THE EFFECTS OF INCORPORATING SILICA GEL IN POLYOLEFIN FILM PACKAGE ON THE SHELF LIFE AND QUALITY OF COLD STORED STRAWBERRIES

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CHAPTER I

INTRODUCTION

Strawberries (*Fragaria ananassa*) are a very perishable crop, (Wills et al., 1989) and their shelf life is limited to only few days under good refrigerated storage condition ($-5^{\circ}C$ - $+5^{\circ}C$) (Luoto, 1984). During storage, the quality of strawberries goes through a fast deterioration process. Quality is a very important factor since it plays a major role in determining the acceptability of the fruit. Color, texture, flavor, and nutritional value are the four major factors that determine the quality of strawberries.

Color

Of the three major types of pigments (chlorophyll, carotenoids, and anthocyanins) found in strawberries, anthocyanins are the ones that give strawberries their characteristic red color. Anthocyanins which belong to the flavonoids, are a large group of water soluble pigments that are responsible for the various shades of blue and red of many fruits. Anthocyanins are polyphenol substances composed of glycosides of anthocyanidins, which have a flavylium cation structure differing in the position and number of methylated or free hydroxyl groups (Eskin, 1979).

Anthocyanins are very unstable pigments and deteriorate to produce brown-colored products that are water insoluble. These changes occur during thawing of frozen fruits and during storage and processing of fresh strawberries for the production of preserves, purees, juices, concentrates, and wine (Wrolstad et al., 1980).

The loss of the pigments is mainly due to the hydrolysis of unstable aglycones (Markakis, 1975), the formation of intermediaries which are formed during the copolymerization with melanin or during the nonenzymatic browning (Chichester and Mc Feeters, 1971), the formation of copigment complexes with heavy metals, flavonoids and other compounds ending up in bathochromic changes (Markakis, 1975), and the high pH and temperatures which are responsible for the development of unstable products such as chalcones, quinoidal bases, and carbinol pseudo bases (Brouillard, 1982).

The two main anthocyanin pigments present in strawberries are pelargonidin-3-glucoside (PGN) and cyanidin-3-glucoside (CYN). PGN accounts for 72% to 95% of the total anthocyanins (Wrolstad and Erlandson, 1973).

Color inestability creates a great problem for stored fresh strawberries and processed strawberry products. Factors that are responsible for the color loss in isolated strawberry pigments and juice are temperature of storage and O_2 content (Nebesky et al., 1949). Ke et al., 1991, demonstrated that storage of strawberries at 0°C and 5°C under modified atmosphere containing 20% CO_2 had no significant effects on the fruits' color. However, when the CO_2 content of the atmosphere increased to 50 and 80% the red color in Selva strawberries was lightly reduced.

Texture

Texture is the structural feature of vegetables and fruits. The textural properties of strawberries which include firmness, wholeness, mushiness, seediness, and softness, is influenced by genetical and environmental factors such as cultivar, stage of maturity, size, and methods of harvesting, handling, preparation, and processing (Sistrunk and Morris, 1985). Changes in firmness of strawberries during senescence and in the absence of polygalacturonase is linked to the changes in the ionic stability of the middle lamella (Clarkson and Hanson, 1980). In the middle lamella, divalent calcium ions (Ca^{++}) occur and form crosslinks between the carboxylic groups of adjacent polyuronide chains (Van Buren, 1974). Softening of strawberries tissues may be caused by the chelation of such divalent calcium ions (Main et al., 1986).

The maintenance of textural properties of strawberries has been one of the major problems for strawberry producers (Sistrunk and Moore, 1967). It has been found that dipping strawberries in divalent solutions of calcium, copper, or magnesium is effective in refirming the tissue. Baker (1941) found that copper sulfate, calcium chloride, and ferric chloride presented good results in frozen strawberries when were used by themselves after or before treating the fruits with low methoxyl pectin. Morris et al., (1985) found out that immersing the strawberries in a 1% citric acid and 0.5% calcium lactate or a 0.5% calcium lactate solutions for one minute improved the firmness of processed and frozen fruits. However, calcium dips were more efficient in firming sliced berries than whole ones.

Ke et al., (1991), showed that fruits stored in modified atmospheres containing 20%, 59%, and 80% CO_2 at 0°C or 5°C were firmer than those stored in air under the same refrigerated conditions. However, after 8 days of storage, fruits stored in 50% and 80% CO_2 showed CO_2 injury.

Flavor

Flavor consists of two factors: aroma and taste. Aroma is produced by the stimulation of the olfatory senses with volatile organic compounds. These volatile compounds are found in the oil fraction which represents 7% of the total essence of strawberries (Sistrunk and Morris, 1985). The most important volatile components that have been isolated and identified are ethyl and methyl butanoate, trans-2-hexenyl acetate, methyl and ethyl hexanoate, 2,5-dimethyl-4-methoxy-3(2H)-furanone, trans-2-hexen-1-ol, and trans-2-hexenyl. The concentration of these compounds depend to a great deal on the condition of the fruits, cultivar, and growing conditions (Schreier, 1980). In general, the concentration of the aromatic compounds are decreased by freezing temperatures. However, the amounts of 2,5-dimethyl-4-methoxy-3(2H)-furanone was found to be higher in frozen fruits than in fresh ones (Sistrunk and Morris, 1985).

There are other volatile compounds, the C_6 elements, which are called secondary aroma components. They are so named because they are not formed in the fresh fruits but formed as a result of the rupture of the tissue by enzymatic-oxidative division of linolenic and linoleic acids in the existence of oxygen (Schreier 1980).

Taste is the human sensation provoked by chemicals in the mouth. The principal sensations are salty, sweet, bitter and sour tastes. In vegetables and fruits, taste is generally determined by the amount and type of organic acids, carbohydrates, phenols, amino acids, and lipids (Martens and Baardseth, 1987).

The total acidity of strawberries, ranges from 0.57 to 2.26% and the pH is around 3.26. The main organic acid present in strawberries is citric acid (10-18 meq) followed by malic acid (1-3 meq), quinic acid (0-1 meq), and succinic acid (0-1 meq)/100 g of fruits (Hulme, 1970).

The total sugar content of strawberries, is 5.00% and the sugar/acid ratio is 5.3. The main sugars present in strawberries are glucose, fructose, and sucrose which form 2.59%, 2.32%, and 1.30% by weight of edible portion, respectively (Widdowson and Mc Cance, 1935). The composition of sugars in strawberries, changes after freezing and thawing. During thawing, up to 70% of sucrose is inverted into glucose and fructose as a result of invertase activity. This conversion of sucrose to monosaccharides can be minimized by rapid thawing (Skrede, 1983).

The term tannins includes complex polyphenolic materials as well as the leucoanthocyanins. The total amount of tannins present in strawberries is 0.11 - 0.15%. The main tannin present in both unripe and ripe strawberries are the glycosylated leucoanthocyanidins (Co and Markakis, 1968). There have been different reports about the amounts and types of amino acids present in strawberries. Generally, the predominant amino acids are glutamine and asparagine.

Guadagni et al., (1961) stated that changes in the flavor of frozen strawberries, occur when they are stored at or above -18°C. Winter and Trantanella (1959), reported that gas-tight packages are very important in the prevention of oxidative changes in flavor, ascorbic acid, and color of fresh strawberries. An off-flavor was detected in frozen strawberries that were dipped in $CaCl_2$ solution before freezing (Sidwell and Cain, 1955). However, no objectionable flavor was detected when alginates and low and high methoxy pectins were added to frozen strawberries in order to improve their texture (Sistrunk and Morris, 1985).

Siriphanich (1980) reported that strawberries which were stored in atmosphere enriched with 20% CO_2 have a pH and soluble solids content higher than those stored in air. El-Kazzaz et al., (1983) did not find any differences in titratable acidity and soluble solids content between fruits which were stored in air and those stored under controlled atmospheres consisting of 2.3% O_2 + 5% CO_2 and air + 15% CO_2.

Nutritive Value

Nutritive values of fruits are very important for the health of every individual. However, nutrition is probably the least important feature considered by the consumer when purchasing a commodity. Two very important nutritional components of fruits and vegetables are vitamins and minerals (Zagory and Kader, 1989). The most important vitamin present in strawberries is vitamin C or ascorbic acid. The typical average value of ascorbic acid in strawberries is 60mg in 100g of fruits (Hulme, 1958). Other vitamins which are also present but in much less amount are thiamine, riboflavin, nicotinic acid, and carotene (Watt and Merrill, 1963). The minerals that are present in strawberries are calcium, phosphate, potassium, magnesium, sodium, sulfur, iron, and others (McCance and Widdowson, 1960).

The purpose of this study was to extend the shelf life and maintain the quality of fresh refrigerated strawberries.

Objective

1. To maintain the quality and extend the shelf life of refrigerated fresh strawberries by packaging the fruits in polypropline trays and wrapping the trays with polyolefin film.
2. To maintain the quality and extend the shelf life of refrigerated fresh strawberries by incorporating hygroscopic material (silica gel) in their packages.

Hypothesis

1. Maintaining the quality and extending the shelf life of refrigerated fresh strawberries can not be achieved by packaging the fruits in polyproline trays and wrapping the trays with polyolefin film.
2. Maintaining the quality and extending the shelf life of refrigerated fresh strawberries can not be achieved by incorporating hygroscopic material (silica gel) in their packages.

CHAPTER II

MATERIALS AND METHODS

Raw Materials

Fresh strawberries (Cardinal cultivar) were obtained from Bixby Vegetable Research Station. Fruits were hand picked and transferred (100Km) to the department of Nutritional Sciences OSU, Stillwater, Oklahoma. Upon arrival, fruits were inspected and injured, mishaped, or blemished fruits were discarded. Sound fruits were washed with tap water and desinfected from vegetative microorganisms by soaking in a 100ppm chlorine solution for ten minutes. Fruits were then dewatered on paper towels with a current of air from a fan to remove surface moisture.

Treatments

Thirty six polypropeline trays were fitted with five mesh plastic screen mounted on a wooden frame (5mm in thickness) were used to conduct this experiment. The trays were randomly coded and weighed. Two hundred grams of fruits were randomly obtained and placed on the top of the mesh screen inside the trays. Twelve trays were wrapped with low density polyolefin film (75 gauge; oxygen permeability of 0.5624 $cc/cm^2/24hr$; water vapor transmission rate of 1.928 $g/cm^2/24hr$) and sealed with a heat impulse sealer. To another twelve trays, 50 grams of dry silica gel were placed under the mesh screen and wrapped with low density polyolefin film. The remaining twelve trays were used as a control without any wraps or treatment. All the trays were placed in a cooler at $4^{\circ}C$ with 85-90% of relative humidity.

Quality Evaluation

Three trays of each treatment were randomly pulled out from the cold storage on days 0, 5, 10, and 15 for quality evaluation.

Determination of Weight Loss. Strawberries were weighed and the percentage of weight loss was determined.

Percentage of Rotten Fruit. Strawberries were visually inspected and the percentage of spoiled fruits was calculated.

Color. A Minolta Chroma Meter (Series CR-200) was used to measure the tristimulus L^*, a^*, and b^* (Trail and et al., 1992) after calibration with a white standard tile (L=97.78, a= -0.69, and b= 2.31). Ten measurements were obtained on ten different areas of each fruit.

Texture. A Food Technology Corporation Texture System (model T-1200G equipped with shear compression cell model

CS-2) was used to determined the texture of the fruit. The cell was equipped with ten blades. Each moveable blade of the shear compression cell was 3.178 mm thick and the speed of the stroke was held constant at 30 sec. The peak force required to shear and compress 50g of fresh refrigerated strawberries was recorded (Gonzalez et al., 1989).

Soluble Solids. The percentage of soluble solids was directly read using an Abbe refractometer equipped with a refrigerated, circulation pump at 20°C (Pomeranz and Meloan, 1978).

pH and Total Acidity. Ten grams of fruits were placed in a waring blender and 90 ml of distilled water were added, then blended for 1 min at low speed and 2 min at high speed. The pH was directly determined by using a pH meter (Sargent Welch pH 8200) equipped with a glass electrode. The total acidity was obtained by titrating the previously prepared blended samples with 0.1 N NaOH solution to a pH of 8.1. The amount of total acidity was expressed as percentage of citric acid using the following formula:

$$\text{Total Acidity} = \frac{\text{ml of NaOH} \times \text{N} \times \text{eq. of citric acid}}{\text{sample size} \times 1000} \times 100$$

Total Anthocyanins. Total anthocyanins was determined by using the method of Fuleki and Francis (1968) as modified by Lundergan and Moore (1975). The anthocyanins were extracted by blending 25 g of the fruits with a 100 ml of 1% oxalic acid solution in a waring blender for 1 min at high speed, the extract was filtered through a Whatman filter paper #1. One ml of the filtered extract was mixed with 9 ml of acidified alcohol (131 parts of distilled water: 850 parts of 95% ethanol: 19 parts of concentrated HCl). The optical density of the mixture was determined using a Gilford (Response model) spectrophotometer at a wavelength of 500 nm. The percentage of total anthocyanins was calculated by using the following formula (Fuleki and Francis, 1968):

$$T\ Acy \text{ in mgs per } 100g = OD \times DV \times 100/SV \times TEV/StW \times 1/98.2$$

Where:

T Acy= Total Anthocyanins.

OD = The absorbancy reading of diluted sample (1 cm cell).

DV = The volume in mls of diluted extract prepared for the O.D. measurement.

SV = Sample volume or the volume of extract used for the absorbancy measurement.

TEV = Total extract volume. The total volume of the extract in mls obtained from the strawberry sample used for extraction.

StW = Strawberry weight.

Respiration Rate. An infrared gas analyzer (Horiba PIR 2000) was used to measure carbon dioxide production and calculate the respiration rate (Freeman and Sistrunk, 1978). Subsamples (50g) of each sample were placed in 1 L jars and the jars were placed in a refrigerator at 4°C. After 30 min, 1 ml of the atmospheric air of each jar was removed to determine the respiration rate. Respiration rate was calculated in mls of Carbon Dioxide per kg hr by using the following formula:

$$\text{Respiration Rate} = \frac{(CO_2\text{ppm} - CO_2\text{ppm ambient}) \times K \times \text{Time(hr)}}{1000}$$

$$K = \text{Vol. of container} = \frac{(480\text{ ml} - \text{St W})}{\text{St W}}$$

Statistical Analysis

At the end of the experiment, data were collected and statistically analyzed using analysis of variance (ANOVA) and Duncan's Multiple Range tests procedures (SAS Institute Inc., 1985).

CHAPTER III

RESULTS & DISCUSSION

In general, weight loss of cold stored strawberries at 4°C increased with storage time (Fig. 1). The results (Table 1) indicates that strawberries stored in open containers lost about 20.44% of their weight at day 15 of storage. However, strawberries wrapped with polyolefin film lost only about 0.5% of their weight and strawberries wrapped with polyolefin film after incorporating silica gel inside the packages lost about 4.19% of their weight after 15 days of storage at 4°C. There were no significant differences ($P \leq 0.05$) in weight loss between strawberries wrapped with polyolefin film and strawberries wrapped with polyolefin film after incorporating silica gel inside the packages. However, the weight loss of strawberries stored in open containers was significantly higher ($P \leq 0.05$) than those wrapped and wrapped with silica gel. The significant reduction in the weight loss of wrapped and silica gel's strawberry treatments was due to the use of the polyolefin film which created microenvironments inside the packages that were saturated with water vapor resulting in minimizing fruit shrinkage (Hardenburg, 1971).

Storing strawberries in open containers, wrapping the containers with polyolefin film and incorporating silica gel inside the packages before wrapping with polyolefin film had no significant effects on the fruits' pH. However, the pH of strawberries for all the previously mentioned treatments dropped significantly on day 10 and then increased to the level of days 0 and 5 after 15 days of storage (Table 2). This may be due to the advance in ripeness of the berries during storage. These results disagree with findings of Chingying and Kader (1989) and Ke et al., (1991) which show no significant difference in the pH of strawberries stored in air or under modified atmosphere conditions of elevated CO_2 for 10 days at 5°C.

Wrapping with polyolefin film and incorporating silica gel inside the packages had no significant effects on the total acidity of cold stored strawberries (Table 3). This result is in aggreement with El Kazzaz et al., (1983) who reported no significant differences in the titratable acidity between strawberries stored under controlled atmosphere (air + 15% CO_2 or 2.3 % O_2 + 5% CO_2) conditions and those kept in air after 21 days of storage at 3.3°C.

Texture is an important quality factor that consumers take into consideration when buying fresh produce. The texture of cold stored strawberries were not significantly affected by storing the fruits in open containers, wrapping the containers with polyolefin film or incorporating silica gel inside the packages (Table 4). This might be due to the low pH of the berries which minimizes the degradation of pectic substances in the middle lamella of the fruits.

The soluble solids contents of cold stored strawberries wrapped with polyolefin film and those wrapped with the same film after incorporating silica gel in the packages were not significantly different. However, the soluble solids contents were significantly ($P \leq 0.05$) higher at day 15 of storage for strawberries packaged in open containers compared to the soluble solids contents of berries stored for 0, 5, 10, and 15 after wrapping with polyolefin film and incorporating silica gel inside the packages before wrapping (Table 5). These results disagree with the findings of Ke, et al., (1991) which show no effects for storing strawberries under controlled atmosphere conditions (Low O_2 and High CO_2) on the soluble solids of strawberries. The results can be explained by the fact that storing strawberries in open containers results in high moisture loss (Table 1) and thus increasing the concentration of total soluble solids.

The percentage of rotten strawberries increased significantly ($P \leq 0.05$) as storage time increased in all treatments (Fig.2). Also, wrapping strawberries with polyolefin film after incorporating silica gel inside the packages resulted significantly in higher percentage of rotten fruits compared to packaging the fruits in open containers and wrapping the containers with polyolefin film (Table 6). These results may be attributed to the use of silica gel which regulated the water vapor in side the containers allowing maximum growth of mold and thus increasing the incidence of decay.

Figure 3 illustrates the effects of wrapping with polyolefin film and incorporating silica gel inside the packages on total anthocyanins of strawberries stored at 4°C for 15 days. There was a significant difference between total anthocyanins of strawberries packaged in open containers and those wrapped with polyolefin film, and wrapped after incorporating silica gel inside the packages. Total anthocyanins content of strawberries packaged in open containers increased significantly at days 10 and 15 of storage. The increase of total anthocyanins in cold stored strawberries packaged in open containers is due to the high loss of moisture (Fig. 1) of the fruits which is responsible for the concentration of solids including total anthocyanins. Storing wrapped strawberries with polyolefin film and wrapped after incorporating silica gel inside the packages at 4°C had significant effects on increasing the total anthocyanins after 10 days. However, the total anthocyanins remained at day 10 level after 15 days of storage. The respiration of the fruits inside the microenvironment created by the polyolefin film resulted in the reduction of O_2 level inside the packages. The low level of O_2 reduces the degradation of anthocyanins by polyphenol oxidase (Sakamura, et al., 1965).

Colorimeter is one of the most objective and fastest ways to measure the color of fruits. Minolta Chroma Meter (CR-200) was used to determined the Tristimulus L^*, a^*, and b^*. The tristimulus photoelectric colorimeter were develop by Hunter in 1952. Hunter L^* measure the lightness of an object using a scale from 0 - 100, where 0 is absolute dark and 100 is absolute light. Hunter a^* measures absolute greenness at -60 and absolute redness at +60, while Hunter b^* denotes absolute blueness at -60 and absolute yellowness at +60.

Packaging strawberries in open containers and wrapping the containers with polyolefin film had no significant ($P \leq 0.05$) effects on Hunter L^* readings during the 15 days of storage at 4°C. However, incorporating silica gel inside the packages before wrapping with the film had significantly increased the L^* readings, indicating lighter fruits at day 15 of storage (Table 8). The reason for this increase in the lightness of the fruits may be due to the excessive growth of the mold on the berries packaged with silica gel.

Packaging strawberries in open containers resulted in a significant decrease in Hunter a^* readings at days 10 and 15 of storage at 4°C (Table 9), indicating a decrease in the redness of the fruits. These results may have been due to the oxidation of anthocyanins. Incorporating silica gel inside the packages before wrapping with polyolefin film had no significant effect on Hunter a^* values of cold stored strawberries after 15 days of storage. However, wrapping the containers with polyolefin film and incorporating silica gel inside the packages had significantly increased the a^* values (more red) of cold stored strawberries for 10 and 15 days compared to storing the berries under the same conditions in open containers. The Hunter a^* readings of strawberries stored for day 5 were significantly lower (less red) than those stored for 15 days in the wrapped treatment. Furthermore, there was a positive correlation (0.66) between Hunter a^* and total anthocyanins of the fruits, indicating that the a^* value is a good instrument for color measurement of strawberries. These results disagree with Ke et al., (1991) who reported a slight or no effect on the red color development of strawberries kept in 0.25%, 0.5%, and 1.0% of O_2 after 10 days of storage at 5°C. These disagreements are due to the differences in storage conditions.

Storing strawberries in open containers at 5°C for 15 days did not significantly effect ($P \leq 0.05$) Hunter b^* readings. However, wrapping the containers with polyolefin film and incorporating silica gel inside the packages resulted in a significant increase in Hunter b^* readings (more yellow) at day 15 of storage at 4°C (Table 9). These results suggests that Hunter b^* readings is not a good indicator to measure the color of strawberries.

Wrapping the containers with polyolefin film and incorporating silica gel inside the packages had no significant ($P \leq 0.05$) effect on the respiration rate of cold stored strawberries. The respiration rate of strawberries stored in open containers increased significantly at day 10 and then dropped to the level of day 5 after 15 days of storage (Table 11; Fig. 4). These results agree with the findings of Woodward and Topping (1972) who reported an initial decrease followed by a differential increase in respiration rates of strawberries stored in air, 1, 2 or 5% O_2 at 4.5°C.

CHAPTER IV

CONCLUSIONS

Quality of strawberries was well maintain for about 10 days at 4°C when silica gel was incorporated or not incorporated in the packages of the fruits which were wrapped with polyolefin film before storage. After 15 days of storage, the weight losses of strawberries packaged in open containers, wrapped with polyolefin film and wrapped with the same film after incorporating silica gel were 20.4%, 0.5% and 4.19%, respectively. After 15 days of storage, the pH, total acidity, texture, soluble solids, Hunter a^* readings, and respiration rate of fruits wrapped with polyolefin film with or without incorporating silica gel were maintained at day 0 levels.

Hunter a^* which showed a positive correlation ($r = 0.66$) with total anthocyanins of the fruits is better instrument than Hunter L^* and b^* for color measurement of strawberries.

The effects of stronger hygroscopic materials than silica gel on extending the shelf life of strawberries should be conducted.

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TABLE 1

EFFECTS OF WRAPPING WITH POLYOLEFIN FILM AND INCORPORATING SILICA GEL IN THE PACKAGES ON THE WEIGHT LOSS (%) OF COLD STORED STRAWBERRIES

	Time of storage (days)			
Treatments	Day 0	Day 5	Day10	Day 15
Open Container	0.00^{d}	8.56^{bc}	11.52^{b}	20.44^{a}
Silica Gel	0.00^{d}	4.74^{cd}	4.15^{cd}	4.19^{cd}
Wrapped	0.00^{d}	0.90^{d}	1.03^{d}	0.50^{d}

$^{a-d}$ Means with different superscripts are significantly different ($P \leq 0.05$; Duncan's).

TABLE 2

EFFECTS OF WRAPPING WITH POLYOLEFIN FILM AND INCORPORATING SILICA GEL IN THE PACKAGES ON THE pH OF COLD STORED STRAWBERRIES

	Time of storage (days)			
Treatments	Day 0	Day 5	Day 10	Day 15
Open Container	3.55[ab]	3.43[abc]	3.24[de]	3.47[ab]
Silica Gel	3.55[ab]	3.58[a]	3.1067[e]	3.51[ab]
Wrapped	3.55[ab]	3.42[abcd]	3.28[cde]	3.36[bcd]

[a-e] Means with different superscripts are significantly different ($P \leq 0.05$; Duncan's).

TABLE 3

EFFECTS OF WRAPPING WITH POLYOLEFIN FILM AND INCORPORATING SILICA GEL IN THE PACKAGES ON THE TOTAL ACIDITY OF COLD STORED STRAWBERRIES

	Time of storage (days)			
Treatments	Day 0	Day 5	Day 10	Day 15
Open Container	1.00^{ab}	1.05^{a}	0.90^{ab}	0.97^{ab}
Silica Gel	1.00^{ab}	0.86^{ab}	0.98^{ab}	0.80^{b}
Wrapped	1.00^{ab}	1.00^{ab}	0.81^{b}	0.96^{ab}

$^{a-b}$ Mean with different superscripts are significantly different ($P \leq 0.05$; Duncan's).

TABLE 4

EFFECTS OF WRAPPING WITH POLYOLEFIN FILM AND INCORPORATING SILICA GEL IN THE PACKAGES ON THE TEXTURE OF COLD STORED STRAWBERRIES

	Time of storage (days)			
Treatment	Day 0	Day 5	Day 10	Day 15
Open Container	102.03[a]	141.03[a]	164.39[a]	148.96[a]
Silica Gel	102.03[a]	120.39[a]	157.33[a]	178.65[a]
Wrapped	102.03[a]	125.83[a]	147.25[a]	157.92[a]

[a] Means with different superscripts are significantly different ($P \leq 0.05$; Duncan's).

TABLE 5

EFFECTS OF WRAPPING WITH POLYOLEFIN FILM AND INCORPORATING SILICA GEL IN THE PACKAGES ON THE PERCENTAGE OF SOLUBLE SOLIDS OF COLD STORED STRAWBERRIES

	Time of storage (days)			
Treatments	Day 0	Day 5	Day 10	Day 15
Open Container	1.34^{ab}	1.34^{ab}	1.34^{ab}	1.34^{a}
Silica Gel	1.34^{ab}	1.34^{b}	1.34^{b}	1.34^{ab}
Wrapped	1.34^{ab}	1.34^{b}	1.34^{b}	1.34^{ab}

$^{a-b}$ Means with different superscripts are significantly different ($P \leq 0.05$; Duncan's).

TABLE 6

EFFECTS OF WRAPPING WITH POLYOLEFIN FILM AND INCORPORATING SILICA GEL IN THE PACKAGES ON THE PERCENTAGE OF ROTTEN FRUIT OF COLD STORED STRAWBERRIES

	Time of storage (days)			
Treatments	Day 0	Day 5	Day 10	Day 15
Open Container	0.00^{e}	21.111^{d}	32.407^{cd}	37.897^{c}
Silica Gel	0.00^{e}	31.005^{cd}	53.788^{b}	100.00^{a}
Wrapped	0.00^{e}	19.722^{d}	41.667^{bc}	46.667^{bc}

$^{a-e}$ Means with different superscripts are significantly different ($P \leq 0.05$; Duncan's).

TABLE 7

EFFECTS OF WRAPPING WITH POLYOLEFIN FILM AND INCORPORATING SILICA GEL IN THE PACKAGES ON THE TOTAL ANTHOCYANINS (mg/100g) OF COLD STORED STRAWBERRIES

	Time of storage (days)			
Treatments	Day 0	Day 5	Day 10	Day 15
Open Container	15.44^{e}	10.17^{e}	52.10^{bc}	84.16^{a}
Silica Gel	15.44^{e}	37.13^{cd}	66.21^{ab}	81.92^{a}
Wrapped	15.44^{e}	34.36^{d}	82.70^{a}	69.35^{ab}

$^{a-e}$ Means with different superscripts are significantly different ($P \leq 0.05$; Duncan's).

TABLE 8

EFFECTS OF WRAPPING WITH POLYOLEFIN FILM AND INCORPORATING SILICA GEL IN THE PACKAGES ON HUNTER L^* OF COLD STORED STRAWBERRIES

	Time of storage (days)			
Treatments	Day 0	Day 5	Day 10	Day 15
Open Container	32.15^b	32.98^b	33.13^b	32.81^b
Silica Gel	32.15^b	31.89^b	33.06^b	35.70^a
Wrapped	32.15^b	31.96^b	31.47^b	33.46^{ab}

$^{a-b}$ Means with different superscripts are significantly different ($P \leq 0.05$; Duncan's).

TABLE 9

EFFECTS OF WRAPPING WITH POLYOLEFIN FILM AND INCORPORATING SILICA GEL IN THE PACKAGES ON HUNTER a* OF COLD STORED STRAWBERRIES

	Time of storage (days)			
Treatments	Day 0	Day 5	Day 10	Day 15
Open Container	32.24^{abc}	30.13^{cd}	29.45^{d}	26.65^{e}
Silica Gel	32.24^{abc}	30.88^{bcd}	32.21^{abc}	33.10^{ab}
Wrapped	32.24^{abc}	30.33^{cd}	31.97^{abc}	33.84^{a}

$^{a-e}$ Means with different superscripts are significantly different ($P \leq 0.05$; Duncan's).

TABLE 10

EFFECTS OF WRAPPING WITH POLYOLEFIN FILM AND INCORPORATING SILICA GEL IN THE PACKAGES ON HUNTER b* OF COLD STORED STRAWBERRIES

	Time of storage (days)			
Treatments	Day 0	Day 5	Day 10	Day 15
Open Container	17.86^{bcd}	15.57^{d}	18.20^{bcd}	16.44^{cd}
Silica Gel	17.86^{bcd}	16.94^{bcd}	19.54^{abc}	21.31^{a}
Wrapped	17.86^{bcd}	17.03^{bcd}	16.94^{bcd}	19.94^{ab}

$^{a-d}$ Mean with different superscripts are significantly different ($P \leq 0.05$; Duncan's).

TABLE 11

EFFECTS OF WRAPPING WITH POLYOLEFIN FILM AND INCORPORATING SILICA GEL IN THE PACKAGES ON THE RESPIRATION RATE (mL CO_2/kg hr) OF COLD STORED STRAWBERRIES

	Time of storage (days)			
Treatments	Day 0	Day 5	Day 10	Day 15
Open Container	*	25.73^{bc}	44.24^{a}	21.07^{c}
Silica Gel	*	43.82^{a}	52.76^{a}	48.66^{a}
Wrapped	*	38.97^{ab}	42.90^{a}	41.62^{a}

$^{a-c}$ Means with different superscripts are significantly different ($P \leq 0.05$; Duncan's).
* Means not available

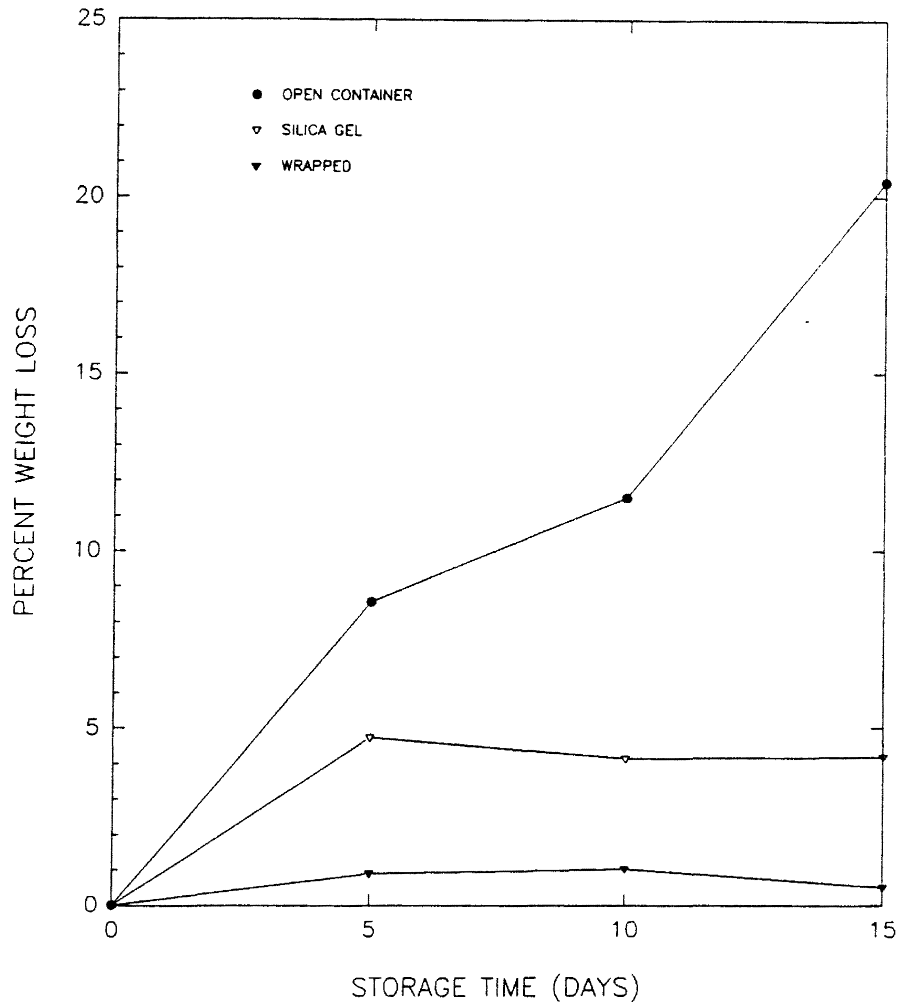

Figure 1. Interaction Plot of the Effects of Wrapping with Polyolefin Film and Incorporating Silica Gel in the Packages on the Percentage of Weight Loss of Cold Stored Strawberries.

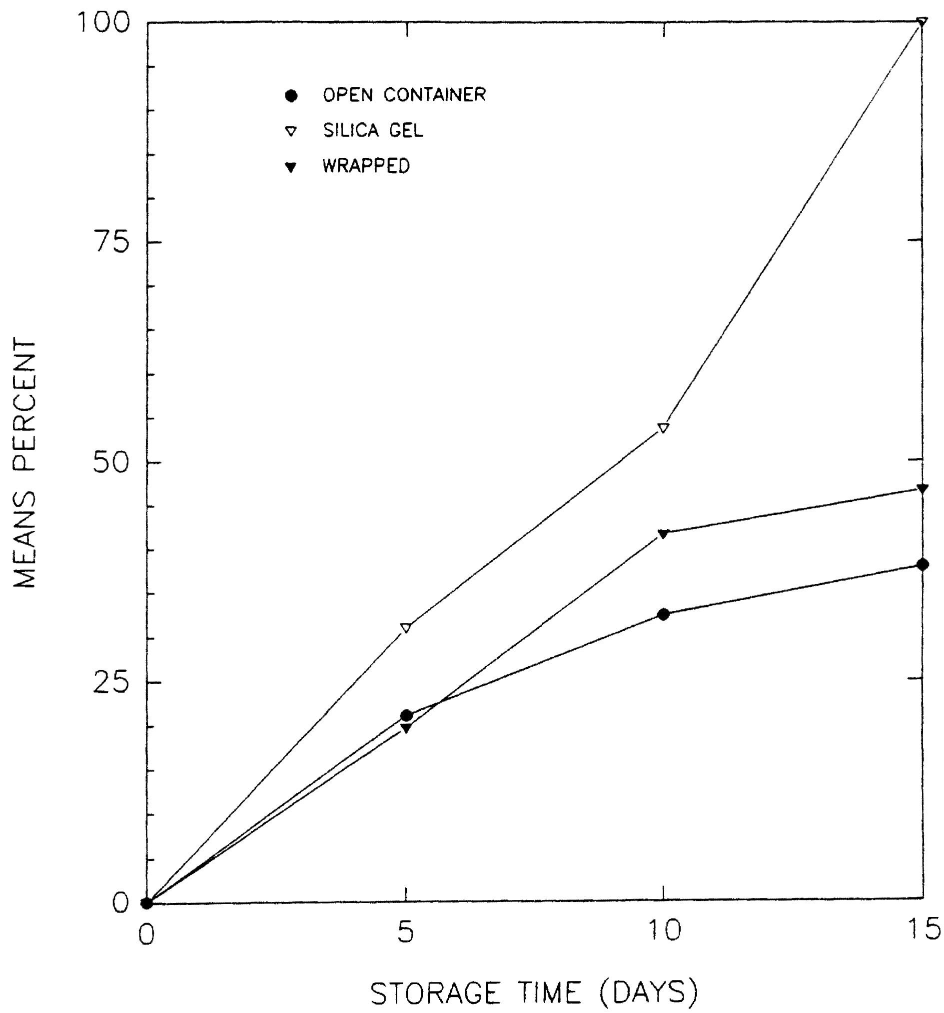

Figure 2. Interaction Plot of the Effects of Wrapping with Polyolefin Film and Incorporating Silica Gel in the Packages on the Percentage of Rotten Fruit of Cold Stored Strawberries.

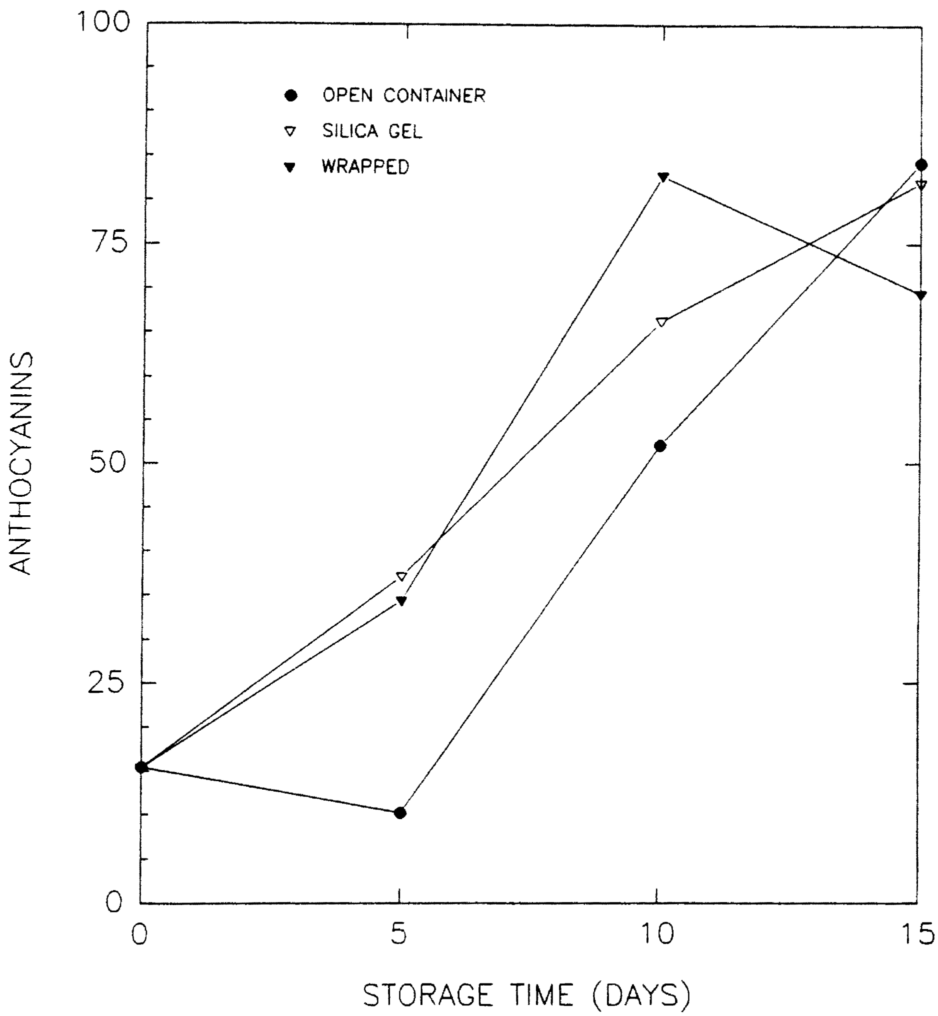

Figure 3. Interaction Plot of the Effects of Wrapping with Polyolefin Film and Incorporating Silica Gel in the Packages on the Total Anthocyanins (mg/100g) of Cold Stored Strawberries.

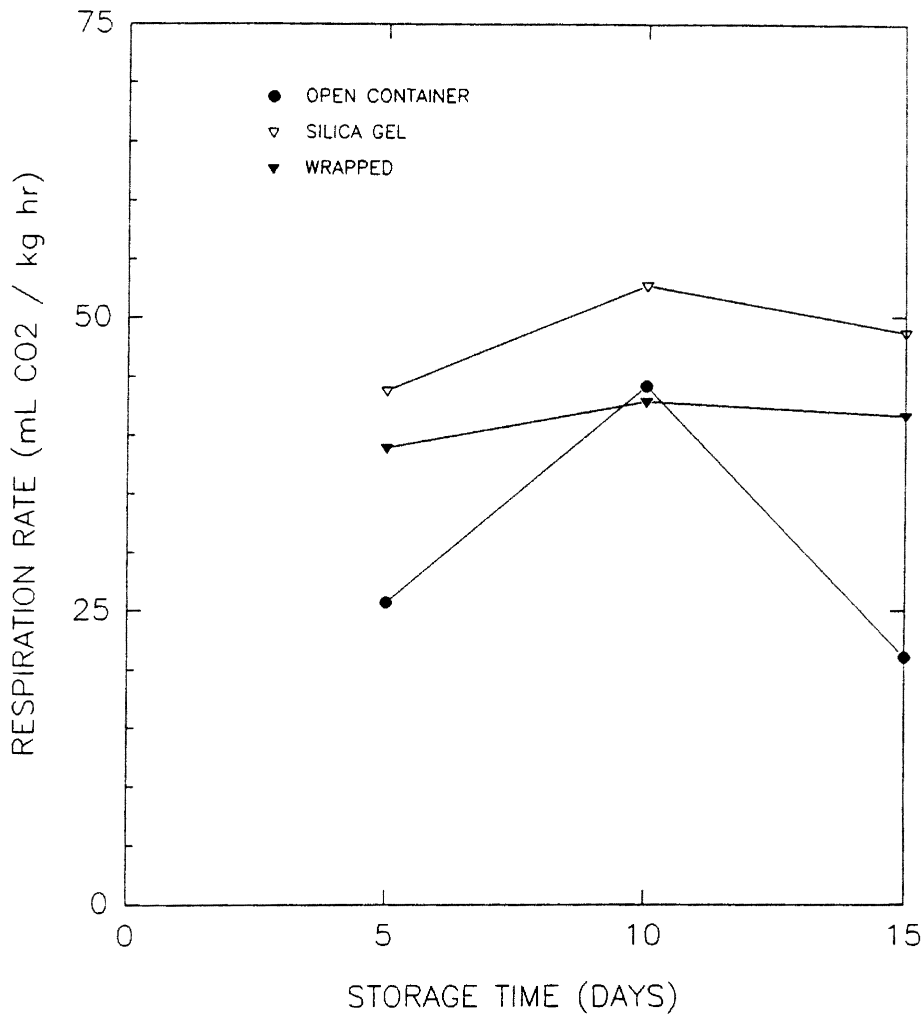

Figure 4. Interaction Plot of the Effects of Wrapping with Polyolefin Film and Incorporating Silica Gel in the Packages on the Respiration Rate (mL CO_2/kg hr) of Cold Stored Strawberries.

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