Title of Paper: EFFECTS OF LOW OXYGEN ATMOSPHERES ON FRUIT QUALITY AND SHELF LIFE OF ‘NAMDOKMAI’ MANGO (MANGIFERA INDICA L.) AT CHILLING AND NONCHILLING TEMPERATURES

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ABSTRACT

Mature-green fruit of ‘Namdokmai’ mango (Mangifera indica L.) were stored in air (21% O₂) or 3-5% O₂ (balanced N₂). At 13°C (non-chilling), low O₂ retarded ripening indicated by a much delayed softening, measurable as firmness decrease. 5% O₂ delayed softening by 5 days while 3% O₂, by 10 days over that of the softening period of fruit in air. Climacteric rise in respiration rate was also delayed by 10 days and maximum respiration was higher at 5% O₂ than at 3% O₂. Changes in fruit color with ripening occurred later than firmness changes, with the pulp showing yellowing manifested as decreases in colorimetric lightness (L*) and increases in b* values compared to that of the peel. Low O₂ similarly retarded these changes in color but the fruits were less yellow than that in air when ripe-soft, particularly at 3% O₂. At 8°C (chilling), the fruits were chill-injured and failed to ripen both in air and low O₂ atmospheres indicated by the absence of ripening-associated changes in firmness, L*, b* and respiration rates. Degree of electrolyte leakage did not consistently show differences attributable to the various treatments. On the other hand, weight loss of the fruits was remarkably and comparably inhibited by 3-5% O₂ both at 8°C and 13°C. Weight loss of fruits in air was higher at 8°C than at 13°C.

Key words: Mango; Mangifera indica L.; low oxygen, controlled atmosphere; ripening; postharvest life

INTRODUCTION

Mango (Mangifera indica L.) is a major tropical fruit in the domestic and export markets of Thailand. ‘Namdokmai’ is the most popular variety and leads all commercial mango varieties in terms of area and volume of production. The fruits are usually harvested mature-green, about 91-105 days from full bloom and with a starch content of about 18-20% (Tungtirmthong, 1998). After harvest, ripening rapidly sets in, with the fruits becoming full ripe in 4-5 days at ambient (Yantarasri et al., 1994). At the ripe stage, diseases particularly
stem-end rot and anthracnose usually develop. Softening of the ripe fruits also render them susceptible to impact and compression bruises. Thus, cold storage is recommended to retard ripening and prolong shelf life of the fruits. Mangoes are usually recommended to be stored at 10-15°C which can extend shelf life to about 2 weeks or more than two times the shelf life at ambient temperatures (Tungtirmthong, 1998). However, cold storage alone may not provide sufficient leeway during prolonged periods of distribution and marketing of the fruits. Other treatments should therefore be explored to supplement proper temperature and relative humidity management in maintaining quality and reducing losses of fruits.

Atmosphere modification during cold storage could be beneficial in improving further the shelf life of fruits particularly the climacteric type such as mango. One method of such atmosphere regulation is the use of low O₂ atmosphere (LOA). O₂ is known to be directly involved in primary metabolic processes, particularly respiration and ethylene production and action, as well as secondary metabolic processes, hence using LOA inhibiting these processes would invariably result to attendant inhibition of ripening and corresponding extension of ripening period and shelf life (Kader, 1994; Beaudry, 1999; Brecht et al, 2003). Silva (1998) showed that, at least in asparagus, metabolic processes in plant tissues differ across the O₂ partial pressure range of 0.16-16 kPa and that a number of important glycolytic enzymes underwent marked changes across this O₂ range. In fact in certain commodities, atmosphere recommendation specifies only the use of LOA such as in lettuce in which 1.5-2.5 kPa O₂ and 0 kPa CO₂ is recommended (Saltveit, 1997). In apples, LOA decreased fruit aroma (Chervin et al., 2000) through its action on ethylene action and oxidative processes (Beaudry, 1999). In addition, O₂ concentrations below 2% during storage at 3.5°C lowered the rate of loss of flesh firmness but below 1% O₂, ethanol was formed and tainting of flesh was observed (Stow, 1989; Stow et al., 2000). Thus, too low O₂ levels or prolonged exposure to LOA could be detrimental by increasing ethanol and off-flavor production and inducing tissue damage. In mature-green ‘Haden’ and ‘Tommy Atkins’ mangoes, the lag time before the onset of ethanol production was determined to be 5 days at 2% O₂ and 2 weeks at 5% O₂ at 12°C (Bender et al., 2000). Ethanol production in LOA-stored fruits was attributed to upregulation of alcohol dehydrogenase isozymes as earlier observed in pears (Ke et al., 1990). The onset of fermentation or ethanol production, as an indicator of fruit tolerance to LOA, is also affected by storage temperature. As temperature decreases, the lowest O₂ concentration that does not induce fermentation also decreases (Beaudry et al., 1992; Joles et al., 1994; Maneerat et al., 1997; Lakakul et al., 1999) and such O₂ concentration varies with cultivar (Gran and Beaudry, 1993). In blueberries, the O₂ concentration below which fermentation
occurred decreased from 4% to 1.8% as temperature decreased from 25°C to 5°C (Beaudry et al., 1992). Decreases in O₂ tolerance limit with decreasing temperature were similarly noted in raspberry (Joles et al., 1994), apple slices (Maneerat et al., 1997) and banana (Lakakul et al., 1999).

This study investigated the effects of different LOA levels during storage at chilling and non-chilling temperatures on ripening, quality changes and shelf life of ‘Namdokmai’ mango fruits.

MATERIALS AND METHODS

Experimental Treatments

Freshly harvested, fully mature-green ‘Namdokmai’ fruits were procured from a commercial orchard and selected for uniformity in size and shape, each weighing about 350 grams, and freedom from defects. The fruit samples were dipped in 1000 ppm benomyl for 5 minutes. After air-drying, the samples were placed in 20 l glass chambers, sealed and flushed with the desired gas mixture using the flow-through system. The fruits were subjected to 3% O₂ or 5% O₂ (balance N₂), with air (21% O₂) as control at 8°C (chilling) and 13°C (non-chilling). The study was done following completely randomized design experiments using four replications each with 6 fruits per observation period. Observation of fruit responses was done at 5-day interval.

Measurement of Fruit Responses

Color change. Changes in peel and pulp color were determined using a Minolta DP-301 colorimeter taking the a*, b* and L* values.

Firmness and weight loss. 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. Weight loss was determined as percentage of the initial weight.

Ion leakage. Ion leakage was determined using the method of Gemma et al (1994) with few modifications. Ten (10) whole peel discs 15 mm in diameter were excised with a cork borer, washed with distilled water, and incubated in a beaker with 50 ml distilled water for 3 hours with agitation using a shaker at 50 strokes/min at 20°C. Conductivity of the solution was measured using Orion-124 conductometer. The solution with the discs were then heated to boiling for 20 min. Conductivity of the solution after boiling was taken as a
measure of total ion leakage. Actual ion leakage was calculated as percent of the total ion leakage.

Respiration. Respiration was determined by gas chromatography. Three fruits 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.

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

Firmness

Ripening-associated fruit softening indicated by decreases in firmness was noted during storage at 13°C (Figure 1). This happened more rapidly in air than in low O₂ atmospheres and was detected as early as after 5 days of storage. Firmness of fruits held in air sharply decreased from day 5 to day 15 and from about 70N at the start of storage to less than 10N after 15 days of storage when the fruits became ripe-soft. 5% O₂ appeared to cause a 5-day delay in firmness loss as its firmness after 10 days of storage was comparable to the firmness of fruits in air after 5 days of storage. At 3%O₂, firmness decreased to about 30N after 20 days of storage, a similar degree of firmness of fruits held in air after 10 days of storage. Thereafter, firmness increased, suggestive of tissue hardening. At 8C, the fruits did not softened to levels of less than 10N obtained at 13C (Figure 1). Firmness remained at 40N or higher throughout the storage period in normal or low O₂ atmospheres. These results were indicative of failure of ripening due to chilling injury.

Fruit Color Changes

Peel color changed from green to yellow with ripening measured as increases in L* and b* values typified by fruits stored in air at 13C (Figure 2). L* and b* increased after 15-25 days of storage, indicating that peel yellowing occurred later than tissue softening during ripening. Holding in 3-5% O₂ inhibited these changes. L* and b* values were comparable to or even lower than that obtained at the start of storage (day 0). At 8C, changes in L* and b* were not typical of peel yellowing (Figure 2). L* decreased after 5 days of storage in air or low O₂ atmospheres and stayed at approximately the same level as the storage period
progressed, except at 5% O₂ in which fruits showed an increase in L* after 30 days of storage. b* did not similarly show marked changes with storage, except after 5-10 days of storage in which a slight increase was noted in fruits kept at 3-5% O₂. The range in values of L* and b* of fruits stored at 8C regardless of atmospheric composition was comparable to that of fruits stored in low O₂ atmospheres at 13C.

Pulp color, on the other hand, changed from whitish to yellow or dark yellow with ripening quantifiable as decreases in L* and increases in b* values. These changes were again exhibited by fruits stored at 13C in air (Figure 3). L* started to decrease while b* started to increase after 10 days of storage or 5 days earlier than corresponding changes in peel L* and b* occurred (Figure 2), indicating that pulp ripening occurred earlier than changes in peel color became visible. Low O₂ did not completely inhibit these changes, only it delayed their onset. At 5% O₂, decreases in L* started after 15 days while at 3% O₂, after 25 days of storage. b* values increased after 15 days of storage at 5% O₂ but at 3% O₂, b* did not appreciably differ from the prestorage level. After showing a decreasing trend in L* and an increasing trend in b*, L* decreased while b* increase both in air and 5% O₂. At 8C, L* values remained essentially comparable to the pre-storage level both at normal and low O₂ atmospheres (Figure 2). Only a slight increase in L* was noted in fruits held in air after 20 days of storage and in 5% O₂ after 30 days of storage, resulting in a slightly higher L* than the prestorage value. b* did not reach levels higher than the prestorage value. Instead, it decreased with storage particularly in air.

Respiration Rate

Low O₂ atmosphere reduced respiration rates of fruits stored at 13C (Figure 4). This was very evident after 10 days of storage when fruits in air showed maximum rate of respiration before levelling off with advancing storage period. At 3-5% O₂, the fruits had respiration rates similar to the prestorage rates. Five days later, the fruits held in low O₂ atmospheres showed maximum rates of respiration, although those held in 5% O₂ had much higher rates than those in 3% O₂. Later, respiration rates of low O₂-stored fruits decreased to levels lower than that in air. At 8C, respiration rates of fruits in air or low O₂ did not show dramatic increases during storage that should have been reflective of a climacteric pattern. There was a small increase in respiration (<20 mg CO₂/kg.h) after 5 days of storage but was not as marked as that of fruits held at 13C (20-50 mg CO₂/kg.h).

Ion Leakage

Ion leakage increased during the first 10 days of storage at 13C before decreasing thereafter (Figure 5). Low O₂ had no marked influence as fruits held at 3-5% O₂ had similar
degree of ion leakage as that of fruits held in air. Fruits held in 5% O₂ showed an increase in ion leakage after 30 days of storage but this was still lower than that obtained after 10 days storage. At 8C, similar trend was obtained (Figure 5). However, after 25 days of storage, ion leakage of fruits held in air was distinctly higher than that of fruits held in 3-5% O₂.

Weight Loss

Low O₂ atmospheres remarkably inhibited weight loss (Figure 6). 3% and 5% O₂ were comparable effective in causing this effect at similar degree at 8C and 13C. Weight loss was kept at less than 3% of the initial weight throughout the 30-day storage period. In contrast, weight loss of fruits stored in air increasing with increasing storage period. Weight loss was more rapid at 8C than at 13C. After 15 days of storage, for example, the fruits stored at 8C had more than 5% weight loss while at 13C, less than 5%. At the end of storage, the fruits lost about 15% of its weight at 8C and about 8% at 13C, although the latter was obtained 5 days earlier than the former.

CONCLUSION

Storage at 3-5% O₂ at 13C inhibited fruit ripening measurable in terms of changes in firmness, peel and pulp color, and respiration rate but not in terms of ion leakage. O₂ at 5% appeared to be more beneficial as the fruits normally ripened as compared to that at 3% O₂. At 8C, the fruits were chill-injured shown by failure of ripening regardless of atmosphere condition. Low O₂ was very effective in reducing weight loss both at chilling and non-chilling temperatures.


Figure 1  Firmness of Mango ‘Nam Dok Mai’ during storage at 8°C (A) and 13°C (B)
Figure 2 Peel L* and b-value of Mango ‘Nam Dok Mai’ during storage at 8°C (A) and 13°C (B)
Figure 3 Pulp L* and b-value of Mango ‘Nam Dok Mai’ during storage at 8°C (A) and 13°C (B).
Figure 4  Respiration rate (CO₂ production rate) of Mango ‘Nam Dok Mai’ during storage at 8°C (A) and 13°C (B).
Figure 5 Electrolyte leakage of Mango 'Nam Dok Mai' during storage at 8°C (A) and 13°C (B)
Figure 6  Weight losses (%) of Mango ‘Nam Dok Mai’ during storage at 8°C (A) and 13°C (B).