EVALUATION OF WATERMELON POMACE AS A POTENTIAL FOOD INGREDIENT

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CHAPTER I

INTRODUCTION

1.1 Problem Statement

Watermelon fruit is the most important melon crop and the third most produced vegetable crop in the United States (USDA and NASS 2010). In 2009, 4.0 billion pounds of watermelons were produced for a total value of $461 million, and consumption was 15.3 pounds per person, contributing to 57% of total melon consumption (ERS and USDA 2010b; USDA and NASS 2010). In spite of this, about 30% of watermelons are left in the field each year in Oklahoma due to the fact that most are consumed fresh, leading to the rejection of watermelons that have any visible defect (Williams 2007). Also, as was shown in a survey performed for the Watermelon Promotion Board, 60% of consumers prefer seedless watermelons (Rose Research 2006). This presents a problem in that for producing seedless fruits, farmers have to plant seeded pollinators which are then left wasted on the fields (Williams 2007). With this problem at hand, the need for more value-added products that could make use of these wasted watermelons is evident.

Watermelons contain many nutritional benefits. They are a good source of vitamins A and C, and potassium (Maynard 2001). Watermelon is also the richest known

source of the antioxidant lycopene, containing on average 45.3 µg lycopene/g fresh tissue (Holden 2009).

Recently, Sundia Corporation released the first mass-produced watermelon juice into the market, creating a new value-added product for watermelon fruit (Anon 2006). Pomace is the solid material that remains after removing the juice from the pulp and consists of insoluble carbohydrates, protein, and minerals, while also containing some remaining juice with other soluble components like sugar (Carson and others 1994a). A study performed by Perkins-Veazie and others (2006b) found that the addition of heat at various steps during the processing and pasteurization of watermelon juice concentrated but did not degrade lycopene. They also found that the remaining pomace was a concentrated source of lycopene, containing 110% of that found in the juice (Perkins-Veazie and others 2006b). With this information and the production of watermelon juice creating a new waste stream, it makes sense to evaluate the watermelon pomace composition and its potential use as a food ingredient.

Drying is a process that has been used for centuries to preserve foods. Fruits like watermelon, which have a short shelf life and are sold for only a short season during the summer, can benefit from this process to make it more available throughout the year and to make it more versatile for use in different products. Only a few studies have dealt with drying of watermelon, mainly with osmotic dehydration of the pulp (Falade and others 2007) and spray-drying of the juice (Quek and others 2007), but none have dealt with the pomace. Therefore, it would be of interest to see how drying affects the components of watermelon pomace, especially its lycopene content. Several studies have been performed for this purpose on tomatoes (Sharma and Maguer 1996; Shi and others 1999;

Zanoni and others 1999; Tran and others 2008) since they are the most important source of lycopene due to their high consumption and the variety of products available that are made from them.

There have also been many studies performed with various fruit powders for their use as a nutritional supplement for different bakery products, to increase their dietary fiber content and that of other components such as protein, vitamins, and minerals (Chen and others 1988; Wang and Thomas 1989; Masoodi and others 2002; Giami and others 2005; Pongjanta and others 2006; Sudha and others 2007; Athayde-Uchoa and others 2009). Dried watermelon pomace could also be used for this purpose, especially for the addition of the antioxidant lycopene and also as a source of dietary fiber or as a sugar substitute.

1.2 Assumptions

1. Drying will not significantly affect the chemical composition of samples.
2. Since lycopene is sensitive to heat, oxygen, and light it will be affected by storage temperatures and conditions. Therefore, it will be important to choose an appropriate storage temperature and to minimize its exposure to light and to oxygen whenever samples are handled and/or stored.
3. Also, because of this it will be important to measure lycopene loss after drying and baking, to observe how much it was affected. Since it is sensitive to oxygen, vacuum drying would probably be the better option for drying.

4. Since watermelon is low in fiber, it can be incorporated into bakery products at higher levels than apple pomace without significantly affecting the physical properties of products.

1.3 Research Objectives

The main objectives of this study are to evaluate the composition and use of watermelon pomace as a food ingredient. The chemical and physical properties of watermelon pomace will be evaluated. Also, the pomace will be dried using different drying methods to evaluate any changes in color and composition. Finally, dried watermelon pomace will be incorporated into wheat flour at different levels, and dough rheological properties, baking quality of cookies, and sensory evaluation of cookies will be performed to determine the efficacy of watermelon pomace as a food ingredient. Also, the chemical composition of cookies with added dried watermelon pomace will be evaluated to determine whether nutrient composition was affected by processing.

The specific objectives of this study will be:

1. To evaluate the chemical composition and physical properties of watermelon pomace.
2. To compare the effect of different drying methods on the composition of watermelon pomace.
3. To evaluate the quality of cookies with incorporated dried watermelon pomace.

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CHAPTER II

REVIEW OF LITERATURE

2.1 Watermelon

Watermelon (*Citrullus lanatus*) belongs to the family *Cucurbitaceae*, the same family as cucumber, pumpkin, and squash. It grows in countries that have a long, warm growing season such as China, Africa, India, and the United States (Ahmad and Chwee 2008). China is the world's largest watermelon producer with 13.9 billion pounds produced in 2008, followed by Turkey, Iran, Brazil, and the United States, which produced 4.3 billion pounds that same year (ERS and USDA 2010a). The major producing state is Florida with 817 million pounds produced in 2009, followed by California, Georgia, Texas, and Arizona (USDA and NASS 2010).

Watermelon originated in Africa and it has been an important vegetable in Egypt for at least 4,000 years (Robinson and Decker-Walters 1997). By the tenth century AD, it was grown in China and South Russia and was later introduced to the New World by the Spaniards in the sixteenth century (Robinson and Decker-Walters 1997). For many years, it has been a source of water in the Kalahari Dessert and other areas of Africa (Robinson and Decker-Walters 1997). Watermelons are mostly eaten fresh, but in Africa they can

also be cooked (Robinson and Decker-Walters 1997). In south parts of the old Soviet Union, watermelon juice is made into a fermented drink or it can be boiled down into syrup (Robinson and Decker-Walters 1997). The rind can be pickled or candied and the seeds can be roasted or eaten as it is done in the Orient and Middle East (Robinson and Decker-Walters 1997). In India the seeds are powdered and baked into a type of bread (Robinson and Decker-Walters 1997).

2.2 Watermelon Composition

Watermelons can range in size from 2 to 250 lb, but the preferred commercial size is 18-25 lb (Maynard 2001). They consist of a fleshy edible portion or pulp, which can be white, green, yellow, orange, pink, or red (Maynard 2001). The pulp contains numerous seeds which can range in number from 3,000 to 10,000 seeds/lb, depending on the size of the melon, and can range from white to black in color, as well as brown, red, green, and spotted (Maynard 2001). The outer part or peel can be light to dark green, and may have stripes of various designs which are typical of a certain variety or type (Maynard 2001). The edible pulp of watermelon was found to constitute 60% of the whole fruit weight, while the rind (white portion) was 31%, the peel 5.4%, and the seeds 3.1% (Uddin and Nanjundaswamy 1982). Crandall and Kesterson (1981) reported that juice constituted 40.5% of total wet weight, while pomace was 7.5%, seeds 1.5%, and rind 49.5%.

Pulp chemical composition has been reported as having 91.5% moisture, 0.2% protein, 0.1% fat (reported as ether extracts), and 0.25% total ash (Uddin and Nanjundaswamy 1982). Another study (Taper and others 1985) found that watermelon pulp yield was 57.2% and it was composed of 91.2% moisture, 0.69% protein, 0.48% fat, and 0.3% ash.

2.3 Sugar

Sweetness is one of the prime quality factors in watermelon fruit, which is related to total soluble solids (TSS) as measured by °Brix (Maynard 2001). The U.S. Standards for Grades of Watermelons label watermelons as having good internal quality if they have 8% TSS and very good internal quality if they have TSS of 10% or greater (Maynard 2001). TSS is a measure of the concentration of sugars in the fruit, which can vary depending on its variety and stage of maturity (Maynard 2001). Schmidt and others (2005) found watermelon to have 32.2% fructose, 9.3% glucose, and 27.1% sucrose for a total of 68.6% of sugars on a dry matter basis. Because of this high concentration of sugars, it is important to know the functionality of sugars in foods if dried watermelon is to be used as a potential food ingredient.

2.3.1 Physical Properties

Some important physical properties of sugars related to food processing are solubility and hygroscopicity (Davis 1995). Mono- and disaccharides are generally highly soluble

in water since they have a high affinity for forming hydrogen bonds with water molecules (Chinachoti 1995). Different degrees of solubility exist between sugars due to differences in their configuration and conformation with fructose being very soluble in water (0.80 g/g H_2O), and sucrose and glucose being fairly soluble (0.67 and 0.47 g/g H_2O, respectively) (Davis 1995). Generally, the solubility of sugars increases with temperature and decreases when the sugars cake together, which can happen in sugar powders or granulates (Davis 1995; Belitz and others 2004). Hygroscopicity is the ability of a sugar to absorb water from the atmosphere and is related to its solubility properties (Browne 1922; Davis 1995). This ability can result in decreased water mobility in a food product, which results in less water being available for the growth of microorganisms (Chinachoti 1995). This reduction in available water is commonly known as a reduction in water activity or a_w (Chinachoti 1995). As with solubility, hygroscopicity varies depending on the structure and purity of the sugar and the presence of isomers (Belitz and others 2004). Fructose is very hygroscopic, beginning to absorb water at ~ 55% relative humidity (RH), while sucrose absorbs water only at higher relative humidities ($\geq$ 65% RH) (Hanover 1993; Davis 1995).

2.3.2 Sensory Properties

The sensory properties of sugars involve imparting sweetness, color, flavor, and aroma to food systems. Sweetness is the most important sensory property imparted by sugars (Davis 1995). Because sucrose has a pleasant taste even at high concentrations, it is the standard by which the sweetness of other sugars is compared to and is given a value

of 1.0 (Davis 1995; Belitz and others 2004). Fructose has a relative sweetness higher than sucrose at 1.0-1.7 and glucose has lower relative sweetness at 0.7-0.8 (Davis 1995). The relative sweetness of sugars will vary with their structure, configuration, and presence of other compounds, as well as with pH and temperature (Davis 1995; Belitz and others 2004).

Sugars undergo several chemical reactions that result in the creation of several important sensory properties including color, aroma, and flavors. One of these reactions is caramelization, which occurs when sugars are heated in the presence of acids and/or alkaline catalysts and results in the formation of brown-colored compounds with a typical caramel aroma (Belitz and others 2004). Another important reaction that imparts color and flavor is the Maillard reaction, which occurs during heating between free amino acids and reducing sugars, mainly glucose, fructose, maltose, and lactose (Manley 2000). The Maillard reaction (also known as the browning reaction) actually consists of many complex reactions with different pathways and outcomes that depend on factors such as pH and temperature (Manley 2000). The reaction allows products to brown at much lower temperatures than are needed for caramelization (Manley 2000). Initially, the compounds are colorless and as the reactions continue, the color intensifies, turning yellow, brown, and black, and a caramel-like aroma develops (Davis 1995). Browning occurs more quickly at intermediate water activities, being fastest at a_w's between 0.6 and 0.7, and occurs more in alkaline conditions than in acid ones, with optimum pH being between 7.8 and 9.2 (Davis 1995; Manley 2000). The reactions are also influenced by the hydration properties of the sugars present and the heating time and temperature (Davis 1995).

2.3.3 Functional Properties

Since the main sugars found in watermelon are fructose, glucose, and sucrose, it is important to know their functionality when added to foods.

Fructose is mainly used to impart sweetness in foods since it is the sweetest of all naturally occurring carbohydrates (Hanover 1993). It can be used to either increase the sweetness of a food product without increasing the total amount of sweeteners, or to maintain a satisfactory degree of sweetness when other sweeteners are reduced (Hanover 1993). Fructose is also used to enhance other flavors since its sweetness is perceived earlier than that of sucrose and diminishes more quickly (Hanover 1993). Because of this, many flavors, such as fruit and acids, can be perceived more distinctly since they are not masked by the lingering sweetness of sucrose (Hanover 1993).

Glucose or dextrose, as it is usually called in the food industry, is mainly used in products such as jellies, gums, and marshmallows because of its flavor, sweetness, and hygroscopicity. It is mainly added to foods in the form of corn syrups, which provide viscosity and cohesiveness, as well as preventing the crystallization of other sugars, such as sucrose, in confections, jams, jellies, and preserves (Chinachoti 1995). Also, as mentioned earlier, both fructose and glucose are non-reducing sugars which allow them to take part in the Maillard reaction to impart brown color and characteristic flavor to foods.

Sucrose imparts many desirable functional properties to foods in terms of sweetness, mouth-feel, and viscosity (Chinachoti 1995). As mentioned earlier, it is the standard by which all other sugars' sweetness is compared. Because of caramelization, it

is often added to foods to produce brown color and to add characteristic flavors in meats, breads, and some desserts (Davis 1995).

2.3.4 Amorphous Sugars and Glass Transition Temperature

Mono- and disaccharides can exist in a stable crystal form or in an amorphous or non-crystalline form, usually referred to as a glassy state, which is not stable (Adhikari and others 2001; Jouppila 2006). In the crystal state, molecular movement is highly limited, which is necessary in order for the molecules to be able to align properly and be able to crystallize (Bhandari and Howes 1999). The viscosity is very high and the material is capable of supporting its own weight and maintaining its structure without collapsing (Adhikari and others 2001). However, amorphous materials have the property of transforming from the glassy state to a rubbery state at a specific temperature known as the glass transition temperature or T_g (Davis 1995; Bhandari and Howes 1999). This structural change alters the flow and textural properties of the sugars (Davis 1995; Bhandari and Howes 1999). When a glassy material approaches T_g, the viscosity of the material decreases dramatically from $10^{12\text{-}14}$ Pa.s to $10^{6\text{-}8}$ Pa.s (Adhikari and others 2001). As the product temperature goes above T_g, the amorphous material changes into the rubbery state and the decreasing viscosity causes deformation by enhancing molecular mobility (Aguilera and others 1995; Adhikari and others 2001). This has been linked to stickiness and adhesion (Adhikari and others 2001).

Water can plasticize or soften amorphous food materials resulting in a lower glass transition temperature (Adhikari and others 2001; Jouppila 2006). Water plasticization

can occur if a material absorbs water from the environment and increases its water content (Jouppila 2006). Thermal plasticization can also occur if an amorphous material is stored at temperatures above T_g (Jouppila 2006). The higher the difference between storage temperature (T) and T_g ($T-T_g$), the lower the viscosity will be, resulting in greater molecular mobility (Jouppila 2006).

Besides water, carbohydrates can also influence the T_g of an amorphous material (Bhandari and Howes 1999). Low molecular weight sugars such as fructose, glucose, and sucrose have very low glass transition temperatures (5, 31, and 67°C, respectively), and can also lower the T_g of food products, which is very notable in sugar-rich foods (Bhandari and Howes 1999; Maltini and others 2003). Because of this, low molecular weight sugars are likely responsible for stickiness and caking in these types of foods (Adhikari and others 2001). Caking is very detrimental since it can cause a flowable powder to have lumps or, in more advanced stages, to become an agglomerated solid due to stickiness which can result in a loss of functionality and quality (Aguilera and others 1995). In order to prevent this, it is recommended to control moisture content and to store at low temperatures, and/or to add an anti-caking agent to improve flowability (Aguilera and others 1995).

2.4 Dietary Fiber

Dietary fiber consists of those compounds responsible for the structure and storage in plants that are not digested by humans (ADA 2002). It acts as a buffer by binding excess acid in the stomach, increases fecal bulk and intestinal contraction, and

provides a favorable environment for the growth of desirable micro flora in the intestine (Nawirska and Kwasniewska 2005). Dietary fiber can be classified as either insoluble or soluble in water, with most fiber sources being mixtures of the two (Dreher 1999). About 75% of the dietary fiber in foods is in the form of insoluble fiber, which consists mainly of cell wall components such as cellulose, lignin, and hemicelluloses (Dreher 1999). Insoluble fiber accelerates the passage of food through the intestine, increasing fecal bulk, which is important in order to maintain bowel regularity (Anderson 1990). The most important sources of insoluble fiber are cereal brans and whole-grain cereals; other good sources are dried beans, peas, vegetables, and nuts (Dreher 1999). Soluble fibers constitute about 25% of the dietary fiber consumed and consist of non-cellulosic polysaccharides such as pectin and gums (Dreher 1999). These fibers tend to delay the movement of food from the stomach, slowing its passage through the intestine, and have little effect on fecal bulk (Anderson 1990). They can also lower blood cholesterol and have been shown to help control blood glucose levels in people with diabetes mellitus (Anderson 1990; Dreher 1999). Good sources of soluble fibers are whole-grain oats and barley, oat bran, some fruits, dried beans, and other legumes (Dreher 1999).

Increasing the amounts and varieties of fiber-rich foods can help prevent or treat many diseases including obesity, cardiovascular disease, type 2 diabetes, colonic diverticulosis, and constipation (ADA 2002). Dietary fiber intake also plays a role in the absorption of nutrients and in the metabolism of carbohydrates, fat, and sterol (Tungland and Meyer 2002). It also may protect against colon cancer, which ranks among the top 3 forms of cancer in the US for both men and women (ADA 2002; Tungland and Meyer 2002).

The suggested intake for total fiber is set at 38 g/day for men and 25 g/day for women based on what has been observed as the adequate levels to protect against coronary heart disease (NAS and others 2005). However, median intakes for fiber range between 16.5 to 17.9 g/day for men and 12.1 to 13.8 g/day for women in the United States (NAS and others 2005). The American Dietetic Association (ADA) has stated that the public should consume the suggested amounts of dietary fiber, but many popular American foods contain little dietary fiber and those that do, like legumes and high-fiber bread and cereal, are not commonly consumed (ADA 2002).

In addition to the potential health benefits, fiber can be used in many food formulations to provide bulk and desirable texture, as well as to absorb and hold the natural juices of the food (Andres 1981). The functionality provided to the food will depend on the type of fiber added. Insoluble fibers are most often added to control calories, add bulk, or for added health benefits (Dreher 1999). The most common ones used include cereal brans, oilseed hulls, and purified cellulose (Dreher 1999). Soluble fibers are most commonly added as gums, which have the basic properties of thickening or adding viscosity and gelling foods (Dreher 1999). They are also used to suspend particles, emulsify fat, inhibit ice crystallization, inhibit syneresis, form films, and mimic the properties of fat (Dreher 1999). Other fiber sources, such as oat bran, legumes, and fruit fibers, are also mixture of both soluble and insoluble fibers, and their functionality will depend on the type and level of soluble and insoluble fibers present (Dreher 1999).

Fruit fibers produced from fruit waste are being studied as an alternative source of functional fiber (Palmer 2009). It is estimated that 25 to 40% of the total fruits processed around the world turn up as fruit waste, which has historically been turned into compost

or used as animal feed (Palmer 2009). Many different fruit wastes have been studied and have been found to be very rich sources of total dietary fiber (TDF), soluble dietary fiber (SDF), and insoluble dietary fiber (IDF). Values are shown on Table 2.1.

Table 2.1 Dietary Fiber Composition for Various Fruit Wastes

Fruit	**TDF (%)**	**SDF (%)**	**IDF (%)**	**Source**
Mango	72-74	34	38-40	Gourgue and others (1992)
Pear	43.9	7.6	36.3	Martin-Cabrejas and others (1995)
Kiwi	25.8	7.1	18.7	Martin-Cabrejas and others (1995)
Grape	62.36	4.26	58.1	Valiente and others (1995)
Pineapple Shell	70.6	0.51	70.1	Larrauri and others (1997)
Apple	51.1	14.6	36.5	Sudha and others (2007)

All data reported on a dry matter basis

Apple pomace has been studied extensively as a source of dietary fiber in baked products. Wang and Thomas (1989) added drum-dried apple pomace to moon cookies by replacing 40% (w/w) of all-purpose flour in the crust and 40% (w/w) of quick-cooking oats in the filling, which resulted in cookies that had 1.7 g more TDF, 2.3 g less carbohydrates, and 10 calories less than the control cookies.

Another study performed by Sudha and others (2007) found that, when adding apple pomace to cakes using 25% pomace/75% flour, cakes had a TDF content of 14.2% compared with only 0.47% for control cakes and an SDF content of 5.8% compared with only 0.16% for control cakes (Sudha and others 2007). These studies show that fruit wastes, specifically fruit pomaces, are a rich source of dietary fiber and can be added to

foods, especially to baked goods which are highly consumed products, to increase their TDF content, thereby increasing their nutritional content and the potential health benefits that can be provided by them.

Although no studies have been performed to test the TDF content of watermelon pomace, many studies have researched the TDF, SDF, and IDF content of fresh watermelon pulp. The results have ranged from 0.4 to 1.4% TDF (Marlett 1992; Chang and others 1998; Li and others 2002; Ramulu and Rao 2003), 0.1 to 0.3% SDF, and 0.27 to 0.3% IDF (Marlett 1992; Li and others 2002; Ramulu and Rao 2003).

2.5 Lycopene

Lycopene is a natural pigment that can only be synthesized by plants and microorganisms (Shi and Maguer 2000). It is a powerful antioxidant which studies have suggested can reduce the risk of chronic diseases such as cancer and cardiovascular disease (Omoni and Aluko 2005). Also, it is responsible for giving the rich, red color to ripe tomatoes, red watermelons, and red grapefruits. Humans are unable to synthesize lycopene, so they have to rely on dietary sources to obtain it (Omoni and Aluko 2005). At least 85% of dietary lycopene comes from tomato fruit and tomato-based products, mostly juice, ketchup, soup, and pizza and spaghetti sauces (Bramley 2000). Because of this, most studies on lycopene have been performed with tomatoes. However, watermelons have been found to contain about 58% more lycopene per unit fresh weight than tomatoes (USDA and ARS 2010). Therefore, watermelons could represent an excellent dietary source for this nutrient.

Lycopene is a carotenoid with a linear structure having 13 double bonds, 11 of which are conjugated (Shi and Maguer 2000). This extended structure gives lycopene its color and antioxidant properties (Shi and Maguer 2000). Lycopene is also very sensitive to light, oxygen, high temperature, and acids, and its oxidation can be catalyzed by metallic ions such as Cu^{2+} and Fe^{3+} (Shi and Maguer 2000).

Carotenoids are accumulated in the chromoplasts of fruits, mainly in the mesocarp or pulp, with lycopene being the major carotenoid accumulated in watermelon (Tadmor and others 2005). During ripening, lycopene content increases 3 to 26% depending on cultivar, and represents 84-97% of total carotenoids present (Perkins-Veazie and others 2003; Perkins-Veazie and others 2006a). Its content is higher in red-fleshed watermelons than in yellow and orange-fleshed ones, which were found to have less than 5 mg/kg, compared to 33 to 100 mg/kg for red-fleshed ones (Perkins-Veazie and others 2003; Perkins-Veazie and others 2006a). In general, open-pollinated cultivars, which are often light red in color, have less lycopene than hybrid-seeded types, while seedless watermelons can contain amounts higher than hybrid-seeded ones (Perkins-Veazie and others 2003). Lycopene formation in watermelon can be affected by harvest maturity, vine health, soil fertility, irrigation, light intensity, and day/night temperatures (Perkins-Veazie and others 2001a).

As mentioned before, watermelon contains more lycopene than fresh tomatoes, and it has also been found to contain more lycopene than tomato paste, ketchup, and tomato soup (Djuric and Powell 2001). Also, the antioxidant capacity of watermelon was found to be significantly higher than that of tomato sauce and ketchup (Djuric and Powell 2001). Both organic and aqueous fractions of watermelons, tomatoes, and tomato

products such as juice, canned tomatoes, sauce, and soup, were analyzed for lycopene content and antioxidant activity (Djuric and Powell 2001). Since lycopene is fat-soluble, its levels were found to be relatively higher in the organic fractions of most of the foods, including watermelons (Djuric and Powell 2001). However, antioxidant activity of the foods was found to be higher in the aqueous fraction, indicating the presence of other unknown antioxidants (Djuric and Powell 2001). Only two foods, watermelons and tomato sauce, showed higher antioxidant activity in the organic fraction, indicating that the antioxidant capacity of these two foods could be mainly due to the lycopene present (Djuric and Powell 2001).

2.6 Fruit Dehydration

Drying is a process in which water is removed from a product in order to extend shelf life by stopping or slowing down the growth of spoilage microorganisms as well as the occurrence of chemical reactions (Barbosa-Cánovas and Vega-Mercado 1996). It is the most commonly used process for the preservation of food yet also the most energy-consuming (Ratti 2001). Besides preservation, drying is also used to reduce the product's weight and/or volume in order to reduce cost or difficulty in handling during packaging, storage, and transport (Barbosa-Cánovas and Vega-Mercado 1996).

The drying method used, as well as the physical and chemical changes that occur during drying, can affect important quality properties of the dried product such as color, texture, density, porosity, and sorption characteristics (Mujumdar 2000). This is important since sometimes the dried product can end up being completely different from

the original product depending on the drying method used and the conditions applied (Mujumdar 2000). It is therefore important to know the different types of drying methods available, as well as some of their advantages and disadvantages.

Heat drying can be either indirect or direct. In indirect drying, the heat is conducted from the walls of the dryer into the food and also within the food by the direct contact of hot food particles with cold ones (Barbosa-Cánovas and Vega-Mercado 1996). Examples of this type of drying are vacuum dryers and drum dryers.

Vacuum dryers operate at lower absolute pressures than atmospheric pressure (about 50 mm Hg), which lowers the boiling temperature of water (Yang and Atallah 1985; Barbosa-Cánovas and Vega-Mercado 1996). Because of this they use lower maximum temperatures than direct dryers, but also have lower maximum drying yields (Barbosa-Cánovas and Vega-Mercado 1996). Depending on the pressure used, vacuum dryers cause less damage to the color and aroma of dried products than other dryers, but can also cause them to have higher tissue porosity (Krokida and others 2001).

Drum dryers consist of a hollow metal cylinder or drum that rotates horizontally on an axis (Barbosa-Cánovas and Vega-Mercado 1996). They can be composed of one (single drum dryer) or two drums (double drum or twin drum dryer) and are heated by steam or hot water that travels internally through the drum (Barbosa-Cánovas and Vega-Mercado 1996). When using a drum dryer, it is important that the film applied to the surface of the drum be uniform, since this can affect the drying rate (Barbosa-Cánovas and Vega-Mercado 1996). Other factors that will affect the drying rate are the rotational speed of the drum and the heating temperature used (Barbosa-Cánovas and Vega-Mercado 1996). Compared to other dryers, drum dryers have high drying rates and are

more economical, but only food products that are liquid or in a slurry form can be used and they also have to be able to withstand high temperatures for a short period of time (Barbosa-Cánovas and Vega-Mercado 1996). Examples of drum-dried products are milk, soup mixes, ingredients for baby foods, potato slurries, and instant cereals (Barbosa-Cánovas and Vega-Mercado 1996).

In direct drying, a hot gas, usually air, passes over or through the food, providing more uniform heating than indirect dryers (Barbosa-Cánovas and Vega-Mercado 1996). Because of this, direct air drying is one of the most frequently used methods for food dehydration (Krokida and others 2001). Air dryers are composed of a chamber where the food is placed and a blower that pushes hot air through ducts to allow it to circulate around and across the food (Barbosa-Cánovas and Vega-Mercado 1996). The air is heated when it enters the dryer with the use of heat exchangers or by mixing it with exhaust gases (Barbosa-Cánovas and Vega-Mercado 1996). The hot air removes the water from the product surface and carries it out from the dryer in a single operation (Barbosa-Cánovas and Vega-Mercado 1996). Hot-air drying is relatively cheap, but the drying time is usually long, which results in inferior product quality when compared to other drying methods (Hsu and others 2003). This type of dryer is used widely in the manufacture of cookies and in the drying of fruits and vegetables (Barbosa-Cánovas and Vega-Mercado 1996).

One type of hot-air dryer that is commonly used is a cabinet dryer. In this type of dryer, the product is placed in trays which are moved into a drying compartment (Barbosa-Cánovas and Vega-Mercado 1996). The air is heated at the entrance of the dryer by a heater and is then forced through the stack of trays and over the product

(Barbosa-Cánovas and Vega-Mercado 1996). The main problem with this type of dryer is obtaining uniform drying of the product throughout all the positions in the drying trays (Heldman and Singh 1981). Typical temperature conditions used for fruits and vegetables range from 50 to 90°C (Krokida and others 1998; Krokida and others 2001; Masoodi and Chauhan 1998; Masoodi and others 2002; Hsu and others 2003; Pongjanta and others 2006; Que and others 2008; Tran and others 2008).

2.6.1 Effect of Drying on Color

Color is an important quality attribute of foods, especially when it comes to their acceptability, and therefore, it is important to study how processing may affect it. Color usually changes during drying due to various chemical and biochemical reactions including enzymatic and non-enzymatic browning, caramelization, and ascorbic acid browning (Perera and Baldwin 2001; Perera 2005).

Because color is such an important attribute, many studies have been performed on the color changes during drying, especially when trying to choose an optimum drying method. Each color parameter can be affected differently depending on the drying method used and the fruit or vegetable being studied. Yang and Atallah (1985) compared the color of blueberries dried by different methods and reported an increase in the L value for all drying methods, which indicates a fading of the original color. They also found no significant difference between the a values of the control and the vacuum-dried berries, while they observed a significant decrease in the a values in both forced-air and micro-convection dried berries, which may have been due to anthocyanin oxidation as well as

heat degradation during dehydration (Yang and Atallah 1985). This was further confirmed by the significant decrease in b values, which indicates a shift of color from yellow towards blue (Yang and Atallah 1985).

Krokida and others (2001) found that L values decreased significantly during air and vacuum drying for potatoes, bananas, and carrots, which could be indicative of browning during drying. They also found that both a and b values increased after drying (Krokida and others 2001). The increase in the a value denotes a more red chroma, which is indicative of browning, while the increase in b indicates more yellowness (Krokida and others 2001). Of the produce tested, they found that the increase in a value was not applicable to carrots, which showed a constant redness during conventional drying (Krokida and others 2001). They also found that vacuum-drying caused a smaller increment of redness and yellowness than air drying (Krokida and others 2001).

All of these results show how vacuum-drying seems to preserve color better than air-drying, and how results will vary depending on the material being dried. Interpretation of the results is also dependent on the type of material and consumer preference. In some cases, more lightness may be preferred as was shown by Hsu and others (2003) when testing yam flours prepared from different varieties of yam. They found that, for three varieties of yams tested, drum drying resulted in higher L values, or higher discoloration, than hot-air drying (Hsu and others 2003). For white yams, more lightness means better consumer acceptability in Taiwan (Hsu and others 2003).

Color parameters can also be affected by drying conditions such as temperature. This was evaluated by Krokida and others (1998) during conventional and vacuum drying of apples, bananas, carrots, and potatoes at 50, 70, and 90°C. They observed that the

lightness of dehydrated materials was not affected by temperature for all the examined materials and drying methods, while redness and yellowness were both strongly affected (Krokida and others 1998). Redness increased during drying for all the examined materials and all conditions, and it increased as temperature increased (Krokida and others 1998). An exception was carrots, for which redness decreased when dried at 90°C by the conventional method (Krokida and others 1998). Yellowness also increased during drying for all materials and conditions, but it increased as temperature decreased for all yellow materials (apple, potato, banana), while carrots exhibited increased yellowness at high temperatures during conventional drying (Krokida and others 1998). They found that the redness and yellowness of air dried materials increased more than for the vacuum-dried ones at the same temperature (Krokida and others 1998). From this study, one can see how important it is to choose the appropriate drying temperature and also how results can vary with the material being used.

2.6.2 Effect of Drying on Lycopene Content

Shi and others (1999) observed that the lycopene content decreased for tomatoes during both vacuum and conventional drying. Vacuum-dried tomatoes retained more of their lycopene and showed more redness than conventionally dried tomatoes (Shi and others 1999). This higher loss during conventional air-drying was attributed to the influence of heat and oxygen, since heat treatment can disintegrate tomato tissue and increase its exposure to oxygen and light, resulting in the destruction of lycopene (Shi

and others 1999). In another study, Sharma and Maguer (1996) found no significant difference between freeze-dried and oven-dried tomato pulp solids.

Drying temperature can also affect lycopene content. Zanoni and others (1999) dried tomato halves in a pilot-plant cabinet air dryer at 80 and 110°C. During drying at 80°C no significant lycopene loss occurred, whereas a significant, though small, loss (max 12%) occurred at 110°C (Zanoni and others 1999). Sharma and Maguer (1996) found no significant difference in lycopene content of tomato pulp solids dried in an oven dryer at 25, 50, and 75°C. These studies show how important it is to choose an appropriate temperature when drying and how mild temperatures lower lycopene losses during drying.

2.7 Dough Rheology

Since watermelon pomace will be incorporated into flour for the production of baked products, it will be important to see how this affects the rheological properties of the dough produced. Rheology is the science that studies the flow and deformation of matter (Faridi and Faubion 1990). Studies on the rheology of dough are carried out during the wheat quality screening process in order to predict the quality of the end product (Suchy and others 2000). Wheat flour has two major components that give it its unique rheological properties. These components are protein, which constitute 10-15% (dry basis), and starch, which constitutes 72-80% (Hui 2006).

Some of the proteins in wheat have the unique property of forming a viscoelastic dough when flour is mixed with water (Hui 2006). These proteins, called gliadin and

glutenin, form the water-insoluble fraction of the proteins and together they form a viscoelastic mass denoted as gluten (Hui 2006). Gliadin is somewhat sticky and contributes to the viscous properties of the gluten complex, while glutenin contributes to its elastic properties (Hui 2006). In order to create a dough, flour and water must be combined at a specific ratio, since using too much or too less water results in either a slurry or a powder that lack any of the common properties of wheat dough (Faridi and Faubion 1990). The mass should also be mixed properly in order to obtain a cohesive, viscoelastic dough (Faridi and Faubion 1990).

Starch contributes to viscosity due to the unique behavior of its components, amylose and amylopectin, in the presence of water (Faridi and Faubion 1990). During the absorption of water, the starch granules swell with an increase in diameter of 30-40% and the hydrogen bonds holding the polymers together begin to weaken (Belitz and others 2004; Cauvain and Young 2006). Since the absorption of water is low at these conditions (~30%), there is no discernible rheological effect (Faridi and Faubion 1990). When heat is added, the starch-water system will undergo a series of dramatic changes referred to as gelatinization (Faridi and Faubion 1990). At this point, the starch granules will absorb 20-40 g of water/g starch and the viscosity of the suspension will rise steeply (Belitz and others 2004). The course of gelatinization depends not only on the botanical origin of the starch and the temperature used, but also on the water content of the suspension (Belitz and others 2004).

2.7.1 Studies with Farinograph

Addition of sugar and/or fiber can affect the characteristics of dough. Sai-Manohar and Haridas Rao (1997) prepared different cookie doughs with increasing levels of sugar. They mixed the dough for 1 min and determined consistency, elasticity, and mixing tolerance index (Sai-Manohar and Haridas-Rao 1997). They found that as sugar level increased, consistency, elasticity, and mixing tolerance index decreased (Sai-Manohar and Haridas-Rao 1997).

Addition of apple pomace, which is high in fiber (51-62%), can be used to understand how addition of this component affects dough rheology (Chen and others 1988a; Sudha and others 2007). Two studies, performed by Masoodi (2001) and Sudha (2007), showed similar results. Masoodi and others (2001) replaced apple pomace at levels of 2, 5, 8, 11%, while Sudha and others (2007) used levels of 0, 5, 10, and 15%. Both studies reported an increase in farinographic water absorption, dough development time, and mixing tolerance of the dough with an increase in the percentage of pomace present (Masoodi and others 2001; Sudha and others 2007). Sudha and others reported that the increase in dough development time could have been due to an increase in the fiber content of the blends which slowed the rate of hydration and development of gluten, and that the increase in mixing tolerance index could have been due to the dilution of gluten protein with the fiber content (Sudha and others 2007). Also, the gluten and fiber could have interacted, strengthening the gluten fibrils by binding to the gluten and causing an increase in tolerance (Chen and others 1988b). Masoodi and others (2001) found that the arrival time of blends containing up to 5% pomace was less than that of

control, while it was more than the control at higher levels of pomace. They also found that dough stability increased with the increase in pomace level up to 8% and thereafter decreased, while Sudha and others found that it decreased with an increase in pomace level (Masoodi and others 2001; Sudha and others 2007).

2.8 Cookies

2.8.1 Effect of Ingredients on Baking Quality

Cookies consist mostly of flour, sugar, and fat which greatly affect their texture properties. Flour is the main ingredient, which contributes to the texture, hardness, and shape of the baked product (Manley 2000). However, gluten is not fully developed due to the low water content present and the competition of water between gluten proteins and sugar ingredients (Kulp 1994). This low water content also causes less gelatinization of the starch during baking (Manley 2000). Because of this, most cookies can be made from flour with a low protein content of less than 9%; higher levels can create problems during processing (Manley 2000).

Because of the interactions of sugar with water and flour components, it greatly affects the texture and appearance of the final product. Sugar in cookie doughs dissolves during baking and then re-crystallizes when cooled, forming an amorphous glass making the cookie harder (Manley 2000). If the sugar changes from the glassy state into the rubbery state, the cookie will lose its crispness and it will become soggy or chewy (Davis 1995). The crispness of cookies will also depend on the amount of sugar used and on its

solubility properties (Kulp 1994). The higher the level of sucrose used, the harder the cookies will be (Sai-Manohar and Haridas-Rao 1997; Manley 2000). On the other hand, if sugars that do not crystallize well are used, such as fructose, the cookies will be soft (Kulp 1994).

Sugars can also affect the size and appearance of the cookies. In general, the higher the sugar level, the higher the cookie diameter or spread and the lower the thickness or height (Sai-Manohar and Haridas-Rao 1997; Manley 2000; Pareyt and others 2009). During baking, as the sugar dissolves, a large expansion is observed, followed by a great collapse as the cookie cools and sets (Manley 2000). Pareyt and others (2009) found that this collapse was due to sugar's restriction of the gluten to cross-link, which is necessary in order for the dough to resist collapse. This spread of the dough and collapse are also responsible for the cracked surface of cookies (Manley 2000).

2.8.2 Studies with Sugars and Fiber

Several studies have been performed to evaluate cookie quality after addition of different sugars (mainly fructose and glucose) or different fiber sources.

Kweon and others (2009) investigated the effect of sugar type on the production of wire-cut cookies by replacing sucrose with fructose and glucose. Water retention was higher with glucose, followed by fructose and sucrose, indicating that glucose allowed for greater development of gluten than the other two sugars (Kweon and others 2009). Dough firmness was highest for glucose, while dough with fructose was not significantly different from sucrose (Kweon and others 2009). Width and length was highest for

sucrose, followed by fructose, then glucose, while height was lowest for sucrose, followed by fructose, then glucose (Kweon and others 2009). It was also observed that doughs made with fructose were very soft and sticky (Kweon and others 2009). Percent weight loss was lower for fructose and glucose than for sucrose, with glucose being lower than fructose (Kweon and others 2009).

Another study conducted by Pasha and others (2002) found that cookies with 50% sucrose/50% fructose and 25% sucrose/75% fructose scored higher on sensory tests for overall quality than cookies with 100% sucrose or fructose. They also found that the cookies with 50% sucrose/50% fructose got the highest width and the lowest thickness, while 100% fructose showed the highest thickness and lowest width (Pasha and others 2002).

In terms of addition of fiber, Vratanina and Zabik (1978) added wheat bran to cookies at levels of 10, 20, and 30%. They found that increasing fiber levels lowered the spread factor in cookies, which was calculated by dividing width over height (Vratanina and Zabik 1978). They also found that as the percentage of fiber substituted increased, the lightness and yellowness values decreased (Vratanina and Zabik 1978). In terms of texture, they found that the force required to break and shear the cookies decreased with increasing amounts of bran indicating a less crisp, tenderer cookie as the level of fiber substituted increased (Vratanina and Zabik 1978). They also noted that as the levels of bran were increased, an increase in the amount of water required to produce a dough for optimal handling was needed due to the high water absorption capacity of fiber (Vratanina and Zabik 1978).

2.8.3 Studies with Fruit Powders

Several studies have been performed on the addition of fruit powders to baked products. These powders are mainly used as a nutritional supplement to add dietary fiber, as well as protein, vitamins, and minerals.

Chen and others (1988a) evaluated the effect of apple fiber (added at 4, 8, 12, and 16%) on the baking quality of crisp cookies using wheat and oat brans for comparison. They found that the water holding capacity of apple fiber was 9.35 g water/g solid, while wheat and oat brans had 5.03 and 2.10 g water/g solid, respectively (Chen and others 1988a). As the concentration of apple fiber increased, the diameter of the cookies decreased and their thickness increased (Chen and others 1988a). They observed that cookie dough was drier in appearance than the dough containing wheat and oat brans due to the strong water-binding properties of the apple fiber; this caused the dough to not spread well and the cookies to be small and thick (Chen and others 1988a). Compared with apple fiber, cookies with added wheat and oat brans had better qualities (Chen and others 1988a). For instance, addition of 12% wheat and oat bran caused only 7 and 1% reduction in cookie diameter, respectively, while adding 12% apple pomace caused a reduction of 23% (Chen and others 1988a). It was concluded that apple fiber could be added into cookies at a replacement level of 4% or less without having large adverse effects on the quality of the cookies and could be used as an alternative dietary fiber source (Chen and others 1988a).

A similar study was conducted by Wang and Thomas (1989) in which they produced oriental moon cookies by substituting flour in the crust with 40% (w/w) apple

pomace and quick-cooking oats with 40% (w/w) apple pomace (Wang and Thomas 1989). They used drum-dried apple pomace, which was found to have a sugar profile of 21.85% fructose, 10.55% glucose, and 4.39% sucrose, for a total sugar content of 36.71%; subsequently, the amount of sugar in the crust and in the filling was reduced for this percentage to adjust for the addition of pomace (Wang and Thomas 1989). Total dietary fiber was 33.24% (Wang and Thomas 1989). During sensory testing, the experimental moon cookies were judged to be slightly more moist than the control cookies and also good in sweetness and consistency (Wang and Thomas 1989). The color and appearance of the experimental moon cookies were judged better defined and more appealing than the control moon cookies, which could be have been due to the dried apple pomace keeping the uniformity of the shape and the crust color of the cookies (Wang and Thomas 1989). The overall preference scores showed that the cookies made by incorporating apple pomace were significantly more desirable than the control (Wang and Thomas 1989). Since their main objective was to produce a high fiber product with good quality, they were able to show that apple pomace can be used in the production of high fiber bakery products with better taste, texture and appeal than products made from more conventional fiber sources (Wang and Thomas 1989).

Another important source that has been studied for addition to bakery products is dried pumpkin. Giami and others (2005) looked at fluted pumpkin seed flour (FPF) as a protein supplement for cookies prepared by blending wheat with 0, 5, 10, 15, 20, and 25% FPF. They found that adding FPF to cookies increased the levels of the minerals Ca, Na, K, and P and their protein content (Giami and others 2005). In terms of baking quality, there were no significant differences between the values obtained for spread ratio

(diameter/height) and hardness of 5-15% cookies supplemented with FPF and the control, while blends containing more than 15% pumpkin flour produced softer cookies (Giami and others 2005). Cookies made with 20 and 25% FPF had significantly higher weight and less diameter than the others, while the ones made with 10-25% FPF had lower height than the control (Giami and others 2005). In terms of sensory testing, cookies produced with up to 15% FPF were found to be acceptable and to closely resemble the control, while cookies produced from blends containing more than 15% pumpkin flour had lower overall acceptability, which was attributed by the panelists to a crumbly texture, a beany flavor, and dark color (Giami and others 2005).

Another study using pumpkin was performed by Pongjanta and others (2006), who produced butter and chiffon cakes and cookies by adding pumpkin powder at levels of 10, 20, 30, 40, and 50%. They found that the β-Carotene levels in pumpkin powder were significantly higher than in fresh pumpkin and that pumpkin powder substitution significantly increased the β-carotene content in the samples by 2.5-9.0 times in the cookies (Pongjanta and others 2006). They found that the use of pumpkin powder also increased the level of vitamin A in the products, contributing 3.13 of the recommended daily intake (Pongjanta and others 2006). Sensory panel results showed that the cookies prepared with 10% powder were not significantly different from the control in terms of total acceptance scores (Pongjanta and others 2006). The researchers also conducted a consumer test to determine their acceptance of the products and if they would be willing to buy them. The cookies and the chiffon cake obtained the highest mean scores for total acceptability and the majority of the respondents (90-100%) said they would be willing to buy the products (Pongjanta and others 2006).

A recent study was performed using fruit powders made from dried cashew apple and guava fruit as ingredients in sugar-snap cookies (Athayde-Uchoa and others 2009). The fruit powders were found to have total sugars percentages of 30.6% for cashew apple and 8.69% for guava fruit (Athayde-Uchoa and others 2009). The fruit powders were used by replacing flour with levels of 5, 10, 15, and 20% (Athayde-Uchoa and others 2009). The percentage of total dietary fiber was 3.26% for cashew apple and 24.29% for guava fruit (Athayde-Uchoa and others 2009). They found that the dough containing the highest fruit powder levels showed the highest moisture content due to the high water absorption capacity of the fibers (Athayde-Uchoa and others 2009). Total dietary fiber values of both types of cookies ranged from 3.53 to 8.54 g/100g, which would mean that the consumption of 100 g/day of these cookies would represent around 20% of the recommended daily requirement for dietary fiber, which is 25 g/day (Athayde-Uchoa and others 2009). For the sensory test, they found that the cookies with 20% guava fruit powder had the highest hedonic rating for all sensorial attributes (Athayde-Uchoa and others 2009).

All of these studies show that adding fruit powders to cookies can produce high quality products with increased nutritional value and without greatly affecting their physical and sensory attributes.

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CHAPTER III

WATERMELON POMACE COMPOSITION AND THE EFFECT OF DRYING ON LYCOPENE CONTENT AND COLOR

3.1 Abstract

Watermelon fruit is the most consumed melon crop in the U.S., yet many melons are left in the field due to consumer preference for seedless watermelons and lack of value added products available. Watermelon is also an important source of the antioxidant lycopene. Pomace, which is the solid left after juice processing, could be used as a potential food ingredient. The objectives of this study were to evaluate the physicochemical properties of watermelon pomace and to compare the effect of different drying methods on its composition. Watermelons were juiced and the remaining pomace was dried using a cabinet dryer, a vacuum oven, and a drum dryer. Fresh pomace was found to have a lycopene content of 0.201 mg/g, about 4.5 times higher than what has been reported for fresh watermelon, making it a concentrated source of lycopene. Lycopene loss occurred for all drying methods with drum drying causing a significant loss. In terms of color, drying resulted in an increase in L* and b* values and a decrease in a* values. Vacuum/cabinet drying was the best method in terms of preserving the color and lycopene content of watermelon pomace. However, the vacuum dryer wasn't the most efficient or cost-effective, making the cabinet dryer the second-best option. Drying for extended periods with this method caused a significant loss in sugars and a significant browning of the samples. Also, the sample became stickier and more difficult to handle. Lycopene in dried samples was stable after one year of storage for vacuum packed samples.

Keywords: *Watermelon, lycopene, drying, pomace*.

3.2 Introduction

Watermelon fruit is the most important melon crop and the third most produced vegetable crop in the United States (USDA and NASS 2010). In 2009, 4.0 billion pounds of watermelons were produced for a total value of $461 million, and consumption was 15.3 pounds per person, contributing to 57% of total melon consumption (ERS and USDA 2010b; USDA and NASS 2010). In spite of this, about 30% of watermelons are left in the field each year in Oklahoma due to the fact that most are consumed fresh, leading to the rejection of watermelons that have any visible defect (Williams 2007). A survey performed for the Watermelon Promotion Board found that 60% of consumers prefer seedless watermelons, which presents a problem in that for producing seedless fruits, farmers have to plant seeded pollinators which are then left wasted in the fields (Rose Research 2006; Williams 2007). Therefore, more value added products from watermelon are necessary to utilize these rejected watermelon crops.

Pomace is the solid material that remains after removing the juice from the pulp and consists of insoluble carbohydrates, protein, and minerals, while also containing some remaining juice with other soluble components like sugar (Carson and others 1994a). A study performed by Perkins-Veazie and others (2006b) found that pomace was a concentrated source of lycopene, containing 110% of that found in the juice. To our knowledge, no studies exist on watermelon pomace composition or its potential use as a food ingredient.

Lycopene is a natural pigment responsible for giving the rich, red color to ripe tomatoes, red watermelons, and red grapefruits. It is a powerful antioxidant which

studies have suggested could reduce the risk of chronic diseases such as cancer and cardiovascular disease (Omoni and Aluko 2005). Even though tomatoes are the most important dietary source for lycopene, watermelons have been found to contain about 58% more lycopene per unit fresh weight (USDA and ARS 2010). Watermelon pomace could be used as a source of this nutrient when added to different food products

Drying is a process that has been used for centuries to preserve foods. Fruits like watermelon, which have a short shelf life and are sold for only a short season during the summer, can benefit from this process to make it more available throughout the year and to make it more versatile for use in different products. Only a few studies have dealt with drying of watermelon, mainly with osmotic dehydration of the pulp (Falade and others 2007) and spray-drying of the juice (Quek and others 2007), but to our knowledge none have dealt with the pomace. Because the drying method and the conditions used will impact how different properties of the product are affected, it is important to evaluate the quality of the product after drying. In the case of watermelon, which is rich in lycopene, this is especially important since lycopene is very sensitive to light, heat, and oxygen and therefore, the drying method used will affect how much lycopene will be lost.

Color is an important quality attribute of foods, especially when it comes to their acceptability, and it is important to study how processing may affect it. Color usually changes during drying due to a number of chemical and biochemical reactions including enzymatic and non-enzymatic browning, caramelization, and ascorbic acid browning (Perera and Baldwin 2001; Perera 2005).

The objectives of this study were to evaluate the composition of watermelon pomace and to compare the effect of different drying methods on lycopene content and color.

3.3 Materials and Methods

3.3.1 Generation of Pomace

Seedless red-fleshed watermelons were processed on two separate occasions: one in September 2009 and another in June 2010. Eighteen watermelons were processed in 2009 and 37 in 2010. On both occasions, watermelons were bought from a local fruit and vegetable wholesaler at a mature stage and were brought to the laboratory for analysis. Watermelons were weighed and their exterior was cleaned with a moist paper towel and sanitized by spraying with an SO_2 solution before being cut to big pieces and peeled to obtain the pulp. Peel, pulp, juice, and pomace obtained were weighed to determine the percentage yield of each component, which was calculated by dividing component weight by the total weight of the fruit processed and then multiplied by 100. Then, the pulp was placed in a vertical bladder press (model BP-40, Zambelli Enotech, Italy) to extract the juice and obtain pomace. This pomace was ground using a bowl chopper (model 8185, Hobart, Troy, Ohio) and then placed in the press again to extract excess juice. This process was different for watermelons processed in 2010 which were chopped first and then pressed only one time. This was done in order to see if more juice could be removed from the pulp.

After pressing, the pomace was weighed and divided into nylon/polyethylene vacuum pouches, covered with aluminum foil, and vacuum packed using a pressure of -30 in Hg with a contact time of 6 seconds (Ultravac Solutions, Kansas City, Missouri) . The pomace obtained in 2009 was stored at -20°C, while the pomace obtained in 2010 was stored at -13°C. The extracted juice was analyzed for total soluble solids using a refractometer (Reichert Analytical Instruments, Depew, New York). This test was performed in quadruplicate in 2009 and in quintuplicate in 2010.

3.3.2 Moisture Content and pH evaluation

A non-frozen sample of pomace was used to determine moisture content and pH. Moisture content was determined using Method 950.46 from the AOAC Official Methods (2006), by drying 2.0 g of sample in an Isotemp Oven (Fisher Scientific, Pittsburgh, Pennsylvania) for 16-18 hours at 102°C. The pH was determined by using an Accumet Research AR15 pH meter (Fisher Scientific). All tests were performed in triplicate.

3.3.3 Lycopene Analysis

Lycopene content was analyzed using the method by Sadler and others (1990) as modified by Perkins-Veazie and others (2001b), with some additional modifications. Two grams of fresh pomace was added to beakers covered with aluminum foil to which 25:25:25 mL of ethanol, acetone, and hexane were added, as well as 0.05 g of butylated hydroxy toluene (BHT). Samples were homogenized with the beakers placed on top of

ice using a PowerGen 700 homogenizer (Fisher Scientific) set at medium speed (setting 3) for 4 sets of 20 seconds each, pausing for 10 seconds in between sets. After this, an additional 25 mL of hexane was placed on a beaker, homogenized for 5 seconds to remove any sample from the probe, and then added to the beakers containing the samples, pouring it on the probe first in order to rinse it. Samples were shaken for 10 minutes at room temperature in a Standard Analog shaker (VWR International, West Chester, Pennsylvania) at a low speed (setting 3), after which 15 mL of deionized (DI) water was added, and the samples were shaken for an additional 5 minutes. After this, the samples were left to rest for 15 min and then 1 mL of the top layer was placed in glass cuvettes and analyzed in a DU 520 General Purpose UV/Vis Spectrophotometer (Beckman Coulter, Brea, California) using a wavelength of 503 nm and hexane as blank. The concentration of lycopene in the samples was calculated using the following equation:

$$C = \left[(A/17200) * (50mL/1000mL) * 536.85g/m * 1000mg/g\right]/S \qquad \textit{Equation 3.1}$$

Where C is the concentration of lycopene in mg/g sample, A is the absorbance reading, and S is the amount of sample used (g). This formula uses the lycopene coefficient of extinction of 17,200 mol/cm, 50 mL of extraction volume (hexane), and the molecular weight of lycopene, which is 536.85 g/mol (Fish and others 2002).

Lycopene content for dried samples was performed in the same way except that 0.25 g was used and it was dissolved in 5 mL of water, shaking for 30 minutes before adding solvents, and then homogenizing for 6 sets of 20 seconds.

Lycopene stability during storage was also assessed. For this, dried samples were vacuum-packed, wrapped in aluminum foil, and stored at -20°C. They were analyzed for lycopene content after 5 months of storage and then again after 1 year, using the same method mentioned earlier for dried samples. All tests were performed in triplicate.

3.3.4 Color Analysis

Color was tested using a Spectrophotometer CM-3500d (Konica Minolta, Ramsey, New Jersey) by placing enough wet or dried pomace to cover the bottom of a Petri dish using a 30 mm aperture. Three different readings of different areas for each CIE L*, a*, and b* values were obtained by rotating the dish. All tests were performed in triplicate.

3.3.5 Drying

Prior to drying, frozen pomace was thawed in a refrigerator overnight and then analyzed for moisture content, lycopene content, and color as stated above.

Watermelons processed in September were used for comparing between different drying methods. To accomplish this, approximately 15.0 g of sample was weighed in aluminum cups for drying in the cabinet and vacuum dryers, and about 1 lb of sample was used for drum-drying. Cups were weighed beforehand to determine drying yield. In the case of drum-drying, the amount of sample used was weighed before and after drying to determine drying yield. Drying yield was calculated by dividing dried

sample over wet sample and then multiplying by 100. Percentage water loss was also calculated by subtracting initial water content from final water content, dividing by initial water content, and multiplying by 100.

Samples were placed in each respective dryer and dried until a moisture content close to 12 to 14% was achieved. A Computrac MAX-2000 moisture analyzer (Arizona Instrument, Chandler, Arizona) was used to determine if desired moisture content was reached by drying 2.0 g of sample at 145°C using prediction to calculate final moisture content. The different ovens and conditions used were as follows:

1. Cabinet dryer (Hotpack Relative Humidity Chamber, SP Scientific, Gardiner, New York): samples were dried at 70°C.
2. Vacuum dryer (Isotemp Vacuum Oven Model 281 A, Fisher Scientific): samples were pre-dried in cabinet dryer at 70°C for four hours to reduce excess moisture, and then dried in vacuum oven at 70°C with a vacuum of approximately 20 in Hg. The determination to dry for four hours in the cabinet dryer was based on preliminary experiments performed to determine drying rate of pomace at 70°C (See Appendix 1).
3. Double Drum dryer (6”x8”, Buflovak LLC, Buffalo, New York): a speed of 1.5 to 2 min/revolution was used with a drum temperature ranging from 122 to 141°C. Distance between drums was 0.05 mm.

After drying, the samples were weighed to determine yield, then the sample was ground using a coffee grinder (Mr Coffee, Cleveland, Ohio) and sifted through a 35 mesh sieve (USA Standard Testing Sieve No. 40, 425 μm, ASC Scientific, Carlsbad,

California) to obtain flour. Then, samples were analyzed for moisture content, water activity, color, and lycopene content.

Water activity was determined using an Aqualab Series 3 water activity (a_w) meter (Aqualab Scientific, Sydney, Australia) by placing enough dried pomace to cover the bottom of the measuring cup. All tests were performed in triplicate. After analysis, dried samples were vacuum-packed, covered in aluminum foil, and stored at -20°C.

The procedure described above was also used for watermelons processed in 2010, except that these were only dried using the cabinet dryer and approximately 1.5 lbs of pomace were placed in cookie sheets for drying, which was performed a total of five times. After drying was complete, dried samples from each batch were mixed together and a representative sample of this was analyzed for chemical composition.

3.3.6 Chemical Composition

Cabinet (both in 2009 and 2010) and drum-dried samples were analyzed for moisture content, fat, ash, and protein. Fat (AOAC Official Method 991.36) was determined by extraction with petroleum ether using a Soxtec System HT 1043 Extraction Unit (Foss, Eden Prairie, Minnesota) and ash (AOAC Official Method 923.03) was determined by incinerating the sample at 550°C for 6 hours using a Barnstead/Thermolyne Furnace (Thermo Fisher Scientific, Waltham, Massachussetts) (AOAC 2006). Protein (AOCS Official Method Ba 4e-93) was determined using the Dumas Nitrogen Combustion method using a Truspec N Nitrogen Determinator (Leco,

St. Joseph, Michigan) (AOCS 2004). Total carbohydrate was determined by difference (moisture content–fat–ash–protein). All tests were performed in triplicate.

3.3.7 Total, Insoluble, and Soluble Dietary Fiber

Total, insoluble, and soluble dietary fiber were determined using Megazyme Total Dietary Fiber Assay (Megazyme International, Wicklow, Ireland), which involves enzymatic action by heat stable α-amylase, protease, and amyloglucosidase on 1.0 g of sample, and filtration of residue with ethanol and acetone. Incubation with heat stable α-amylase was performed by placing beakers containing sample into boiling water while shaking with the stirring bar for 35 min instead of placing samples in a hot water bath as suggested. Incubation with protease and amyloglucosidase was performed by placing samples in a water bath (Reciprocal Shaking Bath Model 50, Precision Scientific, Aloha, Oregon) at 60°C for 30 min at 50 rpms. Verification of pH was performed using an Accumet Research AR50 Dual Channel pH/ion/conductivity meter (Fisher Scientific). Sample was dried at 103°C overnight in an Isotemp Oven (Fisher Scientific) and weighed afterwards to obtain residue. Test was performed in duplicate. Duplicate blanks were also run with the samples to measure any contribution from the reagents to the residue. One sample and one blank were analyzed for ash at 525°C for 5 hours and the others were analyzed for protein using the Dumas method instead of the suggested Kjeldhal method. Percentage of dietary fiber was calculated by using the following equations:

$$\left[(R - P_r - A_r - B)/S\right]*100 \qquad \textit{Equation 3.2}$$

$$B = B_r - B_a - B_p \qquad \textit{Equation 3.3}$$

Where R is the average weight of the residues obtained (g), P_r is the average protein weight in the residue (g), A_r is the ash weight in the residue (g), B is the blank (g), and S is the average weight of the sample used (g). The blank was calculated using Equation 3.3, where B_r is the average weight of the residues obtained from the blanks (g), B_a is the ash weight in the blank (g), and B_p is the average protein weight in the blank (g).

3.3.8 Sucrose, Glucose, and Fructose Content

Total sugars were analyzed by weighing 0.50 g of sample and extracting with 2 mL of 95% ethanol while heating in a dry bath incubator (Fisher Scientific) at 80-90°C for 15 min. After heating, the tubes were centrifuged in a Savant SpeedVac concentrator (Thermo Fisher Scientific) for 15 min, after which supernatant was extracted with a Pasteur pipette into a 10 mL volumetric flask. This process was repeated 3 more times for a total of 4 extractions. After all extractions were completed, volume was brought to 10 mL with 95% ethanol and 1 mL of extract was placed into vials (performed in duplicate) and dried in SpeedVac. After drying, the samples were dissolved in 1 mL of DI water, filtered through a 0.45 μm nylon membrane (VWR International), and placed in an HPLC (Agilent Technologies, Santa Clara, California) for analysis using an HPX-87P column (Bio-Rad, Sunnyvale, California) at 85°C with DI water as eluent and a refractive index detector (Agilent 110 Series, Agilent Technologies). Flow rate was 0.6 mL/min and injection volume was 10 μL. The process was also performed with spiked samples

using ¼ of expected sugar to determine percent recovery (0.022 g of sucrose, 0.024 g of glucose, and 0.089 g of fructose). The test was performed in triplicate.

3.3.9 Experimental Design and Statistical Analysis

This research study was designed as a completely randomized design. For comparison of drying methods, four replications were performed for all methods, except for vacuum drying which only had three replications. Only samples dried in the cabinet dryer in September 2009 were used to compare between drying methods. Each replication consisted of thawing sample, analyzing it wet, drying using all methods, and then analyzing dried samples.

The ANOVA procedure was used to look for any differences between treatments in terms of lycopene, color, chemical composition, and a_w. A generalized linear model was used with values (lycopene, color, chemical composition, a_w) being the dependent variables and treatments (drying methods and fresh sample) being the independent variables. Lycopene comparisons were made on a dry matter basis (mg lycopene/g dry matter). Tukey's Studentized Range Test was used to detect which treatments were significantly different from each other using $\alpha=0.05$. For lycopene content and a_w, n was 12 for all treatments except for vacuum drying where n was 9 and for samples dried in 2010 where n was 3. For color, n was 36 except for vacuum drying where n was 27. For chemical composition, n was 3, except for sugars where n was 6. See Appendix 9 for all SAS programs and outputs.

3.4 Results and Discussion

3.4.1 Watermelon Processing

Table 3.1 shows the average weight of watermelons processed in September 2009 and June 2010, as well as the percentage yield of each component part. Peel included the outer green peel and inner white rind and pulp refers to the red, fleshy part of the fruit, which also included immature seeds. The pulp was processed into the juice and the pomace.

Table 3.1. Average Fruit Weights and Percentage Yield for Processed Watermelons

	Sept 2009	**June 2010**
Fruit weight (lbs)	16.14 ± 1.86	16.84 ± 3.01
Peel (%)	43.9	40.8
Pulp (%)	56.0	58.5
Juice (%)	44.9	39.9
Pomace (%)	6.9	15.5

Data reported for fruit weight is mean ± standard deviation (n=18 for Sept, n=37 for June). Percentages are based on total fruit weight.

The pulp was the major component of the fruit, which coincides with what has been previously reported (Uddin and Nanjundaswamy 1982; Taper and others 1985). Crandall and Kesterson (1981) obtained juice using a screw-type finisher and obtained 40.5% juice and 7.5% pomace per total fruit weight. This value for pomace coincides with what was obtained for watermelons processed in 2009 and also with preliminary

findings, where watermelons were processed using a finisher instead of a press and 7% pomace per total fruit weight was obtained.

For watermelons processed in 2009, 34% of pomace was obtained from the pulp after initial pressing. After grinding and pressing a second time, the total yield of pomace was reduced to 12%, not only due to loss of excess juice but also because some pomace was lost when pressing and not all pomace was recovered. The initial pressing removed some of the water, while the grinding weakened the cell structure further releasing even more water, which had to be removed by pressing a second time. However, by this stage the cell structure was so weakened that the pomace was pressed out along with the juice. For the processing performed in 2010, it was decided to do things differently, grinding the pomace first, just enough to reduce the particle size, and then pressing. This process didn't cause as much damage to the structure as the previous processing did, and the pomace wasn't pressed out with the juice. This resulted in more pomace being obtained, but less juice.

3.4.2 Fresh Pomace Composition

The composition of the fresh pomace was obtained using the methods mentioned earlier and is listed in Table 3.2.

Table 3.2. Composition and Properties of Fresh Watermelon Pomace

Component/Property	Sept 2009	June 2010
Moisture content (%)	90.99 ± 0.19	90.16 ± 0.26
pH	5.09 ± 0.03	5.20 ± 0.04
Total soluble solids (°Brix)	8.4 ± 0.2	9.7 ± 0.1
Lycopene (mg/g fresh sample)	0.20 ± 0.05	0.24 ± 0.04

Data reported is mean ± standard deviation (For samples processed in 2009, n=3, except for total soluble solids where n=4. For samples processed in 2010, n=6 for moisture and lycopene and n=4 for pH and Brix)

Lycopene content was found to be equivalent to 220 mg/kg on average, which would indicate that fresh pomace contains more lycopene than the pulp of red-fleshed watermelons, which was found to range from 33 to 100 mg/kg fresh pulp as reported by Perkins-Veazie and others (2006a). This is also higher than the value reported for fresh watermelon by USDA of 45 mg/kg for raw watermelons with a moisture content of 91% (USDA and ARS 2010), making fresh watermelon pomace a concentrated source of lycopene. This higher lycopene content could be due to a concentrating effect (less water), but it could also be due to the opening of the cells by the grinding and pressing processes. Lycopene exists in the chromoplasts of cells and processing such as chopping breaks down the cell walls and disrupts the membranes of the chromoplasts while also reducing the integrity of the cell, making lycopene more available for extraction (Shi and Maguer 2000).

Total soluble solids are highly correlated with the concentration of sugars present in the fruit, which can vary depending on its variety and stage of maturity (Maynard 2001). The value found corresponds to what was reported by Saini and Bains (1994) for

fresh watermelon juice, which was on average 8.4° Brix, while lower than what was reported by Quek and others (2007) which was 12.1 °Brix.

The value for the pH also corresponds to what has been reported in previous works: 5.0 in fresh pulp (Uddin and Nanjundaswamy 1982), and 5.3 and 5.79 in fresh juice (Saini and Bains 1994; Quek and others 2007).

The moisture content found for the fresh pomace is similar to what has been reported for fresh watermelon pulp: 91.54% (Uddin and Nanjundaswamy 1982) and 91.2% (Taper and others 1985).

3.4.3 Chemical Composition of Dried Pomace

After drying the sample using the different drying methods mentioned earlier, cabinet-dried and drum-dried watermelon pomace was analyzed for chemical composition and results are shown in Table 3.3.

This table shows that for pomace obtained in 2009, the drying method (drum or cabinet dryer) used did not affect the composition of the sample except for sugar composition, where sucrose and fructose where found to be significantly lower for the drum dried samples. This could be due to the effect of the higher heat applied during drum drying and the sugars' participation in browning reactions. Browning was notable since drum dried samples were found to be significantly darker (lower L* values) and more yellow (higher b* values) than cabinet dried samples (see Figure 3.2). This could have accounted for the lower amount of sucrose present, since during heating, sucrose is

inverted to glucose and fructose, which then react with amino acids via the Maillard reaction to produce browning (Davis 1995).

Table 3.3. Chemical Composition of Cabinet-Dried and Drum-Dried Watermelon Pomace

Component	Drum-Dried (Sept 2009)	Cabinet-Dried (Sept 2009)	Cabinet-Dried (June 2010)
Moisture content (%)	12.53 ± 0.12^{b}	13.25 ± 0.04^{a}	11.92 ± 0.09^{c}
Fat (%)	0.62 ± 0.02^{ab}	0.71 ± 0.20^{a}	0.38 ± 0.04^{b}
Ash (%)	3.46 ± 0.01^{b}	3.47 ± 0.02^{b}	3.56 ± 0.02^{a}
Protein (%)	12.61 ± 0.10^{a}	12.48 ± 0.03^{a}	6.51 ± 0.12^{b}
Carbohydrate (%)	70.78	70.09	77.63
Total dietary fiber (%)	14.02	14.03	10.27
Insoluble dietary fiber (%)	11.86	12.21	6.34
Soluble dietary fiber (%)	3.71	2.00	3.91
Sucrose (%)	7.29 ± 0.01^{b}	11.21 ± 0.09^{a}	3.10 ± 0.11^{c}
Glucose (%)	9.36 ± 0.01^{b}	9.06 ± 0.10^{b}	11.49 ± 0.27^{a}
Fructose (%)	27.48 ± 0.02^{b}	35.53 ± 0.36^{a}	35.11 ± 0.58^{a}
Total sugars	44.13	55.80	49.70

Data reported is wet basis mean ± standard deviation (n=3, except for total dietary fiber where n=2 and for sugars where n=6). Values for each component with different letters are significantly different (α=0.05).

Another issue with the drum dried samples was that the values for insoluble and soluble dietary fiber, when combined, give a higher value for total dietary fiber than what was obtained experimentally. During the analysis, the insoluble dietary fiber residue is filtered and the filtrate is then precipitated with ethanol to obtain the soluble fraction. Mañas and others (1993) observed that during this precipitation, errors can occur that can

include incomplete precipitation and/or co-precipitation of non-fiber components, which could inflate results. Also, the insoluble fiber can form a matrix which can retain other substances from the analytical solutions (Mañas and others 1994). Some of these compounds might be constituents of the soluble fraction, which could then be quantified as insoluble dietary fiber (Mañas and others 1994).

Samples were dried in the cabinet dryer on two separate occasions, once for comparison with other drying methods in 2009 and another time on a larger scale in 2010, which required longer drying times (about 5 days compared to 40 hours for smaller scale). When comparing both samples dried in the cabinet dryer, the compositions are different. This could have been due to differences in the composition of the watermelons used or in loss of components during extended drying. This is especially true for the total sugars since the total soluble solids content for the fresh sample was higher for samples processed in 2010 than for the sample processed in 2009, yet after drying the total sugars in the dried sample was less (Refer to Table 3.3). This could be due to the sugars participating in browning reactions during prolonged heating as mentioned earlier for drum drying. As with those samples, the samples cabinet-dried in 2010 were found to have significantly lower L* values than samples dried in 2009 (34.41 compared to 53.96), making the sample much darker, which is indicative of browning. In this case, sucrose was also greatly reduced. Microbial growth could have also been responsible for the degradation of sugars since the sample took longer to dry.

Table 3.3 shows that samples had a lower amount of sucrose than those previously reported by Schmidt and others (2005), who found watermelon to have 32.2% fructose, 9.3% glucose, and 27.1% sucrose for a total of 68.6% of sugars on a dry matter

basis. This could have been due to losses during drying or to incomplete recoveries during extraction. Percent recoveries for this study ranged from 75 to 87% for sucrose, 92 to 104% for glucose, and 92 to 106% for fructose.

The differences in sugar composition could have also been responsible for the sticky nature of the sample that was dried for extended periods. After drying, it was observed that the samples were hygroscopic and became sticky and difficult to handle while trying to grind and sift them. After vacuum packaging and storing, the sample caked together and it was necessary to grind or use a mortar and pestle in order to obtain a flowable powder. Because dry products obtained from most drying processes are predominantly in a glassy amorphous form, they can transition to a rubbery state when exposed to temperatures above their glass transition temperature (T_g) (Bhandari and Howes 1999). In the rubbery state, molecular mobility is accelerated which results in deformation and an increase in physicochemical changes such as stickiness and adhesion (Aguilera and others 1995; Bhandari and Howes 1999; Adhikari and others 2001). Low molecular weight sugars such as fructose, glucose, and sucrose have very low glass transition temperatures (5, 31, and 67°C, respectively), and can also lower the T_g of food products, which is very notable in sugar-rich foods (Bhandari and Howes 1999; Maltini and others 2003). Because of this, low molecular weight sugars are likely responsible for stickiness and caking in these types of products (Adhikari and others 2001). Another important value is the sticky point temperature (T_s), which is the point at which a flowable powder will start to cake together (Jaya and Das 2009). This value will always be higher than T_g since stickiness will usually develop only after the transition from glassy to rubbery has occurred (Jaya and Das 2009). Jaya and Das (2009) showed that

the T_g and T_s of samples decreased as moisture content increased. Since the sample dried in 2010 had more glucose and less sucrose, it is possible that it could have a lower T_g than the sample dried in 2009, and would have exceeded this temperature at some point during processing. Because of a lower T_g, T_s could have also been lower and caused the samples to become sticky. Also, since the sample was very hygroscopic, absorbing moisture would have lowered even more the T_g and T_s, making it easier to exceed at room temperature. Also, storing sugar-rich dried products at low temperatures can cause their viscosity to increase substantially due to crystallization of the sugars which can cause them to coalesce into a solid mass (Bhandari and Howes 1999). This could explain why after freezing the sample became cemented and had to be ground again to be able to be analyzed.

3.4.4 Water Activity

The water activity of the dried samples was not significantly different between samples dried using different drying methods ($p = 0.1146$). While the moisture content of a sample represents the total amount of water present in the food, the water activity (a_w) indicates how tightly the water is bound (Fontana 1998). Water activity is defined as "the ratio of the water vapor pressure over a food to that over pure water at a given temperature" (Fontana 1998). This concept is an important property for food safety, since it can predict its stability in terms of microbial growth, chemical/biochemical reaction rates, and physical properties (Fontana 1998). In general, microbial growth will be inhibited at a a_w below 0.65 (Perera 2005). Most oxidation and enzymatic reactions will be inhibited as a_w decreases, but non-enzymatic reactions will occur at intermediate

a_w ranges of about 0.4-0.65 (Perera 2005). It is therefore important to dry to a a_w of around 0.2-0.4 (Perera 2005). For watermelon pomace, the average water activity of all dried samples was 0.244 ± 0.040 (n=36), suggesting it to be a safe and stable product.

3.4.5 Drying Yields and Percentage Water Loss

Table 3.4 shows the average drying times, yields, water loss, and water loss/time for drum, vacuum/cabinet, and cabinet drying.

Table 3.4. Average Drying Times, Yields, Water Loss, and Water Loss/Time for Drum-Dried, Vacuum/Cabinet-Dried, and Cabinet-Dried Watermelon Pomace

Drying Method	**Residence Time**	**Yield (%)**	**Water Loss (%)**	**Water Loss /Time (%/min)**
Drum Dried	2 min	8.40 ± 0.10	98.81 ± 0.04	54.08 ± 11.54
Cabinet/Vacuum Dried	37 h	10.05 ± 0.10	98.27 ± 0.08	0.04 ± 0.00
Cabinet Dried	40 h	9.89 ± 0.09	98.45 ± 0.09	0.04 ± 0.00

Data reported is mean ± standard deviation (n=3, except for cabinet dried where n=4)

Drum drying had the lowest drying time, while vacuum/cabinet and cabinet drying took about 39 hours to reduce the percentage of water in the sample by 98%. Drying yields were similar for all drying methods, with vacuum/cabinet drying having the highest and drum drying having the lowest. The lower yield for the drum dryer could be due to the fact that it was not an enclosed system and the high temperatures may have caused some sample loss. With the other dryers the sample was placed in aluminum cups and was recovered almost in its entirety. Percent water loss per minute was much higher

for drum drying, while about the same for both vacuum/cabinet and cabinet-drying. However, vacuum-dried samples had to be pre-dried in the cabinet dryer for 4 hours; if this hadn't been done, the samples would have taken a lot longer to dry than 37 hours. In the cabinet dryer, air gets re-circulated through the dryer, removing saturated air with fresh air that can remove more moisture. With the vacuum dryer, the moisture was absorbed by a dessicant, which had to be replaced in order for moisture to be absorbed and the total drying time depended on how often this dessicant was replaced.

3.4.6 Lycopene Content

Figure 3.1 shows how the drying methods compare to each other and to fresh pomace in terms of lycopene content. The lycopene content was not significantly different between drying methods ($p = 0.8704$). The average lycopene content of all dried samples was 1.51 ± 0.32 mg/g dry sample ($n=36$), which is greater than what was found for fresh watermelon pomace, making dried watermelon pomace an even more concentrated source of lycopene. As with chopping, thermal processing can disrupt cell walls and chromoplast membranes, releasing lycopene from the food matrix and making it more accessible during extraction (Dewanto and others 2001).

Even though dried watermelon pomace was found to have a high lycopene content, when compared on a drymatter basis, lycopene content decreased with drying. Lycopene content of the fresh sample was not found to be significantly different than that of samples dried in the vacuum or cabinet dryers. However, it was significantly different than that of drum-dried samples. Lycopene is very sensitive to light, heat, and oxygen

(Shi and Maguer 2000) and the vacuum oven offers an oxygen-free environment where the lycopene can be more stable, while the cabinet dried samples were not exposed to light. In contrast, samples in the drum dryer were exposed to high heat and light, which caused a higher loss.

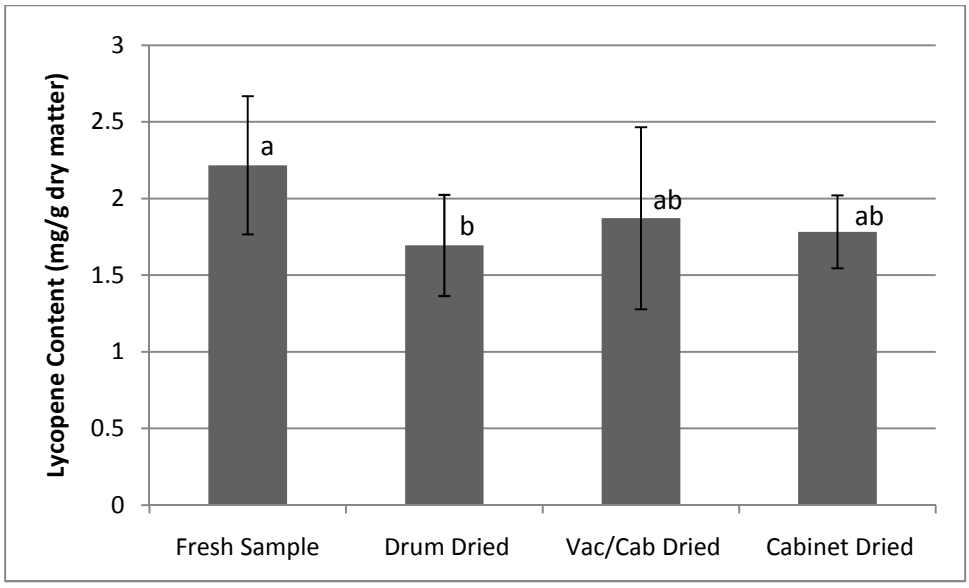

Figure 3.1. Comparison of Lycopene Content of Fresh, Drum-Dried, Vacuum/Cabinet-Dried, and Cabinet-Dried Watermelon Pomace. Data reported is dry matter basis mean ± standard deviation (n=12, except for vacuum dried where n=9). Bars with different letters are significantly different (α=0.05).

Table 3.5 shows the lycopene stability during storage for vacuum-packed and non vacuum-packed samples. Lycopene content was not significantly different for vacuum-packed samples throughout a year of storage ($p = 0.6742$). However, during the study one of the samples tested had lost its vacuum and suffered a significant loss of lycopene (47%) after 5 months of storage which was not significantly different when tested 7 months later. This shows how important the presence of oxygen is in determining

lycopene loss. Lycopene retention in dried tomato powder was found to decrease in the presence of oxygen after storing for long periods of time (Lovric and others 1970).

Table 3.5. Stability of Lycopene Content (mg/g) of Dried Watermelon Pomace after 5 Months and 1 Year of Storage at -20°C

Sample	0 months	5 months	12 months
Vacuum-packed	1.423 ± 0.589^{a}	1.579 ± 0.249^{a}	1.613 ± 0.212^{a}
Non vacuum-packed	1.570 ± 0.385^{a}	0.837 ± 0.295^{b}	0.670 ± 0.028^{b}

Data reported is mean ± standard deviation (n=3). Values for each sample with different letters are significantly different (α=0.05).

3.4.7 Color

Figure 3.2 shows the effects of drying on the color of watermelon pomace. In general, L* values increased for all methods, meaning that the samples became lighter or showed discoloration, and all methods were significantly different from each other and from the fresh sample. Drum-dried samples appeared darker than the other two methods, meaning that browning occurred more readily in these samples. The a* values decreased for all methods with cabinet drying causing the most loss in redness, while vacuum/cabinet-dried and drum-dried samples were not significantly different from each other. This discoloration and loss in redness could be related to lycopene loss and/or isomerization. During drying, the all-trans isomers of lycopene can isomerize into the cis-isomers, which are less red causing the loss of redness (Miers and others 1958; Shi and others 1999). The b* values increased in general, meaning that samples became

more yellow, with drum-dried samples showing the most yellowness, while cabinet-dried and vacuum/cabinet-dried samples were not significantly different from each other.

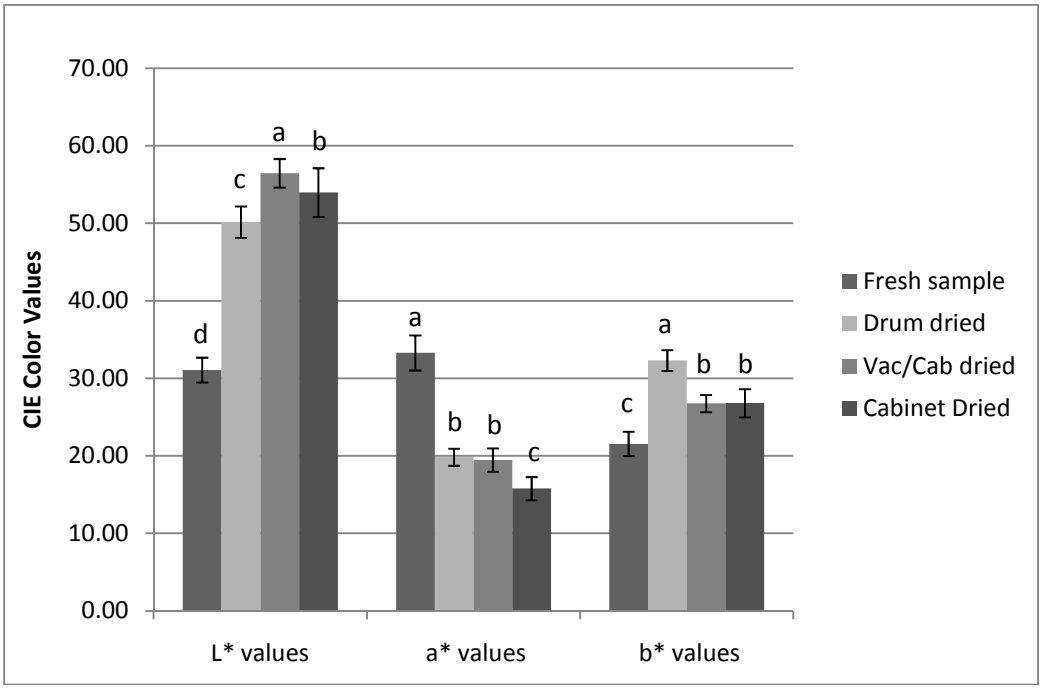

Figure 3.2. Comparison of CIE Color Values (L*, a*, b*) of Fresh, Drum-Dried, Vacuum/Cabinet-Dried, and Cabinet-Dried Watermelon Pomace. Data reported is mean ± standard deviation (n=36, except for vacuum-dried samples where n=27). Bars within each group of color values (L*, a*, b*) with different letters are significantly different (α=0.05).

In terms of color, drum-drying made the sample darker than the other two methods and made it more yellow, so it didn't preserve the color as well as the other methods. Vacuum/cabinet-drying preserved the color of the sample better than cabinet drying alone, in terms of lightness and redness, although they were not significantly different in terms of yellowness. Therefore, vacuum/cabinet-drying helped preserve the color better than the other two methods.

With all this information taken into consideration, vacuum/cabinet drying seems to be the best method for drying watermelon pomace, since it preserved the color the best and didn't cause as much lycopene loss when compared to the fresh sample. Although the drum dryer is more efficient in terms of drying time, it didn't preserve the color as well. However, in terms of efficiency and cost, the vacuum dryer is the least efficient and most expensive. Also, the vacuum dryer used in this study was relatively small which limited the amount of sample that could be dried at a time.

3.5 Conclusion

Fresh watermelon pomace was found to be a concentrated source of lycopene, with contents being higher than what has been previously reported for fresh watermelon. Dried pomace was found to be composed mostly of sugars, with some dietary fiber. Drying caused the sample to become lighter, less red, and more yellow than the fresh sample, and only drum-drying significantly affected the lycopene content of the sample. The combination of cabinet/vacuum drying was found to be the best method for drying watermelon pomace in order to better preserve its color and lycopene content, although it wasn't the most efficient. The lycopene content of stored dried samples was found to be stable after one year of storage, as long as it was vacuum-packaged. Also, drying for extended periods in the cabinet dryer affected the sugar composition of the sample, causing browning and stickiness.

Further research should be performed with other drying methods to observe how they affect the lycopene content and whether they are better options for this type of

product. Also, T_g and T_s should be evaluated to assess adequate processing and storage conditions for the dried product. Future experiments will focus on the addition of watermelon pomace to bakery products.

3.6 Acknowledgments

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CHAPTER IV

INCORPORATION OF DRIED WATERMELON POMACE INTO COOKIES AND ITS EFFECT ON RHEOLOGICAL PROPERTIES, BAKING QUALITY, SENSORY ATTRIBUTES, AND NUTRITIONAL COMPOSITION

4.1 Abstract

Watermelon is the most important melon crop in the US, yet it is mostly consumed fresh and during the summer season since few products with watermelon exist. Watermelon is also the richest known source of the antioxidant lycopene. Dried watermelon pomace could be used as a potential food ingredient to create more value-added products for watermelon and as a source of lycopene. The objectives of this study were to incorporate dried watermelon pomace at different levels into flour and evaluate its effect on the rheological properties of the dough formed, as well as on the baking quality and sensory attributes of prepared cookies. Dried watermelon pomace was used to replace flour at 10, 20, and 30%. It was also used to replace sugar in cookie formulations. Rheological evaluation using a farinograph showed that adding pomace increased dough stability and time to break down, which suggests that it was stronger than 100% wheat flour. Cookies were not affected significantly in terms of spread and texture, although color became darker with increasing amounts of watermelon pomace. Cookies with 10% pomace were not scored significantly differently from control cookies in terms of appearance and taste. Cookies with 20 and 30% pomace were scored lower since their darker color and bitter taste were not as well received, yet they were still found to be acceptable. Addition of pomace increased the lycopene content of the cookies, and even though there was some degradation during baking, the final products were good sources of the nutrient.

Keywords: *Watermelon, lycopene, pomace, rheology, cookies*

4.2 Introduction

Watermelon fruit is the most important melon crop and the third most produced vegetable crop in the United States (USDA and NASS 2010). Nevertheless, it is mostly consumed fresh during the summer season and few products with watermelon exist. Watermelon is also the richest known source of the antioxidant lycopene, containing on average 45.3 μg lycopene/g fresh tissue (Holden 2009). Dried watermelon pomace could be used as a potential food ingredient to create more value-added products for watermelon and as a source of lycopene. To our knowledge, no studies exist on watermelon pomace composition or its potential use as a food ingredient.

There have been many studies performed with various fruit powders for their use as a nutritional supplement for different bakery products to increase dietary fiber content and that of other components such as protein, vitamins, and minerals (Chen and others 1988; Wang and Thomas 1989; Masoodi and others 2002; Giami and others 2005; Pongjanta and others 2006; Sudha and others 2007; Athayde-Uchoa and others 2009). Dried watermelon pomace could also be used for this purpose, not only for the addition of lycopene, but also as a source of dietary fiber or as a sugar substitute.

Several studies have been performed to study the effect of sugar and/or fiber on the rheological properties of dough. Increasing levels of sugar were found to decrease consistency, elasticity, and mixing tolerance index, while increasing levels of apple pomace, which is high in fiber, were found to increase farinographic water absorption, dough development time, and mixing tolerance of the dough (Sai-Manohar and Haridas-Rao 1997; Masoodi and others 2001; Sudha and others 2007).

Cookies consist mostly of flour and sugar, which greatly affect their textural properties. Flour is the main ingredient, which contributes to the texture, hardness, and shape of the baked product (Manley 2000). However, sugar competes with the flour for water, affecting the development of gluten and the gelatinization of starch (Kulp 1994; Manley 2000). The quantity of sugar added will affect the texture, size, and appearance of the cookies. In general, the higher the amount of sugar used, the harder the cookies will be, and the larger the cookie diameter and the lower the thickness or height (Sai-Manohar and Haridas-Rao 1997; Manley 2000; Pareyt and others 2009). Also, the type of sugar used will have an effect. If sugars that do not crystallize well are used, such as fructose, the cookies will be soft (Kulp 1994). Kweon and others (2009) found that width and length of cookies was highest for sucrose, followed by fructose, then glucose. Pasha and others (2002) found that cookies with 100% fructose showed the highest thickness and the lowest width. Addition of fiber will also have an effect; the higher the level of fiber added, the lower the spread factor and the more tender the cookies (Vratanina and Zabik 1978). The incorporation of watermelon pomace, which has both sugar and fiber, will likely also have an effect on the baking quality of cookies.

The objectives of this study are to incorporate dried watermelon pomace at different levels into flour and evaluate its effect on the rheological properties of the dough formed, as well as on the baking quality and sensory attributes of prepared cookies.

4.3 Materials and Methods

4.3.1 Chemical Composition of Dried Pomace

The chemical composition of dried watermelon pomace was determined, including moisture content, fat, ash, and protein. Moisture content was determined using Method 950.46 from the AOAC Official Methods (2006), by drying 2.0 g of sample in an Isotemp Oven (Fisher Scientific) for 16-18 hours at 102°C. Fat (AOAC Official Method 991.36) was determined by extraction with petroleum ether using a Soxtec System HT 1043 Extraction Unit (Foss, Eden Prairie, Minnesota) and ash (AOAC Official Method 923.03) was determined by incinerating the sample at 550°C for 6 hours using a Barnstead/Thermolyne Furnace (Thermo Fisher Scientific, Waltham, Massachussetts) (AOAC 2006). Protein (AOCS Official Method Ba 4e-93) was determined using the Dumas Nitrogen Combustion method using a Truspec N Nitrogen Determinator (Leco, St. Joseph, Michigan) (AOCS 2004). Total carbohydrate was determined by difference (moisture content–fat–ash–protein). All tests were performed in triplicate.

4.3.2 Total, Insoluble, and Soluble Dietary Fiber

Total, insoluble, and soluble dietary fiber was determined using Megazyme Total Dietary Fiber Assay (Megazyme International, Wicklow, Ireland), which involves enzymatic action by heat stable α-amylase, protease, and amyloglucosidase on 1.0 g of sample, and filtration of residue with ethanol and acetone. Incubation with heat stable α-

amylase was performed by placing beakers containing sample into boiling water while stirring for 35 min instead of placing samples in a hot water bath as suggested. Incubation with protease and amyloglucosidase was performed by placing samples in a hot water bath (Reciprocal Shaking Bath Model 50, Precision Scientific, Aloha, Oregon) at 60°C for 30 min at 50 rpm's. Verification of pH was performed using an Accumet Research AR50 Dual Channel pH/ion/conductivity meter (Fisher Scientific). Sample was dried at 103°C overnight in an Isotemp Oven (Fisher Scientific) and weighed afterwards to obtain residue. The test was performed in duplicate. Duplicate blanks were also run with the samples to measure any contribution from the reagents to the residue. One sample and one blank were analyzed for ash at 525°C for 5 hours and the others were analyzed for protein using the Dumas method instead of the suggested Kjeldhal method. Percentage of dietary fiber was calculated by using the following equations:

$$\left[(R - P_r - A_r - B)/S\right]*100 \qquad \textit{Equation 4.1}$$

$$B = B_r - B_a - B_p \qquad \textit{Equation 4.2}$$

Where R is the average weight of the residues obtained (g), P_r is the average protein weight in the residue (g), A_r is the average ash weight in the residue (g), B is the blank (g), and S is the average weight of the sample used (g). The blank was calculated using Equation 4.2, where B_r is the average weight of the residues obtained from the blanks (g), B_a is the ash weight in the blank (g), and B_p is the average protein weight in the blank (g).

4.3.3 Sucrose, Glucose, and Fructose Content

Total sugars were analyzed by weighing 0.50 g of sample and extracting with 2 mL of 95% ethanol while heating in a dry bath incubator (Fisher Scientific) at 80-90°C for 15 min. After heating, the tubes were centrifuged in a Savant SpeedVac concentrator (Thermo Fisher Scientific) for 15 min, after which supernatant was extracted with a Pasteur pipette into a 10 mL volumetric flask. This process was repeated 3 more times for a total of 4 extractions. After all extractions were completed, volume was brought to 10 mL with 95% ethanol and 1 mL of extract was placed into vials (performed in duplicate) and dried in SpeedVac. After drying, the samples were dissolved in 1 mL of DI water, filtered through a 0.45 μm nylon membrane (VWR International), and placed in an HPLC (Agilent Technologies, Santa Clara, California) for analysis using an HPX-87P column (Bio-Rad, Sunnyvale, California) at 85°C with DI water as eluent and a refractive index detector (Agilent 110 Series, Agilent Technologies). Flow rate was 0.6 mL/min and injection volume was 10 μL. The process was also performed with spiked samples using ¼ of expected sugar to determine percent recovery (0.022 g of sucrose, 0.024 g of glucose, and 0.089 g of fructose). Recovery was found to be 82% for sucrose, 99% for glucose, and 106% for fructose. The test was performed in triplicate.

4.3.4 Lycopene Content

Lycopene content was analyzed using the method of Sadler and others (1990) as modified by Perkins-Veazie and others (2001b), with some additional modifications.

Instead of 2 g, 0.25 g of dried pomace was added to beakers covered with aluminum foil to which 5 mL of water was added. Samples were placed in a Standard Analog shaker (VWR International, West Chester, Pennsylvania) at a low speed (setting 3) for 30 minutes, after which 25:25:25 mL of ethanol, acetone, and hexane were added, as well as 0.05 g of butylated hydroxy toluene (BHT). Samples were homogenized with the beakers placed on top of ice using a PowerGen 700 homogenizer (Fisher Scientific, Pittsburgh Pennsylvania) set at medium speed (setting 3) for 6 sets of 20 seconds each, pausing for 10 seconds in between sets. After this, an additional 25 mL of hexane was placed on a beaker, homogenized for 5 seconds to remove any sample from the probe, and then added to the beakers containing the samples. Samples were shaken for 10 minutes at room temperature in the shaker, after which 15 mL of deionized (DI) water was added, and the samples were shaken for an additional 5 minutes. After this, the samples were left to rest for 15 min and then 1 mL of the top layer was placed in glass cuvettes and analyzed in a DU 520 General Purpose UV/Vis Spectrophotometer (Beckman Coulter, Brea, California) using a wavelength of 503 nm and hexane as blank. The concentration of lycopene in the samples was calculated using the following equation:

$$C = \left[(A/17200)*(50mL/1000mL)*536.85g/m*1000mg/g\right]/S \qquad \textit{Equation 4.3}$$

Where C is the concentration of lycopene in mg/g sample, A is the absorbance reading, and S is the amount of sample used (g). This formula uses the lycopene coefficient of extinction of 17,200 mol/cm, 50 mL of extraction volume (hexane), and the molecular

weight of lycopene, which is 536.85 g/mol (Fish and others 2002). All tests were performed in triplicate.

4.3.5 Moisture Content of Flour and Flour/Pomace Blends

Dried watermelon pomace was blended with flour by replacing it at levels of 0, 10, 20, and 30%. Moisture content of flour and blends was determined using AOAC Method 925.10 (2006) by drying 2.0 g of sample at 130 ± 3°C for 1 hour. This moisture content was used to determine sample weight for farinographic analysis and to determine weight of flour/blends to use in cookie recipe (See Appendix 2 for exact values).

4.3.6 Rheological Evaluation of Flour and Flour/Pomace Blends

The effect of incorporation of pomace on the mixing profile of the dough was evaluated using the constant dough weight procedure (AACC Method 54-21) (AACC 1995). For this a Farinograph-E (Brabender, Duisburg, Germany) was used with a 10 g bowl and a test speed of 60 m^{-1} for 20 minutes. Water absorption was set at 68%. Weight of sample used was determined by the software based on its moisture content.

4.3.7 Baking Quality Evaluation

Cookies were prepared using 4 levels of incorporation and baking quality was assessed by AACC Method 10-54 (1995). Table 4.1 shows the ingredient formula for

each level of pomace used, representing 1 batch, which is enough to obtain 2 cookies. Pomace replaced flour weight at 10, 20, and 30% and was also used to replace sugar. High fructose corn syrup (HFCS) was eliminated from the formulas containing pomace since it already contained fructose and glucose. Fine granulated and brownulated sugars were reduced in the same ratio they were present originally (0.76/0.24) in order for all levels to contain a total sugar amount of 17.4 g. The amount of pomace and flour used was determined by their moisture content using Table 1 in AACC Method 10-54 (1995).

Table 4.1. Ingredient Formula for Prepared Cookies

Ingredients	**0% (g)**	**10% (g)**	**20% (g)**	**30% (g)**
Granulated sugar (C & H)	12.8	11.8	10.3	8.8
Brownulated brown sugar (Domino)	4.0	3.7	3.2	2.7
Nonfat dry milk (Great Value)	0.4	0.4	0.4	0.4
Salt (Morton)	0.5	0.5	0.5	0.5
Sodium bicarbonate (Arm & Hammer)	0.4	0.4	0.4	0.4
Shortening (Crisco)	16.0	16.0	16.0	16.0
HFCS, 42% (Cargill)	0.6	0	0	0
Ammonium bicarbonate (Esseco USA)	0.2	0.2	0.2	0.2
All-purpose flour (Shawnee Best)	39.8	35.7	31.8	27.8
DI Water	9.2	9.1	9.1	9.1
Pomace	0	4.0	7.9	11.9

Granulated sugar and nonfat dry milk were ground using a coffee grinder (Mr Coffee, Cleveland, Ohio) and sifted through a 28 mesh sieve (USA Standard Testing Sieve No. 30, 600 μm, ASC Scientific, Carlsbad, California). Dried watermelon pomace was also ground and sifted through a 35 mesh sieve (USA Standard Testing sieve No.40, 425 μm) before weighing, then mixed with the flour before adding to creamed mass. Dried ingredients (except for ammonium bicarbonate) and shortening were mixed using a Kitchen Aid Mixer Model KSM90 (Kitchen Aid, St Joseph, Michigan) for 3 minutes then transferred to a National micro-mixer (National Mfg Co, Lincoln Nebraska) to which water, HFCS, and ammonium bicarbonate were added, then mixed for 1 min. Afterwards, flour or flour/pomace was added and mixed for 30 seconds. Dough was weighed before dividing in half and rolling out into cookie sheets. Cookie sheets and raw cookies were weighed to determine weight before baking. Afterwards, cookie sheets were placed in a rotary baking oven (Bristol Company, Waterbury, Connecticut) at 400°C for 11 minutes. Once out of the oven, the cookies were left to cool for 5 minutes and then placed in a cookie rack.

After preparing all treatments, cookies were weighed and then measured for width and height. Width was determined by laying both cookies side by side and measuring the width of both cookies. They were then rotated a quarter turn and measured 3 more times for a total of four measurements. Height was determined by placing cookies one on top of each other and then measuring the height of both cookies. This was repeated by re-stacking in different order for a total of 2 measurements. Room conditions varied from 25 to 26°C and from 28 to 43% relative humidity.

4.3.8 Color Analysis

Cookie color was tested using a Spectrophotometer CM-3500d (Konica Minolta, Ramsey, New Jersey) by placing the cookie top side down on a Petri dish which was placed on top of a 30 mm aperture and then rotating each dish to take three different readings of different areas for each CIE L*, a*, and b* values. The color of the dough was also determined in this manner.

4.3.9 Texture Analysis

Cookie texture was determined by using a TA-XT2i Texture Analyzer (Texture Technologies Corporation, Scarsdale, New York). A puncture test using a 2 mm diameter probe was performed by puncturing each cookie 5 times around the edges and 1 time in the center. The probe descended at a speed of 1 mm/sec until it detected 5 g of force, at which point it penetrated the cookie for 20 mm at a speed of 0.50 mm/sec. Afterwards, the probe withdrew at a speed of 10 mm/sec. Since there were many fluctuations in the force readings, hardness was determined as the area under the curve and fracturability as the linear distance.

4.3.10 Chemical Composition of Cookies

Both cookies from each treatment were ground using a coffee grinder in order to determine moisture content, water activity (a_w), and lycopene content.

Leftover dough and ground cookies were analyzed for moisture content using the same method mentioned earlier for watermelon pomace. Water activity was determined using an Aqualab Series 3 water activity meter (Aqualab Scientific, Sydney, Australia) by placing enough sample to cover the bottom of the measuring cup.

Lycopene content was also determined using the same method as for watermelon pomace except 3.0 g of ground cookies were used and then mixed with 6 mL of DI water. To obtain lycopene loss during baking it was necessary to calculate the theoretical lycopene content present in the total dough obtained and to make comparisons on a dry matter basis between the wet dough and the prepared cookies. For these calculations, total dough obtained was weighed as well as the cookies before and after baking, and the moisture contents of the dried watermelon pomace, the dough, and the cookies were used to determine dry matter. Values for dough moisture content, total dough used weight, and raw cookies and baked cookie weights can be found in Appendix 3. Moisture content of cookies can be found in Table 4.5. Calculations were done using the following equations:

$$P_{dm} = P * 0.8808 \qquad \textit{Equation 4.5}$$

Where P_{dm} is pomace dry matter (g), P is weight of pomace added in recipe (g), and 0.8808 is the amount of dry matter in the pomace (g).

$$D_{dm} = 1 - (M_D / 100) \qquad \textit{Equation 4.6}$$

Where D_{dm} is the dry matter in the dough (g) and M_D is the moisture content of the dough (%). This equation was used to calculate the dried matter of the total dough obtained and of the dough that was used (weight of raw cookies). From these two values, a ratio was obtained to determine how the dough was divided and to, therefore, determine the amount of pomace present in the raw cookies (P_d). This calculation assumes that the pomace was distributed evenly.

$$P_T = P_d * P_{dm} \qquad \textit{Equation 4.7}$$

Where P_T is the theoretical amount of pomace dry matter present in the raw cookies (g).

$$L_T = P_T * 1.62 \qquad \textit{Equation 4.8}$$

Where L_T is the theoretical amount of lycopene present in the pomace (mg) and 1.62 is the mg lycopene/g dry matter of pomace.

$$L_A = \{[1-(M_C/100)]*C_w\}*L_C \qquad \textit{Equation 4.9}$$

Where L_A is the actual lycopene present in the cookie dry matter (mg), M_c is the moisture content of the cookies (%), C_w is the weight of the cookies (g), and L_c is the mg lycopene/g dry matter of cookie.

$$\%\, loss = [(L_T - L_A)/L_T]*100 \qquad \textit{Equation 4.10}$$

Where % loss represents the percentage of lycopene loss during baking.

4.3.11 Sensory Evaluation of Cookies

For the sensory evaluation, ingredients for 8 batches were used in order to obtain 18 cookies for each level of incorporation. For this occasion all mixing was performed with the Kitchen Aid mixer and cookies were placed on insulated cookie sheets (WearEver, Millville, New Jersey) and baked in a gas oven (Maytag, Whirlpool Corporation, Benton Harbor, Michigan). After baking, cookies were placed in ZipLoc bags and stored in a refrigerator overnight for sensory evaluation. All panelists were untrained and volunteered to participate. Each panelist received one half of each cookie (0, 10, 20, 30%) and was asked to evaluate them for appearance, texture, and taste using a hedonic test with a 9-point scale to quantify the degree of liking or disliking of the products prepared (Lawless and Heymann 1998) (see Appendix 5 for sample score sheet). Each sample was given a random 3-digit number and the order in which the samples were given to each panelist was determined by a balanced randomization in order that each sample would be presented to the panelists first an equal number of times (see Appendix 6 for randomization used). A total of 60 panelists participated in the study.

4.3.12 Nutritional Composition of Cookies

Nutrition labels for control and pomace cookies were obtained using the software Genesis R&D SQL version 9.5.0.0 (ESHA Research, Salem, Oregon). Serving sizes were determined as stated in Food Labeling Requirements for FDA Regulated Products (Vetter 1999). Watermelon pomace was added as a new ingredient using compositional data obtained experimentally. Moisture loss after baking was also included to obtain the correct values.

4.3.13 Experimental Design and Statistical Analysis

This research study was designed as a completely randomized design. For baking studies, three replications were performed which consisted of baking two cookies for each incorporation level, measuring width, height, color, moisture content, water activity and lycopene content. For sensory evaluations, six panels were conducted in order to obtain 60 panelists.

The ANOVA procedure was used to look for any differences between treatments (levels of incorporation) in terms of width, height, hardness, fracturability, moisture content, lycopene content, color, and sensory attributes (appearance, texture, taste). In order to analyze sensory panel results, each value was assigned a number from 1 to 9 (like extremely to dislike extremely). A generalized linear model was used with values (width, height, etc) being the dependent variables and treatments (level of incorporation: 0%, 10%, 20%, 30%) being the independent variables. Tukey's Studentized Range Test

was used to detect which treatments were significantly different from each other using α=0.05. For width, n=6, for height, n=12, for hardness and fracturability, n=36, and for color, n=18. For lycopene, moisture content, and a_w, n=9. For sensory attributes, n=60. See Appendix 10 for all SAS programs and outputs.

4.4 Results

4.4.1 Chemical Composition of Pomace

Table 4.2 shows the composition of dried watermelon pomace. As can be seen, it is high in total sugars (49.7%), contains some dietary fiber and protein, and is also a concentrated source of lycopene, with fresh watermelon being reported as having 0.045 mg of lycopene/g of fresh fruit (USDA and ARS 2010).

Chen and others (1988) reported dried apple pomace as having 1.18% moisture, 1.27% ash, 2.45% fat, 7.25% protein, and 61.90% total dietary fiber. Carson and others (1994b) tested pomace from different varieties of apples and found that composition ranged from 1.2-1.5% moisture, 1.9-2.5% protein, 1.0-1.1% fat, 4.8-6.2% ash, and 33.4-35.5% total dietary fiber. Pongjanta and others (2006) found that dried pumpkin flour had a composition of 6.01% moisture, 3.74% protein, 1.34% fat, and 7.24% ash. Although these products have a lower moisture content than dried watermelon pomace, watermelon pomace has a higher protein content than pumpkin flour with 6.5% and a higher ash content than apple pomace with 3.6%. Dried watermelon pomace also has a lower fat content than both apple pomace and pumpkin flour with 0.38%.

Table 4.2. Chemical Composition of Dried Watermelon Pomace

Component	Watermelon Pomace
Moisture content (%)	11.92 ± 0.09
Fat (%)	0.38 ± 0.04
Ash (%)	3.56 ± 0.02
Protein (%)	6.51 ± 0.12
Carbohydrate (%)	77.63
Total dietary fiber (%)	10.27
Insoluble dietary fiber (%)	6.34
Soluble dietary fiber (%)	3.91
Sucrose (%)	3.10 ± 0.11
Glucose (%)	11.49 ± 0.27
Fructose (%)	35.11 ± 0.58
Lycopene (mg/g)	1.43 ± 0.35

Data reported is wet basis mean ± standard deviation
(n=3, except for total dietary fiber where n=2 and for sugars where n=6).

Since watermelon pomace will be used to replace flour at different levels, it is important to observe differences in their composition. Commercial all-purpose flour was used and the nutrition label states that it contains 0% fat, 10% protein, and less than 3% dietary fiber at a 13% moisture content, which was determined experimentally. When compared to this flour, dried watermelon pomace has a lower protein content and a much higher dietary fiber content. Since the pomace has mostly insoluble fibers, it could be used in bakery products to control calories, add bulk, or for added health benefits (Dreher 1999). Adding dried watermelon pomace to bakery products can also increase lycopene content. Lycopene is a powerful antioxidant which studies have suggested could reduce

the risk of chronic diseases such as cancer and cardiovascular disease (Omoni and Aluko 2005). Also, since dried watermelon pomace is high in sugars, it could also be used as a natural sugar substitute to help decrease the added sugar in the finished product.

4.4.2 Rheological Evaluation

Table 4.3 shows how the mixing properties of the dough were affected by replacing flour with 30% watermelon pomace. Adding pomace increased the time it took to obtain a consistent dough (development time), the mixing tolerance index (MTI), the stability of the dough, and the time for the dough to break down.

Table 4.3. Mixing Properties of Flour and Flour/Pomace Blend (30%)

Sample	*Water Absorption (%)	Dough Development Time (min)	Mixing Tolerance Index (BU)	Stability (min)	Time to Breakdown (min)
0%	65.9 ± 0.4	1.5 ± 0.2	47.0 ± 7.2	7.7 ± 1.6	3.0 ± 0.4
30%	66.4 ± 0.3	7.5 ± 0.4	72.0 ± 9.8	10.3 ± 0.4	10.0 ± 0.3

Data reported is mean ± standard deviation (n=3). *Based on 14% moisture content.

The increase in the dough development time could be due to the pomace delaying the formation of gluten. The MTI is usually used to indicate flour strength; in general the higher the MTI value, the weaker the flour (D'Appolonia and Kunerth 1984). This value is calculated as the difference between the top of the curve at the peak and the top of the curve 5 min after the peak has been reached (D'Appolonia and Kunerth 1984). Since the stability also increased and the curve was kept constant a longer time, this could explain

the higher MTI value. However, the stability is also used to indicate the flour's tolerance to mixing and since it also increased, this indicates that the pomace made the dough more stable during mixing (D'Appolonia and Kunerth 1984). Also, the time it took to break down increased, signifying that the pomace delayed the breakdown of gluten. Since the pomace is mostly composed of sugars, which are hygroscopic, they help to maintain the water inside the gluten complex, keeping the gluten formed for a longer period of time. These results do not agree with what was found by D'Appolonia and Kunerth (1984) who found that as sugar level increased from 3% to 9%, stability decreased. Since the pomace contains other components, such as fiber, this could account for this difference. Water absorption only increased slightly, signifying that the pomace did not increase the water absorption properties of the flour. Also, the amount of water needed in order for the curve to reach the 500 BU line decreased with increasing level of pomace.

4.4.3 Physical Properties of Cookies

Table 4.4 shows the average width, height, hardness, and fracturability of prepared cookies with increasing levels of watermelon pomace.

Cookie width increased with incorporation of 10% pomace, and then remained constant, while height was not significantly different between the cookies with added pomace, but the one with 30% was significantly lower than the control. Studies have shown that the higher the sugar level, the higher the cookie diameter or spread and the lower the thickness or height (Sai-Manohar and Haridas-Rao 1997; Manley 2000; Pareyt and others 2009). In this study, it was intended that all the cookies had the same amount

of total sugars, yet differences can be due to the amount of different sugars. Since the pomace has 35% fructose and 11% glucose, the amounts of these sugars will vary in each cookie. Kweon and others (2009) found that when replacing sucrose with fructose and glucose in wire-cut cookies, width was lower with fructose and glucose than with sucrose, while height was higher for fructose and glucose. Pasha and others (2002) found that cookies with 50% sucrose/50% fructose got the highest width and the lowest thickness, while 100% fructose showed the highest thickness and lowest width.

Table 4.4. Physical Properties of Prepared Cookies

Level of Incorporation	Width (mm)	Height (mm)	Hardness (kg/s)	*Fracturability
0%	132.9 ± 1.9^{b}	23.8 ± 1.2^{a}	10.91 ± 2.04^{a}	3.69 ± 0.99^{ab}
10%	136.3 ± 3.1^{a}	22.7 ± 0.8^{ab}	11.27 ± 1.78^{a}	3.83 ± 0.91^{a}
20%	135.0 ± 3.7^{ab}	23.5 ± 0.5^{a}	9.60 ± 1.94^{b}	3.12 ± 1.12^{bc}
30%	134.3 ± 2.9^{ab}	21.9 ± 0.9^{b}	10.17 ± 1.98^{ab}	3.04 ± 0.93^{c}

Data reported is mean ± standard deviation (n=12 for width, 6 for height, and 36 for hardness and fracturability). Values with different letters in each column are significantly different (α=0.05). *Has no defined units.

In studies with apple pomace, Chen and others (1988) found that as the concentration of apple fiber increased, the diameter of the cookies decreased and their thickness increased. Due to the strong water-binding properties of the apple fiber, the dough did not spread well and the cookies were small and thick (Chen and others 1988).

Since these results don't show a discernible pattern like those in the studies mentioned, it may be due to room conditions and size of batch used. According to the method used, room conditions should be maintained at 21 ± 1 ºC with a relative humidity

of 30-50% since dough consistency and stickiness as well as cookie spread are affected by temperature and humidity (Gaines and Kwolek 1982; AACC 1995). It states that if conditions exceed the ones recommended, the variability in the data will increase (AACC 1995). In this study, room conditions could not be controlled and the room temperature was higher than the one recommended, being 26 ºC on average for all replicates. Also, batch sizes prepared were small in order to conserve materials since the amount of pomace was limited. Creamed mass size was recommended to be 30 batches in order to obtain consistent results (AACC 1995). In this case, it was not possible to make a lot of the creamed mass since it had to be different for each level of incorporation.

In terms of hardness, cookies with 20% watermelon pomace were softer than the control and those with 10% pomace. Sugar in cookie doughs dissolves during baking and then re-crystallizes when cooled, forming an amorphous glass making the cookie harder (Manley 2000). The crispness of cookies will also depend on the amount of sugar used and on its solubility properties (Kulp 1994). In general, the higher the sucrose used, the harder the cookies will be (Sai-Manohar and Haridas-Rao 1997; Manley 2000). On the other hand, if sugars that do not crystallize well are used, such as fructose, the cookies will be soft (Kulp 1994). Since the pomace is mostly composed of fructose, this sugar will be in higher concentrations with increasing level of pomace, making the cookies softer. Fracturability gives an indication of the force required to cause the cookie to crumble; the higher the value, the easier the cookie is fractured. Cookies with 30% pomace were less crumbly than the control and the cookies with 10% pomace, signifying that the increased level of pomace helped to maintain the structure of the cookie better.

Figure 4.1 shows the effect of addition of pomace on cookie color. In general, as pomace level increased, cookies became darker and less yellow. Also, redness increased with addition of 10% pomace, while later decreasing. This same pattern was observed with the raw dough (see Appendix 4), except that yellowness increased with addition of 10% pomace and later decreased. This indicates that effect of color is due to the addition of pomace and not to over-baking. The increase and then loss of redness coincides with the pattern for lycopene, which showed increasing loss as level of pomace increased (see Table 4.6).

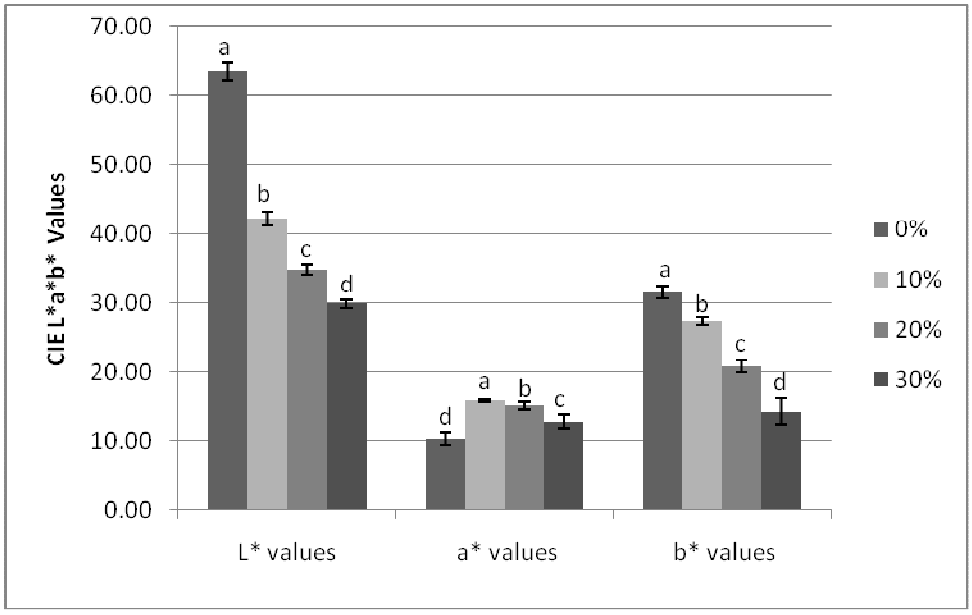

Figure 4.1. Comparison of CIE Color Values (L*, a*, b*) for Each Level of Dried Watermelon Pomace Incorporation (0, 10, 20, 30%) in Prepared Cookies. Data reported is mean ± standard deviation (n=18). Bars with different letters are significantly different (α=0.05).

4.4.4 Chemical Properties of Cookies

Table 4.5 shows the moisture content, water activity, and lycopene content of the cookies. Moisture content was significantly higher at 20 and 30% level of incorporation, signifying that the pomace helped retain more of the water present in the formulation. This could have been due to the increase in the concentration of fructose in the cookies. Moisture retention by sugars in cookies is caused by the hygroscopicity of the types of sugars added to the recipe (Kulp 1994). Fructose is very hygroscopic, beginning to absorb water at ~ 55% relative humidity (RH), while sucrose absorbs water only at higher relative humidities (≥ 65% RH) (Hanover 1993; Davis 1995). Because of this, fructose is an excellent humectant, helping to retain moisture in food products for an extended time period, even at low RH (Hanover 1993).

Table 4.5. Chemical Properties of Prepared Cookies

Level of Pomace Incorporation	**Cookie Moisture Content (%)**	**Water Activity**	**Lycopene Content (mg/g cookie)**
0%	4.99 ± 0.32^{bc}	0.393 ± 0.023^{a}	N/A
10%	4.86 ± 0.11^{c}	0.367 ± 0.020^{a}	0.067 ± 0.011^{c}
20%	5.43 ± 0.46^{ab}	0.385 ± 0.031^{a}	0.12 ± 0.02^{b}
30%	5.67 ± 0.43^{a}	0.380 ± 0.029^{a}	0.15 ± 0.02^{a}

Data reported is mean ± standard deviation (n=9). Values with different letters in each column are significantly different (α=0.05).

The water activity of the cookies was found to not be significantly different for all levels ($p = 0.2072$) and averaged 0.381 ± 0.027. Water activity is an important property for food safety, since it can predict its stability in terms of microbial growth,

chemical/biochemical reaction rates, and physical properties (Fontana 1998). In general, microbial growth will be inhibited at a a_w below 0.65 (Perera 2005). Most oxidation and enzymatic reactions will be inhibited as a_w decreases, but non-enzymatic reactions will occur at intermediate a_w ranges of about 0.4-0.65 (Perera 2005). Therefore, a a_w of around 0.2-0.4 gives a safe, stable product (Perera 2005).

The lycopene content of the cookies increased with increased level of incorporation of watermelon pomace. However, since lycopene is sensitive to heat, it was important to know how much loss occurred during baking. For this, it was necessary to calculate the theoretical amount of lycopene present in the cookies before baking. Table 4.6 shows these values, as well as the actual amount present in the cookies, and the lycopene loss during baking.

Table 4.6. Lycopene Loss in Prepared Cookies

Level of Incorporation	***Theoretical Lycopene Content in Raw Cookies (mg)**	**Lycopene Content in Cookies (mg)**	**Percent Loss (%)**
10%	3.78	2.65	29.80
20%	8.00	4.83	39.62
30%	11.13	5.56	50.08

*Values were calculated as mentioned in Section 4.3.4 of the Materials and Methods.
All values are on a dry matter basis.

As can be seen, lycopene loss was higher with increasing levels of watermelon pomace present in the cookies. This could be due to the effect that the food matrix can have on protection of lycopene during processing. The more pomace present, the less

protected it was, meaning that it was more susceptible to degradation by heat. Lycopene isomerization and oxidation are the main causes for lycopene losses during heat processing (Shi and Maguer 2000). Lycopene exists mostly in the all-trans form and during heating isomerizes to the cis form (Shi and Maguer 2000; Perkins-Veazie and others 2006a). The food matrix, like lipid and fiber components, may contribute to the stability of the all-trans form and prevent its isomerization (Shi and Maguer 2000). Nguyen and Schwartz (1998) found that lycopene was relatively resistant to isomerization during typical food processing of tomatoes and other related products, yet lycopene in organic solvent isomerized readily even in the absence of light and the presence of antioxidants. Apparently, the presence of fat slows down isomerization and protects both lycopene forms against oxidation (Xianquan and others 2005).

4.4.5 Sensory Evaluation

Table 4.7 shows the results for appearance, texture, and taste as evaluated by panelists during sensory panels. In terms of appearance, the control and the 10% cookie were not significantly different and had better scores than the cookies with 20 and 30% pomace. Some panelists liked the golden color that the cookies with 10% pomace had, but did not like the darker color of the other cookies, perceiving them as burned. Texture was not found to be significantly different for all cookies ($p = 0.0765$). In terms of taste, the cookies with 0 and 10% were not scored significantly differently from each other, while the cookies with 30% pomace where scored the lowest, but still under acceptable levels (neither like nor dislike). Many panelists commented that cookies with 20 and

30% pomace had a bitter/burnt taste, which could have been due to over-baking or to the taste of the pomace.

Table 4.7. Sensory Scores for Appearance, Texture, and Taste for Prepared Cookies

Level of Incorporation	Appearance	Texture	Taste
0%	2.8 ± 1.3^{b}	3.3 ± 1.4^{a}	3.6 ± 1.5^{bc}
10%	3.2 ± 1.5^{b}	3.2 ± 1.3^{a}	3.4 ± 1.6^{c}
20%	4.4 ± 2.0^{a}	3.5 ± 1.6^{a}	4.3 ± 2.0^{ab}
30%	4.9 ± 2.0^{a}	3.9 ± 1.8^{a}	5.0 ± 2.1^{a}

Data reported is mean ± standard deviation (n=60). Values with different letters for each column are significantly different from each other (α=0.05). Numbers correspond to a 9-point hedonic scale which goes as follows: 1 – Like extremely, 2 – Like very much, 3 –Like moderately, 4 – Like slightly, 5 – Neither like nor dislike, 6 –Dislike slightly, 7 – Dislike moderately, 8 – Dislike very much, 9 – Dislike extremely.

During preliminary studies, the sugar-snap micro-method (AACC Method 10-52) was used instead of the current method. These cookies had higher sugar content, and even though the sugar was reduced, it was observed that the cookies would increase in their tendency to burn with increasing levels of pomace. This was also true for the current method, but it wasn't as bad as with the other method, since these cookies had less sugar content. For the sensory, since the cookies were baked on insulated cookie sheets, the burning was not noticeable for all levels. Also, during the study, the pomace was tasted and was perceived as tasting burned. Therefore, in the cookies with 20 and 30% pomace, this bitter/burnt taste was more noticeable and was not as masked by the ingredients as with the cookies with 10% pomace. Nevertheless, the cookies were not

rated on average below the value “neither like nor dislike”, making them acceptable at all levels.

4.4.6 Nutritional Composition

Appendixes 7 and 8 show the nutrition labels obtained for control cookies (0%) and those with 30% pomace. Both were basically the same with only a slight reduction in the amount of carbohydrates present. Since there was only a small amount of dried watermelon pomace present, it wasn’t enough to improve the nutritional composition of the cookies. However, watermelon pomace was used successfully to decrease the levels of added sugar in the formulations without affecting the taste too much. Also, in terms of lycopene content, consuming two of the cookies with 10% watermelon pomace would give 2.9 mg of lycopene. Eating the same amount of fresh watermelon (44 g) would give 2.0 mg of lycopene, making these cookies a good source of this nutrient.

4.5 Conclusion

This study showed that it is possible to produce cookies with added dried watermelon pomace. Rheological evaluation showed that addition of watermelon pomace made the dough more tolerant to mixing and therefore more stable, which suggests that the dough became stronger. Cookies were not affected significantly in terms of spread and texture, although color became darker with increasing amounts of watermelon pomace. Also, panelists found all cookies acceptable in terms of appearance,

texture, and taste, although the darker color and bitter taste of cookies with more pomace were not as well received. However, addition of pomace increased the lycopene content of the cookies, and even though there was some degradation, the final products were good sources of the nutrient. Also, dried watermelon pomace could serve as a sugar substitute, if issues with it being bitter can be resolved.

In the future, it would be necessary to improve the drying of watermelon pomace in order to obtain a more acceptable product that can retain more of its color and flavor. This would allow more pomace to be added to the cookies in order to increase their dietary fiber content. Further research should also focus on testing the bioactivity and bioavailability of the lycopene present in the cookies to evaluate its antioxidant properties.

4.6 Acknowledgments

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CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

1. Dried watermelon pomace was found to be high in sugar and a concentrated source of lycopene, even though losses occurred during processing to obtain pomace and during drying.
2. The combination of vacuum/cabinet drying was found to be the best method for drying watermelon pomace in order to better preserve its color and lycopene content, although it wasn't the most efficient or cost-effective.
3. Drying for extended periods in a cabinet dryer affected the color and the sugar composition of the sample, causing browning and stickiness.
4. The lycopene content of dried watermelon pomace was stable after one year of storage when vacuum-packed.
5. Rheological evaluation showed that dried watermelon pomace made the dough more tolerant to mixing by making it more stable, suggesting that it made the dough stronger.

6. It is possible to produce cookies with added dried watermelon pomace. Cookies were not affected significantly in terms of spread and texture, although color became darker with increasing amounts of watermelon pomace. Also, panelists found all cookies acceptable in terms of appearance, texture, and taste, although the darker color and bitter taste of cookies with more pomace were not well received.
7. Addition of pomace increased the lycopene content of the cookies, and even though there was some degradation, the final products were good sources of the nutrient.
8. Dried watermelon pomace could serve as a sugar substitute in bakery products, if issues with it being bitter can be resolved.

5.2 Recommendations

1. Further research should be performed with other drying methods to observe how they affect the lycopene content and if they are better options for this type of product. Excess water should be removed initially by other methods like centrifugation in order to minimize the drying time and the effects on color, taste, and lycopene content. This would allow for more dried pomace to be added to cookies without affecting its color or taste so much.
2. The gelatinization and sticky-point temperatures of the watermelon pomace should be evaluated to assess adequate processing and storage conditions for the dried product.

3. Since the rheological evaluation suggested that the watermelon pomace increased dough strength, it would be interesting to see how it would behave when added to bread which requires strong flours in order to maintain its structure.
4. Further research should also focus on testing the bioactivity and bioavailability of the lycopene present in the cookies to evaluate its antioxidant properties.

APPENDICES

Appendix 1. Preliminary Research

During preliminary research, one experiment was performed to obtain the drying rate for the pomace at 70°C using the cabinet dryer, although samples were not sufficient to obtain information on the whole drying process. Samples were analyzed for water activity and moisture content before being placed in the oven and every two hours after that for ten hours total. The drying rate obtained from this experiment is shown in Figure A1. As can be seen here, water activity was nearly constant during the first 4 hours of drying after which it decreases.

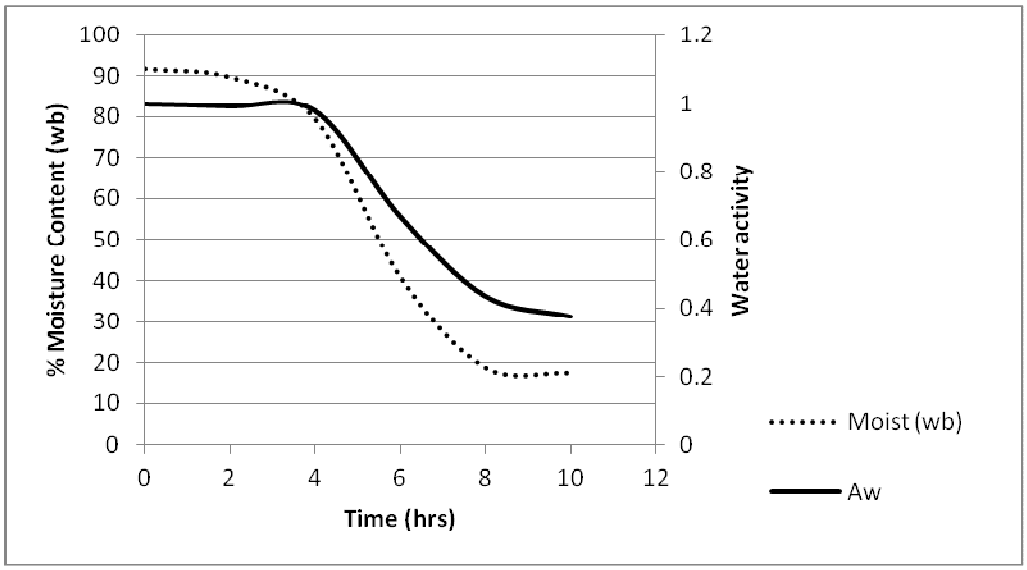


Figure A1. Moisture content and water activity as a function of drying time in a cabinet dryer at 70°C

After drying in the vacuum oven, it became obvious that it would take too long so it was decided to pre-dry to eliminate the free water available. This information was used as the basis for the decision to pre-dry in the cabinet dryer for 4 hours prior to vacuum drying.

Appendix 2. Moisture Content Values for Flour and Flour/Pomace Blends

Level of Incorporation	Moisture Content (%)
0%	12.56 ± 0.04
10%	12.28 ± 0.04
20%	12.42 ± 0.15
30%	12.29 ± 0.05

Data reported is mean ± standard deviation (n=3)

Appendix 3. Values Used for Lycopene Loss Calculations

Level of Incorporation	Dough Moisture Content (%)	Total Dough Used (g)	Raw Cookie Weight (g)	Cookie Weight (g)
10%	17.41 ± 0.20	78.1 ± 0.2	51.6 ± 0.6	43.8 ± 0.2
20%	17.86 ± 0.23	76.5 ± 0.6	54.2 ± 4.0	44.1 ± 1.0
30%	18.16 ± 0.32	74.8 ± 0.4	49.0 ± 2.1	42.8 ± 0.2

Data reported is mean ± standard deviation (n=3, except for moisture content where n=9). Cookie weights are based on the weight of 2 cookies.

Appendix 4. CIE L*a*b* Color Values for Raw Dough

Level of Incorporation	L* values	a* values	b* values
0%	61.36 ± 15.34	4.21 ± 1.06	23.98 ± 6.02
10%	33.78 ± 8.59	17.17 ± 4.30	29.25 ± 7.33
20%	27.58 ± 7.15	16.12 ± 4.04	23.69 ± 6.00
30%	23.92 ± 6.05	14.96 ± 3.78	19.43 ± 4.95

Data reported is mean ± standard deviation (n=9)

Appendix 5. Sensory Evaluation Score Sheet

Sample ID: _____

Please choose the option that best describes how you feel about:

1. Appearance

□	□	□	□	□	□	□	□	□
Like extremely	Like very much	Like moderately	Like slightly	Neither like nor dislike	Dislike slightly	Dislike moderately	Dislike very much	Dislike extremely

2. Texture

□	□	□	□	□	□	□	□	□
Like extremely	Like very much	Like moderately	Like slightly	Neither like nor dislike	Dislike slightly	Dislike moderately	Dislike very much	Dislike extremely

3. Taste

□	□	□	□	□	□	□	□	□
Like extremely	Like very much	Like moderately	Like slightly	Neither like nor dislike	Dislike slightly	Dislike moderately	Dislike very much	Dislike extremely

Comments:

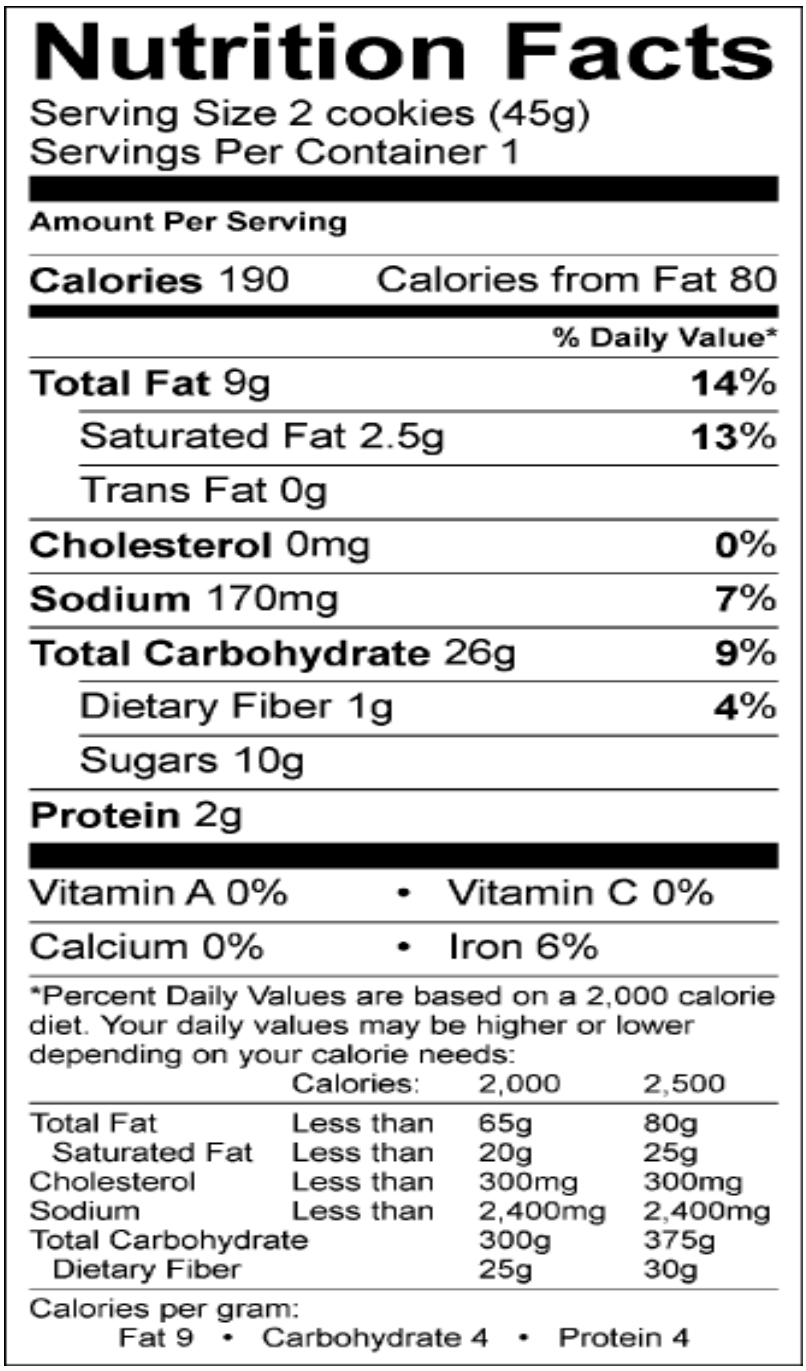
Appendix 6. Sample Randomization per Panelist (1 through 11)

1	2	3	4	5	6	7	8	9	10	11
868	462	375	576	868	462	375	576	868	462	375
576	868	462	375	576	868	462	375	576	868	462
375	576	868	462	375	576	868	462	375	576	868
462	375	576	868	462	375	576	868	462	375	576

Sample ID Key

Sample ID	Level of Incorporation
868	0%
576	10%
375	20%
462	30%

Appendix 7. Nutrition Label for Control Cookies (0%)



Nutrition Facts

Serving Size 2 cookies (45g)
Servings Per Container 1

Amount Per Serving

Calories 190	Calories from Fat 80
	% Daily Value*
Total Fat 9g	**14%**
Saturated Fat 2.5g	**13%**
Trans Fat 0g	
Cholesterol 0mg	**0%**
Sodium 170mg	**7%**
Total Carbohydrate 26g	**9%**
Dietary Fiber 1g	**4%**
Sugars 10g	
Protein 2g	

Vitamin A 0%	• Vitamin C 0%
Calcium 0%	• Iron 6%

*Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:

	Calories:	2,000	2,500
Total Fat	Less than	65g	80g
Saturated Fat	Less than	20g	25g
Cholesterol	Less than	300mg	300mg
Sodium	Less than	2,400mg	2,400mg
Total Carbohydrate		300g	375g
Dietary Fiber		25g	30g

Calories per gram:
Fat 9 • Carbohydrate 4 • Protein 4

Appendix 8. Nutrition Label for Cookies with Watermelon Pomace (30%)

Nutrition Facts

Serving Size 2 cookies (43g)
Servings Per Container 1

Amount Per Serving

Calories 190	Calories from Fat 80
	% Daily Value*
Total Fat 9g	**14%**
Saturated Fat 2.5g	**13%**
Trans Fat 0g	
Cholesterol 0mg	**0%**
Sodium 170mg	**7%**
Total Carbohydrate 24g	**8%**
Dietary Fiber 1g	**4%**
Sugars 10g	
Protein 2g	

Vitamin A 0% • Vitamin C 0%

Calcium 0% • Iron 4%

*Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:

	Calories:	2,000	2,500
Total Fat	Less than	65g	80g
Saturated Fat	Less than	20g	25g
Cholesterol	Less than	300mg	300mg
Sodium	Less than	2,400mg	2,400mg
Total Carbohydrate		300g	375g
Dietary Fiber		25g	30g

Calories per gram:
Fat 9 • Carbohydrate 4 • Protein 4

Appendix 9. SAS Programs and Outputs for Chapter III

9.1 Moisture Content - ca=samples cabinet dried Sept 2009, d=samples drum dried, cb=samples cabinet dried June 2010

```
data moisturecc;
input trt $ moisture;
cards;
ca 13.24378109
ca 13.21143193
ca 13.28963051
d 12.66865079
d 12.45709169
d 12.46382597
cb 11.9736
cb 11.9710
cb 11.8242
proc anova data=moisturecc;
class trt;
model moisture=trt;
means trt/tukey lines;
run;
```

The ANOVA Procedure

Class Level Information

Class	Levels	Values
trt	3	ca cb d

Number of Observations Read 9
Number of Observations Used 9

The ANOVA Procedure

Dependent Variable: moisture

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	2.64103673	1.32051837	169.91	<.0001
Error	6	0.04663228	0.00777205		
Corrected Total	8	2.68766901			

R-Square	Coeff Var	Root MSE	moisture Mean
0.982650	0.701512	0.088159	12.56702

Source	DF	Anova SS	Mean Square	F Value	Pr > F
trt	2	2.64103673	1.32051837	169.91	<.0001

The ANOVA Procedure

Tukey's Studentized Range (HSD) Test for moisture

Note: This test controls the Type I experimentwise error rate, but it generally has a hig her Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	6
Error Mean Square	0.007772
Critical Value of Studentized Range	4.33920
Minimum Significant Difference	0.2209

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	trt
A	13.24828	3	ca
B	12.52986	3	d
C	11.92293	3	cb

9.2 Ash

```
data ash;
input trt $ ash;
cards;
ca 3.497512438
ca 3.456051767
ca 3.471394517
d 3.462301587
d 3.472464057
d 3.447759705
cb 3.540921732
cb 3.571076255
cb 3.571074298
proc anova data=ash;
class trt;
```

model ash=trt;
means trt/tukey lines;
run;

The ANOVA Procedure

Class Level Information

Class	Levels	Values
trt	3	ca cb d

Number of Observations Read 9
Number of Observations Used 9

The ANOVA Procedure

Dependent Variable: ash

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	0.01763907	0.00881954	29.51	0.0008
Error	6	0.00179335	0.00029889		
Corrected Total	8	0.01943242			

R-Square	Coeff Var	Root MSE	ash Mean
0.907713	0.494105	0.017288	3.498951

Source	DF	Anova SS	Mean Square	F Value	Pr > F
trt	2	0.01763907	0.00881954	29.51	0.0008

The ANOVA Procedure

Tukey's Studentized Range (HSD) Test for ash

Note: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	6
Error Mean Square	0.000299
Critical Value of Studentized Range	4.33920
Minimum Significant Difference	0.0433

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	trt
A	3.56102	3	cb
B	3.47499	3	ca
B			
B	3.46084	3	d

9.3 Protein

```
data protein;
input trt $ protein;
cards;
ca 12.509
ca 12.452
ca 12.492
d 12.623
d 12.501
d 12.705
cb 6.51
cb 6.39
cb 6.63
proc anova data=protein;
class trt;
model protein=trt;
means trt/tukey lines;
run;
```

The ANOVA Procedure

Class Level Information

Class	Levels	Values
trt	3	ca cb d

Number of Observations Read 9
Number of Observations Used 9

The ANOVA Procedure

Dependent Variable: protein

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	72.91430067	36.45715033	4240.24	<.0001
Error	6	0.05158733	0.00859789		
Corrected Total	8	72.96588800			

R-Square	Coeff Var	Root MSE	protein Mean
0.999293	0.880187	0.092725	10.53467

Source	DF	Anova SS	Mean Square	F Value	Pr > F
trt	2	72.91430067	36.45715033	4240.24	<.0001

The ANOVA Procedure

Tukey's Studentized Range (HSD) Test for protein

Note: This test controls the Type I experimentwise error rate, but it generally has a hig her Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	6
Error Mean Square	0.008598
Critical Value of Studentized Range	4.33920
Minimum Significant Difference	0.2323

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	trt
A	12.60967	3	d
A			
A	12.48433	3	ca
B	6.51000	3	cb

9.4 Fat

```
data fat;
input trt $ fat;
cards;
ca 0.941607054
ca 0.603445479
ca 0.574731627
d 0.636136553
d 0.605899194
d 0.616790025
cb 0.382047001
cb 0.34163327
cb 0.418702024
proc anova data=fat;
class trt;
model fat=trt;
means trt/tukey lines;
run;
```

The ANOVA Procedure

Class Level Information

Class	Levels	Values
trt	3	ca cb d

Number of Observations Read 9
Number of Observations Used 9

The ANOVA Procedure

Dependent Variable: fat

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	0.17074499	0.08537250	5.91	0.0382
Error	6	0.08669965	0.01444994		
Corrected Total	8	0.25744465			

R-Square	Coeff Var	Root MSE	fat Mean
0.663230	21.12620	0.120208	0.568999

Source	DF	Anova SS	Mean Square	F Value	Pr > F
trt	2	0.17074499	0.08537250	5.91	0.0382

The ANOVA Procedure

Tukey's Studentized Range (HSD) Test for fat

Note: This test controls the Type I experimentwise error rate, but it generally has a hig her Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	6
Error Mean Square	0.01445
Critical Value of Studentized Range	4.33920
Minimum Significant Difference	0.3011

Means with the same letter are not significantly different.

Tukey Grouping		Mean	N	trt
	A	0.70659	3	ca
	A			
B	A	0.61961	3	d
B				
B		0.38079	3	cb

9.5 Sucrose

```
data sucrose;
input trt $ suc;
cards;
d 7.971225922
d 7.953054259
d 6.469948381
d 7.450252335
d 7.112172202
d 6.77034823
ca 11.03918803
ca 11.22705647
ca 11.2294684
ca 11.28026026
ca 11.21923143
ca 11.27260631
cb 2.983423598
cb 2.989555126
```

cb 3.042339623
cb 3.244603774
cb 3.169299242
cb 3.168276515

```
proc anova data=sucrose;
class trt;
model suc=trt;
means trt/tukey lines;
run;
```

The ANOVA Procedure

Class Level Information

Class	Levels	Values
trt	3	ca cb d

Number of Observations Read 18
Number of Observations Used 18

The ANOVA Procedure

Dependent Variable: suc

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	197.4700571	98.7350286	739.86	<.0001
Error	15	2.0017716	0.1334514		
Corrected Total	17	199.4718287			

R-Square	Coeff Var	Root MSE	suc Mean
0.989965	5.074052	0.365310	7.199573

Source	DF	Anova SS	Mean Square	F Value	Pr > F
trt	2	197.4700571	98.7350286	739.86	<.0001

The ANOVA Procedure

Tukey's Studentized Range (HSD) Test for suc

Note: This test controls the Type I experimentwise error rate, but it generally has a hig her Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	15
Error Mean Square	0.133451

Critical Value of Studentized Range	3.67338
Minimum Significant Difference	0.5478

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	trt
A	11.2113	6	ca
B	7.2878	6	d
C	3.0996	6	cb

9.6 Glucose

```
data glucose;
input trt $ gluc;
cards;
ca 8.864904177
ca 9.042406648
ca 9.066461638
ca 9.102658043
ca 9.109979294
ca 9.161318904
cb 11.22398453
cb 11.27309478
cb 11.24286792
cb 11.72828302
cb 11.75236742
cb 11.74212121
d 10.13808285
d 10.21592076
d 8.428032059
d 8.946332042
d 9.331107602
d 9.077037737

proc anova data=glucose;
class trt;
model gluc=trt;
means trt/tukey lines;
run;
```

The ANOVA Procedure

Class Level Information

Class	Levels	Values
trt	3	ca cb d

Number of Observations Read 18
Number of Observations Used 18

The ANOVA Procedure

Dependent Variable: gluc

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	21.18384685	10.59192342	55.18	<.0001
Error	15	2.87946180	0.19196412		
Corrected Total	17	24.06330864			

R-Square	Coeff Var	Root MSE	gluc Mean
0.880338	4.394874	0.438137	9.969276

Source	DF	Anova SS	Mean Square	F Value	Pr > F
trt	2	21.18384685	10.59192342	55.18	<.0001

The ANOVA Procedure

Tukey's Studentized Range (HSD) Test for gluc

Note: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	15
Error Mean Square	0.191964
Critical Value of Studentized Range	3.67338
Minimum Significant Difference	0.6571

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	trt
A	11.4938	6	cb
B	9.3561	6	d
B			
B	9.0580	6	ca

9.7 Fructose

```
data fructose;
input trt $ fruc;
cards;
ca 34.84391745
ca 35.4507913
ca 35.61721586
ca 35.78547294
ca 35.6741767
ca 35.81655124
cb 34.73365571
cb 34.73133462
cb 34.35283019
cb 35.71169811
cb 35.70416667
cb 35.46174242
d 29.98169972
d 29.74875979
d 24.64904721
d 28.22138587
d 26.88808299
d 25.41267436
proc anova data=fructose;
class trt;
model fruc=trt;
means trt/tukey lines;
run;
```

The ANOVA Procedure

Class Level Information

Class	Levels	Values
trt	3	ca cb d

Number of Observations Read 18
Number of Observations Used 18

The ANOVA Procedure

Dependent Variable: fruc

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	246.3815193	123.1907596	68.58	<.0001
Error	15	26.9435028	1.7962335		
Corrected Total	17	273.3250220			

R-Square	Coeff Var	Root MSE	fruc Mean
0.901423	4.097293	1.340236	32.71029

Source	DF	Anova SS	Mean Square	F Value	Pr > F
trt	2	246.3815193	123.1907596	68.58	<.0001

The ANOVA Procedure

Tukey's Studentized Range (HSD) Test for fruc

Note: This test controls the Type I experimentwise error rate, but it generally has a hig her Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	15
Error Mean Square	1.796234
Critical Value of Studentized Range	3.67338
Minimum Significant Difference	2.0099

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	trt
A	35.5314	6	ca
A			
A	35.1159	6	cb
B	27.4836	6	d

9.8 Water Activity

data water activity;
input trt $ wateract;
cards;
drum 0.270
vacuum 0.299
cabinet 0.263
drum 0.260
vacuum 0.295
cabineta 0.268
drum 0.261
vacuum 0.290
cabinet 0.258
drum 0.209

vacuum 0.266
cabineta 0.255
drum 0.210
vacuum 0.262
cabineta 0.261
drum 0.206
vacuum 0.269
cabineta 0.263
drum 0.225
vacuum 0.238
cabineta 0.298
drum 0.225
vacuum 0.245
cabineta 0.291
drum 0.224
vacuum 0.237
cabineta 0.287
drum 0.210
cabineta 0.152
drum 0.207
cabineta 0.150
drum 0.206
cabineta 0.148
cabinetb 0.258
cabinetb 0.258
cabinetb 0.260
proc anova;
class trt;
model wateract=trt;
means trt/tukey lines;
run;

The ANOVA Procedure

Class Level Information

Class	Levels	Values
trt	4	cabineta cabinetb drum vacuum

Number of Observations Read 36
Number of Observations Used 36

The ANOVA Procedure

Dependent Variable: wateract

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	0.00926319	0.00308773	2.14	0.1146
Error	32	0.04617681	0.00144303		
Corrected Total	35	0.05544000			

R-Square	Coeff Var	Root MSE	wateract Mean
0.167085	15.56851	0.037987	0.244000

Source	DF	Anova SS	Mean Square	F Value	Pr > F
trt	3	0.00926319	0.00308773	2.14	0.1146

The ANOVA Procedure

Tukey's Studentized Range (HSD) Test for wateract

Note: This test controls the Type I experimentwise error rate, but it generally has a hig her Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	32
Error Mean Square	0.001443
Critical Value of Studentized Range	3.83162
Minimum Significant Difference	0.0569
Harmonic Mean of Cell Sizes	6.545455

Note: Cell sizes are not equal.

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	trt
A	0.26678	9	vacuum
A			
A	0.25867	3	cabinetb
A			
A	0.24117	12	cabineta
A			
A	0.22608	12	drum

9.9 Lycopene Content (Dried Sample)

```
data lycopeneds;
input trt $ lycopene;
cards;
drum 0.747
drum 1.565
drum 1.431
drum 1.469
drum 1.435
drum 1.715
drum 1.925
drum 1.262
drum 1.428
drum 1.478
drum 1.541
drum 1.699
vacuum 2.354
vacuum 0.828
vacuum 1.616
vacuum 1.694
vacuum 0.915
vacuum 2.057
vacuum 1.856
vacuum 1.33
vacuum 1.548
cabineta 1.3
cabineta 1.399
cabineta 2.011
cabineta 1.4
cabineta 1.399
cabineta 1.511
cabineta 1.509
cabineta 1.794
cabineta 1.553
cabineta 1.631
cabineta 1.351
cabineta 1.488
cabinetb 1.697
cabinetb 1.556
cabinetb 1.033
proc anova;
class trt;
model lycopene=trt;
means trt/hovtest=levene(type=abs);
means trt/tukey lines;
run;
```

The ANOVA Procedure

Class Level Information

Class	Levels	Values
trt	4	cabineta cabinetb drum vacuum

Number of Observations Read 36
Number of Observations Used 36

The ANOVA Procedure

Dependent Variable: lycopene

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	0.07947128	0.02649043	0.24	0.8704
Error	32	3.58741347	0.11210667		
Corrected Total	35	3.66688475			

R-Square	Coeff Var	Root MSE	lycopene Mean
0.021673	22.10663	0.334823	1.514583

Source	DF	Anova SS	Mean Square	F Value	Pr > F
trt	3	0.07947128	0.02649043	0.24	0.8704

The ANOVA Procedure

Levene's Test for Homogeneity of lycopene Variance
ANOVA of Absolute Deviations from Group Means

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
trt	3	0.3088	0.1029	2.24	0.1026
Error	32	1.4705	0.0460		

The ANOVA Procedure

Level of trt	N	lycopene Mean	lycopene Std Dev
cabineta	12	1.52883333	0.20237222
cabinetb	3	1.42866667	0.34983472
drum	12	1.47458333	0.28665356
vacuum	9	1.57755556	0.49853187

The ANOVA Procedure

Tukey's Studentized Range (HSD) Test for lycopene

Note: This test controls the Type I experimentwise error rate, but it generally has a hig her Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	32
Error Mean Square	0.112107
Critical Value of Studentized Range	3.83162
Minimum Significant Difference	0.5015
Harmonic Mean of Cell Sizes	6.545455

Note: Cell sizes are not equal.

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	trt
A	1.5776	9	vacuum
A			
A	1.5288	12	cabineta
A			
A	1.4746	12	drum
A			
A	1.4287	3	cabinetb

9.10 Lycopene stability (0 = time 0, 0.5 = after 5 months, 1 = after 1 year, cd = cabinet dried, dd = drum dried, vd= vacuum dried)

data lycstabilitycd;
input trt lycopene;
cards;
0 1.300
0 1.399
0 2.011
0.5 0.980
0.5 0.497
0.5 1.032
1 0.682
1 0.689
1 0.637

```
proc anova data=lycstabilitycd;
class trt;
model lycopene=trt;
means trt/tukey lines;
run;
```

The ANOVA Procedure

Class Level Information

Class	Levels	Values
trt	3	0 1 0.5

Number of Observations Read 9
Number of Observations Used 9

The ANOVA Procedure

Dependent Variable: lycopene

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	1.37735622	0.68867811	8.75	0.0166
Error	6	0.47228733	0.07871456		
Corrected Total	8	1.84964356			

R-Square	Coeff Var	Root MSE	lycopene Mean
0.744660	27.36589	0.280561	1.025222

Source	DF	Anova SS	Mean Square	F Value	Pr > F
trt	2	1.37735622	0.68867811	8.75	0.0166

The ANOVA Procedure

Tukey's Studentized Range (HSD) Test for lycopene

Note: This test controls the Type I experimentwise error rate, but it generally has a hig her Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	6
Error Mean Square	0.078715
Critical Value of Studentized Range	4.33920
Minimum Significant Difference	0.7029

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	trt
A	1.5700	3	0
B	0.8363	3	0.5
B			
B	0.6693	3	1

```
data lycstabilitydd;
input trt lycopene;
cards;
0 0.747
0 1.565
0 1.431
0.5 1.639
0.5 1.386
0.5 1.465
1 1.729
1 1.670
1 1.931
proc anova data=lycstabilitydd;
class trt;
model lycopene=trt;
means trt/tukey lines;
run;
```

The ANOVA Procedure

Class Level Information

Class	Levels	Values
trt	3	0 1 0.5

Number of Observations Read 9
Number of Observations Used 9

The ANOVA Procedure

Dependent Variable: lycopene

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	0.42024200	0.21012100	2.77	0.1409
Error	6	0.45595600	0.07599267		
Corrected Total	8	0.87619800			

R-Square	Coeff Var	Root MSE	lycopene Mean
0.479620	18.29248	0.275668	1.507000

Source	DF	Anova SS	Mean Square	F Value	Pr > F
trt	2	0.42024200	0.21012100	2.77	0.1409

The ANOVA Procedure

Tukey's Studentized Range (HSD) Test for lycopene

Note: This test controls the Type I experimentwise error rate, but it generally has a hig her Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	6
Error Mean Square	0.075993
Critical Value of Studentized Range	4.33920
Minimum Significant Difference	0.6906

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	trt
A	1.7767	3	1
A			
A	1.4967	3	0.5
A			
A	1.2477	3	0

```
data lycstabilityvd;
input trt lycopene;
cards;
0 2.354
0 0.828
0 1.616
0.5 1.278
```

0.5 1.761
0.5 1.944
1 1.355
1 1.579
1 1.415

```
proc anova data=lycstabilityvd;
class trt;
model lycopene=trt;
means trt/tukey lines;
run;
```

The ANOVA Procedure

Class Level Information

Class	Levels	Values
trt	3	0 1 0.5

Number of Observations Read 9
Number of Observations Used 9

The ANOVA Procedure

Dependent Variable: lycopene

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	0.07086467	0.03543233	0.15	0.8648
Error	6	1.42842333	0.23807056		
Corrected Total	8	1.49928800			

R-Square	Coeff Var	Root MSE	lycopene Mean
0.047266	31.07801	0.487925	1.570000

Source	DF	Anova SS	Mean Square	F Value	Pr > F
trt	2	0.07086467	0.03543233	0.15	0.8648

The ANOVA Procedure

Tukey's Studentized Range (HSD) Test for lycopene

Note: This test controls the Type I experimentwise error rate, but it generally has a hig her Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	6
Error Mean Square	0.238071
Critical Value of Studentized Range	4.33920
Minimum Significant Difference	1.2224

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	trt
A	1.6610	3	0.5
A			
A	1.5993	3	0
A			
A	1.4497	3	1

9.11 Lycopene Comparisons (Dry Matter Basis)

```
data lycopene;
input trt $ lycopene;
cards;
fresh 2.059492
fresh 1.971896
fresh 2.149978
fresh 2.072972
fresh 2.196392
fresh 2.02641
fresh 2.554058
fresh 1.601631
fresh 2.497062
fresh 1.677274
fresh 3.285236
fresh 2.512567
drum 0.856212
drum 1.79455
```

drum 1.641078
drum 1.695952
drum 1.656062
drum 1.979123
drum 2.215978
drum 1.453286
drum 1.644603
drum 1.690111
drum 1.761424
drum 1.942609
vacuum 2.802016
vacuum 0.984851
vacuum 1.923061
vacuum 2.022564
vacuum 1.092295
vacuum 2.455718
vacuum 2.182561
vacuum 1.564204
vacuum 1.820009
cabinet 1.530737
cabinet 1.647256
cabinet 2.368309
cabinet 1.640584
cabinet 1.638838
cabinet 1.770307
cabinet 1.753883
cabinet 2.084766
cabinet 1.803932
cabinet 1.880663
cabinet 1.557552
cabinet 1.716082
proc anova;
class trt;
model lycopene=trt;
means trt/hovtest=levene(type=abs);
means trt/tukey lines;
run;

The ANOVA Procedure

Class Level Information

Class	Levels	Values
trt	4	cabinet drum fresh vacuum

Number of Observations Read 45
Number of Observations Used 45

The ANOVA Procedure

Dependent Variable: lycopene

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	1.88424128	0.62808043	3.74	0.0182
Error	41	6.87699554	0.16773160		
Corrected Total	44	8.76123682			

R-Square	Coeff Var	Root MSE	lycopene Mean
0.215066	21.63725	0.409550	1.892803

Source	DF	Anova SS	Mean Square	F Value	Pr > F
trt	3	1.88424128	0.62808043	3.74	0.0182

The ANOVA Procedure

Levene's Test for Homogeneity of lycopene Variance
ANOVA of Absolute Deviations from Group Means

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
trt	3	0.5112	0.1704	2.40	0.0814
Error	41	2.9072	0.0709		

The ANOVA Procedure

Level of trt	N	lycopene Mean	lycopene Std Dev
cabinet	12	1.78274242	0.23799667
drum	12	1.69424900	0.32984144
fresh	12	2.21708067	0.45099727
vacuum	9	1.87191989	0.59369563

The ANOVA Procedure

Tukey's Studentized Range (HSD) Test for lycopene

Note: This test controls the Type I experimentwise error rate, but it generally has a hig her Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	41
Error Mean Square	0.167732
Critical Value of Studentized Range	3.78673
Minimum Significant Difference	0.466
Harmonic Mean of Cell Sizes	11.07692

Note: Cell sizes are not equal.

Means with the same letter are not significantly different.

Tukey Grouping		Mean	N	trt
	A	2.2171	12	fresh
	A			
B	A	1.8719	9	vacuum
B	A			
B	A	1.7827	12	cabinet
B				
B		1.6942	12	drum

9.12 Color L (f =fresh, d= drum dried, v=vacuum dried, c = cabinet dried)

data color;
input trt $ L;
cards;
f 29.35
f 28.77
f 28.27
f 30.74
f 30.85
f 30.53
f 35.71
f 32.68
f 32.06
f 30.2
f 30.14

f 30.36
f 28.79
f 29.25
f 28.87
f 31.05
f 31.22
f 31.08
f 31.11
f 30.9
f 31.22
f 35.06
f 30.76
f 32.21
f 32.91
f 33.84
f 30.6
f 31.79
f 30.94
f 31.03
f 31.75
f 31.75
f 31.85
f 30.48
f 30.2
f 30.35
d 48.6
d 48.59
d 48.59
d 51.6
d 51.78
d 51.78
d 48.95
d 48.91
d 48.99
d 47.58
d 47.3
d 47.34
d 49.81
d 49.85
d 49.96
d 47.64
d 46.63
d 46.85
d 49.22
d 49.34
d 49.31

d 49.48
d 49.79
d 50.17
d 50.65
d 50.61
d 50.65
d 52.15
d 52.29
d 52.27
d 53.38
d 53.9
d 53.37
d 52.64
d 52.8
d 52.76
v 54.75
v 54.42
v 54.27
v 56.36
v 58.01
v 57.48
v 58.88
v 58.3
v 59.07
v 55.42
v 55.74
v 55.33
v 54.61
v 54.61
v 54.6
v 54.23
v 54.14
v 54.32
v 57.4
v 57.66
v 57.23
v 59.22
v 59.72
v 59.16
v 56.8
v 56.37
v 56.38
c 58.11
c 58.01
c 58.07
c 52.12

c 52.08
c 52.08
c 56.84
c 56.81
c 56.53
c 51.33
c 51.54
c 51.67
c 49.45
c 48.98
c 48.67
c 48.77
c 48.34
c 47.99
c 54.98
c 55.35
c 54.65
c 53.81
c 54.1
c 54.06
c 52.99
c 52.84
c 53.27
c 56.51
c 56.51
c 56.15
c 55.5
c 55.34
c 55.59
c 57.86
c 58.45
c 57.16

```
proc anova data=color;
class trt;
model L=trt;
means trt/tukey lines;
run;
```

The ANOVA Procedure

Class Level Information

Class	Levels	Values
trt	4	c d f v

Number of Observations Read	135
Number of Observations Used	135

The ANOVA Procedure

Dependent Variable: L

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	13633.59387	4544.53129	893.46	<.0001
Error	131	666.32360	5.08644		
Corrected Total	134	14299.91748			

R-Square	Coeff Var	Root MSE	L Mean
0.953404	4.763860	2.255314	47.34215

Source	DF	Anova SS	Mean Square	F Value	Pr > F
trt	3	13633.59387	4544.53129	893.46	<.0001

The ANOVA Procedure

Tukey's Studentized Range (HSD) Test for L

Note: This test controls the Type I experimentwise error rate, but it generally has a hig her Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	131
Error Mean Square	5.08644
Critical Value of Studentized Range	3.68023
Minimum Significant Difference	1.4398
Harmonic Mean of Cell Sizes	33.23077

Note: Cell sizes are not equal.

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	trt
A	56.4622	27	v
B	53.9586	36	c
C	50.1536	36	d
D	31.0742	36	f

9.13 Color a

```
data color;
input trt $ a;
cards;
f 31.64
d 19.62
v 22.26
c 13.37
f 29.91
d 19.84
v 22.43
c 13.27
f 31.51
d 19.83
v 22.28
c 13.21
f 30.55
d 18.02
v 20.94
c 17.85
f 30.37
d 17.68
v 19.79
c 18.02
f 31.99
d 17.71
v 20.37
c 18.19
f 28.55
d 19.1
v 19.03
c 15.51
f 32.71
d 19.14
v 19.7
c 15.41
f 33.63
d 19.06
v 18.94
c 15.27
f 34.68
d 19.3
v 19.19
c 16.5
f 34.63
```

d 19.33
v 18.88
c 16.49
f 34.33
d 19.4
v 19.33
c 16.54
f 34.07
d 18.32
v 19.61
c 16.27
f 34.79
d 18.34
v 19.46
c 16.4
f 35.36
d 18.36
v 19.33
c 17.03
f 35.41
d 19.39
v 20.62
c 17.31
f 35.07
d 19.82
v 20.67
c 17.36
f 34.94
d 19.73
v 20.32
c 17.24
f 33.2
d 21.88
v 18.78
c 15.81
f 33.73
d 21.78
v 18.32
c 15.54
f 32.78
d 21.65
v 18.38
c 16.14
f 29.63
d 21.2
v 16.9

c 16.88
f 34.72
d 21.24
v 16.56
c 16.74
f 31.7
d 21.21
v 16.75
c 16.62
f 29.51
d 20.71
v 19.02
c 16.6
f 28.46
d 20.75
v 18.84
c 16.78
f 32.1
d 21.07
v 18.92
c 16.47
f 34.22
d 20.38
c 14.05
f 35.68
d 20.28
c 14.17
f 35.43
d 20.33
c 14.77
f 35.9
d 19.7
c 15.55
f 35.67
d 19.74
c 5.86
f 35.56
d 19.64
c 15.57
f 35.63
d 20.26
c 13.1
f 35.25
d 20.17
c 12.71
f 34.67

d 20.16
c 13.63

```
proc anova data=color;
class trt;
model a=trt;
means trt/tukey lines;
```

The ANOVA Procedure

Class Level Information

Class	Levels	Values
trt	4	c d f v

Number of Observations Read 135
Number of Observations Used 135

The ANOVA Procedure

Dependent Variable: a

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	6432.914848	2144.304949	619.97	<.0001
Error	131	453.090194	3.458704		
Corrected Total	134	6886.005041			

R-Square	Coeff Var	Root MSE	a Mean
0.934201	8.380173	1.859759	22.19237

Source	DF	Anova SS	Mean Square	F Value	Pr > F
trt	3	6432.914848	2144.304949	619.97	<.0001

The ANOVA Procedure

Tukey's Studentized Range (HSD) Test for a

Note: This test controls the Type I experimentwise error rate, but it generally has a hig her Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	131
Error Mean Square	3.458704
Critical Value of Studentized Range	3.68023

Minimum Significant Difference	1.1873
Harmonic Mean of Cell Sizes	33.23077

Note: Cell sizes are not equal.

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	trt
A	33.2772	36	f
B	19.8372	36	d
B			
B	19.4674	27	v
C	15.5064	36	c

9.14 Color b

```
data color;
input trt $ a;
cards;
f 19.75
f 18.84
f 19.24
f 21.62
f 21.95
f 22.17
f 22.47
f 21.18
f 20.45
f 22
f 21.85
f 21.69
f 22.24
f 23.8
f 22.93
f 21.2
f 21.24
f 20.89
f 19.58
f 20.08
f 19.52
f 18.38
f 20.71
f 18.87
```

f 22.25
f 21.2
f 22.89
f 24.02
f 24.34
f 24.57
f 22.03
f 21.75
f 21.73
f 22.94
f 22.56
f 22.78
d 32.7
d 32.95
d 32.82
d 31.95
d 31.69
d 31.68
d 30.16
d 30.36
d 30.25
d 30.82
d 30.17
d 30.24
d 33.17
d 33.19
d 33.46
d 33.1
d 33.03
d 33.15
d 34.98
d 35.07
d 34.83
d 32.91
d 33.07
d 33.24
d 32.54
d 32.59
d 33.31
d 32.78
d 32.83
d 32.94
d 30.9
d 31.11
d 30.72
d 31.33

d 31.27
d 31.71
v 26.81
v 26.54
v 26.08
v 26.88
v 26.57
v 26.82
v 24.95
v 25.27
v 24.81
v 26.76
v 26.46
v 26.83
v 26.97
v 26.76
v 26.89
v 29.28
v 29.45
v 28.48
v 26.59
v 26.29
v 26.04
v 25.92
v 25.87
v 25.96
v 28.05
v 27.48
v 27.62
c 24.05
c 23.81
c 24.03
c 29.01
c 29.29
c 29.71
c 27.48
c 27.45
c 27.26
c 27.81
c 27.98
c 28.34
c 28.29
c 27.89
c 28.3
c 27.84
c 27.3

c 26.95
c 27.43
c 27.08
c 27.58
c 28.65
c 28.53
c 28.28
c 26.86
c 27.13
c 27.17
c 23.92
c 24.29
c 25.31
c 26.22
c 26.69
c 26.11
c 23.78
c 23.18
c 23.65
proc anova data=color;
class trt;
model a=trt;
means trt/tukey lines;
run;

The ANOVA Procedure

Class Level Information

Class	Levels	Values
trt	4	c d f v

Number of Observations Read 135
Number of Observations Used 135

The ANOVA Procedure

Dependent Variable: a

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	2084.216071	694.738690	305.88	<.0001
Error	131	297.540006	2.271298		
Corrected Total	134	2381.756077			

R-Square	Coeff Var	Root MSE	a Mean
0.875075	5.611329	1.507083	26.85785

Source	DF	Anova SS	Mean Square	F Value	Pr > F
trt	3	2084.216071	694.738690	305.88	<.0001

The ANOVA Procedure

Tukey's Studentized Range (HSD) Test for a

Note: This test controls the Type I experimentwise error rate, but it generally has a hig her Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	131
Error Mean Square	2.271298
Critical Value of Studentized Range	3.68023
Minimum Significant Difference	0.9621
Harmonic Mean of Cell Sizes	33.23077

Note: Cell sizes are not equal.

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	trt
A	32.3061	36	d
B	26.7958	36	c
B			
B	26.7567	27	v
C	21.5475	36	f

Appendix 10. SAS Programs and Outputs for Chapter IV

10.1 Width

```
data width;
input trt width;
cards;
0 130
0 131
0 132
0 130
0 134
0 132
0 133
0 133
0 135
0 135
0 135
0 134.5
10 133
10 134
10 131
10 133
10 139
10 135
10 137
10 137.5
10 138.5
10 139
10 141
10 138
20 133
20 132
20 132
20 132
20 140
20 139.5
20 141
20 139
20 133
20 131
20 134
20 133
30 134
```

30 132.5
30 133
30 133
30 136
30 139.5
30 136
30 139.5
30 132
30 131
30 134.5
30 131

```
proc anova data=width;
class trt;
model width=trt;
means trt/tukey lines;
run;
```

The ANOVA Procedure

Class Level Information

Class	Levels	Values
trt	4	0 10 20 30

Number of Observations Read 48
Number of Observations Used 48

The ANOVA Procedure

Dependent Variable: width

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	74.1250000	24.7083333	2.79	0.0513
Error	44	389.1250000	8.8437500		
Corrected Total	47	463.2500000			

R-Square	Coeff Var	Root MSE	width Mean
0.160011	2.208984	2.973844	134.6250

Source	DF	Anova SS	Mean Square	F Value	Pr > F
trt	3	74.12500000	24.70833333	2.79	0.0513

The ANOVA Procedure

Tukey's Studentized Range (HSD) Test for width

Note: This test controls the Type I experimentwise error rate, but it generally has a hig her Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	44
Error Mean Square	8.84375
Critical Value of Studentized Range	3.77596
Minimum Significant Difference	3.2416

Means with the same letter are not significantly different.

Tukey Grouping		Mean	N	trt
	A	136.333	12	10
	A			
B	A	134.958	12	20
B	A			
B	A	134.333	12	30
B				
B		132.875	12	0

10.2 Height

```
data height;
input trt height;
cards;
0 25
0 25
0 23
0 24
0 23.5
0 22
10 23
10 24
10 22
10 23
10 22
10 22
20 23
```

```
20 24
20 23
20 23
20 24
20 24
30 23
30 23
30 22
30 21.5
30 21
30 21
proc anova data=height;
class trt;
model height=trt;
means trt/tukey lines;
run;
```

The ANOVA Procedure

Class Level Information

Class	Levels	Values
trt	4	0 10 20 30

Number of Observations Read 24
Number of Observations Used 24

The ANOVA Procedure

Dependent Variable: height

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	12.54166667	4.18055556	5.25	0.0078
Error	20	15.91666667	0.79583333		
Corrected Total	23	28.45833333			

R-Square	Coeff Var	Root MSE	height Mean
0.440703	3.885713	0.892095	22.95833

Source	DF	Anova SS	Mean Square	F Value	Pr > F
trt	3	12.54166667	4.18055556	5.25	0.0078

The ANOVA Procedure

Tukey's Studentized Range (HSD) Test for height

Note: This test controls the Type I experimentwise error rate, but it generally has a hig her Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	20
Error Mean Square	0.795833
Critical Value of Studentized Range	3.95829
Minimum Significant Difference	1.4416

Means with the same letter are not significantly different.

Tukey Grouping		Mean	N	trt
	A	23.7500	6	0
	A			
	A	23.5000	6	20
	A			
B	A	22.6667	6	10
B				
B		21.9167	6	30

10.3 Hardness

```
data hardness;
input trt hardness;
cards;
0 10.419
0 14.407
0 10.882
0 12.067
0 12.924
0 9.028
0 12.442
0 11.284
0 12.833
0 14.112
0 14.163
0 9.061
```

0 14.032
0 13.399
0 11.856
0 11.480
0 13.680
0 10.596
0 10.610
0 10.524
0 10.844
0 7.309
0 11.933
0 9.178
0 9.536
0 10.298
0 11.503
0 9.168
0 12.209
0 8.624
0 7.790
0 9.883
0 9.441
0 7.273
0 10.706
0 7.281
10 14.205
10 16.258
10 13.371
10 12.541
10 12.399
10 10.013
10 12.413
10 13.569
10 12.386
10 11.695
10 11.624
10 9.406
10 11.805
10 12.935
10 12.867
10 11.685
10 11.334
10 10.298
10 11.978
10 10.212
10 10.333
10 12.914

10 10.052
10 10.837
10 11.463
10 11.882
10 10.225
10 10.792
10 9.917
10 7.707
10 10.306
10 9.310
10 10.122
10 8.580
10 10.448
10 7.638
20 7.912
20 9.374
20 9.311
20 7.991
20 9.345
20 5.361
20 7.810
20 10.764
20 11.152
20 10.419
20 11.910
20 7.561
20 10.307
20 10.576
20 9.636
20 11.682
20 11.985
20 6.870
20 11.568
20 10.747
20 9.662
20 7.974
20 10.952
20 6.727
20 9.672
20 8.255
20 9.953
20 10.689
20 11.722
20 5.691
20 11.501
20 11.492

```
20 10.636
20 12.074
20 10.478
20 5.674
30 11.447
30 11.679
30 13.038
30 10.332
30 11.334
30 9.328
30 11.754
30 9.353
30 11.551
30 13.099
30 11.305
30 7.670
30 9.865
30 10.750
30 11.495
30 11.695
30 9.878
30 7.174
30 11.336
30 10.916
30 11.722
30 13.360
30 12.485
30 8.567
30 8.813
30 10.148
30 9.740
30 10.917
30 9.841
30 5.346
30 8.333
30 7.811
30 11.624
30 8.618
30 5.344
30 8.450
proc anova data=hardness;
class trt;
model hardness=trt;
means trt/tukey lines;
run;
```

The ANOVA Procedure

Class Level Information

Class	Levels	Values
trt	4	0 10 20 30

Number of Observations Read 144
Number of Observations Used 144

The ANOVA Procedure

Dependent Variable: hardness

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	60.4522919	20.1507640	5.37	0.0016
Error	140	525.1986918	3.7514192		
Corrected Total	143	585.6509838			

R-Square	Coeff Var	Root MSE	hardness Mean
0.103222	18.47258	1.936858	10.48504

Source	DF	Anova SS	Mean Square	F Value	Pr > F
trt	3	60.45229192	20.15076397	5.37	0.0016

The ANOVA Procedure

Tukey's Studentized Range (HSD) Test for hardness

Note: This test controls the Type I experimentwise error rate, but it generally has a hig her Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	140
Error Mean Square	3.751419
Critical Value of Studentized Range	3.67718
Minimum Significant Difference	1.187

Means with the same letter are not significantly different.

Tukey Grouping		Mean	N	trt
	A	11.2644	36	10
	A			
	A	10.9104	36	0
	A			
B	A	10.1699	36	30
B				
B		9.5954	36	20

10.4 Fracturability

```
data fracturability;
input trt frac;
cards;
0 3.707357442
0 3.698387928
0 3.730868157
0 3.326075587
0 3.810158751
0 2.442841368
0 3.84758769
0 3.759250022
0 3.826490815
0 3.456323326
0 3.986965366
0 2.100940506
0 4.908989015
0 5.882229962
0 5.721072875
0 4.449463966
0 4.808202767
0 2.983040826
0 4.104621498
0 3.914462606
0 4.53040697
0 4.273900027
0 4.897573705
0 2.365660886
0 3.424749633
0 5.251975466
0 4.165762648
```

0 3.551218262
0 3.181555025
0 2.072107416
0 3.443592084
0 3.158877116
0 2.59668208
0 2.703305433
0 2.851580611
0 1.800429727
10 4.248127806
10 4.802550433
10 4.550111246
10 4.945370414
10 4.393747172
10 2.480862147
10 4.4147175
10 4.242467132
10 4.143864522
10 3.751582961
10 3.927870219
10 2.038066918
10 3.990033543
10 4.153978233
10 5.979334823
10 4.162154356
10 4.676439079
10 2.270657966
10 4.262714669
10 4.492837879
10 4.176520467
10 4.116668821
10 4.104328861
10 2.506842251
10 3.413739693
10 4.190111875
10 4.00604371
10 3.972318545
10 3.617796141
10 1.819671644
10 3.392590702
10 3.865042294
10 3.605225965
10 3.808380052
10 3.515058981
10 1.73397017
20 2.742197895

20 2.505901181
20 2.586549507
20 2.515898816
20 2.59955335
20 1.220922262
20 2.888080355
20 3.45850257
20 3.841187906
20 3.733935742
20 2.749077781
20 1.973366764
20 5.090424343
20 4.587942593
20 3.4326638
20 3.168090891
20 5.017515936
20 1.834500124
20 5.081193854
20 4.41117299
20 4.692493495
20 4.55687841
20 5.201830291
20 1.903326572
20 2.424195684
20 2.734398491
20 2.45516829
20 3.14679054
20 2.873534946
20 1.252022266
20 2.937364084
20 2.482350202
20 3.062779465
20 3.237052516
20 2.638865033
20 1.248828594
30 3.597246173
30 3.811025647
30 3.667226321
30 4.026779328
30 3.666534105
30 2.156847318
30 3.424363629
30 2.95743191
30 3.449866438
30 3.425211317
30 3.557719227

```
30 1.818291214
30 3.117669527
30 3.819629274
30 3.505101389
30 3.030277508
30 3.048909754
30 1.468170324
30 4.116381653
30 4.226237253
30 5.080040671
30 4.550135388
30 3.521613282
30 2.130562115
30 2.388745349
30 2.719250346
30 2.820765505
30 3.821594206
30 2.477242909
30 1.281167002
30 2.106585992
30 2.280110524
30 2.505418557
30 2.276795641
30 1.125735505
30 2.403201353
proc anova data=fracturability;
class trt;
model frac=trt;
means trt/tukey lines;
run;
```

The ANOVA Procedure

Class Level Information

Class	Levels	Values
trt	4	0 10 20 30

Number of Observations Read	144
Number of Observations Used	144

The ANOVA Procedure

Dependent Variable: frac

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	17.0346812	5.6782271	5.83	0.0009
Error	140	136.4237647	0.9744555		
Corrected Total	143	153.4584459			

R-Square	Coeff Var	Root MSE	frac Mean
0.111005	28.88190	0.987145	3.417868

Source	DF	Anova SS	Mean Square	F Value	Pr > F
trt	3	17.03468121	5.67822707	5.83	0.0009

The ANOVA Procedure

Tukey's Studentized Range (HSD) Test for frac

Note: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	140
Error Mean Square	0.974455
Critical Value of Studentized Range	3.67718
Minimum Significant Difference	0.605

Means with the same letter are not significantly different.

Tukey Grouping		Mean	N	trt
	A	3.8270	36	10
	A			
B	A	3.6871	36	0
B				
B	C	3.1191	36	20
	C			
	C	3.0383	36	30

10.5 Cookie Moisture

```
data moisturecookies;
input trt moisture;
cards;
0 5.1183
0 5.1396
0 5.1278
0 4.5176
0 4.535
0 4.6759
0 5.2866
0 5.2697
0 5.2417
10 4.7886
10 4.7087
10 4.8633
10 4.8438
10 4.8056
10 4.7903
10 4.9933
10 5.0052
10 4.9779
20 5.7279
20 5.2278
20 5.1989
20 4.9821
20 4.9537
20 4.9334
20 5.9051
20 6.0054
20 5.9354
30 5.3991
30 5.3563
30 5.3667
30 5.412
30 5.3962
30 5.3775
30 6.2481
30 6.2481
30 6.2609
proc anova data=moisturecookies;
class trt;
model moisture=trt;
means trt/tukey lines;
run;
```

The ANOVA Procedure

Class Level Information

Class	Levels	Values
trt	4	0 10 20 30

Number of Observations Read 36
Number of Observations Used 36

The ANOVA Procedure

Dependent Variable: moisture

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	3.85228597	1.28409532	10.06	<.0001
Error	32	4.08257179	0.12758037		
Corrected Total	35	7.93485777			

R-Square	Coeff Var	Root MSE	moisture Mean
0.485489	6.817084	0.357184	5.239542

Source	DF	Anova SS	Mean Square	F Value	Pr > F
trt	3	3.85228597	1.28409532	10.06	<.0001

The ANOVA Procedure

Tukey's Studentized Range (HSD) Test for moisture

Note: This test controls the Type I experimentwise error rate, but it generally has a hig her Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	32
Error Mean Square	0.12758
Critical Value of Studentized Range	3.83162
Minimum Significant Difference	0.4562

Means with the same letter are not significantly different.

Tukey Grouping		Mean	N	trt
	A	5.6739	9	30
	A			
B	A	5.4300	9	20
B				
B	C	4.9902	9	0
	C			
	C	4.8641	9	10

10.6 Cookie Water Activity

```
data awcookies;
input trt aw;
cards;
0 0.391
0 0.393
0 0.389
0 0.369
0 0.367
0 0.365
0 0.419
0 0.421
0 0.42
10 0.35
10 0.349
10 0.349
10 0.359
10 0.359
10 0.357
10 0.393
10 0.392
10 0.392
20 0.379
20 0.379
20 0.379
20 0.354
20 0.353
20 0.353
20 0.424
20 0.424
20 0.424
```

```
30 0.356
30 0.354
30 0.354
30 0.368
30 0.368
30 0.368
30 0.418
30 0.418
30 0.417
proc anova data=awcookies;
class trt;
model aw=trt;
means trt/tukey lines;
run;
```

The ANOVA Procedure

Class Level Information

Class	Levels	Values
trt	4	0 10 20 30

Number of Observations Read 36
Number of Observations Used 36

The ANOVA Procedure

Dependent Variable: aw

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	0.00325711	0.00108570	1.61	0.2072
Error	32	0.02162911	0.00067591		
Corrected Total	35	0.02488622			

R-Square	Coeff Var	Root MSE	aw Mean
0.130880	6.819714	0.025998	0.381222

Source	DF	Anova SS	Mean Square	F Value	Pr > F
trt	3	0.00325711	0.00108570	1.61	0.2072

The ANOVA Procedure

Tukey's Studentized Range (HSD) Test for aw

Note: This test controls the Type I experimentwise error rate, but it generally has a hig her Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	32
Error Mean Square	0.000676
Critical Value of Studentized Range	3.83162
Minimum Significant Difference	0.0332

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	trt
A	0.39267	9	0
A			
A	0.38544	9	20
A			
A	0.38011	9	30
A			
A	0.36667	9	10

10.7 Cookie Lycopene Content

```
data lyccookies;
input trt lycopene;
cards;
10 0.051
10 0.07
10 0.062
10 0.05
10 0.081
10 0.066
10 0.083
10 0.07
10 0.069
20 0.12
20 0.147
20 0.106
20 0.112
20 0.142
20 0.119
```

```
20 0.094
20 0.124
20 0.138
30 0.159
30 0.131
30 0.158
30 0.158
30 0.114
30 0.136
30 0.182
30 0.134
30 0.14
proc anova data=lyccookies;
class trt;
model lycopene=trt;
means trt/tukey lines;
run;
```

The ANOVA Procedure

Class Level Information

Class	Levels	Values
trt	3	10 20 30

Number of Observations Read 27
Number of Observations Used 27

The ANOVA Procedure

Dependent Variable: lycopene

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	0.02956296	0.01478148	52.46	<.0001
Error	24	0.00676267	0.00028178		
Corrected Total	26	0.03632563			

R-Square	Coeff Var	Root MSE	lycopene Mean
0.813832	15.02747	0.016786	0.111704

Source	DF	Anova SS	Mean Square	F Value	Pr > F
trt	2	0.02956296	0.01478148	52.46	<.0001

The ANOVA Procedure

Tukey's Studentized Range (HSD) Test for lycopene

Note: This test controls the Type I experimentwise error rate, but it generally has a hig her Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	24
Error Mean Square	0.000282
Critical Value of Studentized Range	3.53170
Minimum Significant Difference	0.0198

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	trt
A	0.145778	9	30
B	0.122444	9	20
C	0.066889	9	10

10.8 Cookie Color L

```
data colorLcookies;
input trt L;
cards;
0 64.06
0 64.27
0 64.77
0 65.7
0 65.69
0 65.63
0 63.46
0 63.33
0 63.42
0 62.42
0 62.08
0 61.95
0 63.67
0 63.81
0 63.78
0 62.16
```

0 62.04
0 61.9
10 42.65
10 42.06
10 42.65
10 41.41
10 41.68
10 41.7
10 44.14
10 44.25
10 43.93
10 42.84
10 42.81
10 42.77
10 41.28
10 41.54
10 41.6
10 41.61
10 41.39
10 40.66
20 34.82
20 34.72
20 34.28
20 33.68
20 33.65
20 33.69
20 35.08
20 34.94
20 35.53
20 34.88
20 35.79
20 35.42
20 34.97
20 35.29
20 34.92
20 35.84
20 35.31
20 35.71
30 30.05
30 30.12
30 30.1
30 30.01
30 30.52
30 30.17
30 28.79
30 28.34

```
30 28.48
30 30.07
30 30.12
30 29.79
30 29.91
30 30.41
30 30.87
30 29.98
30 29.92
30 30.26
proc anova data=colorLcookies;
class trt;
model L=trt;
means trt/tukey lines;
run;
```

The ANOVA Procedure

Class Level Information

Class	Levels	Values
trt	4	0 10 20 30

Number of Observations Read 72
Number of Observations Used 72

The ANOVA Procedure

Dependent Variable: L

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	11884.81923	3961.60641	4245.20	<.0001
Error	68	63.45737	0.93320		
Corrected Total	71	11948.27659			

R-Square	Coeff Var	Root MSE	L Mean
0.994689	2.264451	0.966021	42.66028

Source	DF	Anova SS	Mean Square	F Value	Pr > F
trt	3	11884.81923	3961.60641	4245.20	<.0001

The ANOVA Procedure

Tukey's Studentized Range (HSD) Test for L

Note: This test controls the Type I experimentwise error rate, but it generally has a hig her Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	68
Error Mean Square	0.933197
Critical Value of Studentized Range	3.72464
Minimum Significant Difference	0.8481

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	trt
A	63.5633	18	0
B	42.2761	18	10
C	34.9178	18	20
D	29.8839	18	30

10.9 Cookie Color a

```
data coloracookies;
input trt a;
cards;
0 9.86
0 9.53
0 9.27
0 8.83
0 8.8
0 8.87
0 10.75
0 10.77
0 10.71
0 10.76
0 10.88
0 10.98
```

0 10.6
0 10.52
0 10.57
0 11.61
0 11.61
0 11.67
10 16.21
10 16.08
10 15.96
10 15.72
10 16.15
10 16.15
10 15.54
10 15.74
10 15.63
10 16.07
10 15.95
10 16.11
10 16.12
10 16.36
10 16.08
10 15.64
10 16.13
10 15.94
20 16.26
20 15.87
20 15.81
20 15.57
20 15.59
20 15.6
20 14.68
20 14.26
20 15
20 14.62
20 14.55
20 14.41
20 15.27
20 15.21
20 15.5
20 15.32
20 15.28
20 15.43
30 13.79
30 13.77
30 13.99
30 13.73

```
30 13.84
30 13.68
30 10.83
30 10.83
30 11.42
30 12.48
30 12.57
30 12.56
30 13.65
30 14.01
30 13.33
30 12.97
30 12.4
30 12.67
proc anova data=coloracookies;
class trt;
model a=trt;
means trt/tukey lines;
run;
```

The ANOVA Procedure

Class Level Information

Class	Levels	Values
trt	4	0 10 20 30

Number of Observations Read 72
Number of Observations Used 72

The ANOVA Procedure

Dependent Variable: a

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	346.3731222	115.4577074	197.63	<.0001
Error	68	39.7265889	0.5842145		
Corrected Total	71	386.0997111			

R-Square	Coeff Var	Root MSE	a Mean
0.897108	5.610287	0.764339	13.62389

Source	DF	Anova SS	Mean Square	F Value	Pr > F
trt	3	346.3731222	115.4577074	197.63	<.0001

The ANOVA Procedure

Tukey's Studentized Range (HSD) Test for a

Note: This test controls the Type I experimentwise error rate, but it generally has a hig her Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	68
Error Mean Square	0.584215
Critical Value of Studentized Range	3.72464
Minimum Significant Difference	0.671

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	trt
A	15.9767	18	10
B	15.2350	18	20
C	12.9178	18	30
D	10.3661	18	0

10.10 Cookie Color b

```
data colorbcookies;
input trt b;
cards;
0 31.53
0 30.71
0 30.15
0 30.18
0 30.37
0 30.26
0 32
0 32
0 31.93
0 31.35
```

0 31.31
0 31.25
0 31.89
0 32.41
0 32.32
0 32.89
0 32.96
0 32.95
10 27.73
10 27.57
10 27.96
10 26.99
10 27.57
10 27.6
10 27.84
10 28.12
10 28.21
10 26.92
10 27.13
10 27.16
10 27.04
10 27.5
10 26.93
10 26.92
10 27.57
10 26.44
20 22.36
20 22
20 21.45
20 20.88
20 20.97
20 20.96
20 19.79
20 19.23
20 20.37
20 19.69
20 20.48
20 20.06
20 20.77
20 20.65
20 21.49
20 21.97
20 21.81
20 22.13
30 15.93
30 15.95

```
30 16.5
30 15.62
30 16.09
30 15.94
30 10.46
30 10.76
30 11.49
30 13.28
30 13.54
30 13.63
30 15.63
30 16.29
30 14.98
30 14.62
30 13.8
30 14.15
proc anova data=colorbcookies;
class trt;
model b=trt;
means trt/tukey lines;
run;
```

The ANOVA Procedure

Class Level Information

Class	Levels	Values
trt	4	0 10 20 30

Number of Observations Read 72
Number of Observations Used 72

The ANOVA Procedure

Dependent Variable: b

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	3066.529706	1022.176569	730.00	<.0001
Error	68	95.216689	1.400245		
Corrected Total	71	3161.746394			

R-Square	Coeff Var	Root MSE	b Mean
0.969885	5.019443	1.183320	23.57472

Source	DF	Anova SS	Mean Square	F Value	Pr > F
trt	3	3066.529706	1022.176569	730.00	<.0001

The ANOVA Procedure

Tukey's Studentized Range (HSD) Test for b

Note: This test controls the Type I experimentwise error rate, but it generally has a hig her Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	68
Error Mean Square	1.400245
Critical Value of Studentized Range	3.72464
Minimum Significant Difference	1.0388

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	trt
A	31.5811	18	0
B	27.4000	18	10
C	20.9478	18	20
D	14.3700	18	30

10.11 Appearance

```
data appearance;
input trt appearance;
cards;
0 1
0 3
0 4
0 5
0 3
0 1
0 5
0 4
0 3
0 4
0 3
```

0 2
0 2
0 2
0 4
0 3
0 3
0 2
0 2
0 2
0 2
0 4
0 3
0 3
0 3
0 2
0 2
0 1
0 3
0 3
0 3
0 4
0 3
0 2
0 2
0 2
0 4
0 3
0 2
0 4
0 3
0 2
0 7
0 3
0 1
0 8
0 3
0 2
0 2
0 2
0 3
0 2
0 2
0 2
0 3
0 1
0 3

0 1
0 2
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10 1
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10 4
10 6
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30 4
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30 3

30 1
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30 6
30 7
30 6
30 5
30 6
30 4
30 5
30 4
30 3
30 6
30 4
30 5
30 4
30 3
30 2
30 7
proc anova data=appearance;

```
class trt;
model appearance=trt;
means trt/tukey lines;
run;
```

The ANOVA Procedure

Class Level Information

Class	Levels	Values
trt	4	0 10 20 30

Number of Observations Read 240
Number of Observations Used 240

The ANOVA Procedure

Dependent Variable: appearance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	176.5458333	58.8486111	20.32	<.0001
Error	236	683.4500000	2.8959746		
Corrected Total	239	859.9958333			

R-Square	Coeff Var	Root MSE	appearance Mean
0.205287	44.44195	1.701756	3.829167

Source	DF	Anova SS	Mean Square	F Value	Pr > F
trt	3	176.5458333	58.8486111	20.32	<.0001

The ANOVA Procedure

Tukey's Studentized Range (HSD) Test for appearance

Note: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	236
Error Mean Square	2.895975
Critical Value of Studentized Range	3.65918
Minimum Significant Difference	0.8039

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	trt
A	4.9333	60	30
A			
A	4.3667	60	20
B	3.2167	60	10
B			
B	2.8000	60	0

10.12 Texture

```
data texture;
input trt texture;
cards;
0 4
0 3
0 7
0 4
0 4
0 1
0 1
0 6
0 3
0 4
0 2
0 2
0 3
0 2
0 3
0 6
0 3
0 3
0 3
0 2
0 3
0 5
0 4
0 3
0 4
0 5
0 3
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0 2
0 3
0 3
0 3
0 4
0 4
0 1
0 5
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30 7
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30 5
30 2
30 7
30 4
30 4
30 4
30 7
30 4
30 3
30 2
30 2
30 1
30 3
proc anova data=texture;
class trt;
model texture=trt;
means trt/tukey lines;
run;
```

The ANOVA Procedure

Class Level Information

Class	Levels	Values
trt	4	0 10 20 30

Number of Observations Read	240
Number of Observations Used	240

The ANOVA Procedure

Dependent Variable: texture

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	16.4125000	5.4708333	2.32	0.0765
Error	236	557.5833333	2.3626412		
Corrected Total	239	573.9958333			

R-Square	Coeff Var	Root MSE	texture Mean
0.028593	43.86460	1.537089	3.504167

Source	DF	Anova SS	Mean Square	F Value	Pr > F
trt	3	16.41250000	5.47083333	2.32	0.0765

The ANOVA Procedure

Tukey's Studentized Range (HSD) Test for texture

Note: This test controls the Type I experimentwise error rate, but it generally has a hig her Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	236
Error Mean Square	2.362641
Critical Value of Studentized Range	3.65918
Minimum Significant Difference	0.7261

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	trt
A	3.9167	60	30
A			
A	3.5333	60	20
A			
A	3.3333	60	0
A			
A	3.2333	60	10

10.13 Taste

```
data taste;
input trt taste;
cards;
0 2
0 3
0 5
0 3
0 2
0 1
0 4
0 8
0 3
0 2
0 4
0 2
0 3
0 2
0 4
0 7
0 3
0 3
0 5
0 3
0 2
0 6
0 4
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0 3
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0 4
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```
30 4
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30 3
30 3
30 7
30 4
30 4
30 6
30 4
30 2
30 4
proc anova data=taste;
class trt;
model taste=trt;
means trt/tukey lines;
run;
```

The ANOVA Procedure

Class Level Information

Class	Levels	Values
trt	4	0 10 20 30

Number of Observations Read	240
Number of Observations Used	240

The ANOVA Procedure

Dependent Variable: taste

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	101.8791667	33.9597222	10.19	<.0001
Error	236	786.6166667	3.3331215		
Corrected Total	239	888.4958333			

R-Square	Coeff Var	Root MSE	taste Mean
0.114665	45.12504	1.825684	4.045833

Source	DF	Anova SS	Mean Square	F Value	Pr > F
trt	3	101.8791667	33.9597222	10.19	<.0001

The ANOVA Procedure

Tukey's Studentized Range (HSD) Test for taste

Note: This test controls the Type I experimentwise error rate, but it generally has a hig her Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	236
Error Mean Square	3.333121
Critical Value of Studentized Range	3.65918
Minimum Significant Difference	0.8624

Means with the same letter are not significantly different.

Tukey Grouping		Mean	N	trt
	A	5.0167	60	30
	A			
B	A	4.2500	60	20
B				
B	C	3.5667	60	0
	C			
	C	3.3500	60	10

VITA

Yaymed D. Arocho Torres

Candidate for the Degree of

Doctor of Philosophy

Dissertation: EVALUATION OF WATERMELON POMACE AS A POTENTIAL FOOD INGREDIENT

Major Field: Food Science

Biographical:

Personal Data: Born in Mayaguez, Puerto Rico on May 6, 1977.

Education:

- Completed the requirements for Bachelor of Science in Industrial Microbiology at the University of Puerto Rico, Mayaguez, Puerto Rico in June 2000.
- Completed the requirements for Master of Science in Food Science and Technology at the University of Puerto Rico, Mayaguez, Puerto Rico in June 2003.
- Commenced studies to obtain degree of Doctor of Philosophy in Food Science at Oklahoma State University, Stillwater, Oklahoma in 2007.

Experience:

- Served as Laboratory Technician in Borinquen Dairy, Aguadilla, Puerto Rico in 1999.
- Served as a Teacher's Assistant for General Chemistry Laboratory in the University of Puerto Rico, Mayaguez, Puerto Rico from 2000 to 2002.
- Served as Quality Control Supervisor at Quality Nova Food International, Cabo Rojo, Puerto Rico in 2003.
- Served as Microbiology Laboratory Assistant at Lilly del Caribe, Carolina, Puerto Rico from 2003-2007.

Professional Memberships: Institute of Food Technologists, Golden Key Honor Society, Toastmaster's International, Gamma Sigma Delta.

Name: Yaymed D. Arocho Torres Date of Degree: December 2010

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: EVALUATION OF WATERMELON POMACE AS A POTENTIAL FOOD INGREDIENT

Pages in Study: 199 Candidate for the Degree Doctor of Philosophy

Major Field: Food Science

Scope and Method of Study:

Watermelon fruit is the most consumed melon crop in the U.S., yet it is mostly consumed fresh since few value-added products exist. Watermelon is also the richest known source of the antioxidant lycopene. Pomace, which is the solid left after juice processing, could be used as a potential food ingredient. The objectives of this study were to evaluate the physicochemical properties of watermelon pomace and to compare the effect of different drying methods on its composition. Also, dried watermelon pomace was incorporated at different levels into flour to evaluate its effect on the rheological properties of the dough formed, as well as on the baking quality and sensory attributes of prepared cookies. Watermelons were juiced and the remaining pomace was dried using a cabinet dryer, a vacuum oven, and a drum dryer. The dried watermelon pomace was used to replace flour at 10, 20, and 30% in the preparation of cookies.

Findings and Conclusions:

Fresh pomace was found to have a lycopene content of 0.201 mg/g, 4.5 times higher than what has been reported for fresh watermelon, making it a concentrated source of lycopene. Lycopene loss occurred for all drying methods with drum drying causing a significant loss. In terms of color, drying resulted in an increase in L* and b* values and a decrease in a* values. Vacuum/cabinet drying was the best method in terms of preserving the color and lycopene content of watermelon pomace. However, it wasn't the most efficient or cost-effective, making the cabinet dryer the second-best option.

Rheological evaluation using a farinograph showed that adding pomace increased dough stability and time to break down, which suggests that it made it stronger. Cookies were not affected significantly in terms of spread and texture, although color became darker with increasing amounts of watermelon pomace. Cookies with 10% pomace were not scored significantly different from control cookies in terms of appearance and taste. Addition of pomace increased the lycopene content of the cookies, and even though there was some degradation during baking, the final products were good sources of the nutrient. This study showed that dried watermelon pomace could be used as a potential food ingredient to increase lycopene content and to substitute sugar in bakery products.

ADVISER'S APPROVAL: Danielle Bellmer