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Research Article

Physical, chemical and sensory qualities of Longkong (*Aglaia dookkoo* Griff.) as affected by storage at different atmospheres

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Abstract

Longkong (*Aglaia dookkoo* Griff.) is a highly perishable tropical fruit which requires effective tools to extend its shelf-life. High CO_2 and/or low O_2 such as modified atmosphere packaging (MAP) and/or storage under an optimal temperature were introduced. However, during postharvest handling under MAP conditions, longkong may be exposed to anaerobic stress. Therefore, disorder attributes, especially ethanolic flavour attributes, which affect its organoleptics are formed. In this study, ethanolic flavour accumulation, physical and chemical quality changes, as well as sensory evaluation of longkong as affected by different MAP conditions (5%CO_2:5%O_2, 5%CO_2:10%O_2 and 10%CO_2:5%O_2) were examined. During storage under different MAP conditions at 18°C for 24 days, loss of longkong quality, especially ethanolic-flavour accumulation was higher when CO_2 concentration increased ($p<0.05$). At the end of storage, the highest headspace CO_2 concentration inside the fruit package was observed in the sample stored under the conditions of 10%CO_2:5%O_2. This sample also gave the highest ethanol content of 0.25 g/g fruit weight, which increased from the initial of 0.06 g/g fruit weight in fresh longkong. Decreases of fruit flavour acceptance and increases in perceived ethanolic-flavour intensity were also in agreement with the high concentration of ethanol content. Flavour

acceptance score reduced from 8.3 in fresh longkong to 5.2 during storage for 6 days. At the end of storage for 24 days, flavour acceptance score showed 1.3. In addition, all MAP conditions resulted in reduction of lightness (L*) value, fruit firmness and sugar content, while redness (a*) value and titratable acidity (TA) increased with storage time.

Keywords: fruit, postharvest, modified atmosphere packaging, ethanolic flavour, Thailand.

Introduction

Longkong (*Aglaia dookkoo* Griff.), is a well known commercial fruit in southern Thailand belonging to the Meliaceae family that also includes langsat, duku-langsat and duku. Longkong has its origins in the south of Thailand, Indonesia, the Philippines and the Malau Islands [1]. Longkong is a tropical fruit, which comes in racemes, is round and soft, being roughly 1.2 to 2.4 inches in diameter. It has a somewhat smooth, thin and bright-yellow skin. There are 15 to 25 fruit per raceme, almost seedless (only 1-2 bright green seeds that have a bitter taste), free of latex and the fruit pulp is white, juicy with a typically aromatic smell and a sweet but slightly sour taste [1, 2]. The demand for this fruit is increasing tremendously because the fruit is juicy, has a pleasant taste and contains a variety of nutrients [1, 3]. However, its shelf-life is limited to about 4-7 days under room temperature [4] and it is rapidly effected by changes in colour, texture, appearance and off-flavour after harvesting.

Product respiration plays a major role in the postharvest life of fresh fruit. This process consumes O_2 and produces CO_2. Usually, low O_2 levels combined with moderate to high CO_2 levels are applied to extend the shelf-life of fresh fruit [5]. Generally, reduced utilization rate of substrate results in a reduced rate of respiration and increases postharvest shelf-life of fresh fruit beyond normal span. The effect of modified atmosphere condition on longkong quality has been undertaken by many researchers. The study on shelf-life of longkong using modified atmosphere conditions such as 3%CO_2:21%O_2, 6%CO_2:21%O_2, 0.03%CO_2:2%O_2, 0.03%CO_2:6%O_2, 3%CO_2:6%O_2, 6%CO_2:6%O_2 and using atmospheric conditions by storing longkong in a PVC box at 20°C has been conducted. It was found that the shelf-life of longkong under all atmospheric modification conditions was longer than under atmospheric condition and the shelf-life of longkong was 12 and 8, days, respectively [6]. In another study, it was reported that the longkong raceme which was kept under modified atmosphere packaging (MAP) has longer shelf-life than that at atmospheric condition. In addition, under MAP condition (5%CO_2 and 5% O_2), the longkong raceme which was treated with 1.5% citric acid for 5 min prior to storage under MAP at 18°C had its shelf-life extended for 30 days [7].

One of the major problems encountered in using MAP is the accumulation of anaerobic metabolites in the packages. Under the condition where O_2 is low or not available, the build-up of an anaerobic condition in fruit leads to enhanced anaerobic metabolism and an increase in production of off-flavour volatiles, such as ethanol, which directly influence consumer acceptability of fresh fruit [8]. For example, intensified product of ethanol was found in litchi fruit during storage under cold condition (1.5±5ºC, RH>90%) and the shelf-life under MAP increased with time. It was found that ethanol accumulation was approximately 10 nmol/ml juice in the first week of storage and reached to 75 nmol/ml juice at the end of storage after 4

weeks. In addition, taste score (ranging from 1 to 3) showed a decrease from 2.6 (in the first week) to 1.9 (after 4 week of storage) [9]. Coated 'Mor' mandarin with 9% wax was found to have much higher ethanol accumulation than the unwaxed one at the end of storage (4 weeks) at 5ºC, RH~85%. The results showed that taste score (ranging from 1 to 10) of unwaxed was higher than the 9% wax 'Mor' mandarin [10]. Studies on the effect of modified atmosphere condition on fruit flavour quality have also been undertaken by many researchers; nevertheless, flavours of fresh longkong affected by postharvest treatment have not yet been investigated. Therefore, the objectives of this study were to study the effect of modified atmosphere conditions on the quality changes and possible off-flavour accumulation in longkong during storage and investigate the correlation between instrumental analysis and sensory evaluation on longkong flavour during storage under different atmospheres.

Materials and Methods

Plant material and fruit preparation

Longkong (*Aglaia dookkoo* Griff.) at commercial maturity (13 weeks after anthesis) was obtained from a contract garden in Natawee District, Songkhla Province, Thailand. Longkong free from any apparent skin damage and uniform size (about 3-3.5 cm in diameter, according to Tanyongmut market) was selected. Longkong was prepared in the form of individual fruit by cutting the raceme, cleaning with a brush and submerging into a mixed solution of 500 ppm benomyl and 1.5% citric acid for 5 min to reduce microbial load and anti-browning skin. Following this, the fruit was dried at ambient temperature (~30°C) for 15 min.

Modified atmosphere packaging (MAP) and storage conditions

The 15 individual fruit were placed into a plastic tray. Each plastic tray was covered with a 0.08 mm thickness nylon laminated with linear Low Density Polyethylene (nylon/LLDPE) bag; size 7x11 in^2. The plastic bag was filled with CO_2 and O_2 using 3 different ratios of 5%CO_2:5%O_2, 5%CO_2:10%O_2, 10%CO_2:5%O_2 (balanced with N_2). Following this, each bag was stored at 18ºC for 24 days.

Physical and chemical analysis

At 6 day intervals during storage, physical (fruit skin colour and firmness) and chemical (sugars and titratable acidity; TA) qualities were evaluated. The analysis of fruit skin such as colour and firmness was undertaken using the 15 individual fruit. Fruit firmness was measured on opposite sides of each fruit with a TA-XT2i Texture Analyzer (Stable Micro System, UK) equipped with a 2 mm diameter cylinder probe (P/2) with penetrometric method. The results were expressed as gram force. Colour on two opposite sides of fruit skin were quantified in terms of CIE Lightness (L*), Redness (a*) and Yellowness (b*) values using a Colour Flex, Hunter Lab colourimeter. For chemical quality analyses, the homogenate was prepared. Only longkong flesh (de-seeded) was blended and used. Titratable acidity (TA) was determined by titrating 10 ml of the homogenate to an end point of pH 8.2 with 0.1 N NaOH using 1% phenolphthalein as an indicator. The result was calculated as percentage of citric acid content. Sugars (sucrose, fructose and glucose) were determined by HPLC (Shimadzu, CR 6A Chromatopac) with Hypersil APS-2 column, refractive index detector and 80% acetonitrile was used as a mobile phase. The concentrations were quantified by comparing retention time and peak area of the samples with known standards.

Headspace gas composition analysis

Changes in headspace gas composition were evaluated using GC- thermal conductivity detector (TCD-detector). Determination of headspace CO_2 concentration was conducted by using 1 ml of gas which was withdrawn directly from the headspace inside the package and injected directly to Poropak N columns with a helium carrier flow of 50 ml/min. The temperature of oven and detector were held at 60 and 150°C, respectively. The internal package atmosphere was identified and quantified by comparison with external standard gas.

Ethanol concentration determination

Flesh longkong 100 g was mixed with 100 ml of 20% NaCl (cold solution), blended at constant speed using a blender for 3 min and filtered through the stainless steel sieve, yielding the homogenate. Homogenate (20 ml) was placed into a 125 ml vial followed by addition of 3 g of NaCl and fitted with a rubber septum. The vial was kept at 30ºC and left to equilibrate for 60 min [11]. The volatiles were sampled by headspace solid phase microextraction (HS-SPME). The SPME fibre was coated with (50/30 µm DVB/CAR/PDMS (divinylbenzene/Carboxen on poly (dimethylsiloxane)) (Supelco, Bellafonte, PA, USA)). The headspace phase was adsorbed for 15 min while maintaining the sample at 30°C and desorbed for 5 min in GC-FID (PerkinElmer, Autosystem XL, USA).

The volatiles were analysed on a GC-FID apparatus equipped with a with Rtx-5 (Restek) column (30 m×0.25 mm; film thickness 0.25 µm). The carrier gas was ultra high purity helium at a constant flow of 1.5 ml/min. The injector was kept at 240ºC, set for splitless mode. The column temperature was maintained at 35°C for 3 min and then programmed to 230°C at the rate of 8°C/min and held for 2 min. Ethanol concentration was calculated according to the standard curve of ethanol which was run under the same conditions as used for the samples.

Sensory evaluation

The acceptance methods used included the 9-point hedonic scale and unstructured line scale. The 9-point hedonic scale ranged from "1=dislike extremely" to "9=like extremely". The 150 untrained panelists who like to consume longkong regularly were estimated on the scale. Samples were coded with 3-digit random number and presented to panelists in random order. Panelists were instructed to consume the piece of longkong and rinse their mouth with water between sample evaluations.

The intensity of ethanolic flavour in longkong was rated to record attribute perceived difference during storage by unstructured scale lines. Unstructured scales were represented by straight lines 20 cm long, oriented by score description (ranging from 0 to 100) on the two ends (0=imperceptible ethanolic flavour; 100=strong ethanolic flavour). The intensity of ethanolic flavour was rated by 12 trained panelists who were well versed in detecting ethanolic flavour differences by placing a vertical line on the scale. Assessors sat in individual booths and were asked to score the intensity of ethanolic flavour. For each session 3 pieces of longkong were presented to the assessors in randomly numbered capped container. At intervals, panelists were advised to take some fresh air before proceeding to the next sample to prevent saturation.

Statistical analysis

A factorial design with storage atmosphere and storage time was used to statistically analyse results. All data were tested by analysis of variance (ANOVA) with the Statistical Package for Social Science (SPSS for windows, SPSS Inc., Chicago, IL, USA). Significant differences between means were estimated by Duncan's new multiple range test (DMRT), with a level of significance of 0.05.

Results and Discussion

Changes in headspace carbon dioxide (CO_2) inside the longkong package are shown in Fig. 1. It significantly increased ($p<0.05$) over time in all packages. A change of headspace CO_2 was attributed to fruit respiration which was limited by storage atmosphere and storage time ($p<0.05$). Sharp increases of CO_2 pattern up to 12 days during storage in the ranges of 69.57-72.41% was observed and continued to increase to the ranges of 80.11-84.25% at the end of storage. In the longer-term, under high CO_2 and/or low O_2 condition, longkong also appeared to be much more sensitive to exposure to anaerobic stress and responded by significantly increased ethanol content.

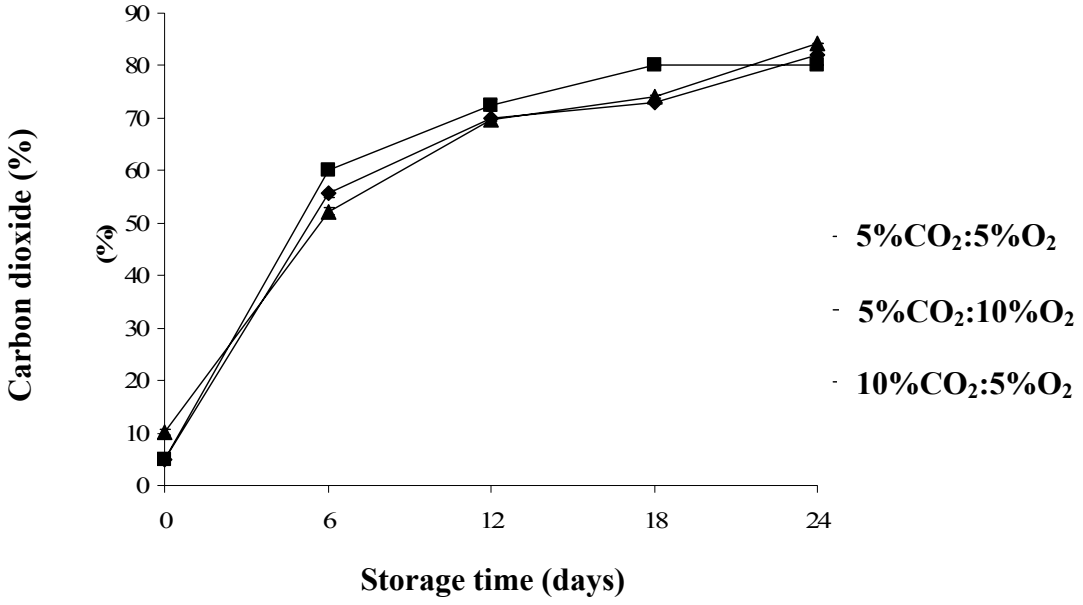

Figure 1. Headspace carbon dioxide inside package under different modified atmosphere conditions during storage at 18ºC.

Following exposure to 24 days under all MAP conditions, the fruit showed a significant increase ($p<0.05$) in ethanol content as can be seen in Fig. 2. Ethanol concentration increased from 0.06 g/g fruit weight in fresh longkong to 0.21, 0.20 and 0.25 g/g fruit weight for longkong which was stored under the MAP conditions of 5%CO_2:5%O_2, 5%CO_2:10%O_2 and

10%CO_2:5%O_2, respectively. The highest concentration of ethanol (0.25 g/g fruit weight) was presented in longkong which was stored under the MAP condition of 10%CO_2:5%O_2. The highest CO_2 concentration detected inside the package was approximately 84.25% at terminate time. High CO_2 concentration can induce anaerobic metabolism. Pyruvate, the end product of glycolysis could undergo decarboxylation to produce acetaldehyde, which was reduced subsequently to ethanol [12, 13]. In contrast, the lowest concentration of ethanol (0.20 g/g fruit weight) was found in longkong which was stored under the MAP condition of 5%CO_2:10%O_2 which presented the lowest concentration of CO_2 inside the package at the end of storage.

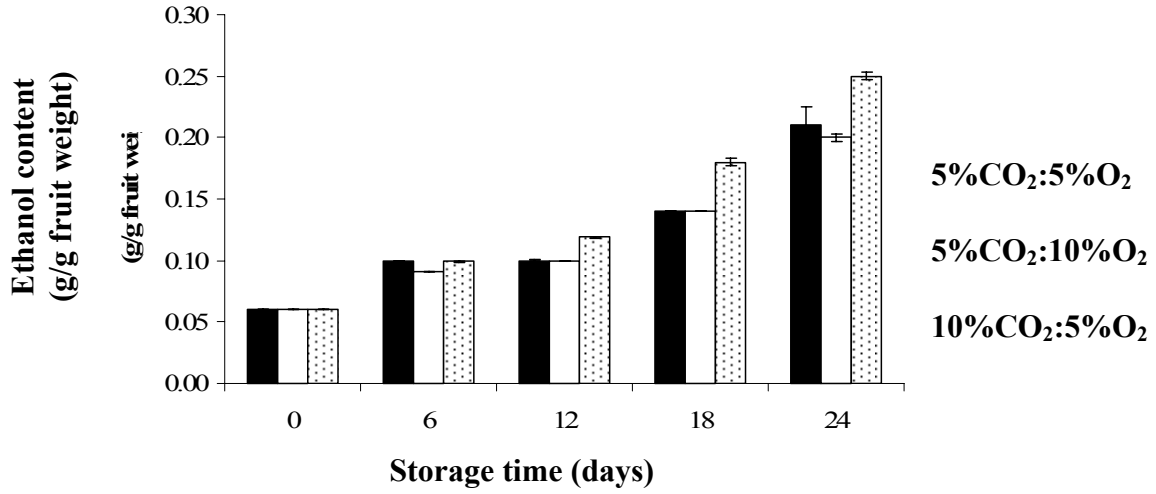

Figure 2. Ethanol content in longkong under different modified atmosphere conditions during storage at 18ºC.

In the first test we observed large incremental increases in ethanol content in longkong during storage under MAP conditions. Correspondingly, this ethanolic flavour attribute was presented in longkong and also detected by human senses. In Fig. 3 it can be seen that ethanolic flavour attribute was detected and high perceived intensity of ethanolic flavour was rated with a higher score with storage time ($p<0.05$). In addition, consumer acceptability on longkong flavour during its storage under different MAP conditions was determined. Reduction of flavour score ($p<0.05$), corresponding to high levels of ethanol content was observed as can be seen in Fig. 4.

Scores were reduced from 8.3 in fresh longkong to 2.8 (5%CO_2:5%O_2), 2.2 (5%CO_2:10%O_2) and 1.3 (10%CO_2:5%O_2) at the end of storage (on day 24). The highest perceived intensity of ethanolic flavour and the lowest score of liking in fruit flavour was correlated with the highest ethanol content which accumulated in longkong that was stored under the MAP condition of 10%CO_2:5%O_2. In addition, off-flavour formation influenced panel choices.

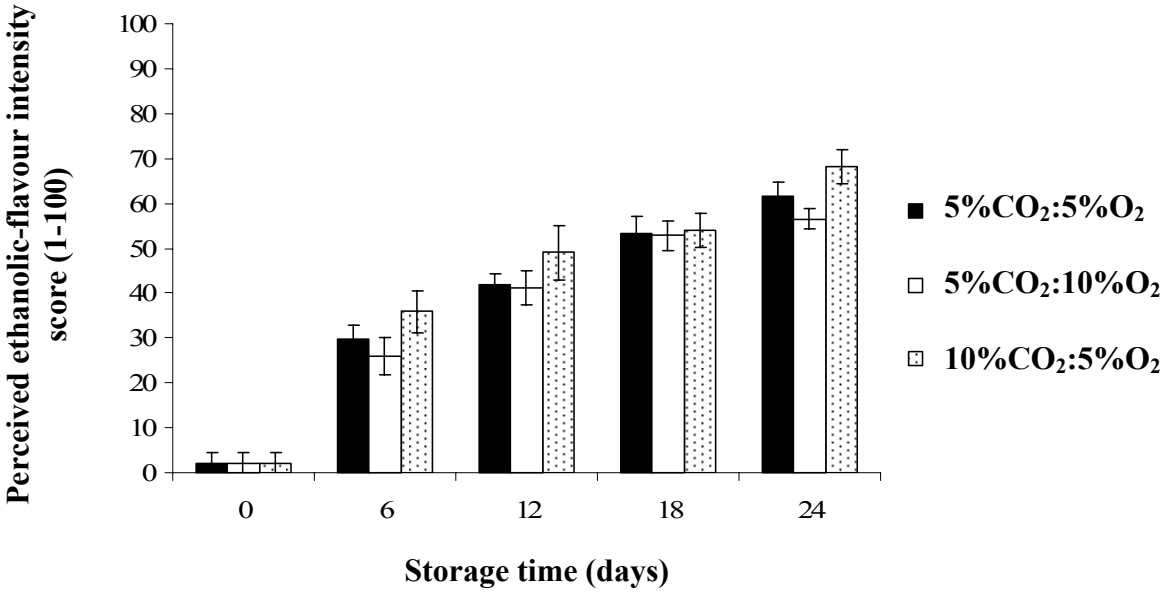

Figure 3. Intensity rating for ethanolic flavour in longkong under different modified atmosphere conditions during storage at 18ºC.

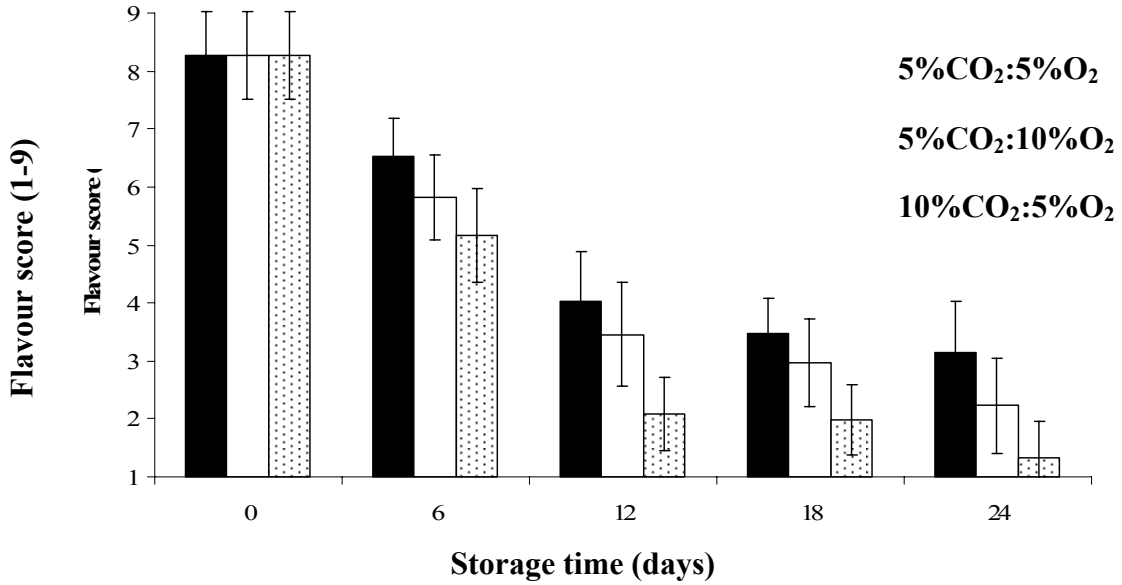

Figure 4. Flavour score of longkong under different modified atmosphere conditions during storage at 18ºC.

Some physical (fruit skin colour and firmness) and chemical (sugars and TA) quality changes during storage were also evaluated. The results are shown in Tables 1 and 2. The storage atmosphere and storage time had a significant effect ($p<0.05$) on the changes in fruit skin colour.

The L* and b* values decreased significantly with storage time. Conversely, the a* value increased significantly ($p<0.05$) in all treatments with storage time. The lowest L* and the highest a* values were found in longkong stored under the MAP condition of 10%CO_2:5%O_2, which indicates that susceptibility of longkong to CO_2 injury is highest during storage, resulting in longkong becoming darker. Reduction in fruit firmness was significantly ($p<0.05$) effected by storage atmosphere and storage time. A decrease in fruit firmness during storage was observed in all MAP treatments corresponding to fruit softening.

Table 1. Fruit skin colour and firmness of longkong under different modified atmosphere conditions during storage at 18ºC.

Storage time (days)	Ratio of %CO_2:%O_2	Fruit skin colour			Fruit firmness
		Lightness (L*)	Redness (a*)	Yellowness (b*)	Force (g)
0	5:5	64.42±0.46^{a}	5.67±0.14^{g}	34.47±0.34^{a}	1849.3±65.3^{d}
	5:10	64.42±0.46^{a}	5.67±0.14^{g}	34.47±0.34^{a}	1849.3±63.5^{d}
	10:5	64.42±0.46^{a}	5.67±0.14^{g}	34.47±0.34^{a}	1849.3±65.3^{d}
6	5:5	38.76±0.47^{c}	8.44±0.57^{c}	18.30±0.38^{b}	1917.9±32.7^{c}
	5:10	44.56±0.26^{b}	6.20±0.12^{f}	16.62±0.11^{c}	1746.3±41.4^{e}
	10:5	36.51±0.26^{d}	9.58±0.25^{b}	16.41±0.22^{c}	1860.9±28.5^{d}
12	5:5	34.53±0.32^{e}	8.56±0.24^{c}	16.52±0.28^{c}	1748.3±43.2^{e}
	5:10	36.40±0.25^{d}	7.65±0.25^{d}	15.54±027^{d}	2139.8±31.7^{a}
	10:5	33.47±0.29^{f}	9.58±0.24^{b}	15.44±0.16^{d}	2110.5±68.1^{a}
18	5:5	31.06±0.10^{h}	6.34±0.25^{f}	15.68±0.22^{d}	2025.8±58.9^{b}
	5:10	31.58±0.23^{g}	8.51±0.08^{c}	11.46±0.31^{e}	1306.4±15.0^{g}
	10:5	31.58±0.23^{g}	8.51±0.08^{c}	11.46±0.31^{e}	1954.8±34.4^{c}
24	5:5	30.26±0.35^{i}	7.37±0.35^{e}	10.25±0.20^{g}	1246.6±25.7^{g}
	5:10	30.52±0.25^{i}	10.27±0.21^{a}	10.56±0.27^{f}	1119.3±15.9^{i}
	10:5	29.51±0.26^{j}	10.41±0.26^{a}	9.57±0.26^{h}	1638.3±36.1^{f}

Values are given as mean±SD**.** Mean with the same letters in the same column are not significantly different at the $p<0.05$ level.

Table 2. Sugars and titratable acidity (TA) of longkong under different modified atmosphere conditions during storage at 18ºC.

Storage time (days)	Ratio of $\%CO_2:\%O_2$	Sugars (%)			TA (% citric acid)
		Fructose	Glucose	Sucrose	
0	5:5	7.94 ± 0.08^{d}	3.58 ± 0.03^{d}	2.56 ± 0.05^{e}	0.591 ± 0.004^{i}
	5:10	7.94 ± 0.08^{d}	3.58 ± 0.03^{d}	2.56 ± 0.05^{e}	0.591 ± 0.004^{i}
	10:5	7.94 ± 0.08^{d}	3.58 ± 0.03^{d}	2.56 ± 0.05^{e}	0.591 ± 0.004^{i}
6	5:5	7.40 ± 0.02^{f}	3.36 ± 0.05^{e}	3.71 ± 0.04^{a}	0.691 ± 0.001^{e}
	5:10	6.79 ± 0.05^{h}	3.10 ± 0.00^{g}	0.73 ± 0.00^{i}	0.678 ± 0.001^{g}
	10:5	7.13 ± 0.06^{g}	3.20 ± 0.04^{f}	3.62 ± 0.00^{b}	0.682 ± 0.005^{f}
12	5:5	8.83 ± 0.11^{b}	4.02 ± 0.12^{b}	3.42 ± 0.01^{c}	0.589 ± 0.000^{i}
	5:10	4.71 ± 0.02^{kl}	2.14 ± 0.01^{jk}	1.59 ± 0.01^{f}	0.525 ± 0.000^{j}
	10:5	9.48 ± 0.10^{a}	4.25 ± 0.08^{a}	3.10 ± 0.01^{d}	0.513 ± 0.001^{k}
18	5:5	6.34 ± 0.07^{i}	2.82 ± 0.02^{h}	0.24 ± 0.03^{k}	0.654 ± 0.002^{i}
	5:10	8.16 ± 0.04^{c}	3.84 ± 0.05^{c}	0.57 ± 0.02^{j}	0.672 ± 0.000^{h}
	10:5	5.17 ± 0.09^{j}	2.39 ± 0.05^{i}	1.38 ± 0.02^{g}	0.736 ± 0.000^{b}
24	5:5	4.62 ± 0.01^{l}	2.07 ± 0.01^{k}	0.24 ± 0.00^{k}	0.716 ± 0.000^{d}
	5:10	4.75 ± 0.05^{k}	2.20 ± 0.04^{j}	0.01 ± 0.00^{l}	0.731 ± 0.002^{c}
	10:5	7.81 ± 0.06^{e}	3.57 ± 0.01^{d}	1.33 ± 0.00^{h}	0.762±0.009a

Values are given as mean±SD**.** Mean with the same letters in the same column are not significantly different at the $p<0.05$ level.

The decrease of sucrose was observed in all treatments during storage, while fructose and glucose tended to increase during 12 days of storage and decreased till the end of storage (Table 2). Change in sugars were significantly ($p<0.05$) effected by storage atmosphere and storage time. It was found that the reduction of sugars with storage time was caused by oxidation of substrate in the respiration process. At the beginning of the storage time, fructose and glucose tended to increase due to each sucrose molecule probably consisting of glucose and fructose molecules, which convert to produce monosaccharide (glucose and fructose) in order to use this as a substrate for respiration process. The highest fructose and glucose content was observed in the longkong stored under the condition of $5\%CO_2:10\%O_2$. These phenomena could be explained by high rate of product respiration caused by high O_2 concentration. The reduction in the percentage of reducing sugar in fruit is due to the quick consumption of sugars [14]. During 12 days of storage, the reduction of TA ($p<0.05$) in longkong was found in all treatments caused by its use as a substrate in the respiration process. After that, a significantly higher TA ($p<0.05$) was observed in longkong. The results could be explained by an increase in acidity indicating an impaired function of Krebs cycle. When the CO_2 concentration was higher than fruit tolerance, anaerobic metabolism can be induced and the Krebs cycle was shut down, caused by the activity of oxidative enzymes. Therefore, the accumulation of organic acids in fruit cells was observed [15].

Conclusions

Modified atmosphere packaging (MAP) was generally applied to extend longkong shelf-life. However, storage under these conditions, off-flavours which especially affect longkong taste are formed. According to the results obtained, loss of fruit taste was higher with CO_2 concentration increase, as evidenced by increasing of headspace CO_2 with higher ethanol accumulation. Reduction of fruit flavour acceptability was positively correlated with high ethanol accumulation.

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