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Evaluation of Shelf-Life Improvements of Wet Pack Clingstone Peaches Designed for Military Operation Rations by Addition of Calcium Salts

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I am submitting herewith a thesis written by Lee Charles Morse entitled "Evaluation of Shelf-Life Improvements of Wet Pack Clingstone Peaches Designed for Military Operation Rations by Addition of Calcium Salts." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Science and Technology.

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Evaluation of Shelf-Life Improvements of Wet Pack Clingstone Peaches Designed for Military Operation Rations by Addition of Calcium Salts

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ABSTRACT

When available, wet pack peaches are produced by repackaging sliced and/or diced canned clingstone peaches into a 5-ounce MRE pouch, followed by a thermal process. In this study, wet pack diced peaches were processed in 5-ounce pouches using canned, fresh, and frozen peaches as the raw material. Calcium chloride was added at 0.0 or 0.5% (w/w) to the pouches. The pouches were then stored at 37°C for six months or 50°C for six weeks. The peaches were evaluated for texture, drained weight, pH, brix and sensory evaluations.

The canned peaches were not significantly different from wet pack peaches processed using frozen and fresh peaches for overall liking when stored at 37°C for six months. Based on the inability of panelists to differentiate between peach types for overall liking, this study suggests that producers should continue to use canned clingstone peaches as the peach source for wet pack peaches.

When calcium chloride was applied to wet pack peaches before thermal processing at 0.5% w/w, a significant increase was seen in the firmness of wet pack peaches after processing. Peaches treated with calcium chloride did not lose firmness as quickly when stored at 50°C for six weeks, but showed no difference in firmness loss rates when stored at 37°C for six months. Sensory analysis of the samples stored at 37°C for six months showed an improvement in firmness scores but a drastic decline in overall acceptance due to the impact of flavor scores.

Multiple levels of calcium chloride showed increased firming effects as the percentage of calcium chloride increased, with negative effects on flavor as the percentage increased. Flavor was not significantly affected by calcium chloride at 0.125% in sensory analysis. This study concludes that to optimize flavor and firmness of wet pack peaches, calcium chloride should only be added at a level up to 0.125%(w/w) that will result in a final pH ≥3.85.

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CHAPTER 1: INTRODUCTION and BACKGROUND

1.1 A GENERAL OVERVIEW OF COMBAT RATIONS

Stressful and challenging living conditions have affected the outcome of many battles, campaigns, and wars. As long as there have been conflicts among human populations, the ability to provide sustenance to combat forces has been a requisite for battlefield success. The Greek and the Roman warriors, Frederick the Great, and the Duke of Wellington were cognizant of the need for good food supplies, and of the dire effect that a lack of suitable provisions had upon the morale, esprit de corps, discipline, and physical condition of an Army (Quartermaster 1949).

Considered a political turning point in Europe, the French invasion of Russia was a crushing defeat for Napoleon and the French Grande Armée; many believe poor logistics to be the main cause for defeat. "The majority of the losses to the Grande Armée were incurred during the march to Moscow during the summer and autumn. Starvation, desertion, typhus, and suicide would rob the French Army of more men than all the battles of the Russian invasion combined… Lack of food and water in thinly populated, much less agriculturally dense regions led to the death of troops and their mounts by exposing them to waterborne diseases from drinking from mud puddles and eating rotten food and forage. The front of the army would receive whatever could be provided while the formations behind starved"(Riehn 1990).

One harsh winter in Valley Forge taught an infant America that adequate food and supplies are a vital part of any military strategy. Concerning the Commissary Department, Washington wrote to the Committee of Conference, "to attempt supplying the army from hand to mouth… scarcely ever having more than two or three days provisions beforehand, and sometimes being much in arrears, is a dangerous and visionary experiment … unless ample magazines are laid up in the course of this winter and the approaching spring, nothing favourable is to be looked for from the operations of the next campaign. " In a letter to Connecticut Governor Jonathan Trumbell, Washington continued his plea; because of "the alarming situation of this Army on account of Provision. . . there is the strongest reason to believe, that its existence cannot be of long duration, unless more constant, regular and larger supplies of the meat kind are furnished" (Reed 1980). Congress began procuring rations by contracts in 1780; this method was better than the previous system for food procurement, but it was found to not be too reliable. Three years later, the improbable happened when the British formally surrendered to the Americans by signing the Treaty of Paris and the Treaty of Versailles.

1.1a First Official U.S. Combat Ration

There have been numerous changes to combat rations since 1776. However, major changes came with the industrial revolution and World War I and World War II, when armies became highly mobilized units that were dispersed globally. During WWI rations were specialized to fit the specific needs of various situations. The Reserve Ration was carried by the soldier and was to be eaten when no other food was available. It sought to provide a man the nutritional requirements for one day. Trench Rations were group rations designed for trench warfare; enough to feed 25 men for one day. Emergency Rations were a last resort to combat starvation. It was an individual ration consisting of three 3-ounce cakes of a beef powder and cooked wheat mixture and three 1-ounce chocolate bars. All rations were canned and therefore very heavy; far from convenient.

WWII showed more substantial improvements in rations, due to the creation of the Quartermaster Subsistence Research and Development Laboratory in 1936. When the US entered WWII there were many new specialized rations: Life Raft Ration, Bail Out Ration, Parachute Ration, Airborne Life Boat Ration, A-Ration, B-Ration, C-Ration, D-Bar, K-Ration, Assault Lunch, Air Crew Lunch, 10 in 1, 5 in 1, Mountain Ration, and Jungle Ration (Department_of_Defense 2010), with the most widely used being the C- and D-Ration. "As a result … the Army entered World War II with two established special-purpose rations: Field Ration D and Field Ration C. Ration D was used throughout the war as the Army's emergency ration and as a supplement to other rations. The C ration went through an evolution which ultimately produced an outstanding ration for the purpose it was designed to meet-a daily food which the soldier could carry and use when he was cut off from regular food supply sources" (Koehler 1958).

1.1b The Meal, Combat, Individual and the Long Range Patrol

In 1958 the Meal, Combat, Individual (MCI) replaced the C-ration. It was designed more on the basis of subsistence, or its nutritional value, than its proportion and appeal. The Long Range Patrol (LRP) was introduced in 1962 as an individual ration and was an offspring of NASA research. LRPs contained dehydrated foods packaged in material much lighter than the traditional cans. The MCI and LRP were widely used throughout the Vietnam Conflict (Department_of_Defense 2010).

1.1c The Meal, Ready-to-Eat

The Meal, Ready-to-Eat (MRE) idea was adopted as a potential combat ration in 1975 by the Department of Defense; although the focus was simply on new packaging and not food content. The first MREs were basically MCIs in flexible packaging which greatly reduced the weight and bulk of the meals (Fisher and Fisher 2011). The packaging used for most MRE components is comprised of a flexible trilaminate material that is able to withstand retort processing. MREs were first produced in 1981 but were not delivered as the primary ration until 1983.

Today's MRE is classified as an individual operations ration; it is compact, has a long shelf life, can be issued directly to the individual soldier, and can be eaten with or without heating (Darsch and Brandler 1995). Described by The Defense Logistics Agency, "the MRE is designed to sustain an individual engaged in heavy activity such as military training or during actual military operations when normal food service facilities are not available. The MRE is a totally self-contained operational ration consisting of a full meal packed in a flexible meal bag. The full bag is lightweight and fits easily into military field clothing pockets" (Defense_Logistics_Agency 2010).

Fruit first appeared as a component of the E ration, a modified version of the early C rations after WWII (Fisher and Fisher 2011). In 1993, wet packaged peaches and pears were introduced as a new side dish item to MREs. In 1995, wet pack pineapples and mixed fruit were added, replacing freeze dried fruit. Raspberry applesauce was introduced in the 2000 MRE menu as a wet pack fruit option, and a carbohydrate fortified applesauce in 2004.

There are nine types of wet pack fruit options currently listed by Natick: 5 types of applesauce; Pineapple, sweetened, tidbits or chunks; Peaches, sweetened, sliced or diced; Pears, sweetened, sliced or diced; and mixed fruit, sweetened. Wet pack peaches are a secondary nutritional component with an approximate caloric value of 112 kcal. However, peaches have not been available as a wet pack fruit option since 2008; they consistently were found unacceptable by inspectors and soldiers. The most common critical defects, one that prevents the item from being consumed, is a soft, mushy texture, caramelized, oxidized, sour or fermented flavor, and browning of the peaches.

When wet pack peaches were available, they were produced by thermally re-processing canned peaches packaged in 5-oz MRE pouches, the same method used for producing the mixed fruit type of wet pack fruit. Based on what is known about the effects of thermal processing, a double thermal process would undoubtedly create a darker and much softer fruit product. Using fresh, frozen, and canned peaches as the fruit source for the MRE pouch and calcium chloride as a firming agent, this study compared the quality, firmness and texture, flavor, and overall acceptability of wet pack peaches over extended periods of high temperature storage.

1.2 NUTRITIONAL REQUIREMENTS OF THE SOLDIER

Army regulation 40-25 establishes nutritional standards, termed "military dietary reference intakes" (MDRIs), for military feeding and establishes nutritional standards for operational rations (NSOR). The MDRIs are intended for use by personnel involved in menu development, menu evaluation, nutrition education, nutrition research, and food research and development. The U.S. Army Research Institute of Environmental Medicine (USARIEM) has the responsibility of setting the nutrient compositions of the rations in compliance with nutrition standards established by the Surgeon General of the US Army. The MDRIs are quantitative estimates of nutrient intakes to be used for planning and assessing diets for the healthy military population.

Operational rations include the individual ration (Meal, Ready-to-Eat (MRE)) and group feeding rations (T-ration, Unitized B ration, and Unitized Group Rations (UGR-A and UGR-H&S (heat and serve)), and are designed to be nutritionally adequate. Operational ration menus will be designed so the menus, when averaged, meet the NSOR. The MRE may be consumed as the sole ration for up to 21 days. After 21 days, other appropriate rations (for example, the UGR-A, UGR-H&S) will be included in the daily mix of rations. This policy is based on extensive biochemical evaluations of soldiers consuming MREs for 30 days during field training. No degradation of performance or nutritional deficit was found before 21 days. When the MRE is the sole ration, units will provide supplements and enhancements (for example, bread, milk, and fresh fruit) whenever feasible (Department_of_Defense 2010).

The MRE is a general purpose ration that is intended to be carried and consumed in the field in conflict situations where cooks cannot prepare groups meals by virtue of the tactical environment. The MRE is intended to be used no more than 21 days, but in rare cases such as Operation Desert Shield/Storm, have been consumed for over 60 consecutive days. One MRE contains an average of 1300 kcal, with 3 MREs equaling one day's ration. Each meal consists of an entrée, starch, spread (cheese, peanut butter, jam or jelly), dessert, snack, beverages, hot beverage bag, accessory packet, plastic spoon, and since 1993 a flameless ration heater (Fisher and Fisher 2011).

If soldiers do not consume the entire day's ration, they may fail to receive a balanced diet. The term under-consumption describes the event in which an individual's food intake provides fewer calories than the individual's energy expenditure, entering into a "negative energy balance". Under-consumption assumes a longer-term risk of under-nutrition if it persists over an extended period of time. There is a long history of Army sponsored research on performance decrements related to energy deficient diets that reaches back to laboratory studies from the University of Minnesota in the 1940s and 1950s and field studies conducted by the U.S. Army Medical Research Nutrition Laboratory in the 1960s and 1970s (Meiselman 1995).

Since 1983, the MREs have been improved continually based on surveys of troop feedback from the field; from focus groups; and from individual interviews with soldiers (Darsch and Brandler 1995). Interest in what goes on in the field regarding Army personnel and rations and whether there is a problem of under-consumption began in 1983 with the first extended, comparative test of a field ration. The U.S. Army Natick Research, Development and Engineering Center (NRDEC) conducted a field evaluation with the 25th Infantry Division over a 34 day period in which the military personnel ate nothing but MREs three times a day. Although the troops rated the ration as acceptable, consumption rates were low: only about 60 percent of the calories provided were actually consumed. Soldiers given MREs consumed an average of 2189 kcal/day, but their caloric intake continuously declined over the 34-day period, while they rated their food 7.05 on a standard 9-point hedonic scale(Hirsch, Meiselman et al. 1985).

Despite efforts made to improve combat rations over the last 30 years, under-consumption continues to be a problem for soldiers involved in the field and in combat situations. A number of factors including the environment, the specific eating situation, the ration itself, and the individual have been shown to influence under-consumption in field rations. Acceptability of the ration itself is influenced by serving temperature, sensory properties (taste, smell, texture, color, etc…), packaging, ease of use, nutritional content, stability of product, appropriateness to time of day, delivery, presentation, availability, variety, and duration of reliance on operational rations as a major source of available food (Darsch and Brandler 1995).

This study specifically targeted improvements in the firmness of wet pack peaches, a secondary component of the ration, as a potential means of improving consumption rates and reducing waste. This study is a portion of the combat rations network for technology implementation short term project 2030 (CORANET STP-2030) Evaluation of Processes and Additives to Improve Quality and Storage Life of Wet Pack Peaches. "The primary objective [of

STP-2030] is to develop a better quality wet-pack fruit (peaches used as model fruit) MRE pouch item that has a more consistent quality while being produced for a twelve-month delivery schedule" (Mount, Zivanovic et al. 2008). This portion of the project compared the firmness of wet pack peaches as affected by the type of initial fruit material used (fresh, canned, or individually quick frozen) and the calcium chloride level of use. Any concluding recommendations stemming from this phase of the CORANET Short Term Project 2030 will be evaluated and validated at Natick research labs before any new formulations or processing methods are implemented.

1.3 PEACHES

Today there are over 2000 peach varieties cultivated throughout the World. Peaches are grown in temperate and subtropical zones, with the main producers worldwide being Italy, United States, Spain, China and Greece, with China typically being the top producer. In the U.S. in 2009, peaches were commercially produced in 23 states, with the top producers being California, South Carolina, New Jersey and Georgia (USDA 2010) (Appendix A-Table 1.1).

Prunus persica is the species of tree that produces peaches. They were believed to have originated in Persia, due to the fact that they were brought to Europe from Persia, but more recent findings suggest they were indigenous to China. The peach was referenced in Chinese literature roughly 1000 years before being mentioned by European writers; also, there is documented evidence of peach cultivation in China more than 3000 years ago (Layne and Bassi 2008).

The peach tree *Prunus (*subgenus *Amygdalus) persica* is classified in the *Rosaceae (*subfamily Prunoideae), a large family of flowering plants. Several edible fruits come from the Rosaceae family such as apples, apricots, plums, cherries, peaches, pears, raspberries, and strawberries. The largest genus of *Rosaceae* is the *Prunus* with an estimated 430 species; these small shrubs or trees produce such fruits as apricots, almonds, peaches, plums, and cherries. The fruits produced by species of *Prunus* are commonly referred to as drupes. Drupes are identified by their relatively large, hard endocarp covered seed or "stone". The hard endocarp is surrounded by a large fleshy layer of mesocarp, the edible fruit tissue, and the exocarp, the skin.

The most appealing peach tissue for human consumption is the mesocarp. The biological function of this tissue is to attract organisms that may disperse the seeds located within the fruit. It is comprised primarily of parenchyma cells, which are mostly responsible for the fruit's texture resulting from turgor pressure (Oke and Paliyath 2006). Fruits have developed certain color, flavor, taste, and texture characteristics to attract mobile organisms. The mesocarp has a sweet taste whereas the endocarp will have a bitter taste, resulting in the seed being discarded throughout the ecosystem. As the seed reaches maturity, the fruit's biochemistry will change, resulting in a highly sought after energy source for other species. This maturation process is known as ripening.

Color and texture are the most commonly judged characteristics when determining peach ripeness. As a peach ripens, a reddish blush color will develop on the side receiving sunlight, while the ground side will turn from green to yellow. A hand held penetrometer is a useful tool for measuring peach firmness. After removing a small amount of peel, a probe is plunged into the peach's flesh to yield a firmness measure in psi. Peaches with a flesh firmness ranging from 11-14 psi are picked for shipping; 7-10 psi are considered "well mature"; 6-8 psi are considered "ready to buy"; and peaches that measure 2-3 psi are considered "ready to eat" (Crisosto 1994).

Many differences can be found among the peach cultivars, with two basic variety types being freestone and clingstone. Freestones are typically larger, juicier, and have a softer texture. The variety's names describe the interaction of the hard endocarp layer with the surrounding mesocarp tissue. The freestone variety will have a pit, or 'stone', that is freely removed from the soft, fleshy mesocarp tissue. The easy removal of the pit of freestone peaches make them ideal for fresh consumption. The clingstone varieties contain a stone, or pit, that 'clings' to the surrounding mesocarp tissue, requiring more mechanical force to remove the stone. Clingstones typically have a firmer, less juicy texture. This variety is more suitable for canning, and has also been shown to retain more flavor and texture during thermal processing when compared to the freestone (Brunke and Chang 2010). The firm flesh of such fruit is more resistant to physical damage during bulk fruit harvest, transport, processing and fruit slicing (Carles 1984). In 2002, approximately 83% of all processed peach cultivars in the U.S. were of the clingstone variety (Layne and Bassi 2008).

1.4 PROCESSING METHODS

A high percentage of peaches are processed, but consumption of fresh product is also very common. By growing differently ripening cultivars, the supply of fresh fruits can be guaranteed for about 3 months (Hanelt 2001). Due to the seasonal nature of most subtropical fruits, preservation is necessary to minimize losses of fresh fruit that cannot be consumed before spoiling. In 2008, Americans annual consumption of peaches was 8.8 pounds per person, with fresh peach consumption at 5.1 pounds per person and canned consumption estimated at 3.0 pounds per person (Kristy Plattner 2010). Processing fresh fruits can damage the nutrients, flavor and aroma compounds, and the structural molecules, but is nonetheless a very vital part of human survival as processed foods can still provide a high level of nutrition and sustenance.

In 2009, the U.S. had an estimated peach crop of 1.1 million tons: 501,270 tons sold as fresh produce and 581,290 tons were processed. The average grower price for fresh peaches was $816 per ton, while the average grower price for processed peaches was $319 per ton. The average price per ton for canned peaches in 2009 was $338, while the average price for frozen peaches was $275(USDA 2010). Of those processed, 463,740 tons were canned, 92,000 tons were frozen and 7,100 tons were dried. It is also interesting to note, that the clingstone cultivars were the only varieties reported as canned from the state of California, while only freestones from California were reported as being frozen and dried(USDA 2010). This is significant because over 90% of the peaches in the U.S. are produced in California. No other states distinguished between varieties, but it is fair to assume that most utilized the same processing pattern. As stated previously, the firmer texture of clingstone peaches make them better suited for canning while the soft melting flesh and typically high levels of water-soluble anthocyanin pigments found in freestone cultivars result in poor processed quality unless processing is by rapid freezing or dehydration (Layne and Bassi 2008).

Food processing or preservation is essentially the overall steps taken to preserve and package foods. Processing foods has two main objectives: 1) to ensure that the food product is safe for consumption; and 2) to preserve quality attributes of the food at a level that is acceptable for consumption. Both objectives are achieved by manipulating environmental and food-associated factors in order to control or reduce the number of microorganism. Sometimes these steps are used in combination while other times they are used alone to yield a "shelf stable" or "commercially sterile" product. These terms mean that the product is "free of viable microorganisms (including spores) of public health significance as well as those capable of reproducing in the food under normal non-refrigerated conditions of storage and distribution" (GMA 2007).

Foods that are "canned" are not necessarily packaged into a can. "Canning is a method of food preservation that renders a food and its hermetically sealed container commercially sterile by the application of heat, alone or in combination with pH and/or water activity and/or other chemicals" (GMA 2007). The FDA classifies canned foods into 3 categories: low-acid canned foods, which have a pH >4.6; acidified low-acid foods, which have been formulated or treated with an acid or an acid food to yield a product with a pH≤4.6; and acid foods, whose products naturally have a pH≤4.6. The survival of *Clostridium botulinum* spores is the main health concern for canning, due to its ability to produce a deadly neurotoxin. "Botulism" is the term used to describe the illness resulting from an individual ingesting the *C. botulinum* toxin. Preventing the formation of this toxin is the primary goal of low-acid and acidified food regulations. Canning regulations for acid foods are not as strict and detailed as compared to low-acid and acidified foods, due to the inability of *C. botulinum* spores to develop in such acidic conditions. Research has determined that *C. botulinum* will not germinate and grow in food below pH 4.8; therefore a pH of 4.6 was selected to differentiate between acid and low-acid foods.

Time and temperature studies have been conducted over many years to determine the appropriate levels required to destroy pathogens and inhibit spoilage organisms. FDA regulations governing commercially processed foods are contained in Title 21 of the *Code of Federal Regulations* (12CFR). Most fruits have a natural pH≤4.6, so for the purposes of this paper, only the guidelines specific to acid foods will be examined. Controlling spoilage organisms is the primary focus of acid foods processing. However, controlling these organisms can also be a public health concern. Molds are capable of metabolizing acids, and in rare occasions, their growth in foods has raised the pH of products enough to allow *C. botulinum to* grow. Under acidic conditions, pathogenic bacteria will not multiply and consequently only a pasteurization process is necessary. Yeasts, molds, and bacteria can severely affect food quality by changing the flavor, aroma, texture, and appearance. In order to achieve microbiological stability of canned fruit, it is necessary to submit the sealed can to a heat process that will destroy or render inactive all microorganisms capable of causing spoilage. For thermal processing of acid-foods, the sealed containers are pasteurized in hot water or atmospheric steam. This can be achieved in batch retorts, continuous retorts, or agitating retorts. The basic processing vessel is the static retort, which may be vertical or horizontal. The containers are loaded into cages, and placed into this batch style retort and completely covered with the heating medium (Arthey and Ashurst 2001). Cook time will depend on the container type, volume, type of fruit product and the fruit pH.

Most processing involves a common sequence of basic events. To be successful, a cultivar must be compatible with every component of the processing pathway, which explains why fresh clingstone cultivars are more suited for canning than freestones. Typical peach canning processes begin at harvest, followed by transport, grading, halving and pitting, peeling and blanching, sorting and filling, pasteurization, and finally introduce into the market (Appendix A- Figure 1.1). In Title 21 of US Code of Federal Regulations (21CFR145.170), the canned peach is identified:

(a)(1)Canned peaches is the food prepared from one of the fresh, frozen, or previously canned optional peach ingredients *Prunus persica* L., of commercial canning varieties, but excluding nectarine varieties, specified in paragraph (a)(2) of this section, which may be packed as a solid pack or in one of the optional packing media specified in paragraph (a)(3) of this section…

(3) *Packing media.*

(i) The optional packing media referred to in paragraph (a)(1) of this section, as defined in §145.3 are:

(*a*) Water.
(*b*) Fruit juice(s) and water.
(*c*) Fruit juice(s).

Additionally, the “U.S. Standards for Grades” of certain processed fruits, vegetables, and products thereof, are contained in Title 7 of the CFRs, part 52 (7CFR52) and are administered by the Agricultural Marketing Service/U.S. Department of Agriculture (2010).

Freezing is generally superior to canning for preserving the firmness of fruits (Oke and Paliyath 2006) and has become a widely used method for preservation. Clarence Birdseye’s development of the quick freezing process paved the way for fruits and vegetables to be commercially frozen (Salunkhe, Bolin et al. 1991). It is well accepted by the food science community that freezing’s effect on the nutrient contents and quality of fruits is negligible when compared to thermal processing. Furthermore, numerous studies have shown that the sensory properties of frozen fruits and vegetables are comparable to fresh fruits and vegetables except for texture. Some products are frozen before packaging by an individual quick freezing (IQF) procedure. This procedure provides a very rapid freezing rate and the fruits or vegetables are frozen as individual units so that they are free flowing in the frozen state. This is advantageous for the user of these products because they can remove the amount of product they want to use from the package.

1.5 CALCIUM CHLORIDE

The chemical compound known as calcium chloride ($CaCl_2$) is an inorganic salt consisting of a single calcium molecule bound with two chlorine molecules. The calcium atom contains 2 electrons in its outer valence that are readily donated to achieve a more favorable energy state, creating a cation with a 2+ charge. The chlorine atom contains 7 valence electrons and can readily accept an extra electron to achieve a more stable energy state, thus creating a halide ion with a single negative charge. These ions are attracted together by their opposing charges, known as electrostatic attraction, and can form an ionic bond, yielding the compound known as calcium chloride.

Like most ion salts, $CaCl_2$ has a high water solubility, 74.5g/100mL at 20°C and 1 atm, and is extremely hygroscopic. This makes it a good Ca^{++} delivery compound in aqueous solutions such as brines and syrups used in food preservation practices. As a direct food substance, $CaCl_2$ has numerous specifically approved applications (21CFR184.1193):

§184.1193

(c) The ingredient is used as an anticaking agent as defined in §170.3(o)(1) of this chapter; antimicrobial agent as defined in §170.3(o)(2) of this chapter; curing or pickling agent as defined in §170.3(o)(5) of this chapter; firming agent as defined in §170.3(o)(10) of this chapter; flavor enhancer as defined in §170.3(o)(11) of this chapter; humectant as defined in §170.3(o)(16) of this chapter; nutrient supplement as defined in §170.3(o)(20) of this chapter; pH control agent as defined in §170.3(o)(23) of this chapter; processing aid as defined in §170.3(o)(24) of this chapter; stabilizer and thickener as defined in §170.3(o)(28) of this chapter; surface-active agent as defined in §170.3(o)(29) of this chapter; synergist as defined in §170.3(o)(31) of this chapter; and texturizer as defined in §170.3(o)(32) of this chapter.
(d) The ingredient is used in foods at levels not to exceed current good manufacturing practices in accordance with §184.1(b)(1). Current good manufacturing practices result in a maximum level, as served, of 0.3 percent for baked goods as defined in §170.3(n)(1) of this chapter and for dairy product analogs as defined in §170.3(n)(10) of this chapter; 0.22 percent for nonalcoholic beverages and beverage bases as defined in §170.3(n)(3) of this chapter; 0.2 percent for cheese as defined in §170.3(n)(5) of this chapter and for processed fruit and fruit juices as defined in §170.3(n)(35) of this chapter; 0.32 percent for coffee and tea as defined in §170.3(n)(7) of this chapter; 0.4 percent for condiments and relishes as defined in §170.3(n)(8) of this chapter; 0.2 percent for gravies and sauces as defined in §170.3(n)(24) of this chapter; 0.1 percent for commercial jams and jellies as defined in §170.3(n)(28) of this chapter; 0.25 percent for meat products as defined in §170.3(n)(29) of this chapter; 2.0 percent for plant protein products as defined in §170.3(n)(33) of this chapter; 0.4 percent for processed vegetables and vegetable juices as defined in §170.3(n)(36) of this chapter; and 0.05 percent for all other food categories.

The FDA recognizes $CaCl_2$ as a direct food substance affirmed as GRAS, Generally Recognized as Safe, used in accordance with good manufacturing practices. "For the purpose of this part, current good manufacturing practice includes the requirements that a direct human food ingredient be of appropriate food grade; that it be prepared and handled as a food ingredient; and that the quantity of the ingredient added to food does not exceed the amount reasonably required to accomplish the intended physical, nutritional, or other technical effect in food (21CFR184.1(b)). [According to 21CFR184.1(b)(2) (2)] If the ingredient is affirmed as GRAS with specific limitation(s), it shall be used in food only within such limitation(s), including the category of food(s), the functional use(s) of the ingredient, and the level(s) of use. Any use of such an ingredient not in full compliance with each such established limitation shall require a food additive regulation." As a firming agent, calcium chloride has a maximum usage level of 0.2% in canned fruits and fruit juices.

CHAPTER 2: REVIEW OF LITERATURE

2.1 PECTIN AND ITS ROLE IN TEXTURE

Texture can be a very subjective concept. Many have tried to define texture, but no single generally accepted definition has appeared. Szczesniak defines texture as "the sensory and functional manifestation of the structural, mechanical, and surface properties of foods detected through the senses of vision, hearing, touch, and kinesthetics" (Szczesniak 2002). Firmness is a property of texture. In fruits and vegetables, firmness can be generated from different sources. Turgor pressure of living cells, compounds inside the cell, chemical properties of the cell wall, chemical properties of the middle lamella, and the overall structure and shape of separate cells and tissues have shown to affect firmness (Buren 1978). In thermally processed fruits, texture loss can be attributed to degradation of pectic substances (Wiley and Thompson 1960).

Pectin is a classified as a dietary fiber due to human inability to digest the compound. Pectin is an elaborate network of highly hydrated polysaccharides, which fills up the spaces between the microfibrils in the cellulose-matrix glycan network (Paliyath and Murr 2006).This complex set of polysaccharides is found mostly as a structural component in the cell walls and intercellular layers of all land plants and is often more than 50% of the fruit cell wall (Fennema 1996).

Structurally, there is no definitive model for pectin. These complex polysaccharides are often referred to as pectic substances due to the many different combinations of structural and side group combinations. Pectic substances can be classified into three major groups:

homogalacturonan (HGA), a homopolymer of 1→4 α-D-galacturonic acid; rhamnogalacturonan I (RGI), comprised of repeating disaccharide units of (1→2)-α-D-rhamnose -(1→4)-α-D-galacturonic acid; and rhamnogalacturonan II (RGII), consisting of an HGA backbone that exhibits a complex substitution pattern with many diverse sugars (Paliyath and Murr 2006). The term pectin used in this general sense refers only to the HGA and RGI regions of pectic substances. Galacturonyl residues are frequently esterified by methanol. The degree of esterification (DE) of pectin is determined by the percent of methyl esters to total galacturonic acid units. Pectin with >50% DE are known as high methoxyl pectin (HMP) and <50% DE are labeled low methoxyl pectin (LMP). Furthermore, the manner in which pectic substances interact together and with other cell wall components is not fully understood. Typically pectins found in the primary cell walls will have a higher degree of esterification than pectins in the middle lamella (Haard and Chism 1996).

During ripening, pectin is extensively modified by enzymes such as polygalacturonase (PG), and pectin methyl esterase (PME). The pectin backbone is de-esterified by PMEs, leaving negatively charged carboxylic residues that allow calcium associations and pectin cross-linkage to occur (Blumer et al. 2000). PMEs are the first enzymes to become active as the peach ripens; as ripening progresses, PGs will become more active. PGs are catalysts for hydrolysis reactions causing depolymerization of HGA. In peaches there are two forms of PG, the exo-PG and the endo-PG. Exo-PG removes a single galacturonic acid from the non-reducing end of the pectin polymer while endo-PG can break the chain at random sites. The observed phenotypic difference in texture and juiciness between clingstone and freestone peaches is explained by the endo-PG enzyme. Simply put, most clingstone varieties are not capable of producing the endo-PG enzyme; although some clingstone peaches do have the gene for endo-PG, it is expressed at much lower levels than freestone varieties.

The rate of enzymatic reactions will increase as temperature increases. At higher temperatures, they will begin to denature due to the unfolding of molecular structures. Enzymatic activity of peaches during processing is typically controlled by temperature. The blanching step in fruit and vegetable processing is designed to inactivate all enzymes. The most heat tolerant enzymes will begin to unfold at 80°C; consequently a target blanching temperature is usually 85°C. In thermally processed fruits, a separate blanching step is not always necessary due to the high temperatures used in steam-peeling methods coupled with the high temperatures reached to reduce or inactivate microorganisms during the retort step.

After enzymes are inactivated, pectin continues to undergo nonenzymatic degradation as a result of the same chemical reactions that the enzymes catalyze. Nonenzymatic reactions of pectin are not fully understood; however, there has been recent research examining the changes in pectin during thermal processing. Depolymerization of pectin during thermal processing has been identified as one of the main causes of texture deterioration of fruits and vegetables (Sila et al. 2006). β-elimination reactions and acid hydrolysis are thought to be the primary reactions affecting texture. Both reactions are capable of breaking the glycosidic bonds of the pectin polymer, but have very different conditions for reaching maximum reaction rates.

β-elimination requires the presence of a methyl ester at C-6 (BeMiller and Kumari 1974) and therefore as the degree of esterification increases in pectin, this reaction rate has shown to also increase (Krall and McFeeters 1998). β-elimination kinetics have also shown to increase with increasing temperature (Sila et al. 2006). pH can also affect β-elimination reaction rates: A study by Krall and McFeeters in 1998 suggests that water soluble pectins with a DE of 35% and 70% were depolymerized by β-elimination at a higher rate compared to acid hydrolysis at pH of 3.8 and a temperature of 100°C. Fraeye and others concluded that as pH and DE increased β-elimination rates also increased, with the opposite trend seen in acid hydrolysis rates (Fraeye et al. 2007). They expanded upon their conclusion to say that under conditions of thermal fruit processing (high temperature, pH 4-6), acid hydrolysis of pectin was negligible while β-elimination rates were significant.

The optimal pH range for acid hydrolysis reactions is from 2to 4, gradually decreasing as pH increases. At a range of 4.5-6.0, hydrolysis reactions have been observed but at very low rates (Krall and McFeeters 1998). Furthermore, hydrolysis rates increased at pH 3.0 as the degree of esterification decreased (Krall and McFeeters 1998). Research suggests that depolymerization of low methoxyl pectin by acid hydrolysis during thermal processing is only a concern when pH ranges from 2.0->3.5 (Krall and McFeeters 1998; Fraeye et al. 2007).

2.2 MRE RESEARCH

All military subsistence research along with other research related to sheltering, clothing, and equipping the warfighter occurs at the U.S. Army Natick Soldier Research, Development, and Engineering Center (NSREDC a.k.a. Natick). Researchers at Natick take note of soldiers' likes and dislikes in MRE menu development and continually make changes to produce a more acceptable ration (Fisher and Fisher 2011).

2.2a Accelerated Shelf Life Methods

The MRE is designed to have a shelf-life of 3 years when stored at 27°C. Increased menu variety has been identified as a method to improve consumption rates of soldiers in combat situations (Rolls 1995). Studies of new MRE menu components need results quickly in order to keep up with annual menu changes. Accelerated shelf life studies are used by product developers at Natick and are also widely used in universities and the commercial food industry. The concept of accelerated studies is to increase reaction causing factors in order to accelerate changes in the physical, chemical or microbiological characteristics of food products. Increasing storage temperature is the most popular method used in accelerated product studies due to temperatures' ability to accelerate many degradation reactions in foods. The ability to determine shelf-life of products in a shorter amount of time is a necessity for the food industry. Every approach to accelerated self-life testing must be concerned with how to get reliable deterioration data in a short period, what model to use and how eventually to predict the actual shelf-life of the product (Mizrahi 2004). An increase in the storage temperature will proportionately increase the rates of change; this increase from normal storage conditions can also increase the error in measurements (Man 2004). Shelf-life studies with lower storage temperatures, closer to the normal conditions, have been shown to yield more reliable results; nonetheless, shorter shelf-life studies are still a very useful and valuable tool.

2.2b Shelf-Life Prediction Models

In recent years developments in statistical modeling techniques coupled with the advances in statistical software packages have made shelf life predictions a much more convenient process. Researchers examine known rates of chemical reactions, physical changes, and degradation rates of sensory characteristics such as color, flavor, aroma, and texture as functions of specific stress factors (usually storage temperature and time). Using experience of similar products, the likely shelf life of a new or modified product can often be estimated before any storage tests are done (Ellis and Man 2000).

Kinetic modeling helps scientists understand the rates at which chemical reactions occur by calculating forward and backward reaction constants (k_f and k_b) under very specific and controlled conditions: the most widely used are temperature and concentration of reactants. The concept of kinetic modeling is now being applied in food research to quantify the rates at which foods degrade. Due to the seemingly one directional change over time observed in many food quality characteristics, the kinetic equation is adjusted to only include a single *k*-value, called a pseudo-*k*. The equation used to determine *k* will depend on the manner at which the quality measurements respond over time. If the slope of its degradation is linear, a first order equation is used; if the slope is curved showing segments of rapid change that eventual slows until almost negligible (typical of an exponential slope), the equation for a first order reaction is used to solve for k. Most reactions of food quality are found to be zero or first order; however other reaction rate patterns within food are entirely possible. A generic form of the rate equation (2.1) can be used for any order of reaction:

$$f_q(A) = k(C_i, E_j) \cdot t \qquad [2.1]$$

f_q is the function of food quality *A* and will vary depending on the reaction order. The quality function of zero order is $A_0 - A_t$ and $ln(A_0 - A_t)$ for first order reactions, where A_0 is the initial quantification of some food quality parameter and A_t is the measure of that same parameter at time *t*. The rate constant *k* is a function of (C_i, E_j), described as compositional *(C)* factors of the food and environmental *(E)* factors surrounding the food. These are better known as the intrinsic and extrinsic factors that affect foods. The methodology listed here for apparent reaction order and rate constant are interpretations from (Taoukis et al. 1997).

Researchers will estimate the rate constant *k* under very specific conditions to determine just how the intrinsic and extrinsic factors can cause changes in food. Separate isothermal storage tests can estimate the *k* rate constant at multiple temperatures, located within a suitable range, in order to estimate the k_A. This variable is the pre-exponential factor in the Arrhenius equation. Developed in 1889 by Swedish scientist Svante Arrhenius to support his theory stating that for a chemical reaction to occur, specific levels of energy were required. This theory of course seems to be true, and now this simple equation has become useful in any application where rates of reaction are concerned. The theory is simple: if something can precisely be measured on how much it reacts or changes, under very controlled, measurable conditions, the data obtained can be used to predict how the reaction rate may change in response to changing conditions. The Arrhenius equation (Eq. 2.2) uses the pre-exponential

$$k = k_A \exp(-E_A/RT) \qquad [2.2]$$

factor k_A raised to the exp$(-E_A/RT)$ to predict *k*. *R* is simply the universal gas constant, *T* the temperature, and E_A the activation energy requirement of the reaction. The pre-exponential k_A is the rate of reaction when temperature is at absolute 0 or at conditions when no activation energy is required. This theory has proven to be extremely valuable in understanding reaction kinetics; coupled with good statistical models and experimental practices, it has become a very effective method for determining shelf-life.

An older and still commonly used model for determining shelf-life is the Q_{10} parameter. Q_{10} is a way of expressing the change in the reaction rate constant when temperature increases by an interval of 10°C. The equations for Q_{10} does not differ for zero and first order reaction since the ln has already been used to calculate k (Eq. 2.3).

$$k(T + 10)°C / k(T)°C = Q_{10} \quad [2.3]$$

Natick has developed minimum shelf-life time standards for the MRE as a function of its storage temperature (Appendix A-Figure 2.1). Expected shelf-lives are shown at 10°F intervals and apply to every component of the MRE menu. This converts to a difference of 5.5°C intervals in the shelf-life expectancy chart. This $Q_{5.5}$ can be converted to Q_{10} values by using equation (2.4). These specific guidelines will be used as the target shelf-life when developing shelf-life improvement recommendations.

$$Q_{10} = [k_2/k_1]^{10/\Delta T} \quad \text{where } k_2 = k_1 - 10 \quad \text{and } \Delta T = T_2 - T_1 \quad [2.4]$$

2.3 WET PACK PEACHES

Natick has established performance-based contract requirements for any contractor to produce MREs. Wet pack fruit must be comparable to established product standards, be processed until commercially sterile, and must meet the minimum shelf life requirement of 36 months when stored at 27°C. There are also performance requirements for appearance, odor and flavor, texture, net weight, drained weight, palatability and overall appearance, and analytical requirements.

“A Product Standard is set when a first article (FA) or product demonstration model (PDM) passes inspections and tests listed in Section E of the Performance-based Contract Requirements document PCR-F-002C. Should the contractor at any time plan to, or actually produce the product using different raw material or process methodologies from the approved product standard, which result in a product non comparable to the product standard, the contractor shall submit a replacement FA or PDM for approval” (Defense 2010). Producing wet pack peaches from a canned source has proven to yield an unacceptable fruit product. This is considered now to be an inefficient means of production, due to the high amount of food waste it creates and the energy deficit that soldiers may face when under-consuming during sustained operations. Table 2.1 lists in detail the performance-based contract requirements specific to wet pack peaches (Appendix A).

2.4 TEXTURE ANALYSIS

The texture requirements for the Natick Performance-based Contractor requirements only list guidelines for applesauce types. For army field inspectors, the characteristic wet pack peach texture is described simply as “tender but firm” (MIL-F-44067). Just as there is no generally accepted definition of texture, there is also no set standard for quantifying texture. Most research involving the enhancement of diced fruits and vegetables evaluates texture using sensory panels. Sensory evaluations are commonly used to analyze texture of foods because there has yet been a machine that is able to recreate the events that happen in mouth while eating. However, instrumental texture evaluation is often performed to objectively measure and analyze the textural properties of food. Sensory panels can give better data, yielding qualitative and quantitative results while instrumentation analysis can only give quantitative measures. A recent study conducted at Ohio State University compared the resistance to mechanical abuse of diced tomatoes treated with calcium at different stages of processing(Rao and Barringer 2005). Using a TA.*XT* Plus loaded with a Kramer Sheer Probe, they concluded that there were no significant texture differences between calcium treatments. However, sensory evaluation concluded that panelists preferred the tomatoes that were dipped in a calcium solution before undergoing mechanical abuse.

2.4a TA.XT*PLUS* Texture Analyzer

The disadvantage of sensory panels is that they require a large number of samples, along with being time consuming and expensive. Instrumentation analysis has the advantage of yielding relatively quick results compared to sensory analysis. Instrumentation analysis is a valuable means of measuring texture in research and development settings when new treatments or processes need to be compared quickly.

The Texture Technologies Corporation manufactures the TA.XT*Plus* Texture Analyzer, an instrument widely used for measuring the firmness of foods. The TA.XT*Plus* can be equipped with numerous fixtures, allowing it to be used on a wide range of food types. A recent study conducted by Texture Technologies Corporation compared four fixtures commonly used to measure the texture of diced fruit: the TA-91 Kramer Shear Cell, the TA-245 Ottawa Shear Cell, the TA-94 Back Extrusion Fixture, and the TA-65 Multiple Puncture Rig (Texture_Technologies_Corp. 2004). The samples tested were canned 5/8” diced peaches with and without calcium chloride measured for peak force (g), area of work (g*s), and initial slopes of force (g/s).

The study found "using both area of work and peak force, the TA-65 Multiple Puncture Rig was the most sensitive and best discriminated the firming impact of using calcium chloride as a firming agent"; concluding that, while the Kramer Shear Cell has traditionally been used by the fruit industry, for products like diced peaches, they recommend using the TA-65 Multiple Puncture Rig for ease of use, repeatability and differentiation (Texture_Technologies_Corp. 2004). They also concluded, "The area of work is the more significant measure for tests involving bulk products with these fixtures. Peak forces, while differentiating, are subject to momentary spikes which may not represent the population's aggregate behavior. The initial slope did not differentiate treatments, and the results [were] not presented in [their] study" (Texture_Technologies_Corp. 2004).

2.4b Sensory Analysis of Calcium Chloride

Acidity, astringency and sweetness have been found to be correlated with overall acceptance in sensory analysis of fresh peaches (Predieri et al. 2006). In thermally processed peaches, texture becomes an important trait to examine due to softening of fruit tissue caused by high temperatures. Softening occurs partly as a result of solubilization and depolymerization of pectic polymers that are involved in cell-cell adhesion (Greve et al 1994). Strengthening the middle lamella matrix is one of the major techniques used to enhance the firmness of heat-treated fruits and vegetables. This is achieved by the salt-bridge formation between divalent cations and free carboxyl groups of the pectin chain. Calcium salts have been used extensively in whole fresh and processed fruits in order to maintain firmness retention and to extend storage life. Calcium chloride has been used extensively in fruit processing as a firming agent; however it has been characterized primarily as having a bitter taste, and has also been described as salty, metallic, and astringent (Lawless et al. 2003).

Although the effect of calcium on other processed fruits is well known, few studies are available regarding the effect of calcium sources in canned peaches. One study comparing calcium chloride, calcium propionate, and calcium lactate at equimolar levels in canned peaches showed that calcium lactate provided both better textural features and sensory attributes when compared to a no calcium control group (Manganaris et al. 2005). The calcium chloride and calcium propionate treated samples both scored significantly lower than the control and the calcium lactate samples for flavor and aroma, but did show an increase in firmness scores over the control. Manganaris concluded that calcium lactate was potentially a better calcium source in the peach canning industry.

CHAPTER 3: MATERIAL AND METHODS

3.1 PHASE I: PEACH HARVEST, PROCESSING, PACKAGING AND STORAGE

A single lot of fresh, USDA Grade A (picked the previous day) Baby Gold #5 clingstone peaches was used for all samples processed. The lot was obtained and processed at McCall Farms in Effingham, SC. The peaches had an average pH of 3.6, Brix of 8.4, and a penetrometer reading of 7-9psi. They were washed in a hot water bath, before being steam peeled. After peeling, the fruits were halved and the pits were removed mechanically. These peach halves were manually loaded and diced into ¾" cubes. The cubes were immediately canned, pouched, or frozen.

3.1a Canning

The canning process used was established by McCall Farms, a commercial cannery in Effingham, SC. A #10 size can was used to process 40 cans of the diced peaches. In all 40 cans, we added a solution of 2.1g/10mL L-ascorbic acid, 60.3oz diced peaches, initially added 43.7oz of syrup to all cans, but that amount left too much head space in the cans-- adjusted the amount of syrup to 50.0oz in order to better fill the cans. 9.222 grams of calcium chloride were added to half of the cans before filling. Cans were manually placed into a mechanical can sealer. Once sealed, the cans were loaded into a continuous steam retort. The cook time was 23.6 minutes, with the cans reaching 90.6°C or above for an average of 15 minutes and with the two cans reaching a maximum of 99.2°C and 101.0°C. After cooking, the cool time was 30 minutes to reach an average internal temperature of 32.2°C. Cans were stored in a climate controlled environment for 45 days before being repackaged into MRE pouches.

3.1b Freezing

One-third of the diced peaches were individually quick frozen. Peach cubes were immediately taken from the dicer into an IQF chamber. A conveyor carried the peaches through the freezing chamber for 12 minutes where they were subjected to blasts of -40C air while in the chamber. After freezing, the peach pieces were immediately packaged and stored at -20C for 45 days before being repackaged into MRE pouches.

3.1c Packaging

For the wet pack fruit pouch, we used a 5oz rectangular MRE pouch. One-third of the fresh diced peaches were packaged directly in MRE pouches and processed on 8/11/2009. The steps for packaging and processing pouches were kept uniform for each peach type unless otherwise stated. 200 pouches were labeled appropriately for the treatment received-- 100 pouches without calcium chloride, 100 pouches with calcium chloride additive for each peach type. For every 100 pouches 3.6L of syrup was needed. The syrups for all samples were prepared prior to packaging. 100 gallons of approximately 35˚BRIX were made in a lee kettle for the fresh peaches on 8/11/2009. This kettle was leaking so adjustments were made by adding more sucrose to the solutions. For all syrups, 3.6L was fortified with 10.08g of L-Ascorbic Acid (L-AA) to yield an approximate L-AA content of 2800ppm in the syrup alone:

[10.08g L-AA/3.6L syrup = 2800mg/L = 2800ppm L-AA]

[(1.25oz. syrup/5oz. Pouch) x 2800ppm L-AA = 700ppm L-AA/pouch]

For the syrup with calcium chloride, food-grade anhydrous calcium chloride was added to 3.6L of syrup to yield approximately 2.0% w/w $CaCl_2$ in the syrup solution and 0.5% $CaCl_2$ in the individual pouch:

(72g $CaCl_2$/3.6kg syrup) = 2.0% $CaCl_2$ w/w

(1.25oz. syrup/5oz. Pouch) x 2.0% w/w $CaCl_2$ = 0.5% $CaCl_2$/pouch

Each pouch was packaged manually with approximately 3.75oz or 106.125g of diced peaches, followed by 1.25oz or 35.38g of the appropriate syrup. Once filled, each pouch was sealed using a heat sealer set at 66°C. All pouches were placed into a Reid Water Immersion Retort and processed using a uniform procedure. The water fill was measured to take17 minutes with 77°C water. The come up time was measured at 8 minutes where temperatures increased from 77°C to 99.5°C. The cook stage was 11 minutes at 99.5-100°C followed by 10 minutes of cool down to 47°C.

On 9/24/2009 the frozen and canned peaches processed on 8/11/2009 were taken to Sopakco in Bennettsville, SC. Sopakco is one of the top providers of MREs and government rations to the US military. The canned and frozen peaches were pouched following the same procedure used for packaging the fresh diced peaches. However, the canned peaches had to first be drained from the syrup, and the canned peaches did not receive the same amount of calcium chloride due to receiving a small amount initially before canning. When the syrup was tested for sucrose, it was found to be too high at approximately 21°BRIX. The syrups were diluted by water at a ratio of 1:6(water: syrup) to yield a syrup closer to 18°BRIX.

3.1d High Temperature Storage

Pouches were stored at 50˚C for 6 weeks or 37˚c for 6months. Natick claims these storage conditions to have the similar effect of 27°C storage for 36 months: the current shelf-life requirement for MREs (Appendix-Figure2.1). Four reps (pouches) per each treatment combination were removed from incubation weekly for 6 weeks. Two reps (pouches) for each treatment design were removed from incubation monthly for 6 months.

3.1e Weight

Good Commercial Procedures (code 128-A-10) were followed for net weights and (128-A-30) for drained weights. Net weights were determined by measuring weight of entire pouch on a scale tarred with an empty pouch. The drained weight of diced peaches was determined by using a U.S. Standard No. 8 circular sieve. The diameter of the sieve is 20.3 centimeters (8 inches) if the quantity of the contents of the container is less than 1.4 kilograms (3 pounds) or 30.5 centimeters (12 inches) if such quantity is 1.4 kilograms or more. The sieve contains 8 meshes to the inch [0.0937-inch (2.38 mm), ±3%, square openings]. The syrups were collected in a white, laboratory, shallow type tray.

After completing the preliminary steps, the contents were carefully emptied on to a tilted screen with the proper mesh (U.S. No. 8) and diameter. The peaches were drained for precisely two minutes. The peaches were only moved or disturbed to be spread evenly across mesh. Two minutes after drainage began, the peaches were placed into a 250-ml beaker and weighed on a scale tarred for the empty beaker.

3.1f Analysis of Solid Material

Texture analysis of diced peaches was done using a TA.XT*Plus* equipped with the TA-65 Multiple Puncture Rig. The probe began measuring resistive force after traveling 65mm into the 120mm tall cylindrical load cell. Measurements were taken while the probe travelled at rate of 10mm/s for a total of 55 mm. Approximately 75g of each sample was loaded into the load cell. Measurements of peak resistive force and total work (Force*sec) were used for comparative analysis. Work units are typically expressed as *F*d*. Here the machine is set to travel at a constant speed of 10mm/sec; therefore the distance unit in work (force*distance) can be expressed as seconds.

3.1g Analysis of Syrups

Syrups were collected in 100-ml glass beakers after drained weight determinations. Syrups drained from the pouches were tested for pH and BRIX. A digital pH meter was calibrated using pH 4.0, 7.0, and 10.0 each day before use. The pH of each sample was measured and recorded when the meter stabilized. The meter was cleaned with a Kem-wipe between every sample. BRIX was measured using a digital refractometer. To keep the meter from being damaged, syrups were filtered through #4 Whatman filter paper before being placed onto the meter. BRIX was measured and recorded for each sample. Meter was cleaned with a Kem-wipe between every test.

3.1h Sensory Analysis

Prior to sensory testing, certification for exemption from IRB review for research involving human subjects was granted from a departmental review committee. Certification for exemption was granted under category 6 for research per 45CFR46. Testing was conducted in the sensory laboratory of Dr. Marjorie Penfield in the Bio-systems engineering and Environmental Science building at the University of Tennessee. Pouches that were stored for 6 months at 37°C were used for affective sensory evaluations. Panelists were selected to be consumers of canned peaches in heavy syrup from a group of regular attendees of Dr. Penfield's sensory panels. Thirty experienced panelists were given 1-ounce of each treatment combination. Samples were served in 2-ounce clear plastic cups in computerized random order under cool white lighting. Panelists were given a small, unsalted cracker and water between samples for palate cleansing. Panelists were asked to score firmness, flavor, and overall acceptance based on a 9-point hedonic scale where 1=dislike extremely, 5=neither like nor dislike, and 9= like extremely. Firmness of samples was also scored on a 5-point just about right scale where 1= much too soft, 2= slightly too soft, 3= just about right, 4= slightly too firm, 5= much too firm.

3.1i Statistical Analysis

A completely randomized experimental design was used to evaluate the analytical quality parameters of wet pack peaches. The sensory testing was a randomized block design, blocked on judges to control for the differences in individual's personal preferences. A factorial treatment design was used to evaluate the peach treatments and their interactions for data from all lab tests. The treatments, or fixed effects, were type of source fruit (TYPE) and the addition of calcium chloride ($CaCl_2$) to packaging syrups for the initial samples tested. Using SAS Software 9.2 (SAS_Institute_Inc. 2008) and the 'danda.sas' macro(Saxton 2010), mixed model analysis of variance (MMAOV) was used to generate AVOVA tables. The Least Squares estimates of treatment means were grouped using the Fisher's Least Significant Difference at a significance level of $p<0.05$.

Prior to storage, 4 reps of each peach treatment combination were analyzed using the mixed procedure at a significance level of $p<.01$. Accelerated shelf-life samples were analyzed by adding a third treatment factor (WEEK or MONTH) into the factorial design. Mixed model analysis of variance was performed on samples stored at 50°C for 1-6 weeks and at 37°C for 1-6 months. A cut-off of $P<.001$ was used for reporting results of F-tests, due to the high power of the experiment. Weekly and monthly k reaction rate constants were calculated where the analysis of variance showed significant differences in the interaction of treatment factors with weeks or months. K rates of reactions were calculated using the change in averages from the initial measurements to the final storage measurement.

Discriminant analysis was used to create a predictive model that would classify canned peaches as either acceptable or unacceptable using NCSS version 07.1.19 (Hintze 2009). The observations from the sensory analysis of wet pack peaches stored at 37°C were grouped into two groups based on Natick shelf-life standards that OVERALL scores ≥ 5 on a 9-point hedonic scale was considered acceptable: group 1 (G_1) contained all observations where OVERALL <5 and was considered the unacceptable group; group 2 (G_2) considered the acceptable group contained all observations where OVERALL ≥5. Variable selection routine in NCSS showed both the FLAVOR and FIRMNESS hedonics scores to affect OVERALL liking scores. The model was validated using a holdout sample: the data from the sensory evaluation of wet pack peaches treated with multiple levels of $CaCl_2$ described below.

The variable selection routine in NCSS was first used to find which variables might best predict FLAVOR and FIRMNESS hedonic scores of wet pack peaches. Prediction equations for the FLAVOR and FIRMNESS hedonic scores were fitted using JMP® (SAS_Institute_Inc. 2007).

3.2 PHASE II-MULTIPLE LEVELS OF CALCIUM CHLORIDE

3.2a Packaging and Processing of Pouches Treated with Multiple Levels of Calcium Chloride

Twelve cans of commercially available Kroger brand yellow clingstone peach halves in heavy syrup were purchased. The cans were of two lots: LOT 2422E and LOT 2422I. Contents of each can were drained and all solids and syrups were collected in a single container. Peach halves were mechanically diced by Hobart food processor equipped with 5/8” blades. 4-ounces of diced peaches were placed into 5-ounce MRE pouches followed by 1-ounce of syrup. Syrups batches were tested for sugar content using a digital refractometer. BRIX averaged 18.3° and ranged from 17.7-19.1°, and therefore no adjustment of BRIX was necessary. Syrups were prepared containing multiple levels of food-grade anhydrous $CaCl_2$ to yield ten pouches containing syrup with 0, 0.125, 0.25, 0.375, or 0.5% $CaCl_2$. 11-ounces of each syrup batch were prepared. Pouches were heat sealed at 66˚C. Pouches were immersed in hot water for 30min, remained at 100˚C for 12minutes, and cooled for 15 minutes at 20˚C. Pouches were stored at 3˚C for 3 weeks before undergoing sensory evaluation and for 45 days before undergoing analytical tests.

3.2b Sensory Evaluation of Calcium Chloride Levels

Sensory evaluation was conducted in the pilot plant in the Food Safety and Processing building at the University of Tennessee. A single sensory booth was constructed and lit with a small fluorescent light. Panelists were undergraduate students, graduate students, faculty, and staff members of the Food Science and Technology department at the University of Tennessee. Sixty untrained panelists were given three, 1-ounce samples and asked to score firmness, flavor, and overall acceptance on a 9-point hedonic scale where 1=dislike extremely, 5=neither like nor dislike, and 9= like extremely. Panelists were undergraduate students from the Department of Food Science and Technology at the University of Tennessee, Knoxville. Samples were served in 2-ounce clear plastic cups. Balancing of the serving order was done by a balanced incomplete block experimental design, blocking on judges. Each treatment was evaluated by 36 judges, and each judge received three of the five samples. Panelists were given a small, unsalted cracker and water between samples for palate cleansing. Scores were manually recorded on score cards that had the appropriate corresponding three digit random sample number. The scorecards were arranged in the appropriate serving order and the peaches were packaged into the small cups the previous night. Peaches were held in a walk in refrigerator overnight and were removed 30 minutes prior to testing.

3.2c Analytical Tests of Calcium Chloride Levels

Two pouches (reps) of each treatment were measured for drained weight, BRIX, pH, calcium content and firmness using the same methods described in Section 3.1

3.2d Statistical Analysis of Calcium Chloride Levels

Sensory evaluation was conducted as a balanced incomplete block design, blocked on judges to control for the differences in individual's personal preferences. The treatment, or fixed effect, was the level of calcium chloride ($CaCl_2$) added to packaging syrups. Using SAS Software 9.2 (SAS 2009) and the 'danda.sas' macro (Saxton 2010), mixed model analysis of variance (MMAOV) was used to generate AVOVA tables. Results were reported significant at a level of $p< 0.05$. The Least Squares estimates of treatment means were grouped using the Fisher's Least Significant Difference at a significance level of $p<0.05$.

The regression procedure in SAS Software 9.2 (SAS 2009) via the 'danda.sas' macro (Saxton 2010) was used to evaluate the analytical quality parameters of wet pack peaches. Hypothesis testing of the slope were conducted to tests the effects of the levels of calcium chloride on drained weight, FORCE, WORK, pH and brix at a significance level of $p<.05$.

CHAPTER 4: RESULTS AND DISCUSSION

Once a product standard is defined for wet pack fruit, all products must meet all requirements listed in the performance-based contractor requirements (Defense 2010). Wet pack peaches have not been available as a wet pack fruit option since 2008. The quantifiable requirements of wet pack peaches are net and drained weights, pH, BRIX, ascorbic acid content, and a minimum three year shelf-life stored at 27°C or six months at 37°C. In addition to the required parameters listed above, samples were measured for firmness [Force in (g) and Work (g*sec)], and calcium content.

4.1 SENSORY ANALYSIS AFTER 6 MONTHS STORAGE AT 37°C

For overall liking (OVERALL) average hedonic scores of samples treated with $CaCl_2$ were reduced significantly ($p<0.0001$) to 4.01 compared to 5.79(Appendix B-Tables 4.1 and 4.2). This decrease in OVERALL scores shifts the peaches with $CaCl_2$ below the acceptability cut-off value of 5.0 (Appendix B-Table 4.1). Estimates were not found to differ for peach types when averaged across $CaCl_2$ levels ($p=0.0544$) and no interaction was found among peach types and $CaCl_2$ treatments ($p=0.0813$) (Appendix B-Table 4.1).

FLAVOR scores were significantly reduced ($p<.0001$) from 6.38 to 3.81 by $CaCl_2$ addition at 0.5% (Appendix B-Table 4.3 and 4.4). Flavor scores were also affected by the type of peach used ($p=0.0008$) (Appendix B-Table 4.3). Canned peaches averaged 5.67 on a 9-point hedonic scale and were significantly higher than the average for frozen peaches of 4.52. Fresh peaches averaged 5.10 and were not found to be significantly different from either canned or frozen peaches for flavor (Appendix B-Table 4.4).

$CaCl_2$ addition at 0.5% had significant improvement on FIRMNESS scores ($p<.0001$; Appendix B-Table 4.5). Average hedonic scores for firmness increased from 4.93 to 6.12 when calcium chloride was added to all peach types (Appendix B-Table 4.6). Also a small difference among peach types interaction with calcium chloride was found ($p=0.0218$; Appendix B-Table 4.5). The canned peach without calcium chloride was significantly lower than the other peach types, with an average hedonic score of 4.13. When treated with $CaCl_2$, the canned peach averaged 6.2 for FIRMNESS scores and was found to be similar to the other peach types when also treated with calcium chloride. All samples scored significantly higher than the canned peach without calcium chloride which had a mean of 4.13 and was the only estimate below 5.0 (Appendix B-Table 4.6).

Just-about-right scores for firmness had a large difference between $CaCl_2$ levels ($p<.0001$; Appendix B-Table 4.7). Average scores improved from 1.76 to 2.84 when peaches were treated with 0.5% $CaCl_2$ (Appendix B-Table 4.8). There was also a difference in peach types ($p<.0001$; Appendix B-Table 4.7). Canned peach average scores were significantly lower than both fresh and frozen peaches when averaged across calcium treatments (Appendix B-Table 4.8). The fresh and frozen peaches with calcium chloride had the highest percentages of panelists score it as just about right (70 and 67%; Appendix B-Figure 4.1). In fact, the frozen peach sample with calcium had 16.67% scored as too firm, which could potentially explain the slightly lower FIRMNESS average on the 9-point hedonic scale for the frozen peaches with

$CaCl_2$. It is also important to report that no judge scored any of the samples without calcium as too firm.

4.2 CALCIUM CHLORIDE LEVELS

Sensory analysis of $CaCl_2$ levels showed significant differences among calcium levels for overall liking ($p<.0001$; Appendix B-Table 4.9), flavor ($p<.0001$; Appendix B-Table 4.11), but not for firmness ($p=0.0716$; Appendix B-Table 4.13). Mean separation for both OVERALL and FLAVOR showed the same grouping pattern: no significant difference between levels 0% and 0.125%, 0.25% and 0.375%; 0.5% was lower than all others (Appendix B-Table 4.10 and 4.12). It is important to note that peaches processed with 0.5% $CaCl_2$ had an average OVERALL score of 4.12 and would therefore be considered unacceptable before storage at normal ambient temperatures.

Peaches treated with multiple levels of calcium chloride showed no significant difference for drained weights ($p=0.151$; Appendix B-Table 4.15), firmness measured as FORCE ($p=0.067$; Appendix B-Table 4.16), or brix ($p=0.3649$; Appendix B-Table 4.19). Differences in WORK ($p=0.0045$; Appendix B-Table 4.17) and pH ($p=0.0007$; Appendix B-Table 4.18) could be explained by percent calcium chloride. WORK and pH were best explained by their linear relationship with calcium chloride. 93% of the differences in WORK were explained by the linear $CaCl_2$ term and 98% of the differences in pH could be explained by the linear $CaCl_2$ term.

[$WORK = 1104.5 + (1355*\%CaCl_2)$] & [$pH = 3.83 – (1.11*\%CaCl_2)$]

4.3 DISCRIMINANT ANALYSIS FOR PREDICTING OVERALL ACCEPTABILITY

Of the 180 observations from the sensory evaluation of peaches stored at 37°C for six months, 82 (n_1) were classified into the unacceptable group while 98 (n_2) were classified into the acceptable group. Discriminant analysis between these two groups using regression was done by creating a new y-variable (CLUSTER). The *n* values were used to develop the CLUSTER variable using a Fischer adjustment. CLUSTER for G_1 was calculated as n_2/n_{total}= 98/180 = 0.544. CLUSTER for G_2 was calculated as $-n_1/n_{total}$ =-82/180 = -0.456

All possible regressions in NCSS examined FLAVOR and FIRMNESS as potential explanatory variables using CLUSTER as the dependent variable (Appendix B-Table 4.20). The best model had both variables (FLAVOR, FIRMNESS) with an R^2 value of 0.618. When the model [CLUSTER = 0.982 – (4.040E-02*FIRMNESS) – (0.149*FLAVOR)] was applied to the data from the sensory evaluation of wet pack peaches treated with varying levels of $CaCl_2$, observations were correctly grouped for OVERALL acceptance at a rate of 96% , yielding a 4% miss rate (Appendix B-Table 4.21). The miss-classified observations were all predicted as unacceptable when they actually scored ≥5 for OVERALL. Of the 7 misses, two were categorized as 5 (neither like nor dislike) and five observations were given a 6 (like slightly) for OVERALL acceptance scores. The validation step suggests this model could be used for predicting acceptance of wet pack peaches based on flavor and firmness estimates.

4.4 PREDICTION MODELS FOR FIRMNESS AND FLAVOR HEDONIC SCORES

Using the average FLAVOR scores as the dependent variable, a variable selection procedure using the All Possible Regression option in NCSS (Hintze J 2009) suggested that the pH of wet pack peaches was the only significant explanatory variable for predicting average hedonic scores (Appendix B-Table 4.22). This supports the ANOVA results from the sensory evaluation of wet pack peaches treated with multiple levels of calcium chloride, where FLAVOR scores significantly decreased as calcium chloride levels increased; the same pattern seen when comparing pH to calcium chloride levels. The estimated model [FLAVOR = -17.7 + 6.19*pH] had an R^2 value of 0.7967. The average pH and FLAVOR scores of the peaches treated with multiple levels of $CaCl_2$ were used to validate the model created from the peaches that had been stored at 37°C for six months. The predicted FLAVOR scores were compared to the actual FLAVOR scores using the correlation procedure in SAS (SAS 2010). The correlation value of r=0.899 resulted in an R^2 value was 0.808. This slight increase in R^2 suggested that the data used as the holdout samples could possible create a model better for predicting actual FLAVOR scores of wet pack peaches.

The FLAVOR hedonic scores from the sensory evaluation of peaches treated with multiple levels of $CaCl_2$ were fitted to their average pH measures using a quadratic regression model using JMP® version 7.0.2 (SAS Institute Inc. 2007) (Appendix B-Figure 4.2). The model [FLAVOR = = -13.82286 + 5.6699394*pH - 11.702183*$(pH-3.55)^2$] was validated using the averages from the sensory evaluation of wet pack peaches stored at 37°C for six months. The predicted FLAVOR scores were compared to the actual FLAVOR scores using the correlation procedure in SAS (SAS 2010). The Pearson correlation value of r=0.9243 resulted in an R^2 value of 0.854. Therefore this model is slightly better for predicting FLAVOR scores than the model listed above and was used in shelf-life predictions for this study.

Using the average FIRMNESS scores as the dependent variable, and the instrumentation analysis averages, a variable selection procedure using the All Possible Regression option in NCSS (Hintze J 2009) suggested the WORK variable of wet pack peaches was the only significant explanatory variable for predicting average hedonic scores (Appendix B-Table 4.23). The relationship between FIRMNESS scores and WORK estimates had a very high R^2 value of 0.983 when a quadratic model was used (Appendix B- Table 4.24). The model [FIRMNESS = -26.93984 + 8.19747*ln(WORK) – 0.50801*ln(WORK)^2] could not be validated using the same holdout sample as FLAVOR because the untrained sensory panelists did not find levels of $CaCl_2$ treatments to differ significantly for FIRMNESS. However, this model was used for predicting FIRMNESS estimates due to its high R^2 value.

4.5 FIRMNESS OF DIFFERENT PEACH TYPES WITH 0% AND 0.5% $CACL_2$

4.5a Initial Effects of Thermal Processing

Firmness as a measure of WORK (g*sec) had the largest difference between $CaCl_2$ treatment levels (p<.0001; Appendix B-Table 4.25). Peaches treated with 0.5% $CaCl_2$ had a significantly higher average than those without $CaCl_2$: 4885.4 g*s and 1300.5 g*sec (Appendix B-Table 4.26) There was also a significant difference in WORK averages for peach types (p<.0001; Appendix B-Table 4.25). All peach types were grouped separately from highest to lowest being fresh, frozen, and canned (Appendix B-Table 4.26).

4.5b Firmness of Peaches during Storage of 1-6 Weeks at 50°C

The pattern of texture loss was observed to be first-order; decreasing very rapidly at first and then slowing down as storage time increased. The distribution of observations was skewed to the right and required a transformation by the natural log to be normally distributed.

Differences in WORK were found when comparing $CaCl_2$ levels among weeks ($p<.0001$; Appendix B-Table 4.27). The rate of firmness (WORK) loss was calculated as *k*-values after each week of storage and averaged for both calcium chloride treatments. *K*-values decreased from 0.249 to 0.180 for firmness rate loss per week when peaches were treated with 0.5% $CaCl_2$.

4.5c Firmness of Peaches during Six Months Storage at 37°C

No treatment interactions for WORK were found to differ among months of storage at 37°C. Months showed to significantly affect the WORK variable ($p<.0001$; Appendix B-Table 4.29). The rate of decline was found to be k = 0 .128. When compared to the higher temperature storage, these results differ. Here neither calcium chloride nor peach types showed any interactions with the storage time period MONTH. When at higher temperatures, calcium chloride reduces the rates of texture loss per week in all peach types. This shift in results may be caused by a shift in the type of reactions occurring within the peach tissue matrix. Research has shown that β-elimination reactions can occur at a pH as low as 3.8 at elevated temperatures. Further research has also suggests that calcium chloride can slow the reaction rates of β-elimination reactions, but has no effect on hydrolysis reaction rates. Perhaps at 50°C depolymerization reactions of soluble pectin shift from acid hydrolysis to β-elimination. Comparing the results of the monthly storage to the initial results of firmness supports this theory. Thermal processing involves extremely high temperatures in comparison with normal storage conditions. Research on thermal processing of fruits and vegetables has attempted to explain the kinetics behind pectin breakdown, and subsequently, firmness loss. The main reaction causing pectin breakdown during thermal processing has been suggested to be β-elimination reactions. If we assume this to be correct, and the initial results of firmness showed calcium chloride greatly improved the firmness retention in all peach types during processing, that too suggests calcium chloride's interaction with pectin has a significant effect on β-elimination reaction rates.

4.6 DRAINED WEIGHT

Initial drained weight showed no significant difference, among peach types, $CaCl_2$ or their interactions (Appendix B-Table 4.31). During storage of wet pack peaches at 50°C, the largest differences in drained weights were found in the main effects of $CaCl_2$ and weeks ($p<.0001$; Appendix B-Table 4.33). The drained weight of $CaCl_2$ treated peaches were significantly higher among weeks ($p<.0001$; Appendix B-Table 4.33) and the peach types also showed an interaction with weeks ($p<.0001$; Appendix B-Table 4.33). The addition of calcium chloride decreased the rate of drained weight loss per week as a reduction in *k*-values from 0.0341 to 0.0081. Comparing peach types among weeks, fresh and IQF have a constant rate of solid material loss per week of k = 0.021 and 0.020, while canned peaches showed a slower rate of solid mass loss of k = 0.016 per week.

During the six month storage tests, the treatment of peaches with 0.5% calcium chloride was the only factor found to significantly affect drained weights ($p<.0001$; Appendix B-Table

4.35). In fact, with all peach types and calcium treatments averaged across months, they did not show a significant decrease from month 1-6: although the estimates did decrease from 99.4 g at month one to 96.3 g at month six, they were not found to be significantly lower ($p=0.2718$; Appendix B-Table 4.35 and 4.36). Samples with calcium chloride averaged 102g when averaged over all types and months; samples without had an estimate of 95.1g (Appendix B-Table 4.36). No treatment interactions differed across months, suggesting that if calcium chloride does indeed slow the rate of solid material loss during storage at 37°C, it is a negligible effect. This further supports the firmness results found that also suggests calcium chloride addition protects the peach during thermal processing. It also suggests that a shift in the type of degradation reactions occurs during the higher temperature storage at 50°C.

4.7 pH

Initially peaches treated with calcium chloride showed a significant decrease in their pH of 3.39 compared to 3.99 for peaches without calcium ($p<.0001$; Appendix B-Table 4.37 and 4.39). Military guidelines require pH to be within a range of 3.85-4.15. Testing at Natick has shown that a reduction in pH can cause significant flavor loss (Mount et al. 2008). Furthermore, pH did not show significant change across storage weeks at 50°C (Appendix B-Table 4.39). During storage at 37°C, there was a significant difference found between the calcium treated samples among months ($p<.0001$; Appendix B-Table 4.41). The peaches treated with calcium chloride had an increase in pH from 3.30 to 3.49 (Appendix B-Table 4.42), resulting in a rate constant of k = 0.3834. The samples without calcium showed a different trend over months by decreasing from 3.95 to 3.88; however none of the weekly estimates of peaches without $CaCl_2$

significantly differed (Appendix B-Table 4.42). The pH of fresh peaches also changed over the months of storage differently than the other types of peaches (p=0.0003; Appendix B-Table 4.41). When averaged across calcium levels, the canned and IQF peaches showed an increase in pH, both finishing storage at 3.71 and 3.72 (Appendix B-Table 4.42). The fresh peach showed a slight decrease in pH from 3.73 to 3.67 during storage (Appendix B-Table 4.42).

4.8 BRIX

Canned peaches showed a significant increase (p=0.0003; Appendix B-Table 4.43) compared to both fresh and IQF peaches with an estimate of 19.1 (Appendix B-Table 4.44). This variation may be explained by human error involved when filling the pouches. The kettle used for mixing syrups used in packaging the fresh peach pouches had a large leak. Extra sugar was added to the solution during production due to a leaky kettle. This could have contributed to the low BRIX average of fresh pouches, thus making the processing effect seem significantly different on the ANOVA F-test. This is also a concern, as military guidelines require BRIX to range from 18.0 to 20.0. There were only detectable differences for sugar content among weeks (p<.0001; Appendix B-Table 4.45). After an initial BRIX average of 17.48 a rate of reaction of k = 0.0022 was calculated across all weeks, a very minimal change. During monthly storage testing at 37°C, BRIX did not change (p=0.3370; Appendix B-Table 4.47) and there were no interaction differences found for peach type or calcium chloride with months of storage (p=0.3256 and 0.0664; Appendix B-Table 4.47).

4.9 SHELF-LIFE PREDICTION MODEL

By integrating the best prediction models for FLAVOR [FLAVOR = = -13.82286 + 5.6699394*pH - 11.702183*$(pH-3.55)^2$] and FIRMNESS [FIRMNESS = -26.93984 + 8.19747*ln(WORK) – 0.50801*$\ln(WORK)^2$] into the model for predicting CLUSTER [CLUSTER = 0.9823 – (4.034E-02*FIRMNESS) – (0.1491*FLAVOR)], a single model for predicting acceptance was determined using only the pH and lnWORK measurements of wet pack peaches [CLUSTER = 4.131 -0.3312*lnWORK +0.0205*$\ln WORK^2$ -0.8452*pH +1.7444*$(pH-3.55)^2$]. Products are considered acceptable when the predicted CLUSTER values are <0 and when the pH estimates are within the range mandated by Natick (3.85-4.15). A producer of wet pack peaches would need to measure the pH of canned peaches before formulating the amount of calcium chloride to add. Using the model for pH as a function of calcium chloride, a maximum allowable amount of calcium chloride can be found (Appendix B-Table 4.49). As the pH of the canned peach source increases so does the maximum allowable amount of calcium chloride. It may be advantageous for producers of wet pack peaches to seek canned peaches with a relatively higher pH, therefore more calcium chloride can be added; subsequently creating a product with a longer shelf-life at higher storage temperatures. Calcium chloride estimates based on this model show that peaches with a starting pH of 3.99 should be treated with 0.126% calcium chloride. Previous sensory analysis showed that at 0.125%, calcium chloride would not negatively affect flavor. This suggests that wet pack peach producers should seek canned peaches with a pH of 3.99 and treated them with 0.126% calcium chloride in order to maximize flavor and firmness.

CHAPTER 5: CONCLUSION

In this study, wet pack diced peaches were processed using canned, fresh, and frozen peaches. The canned peaches were not significantly different from wet pack peaches processed using frozen and fresh peaches for overall liking when stored at 37°C for six months. Based on the inability of panelists to differentiate between peach types for overall liking, this study suggests that producers should continue to use canned clingstone peaches as the peach source for wet pack peaches.

Overall liking of wet pack peaches was negatively affected by the addition of 0.5% (w/w) calcium chloride. Average overall liking scores of peaches with 0.5% calcium chloride were 4.01, well below the acceptability cut-off of 5.0. Based on the conclusion that 0.5% $CaCl_2$ was not a working option for wet pack peaches, other levels of $CaCl_2$ (0.125%, 0.250%, and 0.375%) were compared to the levels of $CaCl_2$ (0% and 0.5%) used in Phase I. The above conclusion was supported by this comparison, as peaches with 0.5% $CaCl_2$ scored 4.12 for overall liking, again below the acceptability cut-off of 5.0. Calcium chloride was found to negatively affect flavor, however at 0.125% there was no detectable flavor difference compared to samples without calcium chloride. Both the flavor and firmness of wet pack peaches were shown to affect consumers' overall liking

This study also concluded that the WORK (g*s) measurement using the TA-65 multiple puncture rig could be used as an effective method of predicting the sensory quality of firmness in diced fruit. Using the natural log of WORK (g*s), a quadratic model fit very well (R^2=.98) to the average sensory scores. This model could not be validated and should be tested further as to its precision. The pH of wet pack peaches showed to be highly correlated with the sensory quality of flavor. A quadratic regression equation was found to have a high precision for predicting flavor and was validated using independent sensory observations..

Strong linear relationships between calcium chloride concentrations were found with pH and firmness measured as WORK (g*s). Because of this relationship with pH, calcium chloride may only be added to canned peaches at a level that results in a pH of no more than 3.85. The maximum estimated level of calcium chloride that can be used on canned peaches with a pH of 3.99 was 0.126%.

High temperature storage resulted in mixed results when tested six-weeks at 50°C and six-months at 37°C. The increased temperature results were inconsistent with the lower temperature, suggesting that a shift in pectin degradation reactions might occur in wet pack peaches when stored above 37°C. This further supports that the use of $CaCl_2$ in wet pack peaches should be pursued further, since the environmental temperatures of combat areas can easily exceed 37°C.

LIST OF REFERENCES

(2010). Code of Federal Regulation-USDA Grading Standards. 7CFR52. FDA.
Arthey, D. and P. R. Ashurst (2001). Fruit processing : nutrition, products, and quality management. Gaithersburg, MD, Aspen Publishers.
BeMiller, J. N. and G. V. Kumari (1974). "Beta-elimination in uronic acids- Evidence for an ElcB mechanism." Carbohydrate Research **25**(2): 419-428.
Blumer, J. M., R. P. Clay, C.W. Bergmann, P. Albersheim and A. Darvill (2000). "Characterization of changes in pectin methylesterase expression and pectin esterification during tomato fruit ripening." Canadian Journal of Botany: 78 (5) 607-618 **78**(5): 607-618.
Brunke, H. and M. Chang. (2010). "Peach Profile." Agricultural Issues Center Retrieved March, 2010, from http://www.agmrc.org/commodities__products/fruits/peach_profile.cfm#.
Buren, J. P. V. (1978). "The chemistry of texture in fruits and vegetables." Journal of Texture Studies **10**(1).
Carles, L. (1984). "Clingstone Peaches, fruits specially adapted for the manufacture of fruits in syrup." Arboriculture Fruitiere **31**: 47-48.
Crisosto, C. H. (1994). "Stone fruit maturity indices: a descriptive
review." Postharvest News and Information **5(6):65N-68N**.
Darsch, G. A. and P. Brandler (1995). Evolution of Rations: The Pursuit of Universal Acceptance. Not eating enough : overcoming underconsumption of military operational rations. Washington, D.C.**:** xiii, 483 p.
Defense, D. o. (2010). Performance-based Contract Requirments: Fruits, Wet Pack PCR-4-002C.
Defense_Logistics_Agency (2010). Troop Support: Substinence. **2011**.
Department_of_Defense (2010). An Overview of US Military Rations, U.S. Army Research, Development, and Engineering Command.
Ellis, M. J. and C. M. D. Man (2000). The Methodology of Shelf-Life Determination. Shelf-Life Evaluation of Foods. C. M. D. Man and A. Jones**:** 23-33.
Fennema, O. R. (1996). Food chemistry. New York, M. Dekker.
Fisher, J. C. and C. Fisher (2011). Food in the American military : a history. Jefferson, N.C., McFarland & Co.
Fraeye, I., A. De Roeck, T. Duvetter, I. Verlent, M. Hendrickx and A. Van Loey. (2007). "Influence of pectin properties and processing conditions on thermal pectin degradation." Food Chemistry **105**(2): 555-563.
GMA (2007). Canned Foods: Principles of Thermal Process Control, Acidification and Container Closure Evaluation. Washington, D.C., GMA Science and Education Foundation.
Haard, N. F. and G. W. Chism (1996). Characteristics of Edible Plant Tissue. Food Chemistry. O. R. Fennema**:** 948.
Hanelt, P. (2001). Institute of Plant Genetics and Crop Plant Research Mansfeld's Encyclopedia of Agricultural and Horticultural Crops, Springer Heidelberg**:** 3716
Hintze, J. (2009). NCSS 7.1.19. Kaysville, UT.
Hirsch, E., H. L. Meiselman, R.D. Popper and B. Jezior. (1985). The effects of prolonged feeding Meal, Ready-to-eat (MRE) operational rations. Technical Report TR-85/035. Natick, MA, U.S. Army Natick Research, Development and Engineering Center.
Koehler, F. A. (1958). "Special Rations for the Armed Forces, 1946-53." QMC Historical Studies **Series II**(No. 6): Chapter 1.

Krall, S. M. and R. F. McFeeters (1998). "Pectin hydrolysis: Effect of temperature, degree of methylation, pH, and calcium on hydrolysis rates." Journal of Agricultural and Food Chemistry **46**(4): 1311-1315.

Kristy Plattner, E. D., Agnes Perez (2010). Fruit and Tree Nuts Outlook, USDA.

Lawless, H. T., F. Rapacki, J. Horne and A. Hayes (2003). "The taste of calcium and magnesium salts and anionic modifications." Food Quality and Preference **14**: 319-325.

Layne, D. R. and D. Bassi (2008). The peach : botany, production and uses. Wallingford, Oxfordshire, UK ; Cambridge, MA, CABI.

Man, C. M. D. (2004). Shelf-life Testing. Understanding and Measuring the Shelf-Life of Food. R. Steele: 340-356.

Manganaris, G. A., M. Vasilakakis, G. Diamantidis and I. Mignani (2005). "Effect o calcium additives on physicochemical aspects of cell wall pection and sensory attributes of canned peach." Journal of the Science of Food and Agriculture **85**: 1773-1778.

Meiselman, H. L. (1995). Introduction to the Concepts and Issues Underlying Underconsumption of Field Rations. Not Eating Enough. B. M. Marriot. Washington, D.C., National Academy Press: 57-64.

Mizrahi, S. (2004). Accelerated Shelf-life Tests. Understanding and Measuring the Shelf-Life of Foods. R. Steele: 317-337.

Mount, J., L. Zivanovic and C. Sams (2008). Evaluation of Processes and Additives to Improve Quality and Shelf Life of Wet Pack Peaches. The University of Tennessee, The Combat Rations Network for Technology Implementation.

Oke, M. and G. Paliyath (2006). Biochemistry of Fruit Processinh. Food Biochemistry & Food Processing. Y. H. Hui. Ames, IA.

Paliyath, G. and D. P. Murr (2006). Biochemistry of Fruits. Food biochemistry and food processing. Y. H. Hui. Ames, Iowa, Blackwell Pub. Professional: xiv, 769 p.

Predieri, S., P. Ragazzini and R. Rondelli (2006). "SENSORY EVALUATION AND PEACH FRUIT QUALITY. ." Acta Hort. (ISHS)(713): 429-434.

Quartermaster (1949). The History of Rations. Rations, Fort Lee, Virgina, US Army Quartermaster Foundation.

Rao, S. N. and S. A. Barringer (2005). "Timing of Calcium Treatment on Resistance of Raw and Canned Diced Tomatoes to Mechanical Abuse." Journal of Food Processing and Preservation **29**: 1-7.

Reed, J. F. (1980). Valley Forge Commissariat. The Picket Post, The Valley Forge Historical Society.

Riehn, R. K. (1990). 1812 : Napoleon's Russian campaign. New York, McGraw-Hill.

Rolls, B. J. (1995). Effects of Food Quality, Quantity, and Variety on Intake. Not Eating Enough. B. M. Marriott: 203-216.

Salunkhe, D. K., H. R. Bolin and N.R. Reddy (1991). Storage, processing, and nutritional quality of fruits and vegetables. Boca Raton, Fla., CRC Press.

SAS_Institute_Inc. (2007). JMP 7.0.2. Cary, NC.

SAS_Institute_Inc. (2008). SAS 9.2. Cary, NC.

Saxton, A. (2010). Stats Design and Analysis Web Guide.

Sila, D. N., C. Smout, F. Elliot, A. Van Loey and M. Hendrickx (2006). "Non-enzymatic depolymerization of carrot pectin: Toward a better understanding of carrot texture during thermal processing." Journal of Food Science **71**(1): E1-E9.

Szczesniak, A. S. (2002). "Texture is a Sensory Property." Food Quality and Preference **13**: 215-225.

Taoukis, P. S., T. P. Labuza and I. S. Saguy (1997). Kinetics of Food Deterioration and Shelf-life prediction. Handbook of Food Engineering Practice. V. ., Rotstein and Singh. New York, CRC Press**:** 361-403.

Texture_Technologies_Corp. (2004). TA.XTPlus Texture Application Study: Diced Peach Firmness.

USDA (1998). Canned Clingstone Peach Manual. Scoring Guide for Character. Washington, DC.

USDA (2010). Noncitrus Fruits and Nuts. N. A. S. Service, USDA.

Wiley, R. C. and A. H. Thompson (1960). "Influence of variety, storage, and maturity on the quality of canned apple slices." Proc Am Soc Hor Sci **75**: 61-85.

APPENDIX A

Table 1.1 Top Peach Producing States from 2008-2010 (USDA 2010)

State	Total Production (tons)		
	2008	**2009**	**2010**
California	859,000	819,000	817,000
South Carolina	60,000	75,000	110,000
New Jersey	34,000	35,000	36,000
Georgia	28,000	32,000	40,000

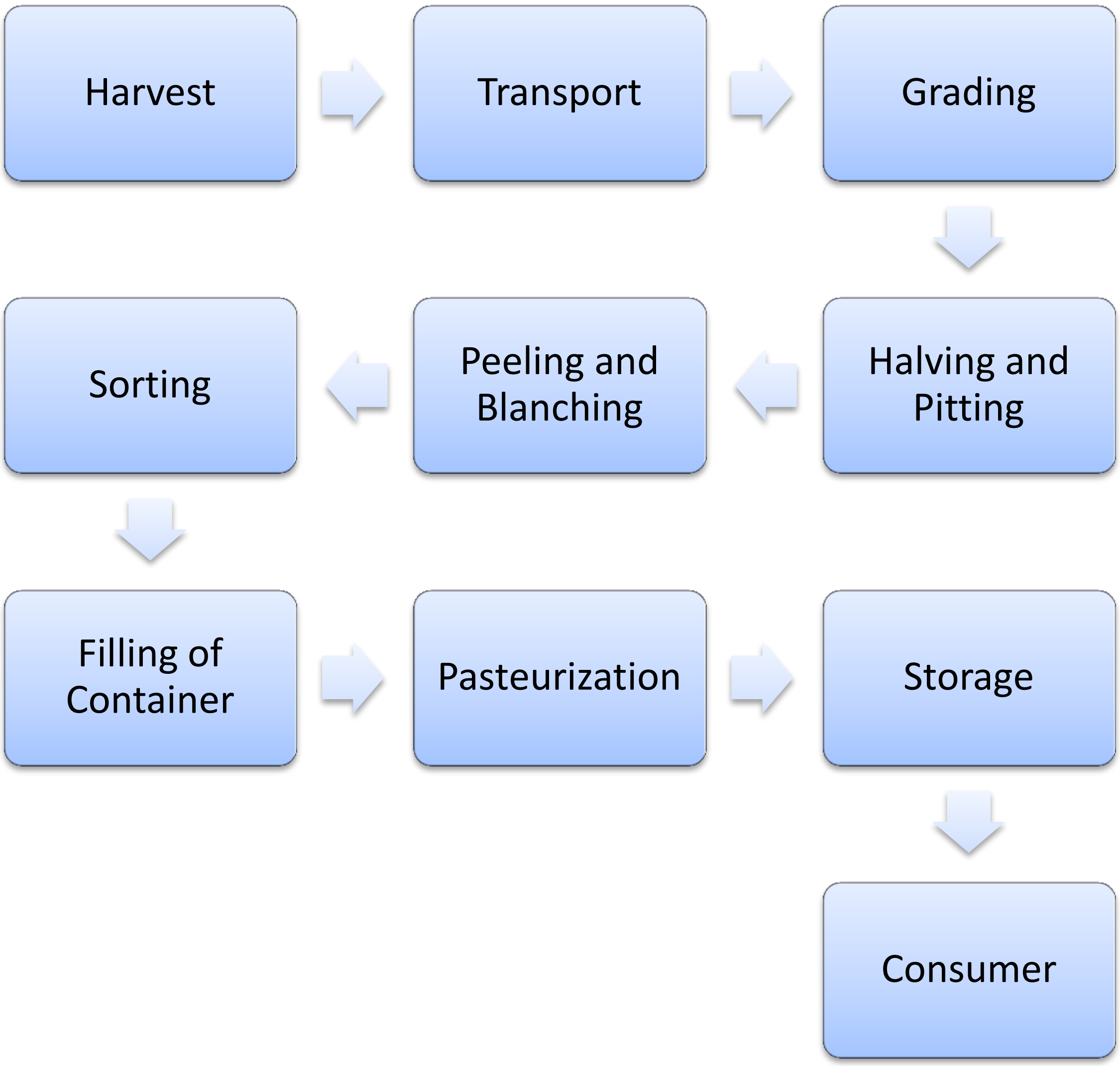


Figure 1.1 A Diagram of the Basic Steps in the Peach Canning Process. This was the basic process used in producing the canned and fresh peaches used for wet pack peaches. The frozen peaches had the extra processing step of freezing and cold storage before being filled into containers and pasteurized.

Table 2.1 Performance-based Contractor Requirements for producing Wet Pack Peaches. Taken from the Natick requirements for all wet pack fruit (Defense 2010), listed are only those specific to wet pack peaches.

Appearance and USDA Grading Standards: The finished product must be free from foreign materials. Peaches shall be U.S. Grade B or better of the U.S. Standards for Grades of Canned Clingstone Peaches. USDA grading of canned clingstone peaches is based on a 30 point scale. Grade B will have a score of 24-26 points.
Mixed fruit shall meet or exceed the odor, flavor, clearness of liquid media, color, and uniformity of size requirements for U.S. Grade B of the U.S. Standards for Grades of Canned Fruit Cocktail. The character shall meet or exceed the requirements for U.S. Grade B of the U.S. Standards for Grades of Canned Fruit Cocktail, except for the peaches component. The peach component shall contain not greater than 40 percent, by weight, of excessively frayed or mushy peaches.

USDA Scoring Guide for Diced Peach Character (USDA 1998)

Grade	Texture Variation Between Units	Appearance or Eating Quality	Firm, Frayed or Mushy Units (percent)	Character Description (percent)
A (27-30 pts)	Tender, Pliable, Fleshy,	Not more than slightly affected by one unit possessing "reasonably good character"	"Insignificant Fraying", Reasonably well-defined, Not more than 3% may be excessively frayed or mushy	Units possess "Good Character", and reasonably free from crushed units.
B (24-26 pts)	Variable tenderness in units.	Not materially affected by one unit possessing "fairly good character"	"Slight Fraying", slightly firm or soft, not more than 5% may be excessively frayed or mushy.	Units possess "Reasonably Good Character", and reasonably free from crushed units.
C (21-23 pts)	Units of variable fleshiness no uniform tenderness.	Materially affected, moderate but not excessively. Units of "Fairly Good Character".	"Frayed"units, not more than 10% of units are excessively frayed or mushy	Units possess "Fairly Good Character", and fairly free from crushed units.
D (0-20 pts)	Noticeably variable texture, not tender.	Appearance eating quality of units are seriously affected.	"Excessively Frayed" units, not more than 25% may consist of mushy units	Character of units is excessively firm or soft as to be slightly objectionable.

Odor and Flavor: The packaged food shall be free from foreign odors and flavors.

Net Weight and Drained Weight: The average net weight shall be not less than 4.5 ounces (128 grams). The net weight of an individual pouch shall be not less than 4.0 ounces (113 grams). The average drained weight shall be not less than 3.5 ounces (99 grams). The drained weight in an individual pouch shall be not less than 3.0 ounces (85 grams).
Palatability and Overall Appearance: The finished product shall be equal to or better than the approved product standard in palatability and overall appearance.
Analytical Requirements: The pH of pineapple, peaches, pears, and mixed fruit shall be 3.85 to 4.15. The pineapple, peaches, pears, and mixed fruits shall be not less than 18° and not more than 22° BRIX measurement. The ascorbic acid content of pineapple, peaches, pears, and mixed fruit shall be 200 – 1500 ppm.
Shelf Life: The contractor shall provide a certificate of conformance that the product has a 3 year shelf life when stored at 80°F (27°C). Government verification may include storage for 6 months at 100°F (37°C) or 36 months at 80°F (27°C). Upon completion of either storage period, the product will be subjected to a sensory evaluation panel for appearance and palatability and must receive an overall score of 5 or higher based on a 9-point hedonic scale to be considered acceptable.

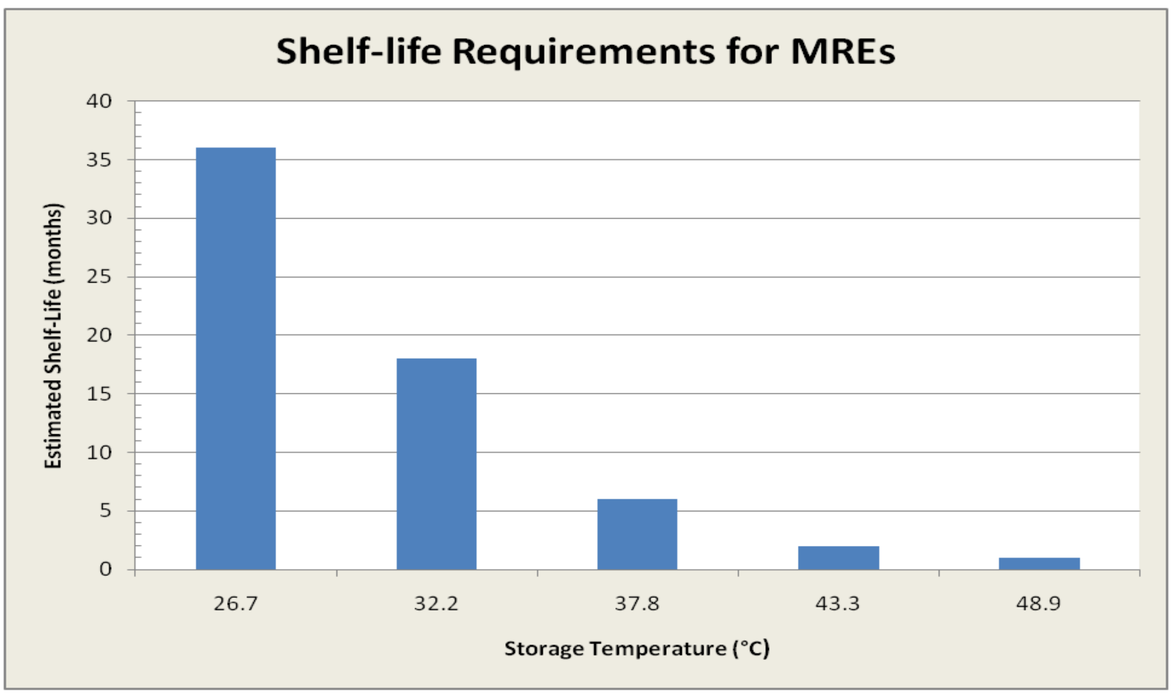


Figure 2.1 MRE Estimated Shelf-Life. Natick requirements for shelf-life estimates of all MRE components as described by the Department of Defense (Defense 2010). As temperature increases, shelf-life estimates decrease exponentially.

APPENDIX B

Table 4.1 Analysis of Variance for Overall Liking Hedonic Scores of Wet Pack Peaches stored at 37°C for 6 months.

Fixed Effect	Degrees of Freedom	F-statistic	P > F
Type	2	2.97	0.0544
$CaCl_2$	1	47.65	<.0001
Type*$CaCl_2$	2	2.55	0.0813

Table 4.2 Means for Overall Liking Hedonic Scores of Wet Pack Peaches stored at 37°C for 6 months: Scores based on a 9-point hedonic scale where 1= dislike extremely, 5=neither like nor dislike, and 9=like extremely. Letter Grouping$^{A\text{-}B}$ based on Fisher's Least Significance Difference test (α=.05). Means labeled with the same letter did not differ significantly.

Type	% $CaCl_2$	OVERALL Mean	Std. Dev.
Canned	All	5.20	2.17
Fresh	All	5.03	2.03
Frozen	All	4.47	2.21
All	0	5.79^{A}	2.08
All	0.5	4.01^{B}	2.19
Canned	0	5.70	2.05
Canned	0.5	4.70	2.28
Fresh	0	6.23	1.77
Fresh	0.5	3.83	2.28
Frozen	0	5.43	2.42
Frozen	0.5	3.50	2.01

Table 4.3 Analysis of Variance for Flavor Hedonic Scores of Wet Pack Peaches stored at 37°C for 6 months.

Fixed Effect	Degrees of Freedom	F-statistic	P > F
Type	2	7.44	0.0008
$CaCl_2$	1	111.21	<.0001
Type*$CaCl_2$	2	1.09	0.3376

Table 4.4 Means for Flavor Hedonic Scores of Wet Pack Peaches stored at 37°C for 6 months: Scores based on a 9-point hedonic scale where 1= dislike extremely, 5=neither like nor dislike, and 9=like extremely. Letter Grouping^{A-B} based on Fisher's Least Significance Difference test (α=.05). Means labeled with the same letter did not differ significantly within each main effect comparison.

Type	% $CaCl_2$	Flavor Mean	Std. Dev.
Canned	All	5.67^{A}	1.91
Fresh	All	5.10^{AB}	2.01
Frozen	All	4.52^{B}	2.31
All	0	6.38^{A}	1.97
All	0.5	3.81^{B}	2.18
Canned	0	6.87	1.57
Canned	0.5	4.47	2.24
Fresh	0	6.63	1.79
Fresh	0.5	3.57	2.22
Frozen	0	5.63	2.54
Frozen	0.5	3.40	2.08

Table 4.5 Analysis of Variance for Firmness Hedonic Scores of Wet Pack Peaches stored at 37°C for 6 months.

Fixed Effect	Degrees of Freedom	F-statistic	P > F
Type	2	2.98	0.0540
$CaCl_2$	1	28.81	<.0001
Type*$CaCl_2$	2	3.93	0.0218

Table 4.6 Means for Firmness Hedonic Scores of Wet Pack Peaches stored at 37°C for 6 months: Scores based on a 9-point hedonic scale where 1= dislike extremely, 5=neither like nor dislike, and 9=like extremely. Letter Grouping$^{A\text{-}B}$ based on Fisher's Least Significance Difference test (α=.05). Means labeled with the same letter did not differ significantly within each main effect comparison.

Type	% $CaCl_2$	Firmness Mean	Std. Dev.
Canned	All	5.17	1.74
Fresh	All	5.82	1.57
Frozen	All	5.60	1.83
All	0	4.93^{B}	1.84
All	0.5	6.12^{A}	1.59
Canned	0	4.13^{C}	1.94
Canned	0.5	6.20^{A}	1.54
Fresh	0	5.43^{B}	1.72
Fresh	0.5	6.20^{A}	1.42
Frozen	0	5.23^{B}	1.85
Frozen	0.5	5.97^{AB}	1.81

Table 4.7 Analysis of Variance for Firmness Just-about-Right Scores of Wet Pack Peaches stored at 37°C for 6 months.

Fixed Effect	Degrees of Freedom	F-statistic	P > F
Type	2	13.91	<.0001
$CaCl_2$	1	221.47	<.0001
Type*$CaCl_2$	2	2.10	0.1264

Table 4.8 Means for Firmness Just-about-Right Scores of Wet Pack Peaches stored at 37°C for 6 months: Scores based on a 5-point just-about-right scale where 1= much too soft, 2= slightly too soft, 3= just about right, 4= slightly too firm, and 5= much too firm. Letter Grouping$^{A\text{-}B}$ based on Fisher's Least Significance Difference test (α=.05). Means labeled with the same letter did not differ significantly within each main effect comparison.

Type	% $CaCl_2$	Firmness Mean	Std. Dev.
Canned		2.03^{B}	0.64
Fresh	All	2.38^{A}	0.72
Frozen		2.48^{A}	0.68
All	0	1.76^{B}	0.68
	0.5	2.84^{A}	0.68
Canned	0	1.40	0.62
Canned	0.5	2.67	0.66
Fresh	0	1.93	0.73
Fresh	0.5	2.83	0.70
Frozen	0	1.93	0.69
Frozen	0.5	3.03	0.67

Figure 4.1 Pie Charts of Just about Right Scores for all Treatment Combinations of Wet Pack Peaches stored 6-months at 37°C. Scores based on a 5-point just-about-right scale where 1= much too soft, 2= a little too soft, 3= just about right, 4= a little too firm, and 5= much too firm. Percentages based on number of scores 1 or 2=too soft, 3=just about right, and 4 or 5= too firm.

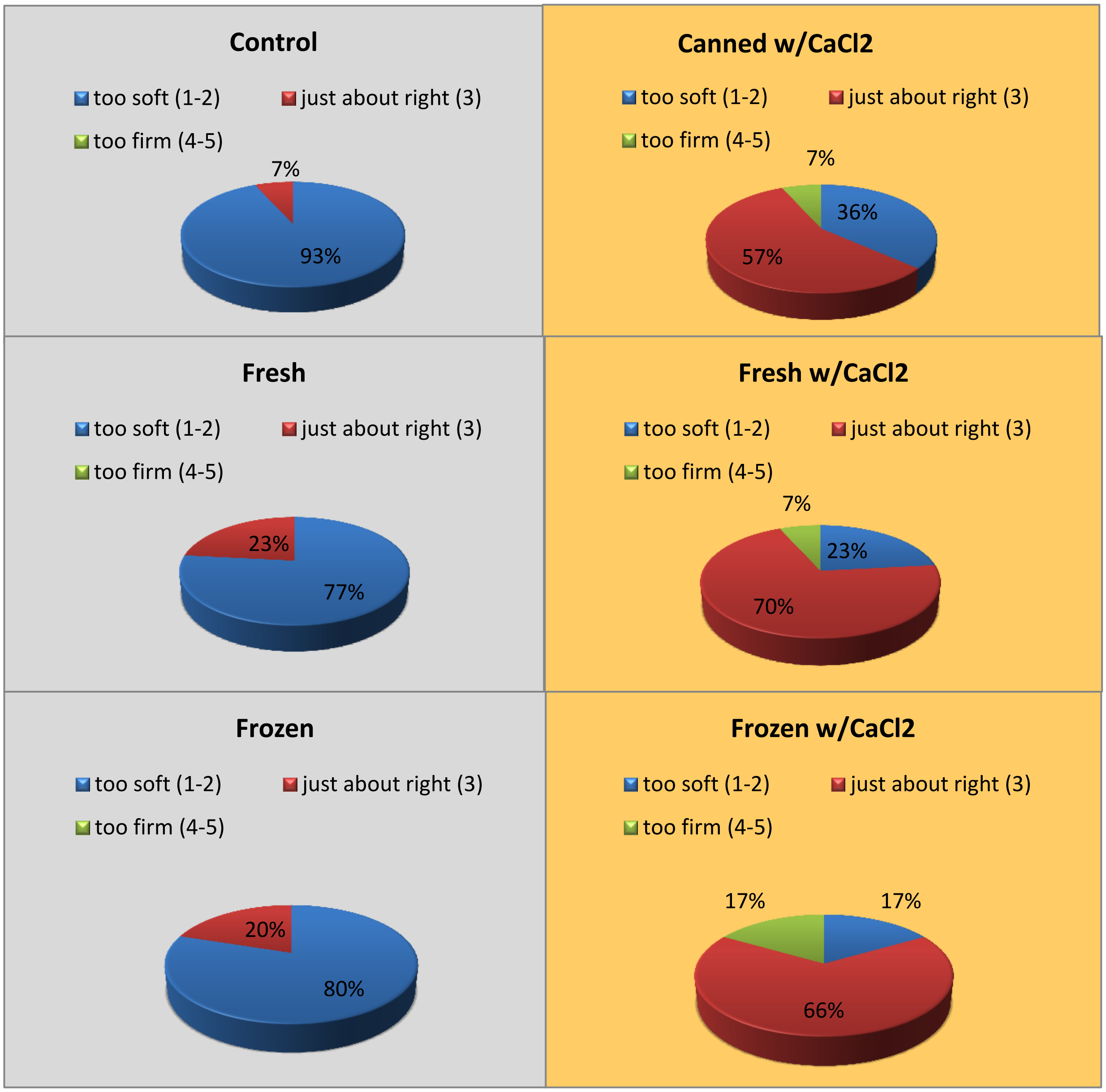


Table 4.9 Analysis of Variance for Overall Liking Hedonic Scores of Wet Pack Peaches treated with Multiple Levels of Calcium Chloride.

Fixed Effect	Degrees of Freedom	F-statistic	P > F
$CaCl_2$	4	28.45	<.0001

Table 4.10 Means for Overall Liking Hedonic Scores of Wet Pack Peaches treated with Multiple Levels of Calcium Chloride: Scores based on a 9-point hedonic scale where 1= dislike extremely, 5=neither like nor dislike, and 9=like extremely. Letter Grouping$^{A\text{-}B}$ based on Fisher's Least Significance Difference test (α=.05). Means labeled with the same letter did not differ significantly within each main effect comparison.

% $CaCl_2$	OVERALL Means	Std. Dev.
0	7.12^{A}	1.26
0.125	7.02^{A}	1.31
0.250	6.16^{B}	1.81
0.375	5.66^{B}	1.78
0.5	4.12^{C}	2.30

Table 4.11 Analysis of Variance for Flavor Hedonic Scores of Wet Pack Peaches treated with Multiple Levels of Calcium Chloride.

Fixed Effect	Degrees of Freedom	F-statistic	P > F
$CaCl_2$	4	25.19	<.0001

Table 4.12 Means for Flavor Hedonic Scores of Wet Pack Peaches treated with Multiple Levels of Calcium Chloride: Scores based on a 9-point hedonic scale where 1= dislike extremely, 5=neither like nor dislike, and 9=like extremely. Letter Grouping$^{A\text{-}B}$ based on Fisher's Least Significance Difference test (α=.05). Means labeled with the same letter did not differ significantly.

% $CaCl_2$	Flavor Mean	Std. Dev.
0	6.98^{A}	1.43
0.125	6.76^{A}	1.49
0.250	5.96^{B}	2.04
0.375	5.49^{B}	1.93
0.5	3.85^{C}	2.06

Table 4.13 Analysis of Variance for Firmness Hedonic Scores of Wet Pack Peaches treated with Multiple Levels of Calcium Chloride.

Fixed Effect	Degrees of Freedom	F-statistic	P > F
$CaCl_2$	4	2.22	0.0716

Table 4.14 Means for Firmness Hedonic Scores of Wet Pack Peaches treated with Multiple Levels of Calcium Chloride: Scores based on a 9-point hedonic scale where 1= dislike extremely, 5=neither like nor dislike, and 9=like extremely.

% $CaCl_2$	Firmness Mean	Std. Dev.
0	6.35	1.56
0.125	6.81	1.51
0.250	6.59	1.41
0.375	6.24	1.69
0.5	5.88	1.74

Table 4.15 Analysis of Variance for Drained Weight of Wet Pack Peaches treated with Multiple Levels of Calcium Chloride.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-statistic	P > F
Model	4	113.1	28.3	2.72	0.151
Error	5	52.0	10.4		
Total	9	165.1			

Table 4.16 Analysis of Variance for FORCE of Wet Pack Peaches treated with Multiple Levels of Calcium Chloride.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-statistic	P > F
Model	4	3.93E^4	9.83E^3	4.45	0.067
Error	5	1.11E^4	2.21^3		
Total	9	5.04E^4			

Table 4.17 Analysis of Variance for WORK of Wet Pack Peaches treated with Multiple Levels of Calcium Chloride.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-statistic	P > F
Model	4	9.21E^5	2.30E^5	16.22	0.005
Error	5	7.10E^4	1.42E^3		
Total	9	9.92E^5			

Table 4.18 Analysis of Variance for pH of Wet Pack Peaches treated with Multiple Levels of Calcium Chloride.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-statistic	P > F
Model	4	0.308	0.077	62.84	0.0007
Error	5	0.005	0.0012		
Total	8	0.313			

Table 4.19 Analysis of Variance for Brix of Wet Pack Peaches treated with Multiple Levels of Calcium Chloride.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-statistic	P > F
Model	4	1.38	0.345	1.45	0.365
Error	5	0.96	0.239		
Total	8	2.34			

Table 4.20 All Possible Regressions and the T-tests of the best Regression Equation. Using CLUSTER as the dependent variable, observations are considered either acceptable (-) or unacceptable (+).

Model Size	**R-Squared**	**Root MSE**	**Cp**	**Model**
1	0.596617	0.3180772	10.931258	A (FLAVOR)
1	0.089041	0.4779946	246.146268	B (FIRMNESS)
2	0.618048	0.3103856	3.000000	AB

Independent Variable	**Regression Coefficient b(i)**	**Standard Error Sb(i)**	**T-Value to test H0:B(i)=0**	**Prob Level**
Intercept	0.9823	0.0808	12.156	0.0000
FIRMNESS	-0.0404	0.0128	-3.151	0.0019
FLAVOR	-0.1491	0.0095	-15.657	0.0000

Table 4.21 Classification Matrix of Overall Acceptability of Wet Pack Peaches. Predicted values were based on the sign (-, +) or the dependent variable CLUSTER from the model in Table 4.11 above. Actual acceptance values were based on the OVERALL scores of each observation from the sensory analysis of wet pack peaches that were thermally processed after being treated with multiple levels of $CaCl_2$.

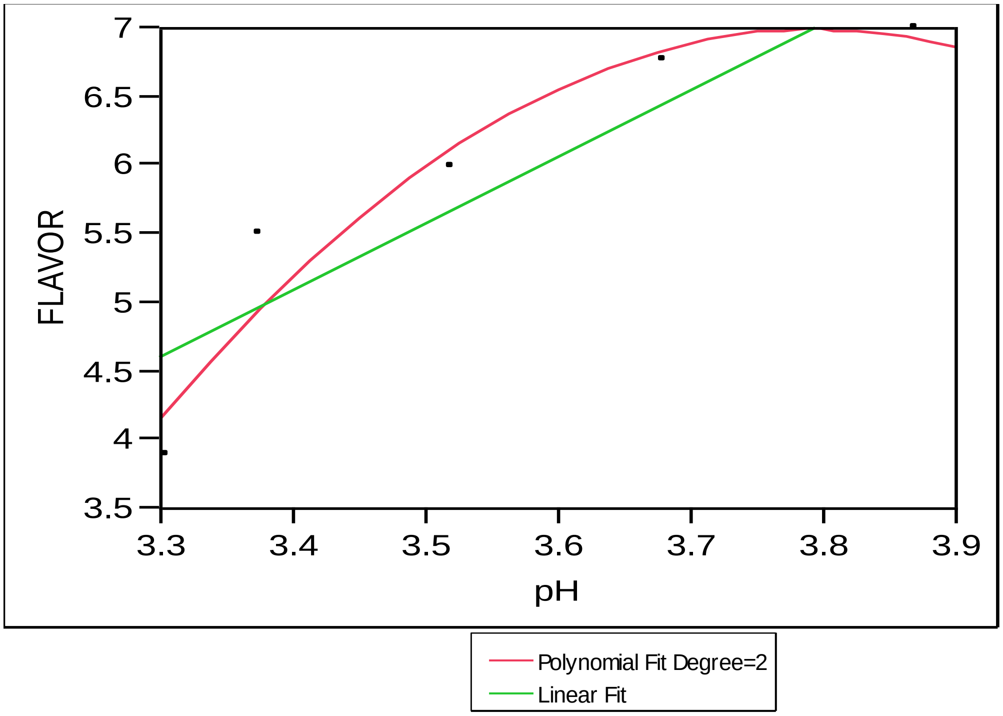
	Predicted(CLUSTER)		
Actual (OVERALL)	Accept (-)	Reject (+)	Total
Accept (≥5)	126	7	133
Reject (<5)	0	47	47
TOTAL	126	54	180

Table 4.22 Results from Varible Selection for a Model Predicting the Average Hedonic Scores for FLAVOR of Wet Pack Peaches. The model chosen included one explanatory variable (pH) based on the T-test of variable BRIX and is listed in the last row.

Model Size	R-Squared	Root MSE	Cp	Model	
1	0.796709	0.7605804	1.398702	A (pH)	**Variables in Best Model: pH**
1	0.036589	1.655739	14.106696	B (BRIX)	
2	0.820557	0.8251228	3.000000	AB	**Variables in Best Model: pH, BRIX**

Independent Variable	Regression Coefficient b(i)	Standard Error Sb(i)	T-Value to test H0:B(i)=0	Prob Level	Reject H0 at 5%?	Power of Test at 5%
Intercept	-20.1154	7.3200	-2.748	0.0709	No	0.4699
BRIX	0.1371	0.2172	0.631	0.5726	No	0.0744
pH	6.1442	1.6971	3.620	0.0362	Yes	0.6782

Independent Variable	Regression Coefficient b(i)	Standard Error Sb(i)	T-Value to test H0:B(i)=0	Prob Level	Reject H0 at 5%?	Power of Test at 5%
Intercept	-17.7202	5.7708	-3.071	0.0373	Yes	0.6383
pH	6.1886	1.5630	3.959	0.0167	Yes	0.8364



Polynomial Fit Degree=2

FLAVOR = -13.82286 + 5.6699394*pH - 11.702183*(pH-3.55)^2

RSquare	0.928163
RSquare Adj	0.856325
Root Mean Square Error	0.469011
Mean of Response	5.81194
Observations (or Sum Wgts)	5

Figure 4.2 Fit of FLAVOR By pH. Average FLAVOR scores of Peaches treated with multiple levels of $CaCl_2$ predicted by their average pH measurement.

Table 4.23 Results from Varible Selection for Model Predicting the Average Hedonic Scores for FIRMNESS of Wet Pack Peaches. The model chosen included one explanatory variable (lnWORK) based on the T-tests and is listed in the last row.

No.Terms	No.X's	R-Squared Value	R-Squared Change
1	1	0.9052	0.9052
2	2	0.9480	0.0427
0	0	0.0000 -	0.9480

Step	Action	No. of Terms	No. of X's	R2	Term Entered
0	Add	0	0	0.0000	Intercept
1	Add	1	1	0.9052	lnWORK
2	Add	2	2	0.9480	lnFORCE

Independent Variable	Regression Coefficient b(i)	Standard Error Sb(i)	T-Value to test H0:B(i)=0	Prob Level	Reject H0 at 5%?	Power of Test at 5%
Intercept	-1.2081	0.9386	-1.287	0.2884	No	0.1513
lnFORCE	-2.0748	1.3214	-1.570	0.2144	No	0.1999
lnWORK	2.6886	1.1284	2.383	0.0974	No	0.3789

Independent Variable	Regression Coefficient b(i)	Standard Error Sb(i)	T-Value to test H0:B(i)=0	Prob Level	Reject H0 at 5%?	Power of Test at 5%
Intercept	-1.2161	1.0971	-1.108	0.3298	No	0.1390
lnWORK	0.9284	0.1502	6.182	0.0035	Yes	0.9935

Table 4.24 Quadratic Regression Equation Predicting FIRMNESS of Wet Pack Peaches. The linear regression for FIRMNESS had an R^2 value of 0.9052 as seen in Table 4.14. By adding the lnWORK^2 variable, R^2 increased to 0.983.

Parameter	Estimate	Standard Error	t Value	Pr > |t|
Intercept	-26.93984031	7.07852249	-3.81	0.0319
lnWORK	8.19747481	1.99575070	4.11	0.0261
lnWORK*lnWORK	-0.50801324	0.13937918	-3.64	0.0356

R-Square	Coeff Var	Root MSE	Firmness Mean
0.982543	2.415523	0.133619	5.531667

Table 4.25 Analysis of Variance for WORK of Wet Pack Peaches prior to storage.

Fixed Effect	Degrees of Freedom	F-statistic	P > F
Type	2	69.55	<.0001
$CaCl_2$	1	534.90	<.0001
Type*$CaCl_2$	2	4.57	0.0248

Table 4.26 Means for WORK of Wet Pack Peaches prior to storage: Letter grouping^{A-B} based on Fisher's Least Significance Difference test (α=.05). Means labeled with the same letter did not differ significantly within each main effect comparison. Means without letter grouping were not compared due to ANOVA F-test resulting in P>.01.

Type	% $CaCl_2$	WORK (g*s) Mean	Std. Dev.
Canned	All	1583.5^{C}	339.1
Fresh	All	3491.9^{A}	378.1
Frozen	All	2896.0^{B}	547.8
All	0	1300.5^{B}	154.1
All	0.5	4885.4^{A}	689.2
Canned	0	725.0	153.2.
Canned	0.5	3458.9	525.0
Fresh	0	1956.1	145.8
Fresh	0.5	6233.5	610.4
Frozen	0	1551.1	163.3
Frozen	0.5	5407.3	932.3

Table 4.27 Analysis of Variance for WORK of Wet Pack Peaches during storage at 50°C.

Fixed Effect	Degrees of Freedom	F-statistic	P > F
Type	2	39.66	<.0001
$CaCl_2$	1	1560.83	<.0001
Type*$CaCl_2$	2	9.50	0.0002
Week	5	88.44	<.0001
Type*Week	10	3.32	0.0010
Calcium*Week	5	10.12	<.0001
Type*Calcium*Week	10	2.54	0.0094

Table 4.28 Means for WORK of Wet Pack Peaches during storage at 50°C: Letter grouping^{A-B} based on Fisher's Least Significance Difference test (α=.05). Means labeled with the same letter did not differ significantly within each main effect comparison. Means without letter grouping were not compared due to ANOVA F-test resulting in P>.0001.

Type	% $CaCl_2$	Week	WORK (g*s) Mean	Std. Dev.
Canned	All	All	927.3^{B}	183.9
Fresh			1299.2^{A}	257.4
Frozen			1266.4^{A}	252.2
All	0	All	588.5^{B}	139.8
	0.5		2246.9^{A}	322.5
Canned	0	All	468.5	108.7
Canned	0.5		1823.5	259.1
Fresh	0		729.5	173.0
Fresh	0.5		2313.9	341.7
Frozen	0		596.5	137.9
Frozen	0.5		2688.9	366.6

Table 4.28 Continued

Type	% $CaCl_2$	Week	WORK (g*s) Mean	Std. Dev.
All	All	1	2011.8^{A}	425.9
		2	1511.6^{B}	256.9
		3	1268.6^{BC}	155.1
		4	1057.5^{C}	226.5
		5	814.4^{D}	170.5
		6	695.9^{D}	152.0
Canned	All	1	1574.8	204.1
		2	1056.6	113.7
		3	1008.5	180.1
		4	990.8	285.9
		5	563.0	156.8
		6	666.2	163.0
Fresh		1	2488.2	597.5
		2	1863.9	427.4
		3	1420.0	169.2
		4	1003.5	76.2
		5	1048.0	139.1
		6	694.4	134.9
Frozen		1	2077.9	476.1
		2	1753.9	229.7
		3	1425.8	116.0
		4	1189.8	317.6
		5	915.8	215.8
		6	728.5	158.3
All	0	1	1222.7^{D}	285.2
		2	849.3^{E}	89.5
		3	665.7^{EF}	123.6

Table 4.28 Continued

Type	% $CaCl_2$	Week	WORK (g*s) Mean	Std. Dev.
All	0	4	549.6^{F}	89.9
		5	373.9^{G}	151.6
		6	292.6^{G}	99.2
	0.5	1	3310.3^{A}	566.6
		2	2690.5^{AB}	424.3
		3	2417.7^{B}	186.5
		4	2035.1^{BC}	363.1
		5	1774.4^{C}	189.4
		6	1655.4^{C}	204.8
Canned	0	1	1000.7	171.6
		2	531.0	34.6
		3	489.7	155.2
		4	560.7	84.8
		5	232.2	116.3
		6	312.2	89.8
Canned	0.5	1	2478.5	236.5
		2	2102.3	192.8
		3	2077.2	204.9
		4	1750.9	487.0
		5	1364.9	197.2
		6	1421.5	236.2
Fresh	0	1	1546.7	377.3
		2	1198.2	121.9
		3	795.2	141.1
		4	528.9	77.4
		5	648.7	235.6
		6	298.1	84.5

Table 4.28 Continued

Type	% $CaCl_2$	Week	WORK (g*s) Mean	Std. Dev.
Fresh	0.5	1	4002.6	817.6
		2	2899.5	732.9
		3	2535.6	197.3
		4	1903.6	74.9
		5	1692.9	42.5
		6	1618.1	185.2
Frozen	0	1	1180.9	306.6
		2	962.8	112.0
		3	757.6	74.6
		4	559.8	107.6
		5	346.9	102.9
		6	269.2	123.4
Frozen	0.5	1	3656.3	645.6
		2	3194.9	347.3
		3	2683.6	157.3
		4	2528.8	527.5
		5	2393.5	328.6
		6	1971.8	193.1

Table 4.29 Analysis of Variance for WORK of Wet Pack Peaches during storage at 37°C.

Fixed Effect	Degrees of Freedom	F-statistic	P > F
Type	2	85.92	<.0001
$CaCl_2$	1	942.00	<.0001
Type*$CaCl_2$	2	5.72	0.0071
Month	5	14.52	<.0001
Type*Month	10	1.12	0.3781
Calcium*Month	5	1.18	0.3408
Type*Calcium*Month	10	1.46	0.1965

Table 4.30 Means for WORK of Wet Pack Peaches during storage at 37°C: Letter Grouping^{A-B} based on Fisher's Least Significance Difference test (α=.05). Means labeled with the same letter did not differ significantly within each main effect comparison. Means without letter grouping were not compared due to ANOVA F-test resulting in P>.001.

Type	% $CaCl_2$	Month	WORK (g*s) Mean	Std. Dev.
Canned	All	All	1237.4^{B}	192.5
Fresh			2230.8^{A}	224.4
Frozen			2095.4^{A}	386.8
All	0	All	961.3^{B}	143.2
	0.5		3352.0^{A}	392.9
Canned	0	All	608.2	96.7
Canned	0.5		2517.7	288.4
Fresh	0		1294.5	182.9
Fresh	0.5		3844.1	265.8
Frozen	0		1128.3	150.2
Frozen	0.5		3890.9	670.8

Table 4.30 Continued

Type	% $CaCl_2$	Month	WORK (g*s) Mean	Std. Dev.
All	All	1	2363.3^{A}	318.6
		2	1974.8^{AB}	180.2
		3	1991.0^{AB}	224.8
		4	1587.8^{BC}	415.7
		5	1581.0^{BC}	173.3
		6	1434.3^{C}	267.9
Canned		1	1609.9	334.7
		2	1168.8	178.6
		3	1313.4	251.3
		4	1155.2	256.3
		5	1245.1	11.3
		6	1010.2	123.5
Fresh		1	2827.4	95.3
		2	2637.3	250.3
		3	2614.9	297.9
		4	1868.1	390.1
		5	1918.3	148.8
		6	1763.9	163.9
Frozen		1	2900.4	525.8
		2	2498.6	111.7
		3	2298.0	26.2
		4	1854.9	600.9
		5	1654.7	359.7
		6	1655.6	516.3
All	0	1	1371.6	81.3
		2	1060.2	134.9
		3	1117.0	202.0

Table 4.30 Continued

Type	% $CaCl_2$	Month	WORK (g*s) Mean	Std. Dev.
All		4	824.0	199.1
	0	5	812.6	132.5
		6	725.7	109.6
	0.5	1	4072.4	555.9
		2	3678.3	225.4
		3	3548.9	259.0
		4	3059.5	632.3
		5	3076.0	214.0
		6	2834.7	426.1
Canned	0	1	996.0	92.8
		2	581.3	119.3
		3	616.9	91.8
		4	517.6	241.0
		5	621.2	14.7
		6	440.8	20.3
Canned	0.5	1	2601.9	576.5
		2	2439.8	237.8
		3	2796.7	410.1
		4	2578.1	271.5
		5	2495.4	7.8
		6	2315.1	226.7
Fresh	0	1	1547.8	43.5
		2	1554.5	160.1
		3	1729.3	487.9
		4	1018.2	198.8
		5	1152.4	122.3
		6	964.1	84.8

Table 4.30 Continued

Type	% $CaCl_2$	Month	WORK (g*s) Mean	Std. Dev.
Fresh	0.5	1	5164.7	147.0
		2	4474.3	340.5
		3	3954.5	107.8
		4	3427.5	581.3
		5	3192.9	175.3
		6	3227.6	242.9
Frozen	0	1	1673.7	107.5
		2	1319.0	125.4
		3	1306.5	26.2
		4	1061.7	157.6
		5	749.6	260.5
		6	899.3	223.8
Frozen	0.5	1	5026.1	944.1
		2	4733.4	98.0
		3	4041.6	-
		4	3241.2	1044.2
		5	3653.0	458.9
		6	3047.9	808.8

Table 4.31 Analysis of Variance for Drained Weight of Wet Pack Peaches prior to storage.

Fixed Effect	Degrees of Freedom	F-statistic	P > F
Type	2	3.88	0.0398
$CaCl_2$	1	1.67	0.2132
Type*$CaCl_2$	2	1.33	0.2881

Table 4.32 Means for Drained Weight of Wet Pack Peaches prior to storage: Letter grouping[A-B] based on Fisher's Least Significance Difference test (α=.05). Means labeled with the same letter did not differ significantly within each main effect comparison. Means without letter grouping were not compared due to ANOVA F-test resulting in P>.01.

Type	% $CaCl_2$	Drained wt. (g) Mean	Std. Dev.
Canned	All	104.7	6.4
Fresh	All	98.9	2.4
Frozen	All	102.6	1.9
All	0	101.0	4.2
All	0.5	103.2	2.9
Canned	0	101.7	8.3
Canned	0.5	107.7	4.5
Fresh	0	99.3	2.8
Fresh	0.5	98.5	1.9
Frozen	0	101.8	1.5
Frozen	0.5	103.3	2.3

Table 4.33 Analysis of Variance for Drained Weight of Wet Pack Peaches during storage at 50°C.

Fixed Effect	Degrees of Freedom	F-statistic	P > F
Type	2	7.91	0.0006
$CaCl_2$	1	144.03	<.0001
Type*$CaCl_2$	2	9.13	0.0002
Week	5	31.01	<.0001
Type*Week	10	5.33	<.0001
Calcium*Week	5	5.80	<.0001
Type*Calcium*Week	10	1.90	0.0536

Table 4.34 Means for Drained Weight of Wet Pack Peaches during storage at 50°C: Letter grouping$^{A\text{-}B}$ based on Fisher's Least Significance Difference test (α=.05). Means labeled with the same letter did not differ significantly within each main effect comparison. Means without letter grouping were not compared due to ANOVA F-test resulting in P>.0001.

Type	% $CaCl_2$	Week	Drained wt. (g) Mean	Std. Dev.
Canned	All	All	93.2	4.7
Fresh			92.5	3.5
Frozen			96.3	2.9
All	0	All	89.0^B	3.4
	0.5		99.1^A	3.9
Canned	0	All	85.6	4.2
Canned	0.5		100.8	5.2
Fresh	0		89.2	3.2
Fresh	0.5		95.9	3.8
Frozen	0		92.0	3.0
Frozen	0.5		100.7	2.8

Table 4.34 Continued

Type	% $CaCl_2$	Week	Drained wt. (g) Mean	Std. Dev.
All	All	1	101.3^{A}	2.0
		2	97.9^{AB}	3.7
		3	94.8^{BC}	2.6
		4	95.6^{AB}	4.4
		5	85.2^{D}	5.0
		6	89.4^{CD}	4.5
Canned	All	1	104.4^{A}	2.1
		2	92.6^{BCD}	7.3
		3	92.2^{BCD}	5.0
		4	100.3^{ABC}	4.4
		5	78.9^{E}	6.4
		6	90.9^{BCDE}	4.0
Fresh		1	99.3^{ABC}	1.8
		2	98.9^{ABC}	2.0
		3	91.8^{BCD}	1.9
		4	92.1^{ABCDE}	7.1
		5	86.5^{DE}	3.4
		6	86.6^{DE}	4.8
Frozen		1	100.3^{ABC}	2.1
		2	102.1^{AB}	1.7
		3	100.5^{ABC}	1.1
		4	94.3^{ABCD}	1.7
		5	90.2^{CDE}	6.0
		6	90.6^{BCDE}	4.9
All	0	1	98.8^{ABC}	1.7
		2	94.0^{BC}	1.3
		3	90.5^{C}	3.1

Table 4.34 Continued

Type	% $CaCl_2$	Week	Drained wt. (g) Mean	Std. Dev.
All	0	4	92.3^{BC}	4.6
		5	77.3^{D}	4.1
		6	80.8^{D}	5.8
	0.5	1	103.9^{A}	2.3
		2	101.8^{AB}	6.0
		3	99.1^{ABC}	2.2
		4	98.9^{ABC}	4.1
		5	93.0^{BC}	5.6
		6	97.9^{ABC}	3.2
Canned	0	1	100.0	1.5
		2	83.7	1.6
		3	82.9	6.6
		4	98.2	4.4
		5	67.0	-
		6	81.7	6.7
Canned	0.5	1	108.7	2.7
		2	101.5	12.9
		3	101.5	3.4
		4	102.4	4.4
		5	90.7	6.4
		6	101.0	1.2
Fresh	0	1	98.9	1.7
		2	98.0	1.0
		3	90.9	1.4
		4	89.8	8.2
		5	79.5	1.8
		6	78.4	4.9

Table 4.34 Continued

Type	% $CaCl_2$	Week	Drained wt. (g) Mean	Std. Dev.
Fresh	0.5	1	99.8	1.9
		2	99.9	3.0
Fresh	0.5	3	92.7	2.3
		4	94.4	5.9
		5	93.5	5.0
		6	94.8	4.6
Frozen	0	1	97.5	1.9
		2	100.3	1.3
		3	97.8	1.2
		4	88.8	1.3
		5	85.5	6.4
		6	82.2	5.9
Frozen	0.5	1	103.1	2.2
		2	103.9	2.1
		3	103.2	0.9
		4	99.9	2.1
		5	94.9	5.5
		6	99.0	3.9

Table 4.35 Analysis of Variance for Drained Weights of Wet Pack Peaches during storage at 37°C.

Fixed Effect	Degrees of Freedom	F-statistic	P > F
Type	2	2.64	0.0853
$CaCl_2$	1	22.02	<.0001
Type*$CaCl_2$	2	6.33	0.0044
Month	5	1.34	0.2718
Type*Month	10	0.84	0.5980
Calcium*Month	5	0.84	0.5276
Type*Calcium*Month	10	0.83	0.6024

Table 4.36 Means for Drained Weights of Wet Pack Peaches during storage at 37°C: Letter Grouping$^{A\text{-}B}$ based on Fisher's Least Significance Difference test (α=.05). Means labeled with the same letter did not differ significantly within each main effect comparison. Means without letter grouping were not compared due to ANOVA F-test resulting in P>.001.

Type	% $CaCl_2$	Month	Drained wt. (g) Mean	Std. Dev.
Canned	All	All	97.3	4.4
Fresh			97.3	3.9
Frozen			100.9	4.6
All	0	All	95.1^B	4.4
	0.5		102.0^A	4.2
Canned	0	All	90.1	7.0
Canned	0.5		104.5	1.8
Fresh	0		95.6	1.8
Fresh	0.5		99.1	5.9
Frozen	0		99.4	4.4
Frozen	0.5		102.4	4.9

Table 4.36 Continued

Type	% $CaCl_2$	Month	Drained wt. (g) Mean	Std. Dev.
All	All	1	99.4	5.5
		2	99.5	3.0
		3	101.4	6.1
		4	98.7	5.1
		5	95.9	3.5
		6	96.3	2.6
Canned		1	100.9	4.0
		2	100.4	2.9
		3	98.0	6.3
		4	93.7	4.5
		5	96.0	5.0
		6	94.8	3.7
Fresh		1	97.7	1.9
		2	97.9	4.7
		3	97.7	2.3
		4	100.8	9.0
		5	93.8	3.2
		6	96.2	2.4
Frozen		1	99.5	10.6
		2	100.2	1.4
		3	108.4	9.7
		4	101.5	1.8
		5	97.8	2.5
		6	98.1	1.8
All	0	1	98.3	3.4
		2	97.0	3.1
		3	98.7	9.3

Table 4.36 Continued

Type	% $CaCl_2$	Month	Drained wt. (g) Mean	Std. Dev.
All	0	4	93.2	2.7
		5	91.2	4.6
		6	91.9	3.2
	0.5	1	100.4	7.6
		2	101.9	2.8
		3	104.1	2.8
		4	104.1	7.5
		5	100.5	2.4
		6	100.7	2.0
Canned	0	1	97.1	5.8
		2	96.1	5.3
		3	87.6	10.8
		4	86.8	5.2
		5	88.6	9.1
		6	84.7	5.7
Canned	0.5	1	104.7	2.1
		2	104.7	0.5
		3	108.5	1.7
		4	100.7	3.7
		5	103.4	0.9
		6	104.8	1.6
Fresh	0	1	96.7	2.0
		2	97.1	1.9
		3	96.9	1.1
		4	94.2	1.3
		5	93.2	1.8
		6	95.6	2.9

Table 4.36 Continued

Type	% $CaCl_2$	Month	Drained wt. (g) Mean	Std. Dev.
Fresh	0.5	1	98.7	1.7
		2	98.7	7.4
		3	98.5	3.5
		4	107.3	16.7
		5	94.4	4.5
		6	96.7	1.8
Frozen	0	1	101.2	2.3
		2	98.0	2.2
		3	111.5	16.1
		4	98.7	1.5
		5	91.8	3.0
		6	95.4	1.0
Frozen	0.5	1	97.9	18.9
		2	102.4	0.5
		3	105.3	3.3
		4	104.3	2.1
		5	103.9	1.9
		6	100.7	2.5

Table 4.37 Analysis of Variance for pH of Wet Pack Peaches prior to storage.

Fixed Effect	Degrees of Freedom	F-statistic	P > F
Type	2	5.68	0.0122
$CaCl_2$	1	502.96	<.0001
Type*$CaCl_2$	2	5.71	0.0120

Table 4.38 Means for pH of Wet Pack Peaches prior to storage:. Letter grouping$^{A\text{-}B}$ based on Fisher's Least Significance Difference test (α=.05). Means labeled with the same letter did not differ significantly within each main effect comparison. Means without letter grouping were not compared due to ANOVA F-test resulting in P>.01.

Type	% $CaCl_2$	pH Mean	Std. Dev.
Canned	All	3.63	0.06
Fresh		3.70	0.06
Frozen		3.74	0.08
All	0	4.00^{A}	0.07
	0.5	3.39^{B}	0.06
Canned	0	3.87	0.08
Canned	0.5	3.39	0.03
Fresh	0	4.04	0.07
Fresh	0.5	3.36	0.04
Frozen	0	4.08	0.05
Frozen	0.5	3.41	0.10

Table 4.39 Analysis of Variance for pH of Wet Pack Peaches during storage at 50°C.

Fixed Effect	Degrees of Freedom	F-statistic	P > F
Type	2	6.20	0.0028
$CaCl_2$	1	1100.05	<.0001
Type*$CaCl_2$	2	10.15	<.0001
Week	5	1.49	0.2001
Type*Week	10	1.84	0.0624
Calcium*Week	5	1.36	0.2439
Type*Calcium*Week	10	0.89	0.5409

Table 4.40 Means for pH of Wet Pack Peaches during storage at 50°C: Letter grouping^{A-B} based on Fisher's Least Significance Difference test (α=.05). Means labeled with the same letter did not differ significantly within each main effect comparison. Means without letter grouping were not compared due to ANOVA F-test resulting in P>.0001.

Type	% $CaCl_2$	Week	pH Mean	Std. Dev.
Canned	All	All	3.67	0.04
Fresh			3.65	0.05
Frozen			3.71	0.05
All	0	All	3.93^{A}	0.04
	0.5		3.43^{B}	0.05
Canned	0	All	3.87^{B}	0.05
Canned	0.5		3.46^{C}	0.03
Fresh	0		3.93^{AB}	0.05
Fresh	0.5		3.37^{C}	0.05
Frozen	0		3.99^{A}	0.03
Frozen	0.5		3.44^{C}	0.07

Table 4.40 Continued

Type	% $CaCl_2$	Week	pH Mean	Std. Dev.
All	All	1	3.70	0.05
		2	3.67	0.05
		3	3.70	0.05
		4	3.65	0.05
		5	3.65	0.05
		6	3.69	0.04
Canned	All	1	3.67	0.06
		2	3.69	0.03
		3	3.67	0.04
		4	3.68	0.03
		5	3.67	0.05
		6	3.62	0.03
Fresh		1	3.68	0.04
		2	3.66	0.03
		3	3.70	0.04
		4	3.63	0.06
		5	3.58	0.07
		6	3.67	0.07
Frozen		1	3.75	0.05
		2	3.67	0.07
		3	3.74	0.07
		4	3.65	0.07
		5	3.69	0.03
		6	3.79	0.03
All	0	1	3.95	0.05
		2	3.93	0.03
		3	3.99	0.03

Table 4.40 Continued

Type	% $CaCl_2$	Week	pH Mean	Std. Dev.
All	0	4	3.91	0.03
		5	3.87	0.06
		6	3.93	0.05
	0.5	1	3.45	0.05
		2	3.41	0.05
		3	3.41	0.06
		4	3.40	0.07
		5	3.43	0.04
		6	3.45	0.04
Canned	0	1	3.87	0.08
		2	3.88	0.03
		3	3.90	0.05
		4	3.89	0.02
		5	3.89	0.08
		6	3.81	0.04
Canned	0.5	1	3.46	0.04
		2	3.50	0.03
		3	3.45	0.02
		4	3.48	0.04
		5	3.46	0.02
		6	3.43	0.02
Fresh	0	1	3.94	0.04
		2	3.95	0.02
		3	4.00	0.02
		4	3.90	0.05
		5	3.81	0.07
		6	3.98	0.07
Fresh	0.5	1	3.42	0.04

Table 4.40 Continued

Type	% $CaCl_2$	Week	pH Mean	Std. Dev.
Fresh	0.5	2	3.37	0.03
		3	3.39	0.05
		4	3.36	0.06
		5	3.35	0.07
		6	3.36	0.06
Frozen	0	1	4.03	0.03
		2	3.98	0.04
		3	4.08	0.03
		4	3.94	0.02
		5	3.92	0.02
		6	4.01	0.03
Frozen	0.5	1	3.47	0.07
		2	3.36	0.10
		3	3.40	0.10
		4	3.35	0.11
		5	3.47	0.03
		6	3.57	0.03

Table 4.41 Analysis of Variance for pH of Wet Pack Peaches during storage at 37°C.

Fixed Effect	Degrees of Freedom	F-statistic	P > F
Type	2	7.33	0.0021
$CaCl_2$	1	1934.00	<.0001
Type*$CaCl_2$	2	26.43	<.0001
Month	5	9.13	<.0001
Type*Month	10	4.57	0.0003
Calcium*Month	5	16.82	<.0001
Type*Calcium*Month	10	2.27	0.0355

Table 4.42 Means for pH of Wet Pack Peaches during storage at 37°C: Letter Grouping$^{A\text{-}B}$ based on Fisher's Least Significance Difference test (α=.05). Means labeled with the same letter did not differ significantly within each main effect comparison. Means without letter grouping were not compared due to ANOVA F-test resulting in P>.001.

Type	% $CaCl_2$	Month	pH Mean	Std. Dev.
Canned			3.61	0.02
Fresh	All	All	3.65	0.05
Frozen			3.67	0.05
All	0	All	3.91^{A}	0.04
	0.5		3.37^{B}	0.04
Canned	0		3.81^{B}	0.01
Canned	0.5		3.41^{C}	0.03
Fresh	0	All	3.96^{A}	0.07
Fresh	0.5		3.34^{C}	0.03
Frozen	0		3.96^{A}	0.04
Frozen	0.5		3.37^{C}	0.05

Table 4.42 Continued

Type	% $CaCl_2$	Month	pH Mean	Std. Dev.
All	All	1	3.62^{AB}	0.05
		2	3.65^{AB}	0.04
		3	3.62^{AB}	0.03
		4	3.58^{B}	0.03
		5	3.70^{A}	0.04
		6	3.69^{A}	0.04
Canned		1	3.48^{C}	0.02
		2	3.65^{ABC}	0.04
		3	3.61^{ABC}	0.03
		4	3.54^{BC}	0.03
		5	3.71^{AB}	0.01
		6	3.68^{AB}	0.02
Fresh		1	3.73^{A}	0.08
		2	3.64^{ABC}	0.05
		3	3.61^{ABC}	0.01
		4	3.57^{ABC}	0.04
		5	3.69^{AB}	0.05
		6	3.67^{ABC}	0.07
Frozen		1	3.66^{ABC}	0.08
		2	3.66^{ABC}	0.04
		3	3.63^{ABC}	0.06
		4	3.64^{ABC}	0.04
		5	3.70^{AB}	0.07
		6	3.72^{AB}	0.04
All	0	1	3.95^{A}	0.06
		2	3.93^{A}	0.05
		3	3.94^{A}	0.02
		4	3.88^{A}	0.04

Table 4.42 Continued

Type	% $CaCl_2$	Month	pH Mean	Std. Dev.
All	0	5	3.89[A]	0.04
		6	3.88[A]	0.04
	0.5	1	3.30[C]	0.04
		2	3.37[BC]	0.04
		3	3.29[C]	0.04
		4	3.28[C]	0.03
		5	3.51[B]	0.04
		6	3.49[B]	0.04
Canned	0	1	3.70	0.04
		2	3.83	0.01
		3	3.89	0.00
		4	3.78	0.04
		5	3.88	0.00
		6	3.83	0.01
Canned	0.5	1	3.26	0.00
		2	3.47	0.00
		3	3.34	0.06
		4	3.30	0.06
		5	3.55	0.02
		6	3.52	0.01
Fresh	0	1	4.08	0.04
		2	4.03	0.08
		3	3.96	0.06
		4	3.89	0.02
		5	3.88	0.06
		6	3.89	0.06
Fresh	0.5	1	3.37	0.12
		2	3.25	0.08

Table 4.42 Continued

Type	% $CaCl_2$	Month	pH Mean	Std. Dev.
Fresh	0.5	3	3.26	0.04
		4	3.25	0.00
		5	3.50	0.01
		6	3.44	0.04
Frozen	0	1	4.05	0.01
		2	3.93	0.07
		3	3.98	0.05
		4	3.98	0.01
		5	3.91	0.06
		6	3.93	0.01
Frozen	0.5	1	3.28	0.04
		2	3.39	0.01
		3	3.28	0.06
		4	3.30	0.06
		5	3.49	0.07
		6	3.52	0.06

Table 4.43 Analysis of Variance for Brix of Wet Pack Peaches prior to storage.

Fixed Effect	Degrees of Freedom	F-statistic	P > F
Type	2	13.11	0.0003
$CaCl_2$	1	0.46	0.5047
Type*$CaCl_2$	2	4.94	0.0195

Table 4.44 Means for Brix of Wet Pack Peaches prior to storage: Letter grouping^{A-B} based on Fisher's Least Significance Difference test (α=.05). Means labeled with the same letter did not differ significantly within each main effect comparison. Means without letter grouping were not compared due to ANOVA F-test resulting in P>.01.

Type	% $CaCl_2$	Brix° Mean	Std. Dev.
Canned	All	19.1^{A}	1.3
Fresh		16.1^{B}	0.3
Frozen		17.3^{B}	1.2
All	0	17.6	1.3
	0.5	17.3	0.5
Canned	0	20.3	1.3
Canned	0.5	17.9	1.3
Fresh	0	16.0	0.6
Fresh	0.5	16.2	0
Frozen	0	16.7	2.1
Frozen	0.5	17.9	0.3

Table 4.45 Analysis of Variance for Brix of Wet Pack Peaches during storage at 50°C.

Fixed Effect	Degrees of Freedom	F-statistic	P > F
Type	2	324.77	<.0001
$CaCl_2$	1	0	0.9745
Type*$CaCl_2$	2	9.44	0.0002
Week	5	13.00	<.0001
Type*Week	10	3.42	0.0006
Calcium*Week	5	1.90	0.0995
Type*Calcium*Week	10	0.86	0.5745

Table 4.46 Means for Brix of Wet Pack Peaches during storage at 50°C: Letter grouping$^{A\text{-}B}$ based on Fisher's Least Significance Difference test (α=.05). Means labeled with the same letter did not differ significantly within each main effect comparison. Means without letter grouping were not compared due to ANOVA F-test resulting in P>.0001.

Type	% $CaCl_2$	Week	Brix° Mean	Std. Dev.
Canned	All	All	20.8^{A}	0.73
Fresh			17.5^{C}	0.43
Frozen			18.2^{B}	0.59
All	0	All	18.8	0.58
	0.5		18.8	0.58
Canned	0	All	20.5	0.70
Canned	0.5		21.1	0.75
Fresh	0		17.4	0.51
Fresh	0.5		17.5	0.34
Frozen	0		18.5	0.53
Frozen	0.5		17.9	0.64

Table 4.46 Continued

Type	% $CaCl_2$	Week	Brix° Mean	Std. Dev.
All	All	1	19.1^{A}	0.39
		2	19.2^{A}	0.66
		3	19.2^{A}	0.47
		4	18.3^{BC}	0.61
		5	18.2^{C}	0.85
		6	18.9^{AB}	0.49
Canned	All	1	21.3	0.32
		2	21.0	0.99
		3	21.3	0.32
		4	20.2	1.13
		5	20.2	0.86
		6	20.9	0.75
Fresh		1	17.6	0.48
		2	18.0	0.27
		3	17.4	0.65
		4	17.7	0.44
		5	16.7	0.46
		6	17.3	0.27
Frozen		1	18.7	0.39
		2	18.7	0.73
		3	19.0	0.45
		4	16.9	0.28
		5	17.4	1.22
		6	18.6	0.45
All	0	1	19.1	0.37
		2	19.3	0.75
		3	18.9	0.68
		4	18.5	0.62

Table 4.46 Continued

Type	% $CaCl_2$	Week	Brix° Mean	Std. Dev.
All	0	5	18.2	0.63
		6	18.9	0.45
	0.5	1	19.2	0.42
		2	19.1	0.57
		3	19.5	0.27
		4	18.1	0.61
		5	18.0	1.06
		6	19.0	0.53
Canned	0	1	20.9	0.17
		2	20.5	1.34
		3	20.6	0.59
		4	20.2	1.10
		5	20.1	0.45
		6	20.9	0.57
Canned	0.5	1	21.6	0.46
		2	21.4	0.64
		3	22.0	0.05
		4	20.2	1.16
		5	20.3	1.27
		6	20.8	0.93
Fresh	0	1	17.6	0.42
		2	18.0	0.31
		3	17.1	0.87
		4	17.8	0.57
		5	16.7	0.41
		6	17.0	0.48
Fresh	0.5	1	17.6	0.54
		2	18.0	0.22

Table 4.46 Continued

Type	% $CaCl_2$	Week	Brix° Mean	Std. Dev.
Fresh	0.5	3	17.6	0.42
		4	17.6	0.30
		5	16.8	0.50
		6	17.6	0.06
Frozen	0	1	18.9	0.51
		2	19.4	0.60
		3	19.0	0.57
		4	17.3	0.19
		5	18.0	1.02
		6	18.7	0.31
Frozen	0.5	1	18.5	0.26
		2	17.9	0.86
		3	19.0	0.33
		4	16.5	0.36
		5	16.9	1.42
		6	18.6	0.59

Table 4.47 Analysis of Variance for Brix of Wet Pack Peaches during storage at 37°C.

Fixed Effect	Degrees of Freedom	F-statistic	P > F
Type	2	70.81	<.0001
$CaCl_2$	1	12.43	0.0012
Type*$CaCl_2$	2	2.17	0.1290
Month	5	1.18	0.3370
Type*Month	10	2.65	1.0157
Calcium*Month	5	1.21	0.3256
Type*Calcium*Month	10	1.97	0.0664

Table 4.48 Means for Brix of Wet Pack Peaches during storage at 37°C: Letter Grouping$^{A\text{-}B}$ based on Fisher's Least Significance Difference test (α=.05). Means labeled with the same letter did not differ significantly within each main effect comparison. Means without letter grouping were not compared due to ANOVA F-test resulting in P>.001.

Type	% $CaCl_2$	Month	Brix° Mean	Std. Dev.
Canned	All	All	20.2^{A}	0.56
Fresh	All	All	16.5^{C}	0.39
Frozen	All	All	18.2^{B}	0.36
All	0	All	18.7	0.45
All	0.5	All	17.9	0.43
Canned	0	All	20.7	0.60
Canned	0.5	All	19.7	0.53
Fresh	0	All	16.6	0.25
Fresh	0.5	All	16.4	0.54
Frozen	0	All	18.9	0.50
Frozen	0.5	All	17.4	0.23

Table 4.48 Continued

Type	% $CaCl_2$	Month	Brix° Mean	Std. Dev.
All	All	1	17.9	0.10
		2	17.9	0.73
		3	18.2	0.35
		4	18.6	0.56
		5	18.5	0.39
		6	18.7	0.51
Canned	All	1	20.9	0.11
		2	18.5	1.60
		3	20.4	0.29
		4	20.2	0.60
		5	20.8	0.14
		6	20.6	0.64
Fresh		1	16.5	0.14
		2	15.9	0.50
		3	16.5	0.35
		4	16.9	0.61
		5	16.6	0.60
		6	16.8	0.18
Frozen		1	16.5	0.06
		2	19.3	0.11
		3	17.8	0.43
		4	18.7	0.46
		5	18.1	0.43
		6	18.7	0.71
All	0	1	18.9	0.07
		2	18.4	0.79
		3	18.7	0.35
		4	18.7	0.66

Table 4.48 Continued

Type	% $CaCl_2$	Month	Brix° Mean	Std. Dev.
All	0	5	19.2	0.31
		6	18.7	0.49
	0.5	1	17.0	0.13
		2	17.4	0.67
		3	17.8	0.35
		4	18.6	0.45
		5	17.8	0.47
		6	18.6	0.52
Canned	0	1	21.1	0.07
		2	20.1	2.10
		3	20.8	0.07
		4	20.5	0.78
		5	20.9	0.28
		6	20.8	0.28
Canned	0.5	1	20.7	0.14
		2	17.0	1.10
		3	20.0	0.50
		4	19.8	0.42
		5	20.6	0.00
		6	20.3	1.00
Fresh	0	1	16.5	0.07
		2	15.8	0.14
		3	16.4	0.42
		4	16.9	0.57
		5	17.6	0.00
		6	16.6	0.28
Fresh	0.5	1	16.5	0.21
		2	15.9	0.85

Table 4.48 Continued

Type	% $CaCl_2$	Month	Brix° Mean	Std. Dev.
Fresh	0.5	3	16.5	0.28
		4	17.0	0.64
		5	15.7	1.20
		6	17.0	0.07
Frozen	0	1	19.1	0.07
		2	19.4	0.14
		3	18.8	0.57
		4	18.7	0.64
		5	19.0	0.64
		6	18.8	0.92
Frozen	0.5	1	13.9	0.05
		2	19.3	0.07
		3	16.8	0.28
		4	18.8	0.28
		5	17.3	0.21
		6	18.6	0.50

Table 4.49 Maximum Allowable Percentage of Calcium Chloride for Wet Pack Peaches from a Canned Clingstone Peach Source.

Initial pH	Max %CaCl2
3.85	0.000
3.86	0.009
3.87	0.018
3.88	0.027
3.89	0.036
3.90	0.045
3.91	0.054
3.92	0.063
3.93	0.072
3.94	0.081
3.95	0.090
3.96	0.099
3.97	0.108
3.98	0.117
3.99	0.126
4.00	0.135
4.01	0.144
4.02	0.153
4.03	0.162
4.04	0.171
4.05	0.180
4.06	0.189
4.07	0.198
4.08	0.207
4.09	0.216
4.10	0.225
4.11	0.234
4.12	0.243
4.13	0.252
4.14	0.261
4.15	0.270

VITA

Lee Morse was born outside Atlanta, GA in 1980. After graduating from Ooltewah High School in 1999 he enrolled at the University of Tennessee Chattanooga (UTC) in 2001. In 2006 he graduated from UTC with a B.S. in molecular biology and a minor in chemistry. After graduating college Lee worked as an assistant brewer at Big River Brewery in downtown Chattanooga (owned and operated by Gordon Biersch) before returning to school. In 2008 he enrolled in the graduate program at the University of Tennessee Knoxville to study food science and technology. Initially enlisted as a food microbiology student, his course of study changed when an opportunity as a graduate research assistant for a food processing project was offered. While as graduate student, Lee also spent a semester as the teaching assistant in the laboratory section of the food microbiology course. He also assisted with teaching the laboratory portion of the food preservation and packaging course while taking it for credit.

Upon completion of his Thesis, Lee will pursue opportunities in the beer or wine industries and may one day return to school as a PhD student.