0.71	0.72	0.69	0.69	0.67	0.70
31	0.51	0.50	0.48	0.49	0.50	0.50	31	0.54	0.49	0.50	0.51	0.54	0.51
50WI-2							10WI-2						
Hour	a_w					Mean	Hour	a_w					Mean
0	0.98	0.99	0.99	0.99	0.99	0.99	0	0.98	0.99	0.99	0.99	0.99	0.99
2	0.98	0.98	0.98	0.98	0.98	0.98	2	0.98	0.98	0.98	0.98	0.98	0.98
7	0.96	0.96	0.96	0.96	0.96	0.96	7	0.94	0.95	0.95	0.95	0.94	0.95
19	0.62	0.62	0.64	0.66	0.63	0.63	19	0.66	0.64	0.64	0.62	0.68	0.65
31	0.51	0.43	0.47	NA	NA	0.47	31	0.53	0.50	0.54	NA	NA	0.52
50WI-3							50NO-2						
Hour	a_w					Mean	Hour	a_w					Mean
0	0.99	0.99	0.99	0.99	0.99	0.99	0	0.99	0.99	0.99	0.99	0.99	0.99
2	0.98	0.98	0.98	0.98	0.98	0.98	2	0.98	0.98	0.98	0.98	0.98	0.98
7	0.95	0.96	0.96	0.96	0.96	0.96	7	0.96	0.96	0.97	0.95	0.96	0.96
19	0.66	0.68	0.65	0.63	0.66	0.66	19	0.72	0.69	0.68	0.74	0.73	0.71
31	0.56	0.51	0.52	0.52	0.52	0.52	31	0.57	0.57	0.57	0.60	0.56	0.57

H. Hunter Color Values (L, a, b) of Raw watermelon and Dehydrated Watermelon Samples in Treated with and without Additives Experiment

Replicate-1	Treatments	Hunter Lab Value	Readings			Mean
Raw		L	42.15	41.78	39.19	41.08
		a	27.73	33.43	32.61	31.53
		b	29.89	29.72	31.35	29.97
19hr	With Additives	L	28.32	27.98	27.67	27.99
		a	29.79	29.91	29.07	29.59
		b	26.68	26.82	24.43	25.98
	Without additives	L	26.75	26.60	25.13	26.16
		a	30.24	29.54	29.94	29.91
		b	30.41	25.98	28.94	28.44
31hr	With Additives	L	32.48	32.07	31.18	31.91
		a	25.02	27.17	26.53	26.24
		b	19.38	24.03	21.65	21.69
	Without additives	L	29.01	28.38	27.49	28.29
		a	21.99	27.46	28.59	26.01
		b	24.55	24.75	26.84	25.38
Replicate-2	Treatments	Hunter Lab Value	Readings			Mean
Raw		L	43.92	43.45	45.96	42.75
		a	30.85	31.14	31.22	31.57
		b	26.92	26.30	26.93	27.78
19hr	With Additives	L	30.89	34.59	30.45	32.09
		a	26.39	24.89	26.81	25.85
		b	18.87	17.13	19.91	18.33
	Without additives	L	24.59	24.92	28.78	26.29
		a	28.65	28.04	22.87	26.35
		b	23.37	22.29	14.39	19.65
31hr	With Additives	L	32.49	32.80	32.51	32.60
		a	24.69	24.67	24.45	24.60

		b	19.16	17.98	17.55	18.23
	Without additives	L	32.26	31.08	30.65	31.33
		a	23.74	24.04	24.16	23.98
		b	17.81	18.17	18.77	18.25
Replicate-3	Treatments	Hunter Lab Value	Readings			Mean
Raw		L	40.28	40.96	34.33	38.49
		a	30.08	32.70	33.73	32.09
		b	31.72	34.98	40.09	35.96
19hr	With Additives	L	35.47	34.56	34.14	34.72
		a	26.04	27.20	27.70	26.98
		b	22.68	26.66	25.17	24.84
	Without additives	L	27.65	29.42	26.92	28.00
		a	28.19	27.47	29.54	28.40
		b	26.81	26.67	29.63	27.70
31hr	With Additives	L	40.16	36.72	36.15	37.68
		a	25.57	25.85	26.13	25.85
		b	23.48	22.70	22.87	23.02
	Without additives	L	30.10	31.46	32.72	31.43
		a	27.99	26.68	26.09	26.92
		b	25.55	25.04	24.51	25.03

I. Texture Peak Force Readings of Raw Watermelon and Dehydrated Watermelon Samples in with and without Additives Experiment

With-1						Without-1					
a_w	0.99	0.98	0.95	0.61	0.50	a_w	0.99	0.98	0.96	0.70	0.51
Hour	0	2	7	19	31	Hour	0	2	7	19	31
TEST01	565.90	922.23	1823.26	904.88	3189.67	TEST01	565.90	984.41	1988.28	805.69	3084.90
TEST02	553.11	1100.00	1879.37	995.93	2896.10	TEST02	553.11	619.99	855.98	916.34	4363.80
TEST03	596.25	933.46	1274.70	1209.52	2585.02	TEST03	596.25	789.56	759.65	776.13	2255.30
TEST04	529.00	960.21	2352.37	1304.13	2696.23	TEST04	529.00	760.84	1762.12	1036.05	3518.10
TEST05	645.54	813.06	968.93	1526.01	3875.07	TEST05	645.54	619.60	765.57	789.74	2549.80
TEST06	555.98	796.34	1725.13	1112.33	4536.92	TEST06	555.98	806.46	1275.12	978.42	3305.40
TEST07	621.75	912.76	2174.53	899.89	3689.75	TEST07	621.75	978.56	1269.11	1111.46	2707.10
TEST08	534.89	1362.57	1861.70	1260.27	4214.56	TEST08	534.89	597.56	1034.79	881.54	3638.00
Mean	575.30	975.08	1757.50	1151.62	3460.42	Mean	575.30	769.62	1213.83	911.92	3177.80
Stdev	41.85	182.28	449.41	216.67	726.46	Stdev	41.85	154.05	458.96	122.61	678.87

With-2						Without-2					
a_w	0.99	0.98	0.96	0.63	0.47	a_w	0.99	0.98	0.95	0.65	0.53
Hour	0	2	7	19	31	Hour	0	2	7	19	31
TEST01	563.31	965.88	876.38	644.47	2343.57	TEST01	563.31	924.09	848.15	744.28	2179.83
TEST02	535.73	1024.61	1757.54	812.01	3078.72	TEST02	535.73	719.36	1306.33	817.61	3111.20
TEST03	433.89	1080.03	909.80	846.55	3207.80	TEST03	433.89	1020.87	1198.04	958.13	2164.92
TEST04	489.99	1305.36	1056.06	925.48	1903.15	TEST04	489.99	962.54	1241.84	803.35	1886.05
TEST05	548.04	1299.41	2169.96	957.75	3263.27	TEST05	548.04	673.76	721.74	807.03	2687.49
TEST06	423.51	1304.29	1264.22	1043.09	1731.08	TEST06	423.51	885.89	1063.66	1040.65	1945.78
TEST07	467.34	1327.71	1200.83	1113.90	3541.66	TEST07	467.34	853.41	994.97	1058.74	3149.07
TEST08	448.15	1048.65	1085.53	1201.96	2496.69	TEST08	448.15	803.45	718.46	1214.78	2091.94
Mean	488.75	1169.49	1290.04	943.15	2695.74	Mean	488.75	855.42	1011.65	930.57	2402.04
Stdev	54.32	152.88	449.40	178.24	672.84	Stdev	54.32	118.75	231.24	164.31	509.71

With-3						Without-3					
a_w	0.99	0.98	0.96	0.66	0.52	a_w	0.99	0.98	0.96	0.71	0.57
Hour	0	2	7	19	31	Hour	0	2	7	19	31
TEST01	414.93	941.37	1406.86	1488.02	1861.34	TEST01	414.93	1057.80	763.46	1218.25	2159.89
TEST02	413.41	780.69	1587.75	1358.25	1933.17	TEST02	413.41	1034.52	1515.52	1117.25	1722.88
TEST03	564.96	1260.09	860.86	1428.61	1567.41	TEST03	564.96	577.30	990.34	1226.13	2873.02
TEST04	402.95	962.04	1226.82	1027.26	2208.85	TEST04	402.95	682.38	751.03	765.80	2542.69
TEST05	464.37	1050.24	1797.97	1045.24	1327.32	TEST05	464.37	675.31	512.73	1166.41	3054.17
TEST06	460.74	928.86	1444.85	1574.24	1939.67	TEST06	460.74	705.46	747.68	1204.36	2252.95
TEST07	411.81	899.32	895.15	1044.69	1859.79	TEST07	411.81	757.39	575.08	1389.34	3225.13
TEST08	536.82	1002.44	1195.40	917.96	1694.74	TEST08	536.82	962.63	736.45	930.11	2593.67
Mean	458.75	978.13	1301.96	1106.19	1799.04	Mean	458.75	806.60	824.04	1127.21	2553.05
Stdev	61.76	138.63	324.30	252.89	267.35	Stdev	61.76	184.12	313.32	194.14	498.68

J. Texture Force Area Readings of Raw Watermelon and Dehydrated Watermelon Samples in with and without Additives Experiment

With-1						Without-1					
a_w	0.99	0.98	0.95	0.61	0.50	a_w	0.99	0.98	0.96	0.70	0.51
Hour	0	2	7	19	31	Hour	0	2	7	19	31
TEST01	13990.71	18200.49	15601.96	17196.40	49265.04	TEST01	13990.71	19636.27	15806.37	14162.27	43733.10
TEST02	12711.69	18992.35	16024.12	20374.61	53286.54	TEST02	12711.69	16222.74	14947.93	12261.10	84000.20
TEST03	11603.02	15154.44	16844.40	16687.46	44314.19	TEST03	11603.02	20046.52	10854.09	13704.67	58000.60
TEST04	12722.43	17884.87	20200.39	20839.03	40889.50	TEST04	12722.43	15243.14	16195.16	15132.63	60157.50
TEST05	13615.10	19785.45	16073.57	21914.67	70144.06	TEST05	13615.10	11272.71	12624.24	12456.75	71225.90
TEST06	12266.90	17342.09	22793.60	23893.12	74054.55	TEST06	12266.90	13067.44	15715.29	13535.77	67201.10
TEST07	14260.04	17126.86	19204.43	15317.88	48535.93	TEST07	14260.04	17203.99	16580.28	15164.21	78726.80
TEST08	12177.97	18454.01	16313.60	15343.83	62512.04	TEST08	12177.97	11249.46	12182.35	14674.37	146620.7
Mean	12918.48	17867.57	17882.01	18945.88	55375.23	Mean	12918.48	15492.78	14363.21	13886.47	76208.24
Stdev	942.59	1393.06	2583.04	3234.03	12180.93	Stdev	942.59	3446.02	2158.65	1116.39	31109.72

With-2						Without-2					
a_w	0.99	0.98	0.96	0.63	0.47	a_w	0.99	0.98	0.95	0.65	0.53
Hour	0	2	7	19	31	Hour	0	2	7	19	31
TEST01	11566.57	18962.29	12383.25	12719.08	33586.04	TEST01	11566.57	15983.34	9296.76	12567.12	39740.84
TEST02	13621.76	19705.31	15936.37	12795.82	55881.08	TEST02	13621.76	14505.96	12459.35	9658.97	50256.38
TEST03	11519.35	20658.35	14929.96	12227.96	36028.23	TEST03	11519.35	17633.54	8694.31	11354.44	24168.69
TEST04	11515.92	22639.39	13519.87	12183.86	46400.07	TEST04	11515.92	14888.25	11522.94	9862.25	45483.91
TEST05	13691.64	18335.79	14740.19	13698.46	38516.58	TEST05	13691.64	14890.53	8678.11	11035.22	62132.87
TEST06	11716.16	25872.84	14494.11	12441.70	25480.51	TEST06	11716.16	14550.41	11653.83	10906.43	44706.83
TEST07	11446.42	22995.59	9752.41	10899.23	59503.52	TEST07	11446.42	17764.85	5998.56	11963.10	51036.56
TEST08	11865.20	19059.66	18229.04	13181.06	34253.40	TEST08	11865.20	15652.26	12298.12	12633.56	26416.34
Mean	12117.88	21028.65	14248.15	12518.40	41206.18	Mean	12117.88	15733.64	10075.25	11247.64	42992.80
stdev	959.09	2597.14	2498.14	825.73	11740.48	Stdev	959.09	1316.77	2277.13	1120.57	12720.34

With-3						Without-3					
a_w	0.99	0.98	0.96	0.66	0.52	a_w	0.99	0.98	0.96	0.71	0.57
Hour	0	2	7	19	31	Hour	0	2	7	19	31
TEST01	10086.98	17613.66	19664.67	26253.40	23659.77	TEST01	10086.98	18524.35	11110.49	13082.85	33824.52
TEST02	10324.14	15322.11	18429.21	24008.42	37145.59	TEST02	10324.14	20023.13	13065.49	9439.40	30825.14
TEST03	10194.14	15488.75	17194.11	26109.38	32182.90	TEST03	10194.14	7839.41	12073.18	12132.23	39745.43
TEST04	11300.94	20649.95	14181.70	17748.19	35918.70	TEST04	11300.94	14661.18	8256.75	10280.08	64629.84
TEST05	9657.53	16807.63	24115.95	12910.78	29981.85	TEST05	9657.53	12090.36	5730.36	8458.33	45114.50
TEST06	9628.46	17522.12	20625.23	17768.97	36161.62	TEST06	9628.46	12789.93	7843.58	11707.23	55726.84
TEST07	10927.70	17493.86	15207.75	15436.47	37794.07	TEST07	10927.70	10450.50	8951.09	13474.58	37356.15
TEST08	11894.78	13134.54	15880.67	16878.55	29666.34	TEST08	11894.78	13815.37	11058.93	9351.90	51027.02
Mean	10501.83	16754.08	18162.41	19639.27	32813.86	Mean	10501.83	13774.28	9761.23	10990.83	44781.16
Stdev	804.83	2197.71	3263.61	5103.65	4877.60	Stdev	804.83	4008.46	2467.30	1865.99	11638.64

K.   Moisture Content During Drying Watermelon Samples in Forced-air and Vacuum Drying Experiment

Forced-air-1					Vacuum-1				
Hour	Readings			Mean	Hour	Readings			Mean
0	87.58	89.87	89.52	88.99	0	87.58	89.87	89.52	88.99
2	78.61	78.70	80.57	79.29	2	78.61	78.70	80.57	79.29
7	49.78	51.74	51.69	51.07	7	70.10	71.70	70.33	70.71
13	10.52	10.94	9.49	10.32	13	34.82	34.58	33.82	34.41
19	6.49	6.02	5.77	6.09	19	8.63	8.56	10.35	9.18
31	4.30	4.73	4.63	4.56	31	3.84	3.52	3.94	3.77
Forced-air-2					Vacuum-2				
Hour	Readings			Mean	Hour	Readings			Mean
0	89.14	89.99	87.60	88.91	0	89.14	89.99	87.60	88.91
2	78.36	78.14	79.34	78.61	2	78.36	78.14	79.34	78.61
7	52.50	56.08	56.46	55.01	7	71.13	66.31	69.21	68.88
13	11.47	12.61	12.37	12.15	13	42.30	39.12	42.19	41.20
19	5.90	6.26	8.78	6.98	19	10.77	6.06	11.45	9.43
31	3.53	2.10	2.44	2.69	31	4.92	4.83	4.72	4.83
Forced-air-3					Vacuum-3				
Hour	Readings			Mean	Hour	Readings			Mean
0	92.58	90.29	90.52	91.13	0	92.58	90.29	90.52	91.13
2	78.61	73.74	78.78	77.05	2	78.61	73.74	78.78	77.05
7	40.34	39.42	40.37	40.05	7	62.38	58.92	59.11	60.14
13	13.39	13.23	11.26	12.63	13	16.81	19.80	21.39	19.33
19	8.20	6.41	7.97	7.53	19	8.98	8.92	6.91	8.27
31	6.45	6.52	5.74	6.23	31	3.01	2.78	2.57	2.79

L. Water Activity During Drying of Watermelon Samples in Forced-air and Vacuum Drying Experiment

Forced-air-1							Vacuum-1						
Hour	a_w					Mean	Hour	a_w					Mean
0	0.987	0.989	0.994	0.988	0.988	0.9892	0	0.987	0.989	0.994	0.988	0.988	0.9892
2	0.981	0.983	0.983	0.983	0.983	0.9826	2	0.981	0.983	0.983	0.983	0.983	0.9826
7	0.946	0.949	0.952	0.958	0.945	0.95	7	0.97	0.979	0.973	0.977	0.974	0.9746
13	0.619	0.663	0.648	0.646	0.628	0.6408	13	0.862	0.848	0.866	0.867	0.848	0.8582
19	0.581	0.547	0.508	0.526	0.533	0.539	19	0.612	0.585	0.64	0.614	0.575	0.6052
31	0.526	0.515	0.523	0.55	0.499	0.5226	31	0.453	0.458	0.478	0.476	0.474	0.4678
Forced-air-2							Vacuum-2						
Hour	a_w					Mean	Hour	a_w					Mean
0	0.986	0.994	0.984	0.991	0.991	0.9892	0	0.986	0.994	0.984	0.991	0.991	0.9892
2	0.983	0.995	0.987	0.985	0.985	0.987	2	0.983	0.995	0.987	0.985	0.985	0.987
7	0.96	0.95	0.953	0.951	0.951	0.953	7	0.974	0.971	0.972	0.972	0.972	0.9722
13	0.758	0.696	0.771	0.746	0.73	0.7402	13	0.935	0.925	0.884	0.93	0.948	0.9244
19	0.553	0.537	0.506	0.543	0.548	0.5374	19	0.56	0.598	0.613	0.589	0.627	0.5974
31	0.408	0.421	0.39	0.403	0.38	0.4004	31	0.49	0.474	0.503	0.462	0.453	0.4764
Forced-air-3							Vacuum-3						
Hour	a_w					Mean	Hour	a_w					Mean
0	0.99	0.988	0.987	0.986	0.99	0.9882	0	0.99	0.988	0.987	0.986	0.99	0.9882
2	0.977	0.979	0.979	0.978	0.981	0.9788	2	0.977	0.979	0.979	0.978	0.981	0.9788
7	0.916	0.918	0.923	0.914	0.9	0.9142	7	0.97	0.967	0.97	0.968	0.964	0.9678
13	0.625	0.661	0.681	0.671	0.672	0.662	13	0.778	0.774	0.809	0.801	0.804	0.7932
19	0.569	0.55	0.541	0.52	0.54	0.544	19	0.557	0.556	0.588	0.575	0.602	0.5756
31	0.574	0.503	0.542	0.482	0.504	0.521	31	0.417	0.46	0.509	0.428	0.465	0.4558

M.   Hunter Color Values (L, a, b) of Raw watermelon and Dehydrated Watermelon Samples in Forced-air and Vacuum Drying Experiment

Replicate-1	Drying Methods	Hunter Lab Values	Readings			Mean
Raw		L	37.52	47.63	38.67	42.37
		a	33.05	28.10	33.05	30.79
		b	38.18	32.24	38.07	35.25
19hr	Forced-air	L	33.68	32.55	33.65	33.29
		a	24.24	23.62	24.58	24.15
		b	21.91	21.23	22.92	22.02
	Vacuum	L	36.41	37.61	36.99	37.00
		a	25.59	23.81	25.00	24.80
		b	24.52	24.52	25.42	24.82
31hr	Forced-air	L	38.89	39.74	37.86	38.83
		a	22.90	23.27	23.57	23.25
		b	24.83	26.33	25.29	25.48
	Vacuum	L	37.19	36.83	36.24	36.75
		a	22.40	22.49	23.38	22.76
		b	22.84	22.70	23.71	23.08
Replicate-2	Drying Methods	Hunter Lab Values	Readings			Mean
Raw		L	44.69	41.38	46.34	43.13
		a	25.66	28.99	24.73	26.88
		b	29.27	34.43	30.32	31.77
19hr	Forced-air	L	37.03	36.94	36.04	36.67
		a	24.55	24.60	25.02	24.72
		b	24.15	24.04	23.02	23.74
	Vacuum	L	38.95	39.06	39.21	39.07
		a	26.25	26.22	26.01	26.16
		b	26.13	25.79	26.23	26.05
31hr	FA	L	38.10	37.55	37.67	37.77

		a	24.08	24.61	24.24	24.31
		b	23.87	24.40	23.48	23.92
	Vacuum	L	37.76	37.41	38.46	37.88
		a	23.86	24.03	24.25	24.05
		b	24.11	24.47	24.66	24.41
Replicate-3	Drying Methods	Hunter Lab Values	Readings			Mean
Raw		L	52.02	41.59	39.58	46.29
		a	24.75	26.40	26.17	25.06
		b	36.70	34.57	35.17	34.88
19hr	Forced-air	L	41.87	42.23	42.68	42.26
		a	23.73	23.51	23.58	23.61
		b	31.07	30.65	30.70	30.81
	Vacuum	L	43.98	43.27	44.16	43.80
		a	23.59	23.97	24.07	23.88
		b	32.33	33.48	33.79	33.20
31hr	Forced-air	L	44.47	48.21	44.47	45.72
		a	20.97	19.27	22.18	20.81
		b	34.10	33.67	34.99	34.25
	Vacuum	L	41.60	42.40	40.61	41.54
		a	22.11	20.27	19.37	20.58
		b	39.11	35.64	33.78	36.18

N.   Texture Peak Force Readings of Raw Watermelon and Dehydrated Watermelon Samples in Force-air and Vacuum Drying Experiment

FA-1							VA-1						
a_w	0.99	0.98	0.95	0.64	0.54	0.52	a_w	0.99	0.98	0.97	0.86	0.61	0.47
Hour	0	2	7	13	19	31	Hour	0	2	7	13	19	31
TEST01	515.82	1213.54	1482.89	615.13	3213.29	2080.77	TEST01	515.82	1213.54	1742.19	1260.97	1336.17	4028.08
TEST02	509.49	1508.30	930.44	844.15	1753.72	1850.23	TEST02	509.49	1508.30	970.27	1374.36	941.46	3881.14
TEST03	661.00	1929.16	1758.33	710.35	4104.32	3749.85	TEST03	661.00	1929.16	1647.65	1211.56	988.14	3045.12
TEST04	505.18	981.35	987.44	810.91	2823.94	1600.23	TEST04	505.18	981.35	839.63	1381.92	908.49	4939.01
TEST05	618.06	1261.31	1253.83	672.56	3557.83	3314.84	TEST05	618.06	1261.31	1763.84	1481.60	990.61	5614.50
TEST06	563.22	928.11	1098.64	761.79	1203.53	2053.25	TEST06	563.22	928.11	1026.84	1051.03	1212.16	7458.06
TEST07	553.10	2040.47	1739.08	886.20	1530.83	3450.88	TEST07	553.10	2040.47	1421.42	1314.02	1476.99	5177.62
TEST08	545.65	1592.83	1542.03	777.75	2943.79	1614.65	TEST08	545.65	1592.83	775.92	819.00	1389.77	4811.67
Mean	558.94	1431.88	1349.09	759.86	2641.41	2464.34	Mean	558.94	1431.88	1273.47	1236.81	1155.47	4869.40
Stdev	55.21	411.09	327.88	90.25	1036.52	887.30	Stdev	55.21	411.09	415.86	212.52	225.55	1329.45

FA-2							VA-2						
a_w	0.99	0.99	0.95	0.74	0.54	0.40	a_w	0.99	0.99	0.97	0.92	0.60	0.48
Hour	0	2	7	13	19	31	Hour	0	2	7	13	19	31
TEST01	370.11	763.68	1076.29	900.65	1430.27	4019.38	TEST01	370.11	763.68	2043.40	788.09	1001.90	9486.71
TEST02	416.59	1107.04	2070.75	733.54	1909.80	3825.97	TEST02	416.59	1107.04	965.90	2343.66	990.17	4800.27
TEST03	332.97	892.93	975.81	752.07	3008.95	3196.07	TEST03	332.97	892.93	1622.03	1151.37	1285.83	6369.33
TEST04	350.22	532.72	843.06	1176.63	1208.20	3307.13	TEST04	350.22	532.72	1478.36	1278.82	874.98	6416.67
TEST05	332.83	922.55	965.11	923.07	2133.70	3528.08	TEST05	332.83	922.55	992.45	2209.22	914.46	9520.13
TEST06	402.09	1241.15	1981.66	928.61	2820.49	2044.30	TEST06	402.09	1241.15	946.83	1771.88	782.89	5534.38
TEST07	363.25	692.65	878.35	703.09	1528.38	6271.76	TEST07	363.25	692.65	1160.58	925.51	1381.52	6881.41
TEST08	375.64	813.77	1110.47	982.86	1222.66	4529.80	TEST08	375.64	813.77	1119.66	926.09	1820.76	7789.50
Mean	367.96	870.83	1237.71	887.58	1907.83	3840.31	Mean	367.96	870.83	1291.13	1424.34	1131.58	7099.80
Stdev	30.21	225.80	495.34	156.69	699.74	1221.36	Stdev	30.21	225.80	390.88	607.05	344.88	1724.50

FA-3							VA-3						
a_w	0.99	0.98	0.91	0.66	0.54	0.52	a_w	0.99	0.98	0.97	0.79	0.58	0.46
Hour	0	2	7	13	19	31	Hour	0	2	7	13	19	31
TEST01	462.59	864.51	704.35	942.14	2987.18	1279.45	TEST01	462.59	864.51	1344.28	804.60	1604.66	4111.75
TEST02	452.97	1660.52	1307.35	1217.38	1935.02	3945.72	TEST02	452.97	1660.52	1973.42	882.75	806.51	3725.44
TEST03	397.29	969.62	1161.19	627.29	1780.55	2399.79	TEST03	397.29	969.62	1125.33	1024.03	1630.93	2947.12
TEST04	297.24	1453.51	673.86	1040.55	765.36	1703.54	TEST04	297.24	1453.51	1359.61	928.78	1390.08	2543.25
TEST05	375.43	798.53	1453.23	710.22	1308.90	2483.92	TEST05	375.43	798.53	989.61	947.51	3268.80	8700.69
TEST06	329.23	1446.58	940.79	721.96	1441.24	3614.53	TEST06	329.23	1446.58	995.75	814.18	3481.26	7219.23
TEST07	446.91	847.72	2335.74	545.84	2236.44	5342.16	TEST07	446.91	847.72	1763.95	1308.73	1849.62	5146.26
TEST08	316.78	560.71	909.97	727.25	2097.35	3434.91	TEST08	316.78	1075.21	735.22	947.53	877.71	6110.78
Mean	384.81	1075.21	1185.81	816.58	1819.01	3025.50	Mean	384.81	1139.53	1285.90	957.26	1863.70	5063.07
Stdev	65.66	391.37	539.74	228.02	670.22	1320.68	Stdev	65.66	332.60	415.94	159.61	1001.89	2154.96

O. Texture Force Area Readings of Raw Watermelon and Dehydrated Watermelon Samples in Force-air and Vacuum Drying Experiment

FA-1							VA-1						
a_w	0.99	0.98	0.95	0.64	0.54	0.52	a_w	0.99	0.98	0.97	0.86	0.61	0.47
Hour	0	2	7	13	19	31	Hour	0	2	7	13	19	31
TEST01	11782.38	17374.01	15563.09	10407.47	59446.34	27280.62	TEST01	11782.38	17374.01	14268.62	17958.55	14121.41	56351.70
TEST02	14276.63	16863.85	17186.89	10527.89	40763.82	36726.92	TEST02	14276.63	16863.85	16386.33	18363.72	13699.45	56334.81
TEST03	12310.94	24098.90	21764.97	9715.32	90962.18	53436.77	TEST03	12310.94	24098.90	20951.94	14874.82	14286.10	47528.54
TEST04	13793.23	25013.90	14834.43	12576.15	62447.34	23600.46	TEST04	13793.23	25013.90	11360.33	12287.60	13916.56	69252.26
TEST05	13052.79	15639.53	17785.41	11026.44	82638.90	51394.12	TEST05	13052.79	15639.53	21402.77	14661.86	15037.02	98785.25
TEST06	12144.21	14739.28	18815.11	11656.21	23739.63	35766.15	TEST06	12144.21	14739.28	16578.54	10349.15	16754.50	121788.3
TEST07	12186.84	15842.01	18666.53	10789.61	36490.05	53694.36	TEST07	12186.84	15842.01	21878.24	13310.99	17336.21	63391.11
TEST08	10670.18	21664.68	18728.11	11564.91	70335.54	34740.50	TEST08	10670.18	21664.68	10983.56	8492.62	12237.79	69683.30
Mean	12527.15	18904.52	17918.07	11033.00	58352.98	39579.99	Mean	12527.15	18904.52	16726.29	13787.41	14673.63	72889.41
Stdev	1149.67	4067.64	2152.30	885.97	23299.78	11853.42	Stdev	1149.67	4067.64	4378.82	3435.55	1667.42	24974.69

FA-2							VA-2						
a_w	0.99	0.99	0.95	0.74	0.54	0.40	a_w	0.99	0.99	0.97	0.92	0.60	0.48
Hour	0	2	7	13	19	31	Hour	0	2	7	13	19	31
TEST01	9182.43	13108.90	8078.88	10253.80	31480.43	48858.11	TEST01	9182.43	13108.90	16017.27	9475.03	13206.61	125177.8
TEST02	9208.01	17267.66	16089.98	8436.51	47302.27	62213.45	TEST02	9208.01	17267.66	14771.27	16941.80	14685.77	70652.20
TEST03	9382.05	17261.80	12448.08	7789.96	51142.45	48806.25	TEST03	9382.05	17261.80	14685.66	17389.07	18866.63	92438.52
TEST04	8945.50	11161.11	14893.07	7241.06	27759.61	58111.71	TEST04	8945.50	11161.11	15393.13	14587.75	11714.38	93926.77
TEST05	8599.21	14315.00	15279.05	9243.86	56625.07	51964.16	TEST05	8599.21	14315.00	11548.84	10889.04	14774.12	97432.14
TEST06	9225.17	11654.01	12748.38	9351.46	55744.38	36735.54	TEST06	9225.17	11654.01	18130.68	18028.96	13163.75	53878.24
TEST07	9042.22	12034.73	13292.20	8286.73	30468.72	68312.73	TEST07	9042.22	12034.73	10692.73	10107.38	21205.03	123944.5
TEST08	9254.50	12978.68	15455.76	12224.05	21792.28	67899.68	TEST08	9254.50	12978.68	14647.91	15256.19	28045.85	96298.63
Mean	9104.89	13722.74	13535.70	9103.45	40289.41	55362.70	Mean	9104.89	13722.74	14486.00	14084.41	16957.78	94218.63
Stdev	243.59	2392.37	2583.79	1578.81	13866.02	10844.27	Stdev	243.59	2392.37	2378.86	3454.72	5483.98	24031.94

FA-3							VA-3						
a_w	0.99	0.98	0.91	0.66	0.54	0.52	a_w	0.99	0.98	0.97	0.79	0.58	0.46
Hour	0	2	7	13	19	31	Hour	0	2	7	13	19	31
TEST01	9452.24	14313.55	7121.63	10490.1	62808.79	21341.15	TEST01	9452.24	14313.55	16723.36	8943.81	24949.22	51606.90
TEST02	6043.99	20673.73	11056.54	11396.9	39246.99	56098.64	TEST02	6043.99	20673.73	18259.55	5174.79	15468.24	39426.40
TEST03	11991.69	15206.3	12214.4	5844.21	29741.96	32642.73	TEST03	11991.69	15206.30	13812.45	10675.59	17273.37	61659.80
TEST04	8606.44	21930.1	11461.43	11983.93	17783.37	28723.36	TEST04	8606.44	21930.10	17572.78	7888.03	21379.41	37851.60
TEST05	6729.84	11814.82	20975.24	8323.52	21976.65	40751.38	TEST05	6729.84	11814.82	12797.55	7142.74	31811.34	114155.1
TEST06	8096.09	22871.11	13528.76	9141.95	22954.98	51938.8	TEST06	8096.09	22871.11	16293.46	9440.28	30302.09	62212.80
TEST07	8450.29	13808.43	16387.36	8264.67	26659.86	61429.83	TEST07	8450.29	13808.43	17183.79	10385.73	26000.93	69084.10
TEST08	9203.5	10536.26	11134.1	8570.4	34151.25	NA	TEST08	9203.50	10536.26	10951.56	10629.49	12601.67	NA
Mean	8571.76	16394.29	12984.93	9251.96	31915.48	41846.56	Mean	8571.76	16394.29	15449.31	8785.06	22473.28	62285.24
Stdev	1808.503	4760.305	4143.06	1982.911	14264.24	15094.59	Stdev	1808.50	4760.31	2610.19	1946.74	6987.94	25725.02

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P. SAS Program Commands and Outputs for Two Independent Sample Test:

In this SAS programming, we recorded the moisture content changes per hour of the treatments of 50º and 10º Brix sugar concentrations in replicate 2.

```
DATA Moisture;
INPUT Brix $ MCwb @@;
cards;
50 5.596 50 0.454 50 4.288
10 2.863 10 1.298 10 2.998
;
Proc TTest data=Moisture;
Class Brix;
Var MCwb;
Title 'Moisture Content TTEST for Two Sugar Concentrations';
RUN;
```

The outputs are given bellow:

```
                Moisture Content TTEST for Two Sugar Concentrations          2
                                         23:37 Wednesday, July 20, 2005

                            The TTEST Procedure

                                Statistics

                            Lower CL            Upper CL  Lower CL              Upper CL
Variable  Brix         N        Mean    Mean        Mean   Std Dev  Std Dev     Std Dev  Std
Err

MCwb      10           3       0.039  2.3863      4.7337     0.492   0.9449      5.9387
0.5456
MCwb      50           3      -3.193   3.446      10.085    1.3914   2.6724      16.795
1.5429
MCwb      Diff (1-2)          -5.603   -1.06      3.4841    1.2009   2.0043      5.7596
1.6365

                                  T-Tests

        Variable      Method          Variances      DF     t Value    Pr > |t|

        MCwb          Pooled          Equal           4      -0.65      0.5526
        MCwb          Satterthwaite   Unequal      2.49      -0.65      0.5719

                            Equality of Variances

           Variable      Method      Num DF    Den DF    F Value    Pr > F

           MCwb          Folded F       2         2        8.00     0.2223
```

In the T-Teest, we considered P-value under the equal variance assumption. The P-value is larger than 0.05 and indicates that there are significant differences between the pre-treatment of 50º and 10º Brix sugar solutions in the replicate 2.

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