Title of Paper: EFFECTS OF LOW OXYGEN OR HIGH CARBON DIOXIDE ATMOSPHERES ON QUALITY AND SHELF LIFE OF FRESH-CUT MANGO CV. ‘NAMDOKMAI’

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ABSTRACT

Ripe fruit slices of ‘Namdokmai’ mango were stored in controlled atmosphere (CA) of 1-3% O$_2$ or 2-5% CO$_2$ (balanced N$_2$) or in air at 1°C with 90-95% RH. The different CA treatments did not markedly influence respiration and ethylene production rates of the slices. Similarly, firmness retention was not appreciably affected, except after 7 days of storage in which high CO$_2$ was more effective than low O$_2$ in maintaining firmer slices. In terms of surface color, low O$_2$ maintained better surface color indicated by higher L* and b* values than those held in air or high CO$_2$ atmosphere. Yeast and mold, total bacteria and lactic bacteria population was reduced by CA, particularly 3% O$_2$ and 5% CO$_2$. However, these favorable effects of CA on firmness and color retention as well as on microbial control were insufficient to influence shelf life. Both CA-stored and air-stored slices had a shelf life of 14 days.

Key words: Mango; Mangifera indica L.; minimal processing; fruit slices; controlled atmosphere storage; quality; postharvest life
INTRODUCTION

Mango (*Mangifera indica* L.) fruit slices are a common fresh-cut product in Thailand’s rapidly growing horticultural fresh-cut produce industry. This is brought about by the increased consumption of ready-to-eat food and the consumers’ desire for convenience. Fresh-cut or minimal processing operations usually include washing, peeling, slicing, and packing in film packages or containers with film overwrap before distribution or retail display in ambient or refrigerated shelves. Because of the wounded nature of the fresh-cut produce which is devoid of the protective skin, shelf life particularly of ripe fruit slices is very short, only one day at ambient and 2-3 days at refrigerated temperature. Shelf life is limited by rapid firmness loss, surface discoloration, overripening and microbial contamination or decay. Consequently, postharvest losses are serious and product prices are incoherently much higher than that of the intact fruit equivalent. To address this problem and meet the consumers’ expectations of product quality and safety, appropriate treatments maintaining freshness and wholesomeness of the fresh-cut produce over reasonable period of time during marketing and distribution would be beneficial.

Controlled atmospheres (CA) of low O₂ and/or high CO₂ could be excellent supplement to proper temperature management to preserve quality and further improve shelf life of fresh-cut produce. It is anchored on the fact that low O₂ and high CO₂ environment maintained by various control systems inhibit or slow down life processes in the fresh produce stressed by the cutting operation. Specifically, it has been reported that CA extends shelf life of fresh-cut produce by slowing browning reactions at cut surfaces, reducing the rates of product transpiration and respiration, and reducing ethylene biosynthesis and action (Gorny, 1997). It could also reduce microbial growth and decay (Madrid and Cantwell, 1993). In addition, fresh-cut products probably can tolerate more extreme levels of O₂ and CO₂ because they do not have as much cuticle or skin to restrict gas diffusion, and the
distance of gas diffusion from the center to outside of the product is much less than that for the whole commodity (Watada and Qi, 1998). However, results from various CA studies on fresh-cut produce have not been consistent perhaps due to differences in treatment conditions and product specificity of CA. Positive effects of CA on product quality and shelf life include maintenance of better visual quality, reduction of microbial growth and decay, firmness loss, translucency and off-odors in melons in 15% CO₂ at 0-5°C (Madrid and Cantwell, 1993; Portela et al., 1997; Portela and Cantwell, 1998), increase in shelf life of persimmons in 12% CO₂ at 5°C due to delayed appearance of black areas on the cut surface (Wright and Kader, 1997), and delayed browning and reduced wound-induced accumulation of phenolic compounds and o-quinones and browning in fresh-cut lettuce in 2% O₂ at 15°C (Jamiel and Saltveit, 2002) or in 1% O₂ and 12% CO₂ at 5°C (Ballantyne et al., 1988). In fresh-cut pear slices, low O₂ (0.25-0.5%) or elevated CO₂ (5-20%) did not effectively prevent cut surface browning or softening (Gorny et al., 2002). Low O₂ (2%) or high CO₂ (12%) at 5°C did not also affect the visual quality of strawberries and the ascorbic acid content of both strawberry and persimmon (Wright and Kader, 1997).

This study examined the effects of different levels of low O₂ and high CO₂ atmospheres during storage at 1°C on quality changes and shelf life of ripe fruit slices of ‘Namdokmai’ mango which is the most important commercial variety in Thailand.

MATERIALS AND METHODS

Experimental Treatments

Ripe fruits of ‘Namdokmai’ mango were procured from a local market, sorted for uniformity in size and shape and freedom from defects, washed in tap water and rinsed. The fruits were peeled using a very sharp stainless steel knife. The pulp or flesh from both sides
of the fruit was sliced and the pulp from each side was further divided into 6 equal slices. After rinsing and air-drying, the slices were placed on a foam tray in a sealed glass chamber flushed with the desired gas mixtures using a flow-through system of air (control) or 1-5% O₂ (balance N₂) or 2-5% CO₂ (balance N₂) at 1°C with 95% relative humidity. The study was done following completely randomized design experiments using four replications with 6 slices per replicate per observation period. Observation of responses was done at 3-day interval.

Measurement of Responses

**Color changes.** Changes in surface color were determined using a Minolta DP-301 colorimeter taking the b* value as a measure of degree of yellowing and L* value as a measure of surface lightness.

**Firmness.** Firmness was measured using TA-TX2 texture analyzer equipped with a 500 kg load cell and 2mm-diameter plunger set to pierce 5 mm deep from the fruit surface. Cross head and chart speed were 100 mm/min and 300 mm/min, respectively.

**Respiration and ethylene production.** Respiration and ethylene production were determined by gas chromatography. The 6 fruit slices were sealed in a respiration jar for 3 hours at 20°C. One ml gas samples were taken using gas-tight hypodermic syringe and injected into the Shimadzu GC-8A gas chromatograph with thermal conductivity detector and molecular sieve 5A column at 50°C for CO₂ analysis and Shimadzu GC-14B with flame ionization detector and Porapak Q column at 50°C for ethylene analysis.

**Microbiological assay.** Total plates counts for bacteria, yeasts and molds, and pathogenic organisms (*Eschirichia coli, Salmonella sp.*) were determined using standard procedures.

Results were analyzed by conducting analysis of variance using the general linear models procedure by SAS (SAS Institute, Cary, N.C.) for completely randomized design
experiments and Duncan’s multiple range test (DMRT) or LSD analysis for mean comparison.

RESULTS

Quality Changes

Surface color. Marked differences in surface color of fruit slices as affected by the different O₂ and CO₂ atmospheres were obtained after 7 days of storage (Figure 1). Slices held in low O₂ atmospheres had higher L* and b* values than those held in air. Among the two low O₂ treatments, the 3% atmosphere caused greater increases in L* and b* than 1% atmosphere. High CO₂ atmospheres of 2-5% did not cause variations in L* and b* that differed much from that in air.

Firmness. Firmness of the fruit slices generally decreased after 3 days of storage and then increased after 7 days of storage before decreasing again with advancing period of storage, except for slices held in air or 3% O₂ in which firmness increase continued after 10-14 days of storage (Figure 1). High CO₂ was more effective than low O₂ in maintaining firmer slices during the first 7 days of storage. Among low O₂ treatments, only the 1% atmosphere effected higher firmness than that of slices stored in air. After 10-14 days of storage, slices kept in air had increased firmness indicating tissue hardening.

Physiological Changes

Figure 2 shows the respiration and ethylene production rates of fruit slices held in air and in low O₂ or high CO₂ atmospheres. Respiration rates decreased after 3 days of storage and then leveled off up to the end of the storage period while ethylene production did not greatly vary from the prestorage level (day 0) during the first 10 days of storage. During these periods, low O₂ or high CO₂ atmospheres did not cause significant variations in
respiration and ethylene production relative to the rates of slices stored in air. However, after 14 days of storage, slices held in air or 1% O₂ exhibited dramatic increase in ethylene production whereas those from the other treatments had still low ethylene production rates similar to that in the earlier part of the storage period.

Microbiological Changes

Yeast and mold count (YMC) was generally lower in all CA-stored slices than those stored in air during the first 7 days of storage (Figure 3A). Low O₂ appeared to be more effective than high CO₂ to elicit this effect. YMC was either similar to the initial count at day 0 (0.5 log CFU/g) or slightly increased to about 0.8 log CFU/g. In contrast, YMC of untreated slices increased to about 1.2 log CFU/g after 7 days of storage. After 10-14 days of storage, the trend was reversed, with all CA-stored slices having higher YMC than those stored in air. Total bacterica count (TBC) exhibited an erratic trend (Figure 3B). However, 3% O₂ or 5% CO₂ consistently resulted to lower TBC than that of the air control, with the latter being more effective than the former in causing this effect. The other CA treatments had no clear effect on TBC. On the other hand, lactic bacteria count (LBC) generally increased during the first 7 days of storage (Figure 3C). The increase in LBC was highest in air, 1% O₂ or 2% CO₂ and lowest in 3% O₂. 5% CO₂ effected an intermediate amount of LBC which was lower than that in air. After 10 days of storage, CA resulted to higher LBC except that for 1% O₂ which had similar LBC as in air. At the end of the 14-day storage period, the same trend as that during the first 7 days of storage was obtained in which 3% O₂ and 5% CO₂ reduced LBC values.
CONCLUSION

Low O\textsubscript{2} or high CO\textsubscript{2} did not extend shelf life of fruits slices which lasted for 14 days regardless of atmosphere condition. However, in certain periods during storage, 2-5\% CO\textsubscript{2} appeared to be effective than 1-3\% O\textsubscript{2} in maintaining better color and firmer texture. CA also seemed to control the proliferation of yeasts and molds during the first 7 days of storage. Some CA treatments, particularly 3\% O\textsubscript{2} and 5\% CO\textsubscript{2}, were effective in reducing total bacteria and lactic bacteria population. Bacterial growth was better controlled by 3\% O\textsubscript{2} than 5\% CO\textsubscript{2}.

LITERATURE CITED


Fig. 1 Color parameter L and b and firmness of ripe fruit slices of “Namokmai” mango stored in 1-3 % O$_2$ or 2-5 % CO$_2$ at 1 °C.
Fig 2. Respiration and ethylene production of ripe fruit slices of “Namdokmai” mango stored in 1-3 % O2 or 2-5 % CO2 at 1 °C
Fig. 3 Yeast and Mold (A), Total bacteria (B) and Lactic bacteria (C) of counts “Namdokmai” mango slices stored in air, 1-3% O₂ or 2-5% CO₂ at 1 °C.