This is to certify that the

thesis entitled

MODIFIED ATMOSPHERE PACKAGING OF MANGO
SLICES IN POLYMERIC FILMS

presented by

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has been accepted towards fulfillment
of the requirements for

MASTER degree in PACKAGING

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Date July 24, 2001

MODIFIED ATMOSPHERE PACKAGING OF MANGO SLICES IN POLYMERIC FILMS

By

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A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

School of Packaging

2001

ABSTRACT

MODIFIED ATMOSPHERE PACKAGING OF MANGO SLICES IN POLYMERIC FILMS

By

Sopacha Apichartvorasilp

Effects of washing treatments, storage temperatures and packaging on the quality of sliced mango were studied. Sliced mangoes were immersed in antibrowning solutions and observed for color change during storage at 5°C and 10°C. Washing with ascorbic acid (0.5%) inhibited enzymatic browning effectively over a 10-day storage period. Browning was more intense in mango slices stored at 10°C. Various concentrations of $CaCl_2$ were investigated to maintain flesh firmness. No differences were observed in flesh firmness between mango slices treated with $CaCl_2$ and control. Combinations of 0.5% ascorbic acid, packaging and modified atmosphere treatments were used to extend shelf life. Packaging in oriented polypropylene (OPP) bags resulted in higher headspace CO_2 and lower O_2 concentrations than in other packaging films. Sliced mangoes packed in OPP with 5% O_2 and 10% CO_2 at 5°C retained good visual quality for 13 days. Yeast and mold counts were performed at the end of storage. No mold was found and yeast populations were $2{\times}10^2$ CFU/g.

The shelf life of mango slices was extended to 13 days using proper storage conditions. Mango should be carefully peeled, sliced, and treated with 0.5% ascorbic acid. Packaging in OPP bags initially flushed with 5% O_2 and 10% CO_2, and stored at 5°C, gave the best results.

ACKNOWLEDGEMENT

I am indebted to Dr.Bruce Harte and Dr.Vanee Chonhenchob for their understanding, patience and kindness. Without their corporation, this research could not have been done. I thank Dr. Susan Selke and Dr.Jerry Cash, my committee, for their kindness and comment. Thanks also go to everyone in packaging Department of Kasetsart University for his/her help and warm welcome. I thank Jurmkwan Suemag and Viphop Tatiyamaneekul, for their unwavering friendship and encouragement. I thank Seree Anutaraporn, for his tenderness and care. Finally, I thank my wonderful family, for their unconditional love and support.

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Introduction

Thailand has great potential to export fresh vegetables, fruits, and flowers to many countries around the world. Mango fruits are considered to have significant economic value by the Thai government. Therefore, plantation research and promotion measures were sought and included in the sixth National Social and Economic Planning (1987-1991) proposal (Department of Agriculture promotion, 1990). The need for better postharvest storage, and export markets were emphasized in this report. Asian markets for mangoes include Malaysia, Hong Kong, Singapore, Japan, and Taiwan (Department of Agriculture promotion, 1990). The popular species of mango are Pimsane Dang, Raad, Thongdum and Nam Dokmai.

Thailand is fundamentally an agricultural country. Surplus of produces are often left unattended to or not properly managed. This study is aimed at increasing chances of exports, maximizing value of farm produces, improving the strength of local economies and the economy of the country as a whole.

Several problems limit the export quantities of ripe mangoes. The high cost of delivery by airfreight necessary due to its short shelf life is one limitation (Vetchachiva, 1976). Though shipment by sea is much cheaper, it takes a long time to arrive at the destination country. Storage of mangoes in refrigeration delays ripening, but will cause chilling injury to the fruits and, consequently, reduce the quality of the fruit (Thomas and Oke, 1983).

Minimally processed fruit adds value to fresh produce. However, cutting, bruising or damaging the integrity of the plant tissue often allows enzymes and their substrates to come into contact, which causes enzymatic browning (Robert, 1994). Several approaches, including chemical treatments, edible coatings, and Modified Atmosphere Packaging (MAP), have been used to reduce this problem. Application of a 0.5% L-cysteine and 2% citric acid mixture effectively prevented browning of potatoes (Gunes and Lee, 1997). Dong and others (2000) reported that a shelf life of 15 to 30 days was achieved for sliced Anjou, Bartlett and Bosc pears using a combination of 0.01% 4-hexylresorcinol, 0.5% ascorbic acid and 1.0% calcium lactate along with partial vacuum packaging.

Mangoes are extremely sensitive to enzymatic browning. MAP is one method that can be used to decrease the rate of the browning reaction. Reduced O_2 and elevated CO_2 levels can extend storage shelf life of minimally processed fruit by controlling the respiration rate (Zagory and Kader, 1988). Hermidal and others (1995) claimed a shelf life of 10 days at 5°C for shredded iceberg lettuce, using MAP. Lowering the temperature reduces respiration and delays senescence. Storage at 1°C resulted in better quality of pomegranates (Gil and others, 1996).

The objective of this study was to determine the quality of mango slices stored under different modified atmospheric conditions in a variety of films. The influence of dipping treatments and storage temperatures on enzymatic browning was determined.

CHAPTER 1

LITERATURE REVIEW

Literature review

Mango (*Mangifera indica* L.) is a tropical fruit, in the Anacardiaceae family, which originated in India and Burma (Mukherjee, 1967). It has become a fruit of significant economic value to many countries — Brazil, Pakistan, Mexico, Philippines, Thailand, Indonesia, Bangladesh, and Haiti, for example (Vangnai, 1986). Many varieties of mangoes are exported to countries around the world from Thailand; most are consumed when ripe. The main varieties are Pimsane Dang, Raad, Thongdum and Nam Dokmai.

Mango trees reach 10-40 meters in height, with trunks of 10-40 cm. in diameter. Branches are widely and densely spread in all directions. The bark is a grayish brown. The trees have spear-shape leaves with a dark green glossy color on the upper side and a light green matte color on the opposite side. New leaves have a light to dark purple color. Flowers are panicle-like with scattered light yellow and sweet smell. The trees usually blossom during January to March and are ready for harvest between April and May (Smittinan, 1978).

The Nam Dokmai variety normally needs 115 days from the bud stage to fully ripen (Dept. of Agricultural Technology, Thailand, 1988) and about 99 -111 days from the infancy of the fruit to fully ripen (Kasarntikul, 1983). It is a pear-shaped, juicy fruit with thin skin, a long flat seed, a light green color when it is unripe, with a rather sour taste. The fruit becomes yellowish when ripe, with a sweet-mild taste and fruity fragrance (Figure 1). Image in this thesis is presented in color. Its flesh is meaty but not pulpy (Dept. of Agricultural Technology, Thailand, 1988).

Figure 1 Picture of Nam Dokmai at 90 days of age.

The demand for minimally processed fruits and vegetables is growing rapidly due to its convenience and fresh-like quality. Two obstacles confront the extension of shelf life of fresh-cut fruit and vegetables. First, cutting, bruising or damaging the integrity of plant tissue triggers enzymatic browning (Figure 2). Second, destroying the natural protective layer encourages microbial proliferation. Phenolase, phenoloxidase, tyrosine, polyphenoloxidase and catecholase are common enzymes responsible for the initiation of enzymatic browning. Enzymatic browning can occur in the presence of active polyphenoloxidase, oxygen, and a suitable substrate.

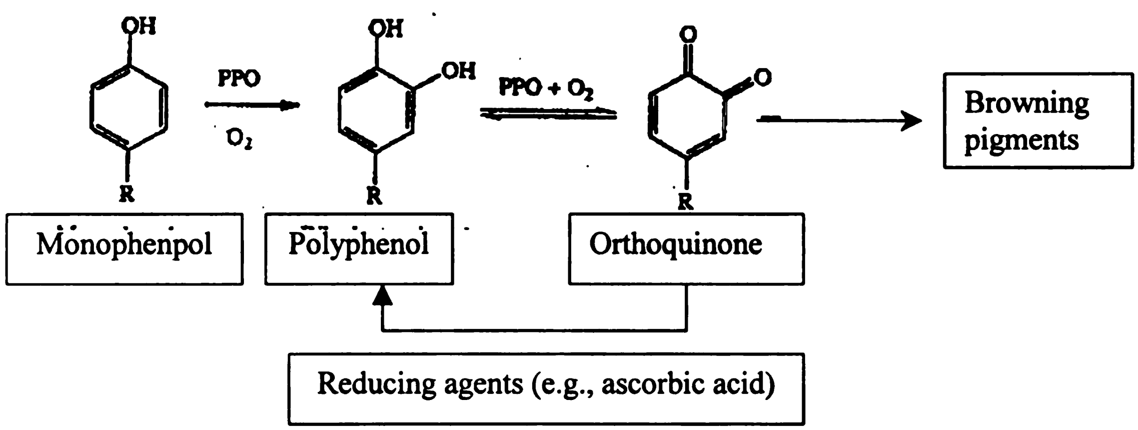


Figure 2 The action of PPO on phenolic compounds (Saper, 1993).

Several ways to control this reaction include destroying the enzymes responsible for it and/or using reducing agents to convert o-quinones back to phenolic compounds.

Common PPO substrates in plant tissues include the amino acid tyrosine and polyphenolic compounds such as catechin, caffeic acid, and chlorogenic acid. Tyrosine is a monophenol and is first hydroxylated to 3,4-dihydroxyphenylalanine (dopa) and then is oxidized to a quinone (Figure 3).

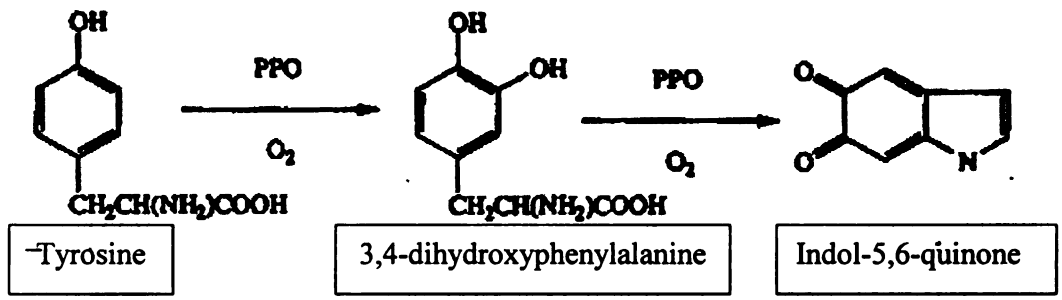


Figure 3 The action of PPO on tyrosine to produce indol-5, 6-quinone (Saper 1993).

Control of enzymatic browning

Many approaches have been used to combat enzymatic browning. Sulfites are excellent browning inhibitors. However, their application has been restricted by the FDA due to an allergic response in some asthmatics (Sapers, 1993). Ascorbic acid (vitamin C) is well known as an effective substitute for sulfites. It has the capability of reducing quinones back to phenolic compounds. A combination of dipping treatments has been used to control enzymatic browning. Sliced Anjou pears had browning-free color for 30 days by dipping the slices into a solution containing1.0% ascorbic acid, and 1.0% calcium lactate. A combination of 0.01% 4-hexylresorcinol (4-HR), 0.5% ascorbic and 1.0% calcium lactate can provide 15 to 30 days shelf life for Anjou, Barlett and Bosc pears (Dong et al, 2000). Sapers et al (1989) have claimed that ascorbic acid-2-phosphate and ascorbic–triphosphate inhibited enzymatic browning at cut surfaces of raw apple but were ineffective in apple juice. Using L-cysteine as an inhibitor of pear PPO has been reported (Halim and Montgomery, 1978).

Kojic acid was used as an inhibitor of PPO in the oxidation of 3,4-dihydroxyphenylalanine (dopa) (Chen and others, 1991). Sapers (1994) reported that a combination of sodium erythorbate, cysteine and EDTA at pH 5.5 was the most effective treatment controlling discoloration of minimally processed mushrooms.

Temperature is a major factor controlling respiration, enzymatic activities, and growth of microorganisms. Shelf life of shredded lettuce was extended by low temperature storage (Bolin and others, 1977). Pigment degradation of minimally processed pomegranate seed was minimized by storage at 1°C (Gil and others, 1996). At low temperature (about 2°C) physiological activity and microbial growth were reduced sufficiently to delay spoilage of grated carrots (Carlin et al., 1990). The respiration rate usually decreases 6 to 8 times when temperature is lowered from 20 to 0°C (Robert, 1994). For tropical fruits and vegetables, very low temperature may cause chilling injury. For example, storage of bananas and mangoes below 10°C may induce chilling injury (Katesa, 1980). Temperature also has an effect on film permeability. As the temperature goes up, the permeability of the film increases. Each film responds to change in temperature differently. Therefore, a suitable film must be used in order to prolong the shelf life of minimally processed fruits and vegetables.

Texture

Texture loss and change in appearance are the most noticeable changes in fruits and vegetables during prolonged storage. These undesirable quality changes are accelerated by mechanical rupturing of the cells that occurs during cutting.

The plant cell wall provides the mechanical support of the plant and individual plant parts. The physical structures of edible plant parts are due to a large extent to the presence of the cell wall (Stanley, 1991). Pectins are complex mixtures of polysaccharides that make up about one third of the cell wall. Pectin acts as an adhesive between cells, and contributes to the mechanical strength of the cell wall. Softening of the plant tissue is usually accompanied by changes in the properties of the pectin (Javis et al., 1988).

In processing of fruits and vegetables, the natural protective layer is usually removed, which induces a high respiration rate and triggers accelerated texture deterioration (Rosen and Kader, 1989). Calcium salt has been reported to retard texture softening (Ponting and others, 1972). Calcium lactate increased the firmness of Bosc pear, compared to a control (Dong and others, 2000). Hedemi and Watada (1994) reported that calcium chloride has a significant effect on texture of shredded carrot.

Calcium is not only associated with retaining texture but it is also said to reduce the respiration rate and ethylene production (Siddiqui and Bangerth, 1993). Carbon dioxide production was higher in untreated melon slices then in calcium treated (intact) fruit (Irene et al., 1999).

Controlled/modified atmosphere packaging

Controlled atmosphere packaging has been used to improve the shelf life of fresh fruits and vegetables. Reduced O_2 and elevated CO_2 reduce the respiration rate and delay maturation of fruits. A suitable range of O_2 and CO_2 must be established for each commodity. Respiration may become anaerobic when the O_2 level is too low or the CO_2 level is too high. The shelf life of fresh ginseng roots was extended to 3 months under a controlled atmosphere condition of 5% CO_2 (Jeon and Lee, 1999). At a concentration of 6% O_2, maturation of mushroom caps was reduced (Roy et al., 1995). Undesirable effects may develop in fruits and vegetables due to improper controlled atmosphere conditions. Knee and Hatfield (1981) reported that apples have been shown to lose flavor when O_2 is too low. Concentration of O_2 at 2% was optimum for reduction of maturation of mushrooms (Roy, 1995). Anaerobic respiration may result in off-flavors and aromas. Off-flavor development in broccoli packed in a low permeability film has been reported (Ballatyne et al., 1988).

Controlled atmosphere packaging (CAP) is costly due to the need for precise control of the initial gas concentration. It is more appropriate for commodities that need extended shelf life, such as apples (Kader et al., 1989). As soon as the product is removed from CAP, the quality will begin to deteriorate. Favorable quality can be maintained in modified atmosphere packaging until the package is opened. Modified atmosphere packaging also requires a lower degree of control of the initial gas concentrations than CAP.

MA storage of fruits and vegetables in plastic bags, plastic film and/or wax coating at low temperature is widely practiced. However, problems with CO_2 injury have resulted in changes in taste and smell due to fermentative deterioration. Selection of polymeric films of appropriate permeability that results in reduction of the respiration rate without inducing anaerobic respiration is a major aspect of modified atmosphere packaging. Pankasemsuk (1988) discovered an off odor after preserving "Kaewsaweii" mangoes in PE bags at 10°C for 12 days. Kongtao (1989) also encountered the same problem with "Raad" variety of mango, stored in PE bags at room temperature, 15°C and 10°C for 3, 14 and 17 days, respectively. Most commercial films are 4 to 5 times more permeable to CO_2 than O_2, which is helpful in developing a modified atmosphere package. Reduced O_2 and elevated CO_2 are attained through respiration of produce within a sealed package. Steady state conditions are achieved when consumption and diffusion of O_2 are equal and production and diffusion of CO_2 are equal. The shelf life of bananas packaged in polymeric films is doubled compared to that of bananas stored in air (Duan et al., 1973). A shelf life of 23 days for Nam Dokmai packed in polyethylene has been claimed by Koolpluksee (1991). Carlin et al (1990) reported that grated carrot was packed in films with very low oxygen permeability. This resulted in anaerobic respiration and loss of potassium. With highly permeable films, grated carrots had aerobic respiration and retained good quality. The firmness of kiwifruit slices stored under modified atmospheric conditions was higher than that of the control (Agar et al., 1999).

Chilling injury

Chilling temperature can injure tropical fruits both before and after harvest, for example, banana, rambutan, and mango (Katesa, 1985); durian, mangosteen (Kosiyajinda, 1986); and pineapple (Paul and Rohrbach, 1985). The degree of injury varies with temperature and species. Severe damage is also likely when storing fruits in a chilling environment (Morris, 1982). Symptoms included damage to the skin, watery flesh, premature ripening, off flavor development and odor (Morris, 1982).

Temperature, duration of storage, and fruit variety are the three main factors contributing to the level of injury (Katesa, 1985). Tropical fruits are more vulnerable to chilling injury (CI) than fruits from non-tropical countries (Katesa, 1985). Different varieties of fruits have different response to low temperature. Keeping mango under low temperature for a long time also increases the severity of CI (Chaplin et al., 1986). Kensington mango and Common varieties are more vulnerable to CI than Zil and Carrie when stored below 1°C for 15 days (Chaplin et al., 1986). Bramlage (1982) also found different types of CI in apples — "McIntosh" had a brown core, "Yellow Newtown" had an internal breakdown in texture, "Grimes Golden" had soft tissue, while "Jonathan" had soft scald.

Other factors, in addition to low temperature, that affect chilling injury include amount of exposure to sunlight before harvest time; nitrogen, phosphorus and calcium concentration in the fruit; fatty acids in the membrane, and level of sugar in the tissue (Wang, 1982).

The appropriate temperature for storage of mango fruit (2-4 weeks) is approximately 12-13°C. Some varieties like "Keaw Sawaii" can be kept safely for 20 days at 10°C, "Nang Klangwan" for 28 days at 12°C, "Oakrong" for 20 days at 10°C, "Pimsen" and "Raad" for 28 days at 9°C and "Thongdam" for 28 days at 9-10°C (Katesa, 1988).

Treating fruit and vegetables with chemical dips after harvest can reduce chilling injury. Dipping apricots into aqueous $CaCl_2$ (Wade, 1981), "Valencia" orange into thiabendazole (TBZ) (Wild and Hood, 1989), and waxing Marsh grapes in a TBZ rich substance helped to reduce CI (Chalutz et al., 1985).

Microbial safety

Minimally processed fruits and vegetables are very perishable. In most cases, they are more perishable than the raw materials; i.e. minimal processing often increases perishablility rather than making products more stable (Rolle and Chism, 1987). Improper handling can increase the population of microorganisms and can compromise quality and safety. Processing such as cutting and peeling can increase the population of microorganisms and shorten shelf life. Cleaning and washing reduces the numbers of microorganisms in most of the minimally processed fruits and vegetables. Chlorine has been used as a preservative dipping treatment (Robert, 1992). Commercially, 100-200 ppm is used as a sanitizer (Ji and Gross, 1998). Calcium and sodium hypochloride are widely used in the wash water for minimally processed fruits and vegetables (Robert, 1994).

According to the Department of Medical Science (Thailand), ready-to-eat fruits and vegetables must not have populations exceeding; 1) yeast 10^4 CFU/g, mold 500 CFU/g, E.coli 10 CFU/g and Salmonella zero.

CHAPTER 2

MATERIALS AND METHODS

Materials and Methods

Materials

Mango.

Mangoes (*Mangifera indica* L. cv. Nam Dokmai) were harvested by hand at the beginning of January, 2001 from a local (Charoen Pokapan) farm in the Ratchaburi province, Thailand and stored at room temperature (25°C) until needed. A sharp, stainless steel knife was used to peel and slice mangoes into eight pieces (approx. 120 g). Diseased and damaged slices were discarded. The knife was immersed in 100 ppm chlorine in water for 5 seconds between each slice in order to reduce cross-contamination. After peeling, sliced mangoes were immersed in 100 ppm chlorine for 20 seconds to reduce the microbial load on the fruit surface.

Polymeric films.

To study the influence of polymeric films on quality of mango slices, three different polymeric films with distinct oxygen transmission rate (OTR) and water vapor transmission rate (WVTR) were used: 70 μm linear low density polyethylene (LLDPE), 60 μm polypropylene (PP) and 80 μm oriented polypropylene (OPP) (Strong Pack company, Bangkok, Thailand). The characteristics of the films used are summarized in Table 1.

Table 1 Oxygen Transmission Rate (OTR) and Water Vapor Transmission Rate (WVTR) of PP, OPP and LLDPE used to package sliced mangoes.

Film	OTR ($cm^3.m^{-2}.d^{-1}$ at 25°C)	WVTR ($g.d^{-1}.m^{-2}$)	
		At 5°C	At 10°C
PP	2533	6.7	7.9
OPP	1474	5.7	7.5
LLDPE	3420	5.8	9.7

Oxygen Transmission Rate (OTR). The OTR of each film was measured using an O_2 transmission rate (8500) machine. Film was cut into an octagonal shape. Grease was applied to the upper sealing surface and the lower cell O-ring. The test film was aligned on the sealing surface and then both halves clamped together using locating pin.

Water Vapor Transmission Rate (WVTR). The WVTR was measured using ASTM standard E 96-93. Each film was cut into a 0.07 m diameter circle. Desciccant was placed in a 0.06 m diameter stainless steel circular dish, which was topped with the film. The edge of the film was sealed with hot wax and then the dish stored at 5 or 10°C. The dish was weighed every day for one week. A graph of time and weight was plotted and the slope was used to determine the WVTR. WVTR was caluated using the following equation:

$$\text{1.} \quad WVTR = \frac{\text{Slope (g/day)}}{\text{Surface area (m}^2\text{)}}$$

Methods

Effect of different antibrowning agents on pigment stability.

To study the influence of *antibrowning agents* on pigmentation stability, four pieces (sliced) mangoes were dipped in the following solutions for 30 seconds: distilled water (control), 0.5% ascorbic acid, 1% citric acid (v/v), and 0.5% ascorbic acid plus 1% citric acid. They were then drained in a perforated plastic container and placed on foam trays stretch wrapped with high density polyethylene films, and stored at 5°C and 10°C until evaluated. Treated mangoes were removed randomly from trays to evaluate color change on day 0, 1, 2, 4, 7, and 10 or until the quality of mango slices was not acceptable. A Hunter Lab Ultrascan XE was used to study the change in color, using the codes L = light/dark, a = green/red and b = yellow/blue. Before analyses, the equipment was standardized with a standard white plate. Six measurements were taken randomly on the surface of each slice. Three replicates per treatment were performed. The most promising treatment was combined with MAP to prolong the shelf life of mango slices in later experiment.

Effect of concentration of calcium chloride on flesh firmness

To study the influence of calcium chloride concentration on flesh firmness, peeled mangoes were immersed in the following solutions for 30 seconds; water (control), 0.5, and 1% calcium chloride. They were then drained in a perforated plastic container and placed on foam trays stretch wrapped with high density polyethylene film, and stored at 5 or 10°C until analyzed. Treated mangoes were removed randomly from trays to evaluate flesh firmness on day 0, 2, 3, 6, and 8. A Lloyd material testing machine equipped with 0.5 cm diameter cylinder stainless steel puncture head was used to measure the flesh firmness of the mango. The mango was cut into one cubic centimeter dices and place on a platform. Each dice was punctured 0.5 cm using the Lloyd material testing machine. The firmness was reported in Newtons. The most promising treatment was combined with MAP to prolong the shelf life of mango slices in the experiment to follow.

Modified Atmosphere Packaging (MAP) of mango slices

Respiration rate of mango slices

The respiration rate of mangoes was measured using a closed system. Treated mangoes (250-300 g) were placed into gas-tight jars (6 L) and sealed. Two tubes were attached to the jar lids which were used as gas sampling ports. The jars were stored at 5 or 10°C. CO_2 content was measured every hour using a gas chromatograph, Chrompack 9002GC, equipped with a thermal conductivity detector and Carboplot capillary column. Respiration rates were calculated using the following equation (Morales-Castro, 1992);

$$RR = \frac{\Delta C \times V}{t \times W} \qquad (2.)$$

where RR is the respiration rate ($mL \cdot kg^{-1} \cdot h^{-1}$); ΔC, the change in concentration of CO_2 or O_2; V, the free volume (mL) in the container; t, time (hr); and W, the weight (kg) of mangoes in the container. Respiration rate measurements were replicated three times.

Effect of MAP on the shelf life of mango slices

To study the effect of different modified atmospheres on product shelf life, treated mango slices were prepared as previously described. Four treated mango slices were placed in trays and sealed in pouches of different polymeric materials. A Multivac packaging machine (A300) was used to seal the pouch containing the gases. Laboratory grade O_2 and CO_2 gases were obtained from Sitiporn gas company, Thailand. The gases were combined using the Multivac packaging machine (A300). The ratio of O_2% to CO_2% was varied as follows: 5:5, 5:10 and air (control). N_2 was used as a filler gas. Sealed packages were then stored at 5 and 10°C. Duplicate samples of each treatment were prepared. O_2 and CO_2 concentrations were monitored on days 0, 1, 3, 6, 8, 10 and 13 using the Chrompack 9002 GC equipped with a thermal conductivity detector and a Carboplot capillary column (0.53mm×30m). Helium at (20cc/min) was used as the carrier gas. Gas samples were drawn from each package using a 25 µl gas tight syringe through self-sealing silicone and directly injected into the GC.

Quality evaluation

To evaluate the quality of mango slices, two packages of mango per treatment were chosen at random. Gas samples were withdrawn from the packages through a self-sealing silicone septum to determine headspace gas concentration. The packages were opened and the mango slices were weighed to determine weight loss. The slices were then used to evaluate color change, Total Soluble Solid (TSS), pH, weight loss and Polyphenol oxidase (PPO) activity.

All measurements were conducted on day 0, 1, 3, 6, 8, 10 and 13 except TSS, pH and % weight loss which were conducted on days 0, 3, 8 and 13 or until the quality was not acceptable

Color.

A Hunter Lab Ultrascan XE was used to study the change in surface color, where L = light/dark, a = green/red and b = yellow/blue. Prior to evaluation, the equipment was standardized with a standard white plate. Six measurements were taken randomly on the surface of each slice. Two replicates per treatment were evaluated.

Total Soluble Solids (TSS).

Mango slices were pushed through a small sieve stainless steel net in order to obtain juice. TSS measurement was conducted using a hand refractometer. 15 μl of mango juice was used. Two replicates per treatment were evaluated.

pH.

Mango juice was prepared as previously described. pH of the mango juice was measured using a pH meter (Mettler), Toledo, Ohio. Two replicates per treatment were evaluated.

Weight loss.

To determine weight loss of the samples an analytical balance was used. The following formula was used to calculate % weight loss (wt/wt);

3. $$\%\ \text{weight loss (wet basis)} = \frac{\text{(Final weight(g)} - \text{Initial weight(g))}}{\text{Initial weight (g)}} \times 100$$

Two replicates per treatment were used.

Polyphenoloxidase (PPO) extraction and assay

PPO extraction and assays were carried out according to Galeazzi (1981). Two replicates per treatment were evaluated. Twenty-five grams of treated mango slices were homogenized in a blender for 25 sec with 50 ml of a 0.2M sodium phosphate buffer, pH 7, containing 1% insoluble polyvinyl pyrrolidone (PVP) and 0.5% Triton X-100. The homogenates were centrifuged at 4°C for 15 min at 12,000G. The supernatant was stored at 5°C until assayed for polyphenoloxidase activity.

25 μl aliquots of the enzyme extracts, 2 ml 0.1M catechol solution and 1 ml distilled water were mixed together and assayed for PPO at pH 6.5. The reference cuvette contained only catechol solution and distilled water. Enzyme activity was determined by measuring the rate of increase in absorbance at 420 nm at 25°C using a Perkin-Elmer Lamda 15 spectrophotometer. The slope of the initial rate of the reaction was used to determine the enzyme activity (U/min.ml).

Microbiological counts

Yeast and mold counts were conducted at the end of storage on the most acceptable quality mango slices using the AOAC (1995) procedure. Ten grams of sample were added to 90 mL sterile water. Decimal dilutions of mango aliquots were made in tubes containing 9 mL sterile water. 0.1 mL of appropriate dilutions were deposited into sterile incubation plates and then 15 mL of PDA (Potato Dextrose Agar) poured onto each plate. The sample plates were then incubated at 37°C for 48 hours. Two replicates of each treatment were done. Ready-to-eat fruits and vegetables should have populations of no more than; 1) yeast 10^4 CFU/g, 2) mold 500 CFU/g, 3) E.coli 10 CFU/g and zero Salmonellae (Department of Medical Science, Thailand).

Statistical analysis

The effect of each treatment on quality characteristic was evaluated using ANOVA. A 3- or 4-way analysis of variance was conducted with storage time, temperature, type of film, and MAP as factors. To control type I error (the rejection of a true null hypothesis), a Fisher LSD multiple comparison test with $p<0.05$ was used to determine differences between treatments.

CHAPTER 3

RESULTS AND DICUSSION

Results and Discussion

Effect of washing treatments on color deterioration

"L" value. The effect of antibrowning agents on the light/dark (L) values of mango slices stored at 5°C is shown in Table 2. There were significant ($p<0.05$) effects on 'L' values. 'L' values dropped rapidly in all treatments except in mango slices treated with ascorbic acid. The brightness (L value) of mango slices treated with ascorbic acid decreased slowly in the first two-days and dropped rapidly after 4 days of storage (Figure 4a). Untreated mango slices (control) and mango slices treated with a combination of citric and ascorbic acid had lower L values than the other treatments. The citric acid solution produced the second best results, contrary to Gil et al. (1996) who reported that washing with citric acid gave no better results than washing with chlorine. Unacceptable L values were observed after 10-days storage with all treatments except ascorbic acid treated mangoes. Therefore, the most effective dipping treatment for mangoes (Nam Dokmai) was a 0.5% solution of ascorbic acid. This finding is in accordance with Ponting et al. (1972) who reported that ascorbic acid effectively inhibited browning on apple slices. Ascorbic acid has the capability of reducing quinones back to phenolic compounds. Combinations of ascorbic acid with an acidic polyphosphate were highly effective with both juice and cut apple surfaces. Gorny et al. (1998) reported that 2.0% ascorbic acid and 1.0% calcium chloride applied as a dipping treatment was effective in reducing surface browning of pears.

Table 2 Effect of antibrowning agents on the light/dark (L) values of mango slices stored at 5°C.

Day	Washing treatment[c]			
	Citric[a]	Ascorbic[b]	Plus[a]	Ctrl[a]
0	69.82	69.82	69.82	69.82
1	67.50	68.98	67.32	67.07
2	66.65	68.56	66.60	65.00
4	65.97	68.17	65.13	64.53
7	63.38	66.72	63.16	62.73
10	61.51	65.03	61.01	60.08

[a-b] Mean of three replicates; mean separation by Fisher LSD multiple comparison test ($p<0.05$); treatments in column followed by similar letters are not significant.

[c] Washing treatments: citric acid (1%); ascorbic (0.5%); plus – citric acid (1%) plus ascorbic acid (0.5%); ctrl - distilled water.

Table 3 illustrates the effect of antibrowning agents on L value of mango slices stored at 10°C. Significant reductions of L values were observed after one-day storage in all treatments. Mango slices treated with citric and with ascorbic acid had higher L values than other treatments, as shown in Figure 4b. Acceptable L values were maintained for 7 days. After 7 days of storage, mango slices treated with ascorbic acid had the highest L value. Dong et al. (2000) reported that dipping Anjou pears in 1.0% Ascorbic acid and 1.0% calcium lactate enhanced browning free color for 30 days. Sapers et al. (1989) found that ascorbic acid-2- phosphate (AAP) and –triphosphate (AATP) inhibited enzymatic browning at the cut surfaces of raw apples but was ineffective in apple juice.

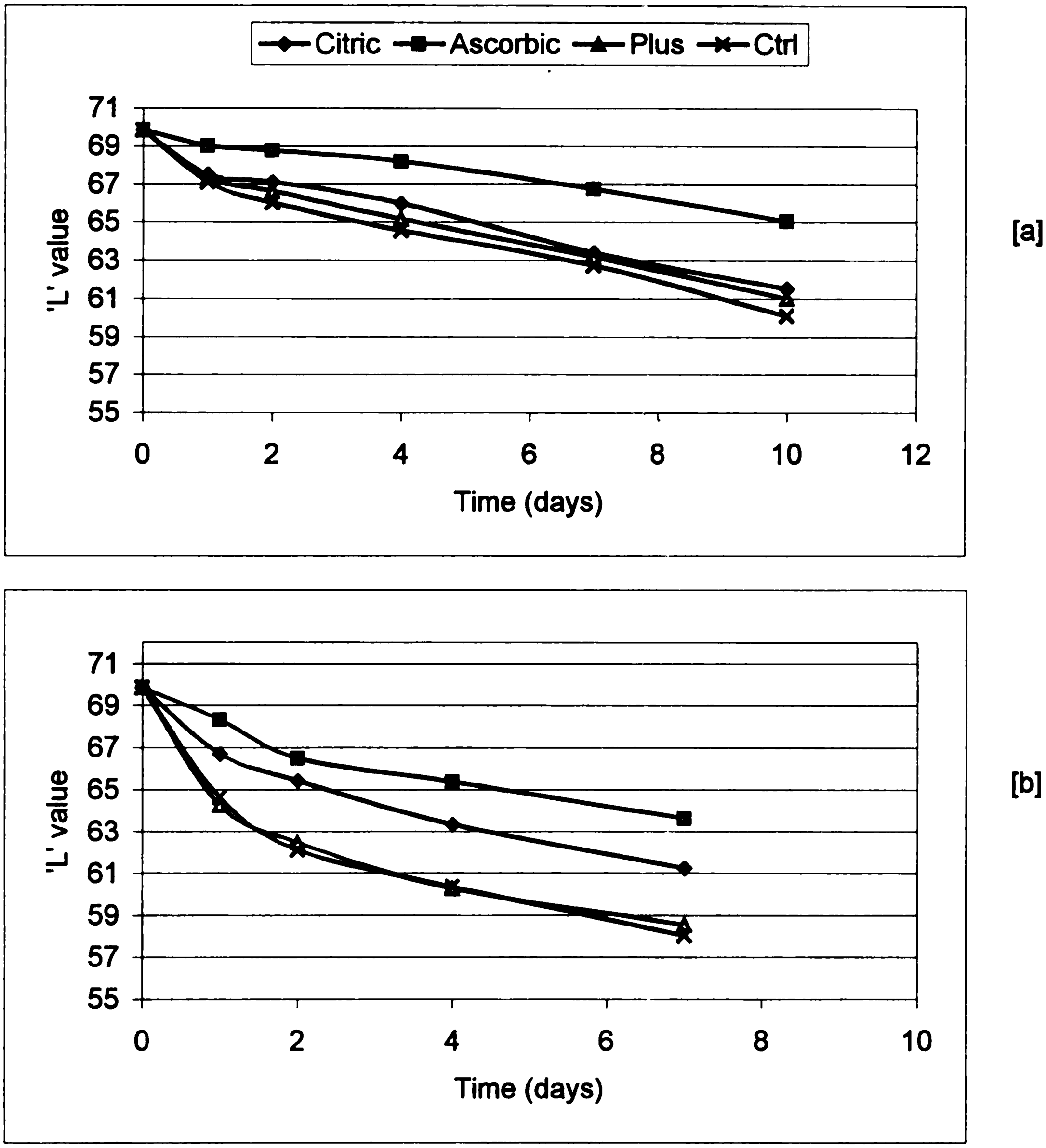


Figure 4 Effect of antibrowning agents on the light/dark (L) values of mango slices stored at 5C [a] and at 10C [b] .

Table 3 Effect of antibrowning agents on the light/dark (L) values of sliced mangoes stored at 10°C.

Day	Washing treatment[c]			
	Citric[a]	Ascorbic[a]	Plus[b]	Ctrl[b]
0	69.82	69.82	69.82	69.82
1	66.67	68.31	64.24	64.62
2	65.42	66.48	62.46	62.12
4	63.32	65.34	60.25	60.34
7	61.24	63.61	58.53	58.00

[a-b] Mean of three replicates; mean separation by Fisher LSD multiple comparison test ($p<0.05$); treatments in columns followed by similar letters are not significantly different.

[c] Washing treatments: citric acid (1%); ascorbic (0.5%); plus – citric acid (1%) plus ascorbic acid (0.5%); ctrl – distilled water.

"a" value. "a" value signifies color, "a" value varies from green to red. Effect of antibrowning agents on "a" values of mango slices stored at 5°C are shown in Table 4. No significant treatment effects were found among mango slices treated with citric, ascorbic acid, or control. An increase in "a" values for all treatments, after one-day storage occurred (Figure 5a). After 2-days storage, the "a" value decreased slightly. It remained almost stable for the remaining storage time.

The effect of antibrowning agents on "a" values of mango slices stored at 10°C is shown in Table 5. No significant treatment effects were found between mango slices treated with citric and ascorbic acid. Figure 5b illustrates the effect of antibrowning agents on "a" values of mango slices stored at 10°C. "a" values increased in all treatments except the control during 7-day storage.

Table 4 Effect of antibrowning agents on the green/red ("a") values of sliced mangoes stored at 5°C.

Day	Washing treatment[c]			
	Citirica[a]	Ascorbic[a]	Plus[b]	Ctrl[ab]
0	6.02	6.02	6.02	6.02
1	6.41	7.14	7.74	6.79
2	6.38	6.11	6.87	6.68
4	6.54	5.73	6.51	6.87
7	6.00	6.13	7.07	6.49
10	5.74	5.65	7.03	6.74

[a-b] Mean of three replicates; mean separation by Fisher LSD multiple comparison test ($p<0.05$); treatments in rows followed by similar letters are not significantly different.

[c] Washing treatments: citric acid (1%); ascorbic (0.5%); plus – citric acid (1%) plus ascorbic acid (0.5%); ctrl - distilled water.

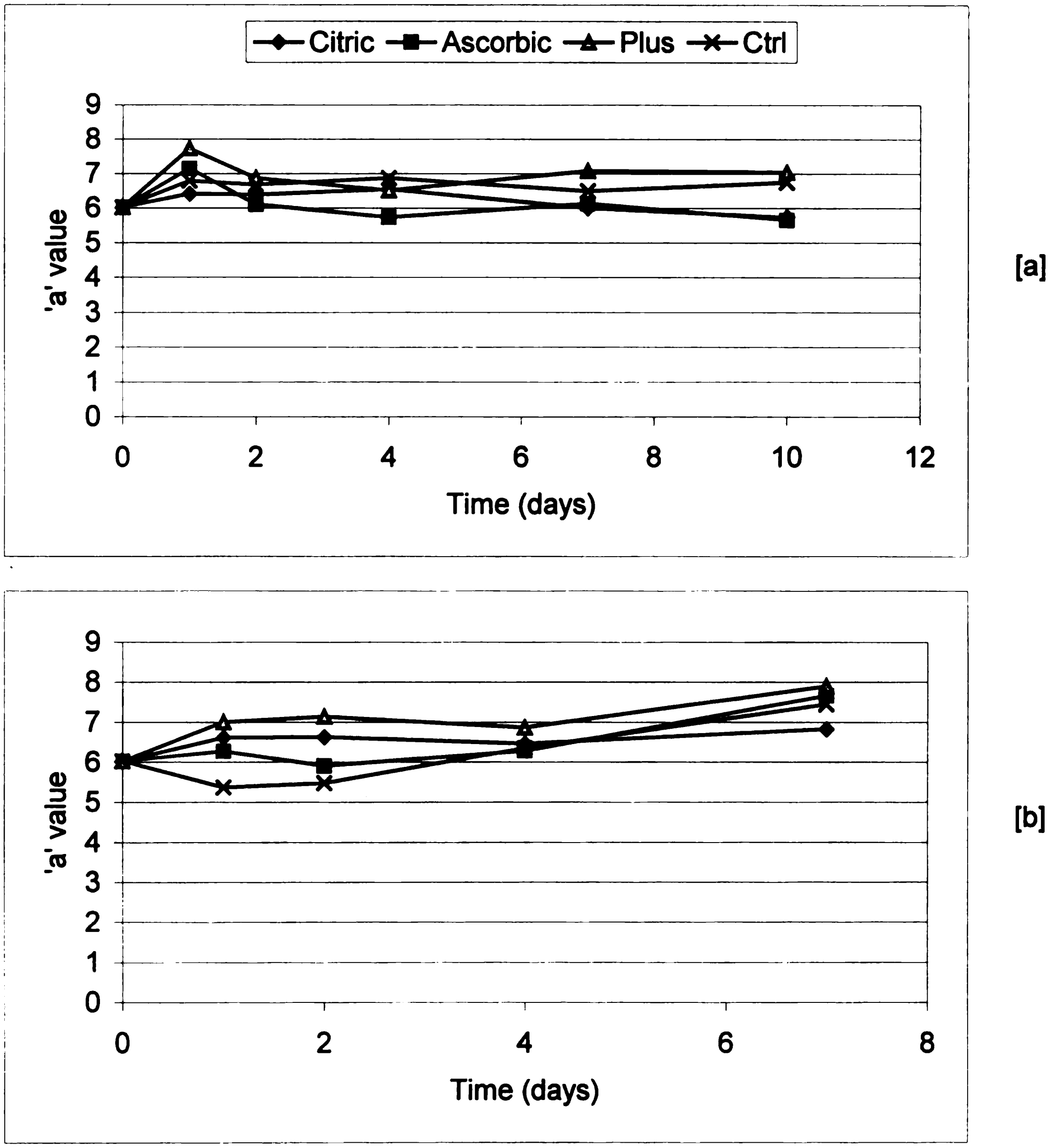


Figure 5 Effect of antibrowning agents on the green/red ('a') values of mango slices stored at 5C [a] and at 10C [b].

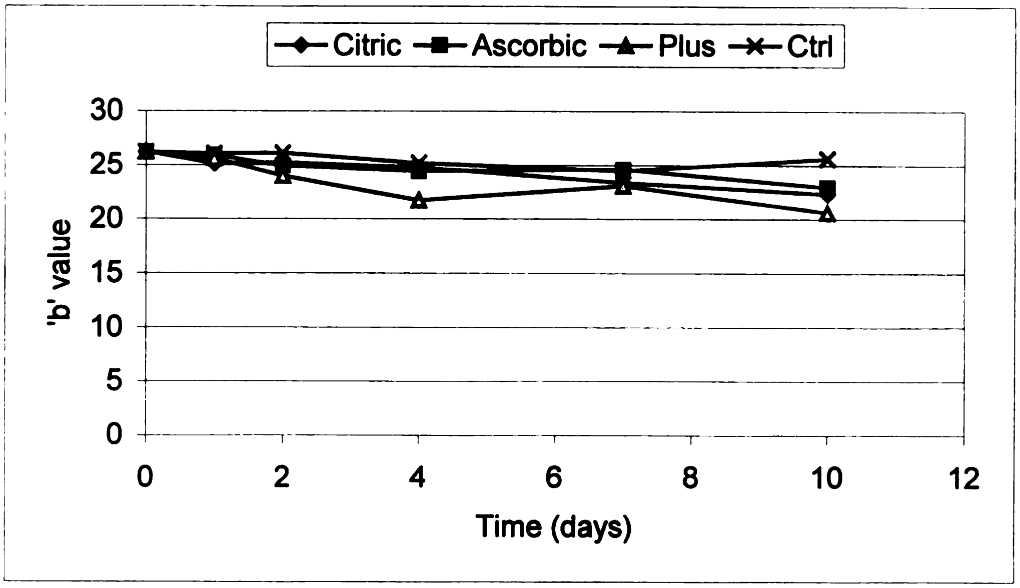
Table 5 Effect of Antibrowning agents on the green/red ("a") values of sliced mangoes stored at 10°C.

Day	Washing treatment[c]			
	Citric[a]	Ascorbic[a]	Plus[b]	Ctrl[b]
0	6.02	6.02	6.02	6.02
1	6.61	6.27	7.00	5.36
2	6.63	5.90	7.14	5.47
4	6.46	6.28	6.86	6.35
7	6.82	7.66	7.90	7.44

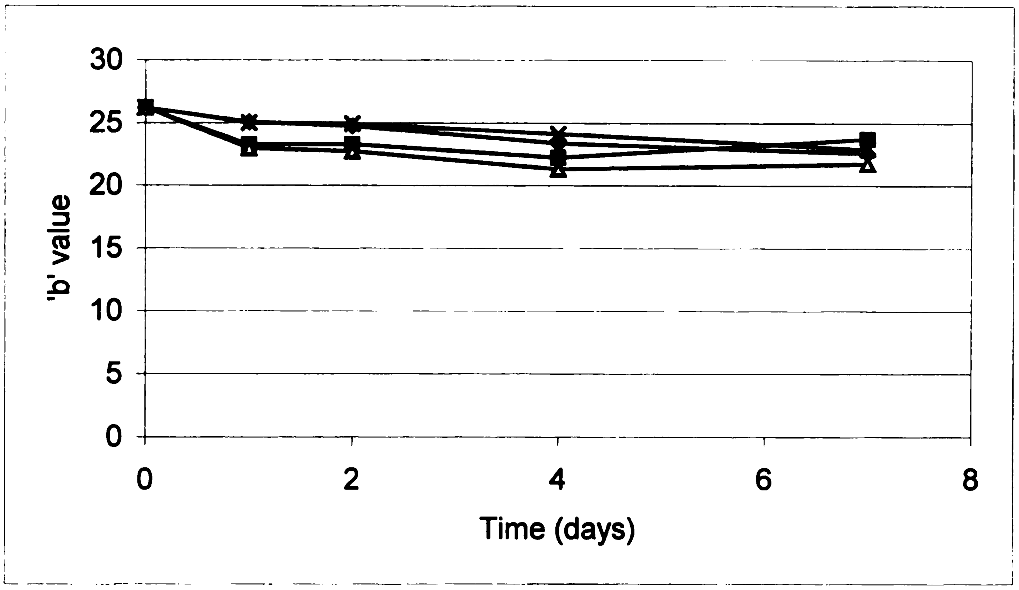
a-b Mean of three replicates; mean separation by Fisher LSD multiple comparison test ($p<0.05$); treatments in columns followed by similar letters are not significantly different.

c Washing treatments: citric acid (1%); ascorbic (0.5%); plus – citric acid (1%) plus ascorbic acid (0.5%); ctrl – distilled water.

"b" value. "b" value signifies color, "b" value varies from yellow to blue. Effect of antibrowning agents on "b" values at 5 and 10°C are shown in Table 6 and 7, respectively. No significant treatment effects were found between mango slices treated with citric and ascorbic acid. As shown in Figure 6, "b" values decreased slightly during storage.



[a]



[b]

Figure 6 Effect of antibrowning agents on the yellow/blue ('b') values of mango slices stored at 5C [a] and at 10C [b].

Table 6 Effect of antibrowning agents on the yellow/blue ("b") values of mango slices stored at 5°C.

Day	Washing treatment[c]			
	Citric[ab]	Ascorbic[ab]	Plus[a]	Ctrl[b]
0	26.20	26.20	26.20	26.20
1	25.10	25.89	25.58	26.04
2	25.21	24.90	23.98	26.08
4	24.76	24.41	21.70	25.16
7	23.36	24.58	23.06	24.45
10	22.33	22.94	20.58	25.57

[a-b] Mean of three replicates; mean separation by Fisher LSD multiple comparison test ($p<0.05$); treatments in columns followed by similar letters are not significantly different.

[c] Washing treatments: citric acid (1%); ascorbic (0.5%); plus – citric acid (1%) plus ascorbic acid (0.5%); ctrl – distilled water.

Table 7 Effect of Antibrowning agents on the yellow/blue ("b") values of mango slices stored at 10°C.

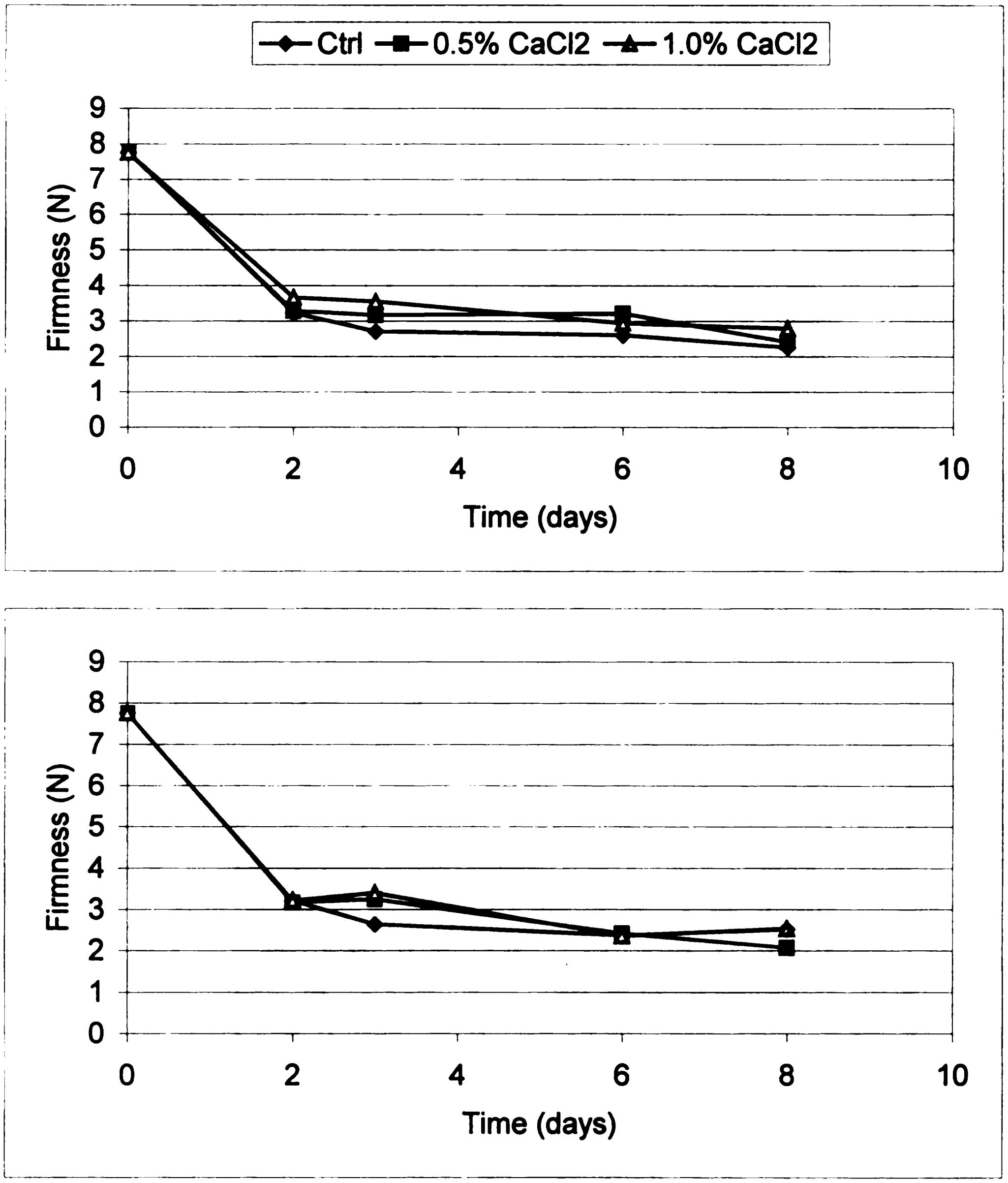
Day	Washing treatment[e]			
	Citric[ad]	Ascorbic[ac]	Plus[bc]	Ctrl[d]
0	26.20	26.20	26.20	26.20
1	25.07	23.24	22.95	24.98
2	24.74	23.29	22.72	24.92
4	23.35	22.22	21.27	24.12
7	22.57	23.70	21.74	22.91

[a-c] Mean of three replicates; mean separation by Fisher LSD multiple comparison test ($p<0.05$); treatments in columns followed by similar letters are not significantly different.

[e] Washing treatments: citric acid (1%); ascorbic (0.5%); plus – citric acid (1%) plus ascorbic acid (0.5%); ctrl – distilled water.

Effect of calcium chloride on flesh firmness

No significant treatment effects were found in any of the treatments (Table 8 and 9). Flesh firmness dropped rapidly after 2 days storage for all treatments and then stabilized as shown in Figure 7. At the end of storage, flesh firmness of 2.068 - 2.783N was obtained.



[a]

[b]

Figure 7 Effect of calcium chloride on firmness of mango slices stored at 5C [a] and 10C [b].

Table 8 Effect of calcium chloride on the flesh firmness of mango slices stored at 5°C

Day	Firmness (N) [NS]		
	Ctrl	$CaCl_2$ 0.5%	$CaCl_2$ 1.0%
0	7.753	7.753	7.753
2	3.215	3.279	3.659
3	2.710	3.166	3.538
6	2.605	3.207	2.933
8	2.255	2.406	2.783

[NS] No significant different at $p < 0.05$ by Fisher LSD multiple comparison test.

Table 9 Effect of calcium chloride on the flesh firmness of mango slices stored at 5°C

Day	Firmness (N) [NS]		
	Ctrl	$CaCl_2$ 0.5%	$CaCl_2$ 1.0%
0	7.753	7.753	7.753
2	3.205	3.167	3.212
3	2.640	3.244	3.394
6	2.362	2.409	2.349
8	2.516	2.068	2.533

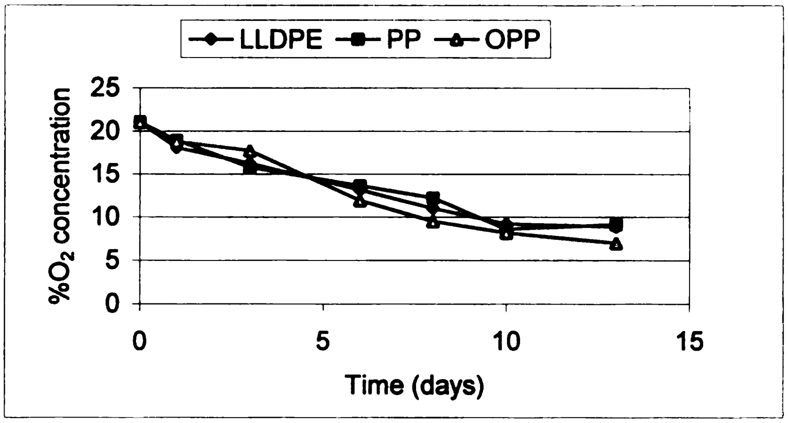
[NS] No significant different at $p < 0.05$ by Fisher LSD multiple comparison test

Effect of polymeric films under modified atmosphere packaging

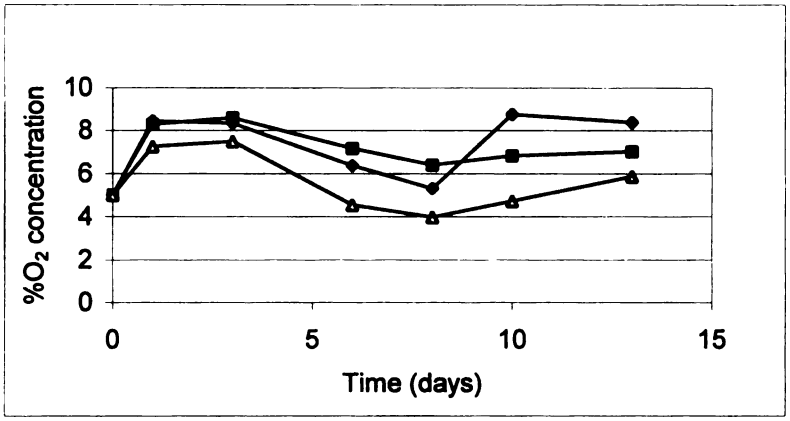
Ascorbic acid was found to be the most effective treatment to inhibit enzymatic browning. Therefore, it was applied as a dipping solution prior to evaluating the effect of polymeric film type. Three polymeric films were chosen: (1) Polypropylene (PP), (2) Oriented polypropylene (OPP), and Linear Low density polyethylene (LLDPE). Respiration rates of mango slices stored at 5 and

10°C were 67.5 and 69.9 $mlCO_2.h^{-1}.kg^{-1}$, respectively. Changes in O_2 concentration in PP, OPP and LLDPE packs of mangoes are shown in Figure 8 and 9. Concentration of O_2 gradually decreased in all control packages (air) at 5 and 10°C as shown in Figure 8a and 9a. O_2 concentrations for treatments which started with 5% O_2 in the headspace varied. After 3 days, the amount of oxygen declined at both temperatures. All packages packed in air reached steady state during 6- and 10-days storage at 10 and 5°C, respectively. Steady state was not achieved in packages starting with 5% O_2 and 5% CO_2. OPP bags which contained10%CO_2 initially reached steady state after 1- and 6- days at 10 and 5°C, respectively. On the other hand, steady state was not achieved in LLDPE and PP bags initially flushed with 10% CO_2 and 5% O_2. The difference in O_2 concentration can be explained by the difference in O_2 permeability through the films. The lowest O_2 concentrations were found in packs of the least permeable films and vice-versa. For example, the O_2 concentration of mango slices packed in PP was lower than the O_2 concentration of mango slices packed in LLDPE (Figure 9b).

Changes in CO_2 concentrations in PP, OPP and LLDPE packs are shown in Figure 10 and 11. Equilibrium values for CO_2 were found only in LLDPE bags. The highest concentration of CO_2 was a result of the lowest film permeability. The permeability of film depends on its degree of crystallinity and mobility between polymeric chains. For example, the concentration of CO_2 in OPP bags was highest in MA treatments, which is a result of an increasing in crystallinity. CO_2 has been reported to inhibit some reactions in the Krebs cycle through



[a]



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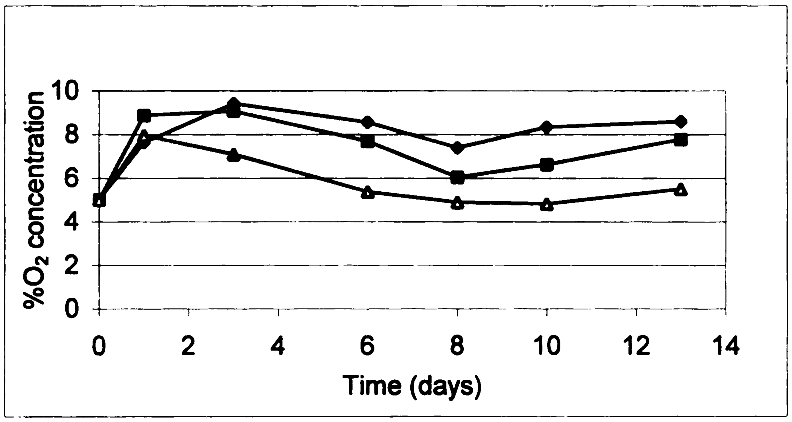


[c]

Figure 8 Changes in O_2 concentration of mango slices packed in different packaging films in air [a] , 5% CO_2 and 5% O_2 [b] , and 10% CO_2 and 5% O_2 [c] at 5C

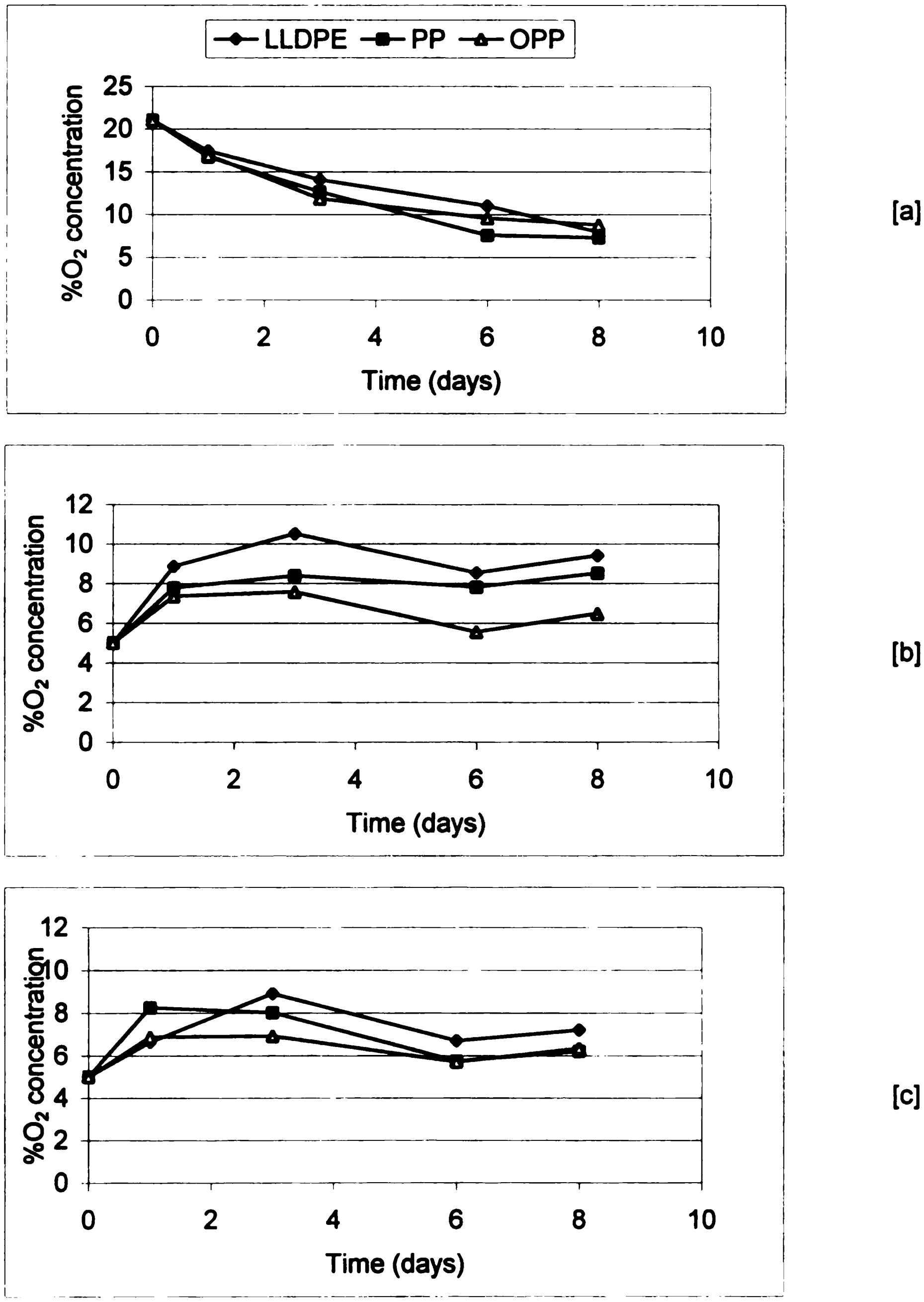


Figure 9 Changes in O_2 concentration of mango slices packed in different packaging films in air [a], 5% CO_2 and 5% O_2 [b], and 10% CO_2 and 5% O_2 [c] at 10C

inactivation of some enzymes (Kader, 1986). CO_2 may inhibit PPO activity (Murr and Morris, 1994).

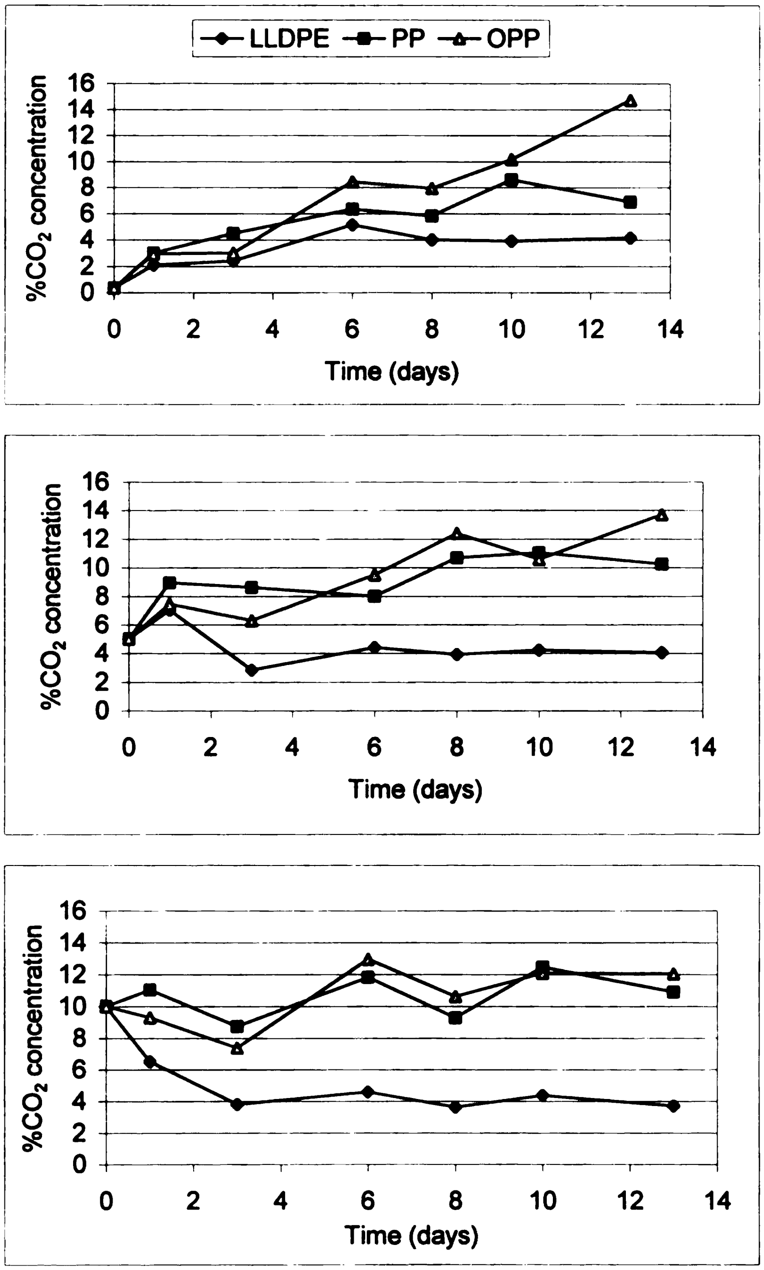
Mango slices in OPP bags containing 5% O_2 and 10% CO_2 had an acceptable visual quality (high 'L' value) after 13- and 8-day storage at 5 and 10°C, respectively, as shown in Figure 12 and 13. 'a' values dropped significantly after 1 day storage and increased slightly afterward as shown in Figure 14 and 15. 'b' values decreased slightly during storage for all treatments. No significant treatment effect was found for 'b' values. Similar results were reported by Gil et al. (1996), who showed that OPP bags were suitable for maintaining the pigment color of pomegranate seeds. Mango slices in LLDPE bags had more browning than those in PP and OPP bags. Koolpluksee (1991) reported that storage of mangoes in PP bags had a shelf life of 23 days.

Effect of low temperature storage

To study the effect of low temperature storage, 5 and 10°C samples were divided into two parts i.e., effect of low temperature storage on mango slices treated with antibrowning agents, and effect of low temperature storage on mango slices packed in polymeric films under modified atmosphere conditions.

Effect of low temperature storage on mango slices treated with antibrowning agents

There were significant differences ($p<0.05$) in 'L' and 'b' values between the two different temperatures. At 5°C, no microbial growth was visually present

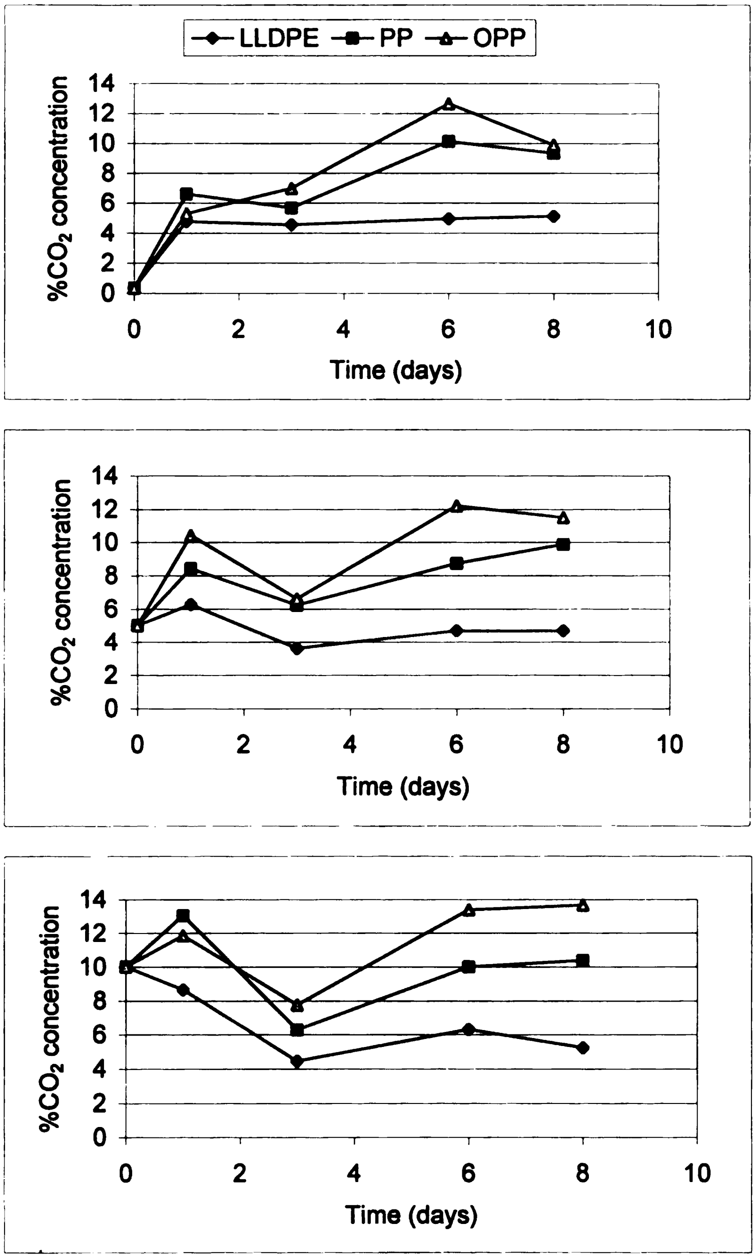


[a]

[b]

[c]

Figure 10 Changes in CO_2 concentration of mango slices packed in different packaging films in air [a], 5% CO_2 and 5% O_2 [b], and 10% CO_2 and 5% O_2 [c] at 5C



[a]

[b]

[c]

Figure 11 Changes in CO_2 concentration of mango slices packed in different packaging films in air [a], 5% CO_2 and 5% O_2 [b], and 10% CO_2 and 5% O_2 [c] at 10C

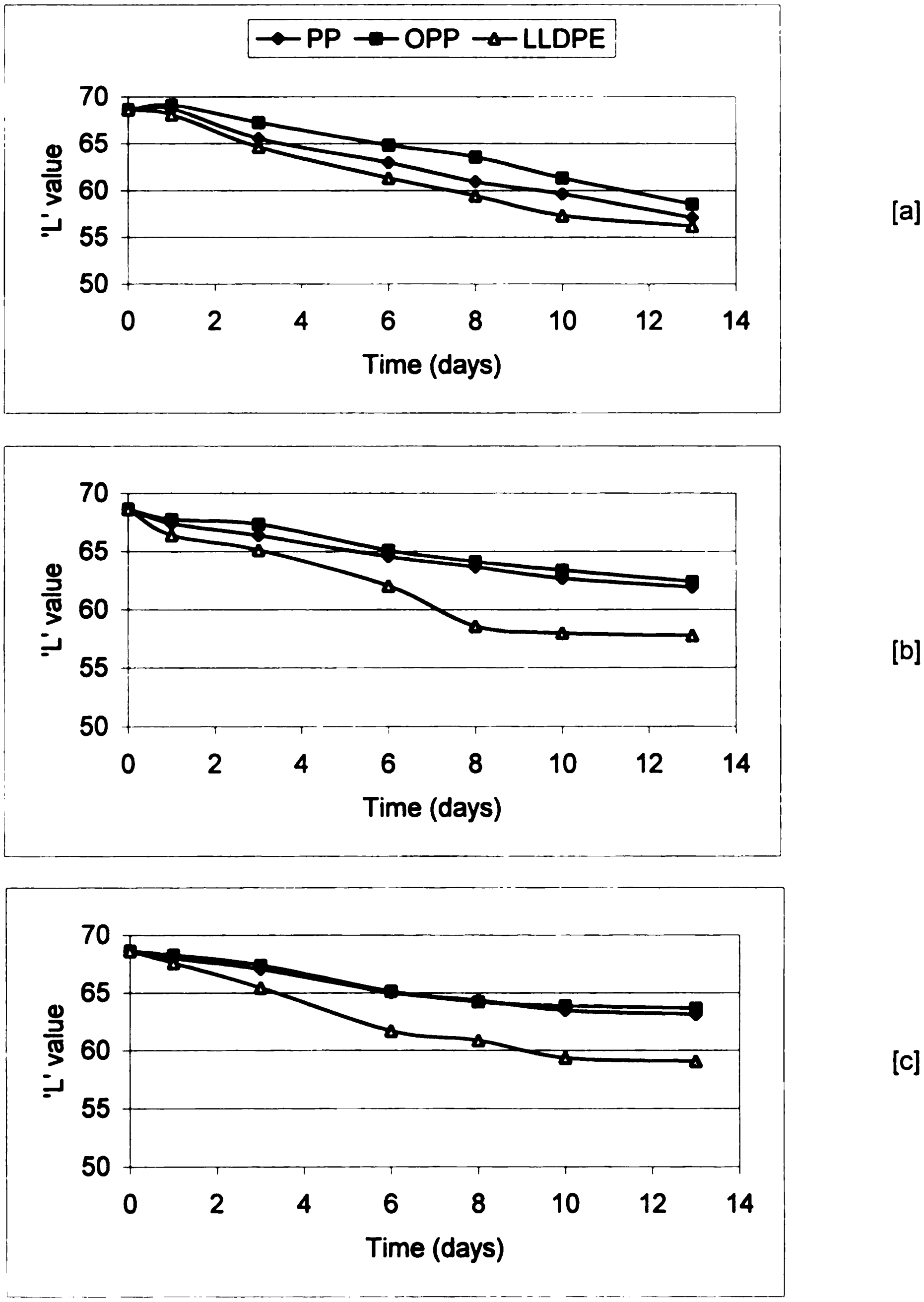


Figure 12 Effect of polymeric film type on the light/dark (L) value. Mango slices were packed in; [a] air, [b] 5% O_2 and 5% CO_2, [c] 5%O_2 and 10%CO_2 at 5C

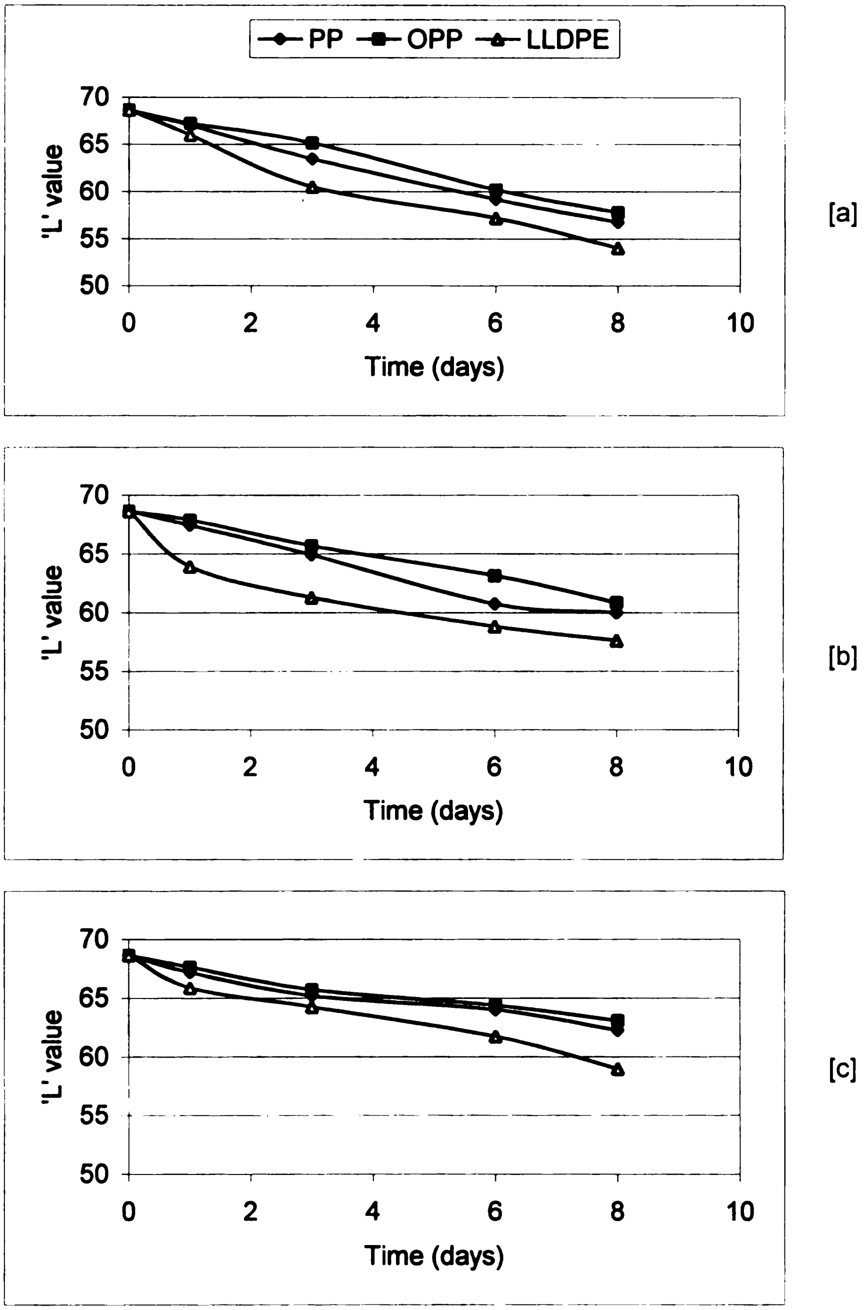


Figure 13 Effect of polymeric film type on the light/dark (L) value. Mango slices were packed in; [a] air, [b] 5% O_2 and 5% CO_2, [c] 5%O_2 and 10%CO_2 at 10C

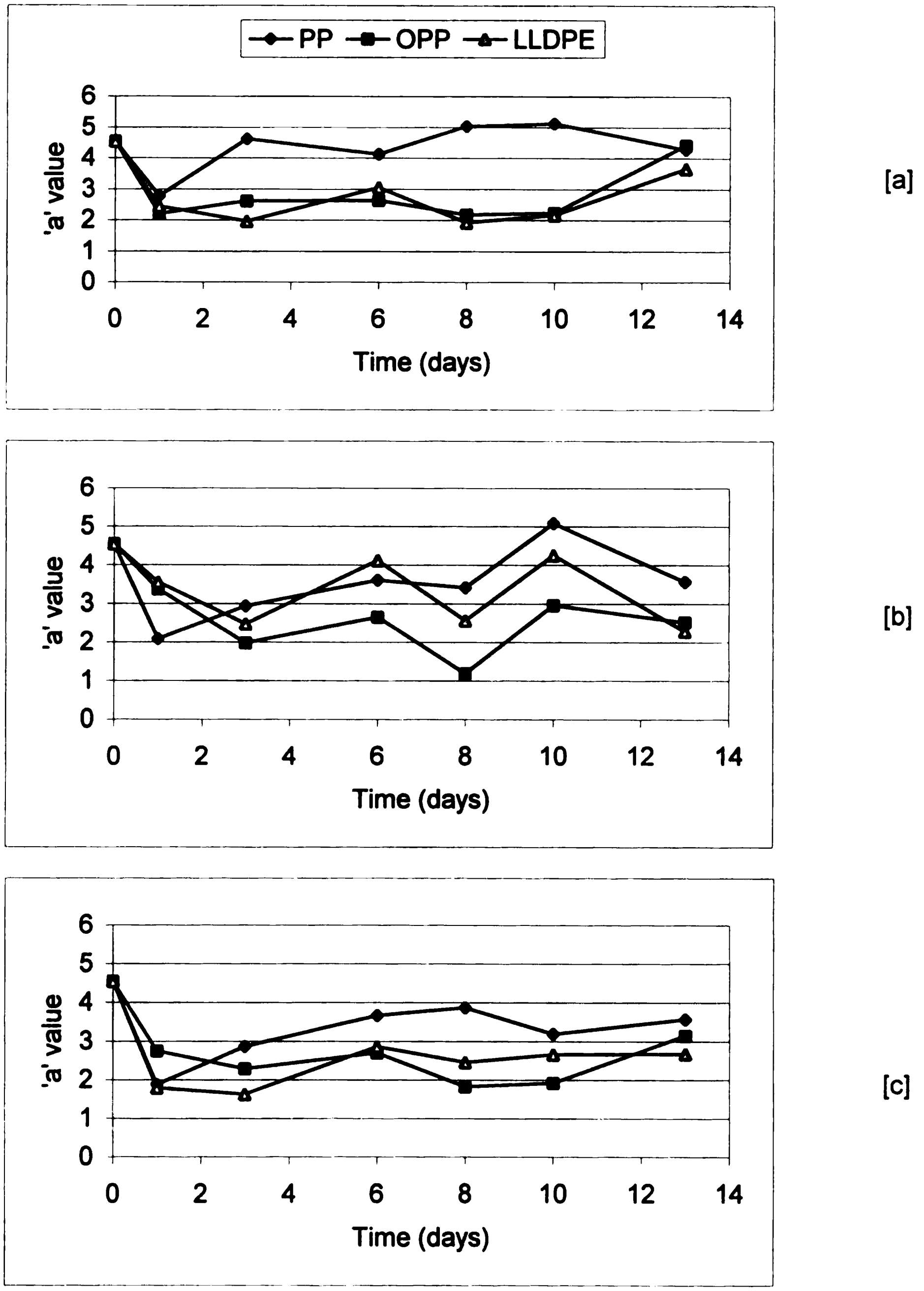


Figure 14 Effect of polymeric film type on the green/red ('a') value. Mango slices were packed in;[a] air, [b] 5% O_2 and 5% CO_2, [c] 5%O_2 and 10%CO_2 at 5C

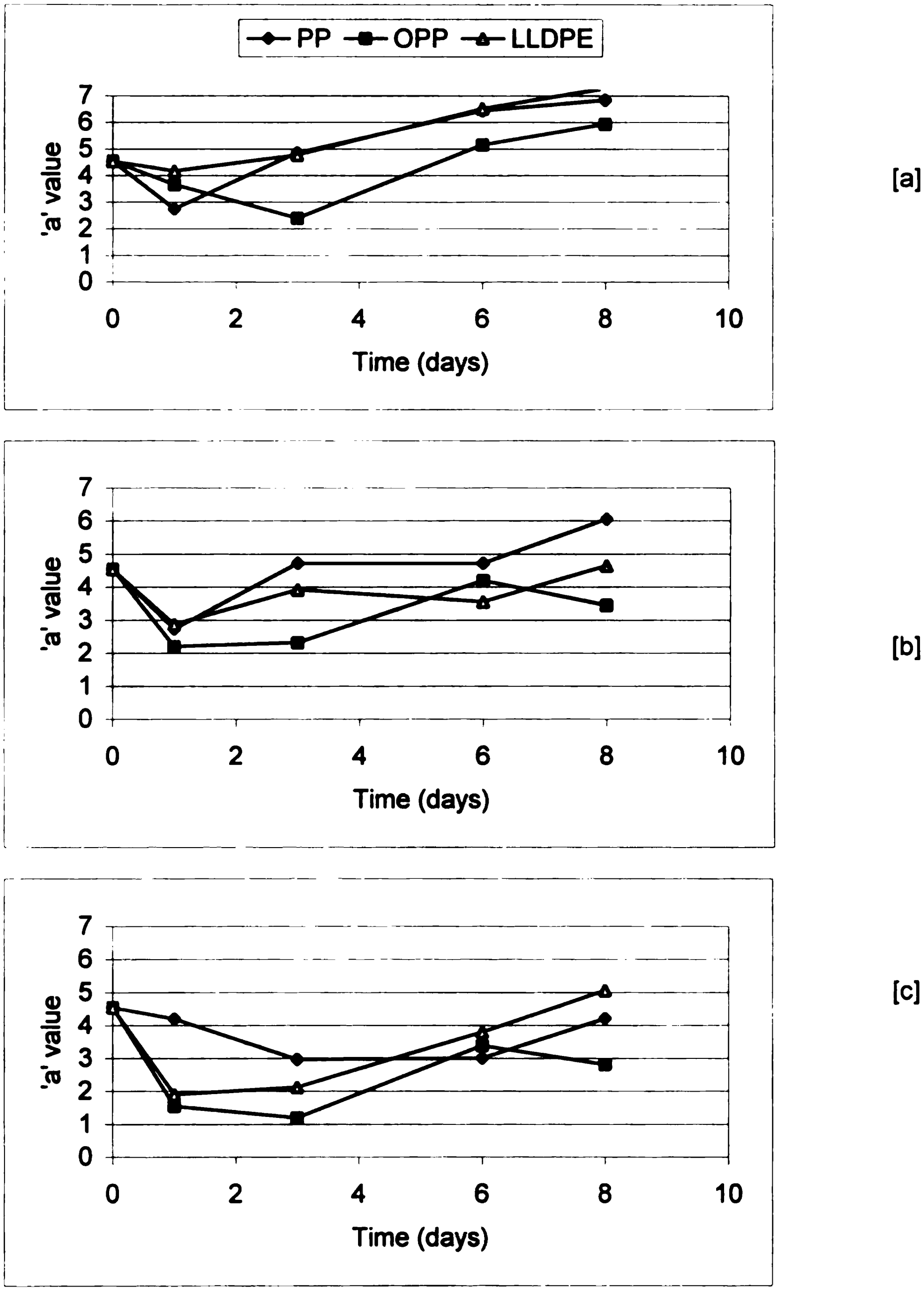


Figure 15 Effect of polymeric film type on the green/red ('a') value. Mango slices were packed in; [a] air, [b] 5% O_2 and 5% CO_2, [c] 5%O_2 and 10%CO_2 at 10C

in any of the packs. The 'L' values of all mangoes were superior to the L values of mango slices stored at 10°C (Figure 16). At 10°C, the quality of all packs was unacceptable, untreated mango slices (control) were spoiled in 7 days. After 10 days, mango slices treated with ascorbic acid and stored at 5°C were satisfactory.

Effect of low temperature storage on mango slices packed in polymeric films under modified atmosphere packaging

Polypropylene (PP), Oriented polypropylene (OPP) and Linear Low density polyethylene (LLDPE) films were used to packaged to package the mangoes. Significant treatment effects ($p<0.05$) occured for 'L', 'a', and 'b' values. Changes in 'L', 'a', and 'b' values in PP, OPP and PE packages at 5 and 10°C are shown in Figures 17, 18 and 19. Mango slices stored at 5°C exhibited a high 'L' value at the end of 13 days storage, while mangoes stored at 10°C had an acceptable visual quality for only 8 days. Carlin et al. (1990), was able to maintain grated carrots in an acceptable quality in low temperature storage, even with a low permeability film. Bolin et al. (1977) found that the shelf life of shredded lettuce was extended under low temperature storage. Pigment degradation of minimally processed pomegranate seed was minimized by storage at 1°C (Gil et al., 1996). Enzyme activities and biochemical changes are temperature dependent. Therefore, optimal temperature minimizes tissue senescence and thus delays enzymatic discoloration.

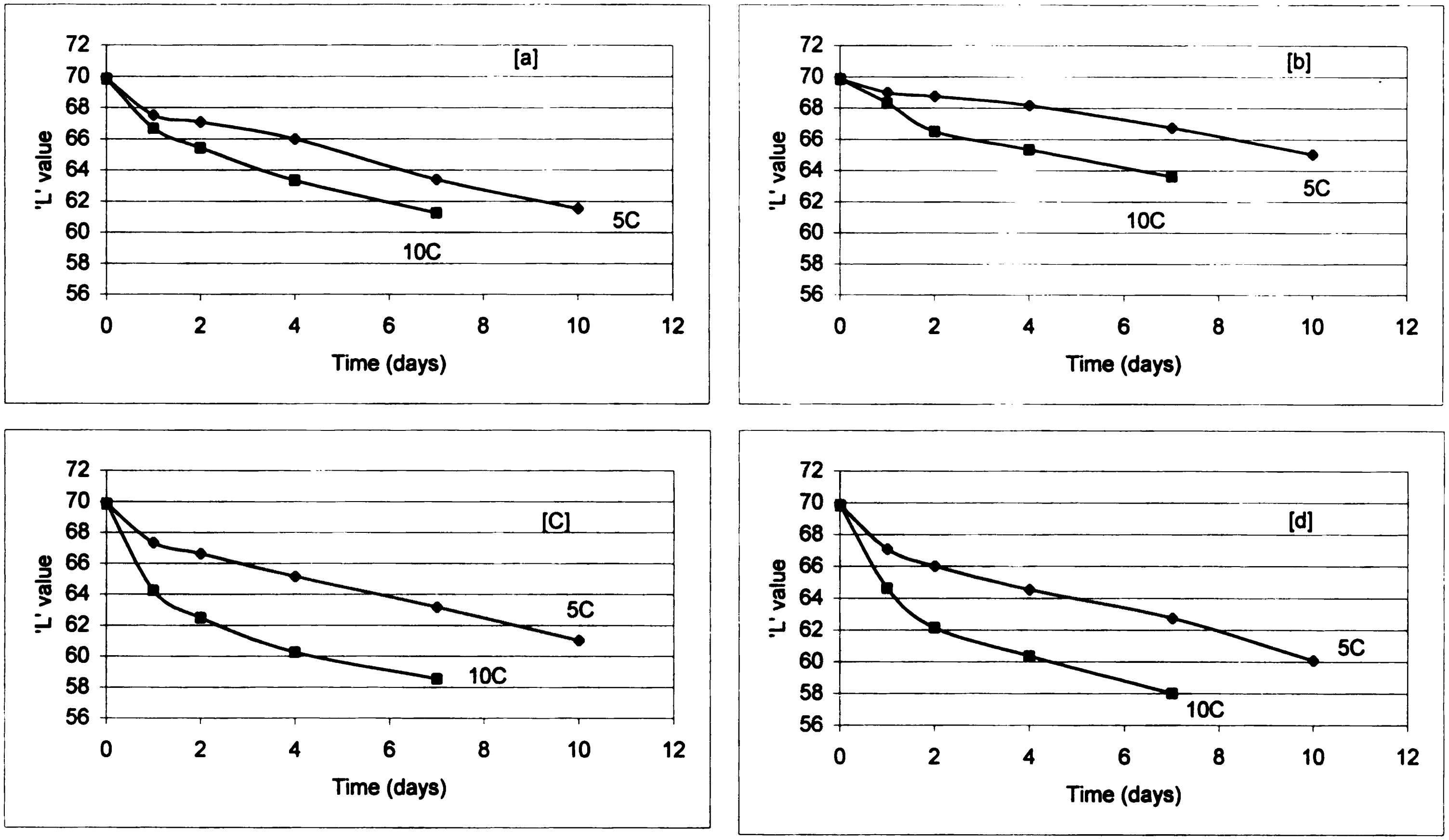
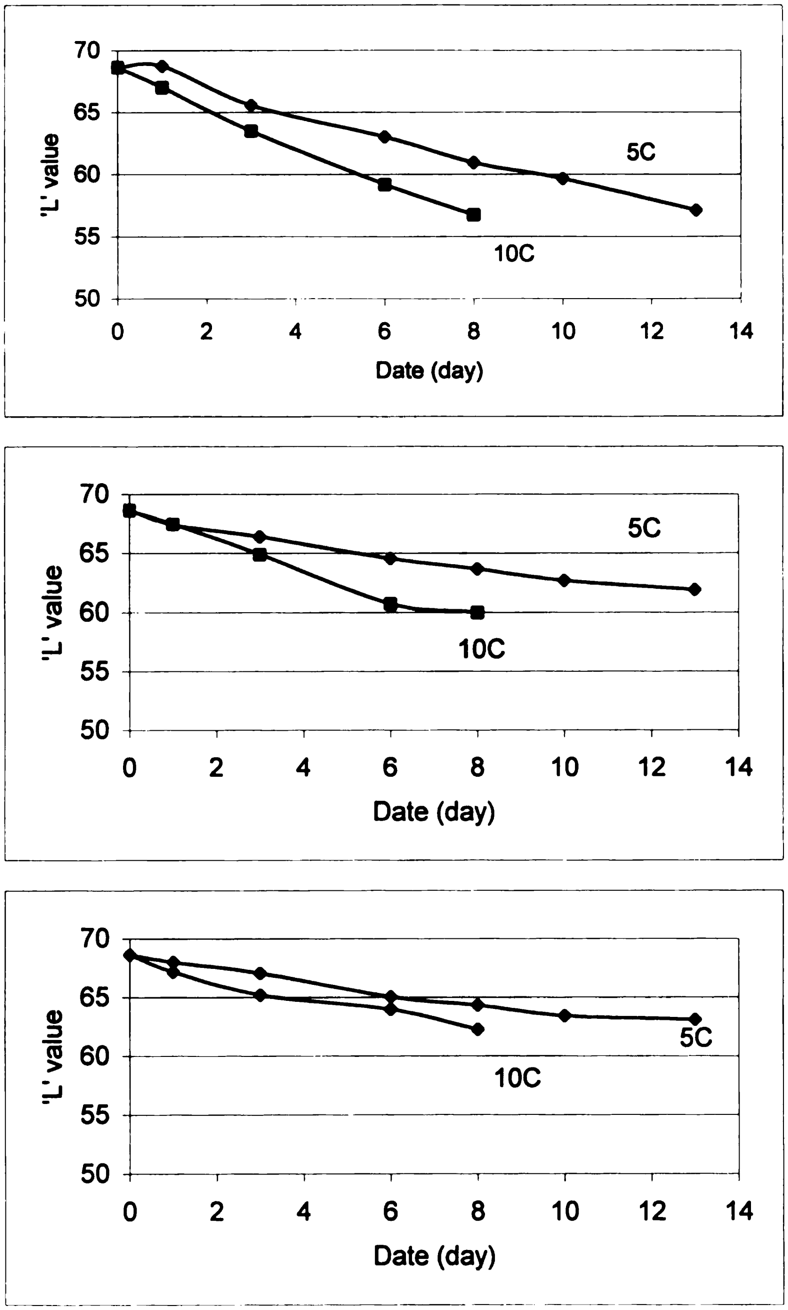


Figure 16 Effect of temperature on the light/dark (L) values, of mangoes subjected to the following treatments; [a] citric acid, [b] ascorbic acid, [c] citric acid plus ascorbic acid, [d] control.



[a]

[b]

[c]

Figure 17 Effect of storage temperatures on 'the light/dark (L) value, of mango slices packed in PP film under modified atmosphere; [a] air, [b] 5% O_2 and 5% CO_2, [c] 5%O_2 and 10%CO_2

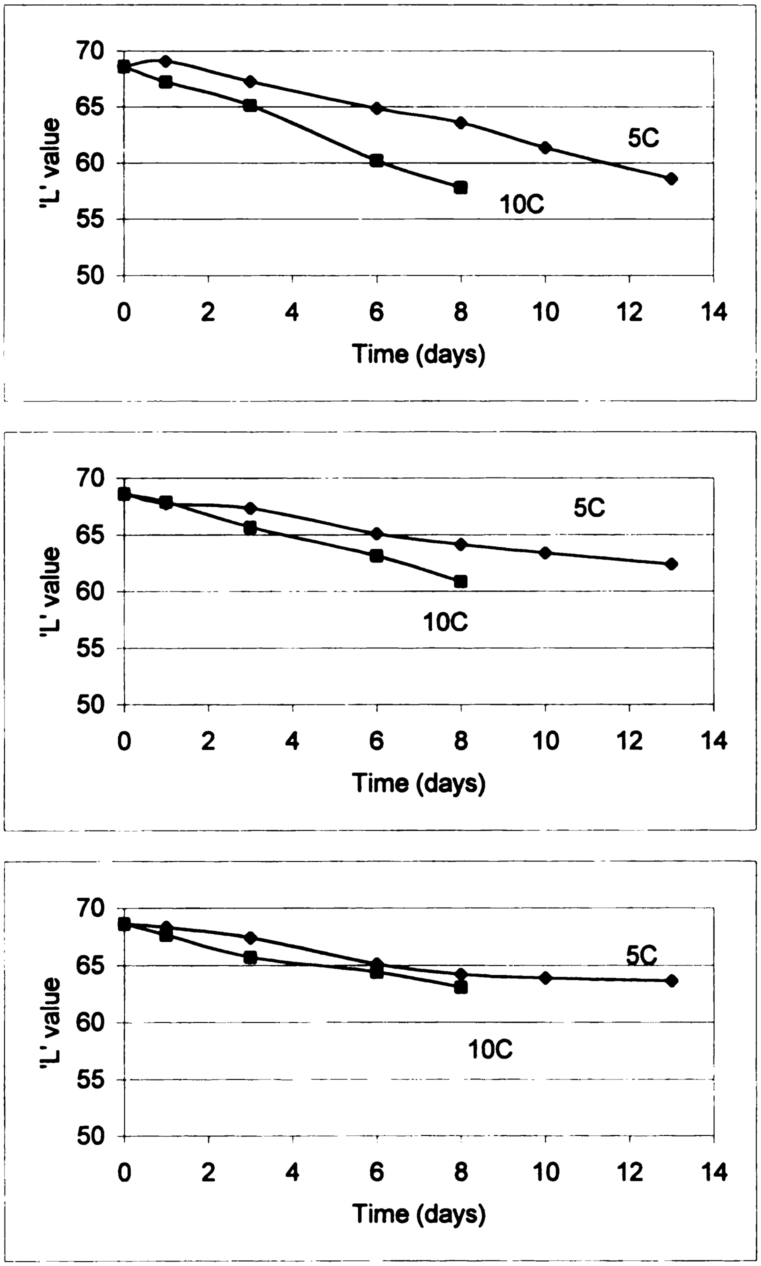
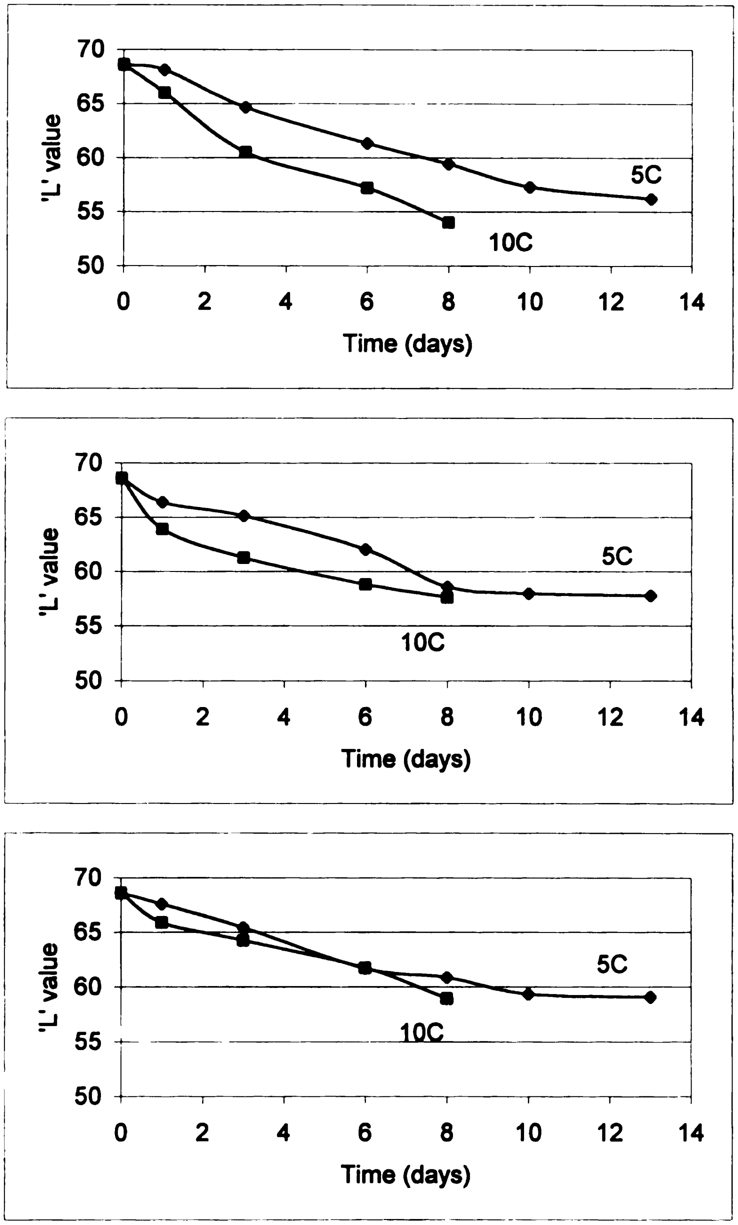


Figure 18 Effect of storage temperatures on the light/dark (L) value, of mango slices packed in OPP film under modified atmosphere; [a] air, [b] 5% O_2 and 5% CO_2, [c] 5%O_2 and 10%CO_2.



[a]

[b]

[c]

Figure 19 Effect of storage temperatures on the light/dark (L) value, of mango slices packed in LLDPE film under modified atmosphere; [a] air, [b] 5% O_2 and 5% CO_2, [c] 5%O_2 and 10%CO_2

Effect of MAP on product quality

Color.

Figures 20 and 21 show the effect of MAP on 'L' values of mango slices stored at 5 and 10°C, respectively. Gas concentration had a significant effect on 'L' values. 'L' values dropped significantly after 2 days storage at 5°C. Mango slices packaged in air were browner than mango slices packed in the other atmospheres. Acceptable visual quality was obtained in mango slices packed in 5% O_2 and 10% CO_2 at both temperatures.

At 5°C no significant treatment effects were found on "a" value. The effect of MAP on the 'a' values of mango slices stored at 10°C are shown in Figure 22. 'a' values dropped after 1-day storage and then gradually increased in all treatments. Gas concentration had a significant effect on 'a' values. The highest 'a' values were obtained in mango slices packed in air.

No significant treatment effects on 'b' values were found. 'b' values changed only slightly during storage.

pH.

Gas content had no significant treatment effects ($p<0.05$) on pH of the mangoes at 5 and 10°C. This was in contrast to the findings of Siripanich and Kader (1986), who reported that lettuce stored at 0°C in16% CO_2 and in air had a decreased pH.

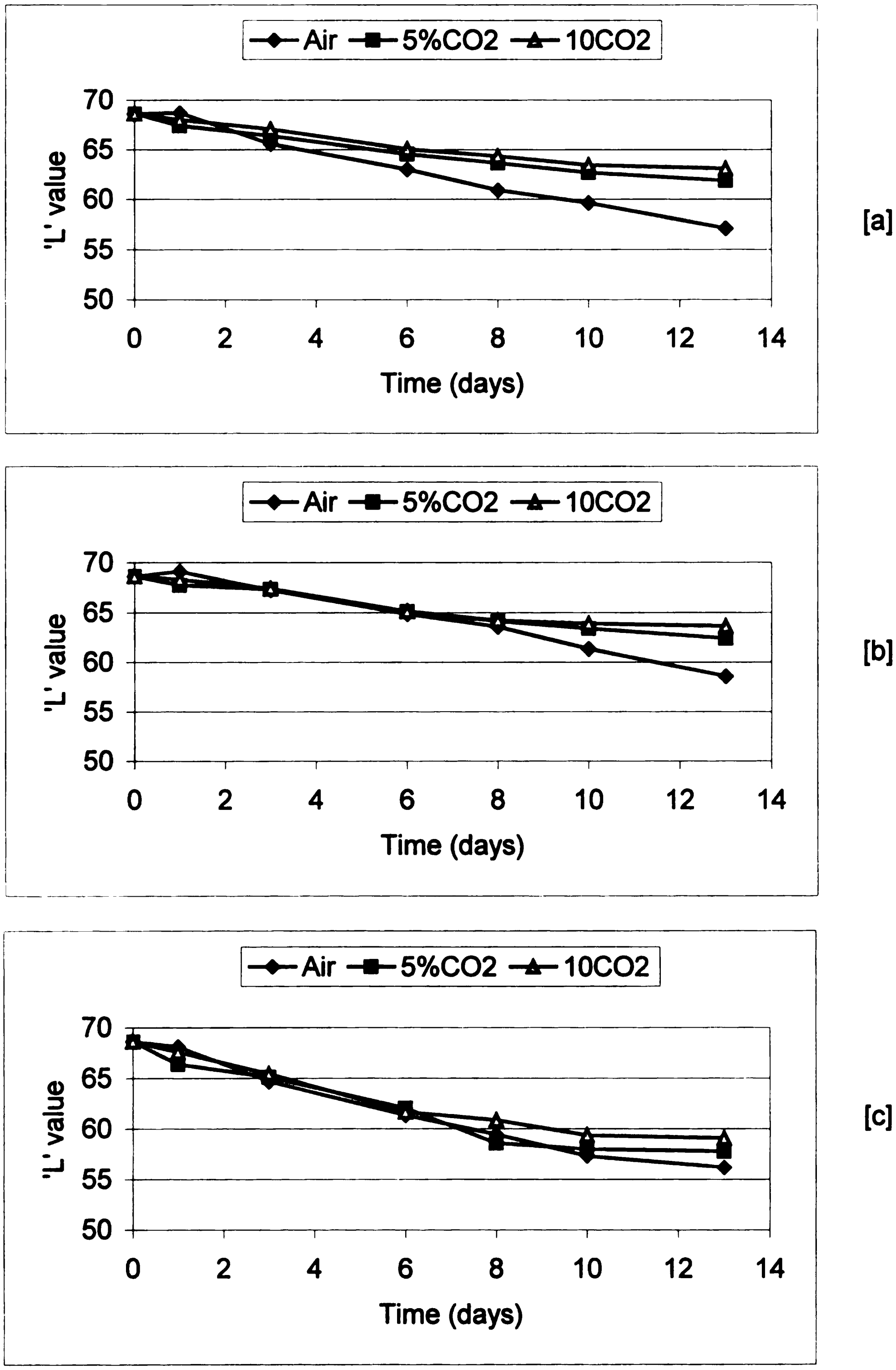
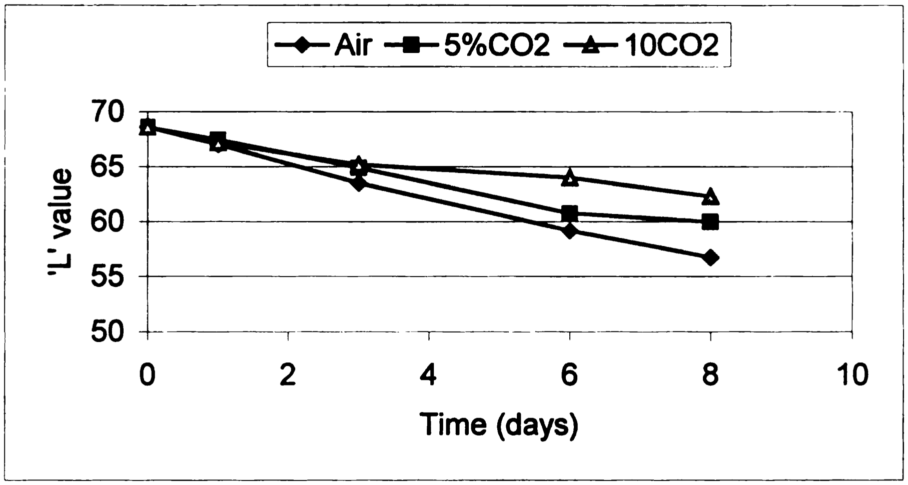
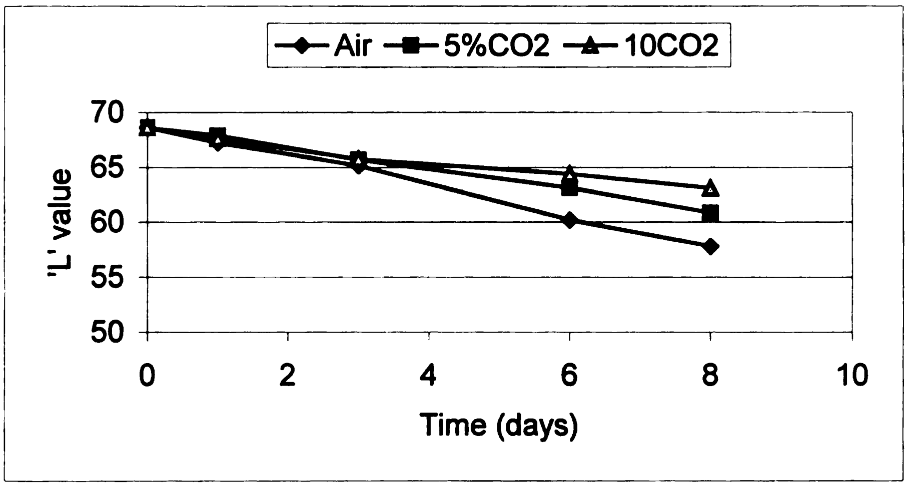


Figure 20 Effect of MAP on the light/dark (L) values, of mango slices packed in, [a] PP, [b] OPP, and [c] LLDPE at 5C



[a]



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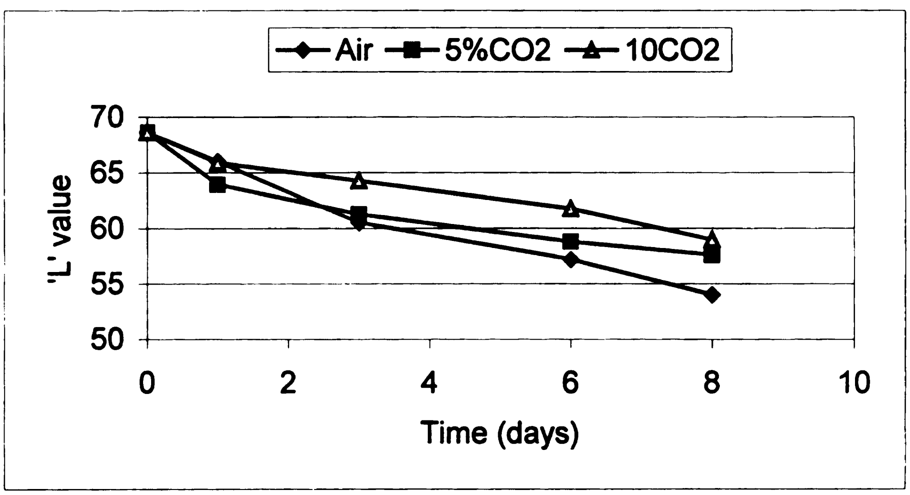


[c]

Figure 21 Effect of MAP on the light/dark (L) values, of mango slices packed in, [a] PP, [b] OPP, and [c] LLDPE at 10C

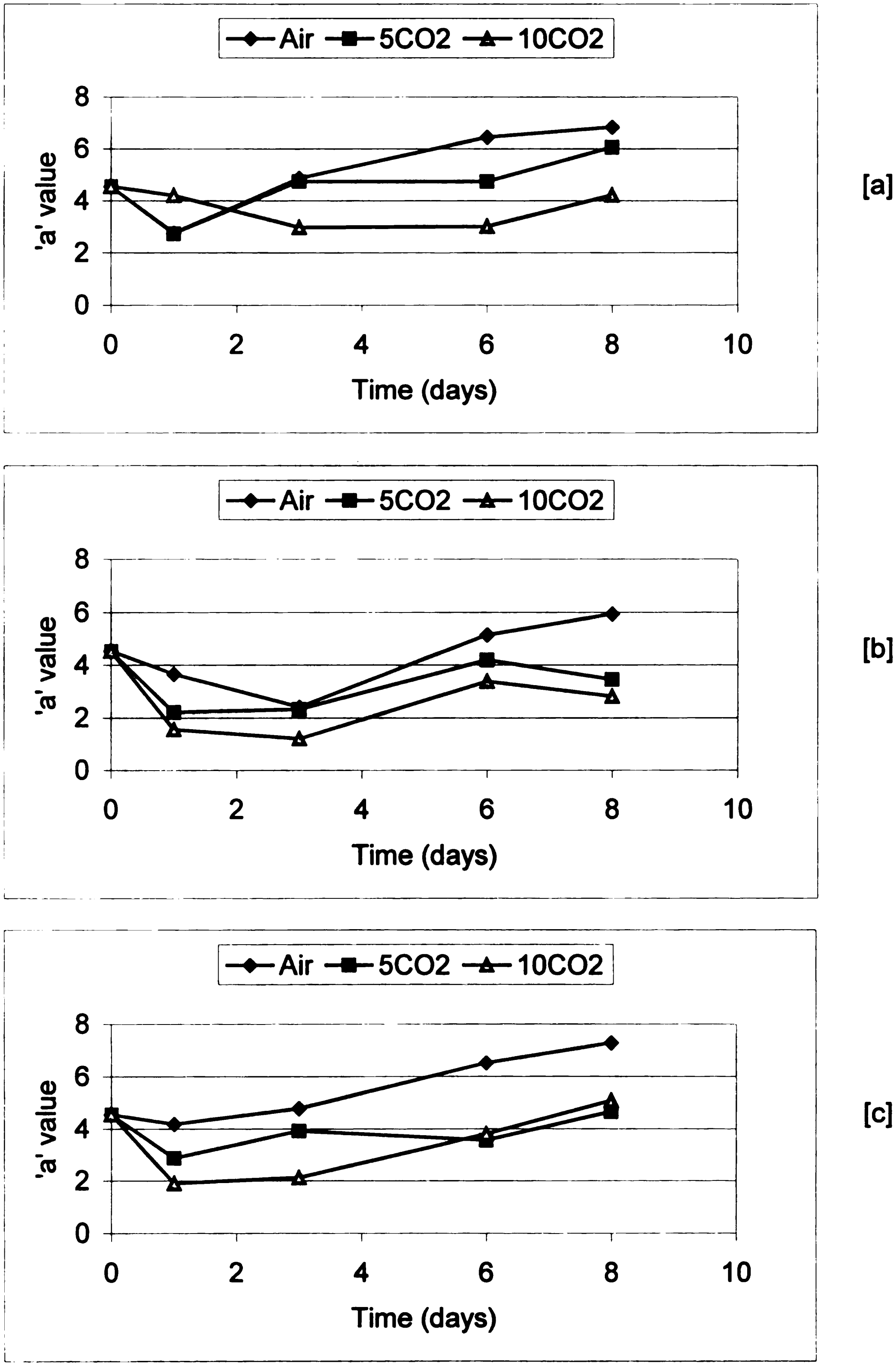


Figure 22 Effect of MAP on the green/red ('a') values, of mango slices packed in; [a] PP, [b] OPP, [c] LLDPE at 10C

Weight loss.

Figure 23 and 24 show the effect of MAP on weight loss of mango slices stored at 5 and 10°C, respectively. Weight loss occurs due to moisture loss by diffusion through the film. Little weight loss occurred in mango slices packed in low water vapor transmission rate (WVTR) films.

Total Soluble Solids (TSS).

The longer mango is stored, the higher will be its TSS. This is because starch in the mango fruit is converted into sugar (Arpaia et al., 1985). However, elevated amounts of CO_2 and lower levels of O_2 will delay its ripening (Katesa, 1985) and, thus, delay the increase in TSS.

Packages that initially had 10% CO_2 in the headspace had lower TSS compared to other treatments. The same result was reported with the "Alphonso" variety (Lakshminarayanas and Subramanyam, 1970). At 5°C, the highest TSS was obtained after 8-day storage (except mango slices packed in air) with a gradual declined (Figure 25). At 10°C, TSS increased rapidly in all treatments after 3-days storage and then gradually declined (Figure 26). Mangoes packaged in PE film had the highest TSS.

Firmness.

No significant treatment effects were found in mango slices stored at 5°C. Figure 27 shows the effect of MAP on the firmness of mango slices stored at 10°C. Flesh firmness dropped significantly after 3-days storage. Mango slices

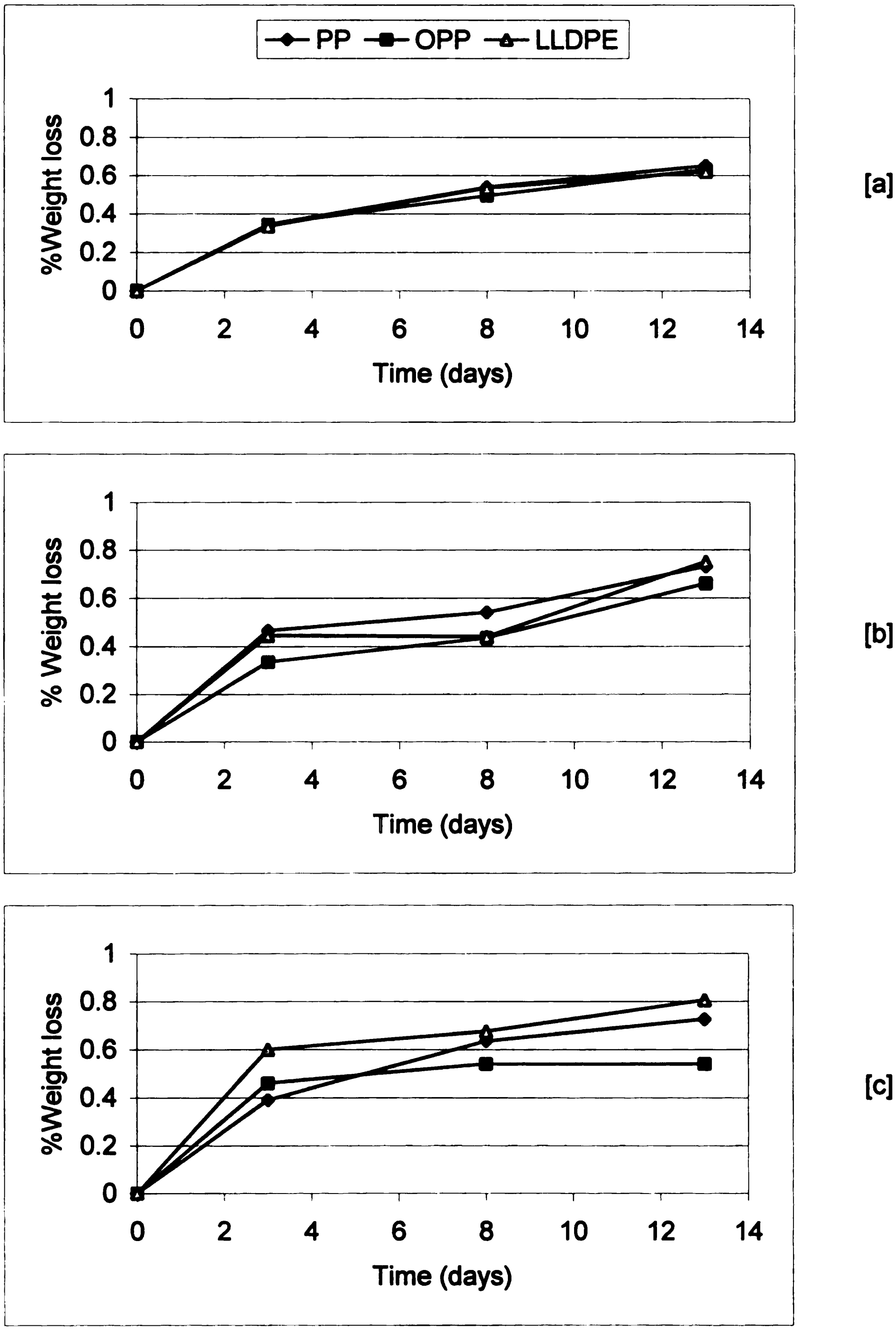


Figure 23 Effect of MAP on %weight loss, mango slices were packed in, [a] air, [b] 5% O_2 and 10% CO_2, [c] 5% O_2 and 10% CO_2 stored at 5C

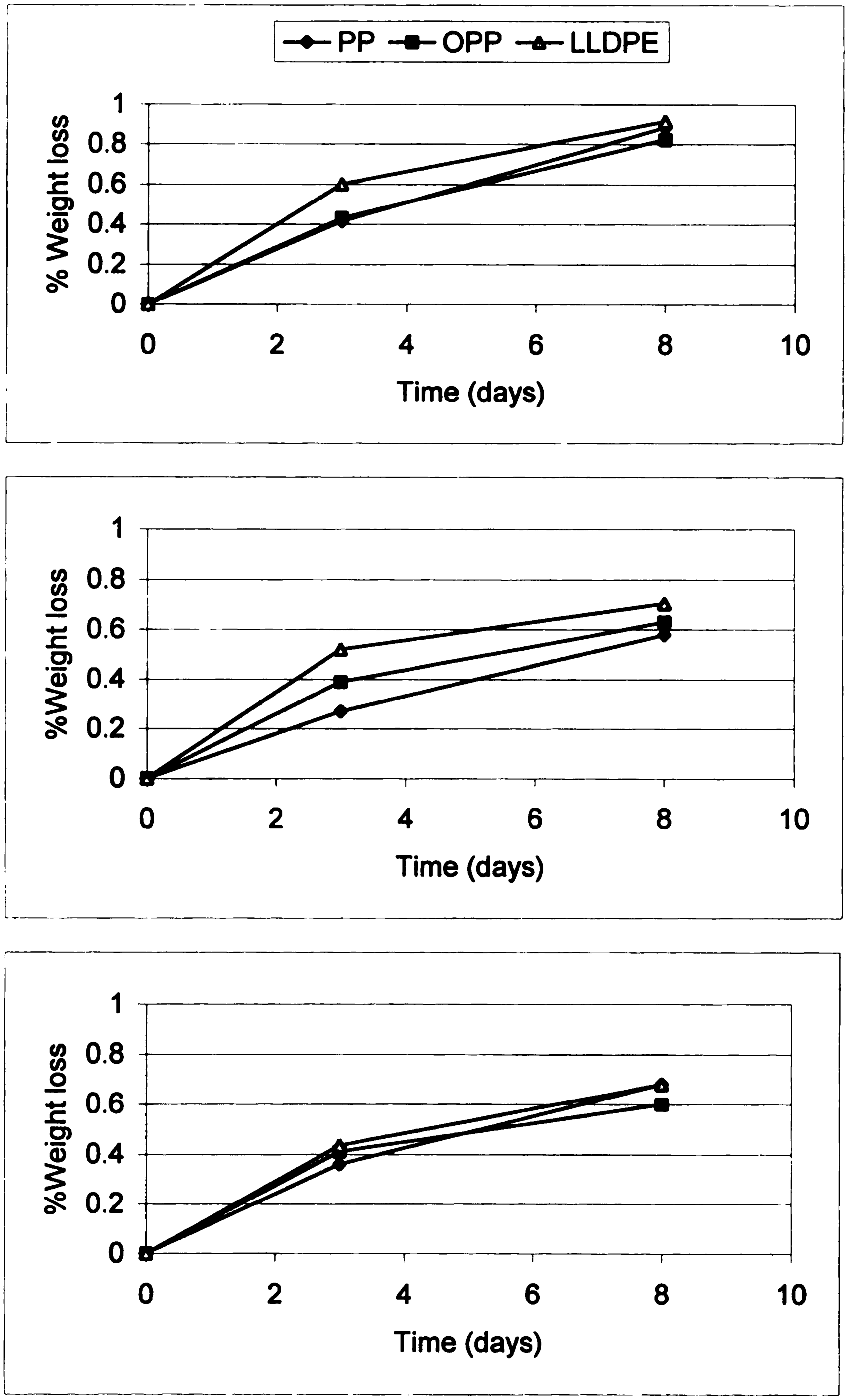
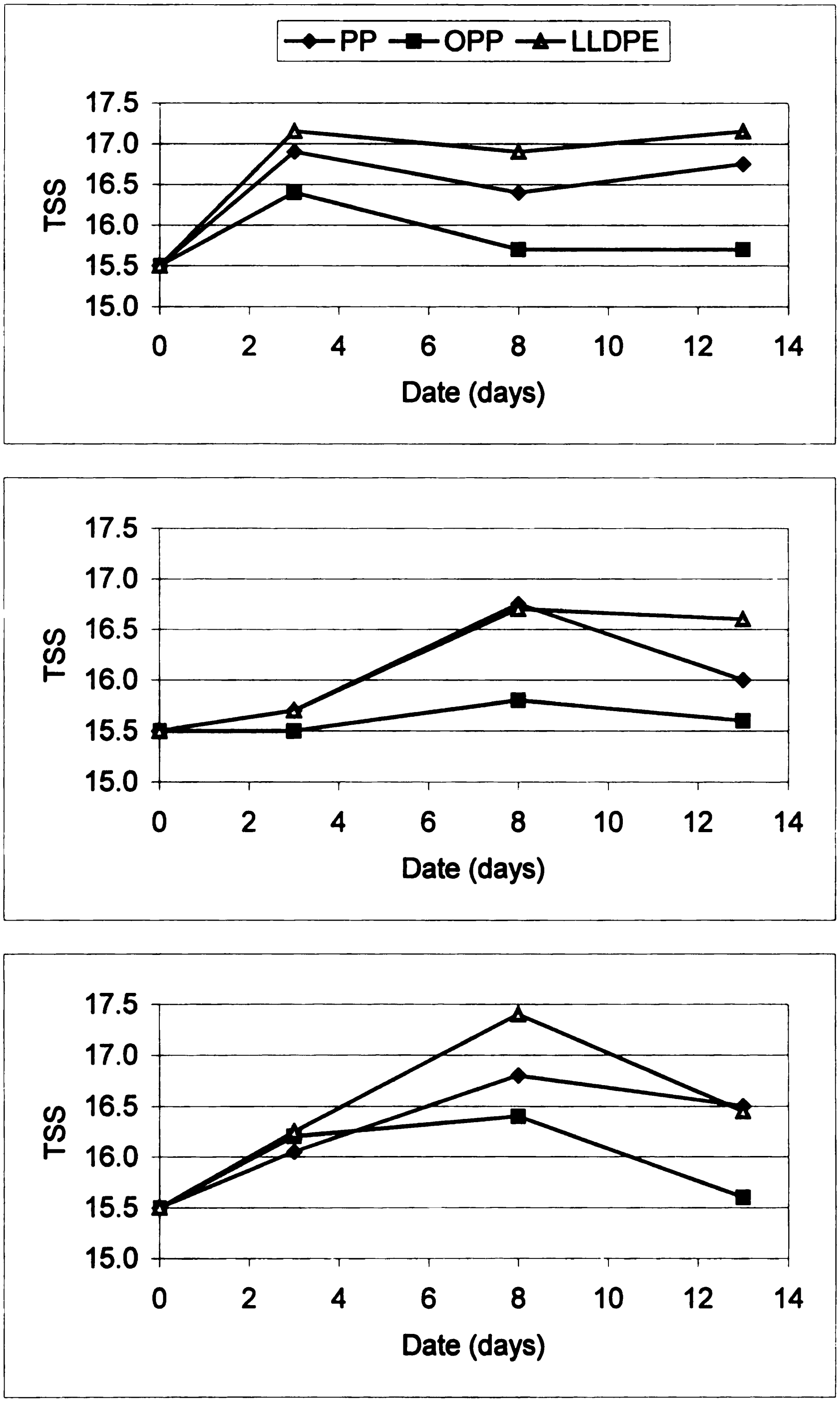


Figure 24 Effect of MAP on %weight loss, mango slices were packed in, [a] air, [b] 5% O_2 and 10% CO_2, [c] 5% O_2 and 10% CO_2 stored at 10C



[a]

[b]

[c]

Figure 25 Effect of MAP the on TSS, of mango slices packed in; [a] air, [b] 5% O_2 and 10% CO_2, [c] 5% O_2 and 10% CO_2 stored at 5C

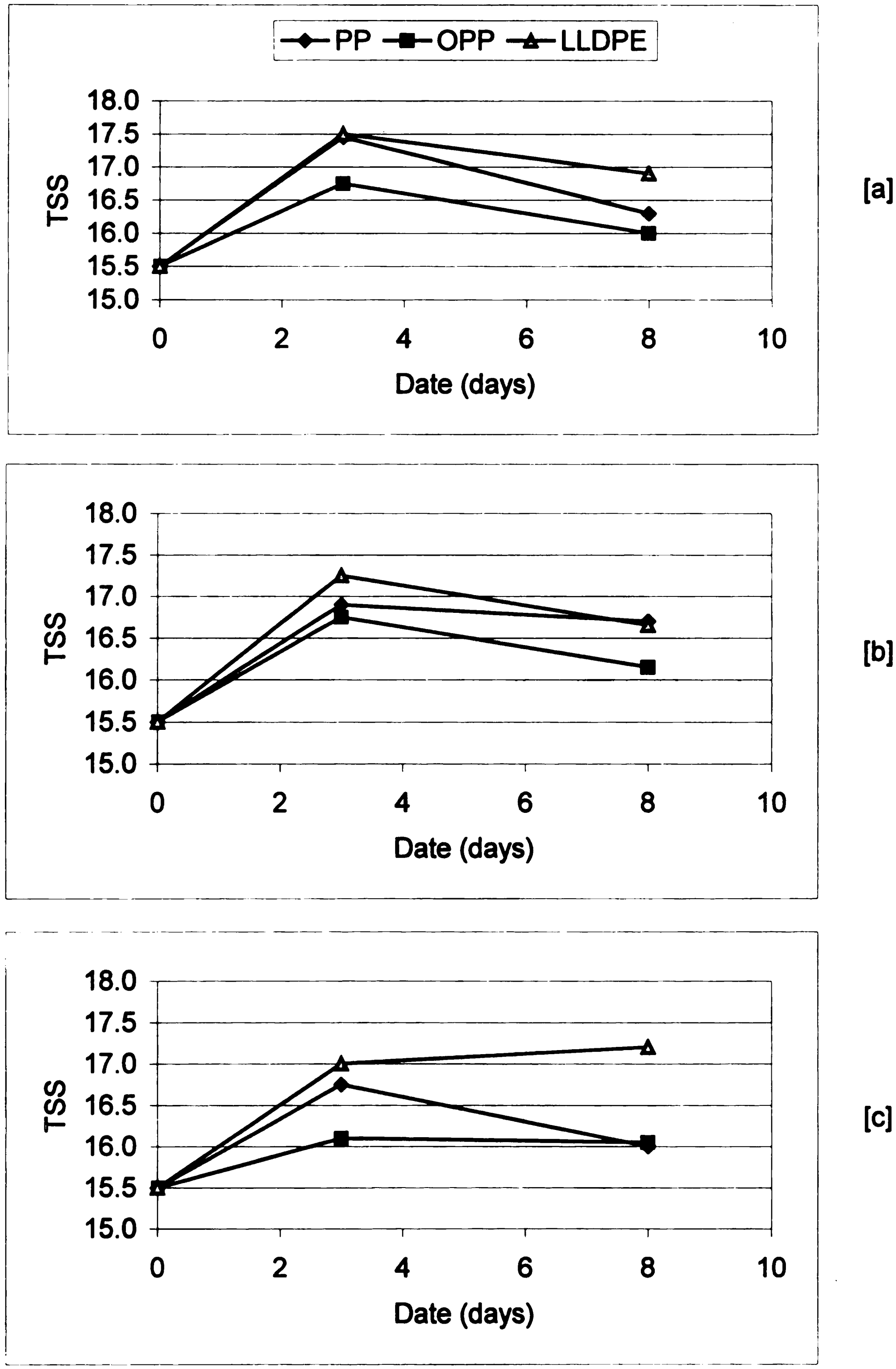
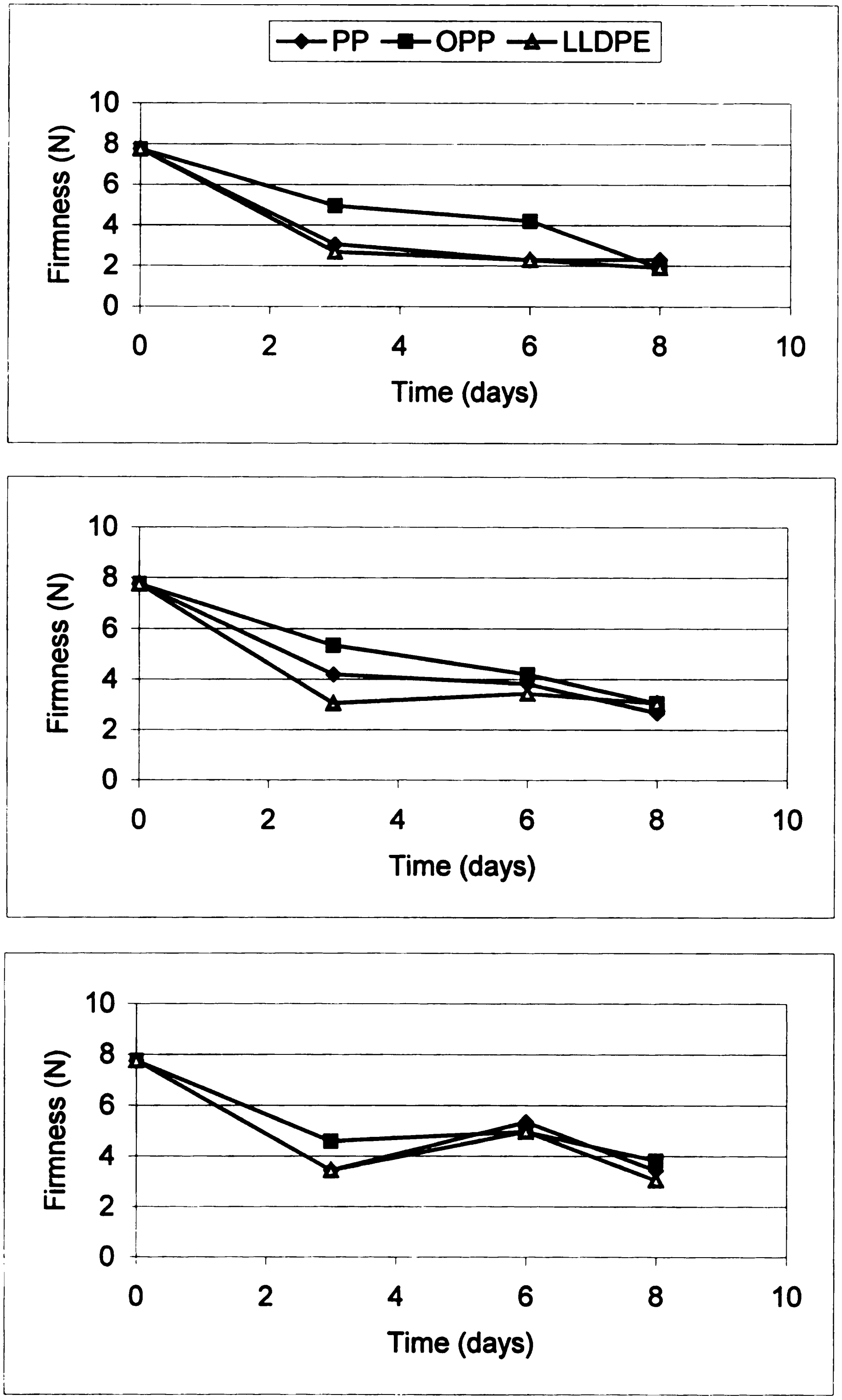


Figure 26 Effect of MAP on theTSS, of mango slices packed in, [a] air, [b] 5% O_2 and 10% CO_2, [c] 5% O_2 and 10% CO_2 stored at10C



[a]

[b]

[c]

Figure 27 Effect of MAP on the firmness, of mango slices packed in, [a] air, [b] 5% O_2 and 10% CO_2, [c] 5% O_2 and 10% CO_2 stored at 10C

packed in air had lower firmness than other treated mangoes. The firmness associated with mango slices is related to the atmospheric conditions within the package. According to Spencer (1965), elevated CO_2 and reduced O_2 helps delay the loss of flesh firmness. Conversion of the insoluble pectin (protopectin) to soluble pectin during storage causes the reduction in firmness (Knee and Bartley, 1981).

PPO.

PPO activity increased during storage for all packaged mangoes (Figure 28 and 29). Mango slices packaged in OPP containing 10% CO_2 and 5% O_2 had lower PPO activity than the other MA packagings. This is in agreement with Siripanich and Kader (1985), who found that high CO_2 concentrations reduced PPO activity.

Low O_2 concentration delays enzymatic browning because PPO has a relatively low affinity for oxygen (Burton, 1974). Therefore, packages with low O_2 concentration and with greater O_2 barrier have the potential to prevent browning. However, the O_2 concentration must be high enough to maintain aerobic respiration. Moderate vacuum packaging in 80 μm polyethylene inhibited enzymatic browning over 10 days storage at 5°C (Heimdal, 1995).

Microbial safety

Mold and yeast were counted at the end of the storage period. Ready-to-eat fruits and vegetables should have populations of; 1) yeast 10^4< CFU/g, mold

< 500 CFU/g, E.coli < 10 CFU/g and none of Salmonellae (Department of Medical Science, Thailand). Mango slices packed in OPP bags in 5% O_2 and 10% CO_2, and stored at 5°C had an acceptable quality after 13 days. No visible sign of decay was observed on the samples. No mold was found and the yeast population was 2×10^2 CFU/g. Therefore, treated mango slices were below the regulation set by the medical board.

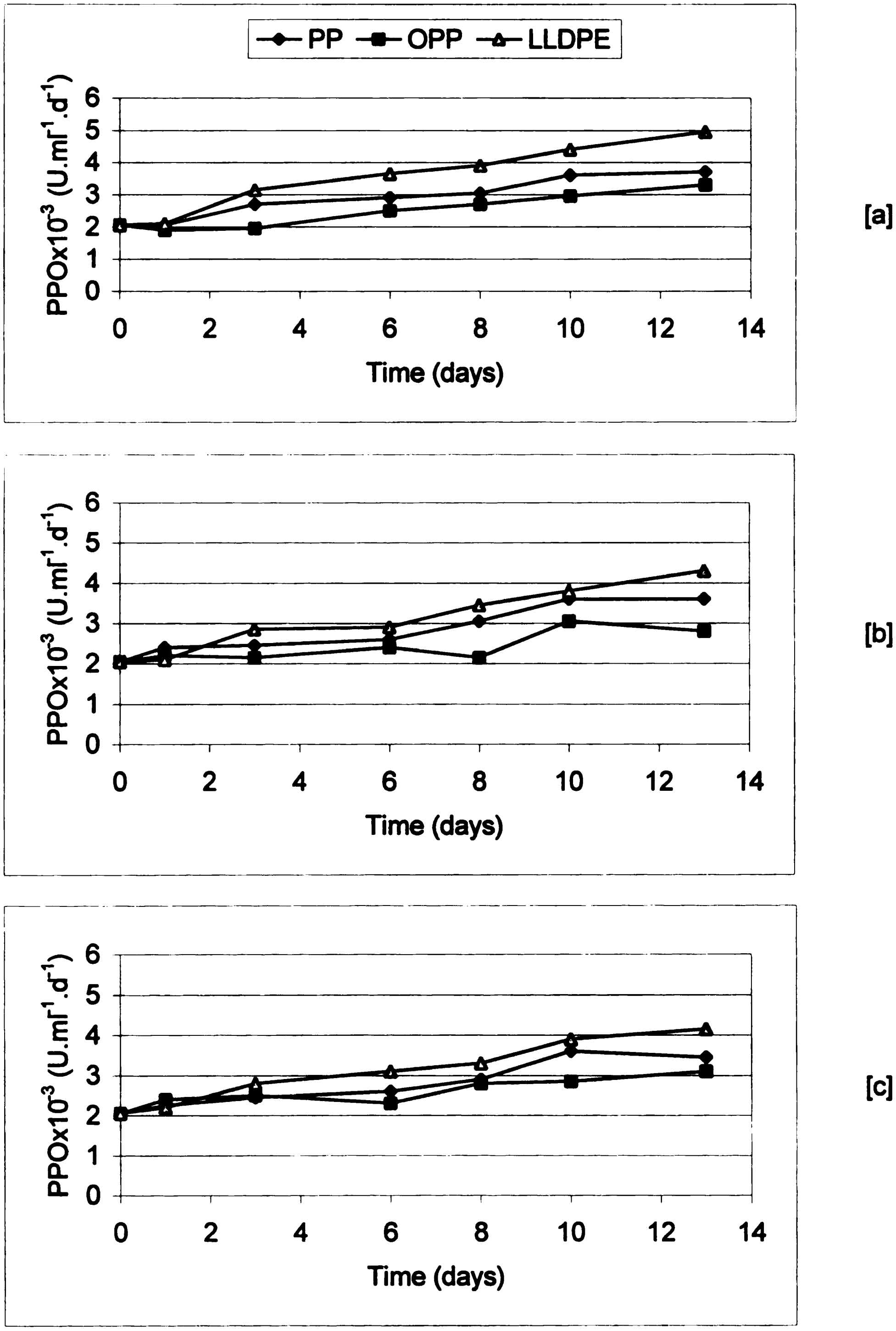
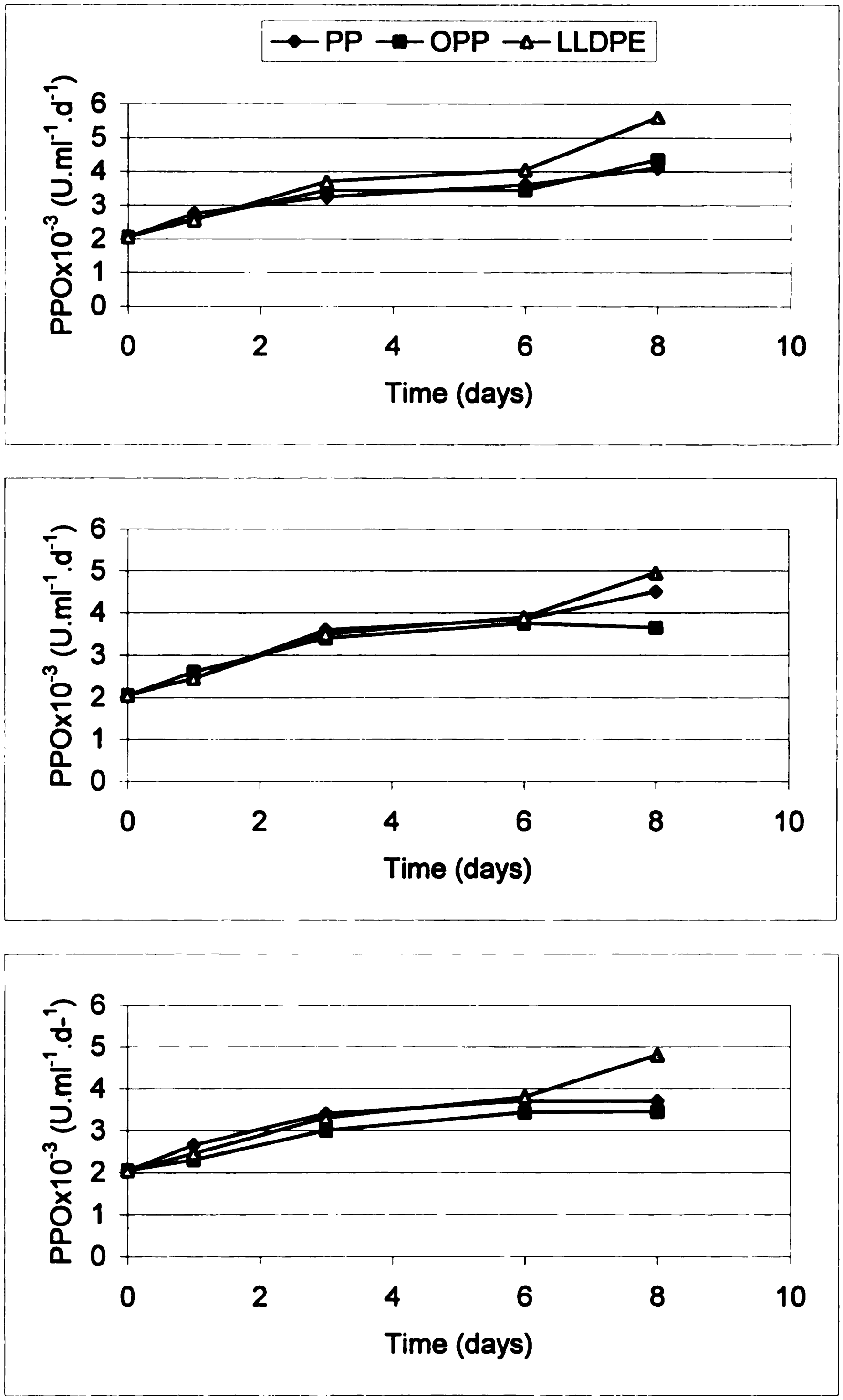


Figure 28 Effect of MAP on the PPO activity of mango slices packed in, [a] air, [b] 5% O_2 and 10% CO_2, [c] 5% O_2 and 10% CO_2 and stored at 5C



[a]

[b]

[c]

Figure 29 Effect of MAP on the PPO activity of mango slices packed in, [a] air, [b] 5% O_2 and 10% CO_2, [c] 5% O_2 and 10% CO_2 and stored at 10C

CHAPTER 4

CONCLUSION AND FUTURE RESEARCH

Conclusion

Minimally processed mangoes are subject to discoloration reactions, associated with condition of the raw material, peeling, and slicing. Ascorbic acid (0.5%) was the most effective browning inhibitor for mango slices (Nam Dokmai). Washing with chlorine plus dipping in calcium chloride gave no better results than washing with chlorine only, with regards to the firmness. Temperature plays an important role in controlling quality. Acceptable visual quality was obtained with mango slices at 5°C, but flesh firmness dropped significantly after 3-day storage. 5°C may be too low to maintain flesh firmness. A suitable temperature should be higher than 5°C but lower than 10°C. The most effectives packaging conditions were obtained with an OPP package in combination with 5% O_2 and 10% CO_2. Carbon dioxide (10%) retarded enzymatic browning of the mango slices. Acceptable visual quality was retained for 13 days. Yeast and mold counts were lower than the regulations allowed by Department of Medical Science, Thailand. High CO_2 and low O_2 concentrations also reduced PPO activity and delayed the increase in TSS. Further research is necessary to evaluate other factors (sensory evaluation, etc.) before the best conditions for storage of this minimally processed product can be recommended.

Extended storage life was obtained through the combination of the following: ascorbic acid (0.5%) dip to reduce enzymatic browning, storage at 5°C, pack in OPP to minimize weight loss and to maintain high level of CO_2, and flush with 5% O_2 and 10% CO_2 to reduce PPO.

FUTURE RESEARCH

This research emphasized application of antibrowning agents and MAP to inhibit enzymatic browning in mango slices, 'Nam Dokmai' variety. However, there is still a vast body of knowledge that remains unexplored. Use of MAP requires further understanding of many interactive components. Below are just a few areas that could be of benefit for further researches:

- Effect of maturities of mango fruits
- Effect of low temperature on chilling injury
- Effect of carbon dioxide on CO_2 injury
- Sensory evaluation of mango slices under MAP

APPENDIX A

Table 10: Analysis of Variance Procedure: the effect of antibrowning treatments on 'L' values.

Dependent Variable: L value

Source	Type I Sum of Squares	df	Mean Square	F	Sig.
TREAT	214.050	3	71.350	23.120	0.000
TEMP	65.104	1	65.104	21.096	0.000
DATE	1027.357	5	205.471	66.581	0.000
TREAT * TEMP	29.115	3	9.705	3.145	0.029
TREAT * DATE	68.044	15	4.536	1.470	0.134
TEMP * DATE	49.840	4	12.460	4.038	0.005
TREAT * TEMP * DATE	11.179	12	0.932	0.302	0.988

Table 11: Analysis of Variance Procedure: the effect of antibrowning treatments on 'a' values.

Dependent Variable: 'a' value

Source	Type I Sum of Squares	df	Mean Square	F	Sig.
DATE	11.597	5	2.319	4.137	0.002
TREAT	9.043	3	3.014	5.377	0.002
TEMP	0.037	1	0.037	0.066	0.799
DATE * TREAT	9.554	15	0.637	1.136	0.337
DATE * TEMP	9.678	4	2.420	4.316	0.003
TREAT * TEMP	2.291	3	0.764	1.362	0.260
DATE * TREAT * TEMP	3.433	12	0.286	0.510	0.903

Table 12: Analysis of Variance Procedure: the effect of antibrowning treatments on 'b' values.

Dependent Variable: 'b' value

Source	Type I Sum of Squares	df	Mean Square	F	Sig.
DATE	170.154	5	34.031	10.400	0.000
TREAT	64.113	3	21.371	6.531	0.000
TEMP	27.879	1	27.879	8.520	0.004
DATE * TREAT	44.464	15	2.964	0.906	0.560
DATE * TEMP	7.111	4	1.778	0.543	0.704
TREAT * TEMP	3.325	3	1.108	0.339	0.797
DATE * TREAT * TEMP	10.041	12	0.837	0.256	0.994

Table 13: Analysis of Variance Procedure: the effect of $CaCl_2$ treatments on flesh firmness.

Dependent Variable: Firmness

Source	Type I Sum of Squares	df	Mean Square	F	Sig.
DATE	350.878	4	87.720	306.920	0.000
TEMP	0.615	1	0.615	2.152	0.148
$CaCl_2$	1.261	2	0.630	2.205	0.119
DATE * TEMP	0.658	4	0.165	0.576	0.681
DATE * $CaCl_2$	1.953	8	0.244	0.854	0.560
TEMP * CACL2	0.292	2	0.146	0.510	0.603
DATE * TEMP * $CaCl_2$	0.348	8	0.043	0.152	0.996

Table 14: Analysis of Variance Procedure: the effect of each treatment and between treatments under modified atmospheric conditions to 'L' values.

Dependent Variable: 'L' value

Source	Type I Sum of Squares	df	Mean Square	F	Sig.
DATE	2375.35	6	395.892	801.290	0.000
TEMP	152.80	1	152.796	309.260	0.000
FILM	277.73	2	138.866	281.065	0.000
GAS	122.42	2	61.209	123.887	0.000
DATE * TEMP	55.77	4	13.941	28.217	0.000
DATE * FILM	85.49	12	7.124	14.419	0.000
TEMP * FILM	1.13	2	0.565	1.143	0.323
DATE * GAS	106.80	12	8.900	18.014	0.000
TEMP * GAS	24.62	2	12.310	24.915	0.000
FILM * GAS	10.66	4	2.664	5.393	0.001
DATE * TEMP * GAS	17.75	8	2.219	4.492	0.000
DATE * TEMP * FILM	6.25	8	0.781	1.581	0.139
DATE * FILM * GAS	14.61	24	0.609	1.232	0.232
TEMP * FILM * GAS	2.09	4	0.524	1.060	0.380
DATE * TEMP * FILM * GAS	10.99	16	0.687	1.390	0.160

Table 15: Analysis of Variance Procedure; the effect of each treatment and between treatments under modified atmospheric conditions to 'a' values.

Dependent Variable: 'a' value

Source	Type I Sum of Squares	df	Mean Square	F	Sig.
DATE	86.052	6	14.342	9.963	0.000
TEMP	34.139	1	34.139	23.714	0.000
FILM	32.835	2	16.417	11.404	0.000
GAS	29.417	2	14.708	10.217	0.000
DATE * TEMP	27.652	4	6.913	4.802	0.001
DATE * FILM	21.467	12	1.789	1.243	0.264
TEMP * FILM	5.050	2	2.525	1.754	0.178
DATE * TEMP * FILM	8.514	8	1.064	0.739	0.657
DATE * GAS	20.873	12	1.739	1.208	0.287
TEMP * GAS	16.222	2	8.111	5.634	0.005
DATE * TEMP * GAS	11.220	8	1.403	0.974	0.460
FILM * GAS	1.176	4	0.294	0.204	0.936
DATE * FILM * GAS	15.529	24	0.647	0.449	0.987
TEMP * FILM * GAS	8.934	4	2.234	1.552	0.193
DATE * TEMP * FILM * GAS	8.334	16	0.521	0.362	0.988

Table 16: Analysis of Variance Procedure; the effect of each treatment and between treatments under modified atmospheric conditions to 'b' values.

Dependent Variable: 'b' value

Source	Type I Sum of Squares	df	Mean Square	F	Sig.
DATE	511.027	6	85.171	40.287	0.000
TEMP	27.605	1	27.605	13.057	0.000
FILM	1.563	2	0.782	0.370	0.692
GAS	2.426	2	1.213	0.574	0.565
DATE * TEMP	14.237	4	3.559	1.684	0.159
DATE * FILM	34.460	12	2.872	1.358	0.197
TEMP * FILM	6.218	2	3.109	1.471	0.234
DATE * TEMP * FILM	24.573	8	3.072	1.453	0.183
DATE * GAS	38.803	12	3.234	1.530	0.125
TEMP * GAS	11.043	2	5.521	2.612	0.078
DATE * TEMP * GAS	25.774	8	3.222	1.524	0.157
FILM * GAS	14.018	4	3.505	1.658	0.165
DATE * FILM * GAS	95.885	24	3.995	1.890	0.015
TEMP * FILM * GAS	17.030	4	4.258	2.014	0.098
DATE * TEMP * FILM * GAS	26.903	16	1.681	0.795	0.688

Table 17: Analysis of Variance Procedure: the effect of each treatment and between treatments under modified atmospheric conditions to pH.

Dependent Variable: pH

Source	Type I Sum of Squares	df	Mean Square	F	Sig.
DATE	1.894	3	0.631	5.496	0.002
TEMP	1.141	1	1.141	9.933	0.002
FILM	0.504	2	0.252	2.195	0.120
MAP	0.330	2	0.165	1.438	0.245
DATE * TEMP	1.009	2	0.505	4.393	0.016
DATE * FILM	0.243	6	0.041	0.353	0.906
TEMP * FILM	0.406	2	0.203	1.766	0.179
DATE * TEMP * FILM	0.359	4	0.090	0.782	0.541
DATE * MAP	0.446	6	0.074	0.648	0.692
TEMP * MAP	0.260	2	0.130	1.130	0.329
DATE * TEMP * MAP	0.283	4	0.071	0.616	0.652
FILM * MAP	0.862	4	0.215	1.876	0.126
DATE * FILM * MAP	0.620	12	0.052	0.450	0.936
TEMP * FILM * MAP	0.335	4	0.084	0.729	0.576
DATE * TEMP * FILM * MAP	0.454	8	0.057	0.494	0.856

Table 18: **Analysis of Variance Procedure: the effect of each treatment and between treatments under modified atmospheric conditions to %weight loss.**

Dependent Variable: %weight loss

Source	**Type I Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
DATE	9.340	3	3.113	228.944	0.000
TEMP	0.081	1	0.081	5.966	0.017
FILM	0.030	2	0.015	1.103	0.338
MAP	0.016	2	0.008	0.589	0.558
DATE * TEMP	0.109	2	0.055	4.008	0.023
DATE * FILM	0.108	6	0.018	1.326	0.259
TEMP * FILM	0.019	2	0.010	0.715	0.493
DATE * TEMP * FILM	0.016	4	0.004	0.298	0.878
DATE * MAP	0.089	6	0.015	1.087	0.380
TEMP * MAP	0.132	2	0.066	4.839	0.011
DATE * TEMP * MAP	0.072	4	0.018	1.321	0.272
FILM * MAP	0.009	4	0.002	0.164	0.956
DATE * FILM * MAP	0.123	12	0.010	0.752	0.695
TEMP * FILM * MAP	0.061	4	0.015	1.115	0.357
DATE * TEMP * FILM * MAP	0.083	8	0.010	0.759	0.639

Table 19: Analysis of Variance Procedure: the effect of each treatment and between treatments under modified atmospheric conditions to TSS.

Dependent Variable: TSS

Source	Type I Sum of Squares	df	Mean Square	F	Sig.
DATE	25.919	3	8.640	9.661	0.000
TEMP	1.311	1	1.311	1.466	0.230
FILM	6.760	2	3.380	3.780	0.028
MAP	1.448	2	0.724	0.809	0.450
DATE * TEMP	2.967	2	1.483	1.659	0.199
DATE * FILM	3.476	6	0.579	0.648	0.692
TEMP * FILM	0.046	2	0.023	0.026	0.975
DATE * TEMP * FILM	1.044	4	0.261	0.292	0.882
DATE * MAP	2.558	6	0.426	0.477	0.823
TEMP * MAP	1.017	2	0.508	0.569	0.569
DATE * TEMP * MAP	1.756	4	0.439	0.491	0.742
FILM * MAP	0.305	4	0.076	0.085	0.987
DATE * FILM * MAP	1.736	12	0.145	0.162	0.999
TEMP * FILM * MAP	0.220	4	0.055	0.062	0.993
DATE * TEMP * FILM * MAP	0.377	8	0.047	0.053	1.000

Table 20: Analysis of Variance Procedure: the effect of each treatment and between treatments under modified atmospheric conditions to flesh firmness.

Dependent Variable: Flesh firmness

Source	Type I Sum of Squares	df	Mean Square	F	Sig.
DATE	726.059	5	145.212	128.233	0.000
TEMP	4.606	1	4.606	4.067	0.047
FILM	1.455	2	0.727	0.642	0.528
GAS	12.034	2	6.017	5.314	0.007
DATE * TEMP	2.494	3	0.831	0.734	0.534
DATE * FILM	5.634	10	0.563	0.498	0.887
TEMP * FILM	12.206	2	6.103	5.389	0.006
DATE * TEMP * FILM	10.334	6	1.722	1.521	0.180
DATE * GAS	9.848	10	0.985	0.870	0.564
TEMP * GAS	5.193	2	2.596	2.293	0.107
DATE * TEMP * GAS	8.558	6	1.426	1.260	0.284
FILM * GAS	6.102	4	1.526	1.347	0.259
DATE * FILM * GAS	18.365	20	0.918	0.811	0.694
TEMP * FILM * GAS	2.561	4	0.640	0.565	0.688
DATE * TEMP * FILM * GAS	12.063	12	1.005	0.888	0.562

Table 21: Analysis of Variance Procedure: the effect of each treatment and between treatments under modified atmospheric conditions to PPO.

Dependent Variable: PPO

Source	Type I Sum of Squares	df	Mean Square	F	Sig.
DATE	0.000	6	0.000	78.691	0.000
TEMP	0.000	1	0.000	126.489	0.000
FILM	0.000	2	0.000	34.633	0.000
GAS	0.000	2	0.000	3.362	0.038
DATE * TEMP	0.000	4	0.000	14.052	0.000
DATE * FILM	0.000	12	0.000	4.675	0.000
TEMP * FILM	0.000	2	0.000	0.389	0.679
DATE * TEMP * FILM	0.000	8	0.000	0.683	0.706
DATE * GAS	0.000	12	0.000	0.670	0.776
TEMP * GAS	0.000	2	0.000	1.267	0.286
DATE * TEMP * GAS	0.000	8	0.000	0.713	0.680
FILM * GAS	0.000	4	0.000	1.418	0.233
DATE * FILM * GAS	0.000	24	0.000	0.319	0.999
TEMP * FILM * GAS	0.000	4	0.000	0.723	0.578
DATE * TEMP * FILM * GAS	0.000	16	0.000	0.234	0.999

APPENDIX B

Table 22 Effect of antibrowning agents on 'L' values of mango slices stored at 5 and 10°C.

Day	L value							
	5°C				10°C			
	Citric	Ascorbic	Plus	Ctrl	Citric	Ascorbic	Plus	Ctrl
0	69.37	69.37	69.37	69.37	69.37	69.37	69.37	69.37
	71.11	71.11	71.11	71.11	71.11	71.11	71.11	71.11
	68.99	68.99	68.99	68.99	68.99	68.99	68.99	68.99
ave	69.82	69.82	69.82	69.82	69.82	69.82	69.82	69.82
1	67.45	68.52	67.33	64.29	64.44	67.59	64.94	64.55
	69.16	70.10	67.24	67.51	69.68	69.18	63.25	63.66
	65.90	68.33	67.39	69.40	65.90	68.15	64.54	65.64
ave	67.50	68.98	67.32	67.07	66.67	68.31	64.24	64.62
2	65.75	68.49	65.61	66.24	65.98	66.95	61.31	62.13
	66.68	68.66	66.65	66.62	64.36	66.15	60.97	62.55
	63.91	68.11	67.54	65.13	65.91	66.34	65.10	61.69
ave	67.07	68.74	66.60	66.00	65.42	66.48	62.46	62.12
4	66.70	67.99	66.70	64.94	59.88	67.20	55.70	59.80
	64.97	68.52	64.36	63.46	64.17	63.32	59.40	60.33
	66.23	67.99	64.33	65.19	65.92	65.51	65.64	60.89
ave	65.97	68.17	65.13	64.53	63.32	65.34	60.25	60.34
7	64.01	66.85	65.16	63.71	61.23	63.67	55.94	54.37
	63.87	67.99	63.98	61.58	60.28	62.64	57.17	59.98
	62.25	65.32	60.35	62.89	62.20	64.53	62.49	59.65
ave	63.38	66.72	63.16	62.73	61.24	63.61	58.53	58.00
10	61.86	65.07	59.48	62.19				
	62.17	65.26	60.98	59.19				
	60.49	64.78	62.55	58.87				
ave	61.51	65.03	61.01	60.08				

Table 23 Effect of Antibrowning agents on 'a' values of mango slices stored at 5 and 10°C.

Day	a value							
	5°C				10°C			
	Citiric	Ascorbic	Plus	Ctrl	Citric	Ascorbic	Plus	Ctrl
0	6.42	6.42	6.42	6.42	6.42	6.42	6.42	6.42
	5.64	5.64	5.64	5.64	5.64	5.64	5.64	5.64
	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
ave	6.02	6.02	6.02	6.02	6.02	6.02	6.02	6.02
1	7.86	7.42	9.27	6.91	7.68	6.64	7.28	4.97
	6.00	6.59	6.01	7.57	6.13	6.47	6.07	6.05
	5.37	7.42	7.93	5.88	6.02	5.71	7.65	5.07
ave	6.41	7.14	7.74	6.79	6.61	6.27	7.00	5.36
2	5.32	6.31	7.47	7.64	5.99	6.02	6.11	6.28
	7.60	5.50	6.71	6.73	6.16	5.63	8.14	5.15
	6.23	6.52	6.42	5.67	7.74	6.06	7.16	4.99
ave	6.38	6.11	6.87	6.68	6.63	5.90	7.14	5.47
4	6.09	6.36	6.73	7.19	6.44	6.70	7.00	6.01
	5.90	4.60	6.39	6.44	7.29	5.54	6.92	7.07
	7.64	6.23	6.42	6.97	5.66	6.61	6.67	5.96
ave	6.54	5.73	6.51	6.87	6.46	6.28	6.86	6.35
7	7.13	6.72	6.24	5.70	7.00	7.91	7.55	7.66
	5.41	7.03	6.96	6.67	6.73	7.97	8.41	7.33
	5.46	4.65	8.02	7.11	6.73	7.10	7.74	7.34
ave	6.00	6.13	7.07	6.49	6.82	7.66	7.90	7.44
10	5.78	6.27	7.53	6.90				
	6.27	6.42	7.12	7.38				
	5.17	4.26	6.45	5.95				
ave	5.74	5.65	7.03	6.74				

Table 24 Effect of Antibrowning agents on 'b' value of mango slices stored at 5 and 10°C.

Day	b value							
	5°C				10°C			
	Citric	Ascorbic	Plus	Ctrl	Citric	Ascorbic	Plus	Ctrl
0	26.47	26.47	26.47	26.47	26.47	26.47	26.47	26.47
	25.52	25.52	25.52	25.52	25.52	25.52	25.52	25.52
	26.60	26.60	26.60	26.60	26.60	26.60	26.60	26.60
ave	26.20	26.20	26.20	26.20	26.20	26.20	26.20	26.20
1	24.31	29.25	26.26	26.52	25.58	23.90	20.31	25.24
	25.29	25.66	25.26	26.23	24.22	25.08	24.84	24.41
	25.70	22.77	25.21	25.37	25.41	20.75	23.70	25.30
ave	25.10	25.89	25.58	26.04	25.07	23.24	22.95	24.98
2	28.09	25.67	20.24	26.72	23.49	24.64	22.90	24.99
	24.67	25.10	27.05	25.74	26.76	22.89	22.45	25.29
	22.87	23.94	24.64	25.77	23.97	22.33	22.80	24.48
ave	25.21	24.90	23.98	26.08	24.74	23.29	22.72	24.92
4	24.49	27.07	21.11	25.34	25.09	19.71	23.52	24.84
	23.35	24.96	26.12	24.98	22.49	22.67	20.46	23.49
	26.43	21.21	17.86	25.15	22.46	24.29	19.84	24.02
ave	24.76	24.41	21.70	25.16	23.35	22.22	21.27	24.12
7	25.36	25.97	26.02	23.88	22.42	24.35	20.45	22.93
	21.09	24.50	22.13	23.81	22.73	24.01	23.44	22.69
	23.64	23.27	21.03	25.65	22.56	22.75	21.33	23.10
ave	23.36	24.58	23.06	24.45	22.57	23.70	21.74	22.91
10	23.80	25.56	15.62	26.24				
	22.96	20.63	21.27	25.30				
	20.22	22.62	24.86	25.16				
ave	22.33	22.94	20.58	25.57				

Table 25 Effect of calcium chloride on flesh firmness of mango slices stored at 5 and at 10°C.

Day	Firmness (N)					
	5°C			10°C		
	Ctrl	$CaCl_2$ 0.5%	$CaCl_2$ 1.0%	Ctrl	$CaCl_2$ 0.5%	$CaCl_2$ 1.0%
0	7.235 8.257 7.766	7.235 8.257 7.766	7.235 8.257 7.766	7.235 8.257 7.766	7.235 8.257 7.766	7.235 8.257 7.766
ave	7.753	7.753	7.753	7.753	7.753	7.753
2	3.210 3.135 3.300	3.321 3.246 3.271	3.310 4.415 3.252	3.246 3.205 3.165	3.056 3.082 3.362	3.259 3.043 3.333
ave	3.215	3.279	3.659	3.205	3.167	3.212
3	3.574 2.223 2.332	3.384 2.722 3.392	3.550 3.593 3.470	3.219 2.490 2.211	3.206 3.564 2.962	3.286 3.318 3.578
ave	2.710	3.166	3.538	2.640	3.244	3.394
6	2.214 3.056 2.546	3.863 2.871 2.888	2.563 3.566 2.671	2.967 2.449 1.669	1.630 3.393 2.203	1.301 3.171 2.574
ave	2.605	3.207	2.933	2.362	2.409	2.349
8	2.900 1.905 1.960	2.340 2.427 2.450	3.119 3.119 2.112	2.854 2.488 2.207	1.628 2.851 1.724	1.641 2.854 3.104
ave	2.255	2.406	2.783	2.516	2.068	2.533

Table 26 Effect of polymericfilm type on 'L' value under modified atmosphere packaging. Mango slices were packed in PP, OPP and LLDPE films and stored at 5°C.

Day	L value								
	PP			OPP			LLDPE		
	Air	$5CO_2$	$10CO_2$	Air	$5CO_2$	$10CO_2$	Air	$5CO_2$	$10CO_2$
0	69.37	69.37	69.37	69.37	69.37	69.37	69.37	69.37	69.37
	68.99	68.99	68.99	68.99	68.99	68.99	68.99	68.99	68.99
ave	69.18	69.18	69.18	69.18	69.18	69.18	69.18	69.18	69.18
1	68.85	67.88	67.83	68.80	67.48	68.54	68.57	66.35	67.41
	68.56	66.88	68.16	69.36	67.99	68.04	67.60	66.38	67.76
ave	68.71	67.38	68.00	69.08	67.74	68.29	68.09	66.37	67.59
3	65.37	66.88	66.11	67.72	68.10	67.39	65.30	64.43	65.96
	65.75	65.83	67.95	66.77	66.55	67.38	64.01	65.78	64.87
ave	65.56	66.36	67.03	67.25	67.33	67.39	64.66	65.11	65.42
6	63.05	64.37	65.22	64.89	65.76	64.29	60.66	62.45	62.42
	62.91	64.70	64.83	64.76	64.39	65.93	61.99	61.58	60.89
ave	62.98	64.54	65.03	64.83	65.08	65.11	61.33	62.02	61.66
8	60.59	63.39	63.88	63.76	64.41	64.04	58.87	59.77	61.66
	61.24	63.87	64.76	63.36	63.81	64.33	59.95	57.35	60.01
ave	60.92	63.63	64.32	63.56	64.11	64.19	59.41	58.56	60.84
10	59.81	63.83	63.23	61.77	63.33	64.57	57.11	58.69	60.01
	59.44	61.49	63.63	60.89	63.41	63.15	57.47	57.21	58.67
ave	59.63	62.66	63.43	61.33	63.37	63.86	57.29	57.95	59.34
13	56.97	61.25	63.32	58.34	61.95	63.55	55.59	58.88	58.77
	57.19	62.50	62.86	58.77	62.81	63.69	56.73	56.60	59.34
ave	57.08	61.88	63.09	58.56	62.38	63.62	56.16	57.74	59.06

Table 27 Effect of polymeric film type on 'L' value under modified atmosphere packaging. Mango slices were packed in PP, OPP and LLDPE films and stored at 10°C.

Day	L value								
	PP			OPP			LLDPE		
	Air	$5CO_2$	$10CO_2$	Air	$5CO_2$	$10CO_2$	Air	$5CO_2$	$10CO_2$
0	69.37	69.37	69.37	69.37	69.37	69.37	69.37	69.37	69.37
	68.99	68.99	68.99	68.99	68.99	68.99	68.99	68.99	68.99
ave	69.18	69.18	69.18	69.18	69.18	69.18	69.18	69.18	69.18
1	67.17	68.21	66.47	67.41	67.28	67.98	66.67	64.86	66.00
	66.82	66.66	67.85	67.03	68.50	67.26	65.30	62.97	65.74
ave	67.00	67.44	67.16	67.22	67.89	67.62	65.99	63.92	65.87
3	63.44	64.78	65.47	65.37	65.92	65.66	61.84	61.55	63.98
	63.52	64.99	64.89	64.89	65.41	65.76	59.13	60.96	64.50
ave	63.48	64.89	65.18	65.13	65.67	65.71	60.49	61.26	64.24
6	59.47	60.11	64.07	60.61	62.72	64.03	57.62	59.42	62.74
	58.84	61.32	63.89	59.77	63.52	64.73	56.75	58.16	60.72
ave	59.16	60.72	63.98	60.19	63.12	64.38	57.19	58.79	61.73
8	57.30	60.74	63.24	57.42	61.00	63.33	54.14	58.71	59.02
	56.14	59.18	61.29	58.12	60.65	62.80	53.87	56.49	58.89
ave	56.72	59.96	62.27	57.77	60.83	63.07	54.01	57.60	58.96

Table 28 Effect of polymeric film type on 'a' value under modified atmosphere packaging. Mango slices were packed in PP, OPP and LLDPE films and stored at 5°C.

Day	a value								
	PP			OPP			LLDPE		
	Air	$5CO_2$	$10CO_2$	Air	$5CO_2$	$10CO_2$	Air	$5CO_2$	$10CO_2$
0	4.88	4.88	4.88	4.88	4.88	4.88	4.88	4.88	4.88
	4.19	4.19	4.19	4.19	4.19	4.19	4.19	4.19	4.19
ave	4.54	4.54	4.54	4.54	4.54	4.54	4.54	4.54	4.54
1	2.31	2.15	3.20	2.10	4.39	2.95	2.13	3.76	1.89
	3.24	2.01	0.55	2.30	2.35	2.54	2.75	3.33	1.68
ave	2.78	2.08	1.88	2.20	3.37	2.75	2.44	3.55	1.79
3	4.98	3.86	2.98	3.40	2.65	1.30	0.17	3.22	0.92
	4.25	2.00	2.73	1.83	1.30	3.26	3.75	1.72	2.33
ave	4.62	2.93	2.86	2.62	1.98	2.28	1.96	2.47	1.63
6	4.91	2.85	4.06	1.19	1.65	2.02	3.56	2.86	3.64
	3.34	4.36	3.27	4.08	3.65	3.37	2.53	5.37	2.08
ave	4.13	3.61	3.67	2.64	2.65	2.70	3.05	4.12	2.86
8	5.10	3.30	4.16	2.28	3.72	4.47	1.99	3.12	3.23
	4.95	3.52	3.57	2.07	-1.35	-0.84	1.84	1.99	1.67
ave	5.03	3.41	3.87	2.18	1.19	1.82	1.92	2.56	2.45
10	4.50	5.51	4.60	3.97	1.88	3.16	0.61	3.06	2.68
	5.73	4.65	1.76	0.49	4.03	0.67	3.71	5.45	2.63
ave	5.12	5.08	3.18	2.23	2.96	1.92	2.16	4.26	2.66
13	3.35	1.88	3.02	3.54	4.76	3.55	2.99	1.23	3.31
	5.19	5.25	4.11	5.28	0.28	2.73	4.33	3.34	2.03
ave	4.27	3.57	3.57	4.41	2.52	3.14	3.66	2.29	2.67

Table 29 Effect of polymeric film type on 'a' value under modified atmosphere packaging. Mango slices were packed in PP, OPP and LLDPE films and stored at 10°C.

Day	a value								
	PP			OPP			LLDPE		
	Air	$5CO_2$	$10CO_2$	Air	$5CO_2$	$10CO_2$	Air	$5CO_2$	$10CO_2$
0	4.88	4.88	4.88	4.88	4.88	4.88	4.88	4.88	4.88
	4.19	4.19	4.19	4.19	4.19	4.19	4.19	4.19	4.19
ave	4.54	4.54	4.54	4.54	4.54	4.54	4.54	4.54	4.54
1	2.67	3.34	4.23	4.59	2.12	2.04	4.15	2.54	1.92
	2.82	2.12	4.16	2.73	2.29	1.05	4.19	3.20	1.87
ave	2.75	2.73	4.20	3.66	2.21	1.55	4.17	2.87	1.90
3	6.15	3.18	3.23	2.10	1.78	0.32	4.28	2.26	2.17
	3.56	6.27	2.69	2.69	2.86	2.06	5.27	5.57	2.06
ave	4.86	4.73	2.96	2.40	2.32	1.19	4.78	3.92	2.12
6	5.42	5.73	3.31	2.99	6.43	3.33	5.71	3.99	2.48
	7.45	3.72	2.68	7.30	1.95	3.43	7.31	3.11	5.11
ave	6.44	4.73	3.00	5.15	4.19	3.38	6.51	3.55	3.80
8	5.77	5.75	3.00	7.31	3.89	3.33	7.71	4.93	4.76
	7.89	6.36	5.41	4.56	3.01	2.28	6.84	4.36	5.36
ave	6.83	6.06	4.21	5.94	3.45	2.81	7.28	4.65	5.06

Table 30 Effect of polymeric film type on 'b' value under modified atmosphere packaging. Mango slices were packed in PP, OPP and LLDPE films and stored at 5°C.

Day	b value								
	PP			OPP			LLDPE		
	Air	$5CO_2$	$10CO_2$	Air	$5CO_2$	$10CO_2$	Air	$5CO_2$	$10CO_2$
0	30.80	30.80	30.80	30.80	30.80	30.80	30.80	30.80	30.80
	31.58	31.58	31.58	31.58	31.58	31.58	31.58	31.58	31.58
ave	31.19	31.19	31.19	31.19	31.19	31.19	31.19	31.19	31.19
1	29.59	29.79	28.29	32.88	30.15	30.80	30.79	31.58	28.74
	29.14	29.77	30.44	30.82	30.22	30.85	25.96	29.21	31.25
ave	29.37	29.78	29.37	31.85	30.19	30.83	28.38	30.40	30.00
3	27.83	30.25	30.31	28.55	28.33	28.69	28.97	28.06	27.48
	28.83	25.08	25.73	29.04	27.53	29.43	28.90	29.19	27.97
ave	28.33	27.67	28.02	28.80	27.93	29.06	28.94	28.63	27.73
6	30.46	25.09	29.06	25.65	27.69	25.88	29.25	30.86	29.37
	29.84	27.25	28.76	27.93	31.87	26.96	30.26	27.29	30.36
ave	30.15	26.17	28.91	26.79	29.78	26.42	29.76	29.08	29.87
8	30.08	26.09	26.96	30.14	27.73	27.24	29.67	29.54	25.19
	30.08	23.58	25.55	30.07	26.93	27.09	27.12	28.63	26.81
ave	30.08	24.84	26.26	30.11	27.33	27.17	28.40	29.09	26.00
10	26.63	25.76	24.58	23.41	28.19	26.05	25.00	26.58	29.64
	25.05	27.39	28.66	24.21	26.24	28.20	28.29	21.95	26.14
ave	25.84	26.58	26.62	23.81	27.22	27.13	26.65	24.27	27.89
13	27.12	26.87	30.42	28.02	24.65	29.19	27.09	28.68	22.49
	28.09	28.61	30.16	26.51	25.02	28.96	24.34	26.22	25.72
ave	27.61	27.74	30.29	27.27	24.84	29.08	25.72	27.45	24.11

Table 31 Effect of polymeric film type on 'b' value under modified atmosphere packaging. Mango slices were packed in PP, OPP and LLDPE films and stored at 10°C.

Day	b value								
	PP			OPP			LLDPE		
	Air	$5CO_2$	$10CO_2$	Air	$5CO_2$	$10CO_2$	Air	$5CO_2$	$10CO_2$
0	30.80	30.80	30.80	30.80	30.80	30.80	30.80	30.80	30.80
	31.58	31.58	31.58	31.58	31.58	31.58	31.58	31.58	31.58
ave	31.19	31.19	31.19	31.19	31.19	31.19	31.19	31.19	31.19
1	30.39	29.36	30.27	29.88	30.26	27.35	28.62	28.35	27.25
	30.57	30.21	28.60	28.62	27.28	29.92	29.40	30.40	28.00
ave	30.48	29.79	29.44	29.25	28.77	28.64	29.01	29.38	27.63
3	29.09	26.04	27.10	25.99	26.65	27.08	30.55	26.83	27.99
	26.01	28.86	29.03	27.14	28.09	30.12	28.72	27.59	27.41
ave	27.55	27.45	28.07	26.57	27.37	28.60	29.64	27.21	27.70
6	29.03	30.01	25.84	26.48	27.49	29.59	25.71	27.27	27.39
	22.89	28.23	29.28	23.08	28.40	27.87	24.19	22.36	27.51
ave	25.96	29.12	27.56	24.78	27.95	28.73	24.95	24.82	27.45
8	26.90	24.55	26.61	26.68	26.52	29.25	27.93	26.75	27.27
	27.77	25.97	27.24	24.18	28.26	27.73	28.25	27.97	24.84
ave	27.34	25.26	26.93	25.43	27.39	28.49	28.09	27.36	26.06

Table 32 Effect of modified atmosphere packaging on pH, of mango slices packed in PP, OPP and LLDPE films and stored at 5°C.

Day	pH								
	PP			OPP			LLDPE		
	Air	$5CO_2$	$10CO_2$	Air	$5CO_2$	$10CO_2$	Air	$5CO_2$	$10CO_2$
0	3.55	3.55	3.55	3.55	3.55	3.55	3.55	3.55	3.55
	4.23	4.23	4.23	4.23	4.23	4.23	4.23	4.23	4.23
ave	3.89	3.89	3.89	3.89	3.89	3.89	3.89	3.89	3.89
3	4.15	3.61	3.04	3.20	3.22	3.49	3.38	3.84	3.54
	3.90	3.50	4.01	3.57	3.17	3.24	3.26	3.45	3.64
ave	4.03	3.56	3.53	3.39	3.20	3.37	3.32	3.65	3.59
8	3.86	3.71	3.58	3.31	3.05	3.19	3.30	3.64	3.97
	4.10	3.76	3.38	3.38	3.35	3.34	3.39	3.62	3.95
ave	3.98	3.74	3.48	3.35	3.20	3.27	3.35	3.63	3.96
13	3.82	4.02	3.28	4.05	3.46	3.74	3.72	3.59	4.11
	3.72	3.61	3.45	3.20	3.41	3.44	3.73	4.17	3.65
ave	3.77	3.82	3.37	3.63	3.44	3.59	3.73	3.88	3.88

Table 33 Effect of modified atmosphere packaging on pH, of mango slices packed in PP, OPP and LLDPE films and stored at 10°C.

Day	pH								
	PP			OPP			LLDPE		
	Air	$5CO_2$	$10CO_2$	Air	$5CO_2$	$10CO_2$	Air	$5CO_2$	$10CO_2$
0	3.55	3.55	3.55	3.55	3.55	3.55	3.55	3.55	3.55
	4.23	4.23	4.23	4.23	4.23	4.23	4.23	4.23	4.23
ave	3.89	3.89	3.89	3.89	3.89	3.89	3.89	3.89	3.89
3	3.64	3.80	3.78	3.45	3.63	3.44	3.34	3.61	3.96
	3.72	3.88	3.55	3.36	4.11	3.39	4.04	3.98	3.90
ave	3.68	3.84	3.67	3.41	3.87	3.42	3.69	3.80	3.93
8	3.92	3.80	3.79	4.48	3.56	4.21	4.54	3.71	3.78
	4.20	3.93	3.96	4.62	4.23	3.29	4.36	3.96	3.90
ave	4.06	3.87	3.88	4.55	3.90	3.75	4.45	3.84	3.84

Table 34 Effect of modified atmosphere packaging on weight loss of mango slices packed in PP, OPP and LLDPE films and stored at 5°C.

Day	%weight loss								
	PP			OPP			LLDPE		
	Air	$5CO_2$	$10CO_2$	Air	$5CO_2$	$10CO_2$	Air	$5CO_2$	$10CO_2$
3	0.34	0.45	0.38	0.32	0.32	0.42	0.28	0.44	0.60
	0.35	0.48	0.40	0.37	0.35	0.50	0.39	0.45	0.60
ave	0.35	0.47	0.39	0.35	0.34	0.46	0.34	0.45	0.60
8	0.56	0.53	0.62	0.54	0.42	0.98	0.52	0.45	0.65
	0.52	0.55	0.65	0.45	0.45	0.10	0.55	0.43	0.70
ave	0.54	0.54	0.64	0.50	0.44	0.54	0.54	0.44	0.68
13	0.64	0.71	0.71	0.67	0.65	0.98	0.62	0.73	0.79
	0.66	0.75	0.74	0.59	0.67	0.10	0.62	0.77	0.82
ave	0.65	0.73	0.73	0.63	0.66	0.54	0.62	0.75	0.81

Table 35 Effect of modified atmosphere packaging on weight loss, of mango slices packed in PP, OPP and LLDPE films and stored at 10°C.

Day	%weight loss								
	PP			OPP			LLDPE		
	Air	$5CO_2$	$10CO_2$	Air	$5CO_2$	$10CO_2$	Air	$5CO_2$	$10CO_2$
3	0.39	0.23	0.36	0.45	0.41	0.43	0.59	0.50	0.43
	0.44	0.31	0.36	0.41	0.37	0.39	0.61	0.54	0.44
ave	0.42	0.27	0.36	0.43	0.39	0.41	0.60	0.52	0.44
8	0.87	0.51	0.69	0.81	0.68	0.60	0.93	0.63	0.66
	0.90	0.65	0.67	0.84	0.58	0.60	0.90	0.78	0.70
ave	0.89	0.58	0.68	0.83	0.63	0.60	0.92	0.71	0.68

Table 36 Effect of modified atmosphere packaging on the TSS, of mango slices packed in PP, OPP and LLDPE films and stored at 5°C.

Day	TSS								
	PP			OPP			LLDPE		
	Air	$5CO_2$	$10CO_2$	Air	$5CO_2$	$10CO_2$	Air	$5CO_2$	$10CO_2$
0	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4
	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6
ave	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5
3	16.8	16.0	18.4	15.4	16.0	16.2	18.8	15.3	16.9
	17.0	15.4	13.7	17.4	15.0	16.2	15.5	16.1	15.6
ave	16.9	15.7	16.1	16.4	15.5	16.2	17.2	15.7	16.3
8	17.8	19.1	17.4	15.2	15.4	16.0	18.8	16.4	16.8
	15.0	14.4	16.2	16.2	16.2	16.8	15.0	17.0	18.0
ave	16.4	16.8	16.8	15.7	15.8	16.4	16.9	16.7	17.4
13	16.4	16.0	16.0	17.0	15.7	15.4	17.2	16.6	16.5
	17.1	16.0	17.0	14.4	15.5	15.8	17.1	16.6	16.4
ave	16.8	16.0	16.5	15.7	15.6	15.6	17.2	16.6	16.5

Table 37 Effect of modified atmosphere packaging on the TSS, of mango slices packed in PP, OPP and LLDPE films and stored at 10°C.

Day	TSS								
	PP			OPP			LLDPE		
	Air	$5CO_2$	$10CO_2$	Air	$5CO_2$	$10CO_2$	AIR	$5CO_2$	$10CO_2$
0	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4
	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6
ave	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5
3	17.5	17.0	17.0	16.0	16.7	16.0	17.7	16.7	17.5
	17.4	16.8	16.5	16.7	16.8	16.2	17.3	17.8	16.5
ave	17.5	16.9	16.8	16.4	16.8	16.1	17.5	17.3	17.0
8	16.0	16.6	16.0	16.3	15.0	16.5	16.4	16.0	17.2
	16.6	16.8	16.0	17.0	17.3	15.6	17.4	17.3	17.2
ave	16.3	16.7	16.0	16.7	16.2	16.1	16.9	16.7	17.2

Table 38 Effect of modified atmosphere packaging on the firmness, of mango slices packed in PP, OPP and LLDPE films and stored at 5°C.

Day	Firmness (N)								
	PP			OPP			LLDPE		
	Air	$5CO_2$	$10CO_2$	Air	$5CO_2$	$10CO_2$	Air	$5CO_2$	$10CO_2$
0	7.235	7.235	7.235	7.235	7.235	7.235	7.235	7.235	7.235
	8.257	8.257	8.257	8.257	8.257	8.257	8.257	8.257	8.257
ave	7.746	7.746	7.746	7.746	7.746	7.746	7.746	7.746	7.746
3	3.052	3.815	5.341	3.815	5.341	3.052	5.341	9.155	3.815
	4.578	3.052	6.866	3.052	5.341	4.578	3.052	3.815	4.578
ave	3.815	3.434	6.104	3.434	5.341	3.815	4.197	6.485	4.197
6	4.578	3.815	2.289	3.052	5.341	2.289	4.578	6.104	5.341
	3.052	4.578	4.578	5.341	3.851	3.052	2.289	5.341	5.341
ave	3.815	4.197	3.434	4.197	4.596	2.671	3.434	5.723	5.341
8	2.289	2.289	2.289	3.815	4.629	3.052	4.104	4.578	3.052
	3.052	3.815	3.052	3.052	3.815	3.052	3.815	4.578	4.578
ave	2.671	3.052	2.671	3.434	4.222	3.052	3.960	4.578	3.815
10	3.052	3.052	5.341	3.052	4.886	4.578	4.392	3.052	3.052
	3.052	3.052	3.815	3.815	3.815	5.341	2.289	4.578	5.341
ave	3.052	3.052	4.578	3.434	4.351	4.960	3.341	3.815	4.197
13	3.052	6.104	3.052	2.289	3.052	3.052	4.578	6.866	3.052
	2.289	2.289	5.341	5.341	3.052	2.289	3.052	2.289	2.289
ave	2.671	4.197	4.197	3.815	3.052	2.671	3.815	4.578	2.671

Table 39 Effect of modified atmosphere packaging on the firmness, of mango slices packed in PP, OPP and LLDPE films and stored at 10°C.

Day	Firmness (N)								
	PP			OPP			LLDPE		
	Air	$5CO_2$	$10CO_2$	Air	$5CO_2$	$10CO_2$	Air	$5CO_2$	$10CO_2$
0	7.235	7.235	7.235	7.235	7.235	7.235	7.235	7.235	7.235
	8.257	8.257	8.257	8.257	8.257	8.257	8.257	8.257	8.257
ave	7.746	7.746	7.746	7.746	7.746	7.746	7.746	7.746	7.746
3	3.052	4.578	3.815	5.341	5.341	6.104	2.289	2.289	3.052
	3.052	3.815	3.052	4.578	5.341	3.052	3.052	3.815	3.815
ave	3.052	4.197	3.434	4.960	5.341	4.578	2.671	3.052	3.434
6	2.289	4.578	4.578	3.052	5.341	5.341	2.289	3.815	4.578
	2.289	3.052	6.104	5.341	3.052	4.578	2.289	3.052	5.341
ave	2.289	3.815	5.341	4.197	4.197	4.960	2.289	3.434	4.960
8	3.052	3.052	3.052	1.526	3.052	3.052	2.289	3.052	3.052
	4.578	2.289	3.815	2.289	3.052	4.578	1.526	3.052	3.052
ave	3.815	2.671	3.434	1.908	3.052	3.815	1.908	3.052	3.052

Table 40 Effect of modified atmosphere packaging on the PPO activity, of mango slices packed in PP, OPP and LLDPE films and stored at 5°C.

Day	PPO ($U.ml^{-1}.d^{-1}$)								
	PP			OPP			LLDPE		
	Air	$5CO_2$	$10CO_2$	Air	$5CO_2$	$10CO_2$	Air	$5CO_2$	$10CO_2$
0	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018
	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023
ave	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021
1	0.0022	0.0029	0.0023	0.0018	0.0025	0.0024	0.0020	0.0021	0.0019
	0.0019	0.0019	0.0022	0.0020	0.0019	0.0024	0.0022	0.0021	0.0025
ave	0.0021	0.0024	0.0023	0.0019	0.0022	0.0024	0.0021	0.0021	0.0022
3	0.0025	0.0026	0.0026	0.0014	0.0023	0.0022	0.0030	0.0029	0.0035
	0.0029	0.0023	0.0023	0.0025	0.0020	0.0028	0.0033	0.0028	0.0021
ave	0.0027	0.0025	0.0025	0.0020	0.0022	0.0025	0.0032	0.0029	0.0028
6	0.0033	0.0025	0.0030	0.0028	0.0026	0.0022	0.0038	0.0027	0.0031
	0.0025	0.0027	0.0022	0.0022	0.0022	0.0024	0.0035	0.0031	0.0031
ave	0.0029	0.0026	0.0026	0.0025	0.0024	0.0023	0.0037	0.0029	0.0031
8	0.0027	0.0044	0.0024	0.0022	0.0021	0.0027	0.0038	0.0030	0.0032
	0.0034	0.0017	0.0034	0.0032	0.0022	0.0029	0.0040	0.0039	0.0034
ave	0.0031	0.0031	0.0029	0.0027	0.0022	0.0028	0.0039	0.0035	0.0033
10	0.0036	0.0033	0.0038	0.0029	0.0032	0.0028	0.0044	0.0037	0.0044
	0.0036	0.0039	0.0034	0.0030	0.0029	0.0029	0.0044	0.0039	0.0034
ave	0.0036	0.0036	0.0036	0.0030	0.0031	0.0029	0.0044	0.0038	0.0039
13	0.0034	0.0035	0.0039	0.0032	0.0025	0.0033	0.0050	0.0040	0.0040
	0.0040	0.0037	0.0030	0.0034	0.0031	0.0029	0.0049	0.0046	0.0043
ave	0.0037	0.0036	0.0035	0.0033	0.0028	0.0031	0.0050	0.0043	0.0042

Table 41 Effect of modified atmosphere packaging on the PPO activity, of mango slices packed in PP, OPP and LLDPE films and stored at 10°C.

Day	PPO ($U.ml^{-1}.d^{-1}$)								
	PP			OPP			LLDPE		
	Air	$5CO_2$	$10CO_2$	Air	$5CO_2$	$10CO_2$	Air	$5CO_2$	$10CO_2$
0	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018
	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023
ave	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021
1	0.0026	0.0023	0.0025	0.0030	0.0021	0.0026	0.0025	0.0028	0.0025
	0.0029	0.0026	0.0028	0.0022	0.0031	0.0020	0.0026	0.0021	0.0024
ave	0.0028	0.0025	0.0027	0.0026	0.0026	0.0023	0.0026	0.0025	0.0025
3	0.0036	0.0033	0.0035	0.0032	0.0039	0.0028	0.0039	0.0036	0.0032
	0.0029	0.0039	0.0033	0.0037	0.0029	0.0032	0.0035	0.0034	0.0034
ave	0.0033	0.0036	0.0034	0.0035	0.0034	0.0030	0.0037	0.0035	0.0033
6	0.0038	0.0040	0.0039	0.0038	0.0034	0.0034	0.0043	0.0036	0.0039
	0.0034	0.0037	0.0035	0.0031	0.0041	0.0035	0.0038	0.0042	0.0037
ave	0.0036	0.0039	0.0037	0.0035	0.0038	0.0034	0.0041	0.0039	0.0038
8	0.0042	0.0041	0.0041	0.0043	0.0039	0.0031	0.0058	0.0048	0.0049
	0.0040	0.0049	0.0033	0.0044	0.0034	0.0038	0.0054	0.0051	0.0047
ave	0.0041	0.0045	0.0037	0.0044	0.0037	0.0035	0.0056	0.0050	0.0048

Table 42 Changes in CO_2 concentration of mango slices packed in different packaging films stored at 5°C

Day	CO_2 concentration								
	PP			OPP			LLDPE		
	Air	5 CO_2	10CO_2	Air	5 CO_2	10CO_2	Air	5CO_2	10CO_2
0	0.33	5.00	10.00	0.33	5.00	10.00	0.33	5.00	10.00
	0.33	5.00	10.00	0.33	5.00	10.00	0.33	5.00	10.00
ave	0.33	5.00	10.00	0.33	5.00	10.00	0.33	5.00	10.00
1	2.20	9.68	10.46	3.27	7.65	10.31	2.09	7.52	6.52
	3.80	8.21	11.63	2.62	7.28	8.30	2.09	6.49	6.53
ave	3.00	8.95	11.05	2.94	7.47	9.31	2.09	7.01	6.52
3	4.33	8.31	6.96	2.76	6.31	7.82	2.41	3.10	3.81
	4.63	8.91	10.52	3.23	6.27	6.94	2.41	2.58	3.81
ave	4.48	8.61	8.74	3.00	6.29	7.38	2.41	2.84	3.81
6	6.16	8.23	10.99	8.43	9.52	13.41	5.36	3.97	4.55
	6.47	7.73	12.65	8.43	9.47	12.52	4.91	4.82	4.60
ave	6.32	7.98	11.82	8.43	9.49	12.97	5.14	4.40	4.57
8	5.94	10.75	8.77	7.46	12.27	10.24	4.03	3.75	3.42
	5.68	10.65	9.79	8.40	12.53	10.99	3.97	4.07	3.84
ave	5.81	10.70	9.28	7.93	12.40	10.62	4.00	3.91	3.63
10	9.03	11.00	11.96	10.86	11.18	13.39	3.22	4.32	4.57
	8.20	11.07	12.98	9.44	9.96	10.76	4.58	4.15	4.14
ave	8.61	11.04	12.47	10.15	10.57	12.07	3.90	4.24	4.35
13	6.99	10.28	11.37	14.85	15.19	12.22	4.22	4.02	3.91
	6.78	10.19	10.41	14.57	12.20	11.86	4.05	4.06	3.48
ave	6.88	10.24	10.89	14.71	13.69	12.04	4.13	4.04	3.70

Table 43 Changes in CO_2 concentration of mango slices packed in different packaging films stored at 10°C

Day	CO_2 concentration								
	PP			OPP			LLDPE		
	Air	5CO_2	10CO_2	Air	5CO_2	10CO_2	Air	5CO_2	10CO_2
0	0.33	5.00	10.00	0.33	5.00	10.00	0.33	5.00	10.00
	0.33	5.00	10.00	0.33	5.00	10.00	0.33	5.00	10.00
ave	0.33	5.00	10.00	0.33	5.00	10.00	0.33	5.00	10.00
1	6.88	6.85	13.98	4.70	11.09	11.12	4.32	6.16	6.19
	6.33	10.01	12.10	5.87	9.78	12.57	5.19	6.39	11.10
ave	6.61	8.43	13.04	5.29	10.43	11.85	4.76	6.27	8.64
3	5.56	7.06	5.69	6.56	5.54	8.07	4.33	3.87	4.61
	5.79	5.39	6.88	7.40	7.68	7.43	4.77	3.35	4.30
ave	5.67	6.23	6.29	6.98	6.61	7.75	4.55	3.61	4.45
6	10.29	8.69	10.83	14.28	12.39	12.86	5.45	4.64	6.12
	9.96	8.75	9.17	11.02	12.01	13.90	4.44	4.71	6.48
ave	10.13	8.72	10.00	12.65	12.20	13.38	4.95	4.68	6.30
8	8.67	9.60	10.48	11.44	11.56	14.02	5.12	4.33	5.30
	9.95	10.16	10.25	8.34	11.44	13.31	5.11	5.02	5.19
ave	9.31	9.88	10.36	9.89	11.50	13.67	5.11	4.68	5.25

Table 44 Changes in O_2 concentration of mango slices packed in different packaging films stored at 5°C

Day	O_2 concentration								
	PP			OPP			LLDPE		
	Air	$5CO_2$	$10CO_2$	Air	$5CO_2$	$10CO_2$	Air	$5CO_2$	$10CO_2$
0	21.00	5.00	5.00	21.00	5.00	5.00	21.00	5.00	5.00
	21.00	5.00	5.00	21.00	5.00	5.00	21.00	5.00	5.00
ave	21.00	5.00	5.00	21.00	5.00	5.00	21.00	5.00	5.00
1	19.28	8.67	8.54	19.15	7.63	8.27	17.71	8.34	7.63
	18.58	7.90	9.23	18.38	6.88	7.64	18.42	8.52	7.63
ave	18.93	8.29	8.89	18.77	7.26	7.96	18.07	8.43	7.63
3	16.08	8.22	9.84	16.89	7.26	7.62	17.29	9.52	9.36
	15.44	8.95	8.29	18.46	7.72	6.55	15.17	7.13	9.47
ave	15.76	8.58	9.06	17.67	7.49	7.09	16.23	8.33	9.42
6	13.65	7.20	7.71	11.90	4.76	5.52	13.15	6.38	8.60
	13.65	7.12	7.67	11.94	4.32	5.23	13.11	6.34	8.51
ave	13.65	7.16	7.69	11.92	4.54	5.37	13.13	6.36	8.56
8	12.02	5.83	6.14	9.70	4.02	4.82	11.37	5.36	7.80
	12.40	6.96	5.93	9.30	3.93	4.95	10.62	5.24	7.00
ave	12.21	6.40	6.04	9.50	3.97	4.89	10.99	5.30	7.40
10	8.96	6.66	6.72	7.22	4.51	4.48	9.49	8.84	8.88
	8.22	6.99	6.53	9.15	4.92	5.14	8.91	8.64	7.79
ave	8.59	6.83	6.62	8.19	4.71	4.81	9.20	8.74	8.34
13	9.00	6.79	8.02	6.97	5.98	5.31	8.80	8.11	8.67
	9.30	7.24	7.52	6.98	5.76	5.69	8.98	8.64	8.51
ave	9.15	7.02	7.77	6.98	5.87	5.50	8.89	8.37	8.59

Table 45 Changes in O_2 concentration of mango slices packed in different packaging films stored at 10°C

Day	O_2 concentration								
	PP			OPP			LLDPE		
	Air	$5CO_2$	$10CO_2$	Air	$5CO_2$	$10CO_2$	Air	$5CO_2$	$10CO_2$
0	21.00	5.00	5.00	21.00	5.00	5.00	21.00	5.00	5.00
	21.00	5.00	5.00	21.00	5.00	5.00	21.00	5.00	5.00
ave	21.00	5.00	5.00	21.00	5.00	5.00	21.00	5.00	5.00
1	16.75	7.45	8.27	15.97	7.24	6.97	17.90	8.22	6.54
	16.69	8.10	8.22	17.94	7.45	6.78	16.96	9.51	6.71
ave	16.72	7.78	8.25	16.95	7.34	6.87	17.43	8.87	6.63
3	13.59	9.39	7.83	12.10	7.30	6.87	13.46	9.98	9.59
	11.71	7.38	8.18	11.61	7.87	6.96	14.68	11.05	8.20
ave	12.65	8.39	8.00	11.86	7.58	6.91	14.07	10.52	8.89
6	7.36	8.11	4.37	9.29	6.44	6.14	9.19	7.91	6.81
	7.81	7.53	7.13	9.87	4.64	5.26	12.82	9.17	6.57
ave	7.59	7.82	5.75	9.58	5.54	5.70	11.01	8.54	6.69
8	7.79	8.75	6.49	9.03	6.23	6.23	7.74	9.35	6.88
	6.74	8.29	5.89	8.53	6.72	6.42	8.15	9.46	7.51
ave	7.27	8.52	6.19	8.78	6.48	6.33	7.95	9.41	7.19

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