การเกิดสารระเหยให้กลิ่นรสในลองกองระหว่างการเก็บรักษาในสภาวะควบคุมบรรยากาศร่วมกับการสลับอุณหภูมิ

Formation of Volatile Flavor Compounds in Longkong During Storage under Controlled Atmospheric Condition Combined with Intermittent Warming Treatment

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บทคัดย่อ

ลองกองเป็นผลไม้เมืองร้อนที่เน่าเสียง่ายต้องการการปฏิบัติหลังการเก็บเกี่ยวที่มีประสิทธิภาพเพื่อใช้ยืดอายุการเก็บรักษา อุณหภูมิต่ำควบคู่กับการควบคุมบรรยากาศได้ถูกนำมาใช้เป็นทางเลือกเพื่อยืดอายุการเก็บรักษาของผลลองกอง อย่างไรก็ตามพบว่าเมื่อเก็บรักษานานขึ้น ผลลองกองแสดงลักษณะที่ไม่พึงประสงค์ เช่น เกิดสีน้ำตาลปนแดงที่เปลือก สูญเสียความแน่นเนื้อ และเกิดการสะสมของเอทานอล ดังนั้นเพื่อที่จะลดการเกิดลักษณะไม่พึงประสงค์ดังกล่าว งานวิจัยนี้จึงศึกษาผลของการใช้อุณหภูมิสลับร่วมกับการควบคุมบรรยากาศ (5% CO_2: 5% O_2) ระหว่างการเก็บรักษาที่อุณหภูมิ 18 องศาเซลเซียส และใช้อุณหภูมิสลับที่ 30 องศาเซลเซียส แตกต่างกัน 9 ชุดการทดลอง (สุ่มตัวอย่างในวันที่ 2, 5, 8, 11, 14, 17, 20, 23 และการใช้อุณหภูมิสลับทุก 2 วัน) และมีชุดที่ไม่ใช้อุณหภูมิสลับเป็นชุดควบคุม จากผลการทดลองพบว่า เมื่อเก็บนาน 24 วัน ผลลองกองในชุดที่มีการใช้อุณหภูมิสลับในทุก 2 วัน ระหว่างการเก็บรักษา มีคุณภาพดีที่สุด โดยมีการสูญเสียน้ำหนักเพียงร้อยละ 0.73 อัตราการเปลี่ยนแปลงของสีผิวของผลลองกองมีค่าต่ำสุด ($p<0.05$) และพบว่าระหว่างการเก็บรักษาภายใต้สภาวะนี้สารระเหยที่แสดงลักษณะกลิ่นรสของผลลองกองที่ดี ได้แก่ 3-hydroxy-2-butanone, linalool และ germacrene มีความคงตัวมากสุด และการเกิดเอทานอลสะสมต่ำสุด ($p<0.05$) โดยมีค่าเท่ากับ 0.21 กรัมต่อกรัมน้ำหนักของผลสด

คำสำคัญ: ลองกอง, อุณหภูมิสลับ, สารระเหยให้กลิ่นรส

Abstract

Longkong is a highly perishable tropical fruit which requires an effective means of extending its postharvest life. Low temperature combined with controlled atmospheric (CA) conditions was used to prolong the postharvest life of the fruit. However, during long-term storage under CA conditions, longkong fruit showed undesirable attributes such as brownish peel color, loss of flesh firmness and high ethanol accumulation. Therefore, in order to reduce those undesirable characteristics, the intermittent warming (IW) treatment (at 30°C) was introduced. The nine IW sampling times (on days 2, 5, 8, 11, 14, 17, 20, 23 with IW treatment at 2-day intervals) were applied to longkong fruits during low-temperature storage (18°C) combined with CA conditions (5% CO_2: 5% O_2). Interestingly, longkong fruit intermittently treated at 2-day intervals showed the highest fruit quality with 0.73% weight loss after 24 days in storage. Under this condition, longkong fruit had the lowest rate of peel color change. The amounts of 3-hydroxy-2-butanone, linalool and germacrene which are desirable volatile compounds were maintained in this IW-treated fruit. In addition, the lowest ethanol accumulation, 0.21 g/g FW, at the end of storage was noticed.

Keywords: longkong, intermittent warming, volatile flavor compounds

Introduction

Controlled atmospheric (CA) conditions can be used as an effective tool for prolonging the longkong shelf-life, but the fruit is subjected to stress during storage under these conditions for a longer time. Under a stress condition, longkong produces off flavors (caused by ethanol accumulation) that directly influence consumer acceptability. Therefore, to delay longkong from being exposed to a stress condition, intermittent warming (IW) treatment is introduced. It involves keeping fruits under low temperature and transferring them to an

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ambient condition. However, the potential for reversal varies with length of time under the stress condition. In addition, re-opening the CA condition, in order to return the fruit to an ambient condition for a while is considered as an alternative way to reduce anaerobic metabolism. Therefore, the objective of this study was to introduce IW treatment to longkong during storage under the CA condition and monitor its quality and off-flavor development.

Materials and Methods

Plant material

Longkong fruits at week 13 after anthesis were purchased from a contact orchard at Songkhla province, southern Thailand. The fruits were cut off from racemes and the defected fruits were discarded. Then, they were washed in tap water and dipped in 500 ppm benomyl solution for 15 min and dried at ambient temperature.

Intermittent warming (IW) treatment and storage

The 12 individual longkong fruit/bag were placed on a polypropylene tray and covered with 18x28 cm nylon/LLDPE bag. Each experiment was carried out with three replicates. The IW treatments were introduced to longkong on different days during storage. The IW treatments were (1) a cycle of IW treatment to ambient condition every 2 days, (2) IW treatment on day 2, (3) IW treatment on day 5, (4) IW treatment on day 8, (5) IW treatment on day 11, (6) IW treatment on day 14, (7) IW treatment on day 17, (8) IW treatment on day 20 and (9) IW treatment on day 23. The sample without IW treatment was used as a control. The IW treatment was performed by transferring longkong fruits from the CA conditions to an ambient condition for 15 min. Thereafter, headspace atmosphere was modified to a condition of 5% CO2: 5% O2 and the fruits were stored at 18oC for 24 days. Sampling time was done on days 0, 3, 6, 9, 12, 15, 18, 21 and 24 for physical and chemical analyses

Statistical analysis

All the experiments were conducted in triplicates. Significant differences among the means were determined by Duncan's new multiple range test (DMRT) at 0.05 level. Statistical Package for Social Science (SPSS) version 6.0 for Windows (SPSS Inc., Chicago, IL, USA) was used for data analysis.

Results and Discussion

Longkong subjected to IW treatment with a cycle to ambient condition every 2 days showed a slow chang in peel color, maintained unique longkong-like flavor as well as produced low concentration of ethanol. The almost constant headspace of O_2 and CO_2 was associated with a cycle of IW treatment to ambient condition every 2 days. Under this condition, high concentration of headspace CO_2 was eliminated. In addition, IW treatment by exposing longkong to an ambient condition for 15 min left the core temperature of longkong equilibrate with room temperature (approximately 30°C).

Longkong lost its bright yellowness and turned brownish. This was indicated by decreases in L* and b* values and an increase in a* value. The L* value significantly decreased from 62.00 to a range of 31.59-32.87 at the end of storing longkong under active MAP+IW treatment for 24 days (Figure 1A). Less yellowness and more brownness reflected a significant decrease in the b* value with an increase in the a* value ($p<0.05$). The b* value significantly decreased from 30.75 to a range of 15.71-18.07 (Figure 1B). In addition, the significant increase in the a* value from 5.75 to a range of 15.09-19.18 was observed ($p<0.05$) (Figure 1C). To eliminate high CO_2 accumulation, IW treatment was introduced in this study. A cycle of IW treatment to ambient condition every 2 days was an effective condition to release CO_2 stress compared to other treatments. Changes in enzymatic browning in longkong were retarded (Venkatachalam and Meenune, 2012).

Weight loss increased throughout the storage period ($p<0.05$). In this study, weight loss in longkong was promoted on day 9 onwards in all conditions. Weight loss continuously increased until the end of storage to reach a range of 0.64-0.73%. The main cause of weight loss is transpiration. Water in fruit might be lost through the stomata, the cracks and the peel damage. According to the study on pericarp ultrastructural changes undertaken by Venkatachalam (2013), longkong had much more epidermal hair changes during storage under CA conditions at 18°C. It was evidence to support epidermal damage appearance. It might be the route for water loss in longkong.

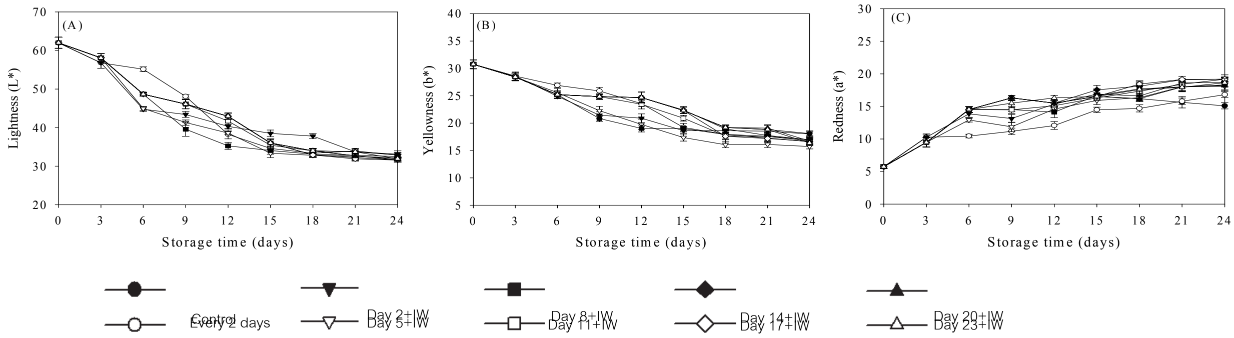

Figure 1 Lightness (A), yellowness (B) and redness (C) values of longkong during storage under CA condition with IW treatment on different days

Volatile flavor compounds in longkong included esters, alcohols, terpenes and their derivatives, acids, ketones and phenols (Table 1). Most of fruity, sweet, floral and herbaceous compounds such as laevo-linalool, 3-hydroxy-2-butanone and delta-germacrene were identified. These compounds declined with storage time. Acetyl-CoA which was a primary compound for ester and terpene formation under insufficient O_2 condition might be lacking (Little and Croteau, 1999; Lara *et al*., 2006). In addition, fermented alcohols and acids from anaerobic metabolism were formed. To maintain unique volatile flavor in longkong and elimination of fermented alcohols and acids, the IW treatment was introduced. It was found that, longkong which was treated with a cycle of IW treatment to ambient condition in every 2 days still had many types of volatile flavor compound compare with the longkong stored under CA condition without IW treatment (control). It was probably due to a frequent turning longkong to adequate O_2 in atmospheric condition retain longkong-like volatile flavor compounds in longkong.

Table 1 Volatile flavor compounds and their attributes in longkong during storage under CA condition with IW treatment every 2 days

Compound	Rt[A]	RI[B]	Peak area (×10^4) TIC[D]								
			Storage time (days)								
			0	3	6	9	12	15	18	21	24
Ester											
ethyl-3-hydroxy butyrate	15.68	1532	2.80	13.24	15.17	17.11	19.95	15.83	13.57	9.87	7.33
Alcohol											
2-methyl propanol	4.96	1107	nd	nd	6.95	8.14	12.76	15.16	14.23	10.5	6.41
n-butanol	6.19	1157	1.25	10.11	17.31	27.41	31.83	32.00	32.84	33.08	55.58
iso-amylalcohol	7.72	1218	0	3.24	3.97	4.56	5.97	29.00	33.25	49.94	55.99
n-hexanol	11.05	1347	1.25	1.86	2.82	3.00	3.63	17.92	29.83	18.21	12.96
2-ethyl hexanol	14.89	1499	1.28	1.95	2.17	8.11	15.7	18.14	26.45	9.21	8.73
benzyl alcohol	23.77	1895	nd	35.25	37.13	39.23	41.17	87.83	38.36	27.86	11.87
phenylethyl alcohol	24.45	2134	nd	4.52	6.96	27.72	35.27	48.00	51.47	40.80	18.15
Terpene and their derivative											
cis-linalool oxide	14.39	1479	nd	nd	5.95	8.01	14.98	54.76	70.27	54.44	42.48
laevo-linalool	16.35	1559	nd	nd	13.04	13.65	14.33	66.79	95.00	60.54	54.41
delta-germacrene	19.75	1706	0.82	10.03	12.09	26.81	27.17	71.17	17.19	22.32	10.28
epoxylinalool	21.21	1707	nd	6.77	7.27	8.14	8.96	72.67	22.06	19.03	16.75
Acid											
acetic acid	14.21	1472	0.5	2.14	7.14	13.56	17.14	36.51	47.2	69.74	78.40
propanoic acid	16.25	1555	nd	nd	nd	9.11	12.42	15.87	28.48	34.05	37.78
butanoic acid	18.32	1643	nd	5.06	12.11	20.81	25.81	32.7	36.36	40.24	46.36
hexanoic acid	23.07	1862	nd	nd	nd	nd	24.98	45.83	69.51	74.44	81.90
Ketone											
3-hydroxy-2-butanone	9.78	1298	12.4	50.33	58.09	61.01	98.78	74.06	38.61	71.6	26.25
phenol											
phenol	26.38	2027	2.89	5.34	13.05	43.81	62.72	54.12	41.26	23.00	14.80

Note: [A] Rt = Retention time (min); [B] RI = Retention index (FFAP column) ; [C] TIC = Total ion current; nd = Not detected

Ethanol accumulation and sensing longkong-like flavor during storage under CA condition+IW treatment for 24 days were monitored. An increase in ethanol concentration with a decrease in longkong-like flavor is presented in Figure 2. Ethanol continuously increased until the end of storage in all conditions. Ethanol concentration significantly increased from 0.06 g/g FW to a range of 0.21-0.28 g/g FW (Figure 2A). At the end of storage, longkong-like flavor was rated from 8.33 to a range of 2.33-4.53 (Figure 2B). The highest longkong-like flavor was correlated with the lowest ethanol concentration found in longkong treated with a cycle of IW treatment to an ambient condition every 2 days. It might be due to frequent transfer of longkong to an ambient condition. Under ambient condition, aerobic metabolism occurs and ethanol fermentation pathway is inhibited. Less ethanol accumulation gives a unique flavor profile of longkong.

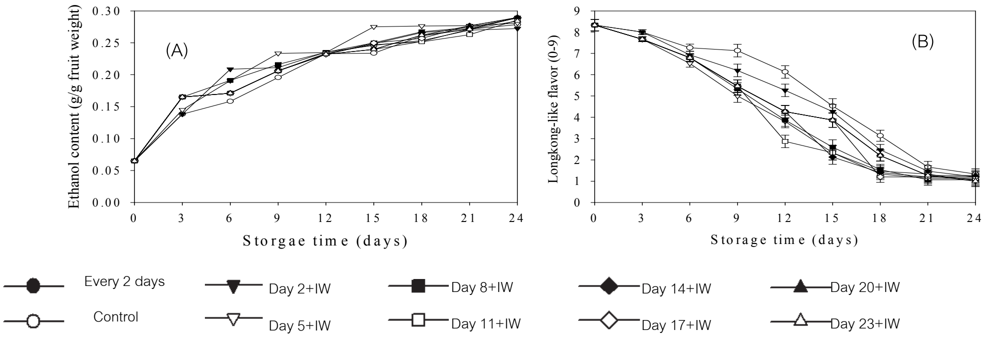

Figure 2 Ethanol content (A) and longkong-like flavor (B) of longkong during storage under CA condition with IW treatment on different days.

Conclusion

CA condition was used as an effective tool for prolonging longkong shelf-life. However, the fruit was subjected to stress in long-term storage under high CO_2 accumulation. The IW treatment was used for longkong quality improvement and for a reduction in CO_2 accumulation. A cycle of IW treatment to ambient condition every 2 days was a successful tool to retard brownish peel and flesh softening. The undesirable off flavors in longkong caused by ethanolic-flavor occurred during storage. It reduced longkong-like flavor. The IW treatment as a cycle of IW treatment to an ambient condition every 2 days was an effective way for aerobic condition refreshment, resulting in low ethanol accumulation and high flavor acceptability.

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