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COLD STORAGE SHELF-LIFE EXTENSION OF MICHIGAN CULTIVATED APPLES USING THE SUCROSE ESTER, SEMPERFRESH™

By

Yen-Ling Chai

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ABSTRACT

COLD STORAGE SHELF-LIFE EXTENSION OF MICHIGAN CULTIVATED APPLES USING THE SUCROSE ESTER, SEMPERFRESH™

By

Yen-Ling Chai

Golden Delicious, Ida Red and McIntosh apples were treated with the sucrose ester, Semperfresh™, to determine its influence on fruit maturity parameters, assess its value to delay ripening and to improve shelf life during noncontrolled atmosphere cold storage. Fruit quality objective and sensory measurements included: Hunter color difference, Magness-Taylor texture, Kramer Shear Press firmness, soluble solids, total acidity, sensory difference from control and consumer acceptability tests. The influences of Semperfresh on storage quality of the apple cultivars varied. Semperfresh retarded fruit ripening, as shown by persistence of green skin and tissue colors, retained tissue firmness and titratable acidity levels. Soluble solids were not affected by Semperfresh treatments. All Semperfresh

treated apple varieties exhibited sensory differences but treatments did not have the same sensory effects on each cultivar. Semperfresh treatment improved consumer acceptability ratings for Golden Delicious and McIntosh apples, with no improvement for Ida Red fruits.

This is dedicated to my husband.

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LITERATURE REVIEW

Quality preservation is a major concern in modern fresh fruit and vegetable marketing systems. Quality is at the forefront of importance in all aspects of the food industry because of consumer demand. Therefore, it is imperative that processors meet the consumer challenge of fresh and fresh quality at minimal cost in order to survive in the marketplace. In terms of fresh fruits, quality is no longer a seasonal event but a year-long phenomenon (Freeman, 1990). Quality of fresh horticultural commodities is a combination of characteristics, attributes and properties that give the produce value to humans for food and enjoyment (Shewfelt, 1986). The definition of good quality varies according to personal perceptions, the commodity's intended use and where it is in the handling or marketing system. Producers are concerned more about good appearance, few visual defects, high yield, strong disease resistance, ease of harvest and good shipping quality. To receivers and market distributors, good appearance is the most important but firmness and long storage life are also major considerations. Consumers consider good quality of fresh produce as good appearance, firm texture, good flavor and nutritive value (Kader, 1985a).

Postharvest Changes

Fresh fruits, vegetables and ornamentals are living tissues which are subject to continuous change after harvest. Numerous postharvest physiological reactions occur in apples which influence their quality attributes such as appearance, texture, flavor and nutritional value. While some of these changes are desirable, most are detrimental to the quality of the commodity and not desirable from the consumer's standpoint (Kader, 1985b).

Biological factors involved in deterioration are respiration, ethylene production, compositional changes, growth and development, transpiration or water loss, physiological breakdown, physical damage and pathological breakdown (Kader, 1985a). The rate of perishability of harvested commodities is generally propotional to their respiration rate. Ethylene is the natural aging and ripening hormone and is physiologically active in trace amounts (less than 0.1 ppm) (Kader, 1985c). Generally, ethylene production increases with maturity, physical injuries, disease incidence, high temperature and water stress. Based on the patterns of respiration and ethylene production during maturation and ripening, fruits can be classified into two groups: climacteric fruits and nonclimacteric fruits. Climacteric fruits exhibit a large increase in carbon dioxide and ethylene production rates coincident with their ripening, whereas the nonclimacteric shows no change in these rates during ripening. Water loss is another one of the main causes of deterioration, because it causes not only direct

quantitative losses, but also losses in appearance, texture and nutrition.

Environmental factors influencing deterioration include temperature, relative humidity, atmospheric composition, ethylene concentration and light (Kader, 1985a). Temperature control is the most important tool to extend the shelf-life of fresh horticultural commodities (Lowings and Cutts, 1982). For each increase of 10°C above optimum, the rate of deterioration increases about two to three times. Undesirable temperature causes many physiological disorders (Kader, 1985b). For example, produce stored below their freezing temperatures will have freezing injury. Many tropical and subtropical commodities held at temperatures above their freezing point but below 5°C to 15°C, depending on commodity, will exhibit chilling injury. Heat injury may result as a response to exposure to excessively high temperatures. In addition, temperature also influences the transpiration rate, the effects of oxygen, carbon dioxide and ethylene on a commodity and the resistance of the commodity to pathogens. According to the sensitivity to chilling injury, commodities can be classified as non-chilling or chilling sensitive. The ideal temperature range for transition and storage of non-chilling sensitive crops is 0°C to 5°C; whereas for chilling sensitive crops it is 10°C to 15°C. Relative humidity can influence water loss, decay development, incidence of some physiological disorders and uniformity of fruit ripening (Kader, 1985a). Proper relative humidity is 85 to 95 percent for fruits and 90 to 98 percent for vegetables. Reduction of

oxygen and elevation of carbon dioxide can either delay or accelerate deterioration of fresh produce depending upon commodity, cultivar, physiological age, oxygen and carbon dioxide level, temperature and duration of holding.(Kader, 1985b; Lau, 1985). Postharvest changes in fresh produce cannot be stopped, but can be slowed down within certain limits. The shelf life of a commodity can be lengthened by placing it in an environment that retards respiration, reduces the autocatalytic production and accumulation of ethylene and diminishes microbial decay (Haard, 1985).

Postharvest Storage

Several techniques are used to preserve postharvest quality of perishable produce during transportation, storage and handling through the market. The overall objective of these techniques is to slow down metabolic rate, disease development and detrimental quality changes to extend product life (Lowings and Cutts, 1982). Refrigeration is the principal technique used, but low temperature alone may not be sufficient to retard ripening and delay senescence. In addition, low temperatures may cause physiological damages, e.g., chilling injury of limes (Motlagh and Quantick, 1988) and low temperature breakdown in apples (Smith et al., 1987b).

Predominant methods used to preserve fresh produce during handling and subsquent marketing include controlled atmosphere (CA) storage or modified atmosphere (MA) storage. The principles of gas storage were first recommended publicly

by Kidd and West (1927). They led to the development of CA storage where produce is held in a gas-tight atmosphere with predetermined concentrations of carbon dioxide and oxygen which are controlled at optima specific for each cultivar. This type of storage has been greatly facilitated by the recent development of automatic control systems (Jameson, 1982). A typical CA storage regimen contains low oxygen and ethylene with elevated carbon dioxide concentrations to reduce the respiration rate while avoiding anaerobic respiration and death (Santerre et al., 1989).

Effects of Controlled Atmosphere Storage

In general, the effect of reduced oxygen and/or elevated carbon dioxide on reducing respiration rate has been assumed to be the primary reason for the beneficial effects of CA storage on fruits and vegetables. Kader (1986) reported that this is an oversimplification, since postharvest deterioration of fresh produce can be caused by many factors besides high respiration rate. Lowering the oxygen level and providing high carbon dioxide concentrations have definite effects on Krebs cycle intermediates and enzymes. Studies have shown a minimum of about 1-3% oxygen is required to avoid a shift from aerobic to anaerobic respiration which results in development of off-flavors and tissue breakdown (Burton, 1978; Solomos, 1982). Elevated carbon dioxide concentrations above a level of about 20% or higher can result in accumulation of ethanol and acetaldehyde within the tissues indicating a shift toward anaerobic respiration. The

effects of reduced oxygen and elevated carbon dioxide on respiration rate and the shift from aerobic to anaerobic respiration are additive. Monning (1983) found that high carbon dioxide concentrations inhibited glycolysis and succinic dehydrogenase activity. This led to reduced formation of citrate and α-ketoglutarate causing succinic acid, a toxicant to plant tissues, to accumulate in apples.

Low oxygen and/or high carbon dioxide concentrations reduce ethylene production and the sensitivity of fresh produce to ethylene. Burg and Burg (1967; 1969) demonstrated that oxygen is needed for ethylene production and action. At 2.5% oxygen, ethylene production is halved and fruit ripening is retarded. At 3% oxygen, the binding of ethylene is reduced to about half of that in air. Lau et al. (1984) reported that the internal ethylene concentration and 1-aminocyclopropane-1-carboxylic acid (ACC) accumulation of Golden Delicious apples stored in 2.5% oxygen were suppressed. The extent of ACC accumulation was closely related to the subsquent flesh softening and increase in internal ethylene concentration. These processes were inhibited in CA storage. The ethylene production of Granny Smith apples was reduced after exposure to 20% carbon dioxide for two hours, indicating a possible effect of high carbon dioxide levels on the enzyme system transfering ACC into ethylene (Chaves and Tomas, 1984). Carbon dioxide can also delay many responses of fresh commodities to ethylene which can be detrimental to quality such as accelerating softening (Kader, 1985c). Fruits which normally produce high levels of ethylene such as ripening

apple, pear and avocado accumulate harmful concentrations of ethylene even under CA storage. Installation of an ethylene removal system in the CA storage room is an effective choice to prevent the development of deterioration (Kader, 1980).

CA storage has been shown to influence the rate of compositional changes of fresh commodities as indicated in a review by Kader (1986). Knee (1980) reported the rates of chlorophyll degradation in peel and cortex, flesh softening and soluble polyuronide formation in apples were half maximal at 2.5-4.0% oxygen. CA conditions can reduce losses in acidity in fresh fruits. Golden Delicious apples stored at 2.5% carbon dioxide atmosphere for eight months maintained a higher titratable acidity (Lau and Looney, 1982). Changes in carbohydrates, organic acids, proteins, amino acids, lipids and phenolic compounds can affect the flavor of fresh fruits and vegetables. The production rates of volatiles of apples, pears and other fruits were decreased by the application of CA technique. Apples kept in low oxygen atmosphere had low levels of esters which were a result of low rates of alcohol synthesis (Knee and Hatfield, 1981). But fruits picked at the preclimacteric stage and stored in 1-2% oxygen for a long time may lose their ability to produce the required amount of volatiles to attain a good aroma. Fruit ripening and softening are retarded, and improved nutrient retention can occur with this preservation method.

Physiological disorders of fresh produce result from undesirable temperature and/or atmosphere. These disorders can be affected by CA storage, which may under varying

circumstances alleviate, induce or aggravate the specific conditions of a disorder. Smock (1979) found that CA conditions reduced the severity of scald on apples and pears. However, some chilling-sensitive commodities, such as cucumber, stored in CA storage at chilling temperature had more severe chilling-injury symptoms. Exposure of fresh fruits and vegetables to oxygen levels below, or carbon dioxide levels above, their tolerance limits can cause various physiological disorders. These may include such things as internal browning of lettuce, apple, pear, peach and surface pitting of cucumber, mushroom, apple and pear (Liu, 1985).

CA storage may directly affect pathogens and decrease postharvest decay. Generally, an atmospheric composition less than 1% oxygen and/or more than 10% carbon dioxide is required to significantly inhibit fungal growth (El-Goorani and Sommer, 1981). However, not all commodities are tolerant to such concentrations of oxygen and carbon dioxide without physiological injury. Water loss may be reduced by application of CA conditions, since a gas-tight environment often results in fairly high relative humidity (Kader, 1986).

CA storage is very useful and beneficial when large quantities of produce are harvested at one time, so that the storage uint can be filled rapidly and sealed. However, both refrigeration and application of CA techniques are expensive, requiring relatively high capital outlay for installation, maintenance and high energy inputs. Skilled management is also necessary (Jameson, 1982). Although increasingly

sophisticated CA storage techniques can successfully extend storage life and maintain fresh quality of produce, there are many disadvantages (Lowings and Cutts, 1982). For instance, it is not practical or economical to apply to small quantities, or short-lived produce. This type of storage is usually limited or unavailable in many less-developed countries. It is not possible to have regular inspection of the produce during CA storage. Closely related species, different cultivars of the same species, and tissue maturation variations, result in dissimilar, and often unpredictable oxygen and carbon dioxide tolerance limits (Haard, 1985; Kader, 1986). Moreover, once produce is removed from the CA storage chamber it is subject to ambient conditions during marketing, which often lead to rapid quality deterioration so the produce must be consumed in a relatively short time.

Effects of Hypobaric Storage

Hypobaric storage involves the mechanical development of very low atmosphere pressures in a chamber, resulting in low oxygen and ethylene levels (Lidster et al., 1985). Although this technique provides very good results in extending shelf life of fresh commodities, the high cost, sophisticated techniques and complex equipment necessary to achieve this type of storage make it relatively unavailable. Besides, once ethylene production is initiated, the effects of ethylene removal from storage atmospheres are reduced (Dover, 1985; Stow, 1986).

Effects of Modified Atmosphere Storage

Smith et al. (1987b) stated that since consumers have increased awareness of quality in fresh produce these days, researchers have tried to find appropriate methods to create microclimates surrounding produce that would mimic the beneficial effects of CA storage into and through the marketing chain, ideally without the use of refrigeration. Modified atmosphere storage (MA) provides the ability to maintain quality, retard ripening and reduce the rate of deterioration, at least for short term storage and transportation. MA packaging systems are developed by holding produce in a package, which is semi-permeable to gases. Respiration of the fruit within the pack creates its own ambient atmosphere which is modified by the permeability of the package. The artificial barrier may result in reduced oxygen and increased carbon dioxide concentrations, different water and ethylene levels, and effects on other physiologically active compounds, e.g., quality-related volatiles such as esters (Blanpied, 1985). These influences are dependent upon species, cultivar, ratio of enclosed produce weight to surface area, and respiration rate. Furthermore, the nature and thickness of the barrier and how it interacts with temperature and humidity also affect its permeability and hence the degree of atmosphere modification.

Film Barriers

Artificial diffusion barriers used in prolonging storage life of fresh produce can be classified into two main

groups, films and coatings. Films are extruded plastic materials that are used to overwrap the produce or enclose it in a heat sealed loose cover. Films have been used to reduce water loss in storage for many years; however, due to sealing difficulties and development of high humidity, their use in modified atmosphere package has been relatively limited (Marcellin, 1974).

Recent investigations reveal the availability of film materials with a broader range of permeability, thus the use of films for MA package has been extended. One of the cheapest and most easily available plastic films is polyethylene (PE). Han et al. (1985) applied different thicknesses of low density (0.89-0.91) PE film to Fuji apple packs which were stored for five months at relative humidity of 86-89% in temperatures that varied from 0 to 7°C, depending on ambient temperatures. They found that the storage using PE film effectively reduced the weight loss and decay occurence but developed slightly higher internal browning than in non-packed storage.

The importance of selecting a suitable packaging film and matching with an appropriate pack design for a particular commodity to achieve the most beneficial effects on maintaining quality has been demonstrated by Geeson et al. (1985). This group of researchers in the U.K. also studied the practical benefits of MA retail packaging for the marketing of apples. They stated that MA packaging in suitably permeable plastic films is an effective means of retarding ripening changes in good quality Bramley and Cox

apples removed from storage in marketing seasons and also beneficial for extending shelf life of the early season apple, Discovery. The primary quality attributes of firmness and background skin color declined less rapidly than in non-MA packs. They suggested that application of these MA package techniques would help to maintain the quality of apples throughout the distribution and marketing chain, and prolong the market life of fruit for the wholesaler, retailer and even consumer (Geeson et al., 1987; Smith et al., 1987a). In addition, they found that the degree of modification of enclosed atmosphere and the effects of MA package on fruit ripening retardation were influenced by the duration and conditions of storage prior to MA packs and by the packaging film used. They also demonstrated that the main cause for retardation in maturity of MA packaging was due to reduced oxygen concentrations rather than to elevated carbon dioxide levels. This finding agreed with Kader's review (1986). They also found that the extent of any beneficial effects and the occurence of any deleterious effects of MA storage were dependent upon the physiological status of the fruit when packed (Smith et al., 1988).

Coating Barriers

Coatings of wax, oil, or other material may be applied to the surface of fruits as an addition to or replacement for the natural protective waxy coating (Smith et al., 1987b). Using coatings to enhance postharvest storage may result in natural respiration creating internal gas atmospheres which

develop in proportions suitable for short or long term storage (Lowings and Cutts, 1981). Researchers have tried to apply coating materials to apples for delaying firmness and color changes since the 1920's (Magness and Diehl, 1924). Many of these early studies used wax- and oil-based materials. Off-flavor development frequently occurred because of their effects on the gaseous exchange properties of the fruit peel which resulted in anaerobiosis (Hulme, 1949; Mathur and Srivastava, 1955). Ideally, a coating material should be edible and semi-permeable to carbon dioxide and oxygen so that oxygen levels within fruit would be greatly lowered without an equivalent rise of internal carbon dioxide concentrations. Moreover, it should be non-phytotoxic, acceptable as a food additive, tasteless, odorless, cheap, effective in extending storage life, easy to transport and apply.

In 1981, Lowings and Cutts reported finding a specific coating mixture of sucrose fatty acid esters, sodium carboxymethyl cellulose, and mono- and diglycerides. This product was marketed under the name 'Prolong', and produced by TAL Chemicals Company, Reading, England. Semperfresh™ developed by Inotek International Co., Painesville, OH is an improved formulation of earlier sucrose esters products. The major difference is improved dispersion due to incorporation of a higher proportion of short chain unsaturated fatty acid esters (Drake et al., 1987). Another water soluble coating, 'Nutri-Save®', was developed by Nova Chem Limited, Halifax, Canada. Nutri-Save is a water soluble polysaccharide derived

from a naturally-occuring bipolymer (Elson et al., 1985). Meheriuk and Lau (1985) demonstrated that Bartlett and d'Anjou pears coated with Nutri-Save were firmer and had higher acid levels and greener skin color than the control; however, treated fruit failed to ripen properly.

Sucrose Fatty Acid Esters

Sucrose has eight hydroxyl radicals which can be esterified with fatty acids. The fatty acids most commonly used in these esters are stearic and palmitic acids (Ebeler and Walker, 1984). The potential range of products, commonly refered to as sucrose esters, is from mono- through octaester (Weiss, 1983). In early synthesis work, sucrose esters were prepared by interesterification, but frequently high temperatures and toxic solvents such as dimethylacetamide, and dimethylformamide, limited the use of sucrose esters in food products. Feuge et al. (1970) developed a solvent-free interesterification process. Further researchers either modified or invented other reaction systems to get higher yield and purity while avoiding toxic solvents (Akoh and Swanson, 1990). Sucrose fatty acid esters were identified by the U.S. Food and Drug Administration (FDA) to be safely used as they are the mono-, di-, and tri-esters of sucrose with fatty acids and are derived from sucrose and edible tallow or vegetable oils. The only solvents which may be used in the preparation are those generally recognized as safe (GRAS) in food or regulated for such uses including ethyl acetate,

methyl ethyl ketone, dimethyl sulfoxide and isobutyl alcohol (Fayson and Gregg, 1989).

Several investigators have used sucrose fatty acid esters as a postharvest preservation treatment for apples in conjunction with a refrigerated storage environment (Banks, 1984a; Smith and Stow, 1984; Chu, 1986; Drake et al., 1987; Santerre et al., 1989). In studies by Smith and Stow (1984) Cox's Orange Pippin apples were coated post-storage with sucrose ester. During 21 days of a simulated marketing period, apple tissues had increased internal carbon dioxide concentrations, decreased yellow color production and retarded firmness loss. Likewise, Banks (1984a) found that Cox's Orange Pippin apples coated with Prolong and stored at 4°C resulted in increased internal carbon dioxide and decreased internal oxygen levels. However, Cox's Orange Pippin apples treated with a 1.25% sucrose ester formulation and stored at 3.5°C for up to five months, did not exhibit changes in texture, color or weight loss (Smith and Stow, 1984).

Succeeding low-oxygen storage of McIntosh and CA storage of Delicious apples, a post-storage application of sucrose esters effectively reduced tissue softening during a three week extended storage period at 15°C and 90-95% relative humidity, but it did not influence the firmness of CA stored McIntosh and Empire fruits. Poststorage Prolong treatment retarded the loss of green ground color of CA stored McIntosh but not low-oxygen stored McIntosh apples (Chu, 1986). The effect of Prolong coating on texture was different from that

on color retention. Smith et al. (1987b) reported that effects of coating application on texture and color in apples were related to the degree of atmosphere modification and also may be cultivar-dependent; whereas effects on coloration may be a result of direct effects on chlorophyll loss through interference with chlorophyll degradation processes or effects on chloroplast structure.

Both Drake et al. (1987) and Santerre et al. (1989) applied Semperfresh to apples. Post-storage application of Semperfresh on Golden Delicious apples following CA and refrigerated storage resulted in retarded color development, higher acid, greater firmness, increased internal carbon dioxide concentration, and decreased internal ethylene values as compared to untreated controls. CA stored, treated apples displayed similar attributes but no difference in firmness was evident (Drake et al., 1987). Santerre et al. (1989) further demonstrated delayed color development and increased firmness in both Golden Delicious and McIntosh apple varieties during four months of storage at 5°C. Semperfresh treatment did not affect pH, total acidity, or soluble solids measurements. No flavor or textural differences were found sensorially when apples treated with 1.2% Semperfresh were compared to untreated apples after two months storage time. Earlier work by Trout et al. (1953) stated that beneficial effects of apple coatings were dependent upon cultivar, coating type, coating thickness, and temperature at which the fruit was held.

Sucrose ester coatings have been tested extensively on other fresh commodities, such as pear, banana, lime and mango. Bartlett and d'Anjou pears coated with Prolong maintained firmer texture, higher total acidity and retarded yellow development, indicating ripening was delayed by the treatment. But these treated fruits had inadequate ripening when they were held at 20°C for ten days and Bartlett pears developed a blotchy skin color (Meheriuk and Lau, 1985). Chen (1986) reported decreased loss of firmness and titratable acidity with reduced ethylene production in sucrose ester treated Bartlett and Bosc pears; no marked benefit to coated d'Anjou pears was observed.

Mangoes and bananas stored in refrigeration are not recommended because of chilling injury (Lakshminarayana and Subramanyam, 1970; Kolekar et al., 1988). These fruits applied with sucrose ester coatings and stored at ambient temperature with high relative humidity had longer storage life due to ripening retardation (Dhalla and Hanson, 1988; Kolekar et al., 1988). Further work on the effects of storage environment on sucrose ester treated fruit was reported by Motlagh and Quantick (1988). They treated limes with different concentrations of Prolong and stored under varied conditions. Results suggested that Prolong successfully extended the shelf life of limes, especially at high relative humidity, low temperature or both, by controlling weight loss and degreening.

Banks (1983, 1984b,c) evaluated the application of Prolong to bananas. He demonstrated that the treatment

modified internal atmospheres, by depressing internal oxygen content without a concomitant increase of internal carbon dioxide level reduced the permeability of the fruit skin to gases and delayed degreening. The skin of the banana was more permeable to carbon dioxide than to oxygen and ethylene, and this differential permeability was enhanced by residues of coating material in the stomatal apertures which physically impeded the diffusion of gases. He stated that the effect of sucrose ester treatment on ripening was associated with depressed rates of respiration and ethylene production in a manner similar to CA storage. A study by Bharadwaj et al. (1984) regarding the migration of externally applied sucrose esters through the skin of fruits supported the results of Bank's research by demonstrating that they remained on the skin and were responsible for delaying the ripening process.

In addition to the use of sucrose fatty acid esters as protective coating components applied to many fresh fruits, melons and avocados to retard ripening, they may be used as emulsifiers or stabilizers in baked goods and baking mixes, in dairy product analogs, in frozen dairy desserts and mixes, and in whipped milk products. Moreover, they may be used as texturizers in biscuit mixes (Ebeler et al.,1986; Watson and Walker, 1986; Buck et al., 1986; Pierce and Walker, 1987). These uses of sucrose esters on food products were approved by FDA in 1982. Investigators also found that these esters had antimicrobial activities. Marshall and Bullerman (1986a,b) demonstrated that antimycotic activity of sucrose esters was detected against several mold species from

Aspergillus, *Penicillium*, *Cladosporium* ,and *Alternaria.* The autolysis of *Bacillus subtilis* was induced by sucrose esters and caused morphological changes in the cells (Tsuchido et al., 1987).

Sucrose Polyester

Sucrose polyester (SPE), an artificial fat-like material, is defined as the class of substances which are mixtures of the hexa - to octaesters of sucrose with naturally occuring long - chain fatty acids, mainlly from C-8 to C-12 (Anon., 1990). It was first synthesized by the Procter & Gamble Co., Cincinnati, OH in 1971 using a solvent-free method (Anon., 1987).

The Procter & Gamble researchers reported the physical properties of SPE such as the appearance , flavor, aroma, lubricity, heat stability, flash point and shelf life are similar to those conventional triglyceride fats and depend on the fatty acids used in preparation of the material. Sucrose polyester is not hydrolyzed by pancreatic lipase thereby resulting in its non-absorption and non-caloric nature (Boggs, 1986).

The research suggested four potential benefits from SPE : (1) By interfering with cholesterol absorption, SPE might lower the blood cholestrol level and benefit the person at high risk for coronary-vascular disease and colon cancer (Mattson et al., 1976; Crouse and Grundy, 1979; Fallat et al., 1976; Mellies et al., 1983; 1985 and Grundy et al., 1986). (2) SPE might make bland fat-free diets more varied

and attractive (Glueck et al., 1979). (3) SPE might help reduce the total dietary fat and caloric intake by replacing a portion of conventional absorbable fats (Glueck et al., 1982; Mellies et al., 1985). (4) It might block absorption of compounds such as DDT and other harmful fat-soluble chemicals and help excrete such toxins from the body (Boggs, 1986; Hunter, 1988). However, SPE is not without drawbacks although most studies showed only a few mild side effects. In human tests, SPE has induced gastrointestinal problems, including flatulence, loose stools, leakage, diarrhea, and an increased urgency or frequency of bowel movements (Mellies et al., 1983). One or two instances of nausea have been reported (Mellies et al., 1985). Fallat et al. (1976) found that there was no consistent pattern of problems. Another problem is that SPE may prevent the absorption of fat-soluble vitamins, especially vitamins A and E, which could lead to serious vitamin deficiencies. Vitamin supplementation has been suggested as a way to avoid this problem (Toma et al., 1988; Hunter, 1988)

Toxicity studies have been performed including short-term and long-term tests in rats, dogs and monkeys. There were some alterations in caloric intake and weight gain after long-term exposure to SPE (Boggs, 1986). Nolen et al. (1987) hypothesized that since SPE is neither absorbed nor metabolized, it remains as a bulk oil phase in the intestine, resulting in effects on the absorption and enterohepatic circulation of lipid-soluble materials. Thus, it could affect an organism by altering the intestinal milieu, which in turn

could interfer with reproduction and/or the normal development of the embryo/foetus. They conducted a study to determine the effects of various levels of dietary SPE on the reproductive and teratological characteristics of two generations of rats. The results indicated that the rats fed SPE increased their feed consumption, whereas SPE had no adverse effect on mating, conception, embryonic development, foetal or post-natal viability, or on post-natal growth. They stated that SPE is not a reproductive or developmental toxin, even at a high dietary level such as 10%. However, biologist Michael Jacobson charged that SPE has caused changes in the livers of test animals and asked the FDA to withhold approval (Gabor, 1988).

So far, FDA has only approved SPE as a protective coating on fruit (Anon., 1987). In April 1987, Procter & Gamble filed a food additive petition to substitute SPE for up to 35% of the fats in home cooking oils and up to 75% of the fats in commercial cooking oils and salty snacks (Anon., 1990).

This study extends previous work conducted in this laboratory (Santerre et al.,1989) and focuses on the use of several concentrations of Semperfresh to prolong noncontrolled atmosphere cold storage shelf life of three Michigan apple cultivars (Golden Delicious, Ida Red and McIntosh). Shelf life extension of treated apples without the need of CA storage would lower costs associated with CA apple storage of less than six months. Because the consumer is the

ultimate assessor of whether treatment differences are of any consequence (Smith and Churchill, 1983), consumer acceptability studies were conducted following sensory discrimination tests.

MATERIALS AND METHODS

Ida Red, McIntosh and Golden Delicious apples were harvested in the fall 1989 from the research orchards of the Department of Horticulture at Michigan State University, East Lansing, MI. General quality of the fruit was good although McIntosh and Golden Delicious apples had a small amount of bruising. Products were stored at 5°C prior to application of Semperfresh coatings. Following refrigerated storage, apples were washed in cold water, air dried and subjectively selected for uniformity according to size, color, general appearance, and freedom from external defects.

Semperfresh Formulation and Product Treatments

Semperfresh™ powder (Inotek International Co., Painesville, OH) was used to prepare a 3.6% (w/v) Semperfresh stock solution as described previously by Santerre et al. (1989) except that solutions were blended for 5 min. Apples from each cultivar were randomly sorted into four 25 kg lots for treatment. Three groups were treated with a three sec dip in either 0.6%, 0.9% or 1.2% Semperfresh solutions. An untreated lot dipped in water served as the control. Fruit samples were air dried and stored at 5°C with 90-95% RH. Samples were removed from storage after two, three and four

month intervals to be analyzed for physical, chemical and subjective parameters.

Objective Evaluations

Color

Whole apple external and internal reflectance color differences were monitored using a Hunter Color Difference Meter (Model D25-2, Hunter Associate Laboratory Inc., Fairfax, VA). Skin color was measured after standardization with a pink tile (L_L = 68.8; a_L = 23.2; b_L = 9.4) for Ida Red and McIntosh varieties and a yellow tile (L_L = 78.4; a_L = -3.0; b_L = 22.7) for the Golden Delicious cultivar. Flesh Color was measured after standardizing the instrument with a white tile (L_L = 92.35; a_L = -1.2; b_L = 0.5).

Firmness

Apple firmness was assessed by two methods. Puncture pressure (lbs. force) was determined by using a Magness-Taylor Fruit Texture tester (D. Ballauf Mfg. Co., Washington, D.C.) with a 5/16 in diameter flat cylinder plunger. Measurements were conducted following the removal of apple skin (1" diameter) and determining penetration force at 90° angles along an equatorial plane of four apples per treatment for each variety. Fruit tissue shear force (lbs. force/g) was measured on a Kramer Shear Press (Model T-2100-C, Food Technology Corp., Rockville, MD) with a ten blade shear extrusion cell. Attenuation was set at 1/10, with 3000 lb. transducer force and 78.5 calibration factor. Center slice

shear force was tested after peeling, coring and slicing the top and bottom off of three apples from each treatment and cultivar.

Total Acidity

Total acidity (% malic acid) was measured on homogenates produced by blending 100 g apple tissue (25 g from four apples per treatment) with 100 ml deionized water for one min. Homogenates (20 ml) were titrated with 0.1 N NaOH to pH 8.0 using a digital pH meter (Model 610A, Corning Glass Works, Medfield, MA).

Soluble Solids

Soluble solids (Brix) concentrations were determined using an Abbe-3L refractometer (Bausch & Lomb Optical Co.). Apple juice was manually squeezed from longitudinal slices from four apples per treatment from each cultivar.

Statistical Analysis

The Semperfresh storage study was a completely cross-classified 3-factorial design (variety, Semperfresh concentration, and storage time). Analysis of variance (ANOVA) was used to determine the significance of main effects and interactions. Polynomial regression analysis was used to determine the specific effects of Semperfresh concentrations and storage times on all chemical and physical parameters. The optimal regression model was selected by RSQUARE and STEPWISE procedures with a significance level

defined at 0.20 to eliminate those nonsignificant variables , considering high R^2 (square multiple correlation coefficient) and suitable C_p (a statistic for a p variable subset of k candidate variables) statistics (Gill, 1987). Data were analyzed using SAS software (SAS, 1985).

Subjective Evaluations

Sliced apples were visually examined for brown core. To evaluate sensorially the control and Semperfresh treated products after storage, two types of sensory evaluation tests were employed. Difference from control tests were used to ascertain whether a difference existed between the Semperfresh treated samples and the untreated controls and to estimate the magnitude of any sample differences. This type of difference testing procedure was selected since quality assurance/quality control and storage studies are cases in which the size of the difference as compared to the control is important for decision making (Meilgaard et al., 1987a). Following difference testing, affective tests were used to assess the personal responses of potential Semperfresh apple product users to determine if the Semperfresh treated products would achieve parity relative to the control fruit cultivars.

Sensory Test Methods

The difference from control procedure was followed according to the Meilgaard et al. (1987a) method. A ten-point category numerical scale with verbal and anchors (0 = no

difference to 10 = extreme difference) was used to rate the size of the overall sensory difference between the samples. The panel consisted of 24 untrained students, faculty and staff from Michigan State University with an age range from 18-55 years. Subjects evaluated three replications of each apple variety (24 subjects x 3 varieties x 3 reps). The test was a completely cross-classified 5-factorial design (storage time, variety, Semperfresh treatment, panelist and replication).

To determine the affective status of all treated and untreated apple varieties, consumer acceptance tests were used according to Meilgaard et al. (1987b). A numerical and verbal anchored nine-point hedonic scale was employed (1 = dislike extremely to 9 = like extremely) to determine the overall acceptability of the fruits. The sensory panel was composed of a total of 270 Michigan State University consumers, including students, faculty and staff. Every 30 subjects evaluated one apple variety one time. The test was replicated three times (30 subjects x 3 varieties x 3 reps). Consumers attending each repetition were different. The experimental design was a 5-factorial mixed (nested-factorial) classification with the panelist factor nested within three other factors (storage time, variety and replication) and the Semperfresh treatment factor was cross-classified with all four factors.

Environmental Conditions

All sensory tests were held in the sensory evaluation laboratory of the Department of Food Science and Human Nutrition at Michigan State University. This laboratory is equipped with fifteen isolated testing booths, temperature regulated positive air flow and constant illumination. Panelists evaluated apple samples under white fluorescent lighting.

The apple test materials and Semperfresh preparation and treatment of the Golden Delicious, Ida Red and McIntosh apple cultivars has been noted above. Sensory tests were conducted on 0% (control), 0.6% and 1.2% Semperfresh treated apples, to minimize the number of consumer tests and to obtain physical and chemical data concomitantly with the sensory data. Fruit varieties were stored in noncontrolled atmosphere cold storage chambers on open racks at 5°C for 8 weeks and 12 weeks prior to sensory evaluation.

Sample Preparation/Presentation

Whole apples were removed from refrigerated storage chambers and held at ambient temperature for approximately one hour, preceding sensory evaluations. The apples were sliced by hand into one-inch thick vertical wedge segments, making certain the apple core was not part of the sample. Weights of each sample were not determined. Fruit samples were prepared and served as soon as subjects were in the testing booth so as to minimize enzymatic discoloration of the apples.

Test samples consisted of one apple wedge segment placed in an unlidded two-ounce plastic container labeled with a three-digit random number with the exception of the control (0% Semperfresh) fruits, which were labeled with "C" for the difference testing method (when required). All sample presentation orders were randomized and balanced. Subjects were instructed to drink the ambient temperature deionized water ad libitum prior to and between sample evaluations. Panelists were also allowed to either expectorate or swallow the apple samples. The difference tests were held 5 days preceding consumer acceptability testing. The former tests were held midmorning and midafternoon. Consumer acceptability tests were held continuously from morning until late afternoon for three days. Three replications of all sensory tests were conducted.

Sensory Statistical Analysis

ANOVA was used to test the significance of main effects and interactions. Nonorthogonal designed contrasts (Bonferroni t statistics) were used to compare the differences among treatment means (Gill, 1987).

RESULTS AND DISCUSSION

External/Internal Color

External green skin colors (measured as the inverse of Hunter a_L values) in all apple cultivars were greater (P=0.01) as Semperfresh fruit treatment concentrations increased (Fig. 1). The Ida Red variety revealed a higher green skin color retention rate (4.73 unit/1% Semperfresh) as compared to the Golden Delicious (3.42 unit/1% Semperfresh) and McIntosh cultivars. Unlike the other two cultivars, the effect of Semperfresh treatments on McIntosh apple skin Hunter a_L values was not a declining linear relationship. Nonlinearity may be the reason for the significant Semperfresh concentration and storage interval interactions found for McIntosh fruit by Santerre et al. (1989). Semperfresh concentrations of less than 0.6% did not retard the change of green skin color of McIntosh fruits as strongly as did higher concentrations. These data suggested that Semperfresh applications inhibited yellow color development. Drake et al. (1987) also demonstrated greener skin color in Golden Delicious fruit treated with SPE than was found in the SPE plus wax treatment and the untreated controls. Semperfresh concentrations did not affect fruit skin brightness (Hunter L_L), yellow color (Hunter b_L) and chroma $(a_L^2 + b_L^2)^{1/2}$ values. These Hunter data are similar to earlier reports (Santerre et al., 1989).

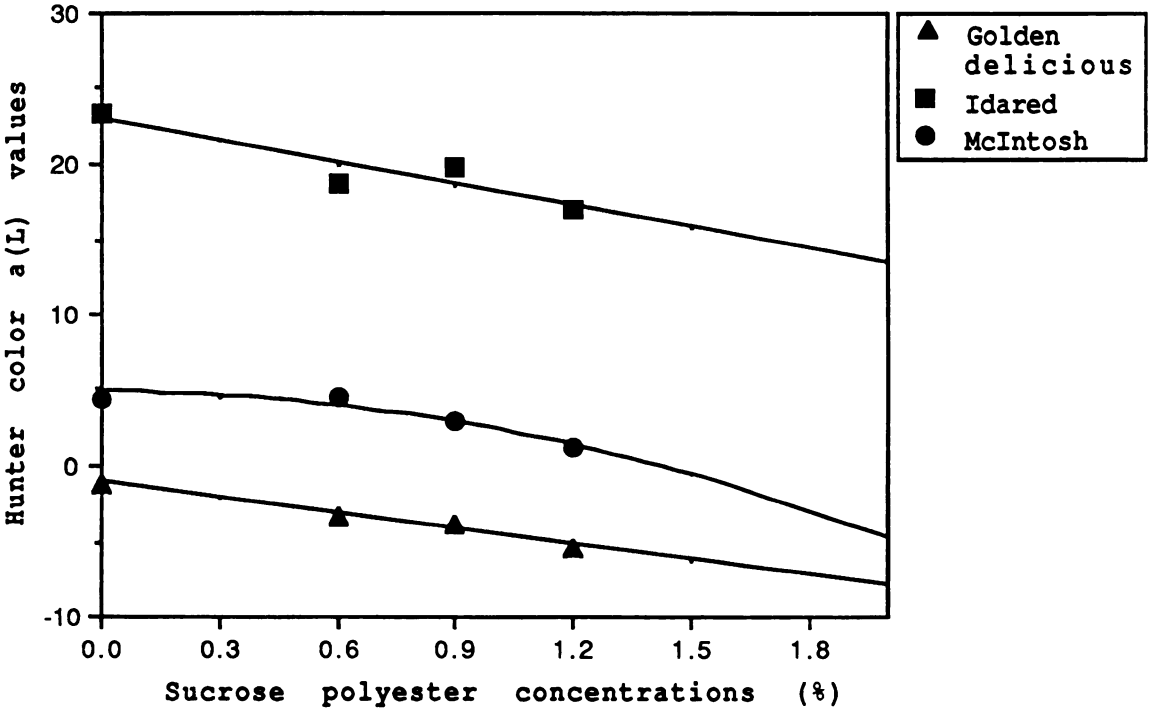

Figure 1. Influence of Semperfresh concentrations on apple skin green color

Since apple skin colors are basically in the red-yellow-green quadrants, hue angle of skin color was defined as $\tan^{-1}$ (b_L/a_L) while it was in the yellow-red quadrant ($+b_L/+a_L$) and $\tan^{-1}$ (b_L/a_L) + 180 while in the yellow-green quadrant ($+b_L/-a_L$). This definition was derived from the concepts of Little (1975) and Francis (1975) who described the function b_L/a_L as a hand sweeping counter-clockwise on a dial, starting at $0\pi r$ (red), to $\pi r/2$ (yellow), to πr (green), to $3\pi r/2$ (blue) and at $2\pi r$ back to red.

Semperfresh concentrations significantly ($P=0.05$) influenced apple skin color hue angles. Semperfresh treated fruits had larger hue angles than untreated controls (Fig. 2). As Semperfresh concentrations were increased, larger impacts on hue angles were apparent for Ida Red and McIntosh cultivars as compared to the Golden Delicious variety. Skin hue angles of Golden Delicious apples increased at a rate of 5.95°/1% Semperfresh and were located in the yellow-green quadrant. In contrast, skin hue angles for the Ida Red and McIntosh cultivars were situated in the yellow-red quadrant. For all apple cultivars, as Semperfresh concentrations increased greener skin colors were evident. These data coincided with the Hunter a_L measurements. Retention of darker green skin colors implied an inhibition of ripening and increased shelf life (Drake et al., 1987). A change of green to greenish yellow to yellow hues has been found to be one of the best apple maturity indexes (Magness and Diehl, 1924).

Varietal differences were evident regarding the influence of Semperfresh treatments on internal flesh colors.

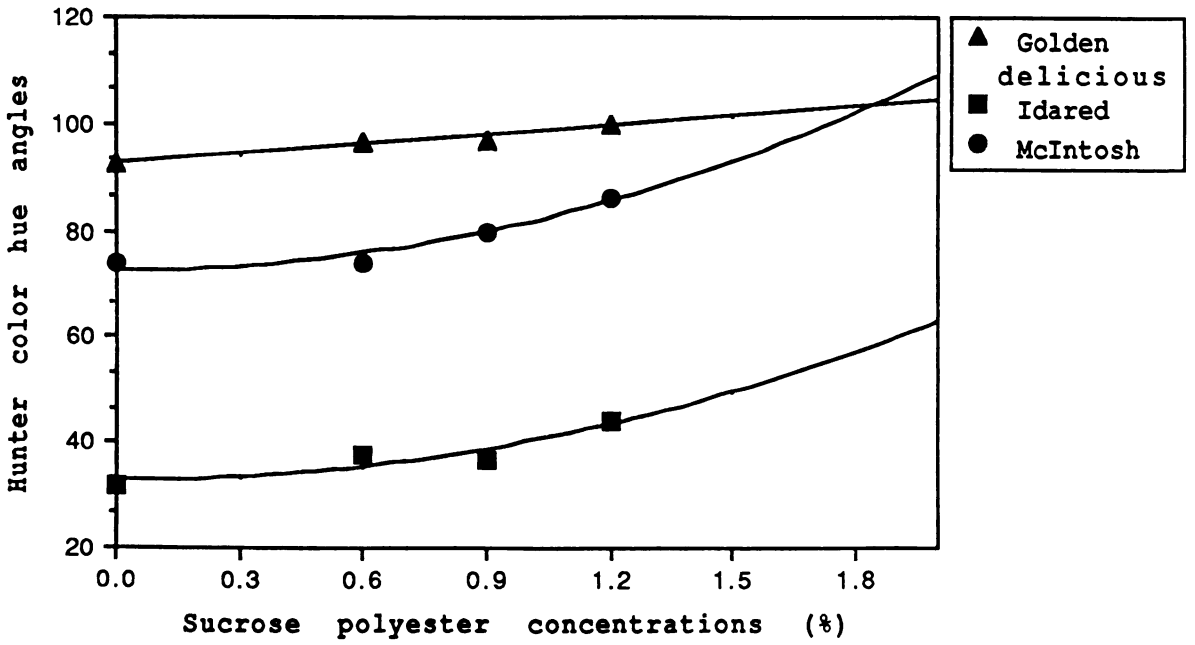

Figure 2. Influence of Semperfresh concentrations on apple skin hue angle values

Internal tissue color of Ida Red apples was not affected by the Semperfresh treatment in contrast to the two other cultivars. Brightness (Hunter L_L) and green (measured as the inverse of Hunter a_L) values were significantly (P=0.01) influenced by either the Semperfresh concentration, storage interval, or their interaction, in McIntosh and Golden Delicious apples. This was also shown by Santerre et al. (1989) for these cultivars. Internal flesh brightness changed during storage (Fig. 3). As storage time progressed, a brighter flesh color was observed in McIntosh and Golden Delicious cultivars; however, the rates of brightness development differed between these varieties. During the first two months of storage, the McIntosh apple flesh became brighter at a faster rate than the Golden Delicious variety. After three months storage, the internal flesh brightness values did not change significantly for Golden Delicious fruits. However, McIntosh apples started losing brightness.

McIntosh green color retention in the flesh tissue was significantly influenced (P=0.01) by the application of Semperfresh. The rate of green color retention was 0.95 unit/1% Semperfresh (Fig. 4a). Golden Delicious apples were significantly influenced by a Semperfresh concentration x storage time interaction (Fig. 4b). As storage time increased, apple flesh was less green in color and this agrees with the findings of Santerre et al. (1989). This loss of green color occurred at the same rate (0.71 unit/month) in all treatment groups, as well as, the control. Green coloration of apple flesh was more apparent when more than

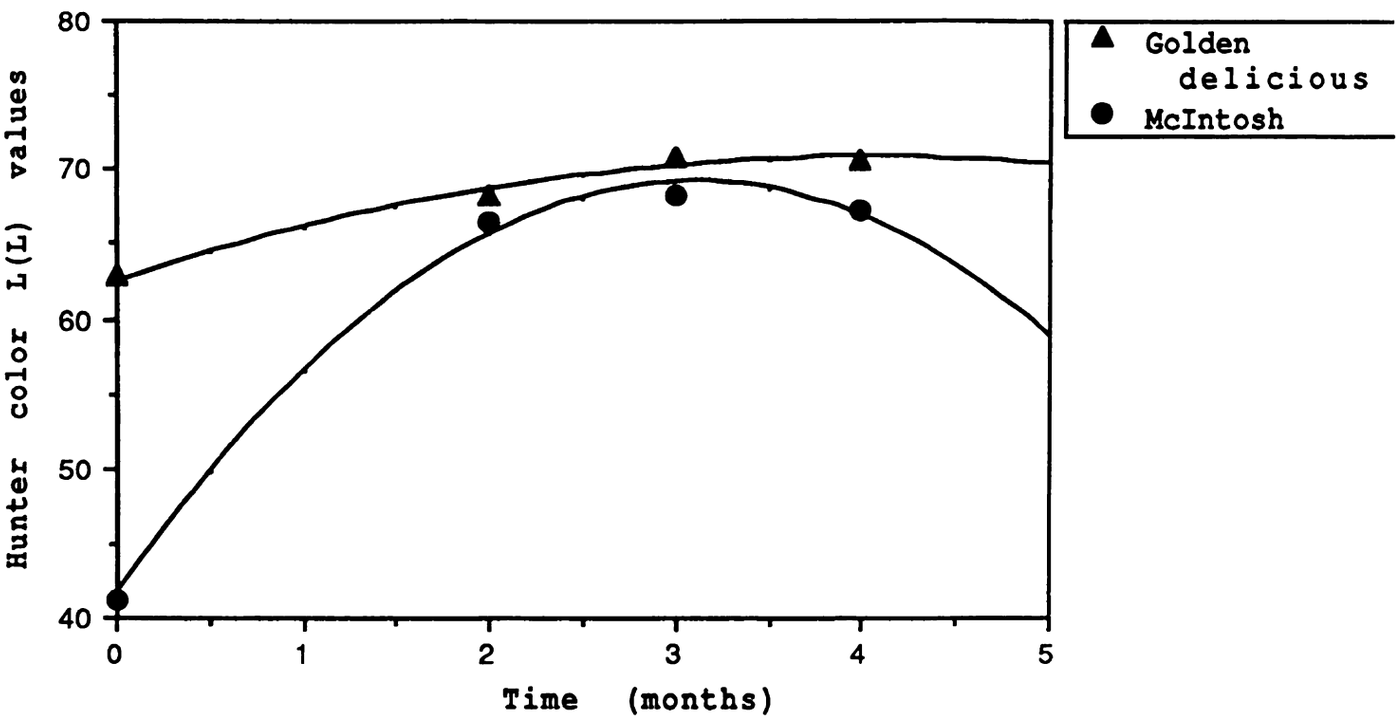

Figure 3. Influence of storage time on apple flesh brightness values

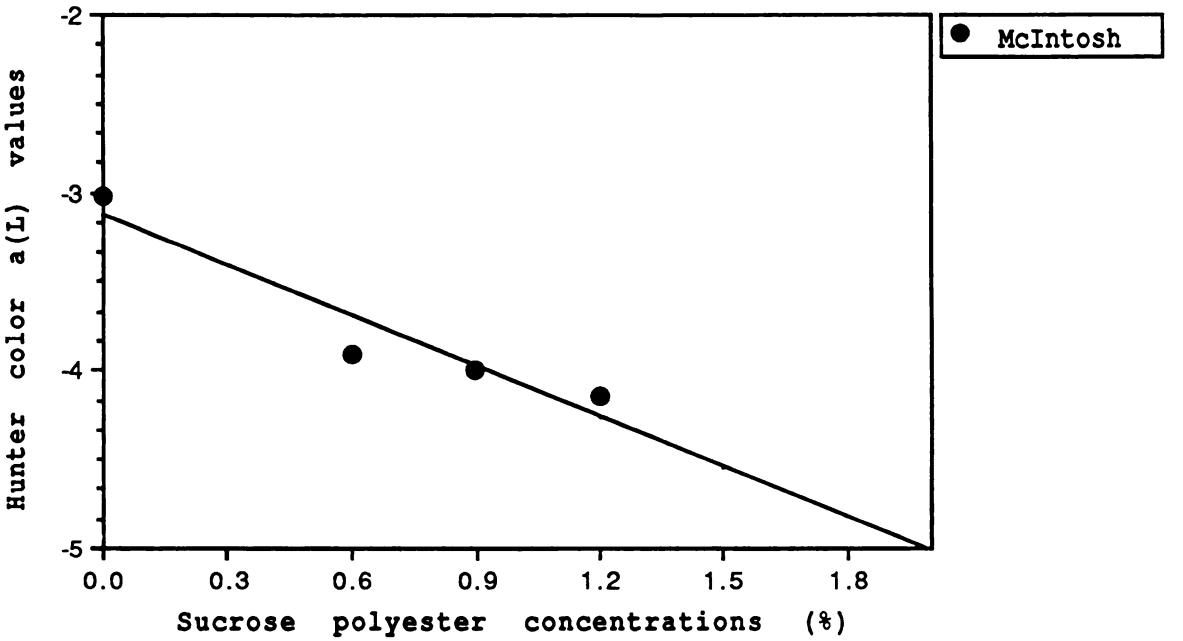

Figure 4a. Influence of Semperfresh concentrations on apple flesh green color

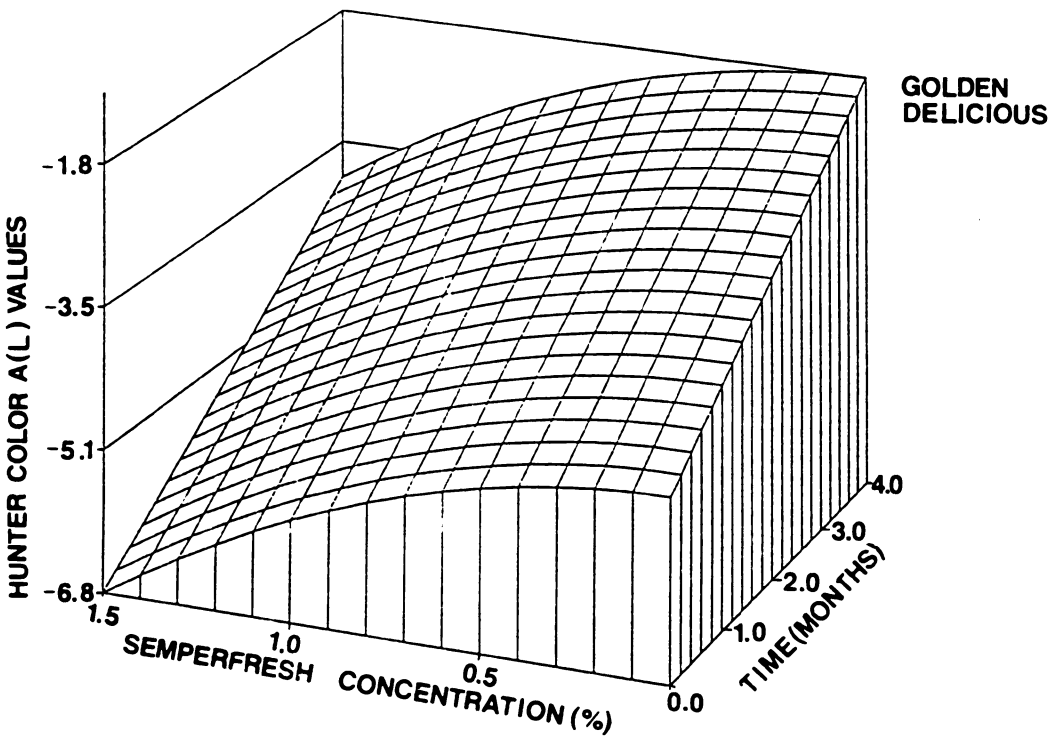

Figure 4b. Influence of Semperfresh concentrations and storage time on apple flesh green color

0.6% Semperfresh concentrations were used. Semperfresh treatments did not affect apple flesh yellow color (Hunter b_L) and chroma values but both characteristics were influenced by storage time (P=0.01). Storage fluctuations in Hunter b_L values were also demonstrated in the Santerre et al. (1989) study. Flesh yellow hues increased throughout storage, whereas chroma decreased. Drake et al. (1987) have shown in Semperfresh plus wax coated Golden Delicious apples that internal green color lingered while yellow color development and ripening were inhibited. Data reported here using McIntosh and Golden Delicious Semperfresh coated cultivars concur with the retarded disappearance of the flesh green color.

Firmness

Varietal differences in firmness were apparent. McIntosh and Golden Delicious apples exhibited significant (P=0.01) interactions between Semperfresh concentrations and storage times for puncture pressure firmness but the application of Semperfresh treatments did not affect the hardness of Ida Red apples (Fig. 5a). Ida Red fruits revealed a loss of firmness at a rate of 1.3 lbs. force/month throughout the refrigerated storage period. Semperfresh concentrations consistently increased the firmness (2.16 lbs. force/1% Semperfresh) of Golden Delicious apples despite the length of storage, whereas a declining firmness rate of 1.57 lbs. force/month due to advanced storage time alone was noted (Fig. 5b). Semperfresh coated McIntosh apples were also

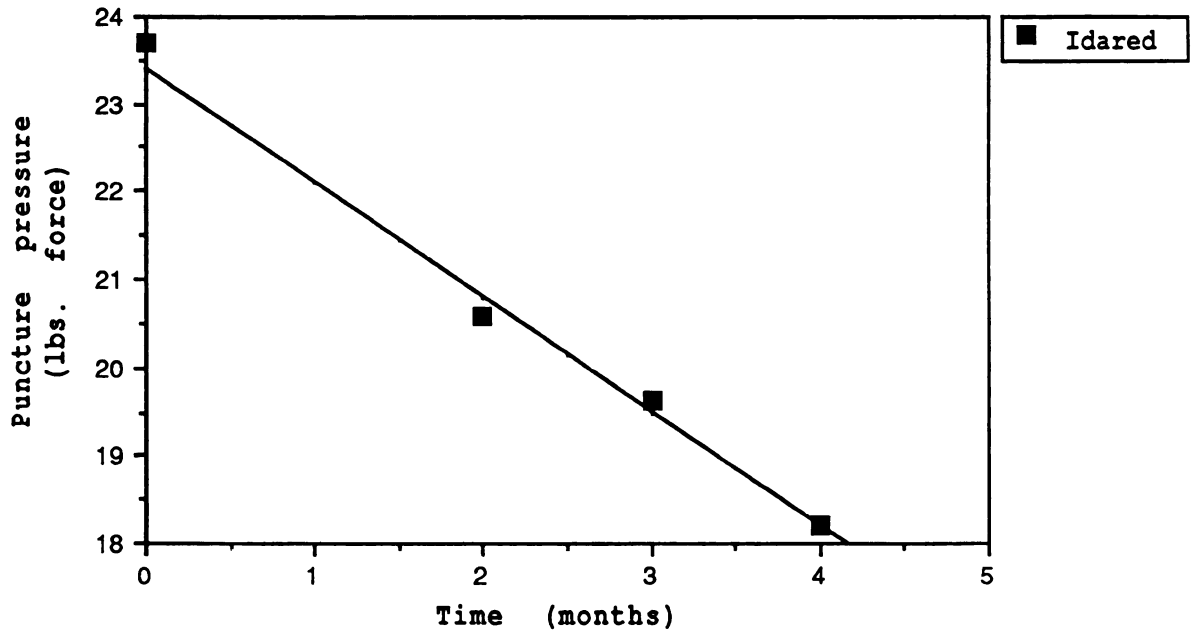

Figure 5a. Influence of storage time on puncture pressure

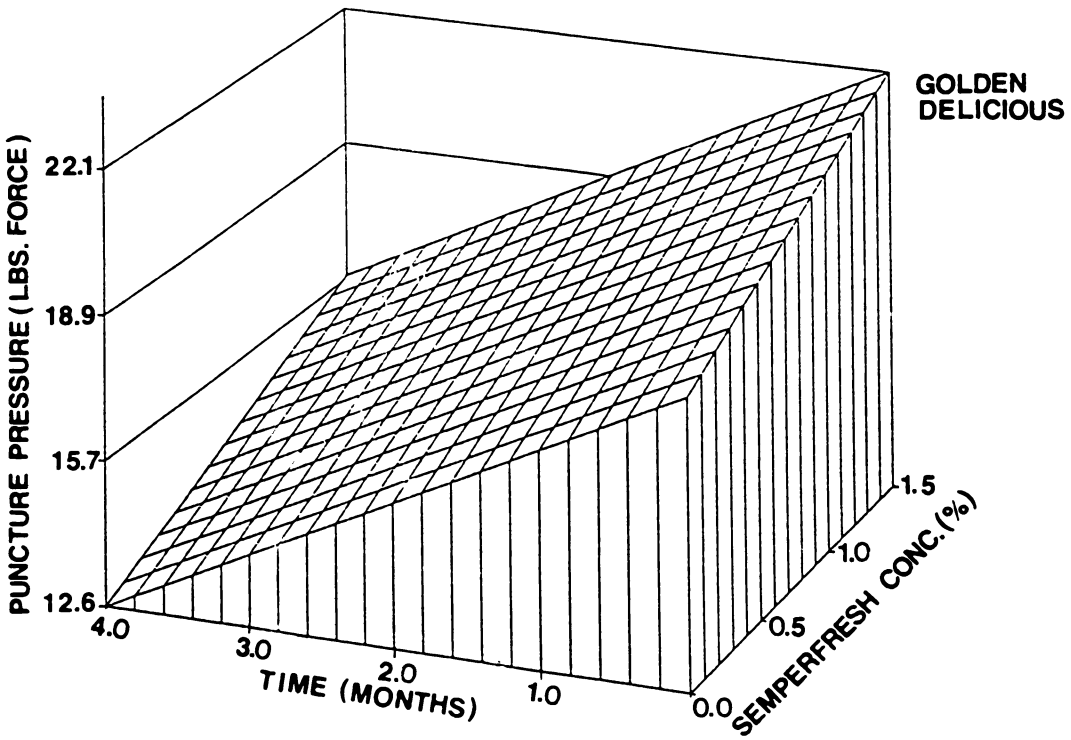

Figure 5b. Influence of Semperfresh concentrations and storage time on puncture pressure

harder than the untreated controls (Fig. 5c). These firmness data for the Semperfresh treated Golden Delicious and McIntosh cultivars coincide with Chu (1986) and Santerre et al. (1989). However, the importance of Semperfresh levels on puncture firmness of the McIntosh variety was highly dependent on the storage interval. As storage time increased, lower Semperfresh concentrations resulted in firmer apple tissues. After one month storage, McIntosh fruits with 1.2% Sempserfresh were the most firm. In contrast, following four months storage, the 0.6% Semperfresh treated McIntosh apples exhibited the firmest texture. Thus, McIntosh fruits treated with the higher Semperfresh concentrations lost firmness more quickly than apples treated with lower Semperfresh levels which is similar to the findings of Drake et al. (1987) with Golden Delicious fruit. It should also be noted that tissue firmness declined more rapidly in the Semperfresh treated groups than in the untreated controls. Therefore, puncture pressure firmness values from 1.2% Semperfresh treated McIntosh apples (13.00 lbs. force) were not significantly different from the untreated controls (13.06 lbs. force) following four months storage. However, Semperfresh coated McIntosh fruits remained firmer than untreated apples throughout the storage period.

Semperfresh treatments of apple cultivars did not significantly affect flesh tissue firmness as monitored by Kramer shear forces. However, there was a trend indicating that as storage time advanced apple tissue shear forces declined.

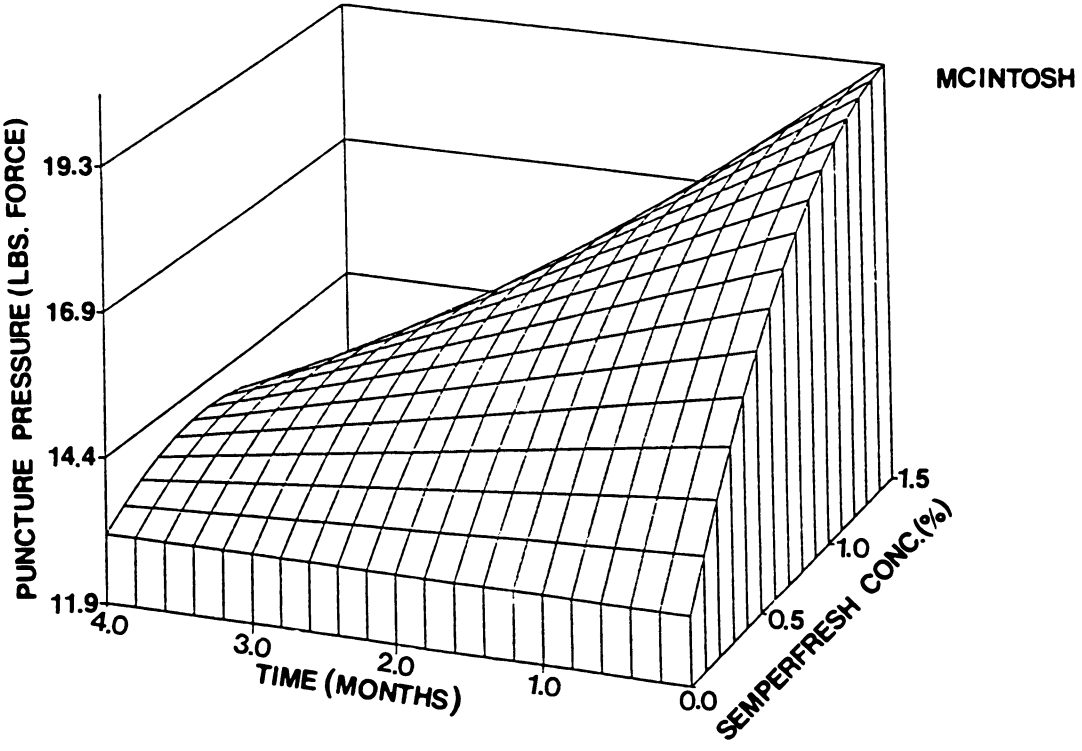

Figure 5c. Influence of Semperfresh concentrations and storage time on puncture pressure

These findings, demonstrating increased apple tissue firmness following Semperfresh treatment, are different from the results of Smith and Stow (1984). These workers used another sucrose ester coating (Prolong™) applied to Cox's Orange Pippin apples prior to 3.5°C storage for five months. Fruit firmness, yellowing and weight loss were not reduced with 1.25% Prolong treatment. Disagreement with our results may be attributed to differences between the cultivars, storage environments, compositions of coating materials, and firmness determination methods used among the studies. However, following the five months controlled atmosphere storage, Smith and Stow (1984) noted that by increasing Prolong concentrations (1-4%), firmness was improved in apples housed in air for three weeks at various temperatures (3.5°C-18°C). There may be an interaction between the Semperfresh treatment, storage interval and temperature. Our data demonstrate Semperfresh concentrations x storage time interactions.

Total Acidity

Cultivar differences were apparent regarding titratable acids or total acidity. Semperfresh treated Golden Delicious and Ida Red apples had higher total acidity than the untreated controls of these cultivars (Fig. 6a & b), but this did not occur for the McIntosh variety (Fig. 6c). Santerre et al. (1989) found that total acidity levels varied over time in both the Golden Delicious and McIntosh cultivars. In our study, McIntosh total acidity concentrations decreased

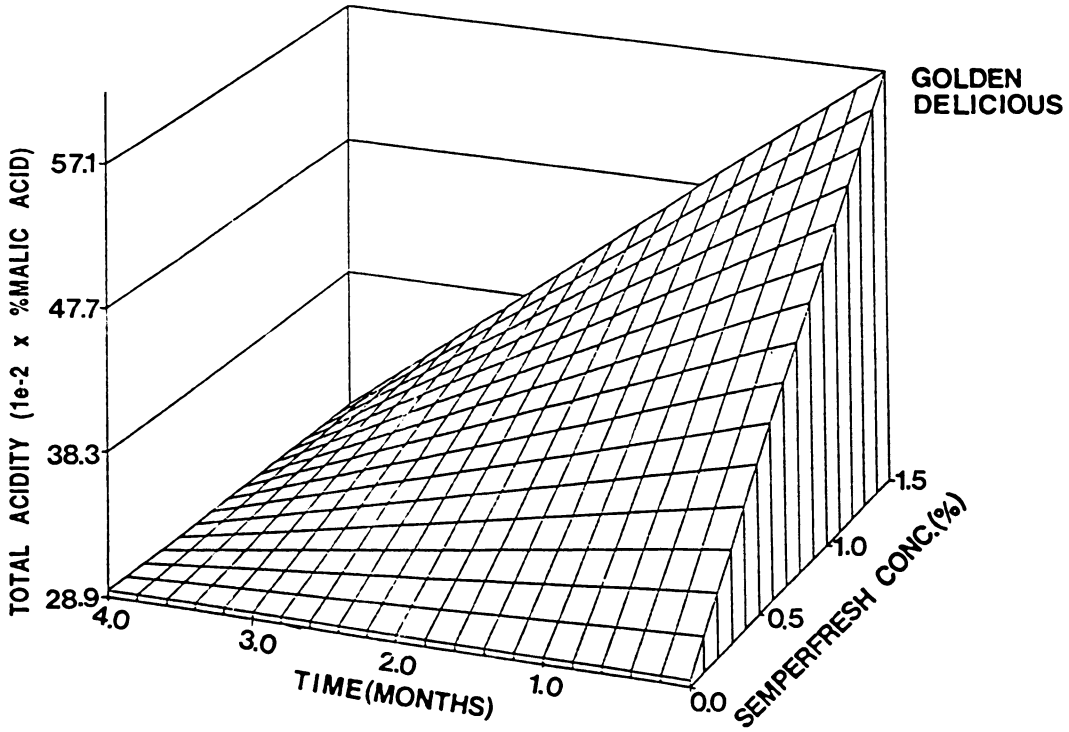

Figure 6a. Influence of Semperfresh concentrations and storage time on total acidity

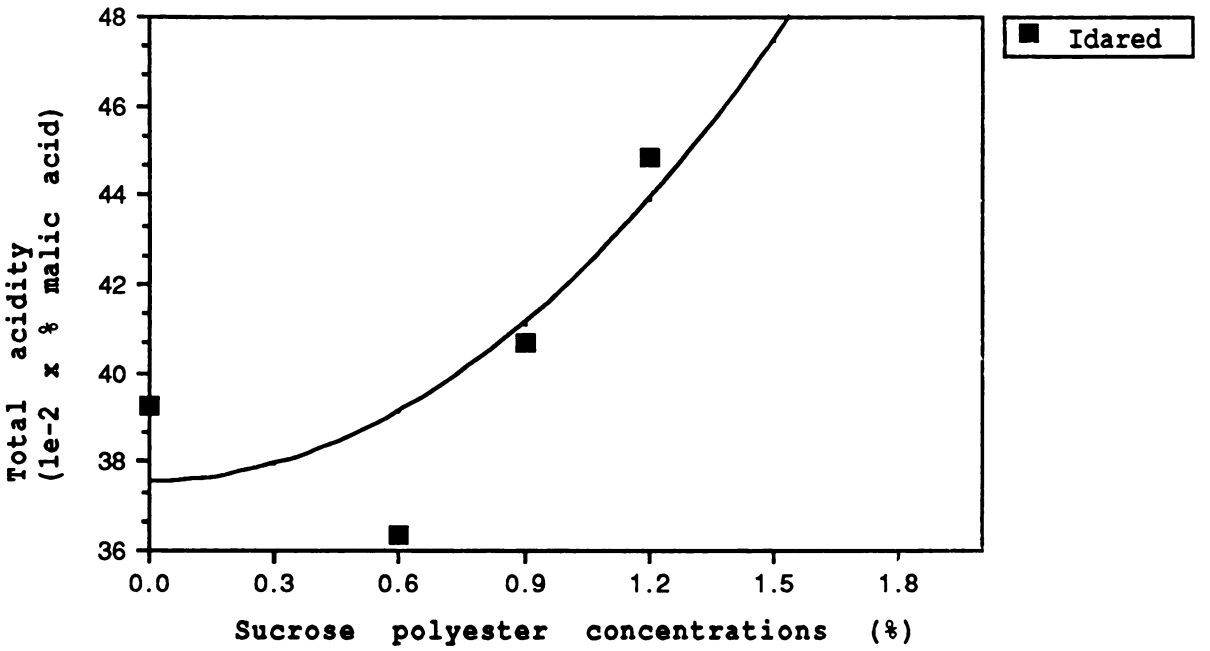

Figure 6b. Influence of Semperfresh concentrations on total acidity

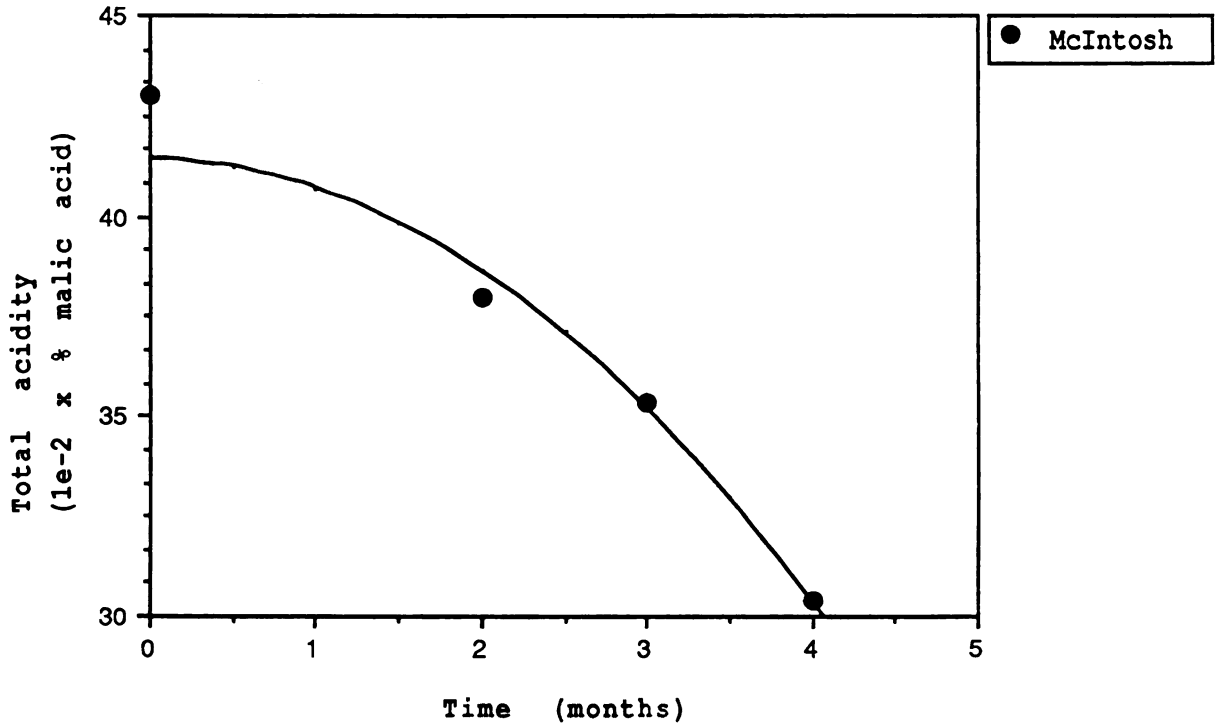

Figure 6c. Influence of storage time on total acidity

sharply after one month storage (Fig. 6c). This agrees with the findings of Santerre et al. (1989) who found a decline in total acidity of McIntosh fruit after two to four months time. A decline in acid contents demonstrates maturation development. Application of increased Semperfresh concentrations to Ida Red apples (Fig. 6b) seems to prevent losses of titratable acids, especially at more than 0.6% Semperfresh levels. A significant interaction (P=0.01) between Semperfresh concentration and storage interval was observed for total acidity of Golden Delicious apples (Fig. 6a). As Semperfresh concentration increased total acidity of Golden Delicious fruits was greater throughout storage but the effect was not significant after four months. These findings were consistent with the results of Drake et al. (1987) who reported higher total acid levels in Semperfresh treated Golden Delicious apples compared to contrcls. Data from the present study also confirmed previous research showing that titratable acids in Golden Delicious apples increased from zero to two months followed by a decline from two to four months storage (Santerre et al., 1989). Our study revealed that with increasing Semperfresh levels, the titratable acid retention rate in Golden Delicious apples changed as storage time increased. At one month storage total acidity increased at a rate of 13.84×10^{-2}% malic acid/1% Semperfresh. This was followed by a rate reduction to 9.13×10^{-2}% malic acid/1% Semperfresh at two months storage time. The retention in total acidity observed in Golden Delicious

and Ida Red cultivars seems to indicate delayed ripening in these cultivars.

Soluble Solids

Soluble solids contents at the beginning of the storage study for Golden Delicious, McIntosh, and Ida Red cultivars were 10.1°, 10.4°, and 11.9°Brix, respectively. These soluble solids values were not affected by advanced storage time or Semperfresh treatment in any of these apple cultivars. These data were in contrast to Santerre et al. (1989) who found decreased soluble solids concentrations at four months for McIntosh fruit, while soluble solids levels in Golden Delicious apples increased after two months and then decreased after four months storage.

Sensory Evaluation

Minimal sensory research has been reported using Semperfresh treated apple products. Where appropriate and applicable previous literature will be discussed.

The difference from control test results are shown in Table 1. Apples treated with 0.6% and 1.2% Semperfresh exhibited significant differences ($P=0.01$) as compared to the untreated controls for the Golden Delicious, Ida Red and McIntosh apple varieties. Storage time was not a significant factor in these data. Semperfresh treatment resulted in stronger differences with the Golden Delicious apple variety when compared to the other two cultivars as noted by the differences among mean intensities (Table 1). The trends for

Table 1

DIFFERENCE FROM CONTROL APPLE SENSORY TEST
SAMPLE MEANS WITH NONORTHOGONAL DESIGNED CONTRASTS[1]

Concentration Semperfresh	Variety		
	Ida Red	McIntosh	Golden Delicious
0%[2]	2.16[4a]	1.96[a]	1.82[a]
0.6%	3.84[b]	3.39[b]	4.45[b]
1.2%	3.55[b]	3.44[b]	4.35[b]

1 Within a column, means not followed by the same letter are significnatly different at P=0.01.

2 Blind control

3 Standard error of mean difference = 0.272

4 A ten point category numerical scale with verbal and anchors (0 = no difference to 10 = extreme difference)

Ida Red and McIntosh Semperfresh treated apples were similar to each other. Santerre et al. (1989), using a triangle testing procedure, detected no flavor or textural changes between 0% and 1.2% Semperfresh treated McIntosh and Golden Delicious apples following two months cold storage (5°C). There were different methods used between the Santerre et al. (1989) study and the project reported here which may account for these conflicting results. In the former investigation, fruits were stored in plastic bags following Semperfresh treatment, whereas in our study, apples were stored openly within the environmental chambers. The sensory difference methods were also dissimilar. Santerre et al. (1989) used an overall difference testing technique to measure two attributes (flavor and texture). These two attributes may not vary among the Semperfresh treated fruits as compared to the untreated controls, but product attributes not measured may be different. The small number of panelists might also be a factor in the inability to detect dissimilarities among the fruit products. Another problem may be that different physical properties were most likely used to describe the same adjective (Bourne, 1983). In addition, fruits have inherent variation in quality attributes and these can vary over a time period. The combined effects of these two sources of variation may obscure treatment variances (Smith and Churchill, 1983). In the difference from control testing method used in our study, the focus was on whether an overall difference existed between the products and to estimate the

size of any such differences. No attributes were specifically identified.

Consumer acceptability results for the effect of time across Semperfresh treatments within variety are shown in Table 2. The Ida Red cultivar demonstrated the same degree of liking (like slightly on the hedonic scale) when tested after two and three months noncontrolled atmosphere refrigerated storage. In contrast, the McIntosh apple variety exhibited a significant decrease (P=0.01) in consumer acceptability after three months storage as compared to the two months storage time period. Mean acceptability values ranged from like moderately/like slightly to like slightly on the hedonic scale. There was also some evidence to indicate the same trend in lower consumer acceptability scores over time for Golden Delicious apples (P=0.10). Again, the mean acceptability scores at two and three months revealed that the Golden Delicious apples were liked slightly.

Table 3 reveals the mean consumer acceptability values for the Semperfresh treatment effect across time within variety. The application of Semperfresh at 0.6% and 1.2% levels resulted in Golden Delicious apples having a significantly (P=0.01) improved acceptability (like slightly) over the untreated samples. However, as Semperfresh concentration increased, from 0.6% to 1.2%, the degree of liking of the Golden Delicious apples was not improved. In contrast, Semperfresh did not change the consumer acceptability of Ida Red apples. Despite the treatment, all

Table 2

CONSUMER ACCEPTABILITY MEAN SCORES WITH NONORTHOGONAL DESIGNED CONTRASTS - TIME EFFECT[1]

Storage Time	Variety		
	Ida Red	McIntosh	Golden Delicious
2 months	6.27[3a]	6.38[a]	6.20[a]
3 months	6.38[a]	5.97[b]**	5.90[b]*

1 Within a column, means not followed by the same letter are significantly different. * P=0.10; ** P=0.01.

2 Standard error of mean difference = 0.130

3 A numerical hedonic scale with verbal and anchors (1 = dislike extremely to 9 = like extremely)

Table 3

CONSUMER ACCEPTABILITY MEAN SCORES WITH
NONORTHOGONAL DESIGNED CONTRASTS - SEMPERFRESH EFFECT[1]

Concentration Semperfresh	Variety		
	Ida Red	McIntosh	Golden Delicious
0%[2]	6.34[4a]	6.01[a]	5.69[a]
0.6%	6.20[a]	6.11[ab]	6.19[b]**
1.2%	6.43[a]	6.41[b]*	6.26[b]**

[1] Within a column, means not followed by the same letter are significantly different. * P=0.05; ** P=0.01.

[2] Control

[3] Standard error of mean difference = 0.159

[4] A numerical hedonic scale with verbal and anchors (1 = dislike extremely to 9 = like extremely)

of the Ida Red apples were liked slightly. The McIntosh cultivar exhibited acceptability ratings in between the other two varieties. There were no differences between the untreated control samples and the 0.6% Semperfresh coated samples in terms of consumer acceptability (like slightly). But, when Semperfresh concentrations were increased to 1.2%, the treated McIntosh fruits demonstrated a significantly higher (P=0.05) degree of consumer acceptability as compared to the untreated controls. Golden Delicious apples were most affected by Semperfresh when compared to McIntosh apples, as noted by the level of significance.

Even though all fruit varieties treated with Semperfresh demonstrated significant differences (P=0.01) as compared to the untreated apple samples (Table 1), these differences did not influence the degree of liking of the varieties in the same manner (Table 3). The Semperfresh treatment differences did not affect the degree of liking of Ida Red apples. Whereas, the McIntosh and Golden Delicious Semperfresh treated apple differences generally resulted in the improvement of the overall acceptability ratings of the treated samples as compared to the untreated controls. These data add to the slight amount of consumer acceptability data regarding fresh fruit reported in the literature. Sensory data has demonstrated that product differences detectable by trained sensory panels can also be distinguished by untrained product users. But, additional consumer acceptability studies are required to provide

definitive information regarding what constitutes a "good quality" apple (Smith and Churchill, 1983).

Experimental Design and Data Analysis

Appropriate experimental design offers a simple and comprehensive approach to develop quality products more efficiently and at lower cost (Dziezak, 1990). Quality is one of the main reasons contributing to Japan's success in the world market and to the United States' loss of its industrial lead in the late 1970's. Quality expert Keki R. Bhote reported that costs for poor quality could be numerous due to the costs for warranty, scrap, rework, analysis, inspection and tests. Using well-designed experiments, researchers can optimize the product formulation while reducing development time and costs.

The present study followed the response surface methodology (RSM) of the optimization designs which are powerful tools helping researchers identify optimum levels of the factors investigated. These methods use quantitative data to build an empirical model that describes the relationship between each factor investigated and the response. Response surface plots provide researchers with an understanding of how they might expect the system to behave when factor levels are changed. Also, the plots suggest optimum levels of the factors needed for achieving specific product attributes. These methods have been used to predict the quality, poststorage disorders and storage life of fruit based on different independent variables such as fruit maturity, size,

weight and mineral concentration (Marmo et al., 1985; Fallahi et al., 1985; Autio et al., 1986). Sayavedra-Soto and Montgomery (1988) applied response surface contour diagrams to determine conditions necessary to maintain acceptable color in dried apples during storage under various circumstances. Our results demonstrate the models bulit from experimental data help to detect the effects of each factor, interactions between and among factors, and curvature successfully.

Some researchers use correlation to demonstrate their experimental results, however, most correlations tend to ignore group differences. For the present study, if the association between instrumental quality measurement and sensory evaluation is of interest, correlation calculated within a Semperfresh treatment should be appropriate. Because the data from instrumentation and panel are influenced by differences in concentration of treatment, if these differences are ignored, the resulting correlation will be inflated and will not properly reflect the strength of association that would occur if concentration were held constant. Therefore, it is not appropriate to have one grand correlation to explain the association interested.

CONCLUSIONS

Objective Studies

Greener skin color persisted in Semperfresh coated McIntosh, Golden Delicious and Ida Red cultivars which implied retarded fruit ripening. Semperfresh effects upon apple flesh color, tissue firmness and total acidity levels were dissimilar among the cultivars. Retarded disappearance of the flesh green color was shown by Semperfresh applied Golden Delicious and McIntosh fruits. Semperfresh did not decrease the firmness loss of Ida Red fruits. Golden Delicious and Ida Red Semperfresh treated apples had higher total acidities demonstrating delayed ripening. In addition, as storage time advanced, titratable acidity concentrations varied between and within apple cultivars. Although the influences of Semperfresh on the storage quality of apples cultivars varied, it was evident that Semperfresh delayed ripening development during storage. Therefore, the use of Semperfresh in place of CA storage remains a viable alternative to delay apple tissue senescence.

Sensory Studies

All apple varieties (Golden Delicious, Ida Red, McIntosh) treated with Semperfresh exhibited significant differences as compared to the untreated controls. However,

Semperfresh treatments did not have the same effects on each cultivar, as was apparent not only in difference testing where the Semperfresh treatment had a stronger impact on the degree of difference for the Golden Delicious cultivar, but varietal inconsistencies were indicated in the consumer acceptability studies. The application of Semperfresh to Golden Delicious apples resulted in an improvement in consumer acceptability ratings. In contrast, Semperfresh treatment did not change the degree of liking scores for Ida Red apples, and an improvement in acceptability values was seen only when the highest Semperfresh concentration was used for the McIntosh fruits. Apple varietal differences were also apparent when focusing upon the effect of time across Semperfresh treatments within variety in terms of consumer acceptability. The Ida Red cultivar during two and three months storage time demonstrated the same degree of liking. In contrast, the McIntosh and Golden Delicious varieties exhibited lower ratings for degrees of liking for prolonged storage times.

Future studies should employ descriptive sensory analysis to determine the cultivar attribute differences and their positive and negative influences upon consumer acceptability scores. Descriptive techniques would also give insight into what consumers desire in a "good quality" apple and aid in focusing upon these critical attributes for future apple sensory investigations. In addition, base line information is needed to determine differences and consumer liking of apple cultivars at time zero and how Semperfresh

treated apples compare, chemically, physically and sensorially to the wax coated varieties currently marketed.

APPENDICES

APPENDIX A

ANALYSIS OF VARIANCE

FOR OBJECTIVE AND SENSORY EVALUATIONS

Table A.1. ANOVA for External Hunter L_L Value Measurement

Sources	DF	SS	MS	F	Prob.
A (time)	2	32.92	16.458	1.27	> 0.10
B (variety)	2	6293.42	3146.712	243.46	< 0.001
AB	4	115.13	28.782	2.23	< 0.10
C (SPE conc.)	3	84.71	28.236	2.18	> 0.10
AC	6	154.34	25.724	1.99	< 0.10
BC	6	63.44	10.573	0.82	> 0.50
ABC	12	150.51	12.542	0.97	> 0.25
Error	36	465.29	12.925		

Table A.2. ANOVA for External Hunter A_L Value Measurement

Sources	DF	SS	MS	F	Prob.
A (time)	2	20.49	10.244	0.80	> 0.25
B (variety)	2	6822.30	3411.149	267.35	< 0.001
AB	4	123.77	30.943	2.43	< 0.10
C (SPE conc.)	3	189.24	63.079	4.94	< 0.01
AC	6	83.74	13.957	1.09	> 0.25
BC	6	34.67	5.778	0.45	> 0.50
ABC	12	138.95	11.579	0.91	> 0.50
Error	36	459.33	12.759		

Table A.3. ANOVA for External Hunter B_L Value Measurement

Sources	DF	SS	MS	F	Prob.
A (time)	2	18.69	9.347	2.08	> 0.10
B (variety)	2	3801.52	1900.759	422.20	< 0.001
AB	4	34.26	8.566	1.90	> 0.10
C (SPE conc.)	3	29.96	9.986	2.22	> 0.10
AC	6	40.90	6.816	1.51	> 0.10
BC	6	11.33	1.888	0.42	> 0.50
ABC	12	66.36	5.530	1.23	> 0.25
Error	36	162.06	4.502		

Table A.4. ANOVA for External Hunter Hue Angle Measurement

Sources	DF	SS	MS	F	Prob.
A (time)	2	25.04	12.520	0.12	> 0.50
B (variety)	2	43796.00	21897.999	207.84	< 0.001
AB	4	1022.28	255.570	2.43	< 0.10
C (SPE conc.)	3	1072.69	357.565	3.39	< 0.05
AC	6	530.65	88.441	0.84	> 0.50
BC	6	167.62	27.937	0.27	> 0.50
ABC	12	981.01	81.751	0.78	> 0.50
Error	36	3792.93	105.359		

Table A.5. ANOVA for External Hunter Chroma Measurement

Sources	DF	SS	MS	F	Prob.
A (time)	2	23.89	11.943	2.49	= 0.10
B (variety)	2	2221.49	1110.743	231.89	< 0.001
AB	4	7.09	1.772	0.37	> 0.50
C (SPE conc.)	3	20.95	6.983	1.46	> 0.10
AC	6	36.13	6.022	1.26	> 0.25
BC	6	40.57	6.762	1.41	> 0.10
ABC	12	75.32	6.277	1.31	> 0.25
Error	36	172.43	4.790		

Table A.6. ANOVA for Internal Hunter L_L Value Measurement

Sources	DF	SS	MS	F	Prob.
A (time)	2	50.78	25.389	9.31	< 0.001
B (variety)	2	78.25	39.127	14.35	< 0.001
AB	4	59.78	14.944	5.48	< 0.005
C (SPE conc.)	3	38.80	12.933	4.74	< 0.01
AC	6	32.40	5.400	1.98	< 0.10
BC	6	18.45	3.074	1.13	> 0.25
ABC	12	54.57	4.548	1.67	> 0.10
Error	36	98.17	2.727		

Table A.7. ANOVA for Internal Hunter A_L Value Measurement

Sources	DF	SS	MS	F	Prob.
A (time)	2	4.05	2.026	2.89	< 0.10
B (variety)	2	77.36	38.680	55.18	< 0.001
AB	4	8.59	2.147	3.06	< 0.05
C (SPE conc.)	3	9.33	3.111	4.44	< 0.01
AC	6	7.67	1.278	1.82	> 0.10
BC	6	3.41	0.568	0.81	> 0.50
ABC	12	16.75	1.396	1.99	< 0.10
Error	36	25.23	0.701		

Table A.8. ANOVA for Internal Hunter B_L Value Measurement

Sources	DF	SS	MS	F	Prob.
A (time)	2	23.83	11.915	15.37	< 0.001
B (variety)	2	707.76	353.882	456.62	< 0.001
AB	4	5.14	1.286	1.66	> 0.10
C (SPE conc.)	3	3.95	1.317	1.70	> 0.10
AC	6	7.44	1.240	1.60	> 0.10
BC	6	6.31	1.052	1.36	> 0.25
ABC	12	9.18	0.765	0.99	> 0.25
Error	36	27.89	0.775		

Table A.9. ANOVA for Internal Hunter Hue Angle Measurement

Sources	DF	SS	MS	F	Prob.
A (time)	2	176.09	88.044	1.90	> 0.10
B (variety)	2	1450.00	725.002	15.61	< 0.001
AB	4	83.18	20.796	0.45	> 0.50
C (SPE conc.)	3	106.82	35.608	0.77	> 0.50
AC	6	129.14	21.524	0.46	> 0.50
BC	6	452.01	75.335	1.62	> 0.10
ABC	12	392.47	32.706	0.70	> 0.50
Error	36	1671.87	46.441		

Table A.10. ANOVA for Internal Hunter Chroma Measurement

Sources	DF	SS	MS	F	Prob.
A (time)	2	21.54	10.770	13.67	< 0.001
B (variety)	2	696.55	348.276	441.97	< 0.001
AB	4	4.65	1.163	1.48	> 0.10
C (SPE conc.)	3	3.24	1.081	1.37	> 0.10
AC	6	6.98	1.163	1.48	> 0.10
BC	6	6.46	1.077	1.37	> 0.10
ABC	12	8.65	0.721	0.91	> 0.50
Error	36	28.37	0.788		

Table A.11. ANOVA for Firmness Measurement

Sources	DF	SS	MS	F	Prob.
A (time)	2	145.63	72.814	69.68	< 0.001
B (variety)	2	694.16	347.078	332.13	< 0.001
AB	4	19.89	4.971	4.76	< 0.005
C (SPE conc.)	3	84.16	28.055	26.85	< 0.001
AC	6	53.65	8.942	8.56	< 0.001
BC	6	9.38	1.563	1.50	> 0.10
ABC	12	30.82	2.568	2.46	< 0.01
Error	108	112.85	1.045		

Table A.12. ANOVA for Shear Force Measurement

Sources	DF	SS	MS	F	Prob.
A (time)	2	5.97	2.983	5.32	< 0.01
B (variety)	2	148.42	74.211	132.28	< 0.001
AB	4	1.03	0.258	0.46	> 0.50
C (SPE conc.)	3	0.25	0.083	0.15	> 0.50
AC	6	9.73	1.622	2.89	< 0.05
BC	6	3.89	0.648	1.16	> 0.25
ABC	12	6.16	0.514	0.92	> 0.50
Error	36	40.38	0.561		

Table A.13. ANOVA for Total Acidity Measurement

Sources	DF	SS	MS	F	Prob.
A (time)	2	155.86	77.931	53.97	< 0.001
B (variety)	2	698.36	349.181	241.82	< 0.001
AB	4	371.89	92.972	64.39	< 0.001
C (SPE conc.)	3	385.67	128.556	89.03	< 0.001
AC	6	420.58	70.097	48.54	< 0.001
BC	6	123.08	20.514	14.21	< 0.001
ABC	12	419.67	34.972	24.22	< 0.001
Error	36	52.00	1.444		

Table A.14. ANOVA for Soluble Solids Measurement

Sources	DF	SS	MS	F	Prob.
A (time)	2	2.22	1.111	0.65	> 0.50
B (variety)	2	78.47	39.234	23.11	< 0.001
AB	4	7.49	1.873	1.10	> 0.25
C (SPE conc.)	3	6.37	2.122	1.25	> 0.25
AC	6	37.43	6.239	3.67	< 0.01
BC	6	12.74	2.123	1.25	> 0.25
ABC	12	13.47	1.122	0.66	> 0.50
Error	36	61.13	1.698		

Table A.15. Difference from Control Test

Sources	DF	SS	MS	F	Prob.
A (time)	1	6.39	6.390	0.269	> 0.50
B (variety)	2	81.41	40.707	7.629	< 0.001
AB	2	15.12	7.559	0.503	> 0.50
C (SPE conc.)	2	995.49	497.746	93.280	< 0.001
AC	2	8.73	4.367	0.818	> 0.25
BC	4	79.84	19.960	3.741	< 0.005
ABC	4	36.68	9.171	1.719	> 0.10
D (panelist)	23	1968.35	85.580	16.038	
E (repetition)	2	55.75	27.876	5.224	
AE	2	47.57	23.783	2.349	
ABE	4	60.11	15.029	2.817	
ADE	46	465.80	10.126	1.898	
Error	1201	6408.80	5.336		

Table A.16. Consumer Acceptance Test

Sources	DF	SS	MS	F	Prob.
A (time)	1	16.81	16.806	3.850	< 0.10
B (variety)	2	20.61	10.305	2.361	< 0.10
AB	2	20.43	10.217	2.341	< 0.10
C (SPE conc.)	2	33.67	16.834	1.502	> 0.25
AC	2	18.49	9.246	1.596	> 0.25
BC	4	21.43	5.358	2.341	< 0.10
ABC	4	6.10	1.525	0.242	> 0.50
D (panelist)	522	2278.34	4.365	1.907	
E (repetition)	2	2.26	1.130	0.259	
CE	4	44.82	11.206	4.896	
ACE	4	23.17	5.793	2.531	
ABCE	8	50.42	6.302	2.753	
Error	1062	2430.73	2.289		

APPENDIX B

SUMMARY OF REGRESSION MODELS - OBJECTIVE MEASUREMENTS

(SAS, 1985)

Table B.1. Regression Models for Golden Delicious Apples

Dependent Var. (Y)	Independent Var. (X_1, X_2, X_1X_2, X_1^2, X_2^2)[1]	Prediction Equation	R^2	C(P)
Hunter A_L Value (Skin)	X_1	$Y=-1.14-3.42X_1$	0.98	1.07
Hunter Hue Angle (Skin)	X_1	$Y=92.37+5.95X_1$	0.97	1.08
Hunter A_L Value (Flesh)	X_2, X_1^2	$Y=-4.66+0.71X_2 -0.93X_1^2$	0.60	0.76
Hunter L_L Value (Flesh)	X_2, X_2^2	$Y=62.52+4.07X_2 -0.50X_2^2$	0.73	2.23
Puncture Pressure	X_1, X_2	$Y=18.84+2.16X_1 -1.57X_2$	0.77	3.73
Total Acidity	X_1, X_1X_2	$Y=29.29+18.55X_1 -4.71X_1X_2$	0.56	2.13

1. X_1: Semperfresh Concentration (%); X_2: Storage Time (month)

Table B.2. Regression Models for Ida Red Apples

Dependent Var. (Y)	Independent Var. (X_1, X_2, X_1X_2, X_1^2, X_2^2)[1]	Prediction Equation	R^2	C(P)
Hunter A_L Value (Skin)	X_1	$Y=22.92-4.73X_1$	0.85	1.13
Hunter Hue Angle (Skin)	X_1^2	$Y=32.54+7.48X_1^2$	0.85	1.12
Puncture Pressure	X_2	$Y=23.40-1.30X_2$	0.68	2.32
Total Acidity	X_1^2	$Y=37.54+4.41X_1^2$	0.16	3.06

1. X_1: Semperfresh Concentration (%); X_2: Storage Time (month)

2. No independent variables met the 0.2 significance level for entry into the models of flesh Hunter A_L and L_L values.

Table B.3. Regression Models for McIntosh Apples

Dependent Var. (Y)	Independent Var. (X_1, X_2, X_1X_2, X_1^2, X_2^2)[1]	Prediction Equation	R^2	C(P)
Hunter A_L Value (Skin)	X_1^2	$Y=4.86-2.41X_1^2$	0.94	6.29
Hunter Hue Angle (Skin)	X_1^2	$Y=72.37+9.09X_1^2$	0.94	6.52
Hunter A_L Value (Flesh)	X_1	$Y=-3.12-0.95X_1$	0.31	11.14
Hunter L_L Value (Flesh)	X_2, X_2^2	$Y=41.56+17.78X_2 -2.86X_2^2$	0.96	2.29
Puncture Pressure	X_1, X_1^2, X_1X_2	$Y=13.06+7.81X_1 -2.42X_1^2-1.24X_1X_2$	0.66	2.73
Total Acidity	X_2^2	$Y=41.42-0.69X_2^2$	0.64	-0.46

1. X_1: Semperfresh Concentration (%); X_2: Storage Time (month)

APPENDIX C

WORKSHEETS AND QUESTIONNARIES FOR SENSORY EVALUATIONS

Table C.1. Overall Worksheet for Difference from Control Test

Date Jan. 5-11, 1990 No. 1-9

Type of samples: Fresh apple slices
Type of test: Difference from control test

Sample	Description	Serving code
I(C)	Idared-control	C, 788, 284, 479
I(0.6)	Idared-0.6% SPE	521, 631, 168
I(1.2)	Idared-1.2% SPE	162, 915, 135
M(C)	McIntosh-control	C, 544, 273, 409
M(0.6)	McIntosh-0.6% SPE	699, 731, 331
M(1.2)	McIntosh-1.2% SPE	854, 642, 824
G(C)	Golden Delicious-control	C, 366, 970, 612
G(0.6)	Golden Delicious-0.6% SPE	474, 324, 118
G(1.2)	Golden Delicious-1.2% SPE	506, 658, 692

Table C.2. Serving Orders for Difference from Control Test

Variety	Run1 M	Run2 G	Run3 I	Run4 M	Run5 I	Run6 G	Run7 I	Run8 M	Run9 G
Subj.#									
1-4	C-544	C-366	C-788	C-642	C-284	C-324	C-479	C-331	C-118
	C-699	C-506	C-162	C-731	C-915	C-970	C-168	C-409	C-692
	C-854	C-474	C-521	C-273	C-631	C-658	C-135	C-824	C-612
5-8	C-699	C-506	C-162	C-273	C-915	C-658	C-168	C-331	C-692
	C-544	C-366	C-788	C-642	C-284	C-970	C-135	C-824	C-612
	C-854	C-474	C-521	C-731	C-631	C-324	C-479	C-409	C-118
9-12	C-854	C-474	C-162	C-642	C-631	C-970	C-135	C-409	C-612
	C-544	C-366	C-521	C-273	C-915	C-324	C-479	C-824	C-692
	C-699	C-506	C-788	C-731	C-284	C-658	C-168	C-331	C-118
13-16	C-544	C-366	C-521	C-731	C-915	C-658	C-479	C-409	C-692
	C-854	C-474	C-162	C-273	C-631	C-324	C-135	C-331	C-118
	C-699	C-506	C-788	C-642	C-284	C-970	C-168	C-824	C-612
17-20	C-699	C-506	C-788	C-731	C-631	C-970	C-168	C-824	C-118
	C-854	C-474	C-521	C-642	C-284	C-658	C-479	C-331	C-612
	C-544	C-366	C-162	C-273	C-915	C-324	C-135	C-409	C-692
21-25	C-854	C-474	C-521	C-273	C-284	C-324	C-135	C-824	C-612
	C-699	C-506	C-788	C-731	C-631	C-658	C-168	C-409	C-118
	C-544	C-366	C-162	C-642	C-915	C-970	C-479	C-331	C-692

Table C.3. Worksheet for Difference from Control Test

Date Jan. 5. 1990 No. 1

Type of samples: Fresh apple slices
Type of test: Difference from Control test

Sample	Description	Serving code
M(C)	McIntosh-control	C, 544
M(0.6)	McIntosh-0.6% SPE	699
M(1.2)	McIntosh-1.2% SPE	854

Serving orders:

	Subject #					
Set #	1-4	5-8	9-12	13-16	17-20	21-25
1	C-544	C-699	C-854	C-544	C-699	C-854
2	C-699	C-544	C-544	C-854	C-854	C-699
3	C-854	C-854	C-699	C-699	C-544	C-544

Notes:

Container used: plastic cup (without cover)
Amount of apple/container: 1 slice
Slice apples by knife into 1 inch thick segments
Serving temperature: room temperature
Prepare napkins, water cups, spit cups, sample cups (labeled) and put on trays
Use pitcher to get deionized water from laboratory
Turn on the light of the booths
Serve samples according to the set number sequence from left to right

Table C.4. Overall Worksheet for Consumer Acceptance Test

Date Jan. 16-18, 1990 No. 1-9

Type of samples: Fresh apple slices
Type of test: Consumer acceptance test

Sample	Description	Serving code
I(C)	Idared-control	299, 374, 337
I(0.6)	Idared-0.6% SPE	537, 436, 192
I(1.2)	Idared-1.2% SPE	989, 772, 728
M(C)	McIntosh-control	866, 651, 400
M(0.6)	McIntosh-0.6% SPE	529, 995, 728
M(1.2)	McIntosh-1.2% SPE	916, 285, 646
G(C)	Golden Delicious-control	616, 350, 541
G(0.6)	Golden Delicious-0.6% SPE	344, 768, 815
G(1.2)	Golden Delicious-1.2% SPE	451, 265, 248

Table C.5. Serving Orders for Consumer Acceptance Test

	Run1	Run2	Run3	Run4	Run5	Run6	Run7	Run8	Run9
Variety	I	G	M	M	I	G	M	G	I
Subj.#									
1-5	537	344	866	285	436	265	400	815	337
	299	616	529	651	374	350	646	248	728
	989	451	916	995	772	768	728	541	192
6-10	299	616	866	651	772	768	728	541	192
	989	344	916	285	374	350	400	248	337
	537	451	529	995	436	265	646	815	728
11-15	989	616	529	995	772	768	646	541	192
	537	451	866	285	436	265	728	815	728
	299	344	916	651	374	350	400	248	337
16-20	989	451	916	651	374	350	728	815	337
	299	616	866	995	436	265	646	541	192
	537	344	529	285	772	768	400	248	728
21-25	537	344	916	285	374	265	400	248	728
	989	451	529	995	772	768	728	541	192
	299	616	866	651	436	350	646	815	337
26-30	299	451	529	995	436	350	646	248	728
	537	344	916	651	772	768	400	815	337
	989	616	866	285	374	265	728	541	192

Table C.6. Worksheet for Consumer Acceptance Test

Date Jan. 16. 1990 No. 1

Type of samples: Fresh apple slices
Type of test: Consumer acceptance test

Sample	Description	Serving code
I(C)	Ida red-control	299
I(0.6)	Ida red-0.6% SPE	537
I(1.2)	Ida red-1.2% SPE	989

Serving orders:

	Subject #					
Sample #	1-5	6-10	11-15	16-20	21-25	26-30
1	537	299	989	989	537	299
2	299	989	537	299	989	537
3	989	537	299	537	299	989

Notes:
Container used: plastic cup (without cover)
Amount of apple/container: 1 slice
Slice apples by knife into 1 inch thick segments
Serving temperature: room temperature
Prepare napkins, water cups, spit cups, sample cups (labeled) and put on trays
Use pitcher to get deionized water from laboratory
Turn on the light of the booths (white light)
Serve samples according to the sample number sequence from left to right

Table C.7. Questionnaire for Difference from Control Test

APPLE DIFFERENCE FROM CONTROL TEST

Name: _____ Date _____ Test # _____
Panelist # _____

INSTRUCTIONS:

1. Before tasting the samples **and** between each sample, rinse your mouth with water.

2. You have received three sets of samples. For each set, there is a control sample labeled **C** and a test sample labeled with a 3-digit number behind this sample.

3. Taste the first set of samples in front of you beginning on the left side of your tray. Taste the sample marked **C** first, then taste the sample marked with the three digit code. Follow the same sequence for the remaining two sets. You may either swallow or spit out the samples (spit cup provided).

4. Indicate the size of the **overall sensory difference**, relative to the control, on the scale below.
   0 = no difference
   1
   2
   3
   4
   5
   6
   7
   8
   9
   10 = extreme difference

5. **Some of the test samples may be the same as the control!**

SET	CODE	SIZE OF OVERALL SENSORY DIFFERENCE
1	C	
	_____	_____
2	C	
	_____	_____
3	C	
	_____	_____

COMMENTS :

Table C.8. Questionnaire for Consumer Acceptance Test

APPLE ACCEPTANCE TEST

Name: _____ Date _____ Test # _____
Panelist # _____

INSTRUCTIONS:

1. Before tasting the samples **and** between each sample, rinse your mouth with water.

2. You have received three samples. For each sample, it is labeled with a 3-digit number.

3. Taste the samples in the order listed on your questionnaires.
   You may either swallow or spit out the samples (spit cup provided).

4. Rate how you feel **overall** about the sample using the scale below.

   9 = Like extremely
   8 = Like very much
   7 = Like moderately
   6 = Like slightly
   5 = Neither like not dislike
   4 = Dislike slightly
   3 = Dislike moderately
   2 = Dislike very much
   1 = Dislike extremely

CODE	**SCORE**
_____	_____

5. What are some of your reasons for this rating?

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