Changes in Ascorbic Acid Content, Antioxidant Capacity and Sensory Quality of Fresh-cut Mangosteens During Storage

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ABSTRACT

Fresh-cut mangosteens, stored in modified atmosphere packaging (MAP; 5% O_2 + 9% CO_2), in vacuum packaging (VAC) and in air (AIR) were examined for ascorbic acid content, antioxidant capacity and sensory quality during 14 days of storage at 4°C. After 4 days-storage, fresh-cut fruits with MAP resulted in better retention of ascorbic acid and antioxidant capacity than those stored in AIR throughout the storage. Furthermore, there were no significant differences in ascorbic acid contents between fruits stored in MAP and VAC, as well as antioxidant capacities, during the remaining period of storage. Fresh-cut fruits with MAP treatment obtained the highest sensory scores, compared with other treatments, throughout the entire period of storage. Fresh-cut mangosteens stored in MAP resulted in the best overall retention of ascorbic acid, antioxidant capacity and sensory quality.

Key words: Mangosteen - Fresh-cut - Modified atmosphere packaging - Ascorbic acid - Antioxidant capacity - Sensory evaluation

INTRODUCTION

Consumption of fruits has been shown in epidemiological studies to be related to reduced risk of degenerative diseases including cancer, cardiovascular and neurological diseases (1,2,3,4). These beneficial effects have been highly associated with the presence of various antioxidant constituents in fruits. Antioxidants play a crucial role in the body defense system against reactive oxygen species, which are the harmful by-products generated during normal cell aerobic respiration (5). Among antioxidants, ascorbic acid is of great importance in the human diet, in order to fight diseases such as scurvy, to maintain collagen, to reduce stress damage, and as an antioxidant. However, antioxidant vitamins present in fresh fruits are highly susceptible to degradation during processes such as drying and canning. Therefore, consumers are increasingly selecting minimally processed or fresh-cut fruits in response to purported health benefits as well as decreased preparation time (6).

Mangosteen (*Garcinia mangostana* L.) is one of the most praised tropical fruits. Its flesh is acclaimed as exquisitely luscious and delicious. Fresh-cut mangosteen called mangkoot-cut (in Thai, mangosteen = mangkoot) is exclusively produced in Nakhon Si Thammarat province in southern Thailand. It is produced from mature mangosteen with scattered pinkish spots on green skin (unripe mangosteen). It is perishable and vulnerable to discoloration and tissue softening. Inhibition of browning and retention of firmness in fresh-cut mangosteens by dipping in a mixture of 2% sodium erythorbate and 0.2% calcium chloride prior to storage under modified atmosphere packaging (5% O_2 + 9% CO_2), was suggested (7).

Apart from extending the shelf-life of fresh-cut products, the benefits of modified atmosphere packaging in maintaining ascorbic acid and antioxidant capacity in many fresh-cut products have been reported (8,9,10). However, little is known about the changes in ascorbic acid and antioxidant capacity in fresh-cut mangosteens stored under modified atmosphere packaging. The purpose of this study was to investigate the effect of modified atmosphere packaging on the ascorbic acid content and antioxidant capacity of fresh-cut mangosteens during storage. Sensory quality was also evaluated for estimation of the general quality losses of fresh-cut mangosteens. In addition, storage treatments with vacuum packaging and air were compared.

MATERIALS AND METHODS

Fruit Preparation

Mangosteens (with skin color having a few red patches on the green surface; average weight 100 g) were purchased from local growers in Nakhon Si Thammarat province. The fruits were manually cleaned and peeled under running tap water. The peeled fruits were dipped in a solution consisting of 2% sodium erythorbate + 0.2% calcium chloride for 30 min, and then drained prior to storage.

Storage Treatments

Fruits were stored at $4^{o}C$ under 3 storage conditions including modified atmosphere packaging (MAP) with initial gas composition of 5% O_2 and 9% CO_2, vacuum packaging (VAC) and air (AIR). Low-density polyethylene bags (14.5×25 cm, 80 μm thick) were used as containers for MAP and VAC (5 fruits per bag).

In-package atmospheric composition, ascorbic acid content, antioxidant capacity and sensory evaluation of fresh-cut mangosteens were monitored at 2-day intervals for up to 14 days.

Gas Analysis

Measurements of O_2 and CO_2 inside the MAP packages were conducted with a packaging atmosphere analyzer (Model MAP test 3050, Hitech Instruments, Luton, UK). A 10 ml gas sample was taken through a septum with a hypodermic syringe for analysis.

Measurements of Ascorbic Acid and Antioxidant Capacity

Fruit samples were ground using a pestle and mortar. After filtration of the homogenate through cheesecloth, the filtrate was centrifuged at 2,500 rpm for 8 min. The supernatant was used for analysis of ascorbic acid and antioxidant capacity.

Ascorbic acid was measured by titrimetric assay (11). Ascorbic acid content was calculated as mg of ascorbic acid per 100 g of fresh weight. Antioxidant capacity was assessed by ABTS free radical decolorization assay (12). Antioxidant capacity was expressed as mg of ascorbic acid equivalent per 100 g of fresh weight (AEAC).

Sensory Assessment

Sensory evaluation of fresh-cut fruit was performed using 15 untrained panelists. Overall acceptance was evaluated using a 9-point hedonic scale (9 = excellent, and 1 = poor).

Statistical Analysis

Statistical analysis was conducted using SPSS version 10.0. An analysis of the variance was processed using the general linear model procedure. Mean comparisons were performed using Duncan's New Multiple Range Test.

RESULTS AND DISCUSSION

In-Package Atmosphere

Change of atmospheric composition inside MAP is shown in **Figure 1**. Concentration of O_2 drastically decreased during 2-day storage to about 0.45%. Thereafter, no significant O_2 reduction was observed over 14 days of storage. Accumulation of CO_2 progressively developed and reached about 22% at the end of storage. During storage, the decrease of O_2 level and increase of CO_2 level in MAP associated with the respiration of fresh-cut mangosteens. Respiration rates of fresh-cut products are generally higher than intact products (13,14). This is problaby due to both the increase surface area exposed to the atmosphere after cutting (which allows oxygen to diffuse into the interior cells more rapidly) and to the increased metabolic activity of injured cells (15). The low O_2 level in combination with the high CO_2 level of the MAP treatment used in this study may have altered the respiratory pathway by increasing anaerobic respiration in fresh-cut mangosteens. It is evident from the literature that the anaerobic respiration results in production of objectionable fermentative volatiles such as ethanol, ethyl acetate, acetaldehyde and methyl esters (16,17,18,19,20). However, development of off-flavor and off-odor in fresh-cut mangosteens stored in MAP was not detected by panelists throughout the storage.

Ascorbic Acid

Initial ascorbic acid content of fresh-cut mangosteens was 6.75±0.05 mg/100g FW **(Figure 2)**. This value is higher than ascorbic acid content reported for ripe mangosteens (4.1±1.2 mg/100 g FW) (12). The difference could be related to several factors revealed by many studies including cultivar, production practices, maturity at harvest, and storage conditions (21,22).

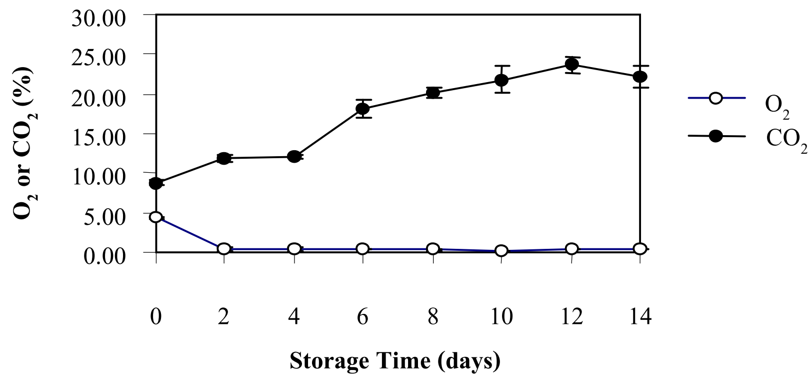

Figure 1. In-package atmosphere changes of O_2 and CO_2 of fresh-cut mangosteens stored in modified atmosphere packaging (5% O_2 + 9% CO_2) during 14-day storage at 4^{o}C. Vertical bars represent standard error of the mean (n = 3).

Over 14-day storage, ascorbic acid content of fruits stored in AIR sharply declined to 2.37±0.09 mg/100g FW at the end of storage. On the other hand, ascorbic acid contents of fruits store in MAP and VAC gradually decreased to 4.66±0.17 and 5.12±0.73 mg/100g FW at the end of storage, respectively **(Figure 2)**. In all treatments, the degradation of ascorbic acid associated with wounds occurred during minimally processing of mangosteens. Deterioration of cellular integrity and enzymatic compartmentation results in releasing of inherent oxidative enzymes. Ascorbic acid oxidase (EC 1.10.3.3) is a Cu-containing enzyme that catalyses the oxidation reaction of ascorbic acid to dehydroascorbic acid with the concomitant reduction of molecular oxygen to water. It is thought to be the major enzyme responsible for the enzymatic degradation of ascorbic acid (23). Yahia et al (24) found that a decrease of ascorbic acid in tomato and bell pepper fruits coincided with an increase in the activity of ascorbic acid oxidase.

Ascorbic acid content of fruits stored in AIR were lower than those of fruits stored in MAP and VAC after 4 and 2 days of storage, respectively **(Figure 2)**. These results related to the degradation of ascorbic acid by non-enzymatic oxidation. High levels of O_2 concentration in the storage atmosphere of AIR resulted in a greater extent of ascorbic acid depletion **(Figures 1 and 2)**. Likewise, reduction of ascorbic acid in MAP treatment during 2-day storage coincided with the remaining headspace O_2 in the package. However, there were no significant differences of ascorbic acid contents between fruits stored in MAP and VAC throughout the storage period. Our findings are congruent with the results of study concerning better retention of ascorbic acid in broccoli florets (8) and whole broccoli spears (25) stored under MAP, compared with AIR treatment.

Antioxidant Capacity

Initial antioxidant capacity of fresh-cut mangosteens was 4.37±0.37 mg/100g FW **(Figure 3)**. Leong and Shui (12) reported that antioxidant capacity of ripe mangosteen used in their study was 150±23.0 mg/100g FW. Although the same ABTS free radical decolorization assay was employed in the determination, our value for fresh-cut mangosteen was much lower. This large variability can apparently be explained by the influences of different varieties, maturity, location and weather conditions, among others, which would affect the level of antioxidants present in mangosteens. Ou et al (26) also indicated that the antioxidant capacities of vegetables were highly dependent on geographical origin and harvesting time.

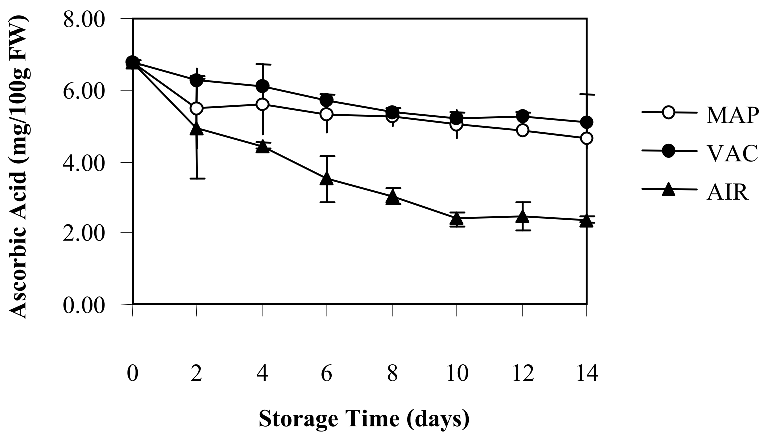

Figure 2. Ascorbic acid content of fresh-cut mangosteens stored in modified atmosphere packaging (MAP), vacuum packaging (VAC) and air (AIR) during 14-day storage at 4°C. Vertical bars represent standard error of the mean (n = 3).

Although ascorbic acid accounts for high contribution to antioxidant capacity in many fruits such as pineapple (12), papaya (12), rambutan (12) and citrus fruits (27), the contribution of this vitamin to antioxidant capacity of ripe mangosteen was not high (12). In addition to the decrease of ascorbic acid content **(Figure 2)**, loss of antioxidant capacity in fresh-cut mangosteens of all treatments during storage **(Figure 3)** could be related to the degradation of other antioxidant constituents including carotenoid. Lycopene seems to be a major carotenoid component present in mangosteen (28).

Figure 3 shows that antioxidant capacities of fruits stored in VAC remained stable and significantly different from those of MAP treatment during 4 days of storage. Thereafter, no significant difference in antioxidant capacities in fresh-cut fruits between VAC and MAP were observed over the entire period of storage. On the other hand, fruits stored in MAP showed significant differences in antioxidant capacities from those stored in AIR throughout the storage period except for the period of 4-day storage. These results revealed that storage in MAP resulted in better retention of antioxidant capacity of fresh-cut mangosteens than in AIR. A high oxygen pressure cause an acceleration of the chain initiation and propagation of the oxidation process and hence a decrease in the oxidation stability, or in the activity of the present antioxidants (29). On the contrary, Alsalvar et al (10) found that no significant differences in antioxidant capacities existed between orange carrots stored in MAP (5% O_2 + 5% CO_2) and in air, although better retention of carotenoid contents by MAP was observed.

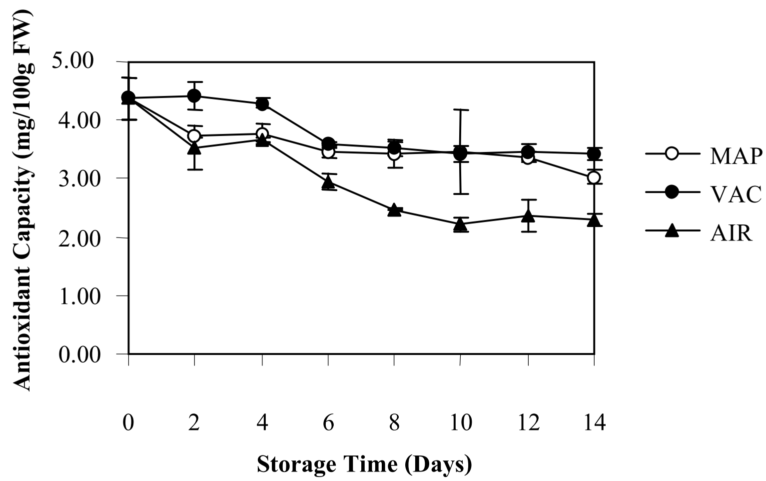

Figure 3. Antioxidant capacity of fresh-cut mangosteens stored in modified atmosphere packaging (MAP), vacuum packaging (VAC) and air (AIR) during 14-day storage at 4°C. Vertical bars represent standard error of the mean (n = 3).

Sensory Quality

Besides the nutritional aspect, acceptability of fresh-cut products depends mainly upon their organoleptic quality. Sensory scores for overall acceptance of fresh-cut mangosteens of all treatments during 14-day of storage are shown in **Table 1**. Sensory scores of all treatments continuously decreased during storage. Fruits stored in MAP obtained the highest scores throughout the entire period of storage. Previously, the MAP condition of 5% O_2 and 9% CO_2 was found to be an effective atmosphere in retarding discoloration of fresh-cut mangosteens (7). Treatment with VAC resulted in translucent flesh of fresh-cut mangosteen. In addition, there was some latex seeping into the flesh and consequently, the appearance of fruits was not desirable. The defect of fresh-cut fruits with VAC treatment could be associated with the great difference of atmospheric pressure between inside and outside the package. A significant difference of sensory scores between fruits stored in VAC and AIR was found after 6 days of storage, not during the first 4 days. Furthermore, panelists rejected to taste the samples after storage in AIR for 8 days due to their unacceptable appearance resulting from discoloration and dehydration. Similar results were reported by Alasalvar et al (10) that MAP (5% O_2 + 5% CO_2)-treated purple carrots gave better sensory quality compared to those kept under air in terms of formation of browning products.

Table 1. Overall acceptance score[1] of fresh-cut mangosteens stored in modified atmosphere packaging (MAP), vacuum packaging (VAC) and air (AIR) during 14-day storage at 4°C.

Treatments	Storage Time (days)							
	0	2	4	6	8	10	12	14
MAP	9.0[a]	7.2[a]	7.1[a]	6.5[a]	6.4[a]	6.2[a]	5.3[a]	4.6[a]
VAC	9.0[a]	6.6[b]	6.4[b]	5.3[b]	4.7[b]	4.8[b]	4.5[b]	4.0[b]
AIR	9.0[a]	6.6[b]	5.9[b]	3.7[c]	nd[2]	nd	nd	nd

[1] Each value is the mean of sensory scores obtained from 15 untrained panelists using hedonic scale (1-9). Means with same letter within columns are not significantly different ($p > 0.05$).

[2] Not determined due to rejection by panelists.

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บทคัดย่อ

สุปราณี มนูรักษ์ชินากร ปัทมา อินทวงษ์ พิลาพา ยืนนาน ศลิษา ทนวัฒนา และอมรรัตน์ ปานกอง

การเปลี่ยนแปลงของปริมาณกรดแอสคอร์บิค ความสามารถในการต้านออกซิเดชัน และคุณภาพทางประสาทสัมผัสของมังคุดคัดในระหว่างการเก็บรักษา

งานวิจัยนี้ได้ศึกษาการเปลี่ยนแปลงของปริมาณกรดแอสคอร์บิค ความสามารถในการต้านออกซิเดชัน และคุณภาพทางประสาทสัมผัสของมังคุดคัดในระหว่างการเก็บรักษาที่อุณหภูมิ 4 องศาเซลเซียส เป็นระยะเวลา 14 วัน ใน 3 สภาวะ คือ สภาพบรรยากาศดัดแปลง (5% ออกซิเจน + 9% คาร์บอนไดออกไซด์) สภาพสุญญากาศ และสภาพบรรยากาศปกติ พบว่าหลังจากการเก็บรักษาเป็นระยะเวลา 4 วันจนกระทั่งสิ้นสุดการทดลอง มังคุดคัดที่เก็บในสภาพบรรยากาศดัดแปลงสามารถรักษาปริมาณกรดแอสคอร์บิค และความสามารถในการต้านออกซิเดชันได้ดีกว่ามังคุดคัดที่เก็บในสภาพบรรยากาศปกติ และไม่พบความแตกต่างอย่างมีนัยสำคัญของปริมาณกรดแอสคอร์บิครวมทั้งความสามารถในการต้านออกซิเดชันระหว่างมังคุดคัดที่เก็บในสภาพบรรยากาศดัดแปลงและสภาพสุญญากาศ มังคุดคัดที่เก็บรักษาในสภาพบรรยากาศดัดแปลงมีคะแนนของคุณภาพทางประสาทสัมผัสสูงที่สุด เมื่อเปรียบเทียบกับการเก็บรักษาที่สภาวะอื่นในตลอดระยะเวลาของการเก็บรักษา ดังนั้นการเก็บรักษามังคุดคัดในสภาพบรรยากาศดัดแปลงสามารถรักษาปริมาณกรดแอสคอร์บิค ความสามารถในการต้านออกซิเดชัน รวมทั้งคุณภาพทางประสาทสัมผัสได้ดีที่สุด

สำนักวิชาเทคโนโลยีการเกษตร มหาวิทยาลัยวลัยลักษณ์ อำเภอท่าศาลา จังหวัดนครศรีธรรมราช 80160