

CONSUMER PERCEPTION AND APPLICATION OF EDIBLE  
COATINGS ON FRESH-CUT FRUITS AND VEGETABLES

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## **ABSTRACT**

Plasticized whey protein coatings have been shown to extend the shelf life of fresh produce. This thesis research was designed to determine consumer acceptance and perception of fresh-cut fruits and vegetables (FCFV) and edible coatings (EC) and to determine effects of plasticized whey protein coatings on quality of fresh-cut apples. Two studies were conducted. In the first study, a questionnaire on FCFV and EC was prepared and completed by 611 consumers. The data were analyzed using Probit analysis. In the second study, physical and microbial quality of fresh-cut (FC) apples coated with three whey proteins (30% glycerol added) each at 5% and/or 10% concentrations and water (as control), were determined during 13-day storage at 2°C. Consumers (30%) preferred commercially available FCFV to whole FV due to less preparation time and serving portions. Females were more likely to consume/use FCFV than males. Hispanic/Spanish consumers were less likely to consume/use FCFV compared to Caucasians. As an income level decreased the probability of eating/using FCFV decreased and preference for canned FV to FCFV increased. Compared to Caucasians, Asians were more and Hispanic/Spanish were less aware of EC. Some consumers would not buy coated FCFV if coating materials were of animal origins. A 7% increase in purchase intent was observed after advantages of EC had been described to consumers. The 10% WPC coating was most effective in minimizing weight loss. There were no changes in color lightness of apples coated with WPC/WPI, whereas significantly decreased lightness was observed for control and PHWPC coated samples by the fourth day of storage. Firmness of coated samples did not change after 13-day storage compared to that of the control, which was undesirably soft. Overall, the total plate count ranged from 0-0.54logCFU/g

for 10-days storage and no *E.coli/Coliforms* were detected. This study demonstrates potential of WPC as an EC for FC apples and helps the food industry meet consumer and market demand regarding FCFV.

## CHAPTER 1. INTRODUCTION

Fresh-cut produce sales are estimated to be \$10 billion, which is 10% of the total produce sales (Bett *et al.*, 2001). Today's consumer is demanding for foods that require minimal process, for example, fresh-cut fruits and vegetables (FCFV). This is mainly because of busy lifestyles, an increase in health consciousness and increased purchasing power of the consumer (Siew *et al.*, 1999; Baldwin *et al.*, 1995). This was not the case a few years back. The food service industry and restaurants were the major users of minimally processed fruits and vegetables (Watada *et al.*, 1996). The reason for their use was to reduce the manpower and control the waste generated.

Minimally processed foods are highly nutritious but highly perishable. Removing the skin from the surface or altering the size leads to leakage of nutrients, accelerated enzymatic reactions, rapid microbial growth, color change, texture change and weight losses, resulting in deteriorated quality of the product.

Many techniques have been studied in order to overcome these problems and extend the shelf life of fresh produce, for example, low temperature and high relative humidity, controlled and modified atmosphere packaging, etc. But each has advantages and disadvantages, with later the predominating. The maintenance of the quality of fresh produce is still a major challenge for the food industry.

Edible coatings have many advantages over other techniques, but only when the coated produces are stored at proper temperatures, which depends on the commodity. They can act as moisture and gas barriers, control microbial growth, preserve the color, texture and moisture of the product, and can effectively extend the shelf life of the product. These coatings have their disadvantages too. But these can be avoided by adding

food grade additives to change their composition and improve properties of coatings or films, which when applied on produce improve its quality.

Whey proteins have been extensively studied, and are known to be good gas and solute barriers, but have poor moisture barrier properties. Adding plasticizers such as sorbitol or glycerol makes the protein-based film more resistant to moisture transfer. Research has been conducted on these films and their application on fresh whole produce, but little has been known about their application on fresh-cut fruits and vegetables and consumer acceptance of fresh-cut fruits and vegetables either uncoated or coated with an edible coating.

Two studies were performed. The first study involved a survey to understand the consumer acceptance and preference of fresh-cut fruits and vegetables with or without an edible coating. The second study involved quality evaluation of fresh-cut apples coated with three different types of whey protein solutions (whey protein concentrate, whey protein isolate and partially hydrolyzed whey protein concentrate).

In the first study, a questionnaire was prepared and completed by students, faculty and a few citizens of Louisiana and Georgia (n=611). The responses were analyzed using Probit analysis. In the second study, plasticized whey protein solutions were prepared at 5% and/or 10% concentrations, and applied to freshly cut Fuji apples, and the quality and shelf life were studied during 13 days of storage at 2°C.

This thesis is divided into 7 chapters. Chapter one provides a brief introduction and the research justification. Chapter two presents the literature review related to the study. Chapter three is a consumer study reporting the consumer responses towards fresh-cut fruits and vegetables with or without an edible coating. Chapter four presents the

physical and microbial quality of fresh-cut apples coated with an edible coating during a 13-day storage at 2°C. Chapter five presents the conclusions of this research and chapter suggests the opportunities for future research. The last section includes a list of references cited for this thesis, followed by the appendices.

## **CHAPTER 2. LITERATURE REVIEW**

### **2.1 Fresh-cut Produce**

“Fresh-cut (FC)” produce is defined as, any fresh fruit or vegetable or any combination thereof that has been physically altered from its original form, but has not been processed by treatments such as heat or chemical preservative and remains in a fresh state (Garrett, 1997; King and Bolin, 1989). Fresh-cut produce includes peeled, trimmed, washed, cored, sliced/cut but still uncooked fruits and vegetables (Baldwin *et al.*, 1996; Lindsay *et al.*, 1999). Fresh-cut vegetables are known as ready-to-use, lightly processed, partially processed, fresh processed or minimally processed products (Carlin *et al.*, 1990; Watada *et al.*, 1996; Cantwell, 2002).

### **2.2 Problems with Whole and Fresh-cut Produce**

Minimal processing results in a convenience product, but it reduces the shelf life. As a result, the maintenance of quality is a challenge to the rapidly expanding minimal processing sector (Jiang and Joyce, 2002).

Fresh-cut products are highly perishable, the main reasons being the removal of skin (the natural protective layer) from their surface area and the physical stress they undergo, while peeling, cutting, slicing, shredding, trimming, coring, etc. (Watada *et al.*, 1996; Rolle and Chism, 1987). Wounding results in increased production of ethylene, surface water activity, weight loss and respiration rates (Baldwin *et al.*, 1995; Watada *et al.*, 1996). It also results in cell wall breakdown (which leads to undesirable enzymatic reactions), leakage of ions and other cellular components, loss of moisture (Baldwin *et al.*, 1995) and finally results in decreased shelf life (Baldwin *et al.*, 1996; Avena-Bustillos *et al.*, 1994; Baldwin *et al.*, 1995; Jiang and Joyce, 2002; Watada *et al.*, 1996;

Lindsay *et al.*, 1999). If not controlled these changes can lead to rapid senescence and deterioration of the product (Baldwin *et al.*, 1995). Consequently fresh-cut produce should be maintained at lower temperatures than that recommended for whole fruits and vegetables (Watada *et al.*, 1996). But even during refrigerated storage the fresh fruits and vegetables are characterized by active metabolism (Guilbert *et al.*, 1996).

Brecht (1995) indicated that some of the factors affecting the intensity of wounding are species, variety, maturity index, temperature, oxygen and carbon dioxide concentrations and water vapor pressure. Research in all of these areas is needed to ensure that wholesome, high quality FC products are marketed to consumers (Watada *et al.*, 1996).

### **2.2.1. Problems with Some Whole Fruits and Vegetables**

**Banana:** i) Rapid quality deterioration of the fruit and ii) Enzymatic browning (Ben-Yehoshua, 1966).

**Bell pepper:** i) Decay and textural changes (Miller *et al.*, 1983); ii) Shriveling, Flaccidity (due to water loss), and wilting (Miller *et al.*, 1983; Lerdthanangkul and Krochta, 1996); iii) High humidity increases bacterial soft rot and iv) Low temperatures cause chilling injury and increase in alternaria rot (Miller *et al.*, 1983).

**Broccoli:** i) Moisture loss and ii) Opening of yellow flowers (Hardenburg, 1949).

**Citrus fruit:** i) Water vapor loss, resulting in peel shrinkage, reduction of turgidity and decrease in resistance to gas diffusion, with negative consequences on the flavor and taste (D'Aquino *et al.*, 2001); ii) Decay; iii) Transpiration and iv) Respiration (Purvis, 1983).

- Lime:** i) Weight loss; ii) Degreening and iii) Fungal attack (Motlagh and Quantick, 1998).
- Litchi:** i) Desiccation; ii) Browning; iii) Decays and iv) Loss of flavor (Zhang and Quantick, 1997).
- Tomatoes:** i) Limited shelf life; ii) Weight loss (Tasdelen and Bayindirli, 1998); iii) Physiological disorders and iv) Physical injuries (El Ghaouth *et al.*, 1992b).

### 2.2.2. Problems With Fresh-cuts

**Minimally Processed Carrots:** i) Formation of a whitish, dried appearance on the surface of peeled carrots; ii) Storage rot and quality deterioration; iii) decreased degradation of carbohydrates and lipids and development of off-flavors due to increased respiration; iv) development of bitter flavor and v) carotene loss (Li and Barth, 1998; Cheah *et al.*, 1997; Ghaouth *et al.*, 1991; Howard and Dewi, 1995; Avena-Bustillos *et al.*, 1994; Krochta, *et al.*, 1993; Chen *et al.*, 1996).

**Fresh-cut Apples:** i) Enzymatic browning; ii) Undesirable changes in flavor and texture and iii) Loss of nutrients and moisture (McHugh and Senesi, 2000).

**Minimally Processed Onions:** i) Odor volatiles and ii) Development of pink discoloration (Howard *et al.*, 1994).

**Fresh-cut Pears:** i) Tissue softening and ii) Surface browning (Gorny and Kader, 1997).

**Fresh-cut Lettuce:** i) Browning; ii) Microbial growth (Watada and Qi, 1999) and iii) High respiration rates (Watada *et al.*, 1996).

**Fresh-cut Cabbage:** i) Browning and ii) Microbial growth (Watada and Qi, 1999).

**Fresh-cut Potatoes:** i) Pink, brown, gray or black discoloration (Sapers *et al.* 1995; Laurila *et al.*, 1998).

**Fresh-cut Peach and Nectarine Slices:** i) Loss of firmness and color and ii) High respiration rates (Watada *et al.* , 1996).

**Zucchini Slices:** i) Chilling injury; ii) Browning; iii) Deterioration (Watada and Qi, 1999) and iv) High respiration rates (Watada *et al.* ,1996).

**Fresh-Cut Tomato Slices:** i) Chilling injury and ii) Fast deterioration (Hong and Gross, 2001).

**Fresh-cut Cantaloupe:** i) Fungal decay; ii) Translucency and iii) Increased Respiration rates (Bai *et al.*, 2001).

**Fresh-Cut Honeydew And Muskmelons:** i) Deterioration at high temperatures; ii) Chilling injury and iii) High respiration rates (Watada *et al.* , 1996).

### **2.3 Techniques Being Used To Preserve The Quality Of Produce And Their Disadvantages**

Methods that are being used to preserve whole fruits and vegetables during storage and marketing are generally based on refrigeration with or without control of composition of the atmosphere (Smith and Stow, 1984; Smith *et al.*, 1987). However, temperature, atmosphere, relative humidity and sanitation must be regulated to maintain quality of fresh-cuts (Watada *et al.*, 1996).

Several techniques that have been used to minimize deleterious effects of minimal processing are refrigeration, controlled atmosphere packaging, modified atmosphere packaging, and chemical preservatives (Baldwin *et al.*, 1996; Zhang and Quantick, 1997; Ahmad and Khan, 1987). For best results, a combination of methods has been used

(Drake *et al.*, 1987). But there have been some disadvantages with these techniques, which are listed below:

### **2.3.1. Low Temperature, High Relative Humidity**

The most prevalent method in maintaining quality or controlling decay in fruits and vegetables is rapid cooling at a low temperature with high relative humidity (Ghaouth *et al.*, 1991). Since it causes chilling injury in fruits and vegetables (El Ghaouth *et al.*, 1992b; Krochta and Mulder-Johnston, 1997) and effective control of temperature is difficult, other means of preservation have been sought, for example, modified atmosphere packaging (MAP), controlled atmosphere packaging (CAP), fungicidal treatment, etc. (Ghaouth *et al.*, 1991). Also, low temperature storage is not economically feasible in most developing countries (Li and Yu, 2000; Smith *et al.*, 1987).

### **2.3.2. Modified Atmosphere Packaging (MAP) & Controlled Atmosphere Packaging (CAP)**

MAP has been used to extend the postharvest shelf life of fruits by reducing respiration rate and delaying senescence (Drake *et al.*, 1987). However, it causes anaerobiosis, and the fruit fails to ripen properly (El Ghaouth *et al.*, 1992b). Research has been conducted on the optimum storage atmosphere for fresh whole produce, but limited information is available on optimum atmosphere for fresh-cut produce (Gunes *et al.*, 2001).

CAP is helpful in extending shelf life of several whole fruits and vegetables but cannot be used with FC products because of the short handling period (Ahmad and Khan, 1987; Watada *et al.*, 1996). Respiration of the product becomes anaerobic when oxygen levels decline (McHugh and Senesi, 2000; El Ghaouth *et al.*, 1992a; Howard and Dewi, 1995; Li and Barth, 1998; Nisperos-Carriedo *et al.*, 1992). Therefore, restriction of

oxygen leads to accumulation of ethyl alcohol or anaerobic metabolism that leads to off – flavors (Purvis 1983).

CAP and MAP are not economically feasible in most developing countries (Li and Yu 2000), and they require the attention of skilled operators (Park *et al.*, 1994). Since these techniques often involve high capital and maintenance costs (Krochta and Mulder-Johnston, 1997) and require relatively skilled operators, it may be uneconomical to store small quantities of fruit in such stores; furthermore, regular inspection of fruit is difficult (Smith and Stow, 1984; Smith *et al.*, 1987). Once the fruit is removed, it is again subjected to air and ambient temperature, which can result in a rapid loss of quality.

### **2.3.3. Fungicides**

Fungicides control postharvest decay of whole fruits, but they leave residues and a number of tolerant pathogens can grow. As they are not safe for consumption they cannot be used on fresh-cuts. They leave residues that are potential risks to humans and the environment (Li and Yu 2000). Thus, natural products that could replace fungicides are being explored (Zhang and Quantick, 1998).

### **2.3.4. Chemical Preservatives**

Many consumers are suspicious of chemicals in their foods, especially in fresh-cut fruits and vegetables (Baldwin *et al.*, 1996). Sulfites were effective chemical preservative as they were both inhibitors of enzymatic browning and antimicrobial. But their use has been banned due to adverse reaction in consumers (Baldwin *et al.*, 1996, Kim *et al.*, 1993). Moreover, chemical preservatives affect the flavor of fresh-cut fruits (Rocha *et al.*, 1998).

### **2.3.5. Plastic Films**

Plastic films are effective in reducing desiccation (moisture loss), but are subject to microbial growth and disposal problems (Zhang and Quantick, 1997; Lerdthanangkul and Krochta, 1996).

### **2.4. Other Possible Techniques**

The disadvantages of the techniques being used to preserve fresh-cuts and increasing environmental concerns (Guilbert *et al.*, 1996; Arvanitoyannis and Gorris, 1999) have created an urgency for the invention of alternative packaging techniques such as edible coatings. Many years of research are conducted to develop a material that would coat fruit so that an internal modified atmosphere would develop (Park *et al.*, 1994). Studies have shown that ripening can be retarded, color changes can be delayed, water loss and decay can be reduced, and appearance can be improved by using a simple and environmentally friendly technology, edible coating (Park *et al.*, 1994; Baldwin, 2001).

The concept of edible films as protective films has been used since the 1800s (Guilbert *et al.*, 1996). The first edible coating used was wax in China (Park, 1999). Extensive research in this area has paved the way for different effective edible films and coatings.

The use of edible films and coatings is extended for a wide range of food products including fresh & minimally processed fruits and vegetables. The reasons for their use are: they extend product shelf life (Park *et al.*, 1994), control degradative oxidation and respiration reactions (McHugh and Krochta, 1994), add to texture and sensory characteristics and are environmentally friendly (Guilbert *et al.*, 1996). Krochta (2001) indicated that the present commercial edible coatings are solvent based (ethanol) and the

food industry should replace these solvent-based coatings with water-based coatings to ensure worker and environmental safety.

#### **2.4.1. Edible Coatings and Films**

Coatings are applied and formed directly on the surface of the food product, whereas films are structures, which are applied after being formed separately (Guilbert *et al.*, 1996). Because they may be consumed, the material used for the preparation of edible films and coatings should be regarded as GRAS (Park *et al.*, 1994; Krochta and Mulder-Johnston, 1997) approved by FDA and must conform to the regulations that apply to the food product concerned (Guilbert *et al.*, 1996). The purpose of edible films or coatings is to inhibit migration of moisture, oxygen, carbon dioxide, or any other solute materials, serve as a carrier for food additives like antioxidants or antimicrobials and reduce the decay without affecting quality of the food.

Specific requirements for edible films and coatings are (Arvanitoyannis and Gorris, 1999):

1. The coating should be water-resistant so as to remain intact and to cover all parts of a product adequately when applied;
2. It should not deplete oxygen or build up excessive carbon dioxide. A minimum of 1-3% oxygen is required around a commodity to avoid a shift from aerobic to anaerobic respiration;
3. It should reduce water vapor permeability;
4. It should improve appearance, maintain structural integrity, improve mechanical handling properties, carry active agents (antioxidants, etc.), and retain volatile flavor compounds.

#### **2.4.1.1. Edible Coatings**

Edible coatings are thin layers of edible material applied to the product surface in addition to or as a replacement for natural protective waxy coatings and provide a barrier to moisture, oxygen and solute movement for the food (McHugh and Senesi, 2000; Nisperos-Carriedo *et al.*, 1992; Lerdthanangkul and Krochta, 1996; Avena-Bustillos *et al.*, 1997; Guilbert *et al.*, 1996; Smith *et al.*, 1987). They are applied directly on the food surface by dipping, spraying or brushing to create a modified atmosphere (McHugh and Senesi, 2000; Krochta and Mulder-Johnston, 1997; Guilbert *et al.*, 1996).

An ideal coating is defined as one that can extend storage life of fresh fruit without causing anaerobiosis and reduces decay without affecting the quality of the fruit (El Ghaouth *et al.*, 1992b). Previously, edible coatings have been used to reduce water loss, but recent developments of formulated edible coatings with a wider range of permeability characteristics has extended the potential for fresh produce application (Avena-Bustillos *et al.*, 1994).

The effect of coatings on fruits and vegetables depends greatly on temperature, alkalinity, thickness and type of coating, and the variety of and condition of fruits (Park *et al.*, 1994). The functional characteristics required for the coating depend on the product matrix (low to high moisture content) and deterioration process to which the product is subject (Guilbert *et al.*, 1996).

#### **2.4.1.2. Edible Films**

Edible polymer film is defined as a thin layer of edible material formed on a product surface as a coating or placed (pre-formed) on or between food components (Krochta and Mulder-Johnston, 1997). Several types of edible films have been applied

successfully for preservation of fresh products (Park *et al.*, 1994). Fruit based films provide enhanced nutrition for food products, while increasing their marketing allure (McHugh and Senesi, 2000).

Edible and biodegradable films must meet a number of special functional requirements, for example, moisture barrier, solute or gas barrier, water/lipid solubility, color and appearance, mechanical and rheological characteristics, non-toxicity, etc. These properties depend on the type of material used, its formation and application (Guilbert *et al.*, 1996).

The benefit of using selective films seems to be the reduction of water loss, which is one of the most important factors in the deterioration of highly perishables (Bussel and Kenigsberger, 1975). The films provide protection against moisture loss and maintain an attractive appearance of the product. Films may consist of single or multiple components (Guilbert *et al.*, 1996).

## **2.5 Types of Edible Coatings and Films**

Edible coatings may be composed of polysaccharides, proteins, lipids or a blend of these compounds (Li and Barth, 1998; Park *et al.*, 1994; Guilbert *et al.*, 1996; Mahmoud and Savello, 1992; Arvanitoyannis and Gorris, 1999). Their presence and abundance determine the barrier properties of material with regard to water vapor, oxygen, carbon dioxide and lipid transfer in food systems (Guilbert *et al.*, 1996).

However, none of the three constituents can provide the needed protection by themselves and so are usually used in a combination for best results (Guilbert *et al.*, 1996; McHugh and Krochta, 1994).

### **2.5.1. Polysaccharide Based Coatings and Films**

Some of the polysaccharides that have been used in coating formulations are starch and pectin (Baldwin, 2001), cellulose (Tien *et al.*, 2001; Li and Barth, 1998; Baldwin, 2001), chitosan (Zhang and Quantick, 1998; Zhang and Quantick, 1997; El Ghaouth *et al.*, 1992a; Ghaouth *et al.*, 1991; Jiang and Li, 2001; Cheah *et al.*, 1997; Li and Yu 2000; Baldwin, 2001) and alginate (Tien *et al.*, 2001; Baldwin, 2001). These films are excellent oxygen, aroma, and oil barriers and provide strength and structural integrity; but are not effective moisture barriers due to their hydrophilic nature (Krochta, 2001; Kester and Fennema, 1986). The oxygen barrier properties are due to their tightly packed, ordered hydrogen bonded network structure and low solubility (Banker, 1966). These coatings may retard ripening and increase shelf life of coated produce, without creating severe anaerobic conditions (Baldwin *et al.*, 1995; Arvanitoyannis and Gorris, 1999).

### **2.5.2. Protein Based Coatings and Films**

Some of the proteins that are used in coating formulations for fruits and vegetables are soy protein, whey protein, casein and corn-zein, maize, egg albumen, collagen and wheat (Baldwin *et al.*, 1995). Like polysaccharide based films, the protein films are also excellent oxygen, aroma, and oil barriers and provide strength and structural integrity; but are not effective moisture barriers (Krochta and Mulder-Johnston, 1997; Baldwin *et al.*, 1995; Krochta, 2001; McHugh and Krochta, 1994; Mahmoud and Savello, 1992). Their oxygen barrier properties are due to their tightly packed, ordered hydrogen bonded network structure, low solubility (Banker, 1966) and the presence of several side residues of amino acids (cysteine, in particular) which can inhibit

polyphenoloxidase (Tien *et al.*, 2001). Research has shown that the presence of fatty acids in whey protein also significantly improves moisture barrier properties.

Proteins make good film formers and are produced from renewable resources and degrade more readily than other types of polymeric material (Baldwin *et al.*, 1995). Use of milk protein based coatings could control enzymatic browning of cut FV (Tien *et al.*, 2001). Whey protein has fatty acids that significantly improve moisture barrier properties.

### **2.5.3 Lipid based Coatings and Films**

Some of the lipids that have been used effectively in coating formulations are beeswax, mineral oil, vegetable oil, surfactants, acetylated monoglycerides, carnauba wax and paraffin wax (Kester and Fennema, 1986). Lipids offer limited oxygen barrier properties, due to the presence of microscopic pores and elevated solubility and diffusivity (Banker, 1966). Lipid films have good water vapor barrier properties, due to their low polarity (Kester and Fennema, 1986), but are usually opaque and relatively inflexible (Guilbert *et al.*, 1996).

### **2.5.4. Composite Coatings and Films**

The three different forms of coatings mentioned above are not effective in preserving the quality of the fruits and vegetables by themselves. They are more effective when used in a combination. For example, plasticized protein films possess good mechanical properties and improved film systems can be developed (McHugh and Krochta, 1994). A film formed by milk protein (casein) and lipid (acetylated monoglyceride) for lightly processed apples and potatoes was reported to provide

protection from moisture loss and oxidative browning for up to 3 days (Baldwin *et al.*, 1995).

## **2.6 Advantages of Edible Coatings and Films**

Advantages of edible coatings (Nisperos-Carriedo *et al.*, 1992; Park *et al.*, 1994; Sothornvit and Krochta, 2000) include:

1. Improved retention of color, acids, sugars, and flavor components
2. Reduced weight loss
3. Maintenance of quality during shipping and storage
4. Reduction of storage disorders
5. Improved consumer appeal
6. Extended shelf life
7. Addition of the value of the natural polymer material
8. Reduction of synthetic packaging

Generally, the potential benefits of EC and films for lightly processed produce are to stabilize the product and thereby extend product shelf life (Ben-Yehoshua, 1966; Baldwin *et al.*, 1995). More specifically, coatings have the potential to reduce moisture loss (Davis and Hofmann, 1973; Avena-Bustillos *et al.*, 1994; Avena-Bustillos *et al.*, 1997; Ben-Yehoshua, 1966; Risse and Miller, 1983; Baldwin *et al.*, 1995), and firmness loss, provide moisture and oxygen barrier properties (Li and Barth, 1998, Avena-Bustillos *et al.*, 1994), retard respiration rates (Banks, 1984), hinder solute movement (Li and Barth, 1998), retard loss of chlorophyll (Banks, 1984), retard ethylene production (Banks, 1984; Baldwin *et al.*, 1995), reduce metabolism and oxidation rates (Li and Barth, 1998), seal in flavor volatiles, carry additives that could reduce discoloration and

microbial growth (Ben-Yehoshua, 1966; Baldwin *et al.*, 1995), and improve the appearance (Davis and Hofmann, 1973; Ben-Yehoshua, 1966). Edible coatings would be very helpful in attaining relative humidity close to 100% (Watada *et al.*, 1996).

The major benefit of EC is that they can be consumed along with food, can provide additional nutrients, may enhance sensory characteristics and may include quality-enhancing antimicrobials (Guilbert *et al.*, 1996).

## **2.7 Disadvantages of Edible Coatings and Films**

While coatings have very desirable effects in reducing color changes, firmness loss, and decay, there are some disadvantages. These disadvantages could be overcome by suitable selection of the type and thickness of the coating and by avoiding treatment of immature, flavorless fruit and storage of coated fruits at high temperature (Park *et al.*, 1994). However, since consumers are concerned with additives, including wax, acceptability of edible coatings must be recognized (Watada *et al.*, 1996).

Thick coatings could restrict the respiratory gas exchange, causing the product to accumulate high levels of ethanol and to develop off-flavors (El Ghaouth *et al.*, 1992a; Howard and Dewi, 1995; Miller *et al.*, 1983; Davis and Hofmann, 1973). Poor water vapor barrier properties of the coatings could result in weight or moisture loss of the product, but it could prevent water vapor condensation, which could be a potential source of microbial spoilage for fruit and vegetable packaging (Ben-Yehoshua, 1985).

Films that have good gas barrier properties could cause anaerobic respiration and interfere with normal ripening (Meheriuk and Lau, 1988). The film should allow a certain amount of oxygen permeation through the coating or film in order to avoid anaerobic conditions.

The spoilage could be rapid for coatings such as whey protein in moist environments, which serves as nutrient for microbial growth (Avena-Bustillos *et al.*, 1997). Addition of antimicrobials like potassium sorbate to the coatings will be able to eliminate this problem.

Basic information on film-coating formulation, properties, methods of application to food surfaces and demonstration of effectiveness are lacking. Tremendous research is required in the area of applications of edible coatings of foods, especially fresh-cut fruits and vegetables.

## **2. 8. Effect of Edible Coatings and Films on Physical, Chemical, Sensory, Physiological Quality and Shelf-life of Fruits and Vegetables**

### **2.8.1. Apple Wraps**

Apple based wraps are made from apple puree with various concentrations of fatty acids, fatty alcohols, beeswax and vegetable oil and have a color of apple sauce. These wraps are excellent oxygen barriers, particularly at low to moderate relative humidity, but are not very good moisture barriers unless lipids were added (McHugh and Senesi, 2000).

Wrapping apple based films formed around apple pieces significantly reduced moisture loss and browning in cut apples, increased the intensity of apple flavor, and maintained the texture during a 12-day storage period at 5°C (McHugh and Senesi, 2000).

### **2.8.2. Cellulose-based Coatings**

Cellulose is a polysaccharide, composed of D-glucose units. It is highly permeable to water vapor (Kester and Fennema, 1986).

By the end of 3 week storage, both 2.7 pH (EC1) and 4.6 pH (EC2) cellulose-based edible coatings treated carrots maintained fresh appearance and had 15% greater carotene retention compared to controls which developed whiteness on the surface (Li and Barth, 1998). EC1 treatment had a significantly higher ethylene production, CO<sub>2</sub> level and phenoxidase activity than both EC2 and control treatments (Li and Barth, 1998).

### **2.8.3. Nature Seal<sup>®</sup> (NS)**

NS, a cellulose-based edible coating, has been used (in combination with antimicrobials, plasticizers, antioxidants, etc.) to coat fresh-cut apples and potatoes. The coating significantly reduced weight loss of apples and potatoes more than those treated with water solutions and were not objectionable in taste during several weeks of storage (Baldwin *et al.*, 1996). The coating has also been used to effectively reduce the discoloration of mini-peeled carrots without affecting microbial and chemical quality (Ghaouth *et al.*, 1991; Howard and Dewi, 1995), but had minor effects on levels of oxygen, carbon dioxide and ethanol in package headspace.

NS treatment provides low pH and water cellulose film on carrot surfaces, which holds more water for a longer period and drops the pH on the surface. The water layer is important for retarding discoloration and carotene loss and is a barrier for O<sub>2</sub> diffusion (Chen *et al.*, 1996).

### **2.8.4. Chitosan Coatings**

Chitosan, a by-product from crustacean shell wastes, is a high molecular weight cationic polysaccharide, normally obtained by the alkaline deacetylation of chitin and refers to as a range of polymers that, unlike chitin, are soluble in dilute organic acids

(Zhang and Quantick, 1998; Zhang and Quantick, 1997; Cheah *et al.*, 1997; El Ghaouth *et al.*, 1991; Jiang and Li, 2001; El Ghaouth *et al.*, 1992b).

Chitosan-based coatings are effective in prolonging the shelf life and improving quality of fruits, by delaying ripening (El Ghaouth *et al.*, 1992a), reducing respiration rate (Ghaouth *et al.*, 1991), reducing desiccation (Zhang and Quantick, 1997), regulating gas exchange, decreasing transpiration losses (Zhang and Quantick, 1998; Jiang and Li, 2001), modifying the internal atmosphere (El Ghaouth *et al.*, 1992b; Jiang and Li, 2001), maintaining the quality of harvested fruits, retaining fruit firmness (Ghaouth *et al.*, 1991), freshness, weight loss, titratable acidity (El Ghaouth *et al.*, 1991), soluble carbohydrates and vitamin C (Jiang and Li, 2001, Li and Yu, 2000), and reducing mold growth.

Chitosan inhibits growth of several fungi (Jiang and Li, 2001; Li and Yu, 2000) by inducing chitinase, a defense enzyme (Zhang and Quantick, 1998; El Ghaouth *et al.*, 1992a; Cheah *et al.*, 1997).

Chitosan is best when it is in close contact with the tissue. Therefore, it may be good for fresh-cut fruits and vegetables (El Ghaouth *et al.*, 1992a). Chitosan could be an ideal preservative coating because of its film forming properties, biochemical properties, inherent antifungal properties, enzyme activity (chitinase), and elicitation of phytoalexins (Zhang and Quantick, 1998; Zhang and Quantick, 1997; El Ghaouth *et al.*, 1991; Li and Barth, 1998; Jiang and Li, 2001; Li and Yu, 2000; Cheah *et al.*, 1997).

Feed trials have recently demonstrated that chitosan is non-toxic and biologically safe (Zhang and Quantick, 1998; Jiang and Li, 2001; Cheah *et al.*, 1997). Though it has been approved in Japan and Canada for various food applications, FDA has not yet approved chitosan for edible use in the USA.

Chitosan has beneficial effects on titratable acidity, ripening and vitamin C content, firmness and reduced decay (inhibited spore germination, germ tube elongation, and radial growth of *B.cinerea* and *Rhizopus* species in the culture) of strawberries (El Ghaouth *et al.*, 1992a), raspberries (Zhang and Quantick, 1998; Ghaouth *et al.*, 1991) and firmness and color changes in tomatoes (El Ghaouth *et al.*, 1992b).

Sensory evaluation confirmed that chitosan coated berries (Zhang and Quantick, 1998), longan fruit (Jiang and Li, 2001), and peaches (Li and Yu, 2000) were better in quality when compared to controls. They also showed that the increase in concentration of the coating or film has resulted in better quality.

The application of chitosan coating delayed changes in contents of anthocyanin, flavonoid, and total phenolics, reduced weight loss and browning of litchi fruit, improved storability, and delayed the increase in polyphenolase activity in litchi fruit (Zhang and Quantick, 1997). Chitosan also reduced decay and improved appearance of carrots (Li and Barth, 1998, Cheah *et al.*, 1997).

Coating tomatoes with chitosan reduced respiration rate, internal O<sub>2</sub> levels, and ethylene production (with a greater effect at 2% than 1% chitosan) and increased titratable acidity (El Ghaouth *et al.*, 1992).

Chitosan treated longan fruit had reduced firmness loss, ascorbic acid content (due to low respiration), titratable acidity, total soluble solids, decay, respiration rates and polyphenolase activity compared to control treated fruits. The coating partially inhibited increase in PPO activity of longan fruit, which is associated with peel discoloration (Jiang and Li, 2001).

Chitosan increased vitamin C content, reduced ethylene production and delayed rate of ripening in peach fruit as indicated by the high content of titratable acidity with a greater effect at higher concentration (Li and Yu, 2000).

#### **2.8.5. Corn-zein Coatings**

Zein is a natural corn protein produced from corn gluten meal and is insoluble in water, but soluble in aqueous alcohol, glycols and glycol esters (Martin-Polo, 1995). It has good film-forming, binding and adhesive properties. Corn-zein coating is a good barrier to oxygen. It delays color change, loss of firmness and weight, and extends shelf life of tomatoes. Its water vapor permeability, however, is about 800 times higher than a typical shrink-wrapping film (Park *et al.*, 1994).

Park *et al.*, (1994), indicated that corn-zein film delayed color changes, reduced weight loss, inhibited ethanol production, delayed ripening, and reduced firmness loss of tomatoes. The degree of color change was mainly dependent on the thickness of coating. Increased thickness was associated with an increased carbon dioxide level and a decreased oxygen level.

The coating was removed from the tomatoes when preparing samples for sensory tests. Acidity, overall flavor and off-flavor attributes were not affected by coating. Increased perceptions of sweetness, delayed softening and color development were observed later in the coated tomatoes more than those not coated. The non-coated tomatoes were not evaluated after 9 days storage at 21°C due to spoilage (Park *et al.*, 1994).

High O<sub>2</sub> and CO<sub>2</sub> barrier and low WV (water vapor) barrier properties of corn-zein film are favorable characteristics for application to coating fruits and vegetables to prevent condensation of WV (Park *et al.*, 1994).

#### **2.8.6. Mineral Oil Based Coatings**

The mineral oil based coating was a desirable edible coating for commercial application for bell pepper fruit (Lerdthanangkul and Krochta, 1996). Its excellent moisture barrier property resulted in reduced moisture loss, maintained fruit firmness and freshness. The coating significantly reduces water loss from fruit and prevents wilting and shriveling and maintains the freshness of the fruit (Lerdthanangkul and Krochta, 1996).

#### **2.8.7. Wax Coatings**

Wax, the first edible coating known (Park 1999), is the most effective coating to block moisture migration (Kester and Fennema, 1986). There are a number of waxes used but the most effective one is paraffin wax, followed by beeswax. The resistance is related to their compositions. Paraffin wax consists of a mixture of long-chain saturated hydrocarbons while beeswax comprises a mixture of hydrophobic, long chain ester compounds, long chain hydrocarbons and long chain fatty acids. The absence of polar groups in paraffin and low levels in beeswax account for their resistance to moisture transport.

An increase in ethanol, acetaldehyde, total soluble solids content and a decrease in total solids and titratable acidity was observed for waxed mandarins during storage relative to unwaxed fruits stored in film lined boxes (Ahmad and Khan, 1987). Storing

waxed mandarins at room temperature can lead to anaerobic respiration with higher levels of ethanol and acetaldehyde.

Oranges coated with commercial solvent type wax had less weight loss than those with comparable amounts of water wax or polyethylene coatings (Davis and Hofmann, 1973).

There was an increase in storage life and a decrease in weight loss when mangoes were coated with a wax emulsion in water compared to mineral oil coated and control samples (Mathur and Shrivastava, 1955).

Minimum amounts of solvent type wax/water wax that impart sufficient gloss should be used in order to avoid off-flavors and should not exceed 0.2-0.3 mg/cm<sup>2</sup> (Davis and Hofmann, 1973).

### **2.8.8. Milk Protein Coatings**

Milk contains two primary proteins: casein and whey protein. Milk proteins are nutritious and have numerous functional properties that are essential for the formation of edible films. Furthermore, considerable interest exists in finding new uses for milk proteins due to their surplus in the US (McHugh and Krochta, 1994).

#### **2.8.8.1. Whey Protein Coatings**

Whey proteins (WP) represent 20% of the total milk protein (Brunner, 1977). It is an extremely high-quality protein that is derived from milk. It contains five protein types: Beta-Lacto globulin (62% of whey protein fraction, molecular weight 18,362 form A and 18,276 form B), Alpha-lactalbumin (25% of WP, MW 14,000), Immunoglobulins, Bovine serum albumin (MW 66,000) and protease-peptones (McHugh and Krochta, 1994).

The mechanical properties of whey protein films adequately provide durability when used as coatings on food products or films separating layers of homogeneous foods (Anonymous, 2002b). Adding glycerol and sorbitol reduces internal hydrogen bonding in films, thereby increasing film flexibility while increasing WVP. Incorporating whey protein edible films in food product development can result in reduction of food losses due to spoilage and extension of shelf life.

#### **2.8.8.2. Casein Coatings**

Casein, a milk protein, contains four protein types: alpha-casein, beta-casein, delta-casein, and gamma-casein. Research conducted showed that casein-lipid coatings provide protection for fruits and vegetables from moisture loss and oxidative browning (Baldwin *et al.*, 1995).

Calcium caseinate and whey protein solutions efficiently delayed browning of apple and potato slices by acting as oxygen barriers (Tien *et al.*, 2001). They were effective gas barriers to internal carbon dioxide and oxygen, inhibited color changes and reduced decay when coated on bell peppers (Lerdthanankul and Krochta, 1996).

Caseinate coating was able to increase water vapor resistance of baby carrots by 65% by using the formulation, sodium caseinate 0.75% and stearic acid 0.25% (Krochta, *et al.*, 1993). Respiration rates (RR) of Red Delicious apples increased for both caseinate coated and uncoated apples (Avena-Bustillos *et al.*, 1997). This indicated that EC formulations did not modify fruit RR.

Carrots coated with sodium caseinate and stearic acid had lower whitish index and could help moisturize the carrot surface (Avena-Bustillos *et al.*, 1994; Krochta, *et al.*, 1993).

### **2.8.9. Mineral Oil and Wax Coatings**

Both wax and oil treatments were found to increase the storage life of 3 varieties of mangoes. Application of mineral oil to the whole surface of mangoes resulted in the production of an oil injury on the skin of the fruits. Mangoes in which only top one third was treated with mineral oil remained free from oil injury and storage life was increased by over 50% (Mathur and Shrivastava, 1955).

Results showed that treatment with mineral oil depresses respiratory activity to a greater degree than does the wax treatment. Wax controls moisture loss and respiration rate (to some extent), whereas oil treatment controls mainly the respiration rate. Wax and mineral oil treatment resulted in a decrease in ascorbic acid content and acidity and an increase in total soluble solids and reducing sugars (Mathur and Shrivastava, 1955).

### **2.8.10. Carbohydrate – Lipid Coatings**

Pro-long with Durkex, a vegetable oil blend, when coated on tomato fruit, reduced ripening, oxygen uptake and CO<sub>2</sub> and ethylene production significantly, compared to controls (Nisperos and Baldwin, 1988).

### **2.8.11. Sucrose Ester Coating**

Pro-long and Semperfresh are two forms of sucrose esters, which have been studied for effective preservation of the quality of fresh produce.

#### **2.8.11.1. Pro-long**

Pro-long is a mixture of sucrose fatty acid esters, sodium CMC and mono- and diglycerides (Park *et al.*, 1994). The mode of action of Pro-long involves the creation of a selectively permeable barrier creating internal atmospheres which preserve the fruit by reducing water loss and chilling injury characteristics, which might be utilized both in the

storage of fruit and for the maintenance of quality during the marketing period (Smith and Stow 1984).

Treatment with 0.75% Pro-long significantly increased the storage life of mangoes, retarded ripening and reduced weight loss and chlorophyll loss, without adversely affecting the sensory quality of the limes (Motlagh and Quantick, 1998).

Pro-long was also beneficial in the retention of firmness, green skin color and titratable acidity in Barlett and d'Anjou pears. However, uneven ripening, loss of ripening capacity and a blotchy appearance in many of the coated fruit remain serious problems in the commercial use of these coating compounds (Meheriuk and Lau, 1988).

A post storage application of Pro-long reduced the softening of low oxygen stored McIntosh and CA stored 'Delicious' apples during a 21-day shelf life period at 15°C and 90-95% RH. Treatment did not affect fruit firmness of CA-stored 'McIntosh' or 'Empire' apples but did retard the loss of ground color in 'McIntosh'. No physiological disorder was found in any treated fruit (Park *et al.*, 1994).

Apples treated with 1.25% sucrose ester formulation were stored in air at 3.5°C for up to 5 months. When applied after storage the coating reduced yellowing, loss of firmness and markedly increased internal carbon dioxide levels during a 21-day simulated marketing period. The treatment did not markedly reduce weight loss in fruit, nor cause accumulation of alcohol or induce any physiological disorders (Smith and Stow, 1984).

Coating bananas with Pro-long reduced weight loss, oxygen uptake, and ethylene release and chlorophyll loss and modified their internal atmosphere by reducing the permeability of the fruit skin to gases. Data suggested that the reduced internal oxygen

levels induced by Pro-long coating did not result in anaerobic respiration in the fruit (Banks, 1984).

#### **2.8.11.2. Semperfresh**

Semperfresh, a food-grade coating used to retard moisture loss, ripening and spoilage of fruit is a mix of sucrose esters with high proportion of short chain unsaturated fatty acid esters, sodium salts of CMC and mixed mono and diglycerides (Tasdelen and Bayindirli, 1998; Drake *et al.*, 1987). Semperfresh is an improved formulation of earlier SPE (sucrose polyester) (Drake *et al.*, 1987). The major difference is improved dispersion due to incorporation of higher proportion of short chain USFA esters.

These fruit coatings were found to be significantly effective (at both 12°C and 23±2°C) in retention of reducing sugars, delaying changes in firmness, titratable acidity, pH, soluble solids, sugars, ascorbic acid and lycopene synthesis (Tasdelen and Bayindirli, 1998).

Semperfresh significantly reduced water loss and internal carbon dioxide of zucchini fruit (Avena-Bustillos *et al.*, 1994) and reduced color changes, retained acid, increased shelf life and maintained the keeping quality of apples (Drake *et al.*, 1987) and tomatoes (Tasdelen and Bayindirli, 1998).

The coating increased titratable acidity, firmness and green color and decreased weight loss, total soluble solids and pH in mangoes when compared with the non-coated fruit. Ascorbic acid decreased in all stored fruit, but the decrease was slower in coated fruit. There were no significant differences in ascorbic acid contents between the different Semperfresh concentrations (Carrillo-Lopez *et al.*, 2000).

## 2.9. Thickness of Films or Coatings

Studies have shown that repeated dipping of products in the coatings give generally better results than single dipping, but lead to some physiological disadvantages (Ben-Yehoshua, 1966). Increase in thickness of the coating or the film cannot only cause detrimental effects by reducing internal oxygen and increasing carbon dioxide concentration leading to anaerobic fermentation, but also affect the original taste and flavor of the product (Park *et al.*, 1994; Park 1999). For example, treatment with 1.0% Pro-long caused anaerobiosis and significant loss of sensory quality in mangoes (Dhalla and Hanson, 1998). An optimum amount of coating should provide sufficient gloss and minimize weight loss without producing off-flavors (Davis and Hofmann, 1973).

## 2.10. Additives and Their Applications

Edible coatings can be furnished with compounds such as plasticizers, emulsifiers, antimicrobials or antioxidants to obtain additional desired effects (Nisperos-Carriedo *et al.*, 1992; Guilbert *et al.*, 1996). Such coatings may protect the product against spoilage, resulting in prolonged shelf-life without destroying the quality of the product. Use of a few additives in coatings and films and results of studies are:

**Soy protein:** The addition of soy protein increased moisture and gas barrier properties of Nature Seal<sup>®</sup> (Baldwin *et al.*, 1996).

**Carboxy methyl cellulose (CMC):** Addition of CMC improved antioxidative potential of casein and whey protein based films. In certain conditions, CMC acts as a chelating agent, interacts with copper binding site of oxygen and reduces polyphenolase activity (Tien *et al.*, 2001).

**Ascorbic acid:** The addition of ascorbic acid in NS solution delayed browning

effectively (Baldwin *et al.*, 1996).

**Sodium Benzoate and Potassium Sorbate:** These preservatives when added to edible coatings or films are effective in controlling microbial populations (Baldwin *et al.*, 1996).

**Acidulants:** They give optimal control of browning and microbial populations when added to the edible coatings or films (Baldwin *et al.*, 1996).

**Beeswax:** Addition of beeswax to the edible films or coatings helps decreasing respiration rates (Lerdthanangkul and Krochta, 1996).

**Plasticizers :** Glycerol and sorbitol are widely used plasticizers. The addition of glycerol to whey protein isolate and sodium caseinate coatings probably influenced respiration elevations and decreased weight loss (Lerdthanangkul and Krochta, 1996; Siew *et al.*, 1999). The addition of stearic acid improves moisture barrier properties and reduces the rate of white blush formation in carrots (Avena-Bustillos *et al.*, 1994).

**Emulsifiers:** The inferior performance of a film in retarding ripening can be traced to its inability to form a complete, uniform coating around the surface (Krochta and Mulder-Johnston, 1997). The addition of a surfactant or an emulsifier may greatly increase the ability of the film to suppress ripening (Nisperos and Baldwin, 1988). Glacial acetic acid is added to dissolve chitosan (Jiang and Li, 2001). The addition of an emulsifier to Durkex coating markedly improved permeability, resulting in better color development and reduction of pathogen invasion in coated fruits (Krochta and Mulder-Johnston, 1997).

## **CHAPTER 3. A SURVEY ON CONSUMER ACCEPTANCE AND PREFERENCE OF FRESH-CUT FRUITS AND VEGETABLES WITH OR WITHOUT EDIBLE COATINGS**

### **3.1 Introduction**

Ghosh (1989) indicated, “Instead of filling up shopping trolleys with their usual frozen assortment, people may soon be able to buy fresh food that has already been washed, sliced and pitted.” The markets demand for minimally processed fruits and vegetables has undergone rapid expansion, mainly due to busy lifestyles, increased purchasing power and health conscious consumers (McHugh and Senesi, 2000; Howard *et al.*, 1994; Baldwin *et al.*, 1995; Jiang and Joyce, 2002; Acuff, 1993).

Previous research has shown that food consumption patterns change constantly, depending on the availability of certain food and the consumer’s purchasing power and habits (Greenwood, 1998). With the busy lifestyles, consumer tends to use less time for preparing meals. Some health conscious consumers prefer eating fruits and vegetables (FV) and prefer a ready-to-eat salad than preparing it themselves. As a result, the maintenance of the quality of fresh-cut produce has become more challenging to the food industry.

There are many techniques that have been explored for maintaining the quality of produces, for example, low temperature, high relative humidity, controlled atmospheric and modified atmospheric packaging, plastic film packaging, etc. These techniques have both advantages and disadvantages and continue to be used.

Other techniques like edible coatings and chemical treatments are being studied to develop a better technique for maintaining the quality of both whole and fresh-cut produce.

Edible coating or film is a thin layer of edible material applied to the fruit surface as an addition or a replacement for the natural protective waxy coating. They have shown potential for controlling transfer of moisture, oxygen, lipids, aroma and flavor compounds in food systems, without affecting the quality of the food (Krochta and De Mulder-Johnston, 1977). Coatings are applied on the food product by dipping, brushing or spraying. Films are applied by wrapping them on the sample surface after being formed.

Research has been conducted to show that edible coatings not only increase the market opportunity for fruits and vegetables, but also are very effective in extending their shelf life. Little research has examined consumer acceptance of these products, especially when applied on fresh-cut fruits and vegetables (Bett *et al.*, 2001) either coated or uncoated. Surveys have been conducted on consumer perception of whole fruits and vegetables, but none has been conducted on the consumer perception of fresh-cut produce or edible films and coatings.

Knowing the consumer perception towards fresh-cut fruits and vegetables and edible coatings would help the food industry understand consumer attitudes and meet the market demand.

### **3.2 Objectives**

The objectives of this survey were (1) to compare consumer preferences among fresh-cut, canned, frozen-cut and whole/raw/unprocessed fruits and vegetables; (2) to evaluate consumer perception and preference of 16 fresh-cut fruits (FCF) and 16 fresh-cut vegetables (FCV); (3) to educate consumers on edible coating applications on fresh-

cut fruits and vegetables (FCFV), and (4) to determine the effect of demographic characteristics on the consumer perception of fruits and vegetables and edible coatings.

### **3.3. The Survey Procedure**

A seven-page questionnaire was prepared, reviewed by several faculty members from the Departments of Food Science, Horticulture and Agricultural Economics, and revised accordingly. A number of questions were asked to estimate consumer attitudes toward FCFV, and to determine whether the consumers understand the applications and advantages of edible coatings and films.

One thousand questionnaires (See Appendix A) were distributed across the Louisiana State University (LSU) and University of Georgia (UGA) campuses. At UGA, the survey was conducted by calling consumers randomly via phone directory. At LSU, the survey was handed to the students personally. The questionnaires were also sent to the secretary of each of the Departments in College of Agriculture' which were distributed to the faculty and staff. When completed they were returned within a week to the Department of Food Science. People above 45 years of age were recruited from the churches (The Chapel on the Campus and Hosanna First Assembly) on Sundays in Baton Rouge. This was done to obtain good distribution of all age groups for this study.

Data were collected on grocery shopper's frequency of use, preference for coatings, attributes affecting their preferences, and purchase intent of whole, canned, frozen and fresh-cut FV (coated and uncoated FV), their knowledge of edible coatings or films and their socio-economic characteristics (gender, age, race, education level, employment status, household income, family size and geographic location). Each questionnaire was coded accordingly for data analysis.

### 3.3.1. Econometric Analysis

Probit and ordered probit analyses were used to determine the effects of gender, age, race, education level, income, and family size on the consumer's perception and preference of fruits and vegetables and their knowledge about edible coatings and films. Probit analysis is used for studying data with a binomial distribution (yes/no response) and ordered probit is used for studying data with multinomial response variables that are inherently ordered in nature: yes, sometimes or no response for preference and lower, same or higher response for price (Liao, 1994; Greene, 1994).

The probit model is given by:  $\text{Prob}(Y=1) = \int_{-\infty}^{\beta x} F(t) dt = F(\beta'x)$

where  $x$  is a vector of independent variables and  $\beta$  is coefficient of  $x$ . The function  $F(\cdot)$  is a commonly used notation for standard normal distribution.

When yes, no and sometimes responses are coded as 0, 1, and 2, then the linear regression would treat the difference between 2 and 1, the same as that between 1 and 0, whereas in fact they are only a ranking. The ordered probit models have a threshold  $\mu$  ( $\mu$ ) that allows us to find the difference between responses. Using the threshold parameter the three probabilities are calculated as:

$$\text{Prob}(y=0) = 1 - F(\beta'x)$$

$$\text{Prob}(y=1) = F(\mu - \beta'x) - F(-\beta'x)$$

$$\text{Prob}(y=2) = 1 - F(\mu - \beta'x)$$

The likelihood ratio index (LRI) is a measure of fit for the model. It ranges between 1 and 0. As LRI value approaches 1, it indicates that the model has a good fit.

The likelihood ratio index was calculated as  $\text{LRI} = 1 - [\ln L / \ln L_0]$ ;

Where  $L_0$  – Restricted log likelihood function

L – Log likelihood function

### 3.4. Results

#### 3.4.1. Consumer Characteristics

The demographic and socioeconomic characteristics of respondents are given in Table 1.

**Table 1. Socio-economic and demographic data of the respondents (n = 611)**

Category	Frequency	Percent
<b>Gender:</b>		
Male	352	57
Female	257	43
<b>Age:</b>		
Under 18 years	2	0
18-25 years	159	27
26-35 years	152	25
36-45 years	116	19
46-55 years	109	18
56-65 years	57	9
66-75 years	9	1
Over 75 years	4	1
<b>Race:</b>		
African-American	53	9
Asian	87	14
Hispanic/Spanish	26	4
White (Caucasian)	416	69
Other	24	4
<b>Education:</b>		
Less than high school	9	1
High school graduate	50	8
Some college	141	23
Completed college	126	21
Graduate degree	280	47
<b>Household income:</b>		
Over \$120,000	30	5
\$110,000– 119,999	14	2
\$100,000– 109,999	17	3
\$90,000 – 99,999	25	4
\$80,000 – 89,999	29	5
\$70,000 – 79,999	43	7
\$60,000 – 69,999	44	8

(Table continued)

\$50,000 – 59,999	41	7
\$40,000 – 49,999	39	7
\$30,000 – 39,999	65	11
\$20,000 – 29,999	39	9
\$10,000 – 19,999	121	21
Under \$10,000	57	10
<b>Employment status:</b>		
Employed full-time	324	53
Employed part-time	33	5
Unemployed	6	1
Homemaker	13	2
Student	214	36
Retired	19	3
<b>Family size:</b>		
Single adult	241	40
Single parent with children in the home	20	3
Couple without children in the home	153	25
Couple with children in-home	192	32

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Out of 1,000 questionnaires distributed, 611 were usable. Three hundred and forty two of the respondents were female and 257 were male. The majority of the respondents were from the age group of 18-25 years (27%) and 26-35 years (25%). There were only 2 respondents under the age of 18 years, 9 from the age group of 66-75 years and 4 respondents above the age of 75 years. There were 19% of the respondents from the age group of 36-45 years, 18% from the age group of 46-55 years and 9% from the age group of 56-65 years.

The majority of respondents were White/Caucasian (69%), followed by 14% Asian, 9% African-American, 4% Hispanic/Spanish and 4% other races. About 47% of respondents had a graduate degree, followed by 23% with some college, 21% had completed college degree, 8% were high school graduates, and 1% had less than a high school diploma. The majority of respondents were from the income group of \$10,000-19,999 (21%), followed by 11% from \$30,000-\$39,999. About 53% of respondents were employed full-time, followed by 36% students, 5% employed part-time, 3% retired, 2%

homemaker and 1% unemployed. About 40% of the respondents were single adults, 32% were part of couple with children in the home, 25% were part of a couple without children in the home and 3% were single parents with children in the home.

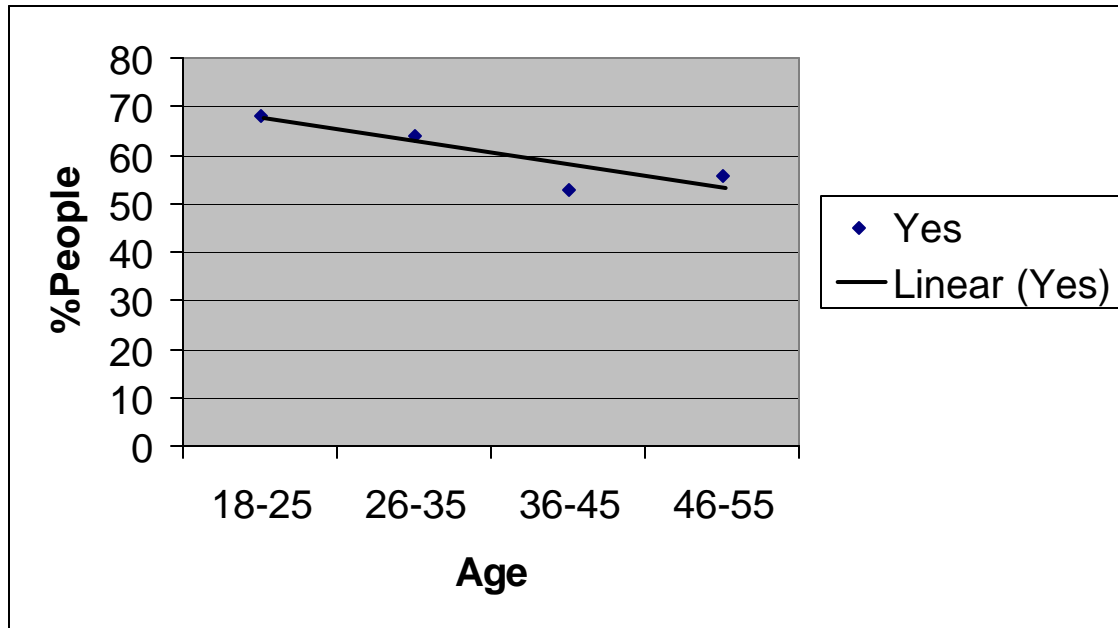
### **3.4.2. Comparison of Consumer Preferences of Different Forms of Fruits and Vegetables**

Data analysis showed that about 70% of the respondents preferred FCFV to canned FV and about 61% of them preferred FCFV to frozen-cut FV, the main reasons being freshness and natural taste/flavor. The others did not prefer FCFV to canned and frozen-cut FV mainly due to short shelf life, cost and convenience. About 30% of the consumers preferred FCFV to whole/unprocessed FV, the main reasons being less preparation time and desirable serving portion. The others did not prefer FCFV to whole FV, the main reasons being cost, not being fresh enough, shelf life and the preference for preparing FCFV themselves.

The chi-square values (Table 2) for the preference of FCFV to canned and whole FV by age were not significant ( $p > 0.05$ ). But the chi-square value for the preference of FCFV to frozen-cut FV by age were significant ( $p > 0.05$ ). As age increased the preference for FCFV relative to frozen-cut FV decreased (Figure 1).

**Table 2. Chi-square values for preference of FCFV to canned, frozen-cut and whole FV by age.**

<b>FCFV to</b>	<b>Chi-square values</b>
Canned FV	0.468
Frozen-cut FV	0.0236
Whole raw/unprocessed FV	0.4962



**Figure 1. Preference of FCFV to frozen-cut FV by age**

### **3.4.3. Frequency of Use of FCFV Based on Age and Gender Characteristics**

Figure 2 shows that majority of the respondents from each age group consumed FCFV at least once a week. Looking at the effect of age and gender (Figure 3) on the frequency of use of FCFV, we can see that for females, as the age increased from 18-45 years, the use of FCFV increased. However, the frequent use decreased for respondents aged between 46-55. But still, in all age groups, the majority of the female respondents purchased FCFV at least once a week. As the age group increased, the purchase of FCFV by males decreased. However, the majority of the males from 18-45 years did purchase FCFV at least once a week.

From Figure 5, it could be said that as the family size increased, the purchase of FCFV at least once a week also increased.

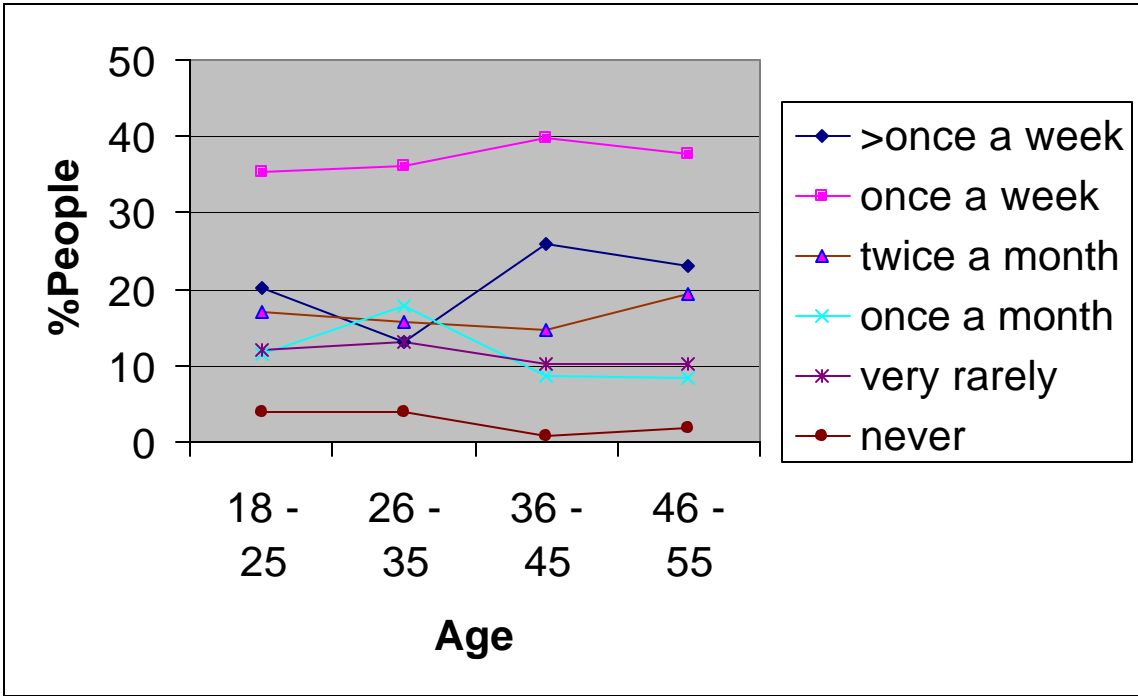


Figure 2. Frequent use of FCFV based on age group

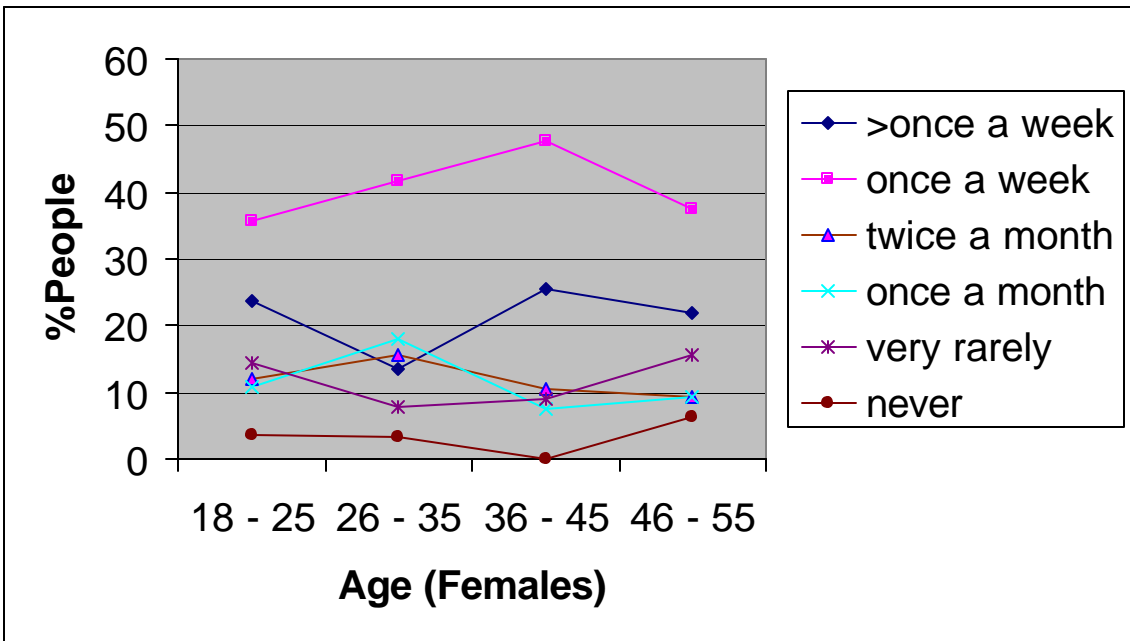


Figure 3. Frequency of use of FCFV by different age groups of females

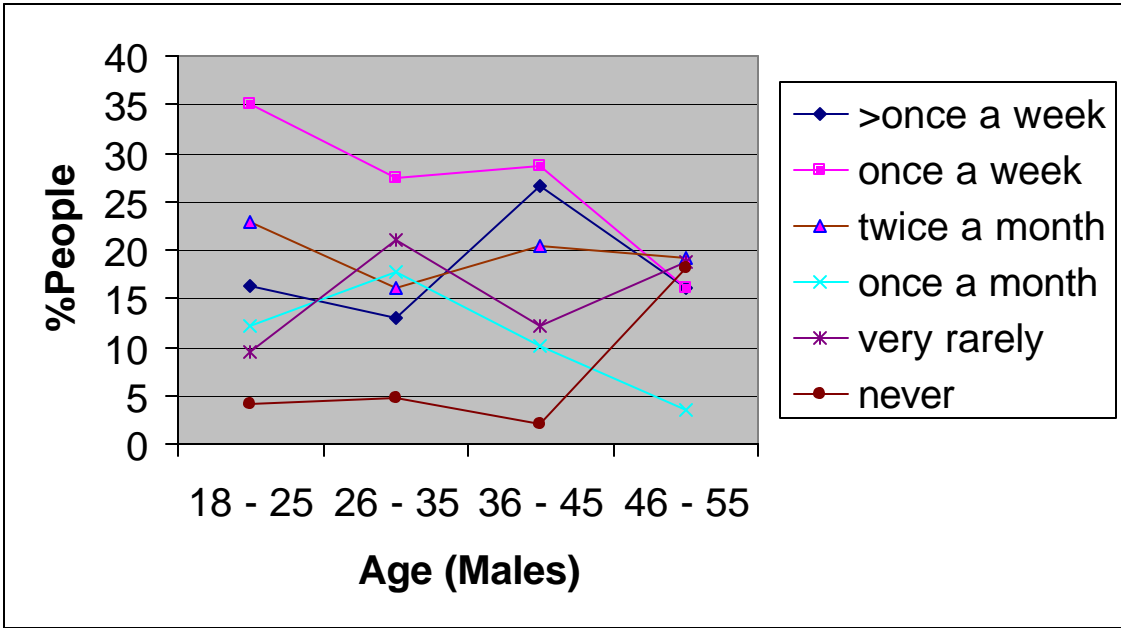


Figure 4. Frequency of use of FCFV by different age groups of males

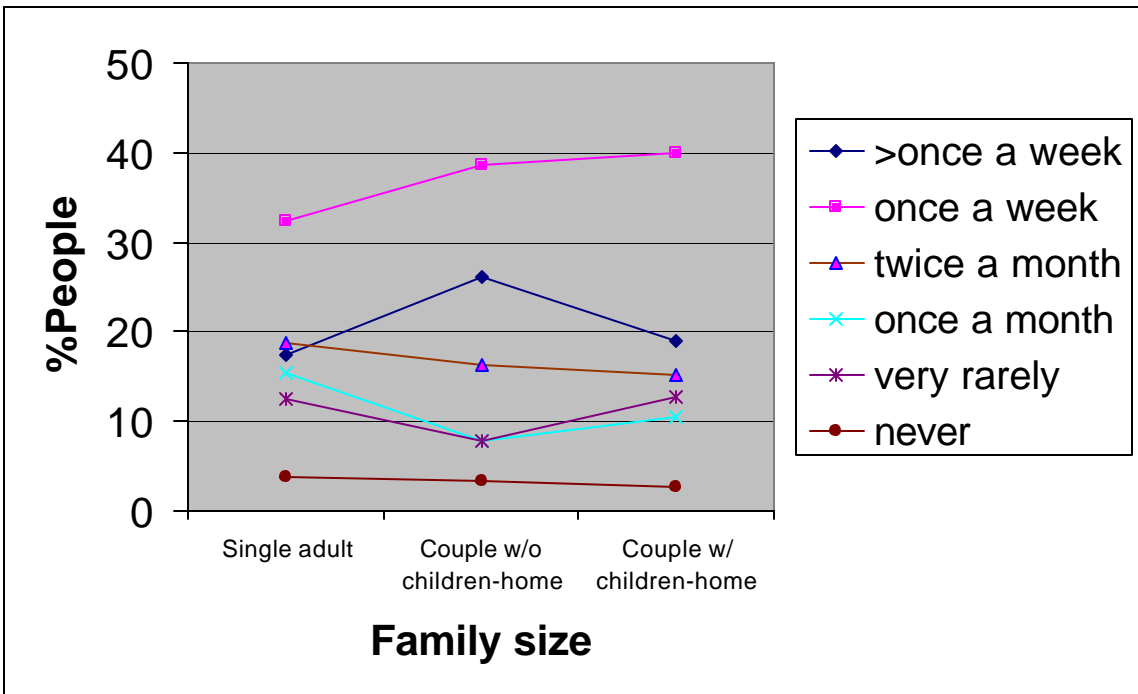


Figure 5. Frequency of use of FCFV based on family size

About 47 to 68.4% of the respondents said they had purchased apple, cantaloupe, honeydew, strawberry, watermelon and pineapple as fresh-cut. Similarly, 50 to 76.6% of the respondents said they had purchased bell pepper, broccoli, cabbage, cauliflower, celery, cucumber, lettuce, spinach, tomato and turnip greens as fresh-cut.

#### **3.4.4. Consumer Perception of Edible Coatings**

Up to 93.5% of the respondents said they knew apple was coated with EC and 74.9% said they knew that cucumber was coated with edible material. However, when asked if they had heard about edible coatings, only 54.6% of the respondents answered yes. Some of the respondents indicated that they have heard about edible coatings and films but they were not sure of what they were made of and their applications. Most of them did not know what an edible coating actually was. They knew that edible wax was being used to coat some FV (such as cucumber), but did not know what its functions were and why it was being used, except that it gives a shiny or glossy appearance to the fruits and vegetables. Some of them thought the advantages of edible coatings were that they give a shiny or glossy appearance to the fruits, prevent dehydration, add nutrition and can reduce the use of plastics.

However, four of the respondents said they would peel/wash off the EC before consumption, and a few said they would not purchase coated fruits or vegetables if the coating were of an animal source. About 79.3% of the respondents said they would buy FCFV coated with EC if the FDA approved the coating and there was a 7% increase in purchase intent after the advantages of the EC were described to the consumers.

### 3.4.5. Probit Analysis for Demographic Variables

For a more completed understanding of the effects of demographic characteristics on the consumer's responses, probit analysis was used to analyze the data. The independent variables were coded as shown in Table 3. The variable abbreviations shown in Table 3 were used in Table 4-18.

**Table 3. Variables coded for Probit analysis.**

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Variables

**Geographic area (Geo)**

Louisiana=1; Georgia=0

**Gender (Gen)**

Female=1; Male=0

**Age (Age)**

< 25 years=1;

26-35 years=2;

36-45 years=3;

46-55 years=4;

56-65 years=5;

>66 years =6;

**Race**

African-American (Aframer)=1; Otherwise=0;

Asian (Asian)=1; Otherwise=0;

Hispanic/Spanish (Hisp)=1; Otherwise=0;

**Education Level (Hsch)**

High school or less=1; some college/college/graduate degree=0;

**Household income (Inc)**

Over \$120,000=13;

\$110,000– 119,999=12;

\$100,000– 109,999=11;

\$90,000 – 99,999=10;

\$80,000 – 89,999=9;

\$70,000 – 79,999=8;

\$60,000 – 69,999=7;

\$50,000 – 59,999=6;

\$40,000 – 49,999=5;

\$30,000 – 39,999=4;

\$20,000 – 29,999=3;

\$10,000 – 19,999=2;

Under \$10,000=1;

(Table continued)

**Family size**

Married (Marry)=1; Unmarried=0;

Have children in the home (Child)=1; otherwise=0;

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A few points to consider before interpreting the results shown in the Tables 4-18:

1. As the variables we are testing do not start from zero, we use a constant so that we are not forcing the curve to start from zero.
2. If the coefficient of the gender variable is positive, it means that the probability of females (gender=1) saying yes to the question is more than males (gender=0).
3. The p values with one, two and three asterisk(s) indicate significance at 10%, 5% and 1% levels, respectively.

When asked if they eat/use whole/raw/unprocessed FV, 96.71% of the respondents answered yes and 3.29% answered no. The data was analyzed using a Probit model (Table 4). The likelihood ratio index was 0.0645. The low LRI index shows that the model does not have a good fit. This could be due to unequal distribution of the data. However, 97% of the cases were correctly predicted “yes” and there were few “no” answers. The demographic variable that was significant at  $\alpha=0.10$  with an expected positive sign was age. As age increased, people were more likely to eat/use whole/raw/unprocessed FV. None of the variables were significant at the a level of 0.05 and, therefore, were not further discussed.

When asked if they eat/use frozen-cut FV, 86.35% of the respondents answered yes and 13.65% answered no. The data was analyzed using a Probit model (Table 5). The likelihood ratio index was 0.0376. About 87% of the cases were correctly predicted. The demographic variables that were significant at  $\alpha=0.05$  were African Americans and

Asians. African Americans were more likely and Asians were less likely to eat/use frozen-cut FV than Caucasians and others.

**Table 4. Coefficients, standard errors and probability values of the demographic variables for the question “Do you eat/use whole/raw/unprocessed fruits and vegetables?”**

Variable	Coefficient	Standard error	P [ Z >z]
Constant	2.21166899	.24643099	.0000
GEN	.4166683212E-01	.16635059	.8022
AGE	.1908389777E-02	.10989024E-02	.0825*
AFRAMER	.5834347141	.36694794	.1118
ASIAN	-.1807768291	.24415257	.4590
HISP	-.4019901766	.32422260	.2150
HSCH	-.5330666742	.33328388	.1097
INC	.1300796270E-03	.47272136E-03	.7832
CHILD	.2346367533	.23723387	.3226
MARRY	-.2776775301	.23745691	.2423
GEO	-.3048459546	.24845874	.2198

Note: Description of the variable abbreviation is shown in Table 3.

**Table 5. Coefficients, standard errors and probability values of the demographic variables for the question “Do you eat/use frozen-cut fruits and vegetables?”**

Variable	Coefficient	Standard Error	P [ Z >z]
Constant	1.179828499	.11935015	.0000
GEN	.1498456326	.10179776	.1410
AGE	-.1633330516E-02	.31175245E-02	.6003
AFRAMER	.4837472675	.22568632	.0321**
ASIAN	-.4755018435	.14853137	.0014**
HISP	-.7537810225E-02	.22772959	.9736
HSCH	.6102676974E-03	.69902296E-03	.3826
INC	.2614787381E-03	.32504814E-03	.4211
CHILD	-.6836542771E-01	.15841881	.6661
MARRY	-.8296323990E-01	.15966398	.6033
GEO	-.5552259659E-01	.13949439	.6906

When asked if they eat/use canned FV, 93.23% of the respondents answered yes and 6.77% answered no. The data was analyzed using a Probit model (Table 6). The likelihood ratio index was 0.08316. About 94% of the cases were correctly predicted. The demographic variables that were significant at  $\alpha=0.05$  were Hispanic/Spanish, Asians and

Geographic location. Asians were less likely and Hispanic/Spanish were more likely to eat/use canned FV than Caucasians and others. Respondents from Louisiana were less likely to eat or use canned FV than those from Georgia; more consumer responses are needed to confirm this observation.

**Table 6. Coefficients, standard errors and probability values of the demographic variables for the question “Do you eat/use canned fruits and vegetables?”**

<b>Variable</b>	<b>Coefficient</b>	<b>Standard Error</b>	<b>P [ Z &gt;z]</b>
<b>Constant</b>	2.185029907	.28858203	.0000
<b>GEN</b>	.8334160330E-03	.15397846E-01	.9568
<b>AGE</b>	-.4365079029E-01	.68423461E-01	.5235
<b>AFRAMER</b>	-.2190186723	.27607146	.4276
<b>ASIAN</b>	-.6142969737	.18975672	.0012**
<b>HISP</b>	.8307906870	.34386787	.0157**
<b>HSCH</b>	-.1791748025E-02	.96157523E-02	.8522
<b>INC</b>	-.2599488627E-03	.35776016E-03	.4675
<b>CHILD</b>	.2197602683E-01	.19524464	.9104
<b>MARRY</b>	-.2413139490E-01	.19520056	.9016
<b>GEO</b>	-.6000904072	.21021280	.0043**

When asked if they eat/use FCFV, 94.35% of the respondents answered yes and 5.65% answered no. The data was analyzed using a Probit model (Table 7). The likelihood ratio index was 0.06626. About 94% of the cases were correctly predicted. The demographic variables that were significant at  $\alpha=0.10$ , with an expected positive sign were gender and income. Females were more likely to eat/use FCFV than males. As income level increased, respondents were more likely to eat/use FCFV. The p value for Hispanic/Spanish was also significant at  $\alpha=0.10$ . They were less likely to eat/use FCFV than Caucasians and others.

When asked if they generally prefer fresh-cut over canned F/V, 69.55% of the respondents answered yes, 22.63% answered sometimes and 7.82% answered no. The data was analyzed using an Ordered probit model (Table 8). The likelihood ratio index

was 0.02715. The demographic variables that were significant at  $\alpha=0.10$  were income, respondents with children in the home and geographic location. Income was significant with an expected positive sign. As the income level increased the preference of FCFV to canned FV increased. Respondents having children in the home were more likely to prefer FCFV to canned FV than those that did not have children in the home. Respondents from Louisiana were less likely to prefer FCFV to canned FV than those from Georgia.

**Table 7. Coefficients, standard errors and probability values the demographic variables for the question “Do you eat/use fresh-cut fruits and vegetables?”**

<b>Variable</b>	<b>Coefficient</b>	<b>Standard Error</b>	<b>P [ Z &gt;z]</b>
<b>Constant</b>	2.463315131	.44727585	.0000
<b>GEN</b>	.2413195355	.13995369	.0847*
<b>AGE</b>	-.9692502301E-01	.72228908E-01	.1796
<b>AFRAMER</b>	.2135165819	.35157951	.5436
<b>ASIAN</b>	-.1857735853	.23962305	.4382
<b>HISP</b>	-.5829586171	.34165725	.0880*
<b>HSCH</b>	.1043812806E-02	.73820074E-03	.1574
<b>INC</b>	.6306363909E-01	.32290687E-01	.0508*
<b>CHILD</b>	-.1089579839E-02	.21240276	.9959
<b>MARRY</b>	-.2416805571	.22277733	.2780
<b>GEO</b>	-.2390106699E-01	.18994942	.8999

When asked what price would they be willing to pay for FCFV compared with canned FV (on a per-pound basis), 36.15% of the respondents answered the same, 54.68% answered higher, and 9.17% answered lower. The data was analyzed using an Ordered probit model (Table 9). The likelihood ratio index was 0.0350. The demographic variables that were significant at  $\alpha=0.10$  were respondents who had children in the home and who were married. Respondents with children in the home were more likely to pay a higher price for FCFV compared with canned FV than those who did not have children in the home. Respondents who were married were less likely to pay a higher price for FCFV

compared with canned FV than those who were not married. Asians were significant at an alpha level of 0.01. Asians were more likely to pay a higher price for FCFV compared with canned FV than Caucasians and others.

**Table 8. Coefficients, standard errors and probability values of the demographic variables for the question “Do you generally prefer FCFV to canned FV?”**

Variable	Coefficient	Standard error	P [ Z >z]
Constant	-.4549940377	.19252646	.0181
GEN	-.3947217710E-01	.10823253	.7153
AGE	.1603692830E-01	.42646655E-01	.7069
AFRAMER	.8841274413E-01	.19006208	.6418
ASIAN	.2309714077	.14689133	.1159
HISP	.1848780466	.24530204	.4510
HSCH	-.6215201695E-03	.12153507E-02	.6091
INC	.7084707475E-03	.35018063E-03	.0431**
CHILD	.2503125326	.14630543	.0871*
MARRY	-.7255331814E-01	.15152502	.6321
GEO	-.2373550275	.11717319	.0428**
Mu	1.258600233	.80027690E-01	.0000

**Table 9. Coefficients, standard errors and probability values of the demographic variables for the question “What price would you be willing to pay for FCFV compared to canned FV (on a per pound basis)?**

Variable	Coefficient	Standard errors	P [ Z >z]
Constant	-.3959486060E-01	.17145761	.8174
GEN	-.6887785870E-01	.10344548	.5055
AGE	.2471675342E-02	.39222081E-01	.9498
AFRAMER	.2828092524	.19183736	.1404
ASIAN	.5575503927	.13969506	.0001***
HISP	.3290679716	.23497472	.1614
HSCH	-.2280771572E-03	.83749878E-03	.7854
INC	.1255814042E-03	.24001915E-03	.6008
CHILD	.2396546420	.12893766	.0631*
MARRY	-.2365328147	.13432925	.0783*
GEO	-.1359387231	.11340458	.2306
Mu	.9355117691	.74495825E-01	.0000

When asked if they would generally prefer FCFV to frozen-cut FV, 60.82% of the respondents answered yes, 27.43% answered sometimes and 11.75% answered no. The

data was analyzed using an Ordered probit model (Table 10). The likelihood ratio index was 0.00752. None of the demographic variables were significant at  $\alpha=0.05$  or 0.10, and therefore, were not further discussed.

When asked what price would they be willing to pay for FCFV compared with frozen-cut FV (on a per-pound basis), 48.78% of the respondents answered the same, 42.37% answered higher, and 8.85% answered lower. The data was analyzed using an Ordered probit model (Table 11). The likelihood ratio index was 0.0090. None of the demographic variables were significant at  $\alpha=0.05$  or 0.10, and therefore were not further discussed.

**Table 10. Coefficients, standard errors and probability values of the demographic variables for the question “Do you generally prefer FCFV to frozen-cut FV?”**

Variable	Coefficient	Standard errors	P [ Z >z]
Constant	-.1303350468	.11441137	.2546
GEN	.5999552768E-02	.10197442	.9531
AGE	-.1865356681E-03	.12670384E-02	.8830
AFRAMER	.2200781052E-01	.14223303	.8770
ASIAN	-.8428540312E-01	.11566163	.4662
HISP	.6275127445E-01	.15802346	.6913
HSCH	.5390848111E-03	.77721142E-03	.4879
INC	-.2007410820E-03	.28192673E-03	.4764
CHILD	.1143403021	.11865381	.3352
MARRY	-.1140122745	.11862552	.3365
GEO	-.1584648379	.10442533	.1291
Mu	.9191187315	.65587415E-01	.0000

When asked if they would generally prefer FCFV to whole/raw/unprocessed FV, 30.41% of the respondents answered yes, 35.81% answered sometimes and 33.78% answered no. The data was analyzed using an Ordered probit model (Table 12). The likelihood ratio index was 0.01017. None of the demographic variables were significant at  $\alpha=0.05$ . However, Geographic location was significant at an  $\alpha$  level of 0.10.

Respondents from Louisiana were less likely to prefer FCFV to whole/raw/unprocessed FV. Again, more consumer responses are needed to confirm this observation.

**Table 11. Coefficients, standard errors and probability values of the demographic variables for the question “What price would you be willing to pay for FCFV compared to frozen-cut FV (on a per pound basis)?”**

Variable	Coefficient	Standard errors	P [ Z >z]
Constant	.2859987025	.11919367	.0164
GEN	-.2692763354E-01	.10153082	.7908
AGE	-.5891284665E-03	.70361624E-02	.9333
AFRAMER	-.3114621162E-01	.13642723	.8194
ASIAN	.7158021180E-01	.11107322	.5193
HISP	-.4047916854E-01	.15725946	.7969
HSCH	-.2087772101E-03	.76213604E-03	.7841
INC	-.2471863879E-03	.27339954E-03	.3659
CHILD	.5993884191E-01	.11756864	.6102
MARRY	-.5925000096E-01	.11754261	.6142
GEO	-.7933616849E-01	.11130960	.4760
Mu	1.567168966	.85111847E-01	.0000

**Table 12. Coefficients, standard errors and probability values of the demographic variables for the question “Do you generally prefer FCFV to whole/raw/unprocessed FV?”**

Variable	Coefficient	Standard errors	P [ Z >z]
Constant	.6391673309	.92075514E-01	.0000
GEN	.1633200191E-02	.15946048E-02	.3057
AGE	-.1070375777E-02	.11669213E-02	.3590
AFRAMER	-.2221783183	.13788313	.1071
ASIAN	.1084303928	.11634633	.3514
HISP	.1151476845	.15967589	.4708
HSCH	-.2453189840E-03	.16513229E-02	.8819
INC	-.1596788433E-03	.24874867E-03	.5209
CHILD	-.2757363378E-01	.10730990	.7972
MARRY	.2647391857E-01	.10728700	.8051
GEO	-.1767962887	.99253018E-01	.0749*
Mu	.9440339988	.56082029E-01	.0000

When asked what price they would be willing to pay for FCFV compared with whole/raw/unprocessed FV (on a per-pound basis), 48.01% of the respondents answered the same, 46.02% answered higher, and 5.97% answered lower. The data was analyzed

using an Ordered probit model (Table 13). The likelihood ratio index was 0.02698. The demographic variable that was significant at  $\alpha=0.10$  is Hispanic/Spanish. They were less likely to pay a higher price for FCFV compared with whole/raw/unprocessed FV than Caucasians and others.

**Table 13. Coefficients, standard errors and probability values of the demographic variables for the question “What price would you be willing to pay for FCFV compared to whole/raw/unprocessed FV (on a per pound basis)?”**

<b>Variable</b>	<b>Coefficient</b>	<b>Standard errors</b>	<b>P [ Z &gt;z]</b>
<b>Constant</b>	.2895023113	.16806178	.0850
<b>GEN</b>	-.7765208699E-01	.12210929	.5248
<b>AGE</b>	-.5925277837E-03	.62641531E-02	.9246
<b>AFRAMER</b>	.2206247618	.18364292	.2296
<b>ASIAN</b>	.1200164552	.14495619	.4077
<b>HISP</b>	-.3407811654	.19375415	.0786*
<b>HSCH</b>	.1431443337E-03	.76826113E-03	.8522
<b>INC</b>	-.4942091927E-04	.26353150E-03	.8512
<b>CHILD</b>	.3348786040E-01	.15937134	.8336
<b>MARRY</b>	-.1875234943	.15547956	.2278
<b>GEO</b>	-.1008030798	.13732564	.4629
<b>Mu</b>	1.712394281	.11026538	.0000

When asked if they had heard about edible coatings and films, 54.85% of the respondents answered yes and 45.15% answered no. The data was analyzed using a Probit model (Table 14). The likelihood ratio index was 0.0534. About 62% of the cases were correctly predicted. The demographic variables that were significant at  $\alpha=0.05$  were Asians, Hispanic/Spanish and geographic location. Asians were more likely and Hispanic/Spanish less likely to have heard about edible coatings and films compared to Caucasians and others. Respondents from Louisiana were less likely to have heard about edible coatings and films than those from Georgia. Again, more data are needed to support this observation.

When asked if they would be willing to pay a higher price for fresh-cut FV than whole (raw/ unprocessed) FV (on a per-pound basis), if they were more convenient, 59.52% of the respondents answered yes and 40.38% answered no. The data was analyzed using a Probit model (Table 15). The likelihood ratio index was 0.0187. About 60.27% of the cases were correctly predicted. None of the demographic variables were significant at  $\alpha = 0.05$  or 0.10, and therefore, were not further discussed.

**Table 14. Coefficients, standard errors and probability values of the demographic variables for the question “Have you heard about edible coatings and films?”**

Variable	Coefficient	Standard errors	P [ Z >z]
Constant	.4190683716	.10122055	.0000
GEN	-.3918294121E-02	.24330075E-01	.8721
AGE	-.2550965732E-02	.52230098E-02	.6253
AFRAMER	.2155251554	.16894074	.2020
ASIAN	.3196918818	.13725986	.0199**
HISP	-.5354623081	.18823481	.0044***
HSCH	-.7468370970E-03	.71127355E-03	.2937
INC	-.2073534725E-03	.24832484E-03	.4037
CHILD	-.6500662467E-01	.12579858	.6053
MARRY	.6847515281E-01	.12577423	.5861
GEO	-.5541078484	.11524969	.0000***

**Table 15. Coefficients, standard errors and probability values of the demographic variables for the question “Would you be willing to pay a higher price for FCFV than whole/raw/unprocessed FV if they were more convenient?”**

Variable	Coefficient	Standard errors	P [ Z >z]
Constant	.4476947326	.16218338	.0058
GEN	-.2649577199E-02	.37701827E-02	.4822
AGE	-.6818505385E-01	.42627664E-01	.1097
AFRAMER	-.3075763934E-01	.20060775	.8781
ASIAN	-.1049285771	.15627368	.5019
HISP	-.4230648156	.26237402	.1069
HSCH	-.2770401208E-03	.75695872E-03	.7144
INC	.6241662518E-04	.25493359E-03	.8066
CHILD	-.1911953971	.12829243	.1361
MARRY	.1918317660	.12826532	.1348
GEO	-.7027042888E-01	.11568585	.5436

When asked if they would buy FCFV (that they normally consume) coated with an edible film that is safe for consumption, 79.63% of the respondents answered yes and 20.37% answered no. The data was analyzed using a Probit model (Table 16). The likelihood ratio index was 0.0199. About 80% of the cases are predicted yes. None of the demographic variables were significant at  $\alpha=0.05$  or 0.10, and therefore, were not further discussed.

**Table 16. Coefficients, standard errors and probability values of the demographic variables for the question “Would you buy FCFV coated with an edible film that is safe for consumption?”**

Variable	Coefficient	Standard errors	P [ Z >z]
Constant	1.056610988	.19238867	.0000
GEN	-.2209490078E-01	.11945680	.8533
AGE	-.1881132797E-01	.46566828E-01	.6862
AFRAMER	.1571306783	.17879347	.3795
ASIAN	-.2248890641	.14161852	.1123
HISP	.6817528074E-01	.19621869	.7283
HSCH	-.3086844985E-02	.22598577E-01	.8914
INC	.1977109139E-03	.28822182E-03	.4927
CHILD	.1262481620	.13751506	.3586
MARRY	-.1285863635	.13749141	.3497
GEO	-.2097712316	.13068936	.1085

When asked if they would buy FCFV that are coated with edible coating considered to be safe by FDA, after informing them of the facts about edible film, 84.63% of the respondents answered yes and 15.37% answered no. The data was analyzed using a Probit model (Table 17). The likelihood ratio index was 0.0349. About 85% of the cases are predicted as “yes”. The demographic variable that was significant at  $\alpha = 0.05$  was Geographic location. Respondents from Louisiana were less likely than those from Georgia to buy FCFV that were coated with edible coating considered to be safe by FDA, after informing them the facts about edible film. The demographic variables that were significant at  $\alpha=0.10$  were respondents who were married and

respondents with children. Respondents with children were more likely to buy FCFV that are coated with edible coating considered to be safe by FDA. Married respondents were less likely to buy them even after informing them of the facts about edible film. More data is required to confirm this observation.

**Table 17. Coefficients, standard errors and probability values of the demographic variables for the question “After knowing the what edible coatings and films are, would you buy FCFV coated with an edible film that is safe for consumption?”**

<b>Variable</b>	<b>Coefficient</b>	<b>Standard errors</b>	<b>P [ Z &gt;z]</b>
<b>Constant</b>	1.532737234	.19642611	.0000
<b>GEN</b>	-.5347869370E-03	.23801676E-01	.9821
<b>AGE</b>	-.7680251854E-01	.49405305E-01	.1201
<b>AFRAMER</b>	-.7716607423E-01	.20074969	.7007
<b>ASIAN</b>	-.1696146010	.15881614	.2855
<b>HISP</b>	.2472926186	.23131694	.2850
<b>HSCH</b>	-.2160149138E-02	.65220028E-02	.7405
<b>INC</b>	-.3628640061E-03	.26184291E-03	.1658
<b>CHILD</b>	.2558941751	.14343797	.0744*
<b>MARRY</b>	-.2579400215	.14341694	.0721*
<b>GEO</b>	-.3060248660	.14146717	.0305**

When asked what price would they be willing to pay for coated FCFV compared with whole/unprocessed FV on a per-pound basis, 70.97% of the respondents answered the same, 16.78% answered higher and 12.25% answered lower. The data was analyzed using an Ordered probit model (Table 18). The likelihood ratio index was 0.0080. None of the demographic variables were significant at an alpha level of 0.05 or 0.10.

### **3.5. Discussions**

Previous research has shown that the intake of fruits and vegetables is more in females than in males (Laforge *et al.*, 1994; Trudeau *et al.*, 1998; Johansson *et al.*, 1999). In our study though gender was not significant for all the questions, the coefficient values showed that females were more likely to prefer the different forms of FV compared to males.

The results of the survey conducted by Johansson and others in 1999 showed that older age groups had a higher intake of fruits and vegetables. In our study we had similar results. As age increased, there was an increase in consumption of whole or unprocessed FV.

**Table 18. Coefficients, standard errors and probability values of the demographic variables for the question “What price would you be willing to pay for coated FCFV compared with whole/raw/unprocessed FV on a per pound basis?”**

<b>Variable</b>	<b>Coefficient</b>	<b>Standard errors</b>	<b>P [ Z &gt;z]</b>
<b>Constant</b>	.8874365762	.10150208	.0000
<b>GEN</b>	-.6282835916E-03	.10556191E-01	.9525
<b>AGE</b>	.1005673924E-02	.10449322E-02	.3358
<b>AFRAMER</b>	.8978320628E-01	.17456783	.6070
<b>ASIAN</b>	-.1549749681	.11684923	.1847
<b>HISP</b>	.6472745808E-01	.19094165	.7346
<b>HSCH</b>	.9161283855E-03	.64950736E-03	.1584
<b>INC</b>	.2061865253E-03	.26342596E-03	.4338
<b>CHILD</b>	-.4818951639E-01	.11165637	.6660
<b>MARRY</b>	.4812065870E-01	.11153476	.6661
<b>GEO</b>	.1107114497	.10969711	.3129
<b>Mu</b>	2.138337061	.83663472E-01	.0000

Respondents with children in the home preferred FCFV to canned FV when compared to respondents without children in the home. The reason could also be health related or the concern for additives added. Previous research showed that families with caretaking responsibility for young children place a higher preference for fruits and vegetables (Devine and Olson, 1992; Wandel, 1995; Laforge *et al.*, 1994). Children inhibit the consumption of more fruits and vegetables, because of preference for other foods (Laforge *et al.*, 1994). So it is possible that the adults in the family tend to include more fruits and vegetables in their child’s diet as the dietary habits of childhood appear to be retained into adulthood.

Asians were less likely to eat/use canned and frozen-cut FV compared to Caucasians and others. Hispanic/Spanish were less likely to use FCFV compared to Caucasians and others. This could be because they prefer to prepare the FC themselves and tend to prepare meals at home rather than eating foods already prepared or in a restaurant/fast food stores. This study showed that the different ethnicity did affect the consumption behavior of different forms of fruits and vegetables and knowledge about edible coatings and films. The results were similar to previous studies conducted on fruits and vegetables consumption (Devine *et al.*, 1999). However, it should be noted that the percentages of African Americans, Asians and Hispanic/Spanish are small compared to Caucasians, and therefore, more data are needed to confirm our observations.

Respondents from Georgia were more likely to have heard about edible coatings and films. This could be due to the reason that more research is conducted on edible coatings and films in Georgia.

### **3.6. Limitations**

This study has a few limitations. The validity of the results depends on the survey method. This survey was conducted in the university campuses as a result of which there was not an equal distribution of age and education level in the data collected (i.e., sampling was not random). Although the university has students from different cultures, our survey could not have enough consumers from different races. People over 55 years were only a few. So they were not included in the data analysis. There were majority of Caucasians therefore results cannot be generalized to minority respondents. People with lower education level could not be recruited. The questionnaire was focused on both fruits and vegetables, which was too general. It is important to study the

consumer acceptance of fruits and vegetables separately, mainly because the use is different for both of them. Fruits are usually sweet and eaten raw, but vegetables are usually bitter and mostly cooked before consumption (Trudeau *et al.*, 1998, Devine *et al.*, 1999). All these resulted in large variations in the responses, low likelihood ratio index and low significance of the demographic variables.

Many people do not know much about edible coatings. The only edible coating they are aware of is edible wax. Consumers must be educated about the composition, advantages and applications of edible coatings in order to help them choose a better product.

## **CHAPTER 4. PHYSICAL AND MICROBIAL QUALITY OF FRESH-CUT APPLES COATED WITH WHEY PROTEIN**

### **4.1. Introduction**

Fresh-cut fruits and vegetables (FCFV) are convenient, nutritious foods with additional benefit of reduced wastage for consumers (Watada *et al.*, 1996). The consumption of fresh-cut fruits and vegetables is increasing tremendously, due the changes in consumer lifestyle, increasing health consciousness and purchasing power. As a result, the maintenance of the quality of FCFV is becoming more challenging. Rapid quality deterioration is mainly due to the high metabolic rates as a result of cutting, trimming, and peeling.

Processing of the fruits or vegetables results in loss of color, texture and moisture, and microbial growth. If not controlled, these changes can lead to rapid senescence and quality deterioration of the product. The techniques that are being used to preserve the quality of whole fruits are not effective for fresh-cut produce. This is because of the physical stress and strain the fresh-cuts undergone during minimal processing, which, in turn, increases respiration rates, ethylene production, color loss, firmness loss, weight loss and other physical, chemical, physiological and microbial changes.

Techniques such as a combined low temperature and high relative humidity, modified atmosphere packaging (MAP) and controlled atmosphere packaging (CAP) are being used for maintaining the quality of fresh produce. Low temperature storage could cause chilling injury and CAP and MAP could cause anaerobic respiration that leads to decay of the produce. The disadvantages of these techniques prompt the development of other improved techniques, like edible coatings and films.

Edible coatings, when used in proper combination can be used effectively to preserve the quality of fresh-cut fruits and vegetables, by acting as oxygen and moisture barriers. Milk protein coatings have been studied for many years. They are very good gas barriers but are poor moisture barriers because of their hydrophilic nature. By adding the plasticizers like sorbitol or glycerol to whey proteins, they have shown to reduce the water vapor permeability of the films. The plasticized films had greater mechanical strength and the water barrier properties (Banker, 1966).

Whey protein and glycerol films have good oxygen and barrier properties. Research has been done to determine the mechanical, oxygen and moisture barrier properties of these films. However, little information is available on the applications of whey protein coatings on FCFV.

Apple is a climacteric fruit, which is a popular and commercially important fresh-cut item (Jiang and Joyce 2002). Fresh-cut apples turn brown rapidly, sometimes in a few seconds. The other problems with them are loss of firmness, weight loss and microbial growth. Milk proteins could be beneficial for maintaining the quality of fresh-cut apples without affecting the sensory properties (Tien *et al.*, 2001).

#### **4.2. Objective**

The objective of this study was to determine the effects of three different whey protein coatings: whey protein concentrate, whey protein isolate, and hydrolyzed whey protein concentrate, on the physical and microbial qualities of freshly cut Fuji apple pieces.

### **4.3. Materials and Methods**

#### **4.3.1 Preparation of Coating Solutions**

Whey protein concentrate (Proliant™ 8000) and partially hydrolyzed whey protein concentrate (Proliant™ 8600) were supplied by Proliant, Inc., Iowa and the whey protein isolate (Provon 190) was supplied by Glanbia Ingredients, Wisconsin. Two concentrations (5% and 10% w/v) for each whey protein solutions were prepared.

The food grade glycerol (Fischer Scientific, New Jersey) was added at 30% of the whey protein powder. It has been shown that the glycerol content should be between 25-35% of the whey protein to obtain better films (Sothornvit and Krochta, 2000).

Distilled water was sterilized (121C for 16 minutes) and used as a control treatment. For a 10% coating solution, 150 grams of the whey protein powder was dissolved in 1305 ml of sterile water for 10 minutes using a stir plate and a magnetic stirrer. Then, 45 grams (which is 30% of the whey protein powder) of food-grade glycerol was added to the solutions and again stirred for another 10 minutes. The solution was filtered using cheesecloth (Lilly Industries, Inc., Michigan).

Similarly, 5% whey protein solutions were prepared using 75 grams of the whey protein powder, 1402.5 ml of sterile water and 22.5 grams of food-grade glycerol.

About 350 ml of each of the six coating solutions and the sterile water was transferred into 4 sterile plastic boxes and wrapped with an aluminum foil and refrigerated until used. The remaining solution was saved for pH measurement.

A total of 6-whey protein coating solutions and a control (water) were prepared. The pH of the control (sterile water) was 7.1, WPC solutions were 6.45, WPI solutions were 6.3 and PHWPC solutions were 6.8.

#### **4.3.2. Preparation of Apple Pieces**

Fuji apples were appropriate for fresh-cut processing, mainly because of their firmness (Hall, 1995). Thus, Fuji apples were selected for use in this study.

Fuji apples were purchased from a local grocery store (Albertson's) in Baton Rouge, Louisiana. The apples with similar size, shape, color and lack of defects were selected. All apples used were from the same orchard.

The apples were stored in a refrigerator at 2°C, before dipping in coating solutions. Apples were rinsed thoroughly with tap water to remove any surface impurities. They were then dipped in a 3% hydrogen peroxide solution for 2 minutes. Finally, the apples were rinsed with sterile water.

A cutting board was marked to aid in equal slicing of apples. An apple wedger (Good Grips, China) was used to core and slice each whole apple into 8 wedges. An additional 2-3 mm slice was removed from the core side of each wedge to minimize browning and decay. A sterile knife was then used to cut each wedge into pieces of 1.5 cm length, discarding the corners of the wedge. The apple pieces were dipped in the refrigerated (2°C) coating solution as soon as they were cut, for about 10 minutes. They were then removed and placed on a wire tray for another 10 minutes. A fan was used to blow air to aid in draining.

For this study, it would be difficult to prepare all cut apple pieces at one time sufficient for all coating treatments. The cut apple pieces would turn brown prior to coating treatments. To minimize this problem, each whole apple was used for each quality parameter test and each coating treatment (See Appendix E). A total of 28 apples were used for 7 coating treatments (including the control) and 4 quality parameters

(weight loss, firmness, color and microbial growth). Three apple pieces from each apple were placed in a sterile plastic container and marked according to the treatments and the storage day (1, 4, 7, 10, and 13) of analysis.

Three pieces from each apple were stored in each container, and a total of 5 containers were used for microbial analysis (15 pieces total). Similarly, three pieces were stored in 5 containers for color analysis. For texture analysis, four pieces from each apple were stored in each of the 5 containers (20 pieces total). For moisture analysis, only 5 pieces from each apple were stored in five individual containers (25 pieces total). The containers were labeled according to the treatment and the storage day of analysis. The experimental design is shown in the appendix E in a table form for better understanding.

The samples were drawn from the refrigerator, at day 1, 4, 7, 10 and 13. Four containers for analysis of color, texture, microbial count and weight loss. The whole experiment was repeated twice (two true experimental replications).

#### **4.3.3. Color Analysis**

The color measurements were performed with a spectrophotometer (Minolta CR 200, Minolta Co., Osaka, Japan). The calibration was done against a standard white plate provided by the manufacturer. The light source for the spectrophotometer was a pulsed xenon arc lamp and the observer angle used was 10°. The CIE L\*, a\*, b\* and colorimetric color (chrome, c and hue angle, h) were recorded on 3 pieces (both sides and averaging five color measurements on the surface of each side) from each treatment every 3 days of storage. The chroma is calculated as  $(a^{*2} + b^{*2})^{1/2}$  and the hue angle as  $\tan^{-1} (b^*/a^*)$ .

#### 4.3.4. Texture Analysis

The firmness of apple pieces was analyzed using a TA-XT2 plus texture analyzer (Texture Technologies Corp., New York). The test used was a shear or cut test on the apple pieces with TA-42 45°- chisel knife blade. The variations in apple size, and geometry were minimized by testing the replicates of pieces of same thickness from the same apple.

The test mode used for the texture analysis was “Force in Compression” with an option of “Repeat until count”. A 5 kg load cell, test speed of 5 mm/s and post-test speed of 10 mm/s were used. The “Trigger type” was set to “Button” and distance to be traveled was set to 38mm.

The following macro function was used to analyze the graph:

#### **Macro**

Clear Graph Results

Redraw

Search Forwards

Go To Min Time

Set Force Thresholds            600g

Go to Peak +ve Value           Force

Mark Value                        Force

Go to Peak +ve Value           Force

Mark Value                        Force

Go to Peak +ve Value           Force

Mark Value                        Force

Go to Peak +ve Value            Force

Mark Value                        Force

### **Calibration**

The texture analyzer was calibrated for force and height before every test. The force was calibrated using 2 kg weight provided by the manufacturer. The height was calibrated to 40 mm.

The test cuts the apple pieces to the bottom, leaving a gap of exactly 2 mm over the base of the texture analyzer. Once the blade had sheared the first piece, the cut piece was quickly removed and the base was wiped with a wet paper towel, to remove the juice expelled so that it did not interfere with the cutting of the next piece (slipping). Then, the next apple piece was immediately placed under the knife blade. This was repeated until all the four pieces for each coating treatment had been tested.

Once the tests were performed, the force (kg) values for sample analysis are automatically obtained by the MACRO. A curve was produced from shearing four apple pieces and the peak values of the force (kg) obtained from a Result file. The greater the maximum force, the greater is the firmness.

### **4.3.5. Microbial Analysis**

**Phosphate Buffer Solution (PBS) Preparation:** Sodium monophosphate (2.4g), sodium diphosphate (2.85g), and sodium chloride (8.4g) were dissolved in 1 liter of distilled water and stirred until the salts were dissolved using a magnetic stirrer on a stir plate. Then the solutions were transferred into bottles and sterilized in an autoclave (121°C, 15 PSI for 16 min).

A sharp knife, test tubes, test tube caps, 1 ml pipette tips and a PBS solution were sterilized in an autoclave before used for analysis. Dilutions were prepared using the PBS solution, transferred into test tubes covered with the test tube caps, and kept under the hood until used. The stomacher bags and the TPC and Ecoli/Coliform plates were labeled.

About 5g of each apple piece was diluted with 5ml of sterile PBS solution in a sterile stomacher bag and blended using a stomacher (Unique Scientific Aparatus, Ohio) for 2 minutes. The homogenate was diluted in the sterile solutions to achieve 10-fold (w/v) dilution ( $10^{-1}$ ) of the sample. The microbial counts included total plate counts and *E.coli/Coliform* plate counts. The petrifilms (3M Microbiological Products, Minneapolis) were incubated at 37°C for 24 hours. Microbial analysis was performed in triplicates and the results were the average of the three determinants. Results were presented as logarithm of colony forming units per gram (log CFU/g) of the product.

#### **4.3.6. Weight Loss Analysis**

Apple pieces from each coating treatment and from each container were removed using a pair of tongs and weighed on a balance (Mettler Toledo, Switzerland). Each apple piece was weighed on the first day and then every three days (i.e., 1, 4, 7, 10, and 13). For each treatment, percentage weight loss was calculated based on the corresponding weight of the apple pieces at day 1.

#### **4.3.7. Statistical Analysis**

Data were analyzed by analysis of variance using PROC GLM of the Statistical Analysis System (SAS). Specific differences in color, texture, microbial counts and weight loss within each treatment during days of storage were determined by least

significant difference (LSD). All comparisons were made at a 5% level of significance.

We did not attempt to statistically compare across coating treatments; however, the trends will be reported.

#### 4.4. Results and Discussions

There was a significant difference in weight loss (Table 19) for the control sample after the 13-day storage, and still the weight loss was higher compared to other treatments (2.519%). A significant weight loss in the PHWPC coated apples was observed after 7 days of storage. The 5%WPC, 10%WPC and 5%WPI prevented significant weight loss of apple pieces for at least 10 days of refrigerated storage.

**Table 19. Effect of coating treatments on weight loss (%) of coated fresh-cut apples**

<b>Treatments/Days</b>	<b>4</b>	<b>7</b>	<b>10</b>	<b>13</b>
<b>control</b>	<b>1.16<sup>a</sup></b>	<b>1.49<sup>ab</sup></b>	<b>2.18<sup>ab</sup></b>	<b>2.51<sup>b</sup></b>
	0.76	1.11	1.52	1.49
<b>5%WPC</b>	<b>1.08<sup>a</sup></b>	<b>1.12<sup>a</sup></b>	<b>1.68<sup>ab</sup></b>	<b>2.26<sup>b</sup></b>
	0.70	0.75	0.85	1.11
<b>10%WPC</b>	<b>1.23<sup>a</sup></b>	<b>1.17<sup>a</sup></b>	<b>1.31<sup>a</sup></b>	<b>1.82<sup>a</sup></b>
	0.66	0.74	0.97	1.39
<b>5%WPI</b>	<b>1.02<sup>a</sup></b>	<b>1.12<sup>a</sup></b>	<b>1.58<sup>ab</sup></b>	<b>2.15<sup>b</sup></b>
	0.49	0.61	0.87	1.22
<b>10%WPI</b>	<b>0.59<sup>a</sup></b>	<b>1.18<sup>ab</sup></b>	<b>1.51<sup>bc</sup></b>	<b>2.12<sup>c</sup></b>
	0.44	0.50	0.88	1.40
<b>5%PHWPC</b>	<b>0.25<sup>a</sup></b>	<b>1.34<sup>b</sup></b>	<b>1.38<sup>b</sup></b>	<b>2.01<sup>c</sup></b>
	0.49	0.82	0.81	0.86
<b>10%PHWPC</b>	<b>0.08<sup>a</sup></b>	<b>0.91<sup>b</sup></b>	<b>1.07<sup>b</sup></b>	<b>2.06<sup>c</sup></b>
	0.30	0.75	0.76	1.09

\*For each treatment values in the second row are standard deviations and the mean values (the first row) with different superscripts are significantly different ( $p < 0.05$ ).

There was no significant difference in weight loss after 13 days of refrigerated storage of 10%WPC (1.826% or 0.12g) coated apple pieces and the weight loss was less than all the other treated apples. This could be due to the composition of WPC (fat 4.3%,

Calcium 556mg/100g, Lactose 4.3% and cysteine 2.8g/100g of the product). This shows that 10%WPC was significantly effective in reducing weight loss of fresh-cut apples. This is advantageous when fresh-cut apples are being transported for further processing or utilization.

There was no significant difference in firmness between day 1 and day 13 in all the treated apple pieces, except for control (Table 20). The control samples were undesirably soft after 13 days.

**Table 20. Effect of coating treatments on firmness loss (reported as shear force in kg) of coated fresh-cut apples**

<b>Treatments/Days</b>	<b>1</b>	<b>4</b>	<b>7</b>	<b>10</b>	<b>13</b>
<b>control</b>	<b>3.57<sup>a</sup></b>	<b>2.62<sup>b</sup></b>	<b>2.96<sup>ab</sup></b>	<b>2.99<sup>ab</sup></b>	<b>2.08<sup>b</sup></b>
	0.31	0.75	0.59	0.90	0.29
<b>5%WPC</b>	<b>3.20<sup>a</sup></b>	<b>3.64</b>	<b>3.03<sup>a</sup></b>	<b>2.86<sup>a</sup></b>	<b>3.02<sup>a</sup></b>
	0.56	0.42	0.61	0.51	1.33
<b>10%WPC</b>	<b>2.48<sup>a</sup></b>	<b>3.33<sup>a</sup></b>	<b>3.10<sup>a</sup></b>	<b>3.12<sup>a</sup></b>	<b>3.16<sup>a</sup></b>
	0.33	0.57	0.59	0.91	0.61
<b>5%WPI</b>	<b>3.20<sup>a</sup></b>	<b>2.79<sup>a</sup></b>	<b>2.81<sup>a</sup></b>	<b>3.14<sup>a</sup></b>	<b>2.92<sup>a</sup></b>
	0.66	1.09	0.53	0.49	0.35
<b>10%WPI</b>	<b>3.25<sup>a</sup></b>	<b>3.12<sup>a</sup></b>	<b>3.02<sup>a</sup></b>	<b>3.24<sup>a</sup></b>	<b>3.73<sup>a</sup></b>
	0.66	0.51	0.62	0.60	0.76
<b>5%PHWPC</b>	<b>2.85<sup>a</sup></b>	<b>3.10<sup>a</sup></b>	<b>2.92<sup>a</sup></b>	<b>2.61<sup>a</sup></b>	<b>2.96<sup>a</sup></b>
	0.56	0.60	0.58	0.69	0.91
<b>10%PHWPC</b>	<b>2.40<sup>b</sup></b>	<b>3.55<sup>a</sup></b>	<b>2.83<sup>ab</sup></b>	<b>2.96<sup>ab</sup></b>	<b>3.16<sup>ab</sup></b>
	0.30	0.55	0.73	0.70	0.66

\*For each treatment values in the second row are standard deviations and the mean values (the first row) with different superscripts are significantly different ( $p < 0.05$ ).

The loss of firmness during storage in apples could be due to the action of endogenous enzymes related to cell wall degradation and growth of microorganisms (Rolle and Chism, 1987; Kim *et al.*, 1993). In our experiment, the softening could be due to action of endogenous enzymes related to cell wall degradation, as we did not find any

microbial growth during the storage. The apple pieces coated with 10% whey protein solutions were firmer than the ones coated with 5% whey protein solutions after 13 days.

The values for total plate count (Table 21) for all the treatments ranged from Non-detectable (ND) to 0.54 log CFU/g, except for the 10%WPC and 10%PHWPC on the 13th day, which had 3.03 and 1.58 log CFU/g, respectively, for the first batch. This could be due to cross-contamination.

**Table 21. Effect of coating treatments on total plate count (log CFU/g) of coated fresh-cut apples**

<b>Treatments/Days</b>	<b>1</b>	<b>4</b>	<b>7</b>	<b>10</b>	<b>13</b>
<b>control</b>	<b>ND<sup>a</sup></b>	<b>0.37<sup>a</sup></b>	<b>0.19<sup>a</sup></b>	<b>0.44<sup>a</sup></b>	<b>ND<sup>a</sup></b>
<b>5%WPC</b>	<b>0.05<sup>a</sup></b>	<b>0.54<sup>a</sup></b>	<b>0.48<sup>a</sup></b>	<b>0.35<sup>a</sup></b>	<b>ND<sup>a</sup></b>
<b>10%WPC</b>	<b>ND<sup>a</sup></b>	<b>0.10<sup>a</sup></b>	<b>0.17<sup>a</sup></b>	<b>0.05<sup>a</sup></b>	<b>1.44<sup>a</sup></b>
<b>5%WPI</b>	<b>0.05<sup>a</sup></b>	<b>0.12<sup>a</sup></b>	<b>0.19<sup>a</sup></b>	<b>0.17<sup>a</sup></b>	<b>ND<sup>a</sup></b>
<b>10%WPI</b>	<b>ND<sup>a</sup></b>	<b>0.28<sup>a</sup></b>	<b>0.30<sup>a</sup></b>	<b>0.10<sup>a</sup></b>	<b>ND<sup>a</sup></b>
<b>5%PHWPC</b>	<b>0.33<sup>a</sup></b>	<b>0.25<sup>a</sup></b>	<b>0.05<sup>a</sup></b>	<b>0.20<sup>a</sup></b>	<b>ND<sup>a</sup></b>
<b>10%PHWPC</b>	<b>ND<sup>a</sup></b>	<b>0.36<sup>a</sup></b>	<b>ND<sup>a</sup></b>	<b>0.10<sup>a</sup></b>	<b>0.34<sup>a</sup></b>

\*For each treatment values the mean values with different superscripts are significantly different (p<0.05).

The *E.coli/Coliform* counts were non-detectable for all the treated apple pieces, except for the controls. In the first batch, there was some growth in the 10% WPC (2.8 log CFU/g) and 10%PHWPC (1.66 log CFU/g) (similar to total plate count) on the 13th day. The colonies were reddish brown without air bubbles around them, so we could not confirm whether they were *E.coli* or *Coliform*. In the second batch, one of the control samples tested on the 4th day had one colony of *E.coli*. The apples were disinfected before cutting, by dipping in 3% hydrogen peroxide. This *E.coli/Coliform* could be due to cross-contamination.

Both the visual observations and L\* values (Table 22) showed that the control, 5%PHWPC and 10%PHWPC coated apple pieces turned brown on the first day. There were no significant changes in the L\* values for the WPC (5% and 10%) and WPI (5% and 10%) coated apple pieces during the 13-day storage, showing that these coatings may have effectively protected the apple pieces from oxygen and retarded enzymatic browning. For apple pieces coated with 10% WPI, 10% WPC, 10% PHWPC solutions, there were slight increases in L\* values. In 5% PHWPC coated apple pieces the L\* value significantly increased from 70.79% to 75.365%. The increase in L\* values during the storage is probably due to the exudation of natural liquid present in the apple or the coating solution that contribute to increase L\* values (Tien *et al.*, 2001).

**Table 22. Effect of coating treatments on L\* values of coated fresh-cut apples**

<b>Treatments/Days</b>	<b>1</b>	<b>4</b>	<b>7</b>	<b>10</b>	<b>13</b>
<b>control</b>	<b>73.23<sup>a</sup></b>	<b>70.02<sup>b</sup></b>	<b>71.7<sup>ab</sup></b>	<b>70.98<sup>ab</sup></b>	<b>71.59<sup>ab</sup></b>
	1.97	1.93	2.05	2.69	2.74
<b>5%WPC</b>	<b>76.24<sup>a</sup></b>	<b>76.14<sup>a</sup></b>	<b>75.90<sup>a</sup></b>	<b>74.89<sup>a</sup></b>	<b>75.78<sup>a</sup></b>
	2.10	2.40	1.96	1.75	1.02
<b>10%WPC</b>	<b>74.94<sup>a</sup></b>	<b>75.08<sup>a</sup></b>	<b>76.51<sup>a</sup></b>	<b>74.86<sup>a</sup></b>	<b>75.66<sup>a</sup></b>
	2.25	1.67	0.79	1.05	2.47
<b>5%WPI</b>	<b>74.68<sup>a</sup></b>	<b>72.25<sup>a</sup></b>	<b>74.1<sup>a</sup></b>	<b>72.84<sup>a</sup></b>	<b>74.08<sup>a</sup></b>
	2.15	2.78	2.33	1.89	3.69
<b>10%WPI</b>	<b>74.53<sup>a</sup></b>	<b>74.12<sup>a</sup></b>	<b>75.32<sup>a</sup></b>	<b>74.30<sup>a</sup></b>	<b>75.94<sup>a</sup></b>
	2.23	2.12	3.67	2.21	1.75
<b>5%PHWPC</b>	<b>70.79<sup>a</sup></b>	<b>72.51<sup>ab</sup></b>	<b>75.15<sup>b</sup></b>	<b>73.47<sup>ab</sup></b>	<b>75.36<sup>b</sup></b>
	2.50	2.59	3.13	3.42	3.08
<b>10%PHWPC</b>	<b>72.48<sup>a</sup></b>	<b>73.41<sup>a</sup></b>	<b>74.94<sup>a</sup></b>	<b>73.02<sup>a</sup></b>	<b>73.99<sup>a</sup></b>
	2.27	2.77	2.16	2.60	2.63

\*For each treatment values in the second row are standard deviations and the mean values (the first row) with different superscripts are significantly different (p<0.05).

The increased colorimetric  $a^*$  values (Table 23) after 13 days of storage were indicative of increased reddish brown color in the cut apples. The visual observation and  $a^*$  values showed that in the control, 5%PHWPC and 10% PHWPC coated apples browning took place on the first day. There were significant differences in  $a^*$  values during the 13 day storage for fruits coated with both 5% WPI and 10% WPI solutions. Comparing 5% WPC and 10% WPC, it can be seen that there is a significant increase in redness after the 7th day. Even though there was a significant difference during the 13-day storage for 10% WPC coating, the visual observation could not differentiate the color changes. The sensory evaluation should also be considered in order to judge the color changes of food samples.

**Table 23. Effect of coating treatments on  $a^*$  values of coated fresh-cut apples**

<b>Treatments/Days</b>	<b>1</b>	<b>4</b>	<b>7</b>	<b>10</b>	<b>13</b>
<b>control</b>	<b>3.54<sup>a</sup></b>	<b>4.04<sup>ab</sup></b>	<b>4.52<sup>ab</sup></b>	<b>4.50<sup>ab</sup></b>	<b>4.89<sup>b</sup></b>
	1.02	0.85	1.24	0.86	0.86
<b>5%WPC</b>	<b>1.96<sup>a</sup></b>	<b>2.85<sup>a</sup></b>	<b>4.45<sup>b</sup></b>	<b>4.682<sup>b</sup></b>	<b>5.11<sup>b</sup></b>
	1.28	1.35	0.90	0.38	0.56
<b>10%WPC</b>	<b>1.01<sup>a</sup></b>	<b>1.84<sup>a</sup></b>	<b>2.36<sup>b</sup></b>	<b>3.13<sup>b</sup></b>	<b>3.15<sup>b</sup></b>
	0.95	0.60	0.68	0.95	1.30
<b>5%WPI</b>	<b>1.88<sup>a</sup></b>	<b>2.46<sup>ab</sup></b>	<b>3.57<sup>b</sup></b>	<b>3.11<sup>ab</sup></b>	<b>3.42<sup>b</sup></b>
	0.77	0.54	1.79	0.90	1.31
<b>10%WPI</b>	<b>1.27<sup>a</sup></b>	<b>2.28<sup>a</sup></b>	<b>2.66<sup>a</sup></b>	<b>3.00<sup>b</sup></b>	<b>3.06<sup>b</sup></b>
	0.84	0.56	1.76	1.64	1.51
<b>5%PHWPC</b>	<b>3.44<sup>a</sup></b>	<b>2.90<sup>a</sup></b>	<b>3.85<sup>a</sup></b>	<b>3.94<sup>a</sup></b>	<b>3.92<sup>a</sup></b>
	1.62	0.56	2.06	2.24	1.88
<b>10%PHWPC</b>	<b>3.15<sup>a</sup></b>	<b>3.23<sup>a</sup></b>	<b>4.21<sup>ab</sup></b>	<b>4.41<sup>b</sup></b>	<b>5.11<sup>b</sup></b>
	0.70	0.65	1.20	1.43	1.16

\*For each treatment values in the second row are standard deviations and the mean values (the first row) with different superscripts are significantly different ( $p < 0.05$ ).

The chroma © values (Table 24) depend on a\* and b\* values [ $c = \sqrt{a^{*2} + b^{*2}}$ ].

The c value indicates the color intensity (saturation) of the sample. There was no significant difference in chroma seen in control, 5% WPC, 10% WPC and/or 5% WPI coated apple pieces between day 1 to day 13. But there was a significant decrease in chroma values of 10% WPI, 5% PHWPC and 10% PHWPC coated apple pieces, during the storage period of 13 days. This could be due to the significant lower b\* values in 10% WPI (20.935-18.636), 5% PHWPC (from 24.42 to 19.09) and 10% PHWPC (from 22.21 to 19.504) coated fruits.

**Table 24. Effect of coating treatments on chroma values of coated fresh-cut apples**

<b>Treatments/Days</b>	<b>1</b>	<b>4</b>	<b>7</b>	<b>10</b>	<b>13</b>
<b>control</b>	<b>24.67<sup>a</sup></b>	<b>24.42<sup>a</sup></b>	<b>25.46<sup>a</sup></b>	<b>25.77<sup>a</sup></b>	<b>24.32<sup>a</sup></b>
	3.49	1.97	2.73	1.57	1.60
<b>5%WPC</b>	<b>19.64<sup>a</sup></b>	<b>20.02<sup>a</sup></b>	<b>18.80<sup>a</sup></b>	<b>19.84<sup>a</sup></b>	<b>20.18<sup>a</sup></b>
	2.45	2.34	1.28	0.65	0.59
<b>10%WPC</b>	<b>20.35<sup>a</sup></b>	<b>20.26<sup>a</sup></b>	<b>19.62<sup>a</sup></b>	<b>19.42<sup>a</sup></b>	<b>19.30<sup>a</sup></b>
	2.33	1.52	1.92	1.39	1.35
<b>5%WPI</b>	<b>21.13<sup>ab</sup></b>	<b>21.02<sup>ab</sup></b>	<b>22.06<sup>a</sup></b>	<b>20.09<sup>b</sup></b>	<b>21.02<sup>ab</sup></b>
	1.31	1.91	2.06	1.80	1.88
<b>10%WPI</b>	<b>20.98<sup>ab</sup></b>	<b>21.15<sup>b</sup></b>	<b>19.91<sup>abc</sup></b>	<b>19.43<sup>ac</sup></b>	<b>18.93<sup>c</sup></b>
	1.67	1.94	2.14	1.42	1.49
<b>5%PHWPC</b>	<b>24.67<sup>a</sup></b>	<b>21.06<sup>b</sup></b>	<b>20.40<sup>b</sup></b>	<b>20.73<sup>b</sup></b>	<b>19.54<sup>b</sup></b>
	6.03	2.07	1.81	2.39	1.66
<b>10%PHWPC</b>	<b>22.43<sup>a</sup></b>	<b>21.33<sup>ab</sup></b>	<b>20.68<sup>c</sup></b>	<b>21.02<sup>bc</sup></b>	<b>20.19<sup>bc</sup></b>
	1.56	1.51	1.38	1.17	0.79

\*For each treatment values in the second row are standard deviations and the mean values (the first row) with different superscripts are significantly different ( $p < 0.05$ ).

The hue angle is calculated as  $\tan^{-1}(b^*/a^*)$ . As the hue angle decreases the red pigment increases. During the storage period, hue angle values (Table 25) for all apple pieces decreased significantly from day 1 to day 13. The 5% PHWPC and 10% PHWPC

coated fruits and the control fruits were brown the first day and had similar hue angle values (approximately 82). Comparing 5%WPI and 10%WPI, it can be seen that the fruits turned brown by the 7th day. 5%WPC coated fruits turned brown on the 7th day and 10%WPC coated fruits turned brown on the 10th day.

**Table 25. Effect of coating treatments on hue angle values of coated fresh-cut apples**

<b>Treatments/Days</b>	<b>1</b>	<b>4</b>	<b>7</b>	<b>10</b>	<b>13</b>
<b>control</b>	<b>81.70<sup>a</sup></b>	<b>80.48<sup>a</sup></b>	<b>79.77<sup>ab</sup></b>	<b>79.89<sup>ab</sup></b>	<b>78.4<sup>b</sup></b>
	2.13	1.72	2.60	2.11	1.65
<b>5%WPC</b>	<b>84.04<sup>a</sup></b>	<b>81.46<sup>a</sup></b>	<b>76.30<sup>b</sup></b>	<b>76.31<sup>b</sup></b>	<b>75.29<sup>b</sup></b>
	4.20	4.68	2.37	1.53	1.99
<b>10%WPC</b>	<b>87.12<sup>a</sup></b>	<b>84.78<sup>a</sup></b>	<b>82.92<sup>ab</sup></b>	<b>80.60<sup>b</sup></b>	<b>80.58<sup>b</sup></b>
	2.51	1.64	2.50	3.04	3.84
<b>5%WPI</b>	<b>84.82<sup>a</sup></b>	<b>83.17<sup>ab</sup></b>	<b>80.79<sup>b</sup></b>	<b>81.00<sup>b</sup></b>	<b>80.64<sup>b</sup></b>
	2.27	1.57	4.03	2.87	3.37
<b>10%WPI</b>	<b>86.49<sup>a</sup></b>	<b>83.79<sup>ab</sup></b>	<b>82.49<sup>b</sup></b>	<b>81.28<sup>b</sup></b>	<b>80.69<sup>b</sup></b>
	2.20	1.36	4.42	4.31	4.49
<b>5%PHWPC</b>	<b>82.25<sup>ab</sup></b>	<b>83.15<sup>a</sup></b>	<b>79.80<sup>ab</sup></b>	<b>79.42<sup>ab</sup></b>	<b>78.66<sup>b</sup></b>
	1.87	4.17	5.54	5.14	4.67
<b>10%PHWPC</b>	<b>81.93<sup>a</sup></b>	<b>81.34<sup>a</sup></b>	<b>78.38<sup>ab</sup></b>	<b>78.01<sup>b</sup></b>	<b>75.37<sup>b</sup></b>
	1.86	1.34	5.30	3.38	8.25

\*For each treatment values in the second row are standard deviations and the mean values (the first row) with different superscripts are significantly different ( $p < 0.05$ ).

As  $b^*$  values decreases, yellow color decreases. There was no significant difference in  $b^*$  values (Table 26) for the 5%WPC and 10%WPC coated fruits during the 13 day storage period. But the control, 5%PHWPC and 10% PHWPC were brown by the first day based on the visual observations.

**Table 26. Effect of coating treatments on b\* values of coated fresh-cut apples**

<b>Treatments/Days</b>	<b>1</b>	<b>4</b>	<b>7</b>	<b>10</b>	<b>13</b>
<b>control</b>	<b>24.4<sup>a</sup></b>	<b>24.07<sup>a</sup></b>	<b>25.03<sup>a</sup></b>	<b>25.36<sup>a</sup></b>	<b>23.84<sup>a</sup></b>
	3.46	1.93	2.68	1.63	1.518
<b>5%WPC</b>	<b>19.5<sup>a</sup></b>	<b>19.77<sup>a</sup></b>	<b>18.25<sup>a</sup></b>	<b>19.28<sup>a</sup></b>	<b>19.52<sup>a</sup></b>
	2.53	2.51	1.20	0.75	0.72
<b>10%WPC</b>	<b>20.31<sup>a</sup></b>	<b>20.17<sup>a</sup></b>	<b>19.46<sup>a</sup></b>	<b>19.14<sup>a</sup></b>	<b>19.08<sup>a</sup></b>
	2.32	1.51	1.98	1.46	1.36
<b>5%WPI</b>	<b>21.04<sup>ab</sup></b>	<b>21.03<sup>ab</sup></b>	<b>21.72<sup>a</sup></b>	<b>19.83<sup>ab</sup></b>	<b>20.73<sup>b</sup></b>
	1.35	1.84	1.89	1.84	1.87
<b>10%WPI</b>	<b>20.93<sup>ab</sup></b>	<b>21.03<sup>b</sup></b>	<b>19.67<sup>abc</sup></b>	<b>19.14<sup>ac</sup></b>	<b>18.63<sup>c</sup></b>
	1.66	1.93	1.98	1.23	1.47
<b>5%PHWPC</b>	<b>24.42<sup>a</sup></b>	<b>20.85<sup>b</sup></b>	<b>19.95<sup>b</sup></b>	<b>20.28<sup>b</sup></b>	<b>19.09<sup>b</sup></b>
	5.86	2.06	1.40	2.04	1.36
<b>10%PHWPC</b>	<b>22.21<sup>a</sup></b>	<b>21.08<sup>ab</sup></b>	<b>19.57<sup>c</sup></b>	<b>20.52<sup>bc</sup></b>	<b>19.50<sup>c</sup></b>
	1.58	1.45	1.58	0.93	0.64

\* For each treatment values in the second row are standard deviations and the mean values (the first row) with different superscripts are significantly different (p<0.05).

WPI is the purest form of whey protein and contains between 90-95% of protein (Anonymous, 2001b). It contains little fat or lactose. WPC is available in different types based upon the protein content of the product, which ranges between 25-89%. It contains some lactose, fat and minerals. As the protein level increases in the whey protein, the amount of lactose decreases. Whey protein concentrate with 80% protein content is the form most readily available as a protein powder supplement. The process of hydrolysis breaks the protein chains (in WPC) down to smaller segments called peptides. Hydrolyzed whey protein is more easily digested and has a reduced potential for allergic reactions versus non-hydrolyzed WP. The quality of the protein, however, remains very high.

Milk proteins delay color changes due to their oxygen barrier properties. But previous studies showed that these coatings are not completely impervious to oxygen (McHugh and Krochta, 1994). They allow enough penetration of oxygen so that it lowers the risks of anaerobic conditions and retards enzymatic browning.

Tien and others (2001) indicated that other agents could also inhibit enzymatic browning. The presence of amino acids (particularly cysteine) in the milk proteins inhibits the polyphenol oxidases via its SH groups. It acts as an agent coupling quinones and forms stable colorless compounds. Research also showed that histidine, tyrosine, phenylalanine, and tryptophan also inhibited enzymatic browning. Furthermore, the prevention of browning was also shown due to the presence of fatty acids (5.4% in whey protein concentrate). The fatty acids helped in moisture barrier properties and significantly reduced browning in fresh-cut apples (McHugh and Senesi, 2000).

This study demonstrated that WPC, which has a bland taste and can form flexible films, is effective in extending the shelf-life by acting as a barrier to moisture and oxygen. It should be further studied and commercialized as an edible coating for fresh-cut apples.

## **CHAPTER 5. CONCLUSIONS**

This research was designed to understand the consumer perception of fresh-cut fruits and vegetables (FCFV) with or without edible coatings and to determine the effect of three different whey protein coatings on the quality of fresh-cut Fuji apples.

The majority of the respondents preferred FCFV to canned and frozen-cut FV but minority preferred FCFV to whole raw/unprocessed FV.

The majority of the female respondents used FCFV at least once a week. But among males, the majority of the respondents used FCFV once a week.

Up to 75% and 93.5% of the respondents, respectively, knew that cucumber and apple were coated with an edible material. However, many of them were not aware of the advantages and applications of edible coatings or films. Some of the respondents wished to peel or wash off the edible coating before use and some did not wish to consume edible coatings from animal sources. Some indicated that they would purchase fresh-cut fruits and vegetables coated with an edible coating that is approved by FDA. The purchase intent increased by 7% after the advantages of edible coatings had been described to the consumers.

The large population study allowed for comparisons of different age, income and ethnic/racial groups. Our results showed that changes in the consumption of FCFV, either coated or uncoated, depends on gender, age, income level, race, and family size of the consumers.

In this study the consumers attitudes and perception of fruits and vegetables and edible coatings and films have been explored and the factors affecting the consumption of FCFV have been identified. However, there is a need to educate the consumers on edible

coatings and films and their applications and advantages in order to help the industry satisfy the consumers' needs. This study suggests that the industry should place greater emphasis on lower income group, males, and people who do not have children in the home when tailoring educational messages to these groups.

The second part of this study showed that 10% WPC coating was the most effective and desirable edible coating for commercial application for fresh-cut Fuji apples. Its excellent moisture barrier property reduced moisture loss, maintained color, fruit firmness and freshness.

WPI coatings were effective in maintaining L\* values but were not effective in preventing weight loss. Compared to WPC, WPI has low fat and lactose content. Even after adding 30% glycerol, WPI was not as effective as WPC in preserving the quality of fresh-cut apple pieces. PHWPC coatings were not effective in either reducing weight loss or preserving the color of the apples. Compared to WPC, PHWPC had lower amino acid content, low lactose content and low calcium. PHWPC was also not effective in preserving the quality of fresh-cut apple pieces, even after addition of 30% glycerol.

Firmness of the coated samples did not significantly change after 13-day storage compared to that of the control, which was undesirably soft. The 10% coating solutions were better than the 5% solutions in maintaining the firmness. The 5% coated samples had no microbial growth during the 13-day storage. No E.coli or Coliform was found in the coated samples.

Use of Whey protein concentrate as an edible coating for fresh-cut apples is beneficial to the food industry in controlling enzymatic browning, moisture loss and firmness loss.

This study provides information that may help in filling a few voids in the area of edible coatings and fresh-cut fruits and vegetables.

## **CHAPTER 6. RECOMMENDED FUTURE WORK**

1. More research should be conducted on sensory and consumer acceptance of fresh-cut fruits and fresh-cut vegetables separately, coated with edible coatings.
2. Tests should be conducted to determine the consumer attitude towards the sensory quality of coated fresh-cut apples.
3. Research should be conducted to understand the mechanism of the effect of whey protein coatings on preserving the quality of fresh-cut apples, in order to develop methods for handling and storage of fresh-cuts without loss of quality and to understand the full potential of whey protein coatings.

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## **APPENDIX A. CONSUMER QUESTIONNAIRE FOR THE FIRST STUDY**



## SURVEY ON FRESH-CUT FRUITS & VEGETABLES

### Definition:

Fresh-cut *Fruits and Vegetables (F/V)* are convenient products prepared from whole F/V, after having been washed to remove dirt and other undesirable materials, and cut into smaller portions depending on their usage. Fresh-cut F/V are ready-to-cook or ready-for-consumption. They are normally prepared without any pre-treatments (like heating/freezing), without added additives/preservatives, and are kept in a fresh state (refrigerated).

1. Please check Yes / No for the following questions.
  - a. Do you eat/use raw (unprocessed) fruits or vegetables?  
 Yes  No
  - b. Do you eat/use frozen-cut fruits or vegetables?  
 Yes  No
  - c. Do you eat/use canned fruits or vegetables?  
 Yes  No
  - d. Do you eat/use fresh-cut fruits or vegetables?  
 Yes  No
2. Which of the following do you consume most frequently? (Please rank from 1 – 4; 1 = most frequently to 4 = least frequently and 0 if you do not consume)  
\_\_\_\_ Fresh raw/unprocessed F/V (needs preparation)    \_\_\_\_ Frozen-cut F/V  
\_\_\_\_ Canned F/V    \_\_\_\_ Fresh-cut F/V (ready-to-eat)
3. How often do you buy fresh-cut F/V from a grocery store, salad bar or restaurant?  
(Please check one)  
 More than once a week     Once a month  
 Once a week     Very rarely  
 Twice a month     Never
4. Do you generally prefer fresh-cut over canned F/V? If “**Yes**” or “**Sometimes**,” go to 4.1. If “**No**,” go to 4.3. (Please check one)  
 Yes     Sometimes     No
- 4.1. Why do you prefer fresh-cut over canned F/V? (Check all that apply)  
 Freshness     Better utility (can be used for various purposes)  
 Natural taste / flavor     Better texture  
 More nutritious     Better appearance/color  
 No additives/preservatives added     Other (Please specify)  
 More convenient  
\_\_\_\_\_

- 4.2. What price would you be willing to pay for fresh-cut F/V compared with canned F/V (on a per-pound basis)? (Please check one)
- Same                                       Higher                                       Lower

4.3. Why do you **NOT** prefer fresh-cut F/V over canned F/V? (Please specify)

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5. Do you generally prefer fresh-cut over frozen-cut F/V? If **“Yes”** or **“Sometimes,”** go to 5.1. If **“No,”** go to 5.3. (Please check one)

- Yes                                       Sometimes                                       No

5.1. Why do you prefer fresh-cut over frozen-cut F/V? (Check all that apply)

- |   |  |
|---|--|
| <input type="checkbox"/> Freshness                        | <input type="checkbox"/> Better utility (can be used for various purposes) |
| <input type="checkbox"/> Natural taste / flavor           | <input type="checkbox"/> Better texture                                    |
| <input type="checkbox"/> More nutritious                  | <input type="checkbox"/> Better appearance/color                           |
| <input type="checkbox"/> No additives/preservatives added | <input type="checkbox"/> Other (Please specify)                            |
| <input type="checkbox"/> More convenient                  |  |
- 

5.2. What price would you be willing to pay for fresh-cut F/V compared with frozen-cut F/V (on a per-pound basis)? (Please check one)

- Same                                       Higher                                       Lower

5.3. Why do you **NOT** prefer fresh-cut F/V over frozen-cut F/V? (Please specify)

---

6. Do you generally prefer fresh-cut F/V over whole (raw unprocessed) F/V? If **“Yes”** or **“Sometimes,”** go to 6.1. If **“No,”** go to 6.3. (Please check one)

- Yes                                       Sometimes                                       No

6.1. Why do you prefer fresh-cut F/V over whole (raw unprocessed) F/V? (Check all that apply)

- Safer
- Less waste and undesirable cuts generated
- Better utility / versatility (can be used for various purposes)
- Serving portion or quantity (if you need less quantity instead of the whole F/V)
- Less preparation time / less clean-up / ready-to-consume
- Defects easily detected through transparent packaging (e.g., cut watermelon)
- Visual quality
- Other (Please specify) \_\_\_\_\_

6.2. What price would you be willing to pay for fresh-cut F/V compared with whole (raw unprocessed) F/V (on a per-pound basis)? (Please check one)

- Same                                       Higher                                       Lower

6.3. Why do you **NOT** prefer fresh-cut F/V over whole (raw/unprocessed) F/V?  
 (Please specify) \_\_\_\_\_

7. Would you be willing to pay a higher price for fresh-cut F/V than whole (raw/unprocessed) F/V (on a per-pound basis), **if it were more convenient?** (Please check one)  
 Yes  No

8. For each of the following fruits and vegetables, please indicate (√) whether you  
**1)** have seen available as fresh-cut in grocery stores, salad bars or restaurants, etc., & not purchased **2)** have seen as fresh-cut and purchased, **3)** have not seen but would purchase if available and **4)** have not seen and would not purchase if available. (**Check all that apply**)

<b>Fruits</b>	<b>Have seen &amp; not purchased</b>	<b>Have seen &amp; purchased</b>	<b>Have not seen but <u>would</u> purchase if available</b>	<b>Have not seen &amp; <u>would not</u> purchase if available</b>
<b>Apple</b>				
<b>Cantaloupe</b>				
<b>Fig</b>				
<b>Grapes</b>				
<b>Honeydew</b>				
<b>Kiwi</b>				
<b>Lemon</b>				
<b>Mango</b>				
<b>Nectarine</b>				
<b>Orange</b>				
<b>Papaya</b>				
<b>Pear</b>				
<b>Pineapple</b>				
<b>Plum</b>				
<b>Strawberry</b>				
<b>Watermelon</b>				

<b>Vegetables</b>	<b>Have seen &amp; not purchased</b>	<b>Have seen &amp; purchased</b>	<b>Have not seen but <u>would</u> purchase if available</b>	<b>Have not seen &amp; <u>would not</u> purchase if available</b>
<b>Bell pepper</b>				
<b>Broccoflower</b>				
<b>Broccoli</b>				
<b>Cabbage</b>				
<b>Carrot</b>				
<b>Cauliflower</b>				
<b>Celery</b>				
<b>Collard greens</b>				
<b>Cucumber</b>				
<b>Lettuce</b>				
<b>Onion</b>				
<b>Potato (80% cooked)</b>				
<b>Red radish</b>				
<b>Spinach</b>				
<b>Tomato</b>				
<b>Turnip greens</b>				

9. Have you heard about edible coatings or edible films? **(Please check one)**

Yes

No

## FACT!!!

An edible film is a thin, transparent layer of edible material coated on foods. The film can be derived from plant (soy protein, corn, etc.) and animal sources (milk protein, chitosan from shrimp, etc.). Examples of coated whole fruits and vegetables are apples and cucumbers; they are coated with edible wax.

10. Which of the following fruits and vegetables **do you think** have been coated with edible coating, film or wax? (Check all that apply)

### FRUITS

<input type="checkbox"/> Apple	<input type="checkbox"/> Honeydew	<input type="checkbox"/> Nectarine	<input type="checkbox"/> Pineapple
<input type="checkbox"/> Cantaloupe	<input type="checkbox"/> Kiwi	<input type="checkbox"/> Orange	<input type="checkbox"/> Plum
<input type="checkbox"/> Fig	<input type="checkbox"/> Lemon	<input type="checkbox"/> Papaya	<input type="checkbox"/> Strawberry
<input type="checkbox"/> Grapes	<input type="checkbox"/> Mango	<input type="checkbox"/> Pear	<input type="checkbox"/> Watermelon

### VEGETABLES

<input type="checkbox"/> Bell pepper	<input type="checkbox"/> Carrot	<input type="checkbox"/> Cucumber	<input type="checkbox"/> Red radish
<input type="checkbox"/> Broccoflower	<input type="checkbox"/> Cauliflower	<input type="checkbox"/> Lettuce	<input type="checkbox"/> Spinach
<input type="checkbox"/> Broccoli	<input type="checkbox"/> Celery	<input type="checkbox"/> Onion	<input type="checkbox"/> Tomato
<input type="checkbox"/> Cabbage	<input type="checkbox"/> Collard greens	<input type="checkbox"/> Potato	<input type="checkbox"/> Turnip greens

11. What do you think the benefits of such edible coatings or films are? (Check all that apply)

- Safety
- F&Vs last longer with delayed spoilage
- Better appearance
- Better quality
- Better nutrition
- Other (Please specify) \_\_\_\_\_

12. Would you buy fresh-cut fruits and vegetables (that you normally consume) coated with an edible film that is safe for consumption? (Please check one)

- Yes
- No

### **FACT!!!**

**Fruits and vegetables coated with edible materials normally last longer.**

13. After knowing the fact about edible film, would you buy fresh-cut fruits and vegetables that are coated with edible coating considered to be safe by FDA (Food and Drug Administration)?(Please check one)

- Yes
- No

14. What price would you be willing to pay for **coated** fresh-cut F/V compared with whole (raw/unprocessed) F/V on a per-pound basis? (Please check one)

- Same
- Higher
- Lower

## DEMOGRAPHIC & SOCIO-ECONOMIC SURVEY

1. Gender

- Female  Male

2. What is your age? (Please check one)

- Under 18 years  36-45  66-75  
 18-25  46-55  Over 75 years  
 26-35  56-65

3. Which do you consider yourself to be? (Please check one)

- African-American  Hispanic/Spanish  
 Asian  White (Caucasian)  
 Other (Please specify) \_\_\_\_\_

4. What is your education level? (Please check one)

- Less than high school  Completed college  
 High school graduate  Graduate degree (M.S., M.A.,  
Ph.D., etc.)  
 Some college

5. What is your average household income? (Please check one)

- Over \$120,000  \$70,000 – 79,999  \$30,000 – 39,999  
 \$110,000– 119,999  \$60,000 – 69,999  \$20,000 – 29,999  
 \$100,000– 109,999  \$50,000 – 59,999  \$10,000 – 19,999  
 \$90,000 – 99,999  \$40,000 – 49,999  Under \$10,000  
 \$80,000 – 89,999

6. Which of the following best describes your employment status? (Please check one)

- Employed full-time  Homemaker  
 Employed part-time  Student  
 Unemployed  Retired

7. Which of the following best describes your household? (Please check one)

- Single adult  
 Single parent with children in home  
 Couple without children in home  
 Couple with children in home

**OPTIONAL:** Please provide the last 4 digits of your Social Security Number. This will be used **for data tracking purpose ONLY.** \_\_\_\_\_

***THANK YOU VERY MUCH***

## **APPENDIX B. DATA ANALYSIS**

## A. SAS CODE

```
DATA ONE;  
INPUT BATCH      TRT $ DAY  REP  A;  
DATALINES;  
;  
PROC SORT;BY TRT;  
PROC GLM;BY TRT;CLASS DAY;  
MODEL A=DAY; MEANS DAY /TUKEY;RUN;
```

## B. LIMDEP CODE

```
DSTAT;      RHS=*      ;OUTPUT=2$
REJECT; Q1A=-999$
PROBIT;LHS=Q1A;
RHS=ONE,GEN,AGE,AFRAMER,ASIAN,HISP,HSCH,INC,CHILD,MARRY,GEO$
```

**Note 1:** Limdep is an integrated program that is used for estimation and analysis of linear and nonlinear models with cross section, time series and panel data. This software is mainly used for estimation of regression models and nonlinear models for limited dependent variables, survival data, qualitative choices, count data, and samples subject to nonrandom selection.

**Note 2:** The variables in RHS (ONE, GEN, etc.) are defined in the Table 3.

## **APPENDIX C. DATA SET FOR THE SECOND STUDY**

a. A Data Set for Color Values of Coated Fresh-Cut Apples

Batch	Trt	Day	Rep	L*	a*	b*	chroma	hue	
1	control		1	1	74.5	2.13	24.05	24.14	84.93
1	control		1	2	70.61	4.96	30.15	30.55	80.65
1	control		1	3	76.02	2.99	26.4	26.57	83.53
1	control		4	1	69.96	4.56	26.19	26.58	80.11
1	control		4	2	72.07	2.69	25.41	25.56	83.95
1	control		4	3	67.09	5.21	26.04	26.56	78.69
1	control		7	1	73.84	4.07	28.52	28.81	81.87
1	control		7	2	71.58	6.49	29.31	30.02	77.52
1	control		7	3	73.2	4.81	27.72	28.13	80.15
1	control		10	1	73.07	4.69	24.98	25.42	79.36
1	control		10	2	74.25	5.96	25.47	26.16	76.82
1	control		10	3	73.77	5.07	23.91	24.44	78.03
1	control		13	1	73.25	5.98	23.45	23.99	75.56
1	control		13	2	76.11	4.84	24.89	25.37	78.78
1	control		13	3	72.2	5.84	26.21	26.85	77.45
1	WPC5		1	1	75.93	1.31	20.58	20.62	86.35
1	WPC5		1	2	76.13	0.95	23.48	23.49	87.68
1	WPC5		1	3	76.28	0.83	17.32	17.34	87.24
1	WPC5		4	1	72.98	1.57	21.13	21.19	85.75
1	WPC5		4	2	74.84	2.19	18.34	18.47	83.2
1	WPC5		4	3	76.27	1.86	23.53	23.6	85.49
1	WPC5		7	1	77.02	3.65	18.76	19.12	78.98
1	WPC5		7	2	73.37	4.66	18.74	19.31	76.02
1	WPC5		7	3	77.62	3.71	17.98	18.36	78.33
1	WPC5		10	1	75.17	4.18	19.91	20.34	78.14
1	WPC5		10	2	76.17	4.41	20.18	20.66	77.67
1	WPC5		10	3	71.87	4.82	18.62	19.23	75.48
1	WPC5		13	1	74.67	4.33	20.18	20.64	77.9
1	WPC5		13	2	75.77	4.97	19.83	20.44	75.94
1	WPC5		13	3	74.87	4.97	20.02	20.63	76.05
1	WPC10		1	1	77.63	-0.53	22.46	22.46	91.35
1	WPC10		1	2	73.07	1	19.24	19.27	87.02
1	WPC10		1	3	75.21	0.52	16.5	16.51	88.2
1	WPC10		4	1	77.01	1.29	17.26	17.31	85.74
1	WPC10		4	2	72.31	1.65	20.14	20.21	85.31
1	WPC10		4	3	76.96	1.07	20.56	20.58	87.02
1	WPC10		7	1	77.6	3.03	17.01	17.28	79.91
1	WPC10		7	2	76.21	3.15	19.67	19.92	80.9
1	WPC10		7	3	76.23	3.25	16.87	17.18	79.09
1	WPC10		10	1	72.5	4.9	19.84	20.44	76.13
1	WPC10		10	2	75.06	3.65	17.21	17.59	78.04
1	WPC10		10	3	75.92	3.9	18.35	18.76	78.01
1	WPC10		13	1	75.64	4.66	18.62	19.2	75.96

1	WPC10	13	2	76.68	3.83	16.76	17.19	77.12
1	WPC10	13	3	75.81	4.76	19.88	19.76	76.06
1	WPI5	1	1	72.29	2.94	19.93	20.14	81.62
1	WPI5	1	2	72.84	1.27	23.68	23.7	86.92
1	WPI5	1	3	73.1	2.08	21.02	21.12	84.35
1	WPI5	4	1	70.79	2.75	20.85	19.64	81.39
1	WPI5	4	2	72.34	1.86	23.44	23.51	85.47
1	WPI5	4	3	68.54	2.61	22.74	22.89	83.45
1	WPI5	7	1	74.52	4.16	19.47	19.91	77.94
1	WPI5	7	2	70.28	6.97	23.06	24.09	73.18
1	WPI5	7	3	76.31	6.08	25.11	25.84	76.4
1	WPI5	10	1	71.05	4.89	17.54	18.21	74.43
1	WPI5	10	2	70.02	3.81	20.53	20.88	79.47
1	WPI5	10	3	71.3	3.94	22.14	22.49	79.92
1	WPI5	13	1	73.43	4.61	19.88	20.41	76.95
1	WPI5	13	2	71.84	5.14	19.66	20.32	75.35
1	WPI5	13	3	66.22	5.51	23.55	24	76.72
1	WPI10	1	1	77.65	1.58	19.98	20.04	85.48
1	WPI10	1	2	71.25	2.57	23.08	23.19	83.63
1	WPI10	1	3	73.45	0.43	21.26	21.26	88.85
1	WPI10	4	1	71.42	3.2	23.26	23.48	82.16
1	WPI10	4	2	74.68	2.38	18.95	19.1	82.83
1	WPI10	4	3	71.39	3.21	21.68	21.91	81.59
1	WPI10	7	1	69.43	5.72	24.19	24.86	76.69
1	WPI10	7	2	79.13	3.63	18.08	18.44	78.66
1	WPI10	7	3	73.95	4.54	20.02	20.53	77.21
1	WPI10	10	1	73.74	4.5	20.29	20.78	77.49
1	WPI10	10	2	71.66	6.35	20.09	21.07	72.45
1	WPI10	10	3	70.67	4.27	19.99	20.44	77.95
1	WPI10	13	1	76.09	4.78	21.34	21.87	77.38
1	WPI10	13	2	75.86	5.33	18.12	18.88	73.61
1	WPI10	13	3	76.03	4.63	17.49	18.09	75.18
1	PHWPC5	1	1	67.67	6.26	34.6	35.16	79.75
1	PHWPC5	1	2	67.98	4.53	26.12	26.51	80.17
1	PHWPC5	1	3	70.4	2.9	26.07	26.23	83.66
1	PHWPC5	4	1	74.26	2.62	23.93	24.08	93.76
1	PHWPC5	4	2	73	3.29	22.55	22.79	81.7
1	PHWPC5	4	3	68.19	4.16	22.61	22.99	79.57
1	PHWPC5	7	1	74.93	4.54	20.02	20.86	74.96
1	PHWPC5	7	2	69.78	5.41	22.23	23.64	70.11
1	PHWPC5	7	3	70.77	8.05	21.88	22.78	73.8
1	PHWPC5	10	1	71.49	6.86	22.89	23.89	73.31
1	PHWPC5	10	2	67.26	7.04	23.74	24.76	73.47
1	PHWPC5	10	3	73.48	6.02	20.93	21.78	73.95
1	PHWPC5	13	1	73.74	5.18	21	21.63	76.15
1	PHWPC5	13	2	69.44	7.39	20.02	21.34	69.73
1	PHWPC5	13	3	72.06	5.97	20.85	21.69	74.02
1	PHWPC10	1	1	72.84	4.43	21.55	22	78.38

1	PHWPC10	1	2	70.32	2.75	23.2	23.27	83.25
1	PHWPC10	1	3	72.85	3.14	21.13	21.36	81.53
1	PHWPC10	4	1	69.37	3.85	24.09	24.39	80.92
1	PHWPC10	4	2	72.55	3.82	22.02	22.35	80.16
1	PHWPC10	4	3	72.46	3.38	20.76	21.03	80.75
1	PHWPC10	7	1	75.34	6.3	16.92	18.06	69.59
1	PHWPC10	7	2	74.87	5.77	17.52	18.44	71.78
1	PHWPC10	7	3	70.57	4.25	20.36	20.8	78.22
1	PHWPC10	10	1	70.1	5.09	19.89	20.53	75.65
1	PHWPC10	10	2	71.64	6.64	22.08	23.06	73.26
1	PHWPC10	10	3	68.1	6.04	21.16	22.01	74.06
1	PHWPC10	13	1	72	5.45	18.6	19.39	73.66
1	PHWPC10	13	2	69.91	6.43	20.19	21.19	72.33
1	PHWPC10	13	3	70.39	7.16	19.7	20.96	70.01
2	control	1	1	72.6	4.43	23.69	24.1	79.4
2	control	1	2	73.94	3.12	21.29	21.52	81.65
2	control	1	3	71.71	3.65	20.82	21.14	80.07
2	control	4	1	68.85	4.45	23.44	23.86	79.26
2	control	4	2	73.12	2.97	21.65	21.85	82.19
2	control	4	3	69.91	3.77	21.69	22.01	80.15
2	control	4	4	69.95	3.57	23.83	24.1	81.47
2	control	4	5	71.36	4.3	22.28	22.69	79.08
2	control	4	6	67.93	4.85	26.18	26.62	79.49
2	control	7	1	68.43	5.41	23.86	24.46	77.23
2	control	7	2	73.6	2.94	22.57	22.76	82.58
2	control	7	3	72.82	2.83	23.19	23.36	83.04
2	control	7	4	72.2	3.73	24.23	24.52	81.24
2	control	7	5	68.38	5.75	22.68	23.4	75.79
2	control	7	6	71.27	4.72	23.25	23.72	78.53
2	control	10	1	65.44	5.1	23.96	24.5	77.99
2	control	10	2	71.5	3.22	23.61	23.82	82.23
2	control	10	3	69.21	4.81	25.46	25.91	79.31
2	control	10	4	70.14	4.14	26.3	26.62	81.06
2	control	10	5	70.46	3.5	28.97	29.18	83.12
2	control	10	6	71.02	4.01	25.58	25.89	81.09
2	control	13	1	71.1	4.72	22.11	22.61	77.94
2	control	13	2	71.31	3.71	21.66	21.98	80.29
2	control	13	3	68.29	5.27	25.36	25.9	78.25
2	control	13	4	74.59	3.57	22.83	23.11	81.12
2	control	13	5	68.51	5.54	24.49	25.11	77.26
2	control	13	6	68.96	4.57	23.56	24	79.02
2	WPC5	1	1	73.49	3.29	18.08	18.38	79.68
2	WPC5	1	2	79.41	3.43	18.08	18.4	79.26
2	WPC5	4	1	79.28	4.16	17.46	17.95	76.58
2	WPC5	4	2	77.36	4.47	18.39	18.93	76.32
2	WPC5	7	1	77.32	4.37	16.32	16.89	75.01
2	WPC5	7	2	74.21	5.89	19.49	20.36	73.2
2	WPC5	10	1	75.22	5.13	18.49	19.19	74.5

2	WPC5	10	2	76.04	4.87	19.21	19.82	75.77
2	WPC5	13	1	76.83	5.81	19.14	20	73.11
2	WPC5	13	2	76.8	5.47	18.43	19.22	73.46
2	WPC10	1	1	77.28	1.14	21.11	21.14	86.91
2	WPC10	1	2	71.93	2	22.73	22.82	84.97
2	WPC10	1	3	74.55	1.97	19.82	19.92	84.31
2	WPC10	4	1	75.59	1.69	19.09	19.16	84.93
2	WPC10	4	2	72.98	2.44	21.89	22.02	83.65
2	WPC10	4	3	74.69	2.57	19.61	19.77	82.53
2	WPC10	4	4	74.13	1.9	22.43	22.51	85.16
2	WPC10	4	5	76.21	2.72	20.08	20.26	82.29
2	WPC10	4	6	75.85	1.28	20.49	20.53	86.42
2	WPC10	7	1	77.34	1.32	20.32	20.37	86.28
2	WPC10	7	2	75.9	2.65	19.64	19.81	82.32
2	WPC10	7	3	75.26	2.16	19.08	19.2	83.53
2	WPC10	7	4	76.01	2.16	23.57	23.67	84.76
2	WPC10	7	5	76.72	1.86	18.85	18.94	84.36
2	WPC10	7	6	77.4	1.71	20.16	20.23	85.15
2	WPC10	10	1	74.87	3.38	17.2	17.53	78.87
2	WPC10	10	2	75.84	3.01	18.77	19.01	80.9
2	WPC10	10	3	74.35	2.79	18.72	18.93	81.53
2	WPC10	10	4	75.78	1.7	20.14	20.21	85.19
2	WPC10	10	5	74.57	2.3	20.98	21.11	83.75
2	WPC10	10	6	74.9	2.58	21.08	21.24	83.01
2	WPC10	13	1	76.11	2.57	18.86	19.03	82.23
2	WPC10	13	2	78.21	1.49	20.32	20.37	85.79
2	WPC10	13	3	70.86	4.39	21.18	21.63	78.28
2	WPC10	13	4	77.65	1.86	18.75	18.84	84.33
2	WPC10	13	5	72.41	3.13	19.78	20.03	81.01
2	WPC10	13	6	77.62	1.71	17.63	17.71	84.45
2	WPI5	1	1	76.25	0.78	20.48	20.5	87.81
2	WPI5	1	2	76.54	2.41	20.91	21.04	83.41
2	WPI5	1	3	77.08	1.82	20.23	20.31	84.86
2	WPI5	4	1	76.87	1.97	17.89	18	83.71
2	WPI5	4	2	74.59	1.54	20.02	20.08	85.59
2	WPI5	4	3	70.66	2.65	22.52	22.67	83.29
2	WPI5	4	4	75.05	2.67	19.24	19.43	82.11
2	WPI5	4	5	72.25	3.02	20.26	20.49	81.53
2	WPI5	4	6	69.23	3.13	22.34	22.55	82.03
2	WPI5	7	1	71.2	2.27	24.02	24.12	84.59
2	WPI5	7	2	75.09	2.69	20.88	21.05	82.66
2	WPI5	7	3	71.9	2.87	20.17	20.37	81.91
2	WPI5	7	4	75.41	2.32	21.08	21.2	83.71
2	WPI5	7	5	76.38	1.92	20.76	20.85	84.71
2	WPI5	7	6	75.81	2.93	20.96	21.17	82.04
2	WPI5	10	1	75.74	2.43	16.98	17.16	81.87
2	WPI5	10	2	72.81	3.01	19.35	19.58	81.16
2	WPI5	10	3	74.54	2.19	21.78	21.89	84.26

2	WPI5	10	4	71.95	2.81	21.44	21.62	82.53
2	WPI5	10	5	74.09	2.46	18.63	18.8	82.48
2	WPI5	10	6	74.13	2.49	20.08	20.23	82.93
2	WPI5	13	1	76.42	2.62	19.24	19.41	82.25
2	WPI5	13	2	76.28	3.2	20.28	20.53	81.04
2	WPI5	13	3	76.75	2.67	20.8	20.97	82.68
2	WPI5	13	4	76.64	2.16	18.38	18.5	83.29
2	WPI5	13	5	71.65	2.94	23.94	24.12	82.99
2	WPI5	13	6	77.57	2.01	20.86	20.95	84.5
2	WPI10	1	1	76.02	1.34	21.02	21.06	86.34
2	WPI10	1	2	75.17	0.25	22.01	22.01	89.34
2	WPI10	1	3	73.65	1.49	18.26	18.32	85.34
2	WPI10	4	1	75.04	1.8	18.21	18.3	84.35
2	WPI10	4	2	73.19	2.37	21.31	21.44	83.65
2	WPI10	4	3	74.6	2.03	20.08	20.18	84.22
2	WPI10	4	4	77.91	1.78	24.28	24.34	85.81
2	WPI10	4	5	72.92	1.96	21.33	21.41	84.75
2	WPI10	4	6	75.93	1.84	20.18	20.26	84.8
2	WPI10	7	1	77.21	0.94	18.35	18.38	87.06
2	WPI10	7	2	75.91	1.29	18.77	18.81	86.06
2	WPI10	7	3	79.85	1.08	21.21	21.24	87.08
2	WPI10	7	4	76.97	1.86	18.55	18.64	84.29
2	WPI10	7	5	69.86	3.71	19.74	20.09	79.35
2	WPI10	7	6	75.6	1.24	18.18	18.22	86.09
2	WPI10	10	1	74.87	2.13	18.3	18.42	83.37
2	WPI10	10	2	75.31	2.11	19.76	19.87	83.91
2	WPI10	10	3	76.51	2.03	17.71	17.83	83.46
2	WPI10	10	4	73.11	2.23	20.64	20.76	83.85
2	WPI10	10	5	75.44	1.45	18.03	18.09	85.42
2	WPI10	10	6	77.41	1.94	17.51	17.61	83.69
2	WPI10	13	1	77.24	1.54	17.04	17.1	84.94
2	WPI10	13	2	75.65	2.51	17.19	17.38	81.69
2	WPI10	13	3	76.86	2.26	18.45	18.59	83.01
2	WPI10	13	4	76.48	2.19	19.47	19.59	83.58
2	WPI10	13	5	71.61	3.2	18.28	18.56	80.06
2	WPI10	13	6	77.69	1.15	20.35	20.38	86.78
2	PHWPC5	1	1	72.9	2.48	18.89	19.05	82.52
2	PHWPC5	1	2	73.32	2.38	19.83	19.97	83.15
2	PHWPC5	1	3	72.48	2.12	21.05	21.15	84.26
2	PHWPC5	4	1	74.5	2.37	18.4	18.55	82.66
2	PHWPC5	4	2	74.11	2.75	20.49	20.68	82.37
2	PHWPC5	4	3	67.88	3.07	18.06	18.32	80.37
2	PHWPC5	4	4	73.71	2.59	19.11	19.29	82.28
2	PHWPC5	4	5	73.97	2.97	20.48	20.7	81.75
2	PHWPC5	4	6	73	2.36	22.09	22.22	83.91
2	PHWPC5	7	1	79.74	1.81	19.26	19.34	84.63
2	PHWPC5	7	2	76.44	2.9	20.28	20.49	81.86
2	PHWPC5	7	3	74.77	1.46	18.55	18.61	85.5

2	PHWPC5	7	4	77.28	4.76	20.39	20.47	85.08
2	PHWPC5	7	5	75.79	3.08	18.54	18.8	80.58
2	PHWPC5	7	6	76.85	2.68	18.45	18.65	81.74
2	PHWPC5	10	1	76.87	2.14	18.32	18.44	83.32
2	PHWPC5	10	2	72.63	4	21.06	21.44	79.24
2	PHWPC5	10	3	75.4	2.33	19.02	19.16	83.01
2	PHWPC5	10	4	73.43	2.75	19.9	20.09	82.13
2	PHWPC5	10	5	79.11	0.68	18.78	18.8	87.93
2	PHWPC5	10	6	71.63	3.64	17.88	18.25	78.48
2	PHWPC5	13	1	75.15	3.94	19.06	19.46	78.31
2	PHWPC5	13	2	77.67	2.28	16.69	16.84	82.22
2	PHWPC5	13	3	76.39	2.9	18.48	18.71	81.1
2	PHWPC5	13	4	77.22	3.36	18.12	18.42	79.5
2	PHWPC5	13	5	78.66	1.88	18.93	19.02	84.32
2	PHWPC5	13	6	77.96	2.41	18.67	18.82	82.63
2	PHWPC10	1	1	70.08	2.98	24.26	24.44	83.01
2	PHWPC10	1	2	72.44	3.28	23.16	23.39	81.94
2	PHWPC10	1	3	76.37	2.37	20.01	20.15	83.25
2	PHWPC10	4	1	77.16	2.84	19.65	19.85	81.78
2	PHWPC10	4	2	76.2	2.2	19.84	19.96	83.69
2	PHWPC10	4	3	71.43	3.98	21.31	21.68	79.41
2	PHWPC10	4	4	70.58	3.69	22.05	22.35	80.51
2	PHWPC10	4	5	76.22	2.74	20.39	20.57	82.34
2	PHWPC10	4	6	74.79	2.58	19.69	19.86	82.54
2	PHWPC10	7	1	76.31	2.86	19.96	20.16	87.86
2	PHWPC10	7	2	76.15	4.07	20.08	20.49	78.54
2	PHWPC10	7	3	72.35	4.75	22.21	22.71	77.93
2	PHWPC10	7	4	76.3	3.23	20.3	20.55	80.97
2	PHWPC10	7	5	77.43	3.1	19.03	19.28	80.76
2	PHWPC10	7	6	75.21	3.56	19.81	20.13	79.8
2	PHWPC10	10	1	74.88	4.49	20.82	21.3	77.84
2	PHWPC10	10	2	72.64	5.22	21.26	21.89	76.21
2	PHWPC10	10	3	75.82	2.88	20.29	20.49	81.93
2	PHWPC10	10	4	74.77	3.2	19.24	19.5	80.56
2	PHWPC10	10	5	74.5	3.46	20.62	20.9	80.49
2	PHWPC10	10	6	74.79	2.68	19.32	19.51	82.12
2	PHWPC10	13	1	74.35	5.27	19.39	20.09	74.79
2	PHWPC10	13	2	76.74	3.53	18.32	18.66	79.11
2	PHWPC10	13	3	77.14	5.37	20.03	20.74	74.99
2	PHWPC10	13	4	75.1	4.17	19.9	20.33	78.17
2	PHWPC10	13	5	75.45	4.25	19.49	19.95	77.69
2	PHWPC10	13	6	74.88	4.38	19.92	20.4	77.6

b. A Data Set for Microbial Growth on Coated Fresh-Cut Apples

Batch	Trt	Day	Rep	Ecoli	TPC
1	control		1	1	0
1	control		1	2	0
1	control		1	3	0
1	control		4	1	0
1	control		4	2	18
1	control		4	3	10
1	control		7	1	14
1	control		7	2	0
1	control		7	3	0
1	control		10	1	4
1	control		10	2	6
1	control		10	3	20
1	control		13	1	0
1	control		13	2	0
1	control		13	3	0
1	WPC5		1	1	0
1	WPC5		1	2	0
1	WPC5		1	3	0
1	WPC5		4	1	14
1	WPC5		4	2	22
1	WPC5		4	3	6
1	WPC5		7	1	10
1	WPC5		7	2	14
1	WPC5		7	3	6
1	WPC5		10	1	2
1	WPC5		10	2	8
1	WPC5		10	3	8
1	WPC5		13	1	0
1	WPC5		13	2	0
1	WPC5		13	3	0
1	WPC10		1	1	0
1	WPC10		1	2	0
1	WPC10		1	3	0
1	WPC10		4	1	0
1	WPC10		4	2	0
1	WPC10		4	3	4
1	WPC10		7	1	0
1	WPC10		7	2	2
1	WPC10		7	3	6
1	WPC10		10	1	0
1	WPC10		10	2	2
1	WPC10		10	3	0
1	WPC10		13	1	20
1	WPC10		13	2	1140
					1820
					200

1	WPC10	13	3	780	1240
1	WPI5	1	1	0	0
1	WPI5	1	2	0	0
1	WPI5	1	3	0	0
1	WPI5	4	1	0	0
1	WPI5	4	2	0	0
1	WPI5	4	3	0	6
1	WPI5	7	1	0	0
1	WPI5	7	2	0	14
1	WPI5	7	3	0	0
1	WPI5	10	1	0	12
1	WPI5	10	2	0	0
1	WPI5	10	3	0	0
1	WPI5	13	1	0	0
1	WPI5	13	2	0	0
1	WPI5	13	3	0	0
1	WPI10	1	1	0	0
1	WPI10	1	2	0	0
1	WPI10	1	3	0	0
1	WPI10	4	1	0	0
1	WPI10	4	2	0	12
1	WPI10	4	3	0	4
1	WPI10	7	1	0	8
1	WPI10	7	2	0	8
1	WPI10	7	3	0	0
1	WPI10	10	1	0	4
1	WPI10	10	2	0	0
1	WPI10	10	3	0	0
1	WPI10	13	1	0	0
1	WPI10	13	2	0	0
1	WPI10	13	3	0	0
1	PHWPC5	1	1	0	0
1	PHWPC5	1	2	0	0
1	PHWPC5	1	3	0	0
1	PHWPC5	4	1	0	8
1	PHWPC5	4	2	0	2
1	PHWPC5	4	3	0	2
1	PHWPC5	7	1	0	0
1	PHWPC5	7	2	0	0
1	PHWPC5	7	3	0	0
1	PHWPC5	10	1	0	4
1	PHWPC5	10	2	0	4
1	PHWPC5	10	3	0	0
1	PHWPC5	13	1	0	0
1	PHWPC5	13	2	0	0
1	PHWPC5	13	3	0	0
1	PHWPC10	1	1	0	0
1	PHWPC10	1	2	0	0

1	PHWPC10	1	3	0	0
1	PHWPC10	4	1	0	0
1	PHWPC10	4	2	0	12
1	PHWPC10	4	3	0	2
1	PHWPC10	7	1	0	0
1	PHWPC10	7	2	0	0
1	PHWPC10	7	3	0	0
1	PHWPC10	10	1	0	4
1	PHWPC10	10	2	0	0
1	PHWPC10	10	3	0	0
1	PHWPC10	13	1	0	0
1	PHWPC10	13	2	0	0
1	PHWPC10	13	3	140	116
2	control	1	1	0	0
2	control	1	2	0	0
2	control	1	3	0	0
2	control	4	1	0	0
2	control	4	2	2	0
2	control	4	3	0	0
2	control	7	1	0	0
2	control	7	2	0	0
2	control	7	3	0	0
2	control	10	1	0	0
2	control	10	2	0	0
2	control	10	3	0	0
2	control	13	1	0	0
2	control	13	2	0	0
2	control	13	3	0	0
2	WPC5	1	1	0	0
2	WPC5	1	2	0	2
2	WPC5	1	3	0	0
2	WPC5	4	1	0	0
2	WPC5	4	2	0	0
2	WPC5	4	3	0	0
2	WPC5	7	1	0	0
2	WPC5	7	2	0	0
2	WPC5	7	3	0	0
2	WPC5	10	1	0	0
2	WPC5	10	2	0	0
2	WPC5	10	3	0	0
2	WPC5	13	1	0	0
2	WPC5	13	2	0	0
2	WPC5	13	3	0	0
2	WPC10	1	1	0	0
2	WPC10	1	2	0	0
2	WPC10	1	3	0	0
2	WPC10	4	1	0	0
2	WPC10	4	2	0	0

2	WPC10	4	3	0	0
2	WPC10	7	1	0	0
2	WPC10	7	2	0	0
2	WPC10	7	3	0	0
2	WPC10	10	1	0	0
2	WPC10	10	2	0	0
2	WPC10	10	3	0	0
2	WPC10	13	1	0	0
2	WPC10	13	2	0	0
2	WPC10	13	3	0	0
2	WPI5	1	1	0	0
2	WPI5	1	2	0	2
2	WPI5	1	3	0	0
2	WPI5	4	1	0	0
2	WPI5	4	2	0	0
2	WPI5	4	3	0	0
2	WPI5	7	1	0	0
2	WPI5	7	2	0	0
2	WPI5	7	3	0	0
2	WPI5	10	1	0	0
2	WPI5	10	2	0	0
2	WPI5	10	3	0	0
2	WPI5	13	1	0	0
2	WPI5	13	2	0	0
2	WPI5	13	3	0	0
2	WPI10	1	1	0	0
2	WPI10	1	2	0	0
2	WPI10	1	3	0	0
2	WPI10	4	1	0	0
2	WPI10	4	2	0	0
2	WPI10	4	3	0	0
2	WPI10	7	1	0	0
2	WPI10	7	2	0	0
2	WPI10	7	3	0	0
2	WPI10	10	1	0	0
2	WPI10	10	2	0	0
2	WPI10	10	3	0	0
2	WPI10	13	1	0	0
2	WPI10	13	2	0	0
2	WPI10	13	3	0	0
2	PHWPC5	1	1	0	4
2	PHWPC5	1	2	0	6
2	PHWPC5	1	3	0	4
2	PHWPC5	4	1	0	0
2	PHWPC5	4	2	0	0
2	PHWPC5	4	3	0	0
2	PHWPC5	7	1	0	0
2	PHWPC5	7	2	0	0

2	PHWPC5	7	3	0	2
2	PHWPC5	10	1	0	0
2	PHWPC5	10	2	0	0
2	PHWPC5	10	3	0	0
2	PHWPC5	13	1	0	0
2	PHWPC5	13	2	0	0
2	PHWPC5	13	3	0	0
2	PHWPC10	1	1	0	0
2	PHWPC10	1	2	0	0
2	PHWPC10	1	3	0	0
2	PHWPC10	4	1	0	0
2	PHWPC10	4	2	0	0
2	PHWPC10	4	3	0	0
2	PHWPC10	7	1	0	0
2	PHWPC10	7	2	0	0
2	PHWPC10	7	3	0	0
2	PHWPC10	10	1	0	0
2	PHWPC10	10	2	0	0
2	PHWPC10	10	3	0	0
2	PHWPC10	13	1	0	0
2	PHWPC10	13	2	0	0
2	PHWPC10	13	3	0	0

c. A Data Set for Firmness Values of Coated Fresh-Cut Apples

Batch	Trt	Day	Rep	Force
1	control		1	4.231
1	control		2	3.509
1	control		3	3.723
1	control		4	3.573
1	control	4	1	2.592
1	control	4	2	2.041
1	control	4	3	1.891
1	control	4	4	1.715
1	control	7	1	2.314
1	control	7	2	4.029
1	control	7	3	3.292
1	control	7	4	2.929
1	control	10	1	4.897
1	control	10	2	2.346
1	control	10	3	3.099
1	control	10	4	2.33
1	control	13	1	2.178
1	control	13	2	2.175
1	control	13	3	1.889
1	control	13	4	1.835
1	WPC5	1	1	2.301
1	WPC5	1	2	2.553
1	WPC5	1	3	3.635
1	WPC5	1	4	3.248
1	WPC5	4	1	3.226
1	WPC5	4	2	3.907
1	WPC5	4	3	4.154
1	WPC5	4	4	2.988
1	WPC5	7	1	2.566
1	WPC5	7	2	2.954
1	WPC5	7	3	2.912
1	WPC5	7	4	2.342
1	WPC5	10	1	3.434
1	WPC5	10	2	2.49
1	WPC5	10	3	2.345
1	WPC5	10	4	2.998
1	WPC5	13	1	2.178
1	WPC5	13	2	2.175
1	WPC5	13	3	1.889
1	WPC5	13	4	1.835
1	WPC10	1	1	2.482
1	WPC10	1	2	2.938
1	WPC10	1	3	2.015
1	WPC10	1	4	2.235

1	WPC10	4	1	3.189
1	WPC10	4	2	2.881
1	WPC10	4	3	3.662
1	WPC10	4	4	3.789
1	WPC10	7	1	2.781
1	WPC10	7	2	4.205
1	WPC10	7	3	2.927
1	WPC10	7	4	3.328
1	WPC10	10	1	4.658
1	WPC10	10	2	2.714
1	WPC10	10	3	2.761
1	WPC10	10	4	2.218
1	WPC10	13	1	3.028
1	WPC10	13	2	3.622
1	WPC10	13	3	2.596
1	WPC10	13	4	4.248
1	WPI5	1	1	3.732
1	WPI5	1	2	2.831
1	WPI5	1	3	2.007
1	WPI5	1	4	2.628
1	WPI5	4	1	2.23
1	WPI5	4	2	1.574
1	WPI5	4	3	1.889
1	WPI5	4	4	3.35
1	WPI5	7	1	3.181
1	WPI5	7	2	3.62
1	WPI5	7	3	2.634
1	WPI5	7	4	1.953
1	WPI5	10	1	2.681
1	WPI5	10	2	3.122
1	WPI5	10	3	3.452
1	WPI5	10	4	4.083
1	WPI5	13	1	2.977
1	WPI5	13	2	2.65
1	WPI5	13	3	2.522
1	WPI5	13	4	2.577
1	WPI10	1	1	3.797
1	WPI10	1	2	3.372
1	WPI10	1	3	4.077
1	WPI10	1	4	2.448
1	WPI10	4	1	2.938
1	WPI10	4	2	2.994
1	WPI10	4	3	2.344
1	WPI10	4	4	3.077
1	WPI10	7	1	2.777
1	WPI10	7	2	2.239
1	WPI10	7	3	2.951
1	WPI10	10	1	3.278

1	WPI10	10	2	3.162
1	WPI10	10	3	3.519
1	WPI10	10	4	4.337
1	WPI10	13	1	3.909
1	WPI10	13	2	2.774
1	WPI10	13	3	3.502
1	WPI10	13	4	5.072
1	PHWPC5	1	1	2.619
1	PHWPC5	1	2	2.189
1	PHWPC5	1	3	2.604
1	PHWPC5	1	4	2.758
1	PHWPC5	4	1	4.363
1	PHWPC5	4	2	2.91
1	PHWPC5	4	3	2.4
1	PHWPC5	4	4	2.846
1	PHWPC5	7	1	3.846
1	PHWPC5	7	2	2.552
1	PHWPC5	7	3	2.497
1	PHWPC5	7	4	2.573
1	PHWPC5	10	1	3.066
1	PHWPC5	10	2	2.807
1	PHWPC5	10	3	3.667
1	PHWPC5	10	4	2.471
1	PHWPC5	13	1	4.077
1	PHWPC5	13	2	2.493
1	PHWPC5	13	3	4.322
1	PHWPC5	13	4	2.002
1	PHWPC10	1	1	2.215
1	PHWPC10	1	2	2.41
1	PHWPC10	1	3	1.981
1	PHWPC10	1	4	2.205
1	PHWPC10	4	1	3.265
1	PHWPC10	4	2	4.659
1	PHWPC10	4	3	3.308
1	PHWPC10	4	4	3.501
1	PHWPC10	7	1	2.796
1	PHWPC10	7	2	2.48
1	PHWPC10	7	3	2.801
1	PHWPC10	7	4	2.232
1	PHWPC10	10	1	3.224
1	PHWPC10	10	2	3.323
1	PHWPC10	10	3	3.382
1	PHWPC10	10	4	2.123
1	PHWPC10	13	1	3.031
1	PHWPC10	13	2	2.834
1	PHWPC10	13	3	3.701
1	PHWPC10	13	4	2.71
2	control	1	1	3.554

2	control	1	2	3.177
2	control	1	3	3.293
2	control	1	4	3.574
2	control	4	1	3.216
2	control	4	2	3.551
2	control	4	3	3.358
2	control	7	1	2.403
2	control	7	2	3.102
2	control	7	3	2.664
2	control	10	1	3.141
2	control	10	2	2.477
2	control	10	3	2.66
2	control	13	1	2.174
2	control	13	2	2.601
2	control	13	3	1.722
2	WPC5	1	1	3.203
2	WPC5	1	2	3.058
2	WPC5	1	3	3.995
2	WPC5	1	4	3.635
2	WPC5	4	1	3.867
2	WPC5	4	2	3.484
2	WPC5	4	3	3.897
2	WPC5	7	1	2.768
2	WPC5	7	2	4.149
2	WPC5	7	3	3.556
2	WPC5	10	1	3.343
2	WPC5	10	2	2.202
2	WPC5	10	3	3.256
2	WPC5	13	1	4.717
2	WPC5	13	2	3.542
2	WPC5	13	3	4.856
2	WPC10	1	1	2.61
2	WPC10	1	2	2.959
2	WPC10	1	3	2.365
2	WPC10	1	4	2.243
2	WPC10	4	1	4.227
2	WPC10	4	2	3.001
2	WPC10	4	3	2.602
2	WPC10	7	1	3.354
2	WPC10	7	2	2.774
2	WPC10	7	3	2.353
2	WPC10	10	1	4.083
2	WPC10	10	2	2.3
2	WPC10	10	3	3.171
2	WPC10	13	1	3.325
2	WPC10	13	2	2.627
2	WPC10	13	3	2.697
2	WPI5	1	1	4.044

2	WPI5	1	2	3.428
2	WPI5	1	3	3.457
2	WPI5	1	4	3.534
2	WPI5	4	1	4.785
2	WPI5	4	2	2.533
2	WPI5	4	3	3.237
2	WPI5	7	1	3.019
2	WPI5	7	2	2.812
2	WPI5	7	3	2.52
2	WPI5	10	1	2.873
2	WPI5	10	2	2.665
2	WPI5	10	3	3.112
2	WPI5	13	1	3.307
2	WPI5	13	2	3.02
2	WPI5	13	3	3.411
2	WPI10	1	1	3.004
2	WPI10	1	2	2.298
2	WPI10	1	3	3.081
2	WPI10	1	4	3.932
2	WPI10	4	1	3.978
2	WPI10	4	2	3.576
2	WPI10	4	3	2.987
2	WPI10	7	1	4.155
2	WPI10	7	2	2.945
2	WPI10	7	3	3.093
2	WPI10	10	1	3.064
2	WPI10	10	2	2.314
2	WPI10	10	3	3.039
2	WPI10	13	1	4.132
2	WPI10	13	2	3.731
2	WPI10	13	3	2.998
2	PHWPC5	1	1	3.973
2	PHWPC5	1	2	3.099
2	PHWPC5	1	3	2.396
2	PHWPC5	1	4	3.219
2	PHWPC5	4	1	2.913
2	PHWPC5	4	2	3.146
2	PHWPC5	4	3	3.181
2	PHWPC5	7	1	2.36
2	PHWPC5	7	2	3.105
2	PHWPC5	7	3	3.542
2	PHWPC5	10	1	1.817
2	PHWPC5	10	2	2.784
2	PHWPC5	10	3	1.688
2	PHWPC5	13	1	3.075
2	PHWPC5	13	2	2.561
2	PHWPC5	13	3	2.192
2	PHWPC10	1	1	2.322

2	PHWPC10	1	2	2.41
2	PHWPC10	1	3	2.884
2	PHWPC10	1	4	2.797
2	PHWPC10	4	1	2.987
2	PHWPC10	4	2	3.263
2	PHWPC10	4	3	3.343
2	PHWPC10	4	4	4.126
2	PHWPC10	7	1	2.132
2	PHWPC10	7	2	2.475
2	PHWPC10	7	3	4.377
2	PHWPC10	7	4	3.376
2	PHWPC10	10	1	4.031
2	PHWPC10	10	2	3.085
2	PHWPC10	10	3	1.908
2	PHWPC10	10	4	2.648
2	PHWPC10	13	1	3.822
2	PHWPC10	13	2	2.334
2	PHWPC10	13	3	4.211
2	PHWPC10	13	4	2.644

d. A Data Set for Weight Loss of Coated Fresh-Cut Apples

Batch	Trt	Day	Rep	%wt loss
1	control		4	1 0.1111
1	control		4	2 -0.252
1	control		4	3 1.2145
1	control		4	4 1.7471
1	control		4	5 0.6687
1	control		4	6 1.8135
1	control		7	1 -0.252
1	control		7	2 0.2521
1	control		7	3 1.5259
1	control		7	4 3.1198
1	control		7	5 1.0742
1	control		7	6 3.5513
1	control		10	1 0.2521
1	control		10	2 0.6894
1	control		10	3 1.2534
1	control		10	4 4.9627
1	control		10	5 1.671
1	control		10	6 4.9059
1	control		13	1 0.6894
1	control		13	2 1.2534
1	control		13	3 4.9627
1	control		13	4 1.671
1	control		13	5 4.9059
1	control		13	6 1.3612
1	WPC5		4	1 0.6524
1	WPC5		4	2 0.2587
1	WPC5		4	3 1.0967
1	WPC5		4	4 0.1847
1	WPC5		4	5 0.7647
1	WPC5		4	6 2.4066
1	WPC5		7	1 0.7183
1	WPC5		7	2 0.2846
1	WPC5		7	3 1.8708
1	WPC5		7	4 0.1076
1	WPC5		7	5 0.357
1	WPC5		7	6 1.9528
1	WPC5		10	1 1.1731
1	WPC5		10	2 1.0704
1	WPC5		10	3 3.2743
1	WPC5		10	4 0.4417
1	WPC5		10	5 0.732
1	WPC5		10	6 1.9242
1	WPC5		13	1 1.6327
1	WPC5		13	2 1.6622

1	WPC5	13	3	4.7848
1	WPC5	13	4	0.9011
1	WPC5	13	5	1.0922
1	WPC5	13	6	1.9135
1	WPC10	4	1	1.373
1	WPC10	4	2	0.984
1	WPC10	4	3	0.2124
1	WPC10	4	4	0.2972
1	WPC10	4	5	2.1757
1	WPC10	4	6	2.0752
1	WPC10	7	1	0.9253
1	WPC10	7	2	1.0474
1	WPC10	7	3	-0.036
1	WPC10	7	4	0.4216
1	WPC10	7	5	1.2639
1	WPC10	7	6	1.489
1	WPC10	10	1	0.4003
1	WPC10	10	2	1.4176
1	WPC10	10	3	-0.277
1	WPC10	10	4	1.2261
1	WPC10	10	5	0.876
1	WPC10	10	6	1.5656
1	WPC10	13	1	0.3125
1	WPC10	13	2	1.8357
1	WPC10	13	3	-0.16
1	WPC10	13	4	2.7066
1	WPC10	13	5	0.939
1	WPC10	13	6	1.8823
1	WPI5	4	1	0.9543
1	WPI5	4	2	0.5487
1	WPI5	4	3	0.4665
1	WPI5	4	4	1.9174
1	WPI5	4	5	1.3643
1	WPI5	7	1	0.8665
1	WPI5	7	2	0.4205
1	WPI5	7	3	0.2391
1	WPI5	7	4	1.6224
1	WPI5	7	5	0.62
1	WPI5	10	1	2.011
1	WPI5	10	2	0.6538
1	WPI5	10	3	0.5442
1	WPI5	10	4	2.7685
1	WPI5	10	5	0.5499
1	WPI5	13	1	2.9263
1	WPI5	13	2	1.0513
1	WPI5	13	3	0.971
1	WPI5	13	4	3.8212
1	WPI5	13	5	0.7714

1	WPI10	4	1	1.0022
1	WPI10	4	2	0.2581
1	WPI10	4	3	0.0695
1	WPI10	4	4	-0.028
1	WPI10	4	5	0.2377
1	WPI10	4	6	0.5235
1	WPI10	7	1	1.5012
1	WPI10	7	2	0.5476
1	WPI10	7	3	0.5807
1	WPI10	7	4	0.382
1	WPI10	7	5	1.2439
1	WPI10	7	6	1.6775
1	WPI10	10	1	1.3332
1	WPI10	10	2	0.7873
1	WPI10	10	3	0.4694
1	WPI10	10	4	0.1718
1	WPI10	10	5	2.5577
1	WPI10	10	6	2.5462
1	WPI10	13	1	1.6218
1	WPI10	13	2	2.4058
1	WPI10	13	3	0.9698
1	WPI10	13	4	0.3696
1	WPI10	13	5	3.9459
1	WPI10	13	6	3.4443
1	PHWPC5	4	1	1.0022
1	PHWPC5	4	2	-0.25
1	PHWPC5	4	3	0.3071
1	PHWPC5	4	4	-0.392
1	PHWPC5	4	5	-0.315
1	PHWPC5	4	6	0.0202
1	PHWPC5	7	1	0.9764
1	PHWPC5	7	2	0.1984
1	PHWPC5	7	3	0.9383
1	PHWPC5	7	4	1.4341
1	PHWPC5	7	5	0.839
1	PHWPC5	7	6	0.1561
1	PHWPC5	10	1	1.0022
1	PHWPC5	10	2	0.1917
1	PHWPC5	10	3	2.117
1	PHWPC5	10	4	1.0232
1	PHWPC5	10	5	0.6469
1	PHWPC5	10	6	0.1745
1	PHWPC5	13	1	1.2456
1	PHWPC5	13	2	1.3092
1	PHWPC5	13	3	3.1431
1	PHWPC5	13	4	1.9541
1	PHWPC5	13	5	1.2495
1	PHWPC5	13	6	0.9145

1	PHWPC10	4	1	0.0842
1	PHWPC10	4	2	-0.208
1	PHWPC10	4	3	-0.145
1	PHWPC10	4	4	0.4738
1	PHWPC10	4	5	-0.182
1	PHWPC10	7	1	0.2718
1	PHWPC10	7	2	0.1879
1	PHWPC10	7	3	0.28
1	PHWPC10	7	4	2.3226
1	PHWPC10	7	5	0.9085
1	PHWPC10	10	1	0.5933
1	PHWPC10	10	2	0.4837
1	PHWPC10	10	3	0.5649
1	PHWPC10	10	4	2.111
1	PHWPC10	10	5	0.9729
1	PHWPC10	13	1	0.7051
1	PHWPC10	13	2	2.6713
1	PHWPC10	13	3	2.016
1	PHWPC10	13	4	3.7379
1	PHWPC10	13	5	1.9152
2	control	4	1	1.3256
2	control	4	2	1.5752
2	control	4	3	1.8267
2	control	4	4	2.0754
2	control	4	5	0.7043
2	control	7	1	0.8767
2	control	7	2	1.4087
2	control	7	3	1.7879
2	control	7	4	2.0011
2	control	7	5	1.1483
2	control	10	1	1.5455
2	control	10	2	1.7615
2	control	10	3	2.8568
2	control	10	4	2.1496
2	control	10	5	1.9522
2	control	13	1	1.5018
2	control	13	2	1.7589
2	control	13	3	3.8409
2	control	13	4	3.084
2	control	13	5	2.6884
2	WPC5	4	1	1.4249
2	WPC5	4	2	1.7598
2	WPC5	4	3	0.6395
2	WPC5	4	4	0.8824
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2	WPC5	7	2	1.6637
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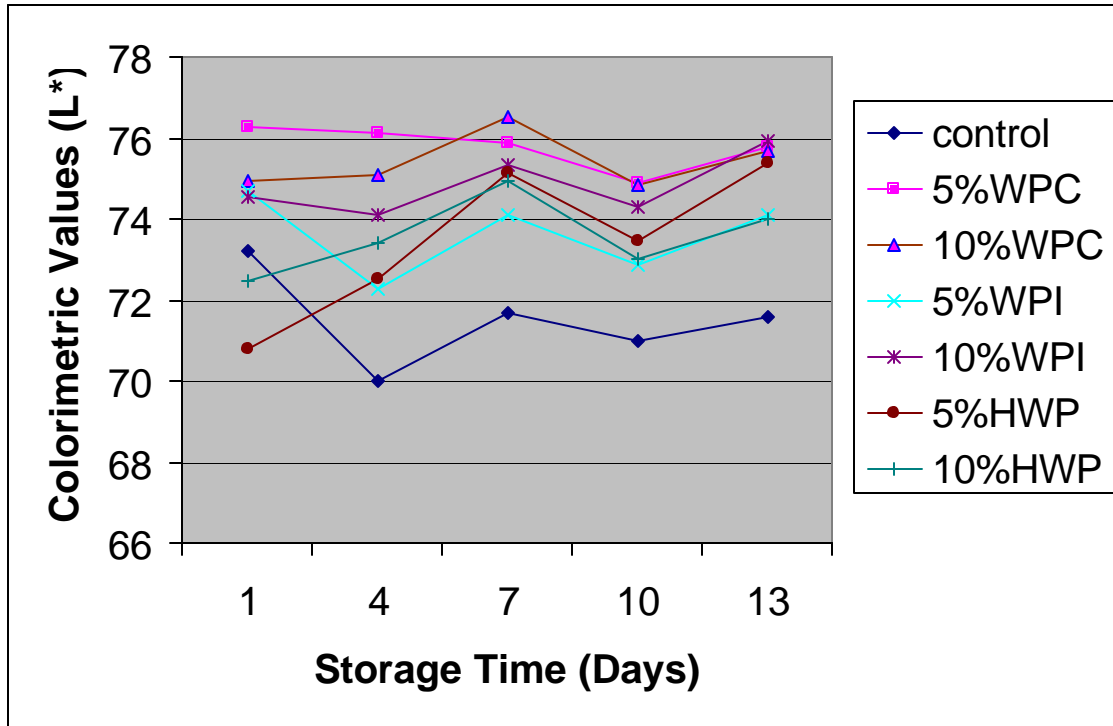
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2	WPC5	7	5	1.498
2	WPC5	10	1	2.8635
2	WPC5	10	2	2.1
2	WPC5	10	3	1.4848
2	WPC5	10	4	1.7052
2	WPC5	10	5	1.8161
2	WPC5	13	1	3.4955
2	WPC5	13	2	2.7462
2	WPC5	13	3	1.9713
2	WPC5	13	4	2.6522
2	WPC5	13	5	2.0804
2	WPC10	4	1	1.2461
2	WPC10	4	2	1.6362
2	WPC10	4	3	0.5724
2	WPC10	4	4	1.6875
2	WPC10	4	5	1.3606
2	WPC10	7	1	1.995
2	WPC10	7	2	1.824
2	WPC10	7	3	0.4016
2	WPC10	7	4	2.463
2	WPC10	7	5	1.1341
2	WPC10	10	1	1.7911
2	WPC10	10	2	2.7871
2	WPC10	10	3	0.1877
2	WPC10	10	4	2.73
2	WPC10	10	5	1.7129
2	WPC10	13	1	1.866
2	WPC10	13	2	4.6126
2	WPC10	13	3	0.657
2	WPC10	13	4	3.3795
2	WPC10	13	5	2.0551
2	WPI5	4	1	0.622
2	WPI5	4	2	1.6519
2	WPI5	4	3	0.7291
2	WPI5	4	4	0.7411
2	WPI5	4	5	1.2247
2	WPI5	7	1	1.409
2	WPI5	7	2	1.6614
2	WPI5	7	3	2.162
2	WPI5	7	4	0.9456
2	WPI5	7	5	1.3178
2	WPI5	10	1	2.3412
2	WPI5	10	2	1.988
2	WPI5	10	3	2.1147
2	WPI5	10	4	0.678
2	WPI5	10	5	2.2122
2	WPI5	13	1	3.7702

2	WPI5	13	2	2.0197
2	WPI5	13	3	3.049
2	WPI5	13	4	0.718
2	WPI5	13	5	2.4341
2	WPI10	4	1	0.6537
2	WPI10	4	2	0.8399
2	WPI10	4	3	0.5078
2	WPI10	4	4	1.0656
2	WPI10	4	5	1.3613
2	WPI10	7	1	1.0901
2	WPI10	7	2	1.6225
2	WPI10	7	3	1.14
2	WPI10	7	4	1.2675
2	WPI10	7	5	1.9759
2	WPI10	10	1	0.8844
2	WPI10	10	2	2.408
2	WPI10	10	3	1.18
2	WPI10	10	4	1.8861
2	WPI10	10	5	2.4444
2	PHWPC5	13	1	0.9507
2	PHWPC5	13	2	3.3273
2	PHWPC5	13	3	1.1859
2	PHWPC5	13	4	1.754
2	PHWPC5	13	5	3.4234
2	PHWPC5	4	1	0.2839
2	PHWPC5	4	2	0.8399
2	PHWPC5	4	3	0.1126
2	PHWPC5	4	4	0.2202
2	PHWPC5	4	5	0.9253
2	PHWPC5	7	1	1.615
2	PHWPC5	7	2	2.3298
2	PHWPC5	7	3	2.0217
2	PHWPC5	7	4	1.5416
2	PHWPC5	7	5	2.7758
2	PHWPC5	10	1	1.5854
2	PHWPC5	10	2	2.1489
2	PHWPC5	10	3	1.9123
2	PHWPC5	10	4	2.1412
2	PHWPC5	10	5	2.314
2	PHWPC5	13	1	1.9826
2	PHWPC5	13	2	2.8581
2	PHWPC5	13	3	2.0436
2	PHWPC5	13	4	2.0383
2	PHWPC5	13	5	2.809
2	PHWPC10	4	1	0.3804
2	PHWPC10	4	2	-0.39
2	PHWPC10	4	3	0.1369
2	PHWPC10	4	4	0.2698

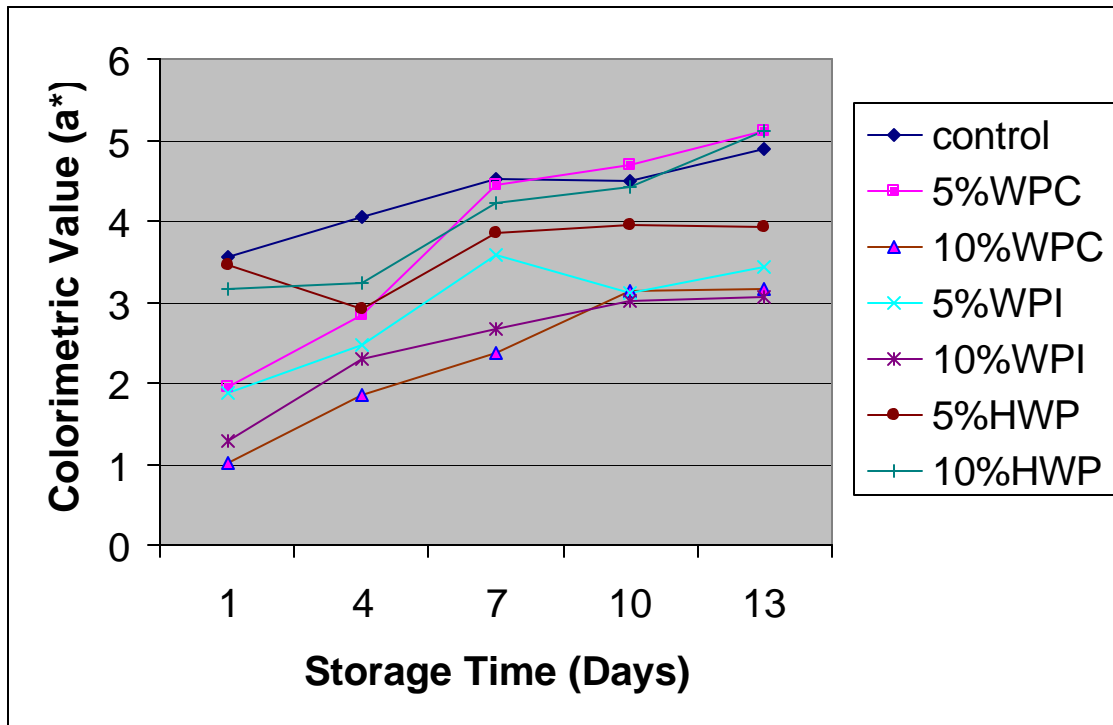
2	PHWPC10	4	5	0.4582
2	PHWPC10	7	1	0.8189
2	PHWPC10	7	2	-0.01
2	PHWPC10	7	3	1.3739
2	PHWPC10	7	4	1.5336
2	PHWPC10	7	5	1.486
2	PHWPC10	10	1	0.7645
2	PHWPC10	10	2	-0.044
2	PHWPC10	10	3	1.5753
2	PHWPC10	10	4	1.4189
2	PHWPC10	10	5	2.3235
2	PHWPC10	13	1	1.5178
2	PHWPC10	13	2	0.2348
2	PHWPC10	13	3	2.6303
2	PHWPC10	13	4	1.85
2	PHWPC10	13	5	3.3606

## **APPENDIX. D. GRAPHS FOR THE SECOND STUDY**

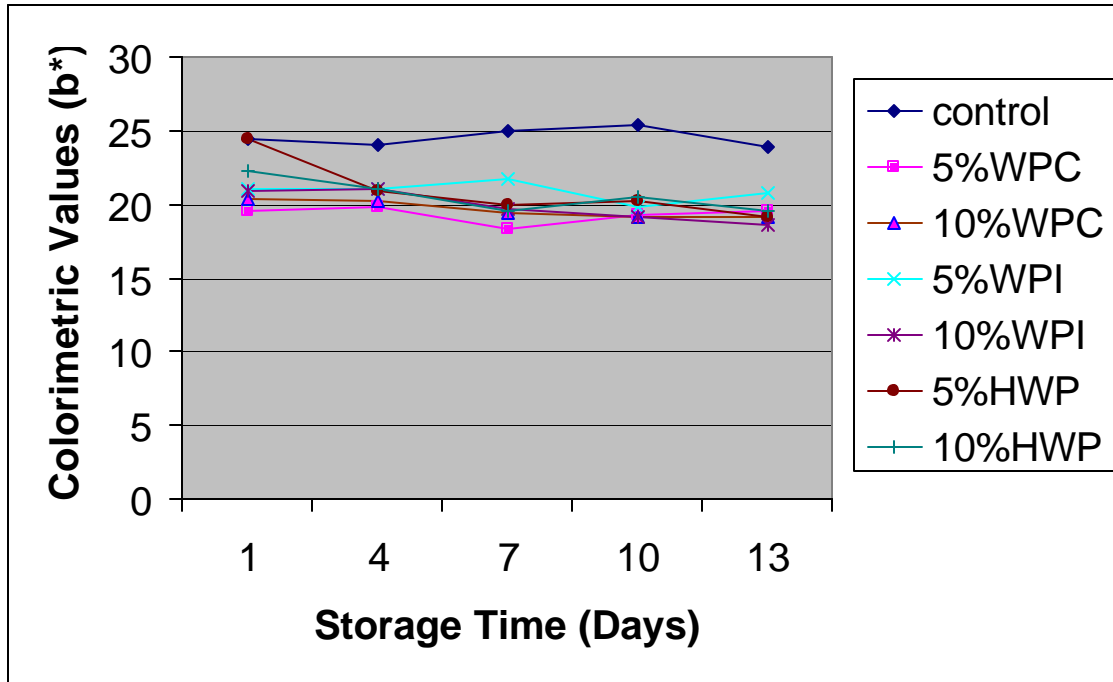
a. Effect of Treatments on the L\* Values of the Fresh-cut Apples



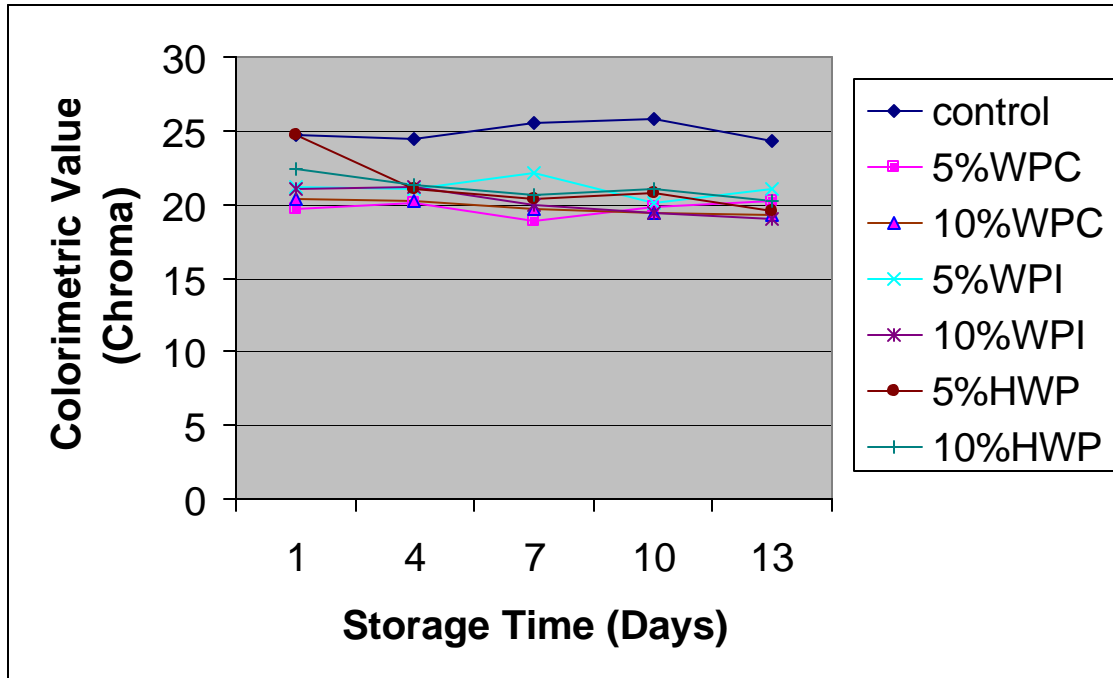
b. Effect of Treatments on the a\* Values of the Fresh-cut Apples



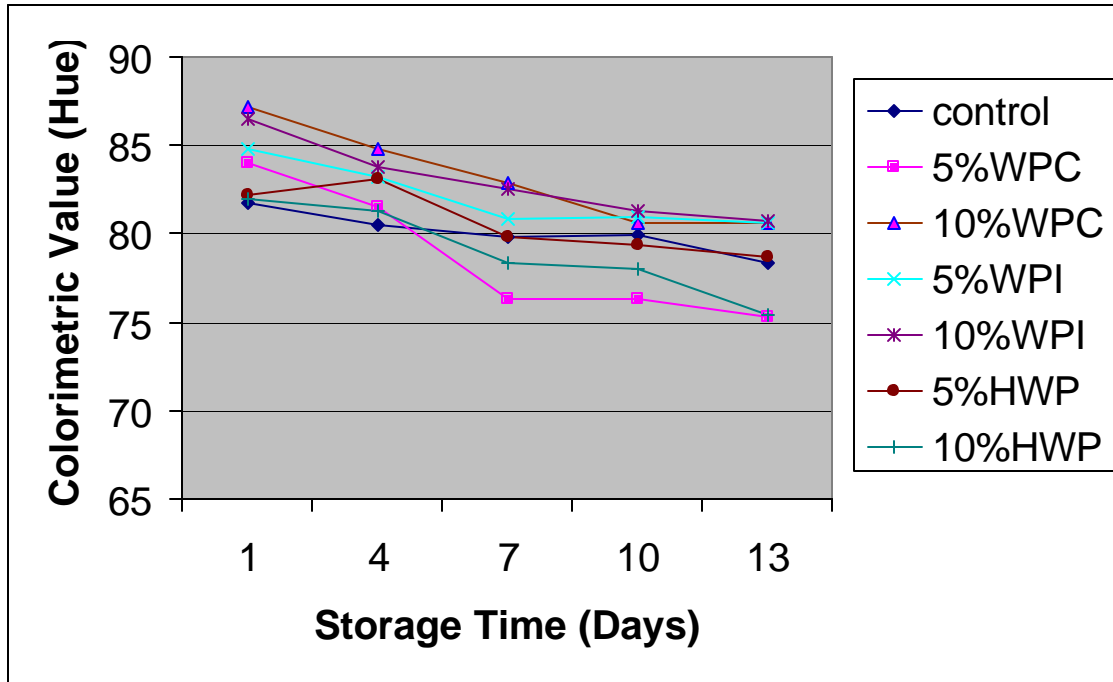
c. Effect of Treatments on the b\* Values of the Fresh-cut Apples



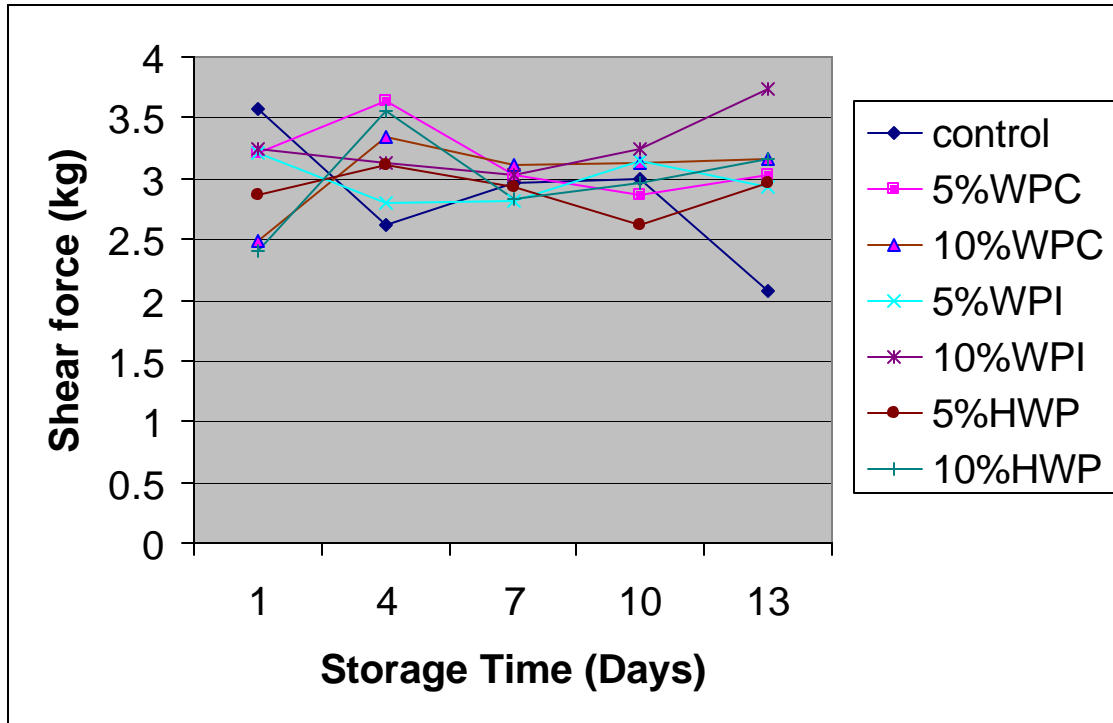
d. Effect of Treatments on the Chroma Values of the Fresh-cut Apples



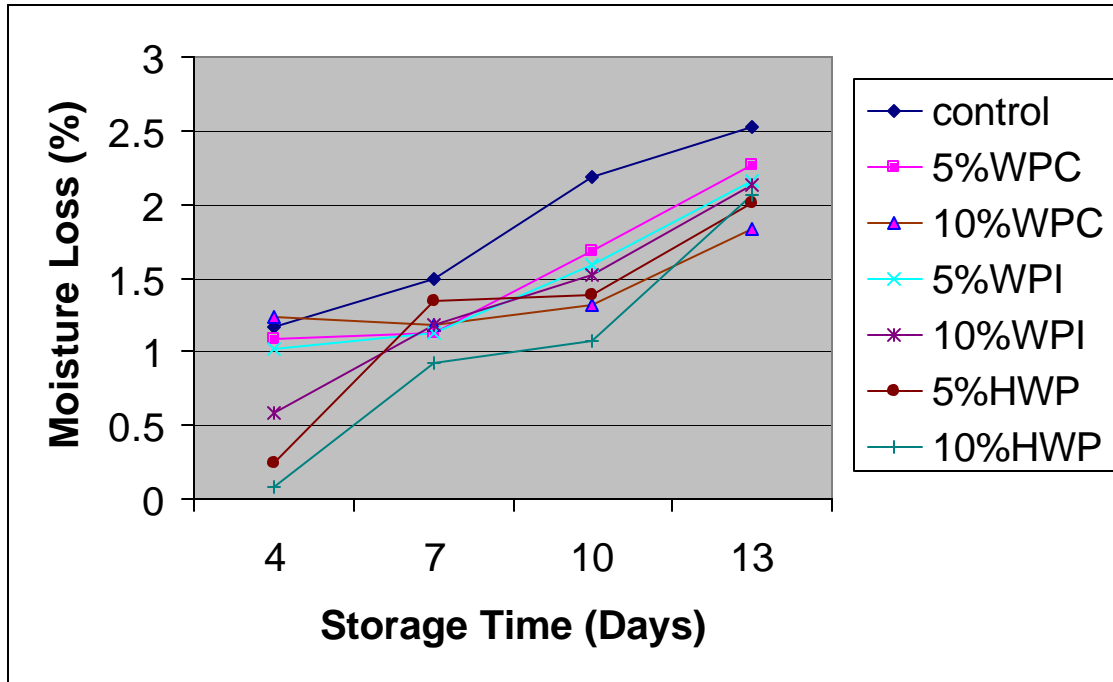
e. Effect of Treatments on the Hue Angle Values of the Fresh-cut Apples



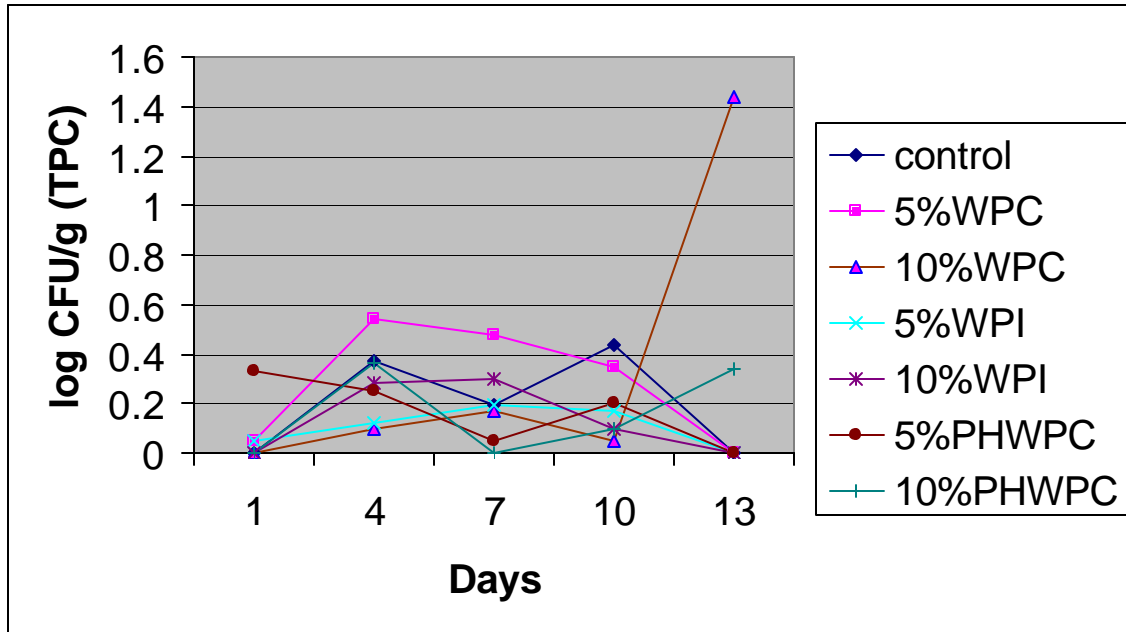
f. Effect of Treatments on the Weight Loss of the Fresh-cut Apples



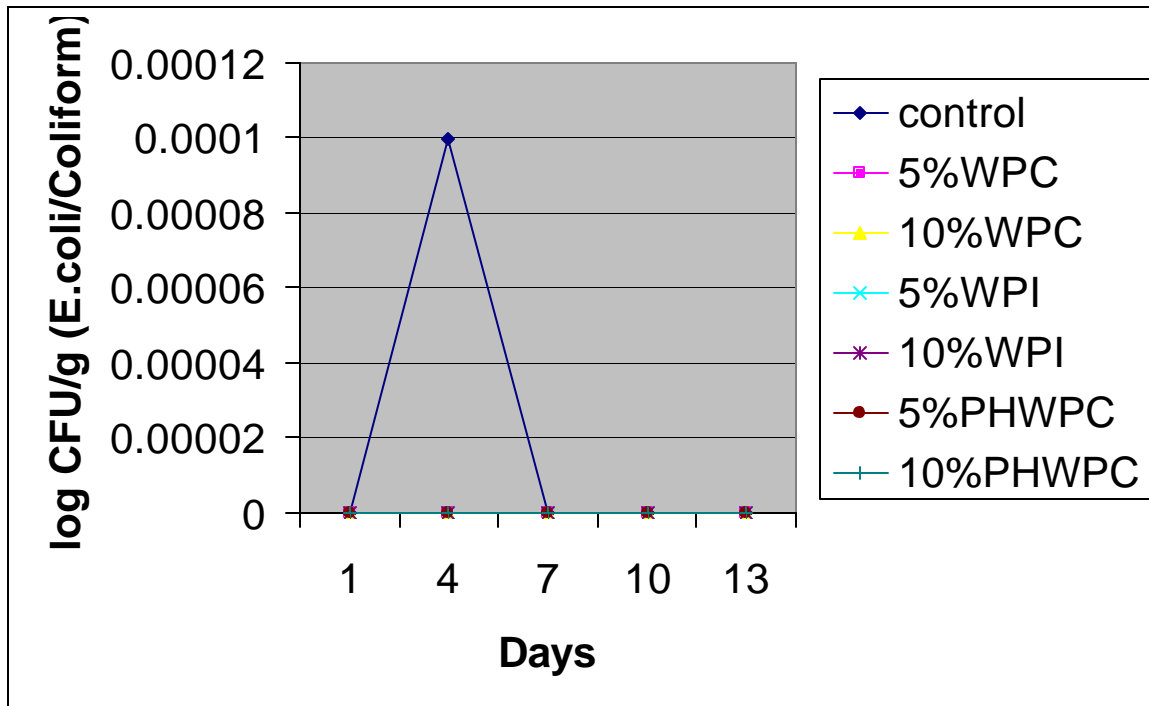
g. Effect of Treatments on the Firmness Loss of the Fresh-cut Apples



h. Effect of Treatments on the Total Plate Count of the Fresh-cut Apples



i. Effect of Treatments on the E.coli/ Coliform Counts of the Fresh-cut Apples



## **APPENDIX E. EXPERIMENTAL DESIGN**

	Control				5%WPC				10%WPC				5%WPI				10%WPI				5%PHWPC				10%PHWPC							
	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	A21	A22	A23	A24	A25	A26	A27	A28				
	Mo	T	C	Mi	Mo	T	C	Mi	Mo	T	C	Mi	Mo	T	C	Mi	Mo	T	C	Mi	Mo	T	C	Mi	Mo	T	C	Mi				
<b>1</b>	5*	4	3	3	5	4	3	3	5	4	3	3	5	4	3	3	5	4	3	3	5	4	3	3	5	4	3	3	5	4	3	3
<b>4</b>	5	4	3	3	5	4	3	3	5	4	3	3	5	4	3	3	5	4	3	3	5	4	3	3	5	4	3	3	5	4	3	3
<b>7</b>	5	4	3	3	5	4	3	3	5	4	3	3	5	4	3	3	5	4	3	3	5	4	3	3	5	4	3	3	5	4	3	3
<b>10</b>	5	4	3	3	5	4	3	3	5	4	3	3	5	4	3	3	5	4	3	3	5	4	3	3	5	4	3	3	5	4	3	3
<b>13</b>	5	4	3	3	5	4	3	3	5	4	3	3	5	4	3	3	5	4	3	3	5	4	3	3	5	4	3	3	5	4	3	3

- WPC - Whey Protein Concentrate
- WPI - Whey Protein Isolate
- PHWPC - Partially Hydrolyzed Whey Protein Concentrate
- A1-A28 - Apple (A total of 28 apples were used for each experimental batch; two batches were conducted)
- Mo - Moisture analysis
- T - Texture analysis
- C - Color analysis
- Mi - Microbial analysis

\* The numbers (3, 4 and 5) indicate replications for each analysis.

## **VITA**

Sirisha Sonti was born on July 20, 1979, in Hyderabad, Andhra Pradesh, India. She graduated from Osmania University College of Technology, Hyderabad, with a Bachelor of Science degree in food processing and preservation technology. Upon receiving her bachelor's degree she joined the graduate school at Louisiana State University Agricultural and Mechanical College in the Department of Food Science in Fall 2000. She is a candidate for the degree of Master of Science in food science in Spring 2003. After receiving that degree she will continue doctoral study in food science at the University of Illinois.