Effect of antibrowning agents, calcium chloride, polymeric films, modified atmosphere packaging conditions, and storage temperatures on quality changes of mango slices (cv. Namdokmai) was studied. Ascorbic acid was the most effective browning inhibitor for mango slices, while calcium chloride had no significant effect on flesh firmness. Mango slices dipped in 0.5% ascorbic acid for 30 seconds were packaged in LLDPE, PP, and OPP under air and modified atmosphere packaging with O₂ and CO₂ ratios of 5:5 and 5:10 and stored at 5 and 10°C. Storage temperature had a pronounced effect on quality of mango slices. Polymeric films with suitable gas permeability combined with optimum modified atmosphere packaging helps maintaining quality and extending shelf-life of mango slices. Mango slices under modified atmosphere packaging with O₂:CO₂ ratio of 5:10 in OPP film, stored at 5°C had the most acceptable quality over the storage period of 13 days.

Key Words: mango, fresh cut, modified atmosphere packaging, polymeric films, browning

e-mail address: vanee.c@ku.ac.th
Introduction

Mango (*Mangifera indica* L.) is a tropical fruit which have a significant economic value to many countries including Thailand. Namdokmai is one of the most popular varieties exported worldwide from Thailand. The demand for minimally processed fruits and vegetables is growing rapidly due to its convenience and fresh-like quality. Minimally processed fruit also adds value to fresh produce. However, bruising and damaging the integrity of the plant tissue often allows the enzyme and its substrate 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 the problem. Previous studies have reported the use of chemical treatments to maintain quality of fresh cut, such as in sliced apple (Soliva et al., 2002) and sliced pear (Gorny et al., 2002). A combination of ascorbic acid, 4-hexylresorcinol, and calcium lactate with partial vacuum packaging was reported to extend shelf-life of sliced pears (Dong et al., 2000).

Modified atmosphere packaging with reduced O₂ and elevated CO₂ levels can extend shelf-life of minimally processed fruits by reducing the respiration rate and delaying the maturity of fruits (Zagory and Kader, 1988). Applications of MAP have been reported to extend shelf-life of shredded iceberg lettuce (Hermidal et al., 1995) and kiwifruit slices (Agar et al., 1999).

Mango slices are extremely sensitive to enzymatic browning. However, information on maintaining quality of mango slices is limited. The objective of this study was to evaluate the quality of mango slices packaged in various polymeric films under different modified atmosphere conditions. The effect of chemical treatments and storage temperatures on quality of mango slices was also determined.

Materials and Methods

Mango

Mangoes (*Mangifera indica* L. cv. Namdokmai) were hand harvested at maturity from the orchard in Ratchaburi. Mangoes were peeled and cut into 8 pieces per fruit with a sharp, stainless steel knife, immersed in 100 ppm chlorine for 20 seconds before use. Uniform mango slices without bruise and decay were used in this study.

Polymeric films

The polymeric films used in this study were obtained from the Strongpack, Co., Thailand. Three different polymeric films were LLDPE (70 µm; WVTR = 9.7 g/d/m²; OTR = 3420 cm³/m²/d), PP (60 µm; WVTR = 7.9 g/d/m²; OTR = 2533 cm³/m²/d), and OPP (80 µm; WVTR = 7.5 g/d/m²; OTR = 1474 cm³/m²/d).
Effect of antibrowning agents on pigment stability of mango slices

Mango slices were dipped in various antibrowning agents for 30 seconds to study their effects on discoloration. The agents used in this study were 0.5% ascorbic acid, 1% citric acid, and the combination of 0.5% ascorbic acid and 1% citric acid. Sliced mangoes dipped in distilled water were used as control. After draining in a perforated plastic container, the samples were placed in a foam tray stretch wrapped with high density polyethylene films, and stored at 5 and 10°C until further analysis. During storage mango samples were randomly selected to evaluate for color changes using a Hunter Lab Ultrascan. Six measurements were taken on each mango slice. The experiments were done in triplicate. The most promising treatment was used in the later experiment to determine the effect of MAP on maintaining quality and shelf-life of mango slices.

Effect of calcium chloride on flesh firmness of mango slices

Sliced mangoes were immersed in 0.5 and 1% of calcium chloride solutions for 30 seconds. Slices dipped in distilled water were used as control. After draining in a perforated plastic container, mango slices were placed in a foam tray wrapped with high density polyethylene films and stored at 5 and 10°C until further analyses. Mango slices were randomly selected and cut into a 1 cm x 1 cm surface area for flesh firmness evaluation using the Lloyd testing machine equipped with a 0.5 cm diameter cylinder puncture probe. The firmness was reported in Newtons. The most promising treatment was selected to use with the MAP experiment.

Modified atmosphere packaging (MAP) of mango slices

Effect of MAP on quality and shelf-life of mango slices

Mango slices treated with 0.5% ascorbic acid were packaged in various polymeric films under different modified atmosphere conditions and stored at 5 and 10°C. The ratios of O₂:CO₂ used in this study were 5:5 and 5:10. Air packaging was used as control. The experiments were done in duplicate. Concentrations of O₂ and CO₂ in the packages were monitored during storage using the Chrompack 9002 GC equipped with a thermal conductivity detector and a Carboplot capillary column (0.53 mm x 30 m). Helium was used as the carrier gas at 20 cc/min. Packages of mango slices were sampled for quality evaluation at various storage times.

Quality Evaluation

Quality of mango slices were evaluated for weight loss, total soluble solids (TSS), pH, and changes in color and firmness. Mango slices with the most acceptable quality were subject to microbiological analysis at the end of the storage according to AOAC methods (1995).

Statistical analysis

The effect of each treatment on quality characteristics was evaluated by ANOVA analysis. The differences between treatments were determined using LSD multiple comparison.
Results and Discussion

Effect of antibrowning agents on pigment stability of mango slices

There were significant (p < 0.05) effects on “L” values of mango slices stored at 5°C. As shown in the results, “L” values dropped rapidly during storage in all treatments except in those treated with 5% ascorbic acid. Rapid decrease in “L” value of mango slices treated with ascorbic acid was found after storage for 4 days.

Mango slices treated with ascorbic acid had the highest “L” values after 7 days of storage at 10°C. This study showed that the most effective dipping treatment for mango slices (cv. Namdokmai) was a 0.5% ascorbic acid. The results correspond to the finding in previous studies. Ascorbic effectively inhibited browning on apple slices (Soliva et al., 2002) and pears (Gorny et al., 1998; Dong et al., 2000).

In all treatments, “a” values of mango slices stored at 5°C generally increased after storage for 1 day, decreased after storage for 2 days, and changed slightly afterwards throughout the storage. At 10°C, the treatment effects of antibrowning agents on “a” values of mango slices were significant (p < 0.05) among citric acid and ascorbic acid. In all treatments, “b” values of mango slices decreased slightly during storage.

Effect of calcium chloride on flesh firmness of mango slices

In all treatment, flesh firmness decreased rapidly after 2-day-storage and then changed only slightly throughout the storage. No significant difference (p < 0.05) was found among treatments. At the end of storage, firmness of mango slices was in the range of 2.068-2.783 N. This finding was contrary to previous studies which reported that calcium chloride had a significant effect on firmness of pear (Dong et al., 2000), shredded carrot (Izumi and Watada, 1994).

Effect of polymeric films under MAP on quality and shelf-life of mango slices

The results previously described in this chapter showed that ascorbic acid was the most effective treatment to inhibit enzymatic browning in mango slices. In this study, mango slices were dipped with 5% ascorbic acid prior to package in Polypropylene (PP), Oriented Polypropylene (OPP), and Linear Low Density Polyethylene (LLDPE).

Concentrations of O₂ in package headspace of air packaging gradually decreased, while CO₂ concentrations increased throughout storage. OPP films under modified atmosphere packaging maintained lowest O₂ levels throughout storage, followed by PP and LLDPE, respectively. Levels of CO₂ were highest in OPP and PP packages. Differences in gas concentrations can be explained by gas permeability of polymeric films. Appropriate gas permeability of films is needed to achieve an equilibrium condition in modified atmosphere packaging of fresh produce. However, availability and cost are limiting factors for the selections of polymeric films in Thailand. Concentrations of O₂ under modified atmosphere packaging with 5% O₂ and 10% CO₂ reached equilibrium after storage for 6
days at 5°C. Changes in concentrations of O₂ and CO₂ in OPP packages under MAP (5% O₂ and 10% CO₂), stored at 5°C are shown in Figure 1.

**Weight loss**

Weight loss of mango slices was due to moisture loss through polymeric film. There was a significant effect (p < 0.05) of storage temperature on weight loss of mango slices. Higher weight loss was observed when mango slices were stored at 10°C, particularly under air packaging.

**Total soluble solid content and pH**

As the storage time increased, total soluble solid contents of mango slices increased and gradually decreased after 8 and 3 days of storage at 5 and 10°C, respectively. An increase in TSS is due to a conversion of starch to sugar in mango fruits (Arpaia et al., 1985). In mango slices packaged under the atmospheric condition of 5% O₂ and 10% CO₂, total soluble solid contents were lower than those packaged under other conditions. Elevated level of CO₂ and reduced level of O₂ delay ripening of mango slices, hence, delay an increase in TSS. Types of films and atmospheric conditions had no significant effects (p > 0.05) on pH of mango slices.

**Color**

Changes in “L” values of mango slices packaged in various polymeric films under different modified atmosphere conditions stored at 5 and 10°C are shown in Figure 2. Modified atmosphere packaging showed a significant effect on “L” values of mango slices stored at 5 and 10°C. Mango slices in air packaging as with the lowest “L” values had the brownest color as compared to other treatments. The most acceptable visual quality was found in mango slices packaged under atmospheric condition of 5% O₂ and 10% CO₂ at both storage temperatures.

**Firmness**

No significant treatment effect (p > 0.05) on firmness of mango slices was found. Similar trends were observed in firmness as shown in TSS.

**Microbiological quality**

Microbiological analysis was conducted at the end of storage to evaluate microbial safety of mango slices. The microbiological quality of mango slices packaged in OPP bags under 5% O₂ and 10% CO₂ and stored at 5°C for 13 days was acceptable. Populations of yeast, mold, *E.coli*, and Salmonellae were below the set standard for ready-to-eat fruits and vegetables.

**Effect of low storage temperature on quality of mango slices**

The results showed that storage temperature had significant effect (p < 0.05) on quality of mango slices. Mango slices stored at 5°C showed acceptable color (high “L” values) after storage for 13 days, whereas those stored at 10°C had acceptable visual quality for only 8 days. Since enzyme activities and biochemical changes are temperature dependent, optimum temperature minimizes tissue senescence, therefore delays enzymatic discoloration.
Figure 1. Changes in concentrations of O<sub>2</sub> and CO<sub>2</sub> in OPP packages under modified atmosphere packaging (5% O<sub>2</sub> and 10%CO<sub>2</sub>), stored at 5°C.

Figure 2. Changes in “L” values of mango slices.
Conclusion

Mango slices are subject to discoloration reactions, affected by state of raw materials, application of browning inhibitors, modified atmosphere packaging, and storage temperature. Ascorbic acid (0.5%) is the most effective browning inhibitors for mango slices. Treatment with calcium chloride showed no differences in terms of firmness from untreated samples. Shelf-life of mango slices (cv. Namdokmai) under modified atmosphere packaging with 5% O₂ and 10% CO₂ in OPP film, stored at 5°C was extended to 13 days.

Acknowledgements

The authors would like to thank School of Packaging, Michigan State University and Postgraduate Education and Research Development Project in Postharvest Technology, Thailand, for financial support.

References