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Effect of modified atmosphere packaging on the preservation of strawberry and the extension of its shelf-life

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A b s t r a c t. The impact of modified atmosphere packaging (MAP) with low oxygen & high carbon dioxide in combination with ozone and an edible film coating on the preservation of strawberry was studied. A combination of 2.5% O_2 with 15% CO_2 was the optimum gas composition for strawberry MAP, which prolonged the shelf-life of strawberry – compared to storage in the open air – by 4~6 days. When strawberry was pre-treated with a 4.3 mg m^{-3} ozone water dip and an edible coating prior to packaging, the shelf-life was extended to 8~10 days. The results showed that Nos 1 and 2 treatments (No. 1: polyvinyl alcohol 134 (2%); monostearatacylglycerol (0.5%); phytic acid (0.05%); sorbitol (0.05%); sodium alginate (0.1%); absolute alcohol (8%); No. 2: polyvinyl alcohol 134 (1%); soluble starch (1%); glucose (1%); sucrose (1%); sodium alginate (0.1%); sorbitol (0.05%)) had better effects on strawberry as compared with No. 3 and No. 4 treatments, and with C.K (check experiments). The contents of soluble sugar, ascorbic acid, acidity and anthocyanin of Nos 1-4 treatments were obviously superior to C.K. Furthermore, the browning index and the commodity ratio and the permeability of the cell membrane also show the same results.

K e y w o r d s: strawberry, MAP, ozone, edible film, storage

INTRODUCTION

Strawberry (*Fragaria ananassa* Duch.) is a highly perishable fruit, due to respiration, weight loss and fungus. The shelf-life of this produce, when fresh, is limited to 1-2 days at room temperature (Ghuoath *et al*., 1991; Lieten *et al*., 1995; Wills and Kim, 1995; Harker *et al*., 2000). The shelf-life of fresh strawberry is inversely proportional to its respiration rate (Day, 1990). Consequently, the method most commonly used for extending its shelf-life is low temperature. Quality can be further improved by altering the gas atmosphere surrounding the fresh strawberry (Kader *et al*., 1989; Church, 1994; Holcroft and Kader, 1999). The respiration rate of fruits and vegetables usually decreases with increasing CO_2 and/or a decrease in the concentration of O_2 (Kader *et al*., 1989), furthermore, a high CO_2 concentration can inhibit the generation of C_2H_4 because it can destroy the enzyme of C_2H_4, thus the permeability of cell membrane does not increase quickly. MAP is often utilized to maintain elevated CO_2 and reduced O_2 concentrations inside consumer produce containers (Erama *et al*., 1993). However, using MAP technology exclusively is not fully sufficient for fresh strawberry because it can be infected by fungus such as the *Botrytimycosis* and *Rhizopus*. Therefore, it needs pre-treating. It is reported that ozone water can sterilize the fruit and inhibit the growth of mould. In addition, research into preservation by means of edible coatings is a hot topic at present; this utilizes edible chemical ingredients in the storage of fruit and vegetables. After coating, a film is formed on the surface of fresh fruit and vegetables. When the selected parameters are reasonable, it retains both humidity and the modified atmosphere.

The aim of the present work was to evaluate the integrated effects of MAP and ozone and edible film and investigate the change of gas, browning index, ascorbic acid content, acidity, anthocyanin, etc. in order to establish an optimum preservation technology for strawberry.

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MATERIALS AND METHODS

Equipment

The gas supply system for modified atmosphere packaging is shown in Fig. 1. The volume of the precise distribution cylinder was 1 L. The mixing cylinder capacity was 10 L.The system accuracy was ±0.5%.

MAP conditions for strawberry

The strawberry variety used in the tests was the Fengxiang, a widely planted variety in Southern China. Fresh strawberries were picked from a local farm (Suzhou, Jiangsu province, China), then dipped into 4.3 mg m^{-3} ozone water (Shanghai ozone generator, China) for 1 min, respectively. The samples were packaged with 2.5% O_2 + 10% CO_2 according to preliminary trials and stored at 4±0.5°C.

Combination procedure of MAP, ozone and edible film for storing strawberry

The procedure of storage tests for strawberries is shown in Fig. 2. After treating with ozone water, the strawberries were dried with a fan at 25°C for 9 min. After coating with edible films, the strawberries were dried with a fan at 20°C for 20 min. A PVC bag-type packaging material with 48 μm thickness was used for the MAP tests.

For the organoleptic assessment of the strawberries during storage, three grades were set as follows: 1) good -- almost the same as a fresh sample; 2) acceptable -- slightly changed in colour, flavour, taste, shape etc.; 3) rejected -- largely changed in colour, flavour, taste, shape etc.

For the control samples, two contrasts were set up: i) the C.K (check experiments) sample was packaged only with air and stored at 4±0.5°C, ii) the C.K' was stored at room temperature without packaging.

The coating compositions were as follows: 1) No. 1 (1#): polyvinyl alcohol 134 (2%); monostearatacylglycerol (0.5%); phytic acid (0.05%); sorbitol (0.05%); sodium alginate (0.1%); absolute alcohol (8%); 2) No. 2 (2#): polyvinyl alcohol 134 (1%); soluble starch (1%); glucose (1%); sucrose (1%); sodium alginate (0.1%); sorbitol (0.05%); 3) No. 3 (3#): polyvinyl alcohol 134 (1%); chitosan (1%); lithium chloride (0.5); glacial acetic acid (2.5%); sodium benzoate (0.05%); 4) No. 4 (4#): monostearatacylglycerol (2%); soluble starch (2%).

The above substances were mixed together and dissolved in water; the mixture was then heated to boiling point and cooled to 45~55°C. The solution formed can then be coated onto the surface of strawberries.

Quality attributes

1) Browning index: grading method. 0 - no browning change; 1- a spot of browning divergence lines, but no emerging browning; 2 - has obvious browning divergence lines, and an obvious browning ribbon emerges, whose width is smaller than one-fifth of the flesh thickness; 3 - an obvious browning ribbon emerges, whose width is smaller than one-third of the flesh thickness; 4 - has obvious browning, whose width is greater than one-fifth of the flesh thickness.

2) Respiration rate: standing method (Zhang *et al.*, 2001; 2002).

3) Ascorbic acid content: 2.6-dichlorophenol indopenol method.

4) Soluble sugar content: Fehling's test.

5) Acid content: Potentiometric titration. The pH of ultimate titration is 8.10.

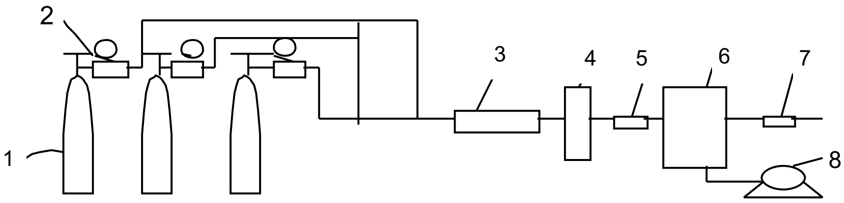

Fig. 1. Gas schemes of modified atmosphere packaging: 1 – gas bottle, 2 – pressure reducing valve, 3 – three-way valve, 4 – precise dosage cylinder, 5 – filling valve, 6 – mixing cylinder, 7 – filling valve, 8 – vacuum pump.

fresh strawberry ⟶ cutting stem ⟶ washing ⟶ dipping in 4.2 mg m^{-3} ozone water for 1min
⟶ air-dried for 9 min ⟶ Nos 1,2,3,4 liquid coating for 30 s ⟶ draining for 20 min
⟶ MAP with 3%O_2+16%CO_2 ⟶ storing at 4±0.5°C

Fig. 2. The procedure of storage tests for strawberries.

6) Anthocyanin content: a discrepancy pH method and then spectrophotometry method (Tibor, 1968).

7) Permeability of cell membranes: The strawberries were cut into pieces of 0.8×0.8×0.4 cm, 10 g samples was weighed then washed with deionized water. After absorbing water, 50 mL of distilled water was added and kept at a constant temperature of 30°C, then the electrical conductivity was determined using a DDS-11A apparatus. The cut strawberries were finally immersed in boiling water for 15 min and the electrical conductivity was determined again. Permeability can be shown by the electrical conductivity ratio of pre-heated and post-heated samples.

8) Rate of commodity: In order to compare the effectiveness of preservation among the stored strawberries, a commodity rate index was adopted in the test according to the local criteria of the production base. The commodity rate was defined as the ratio of the number of strawberries in browning groups grade 0 and 1 and the total number of strawberries stored.

Statistical analysis

The experiments were repeated twice. Since there was no significant difference between the two experiments, the results were pooled and averaged. Data on optimum ozone concentration and multiple assessment for strawberry were treated with MATLAB 5.3 software. Data on the optimum gas composition for strawberry were processed by SAS software.

RESULTS AND DISCUSSIONS

The effects of MAP+Ozone+Coating on preservation

1) Change of gas composition in the package

Since the strawberry is still alive after it is harvested, it also continues its respiration. The change in the gas composition in the MAP package during storage is shown in Fig. 3. From the figure, we can see that the changes in the CO_2 and O_2 concentrations of 1#, 2#, 3# and 4# were small,

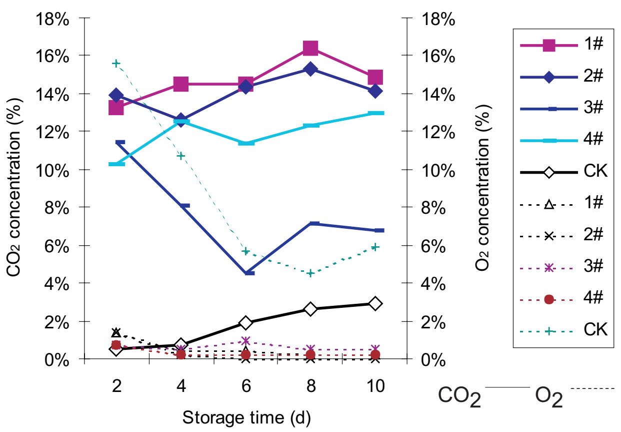

Fig. 3. The change of gas composition in the MAP package.

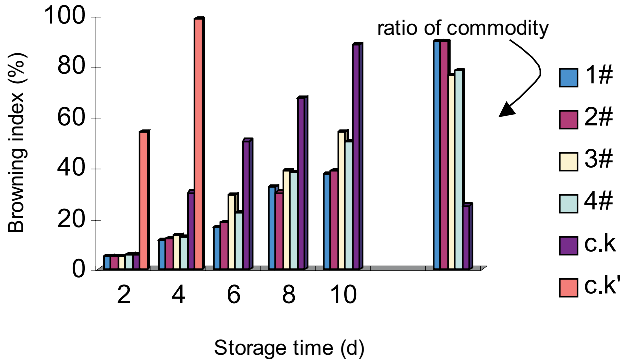

Fig. 4. Effects of MAP and Ozone and Coating on strawberry browning index and ratios of commodity.

while those of C.K were too big. Thus, these treatments could obviously inhibit the respiration of strawberries.

2) Browning index

The browning index is not only a straightforward index of the effects of storage on the strawberry, but it is one of the most important indices as well. It can directly reflect the preservative effect. The effects of MAP and Ozone and Coating on the strawberry browning index and the commodity ratios are shown in Fig. 4. After 4 days, the C.K' strawberries were found to be almost rotten. Furthermore, the browning index of C.K was obviously higher than that of 1#, 2#, 3#, 4# – of the four treatments, the effects of 1# and 2# were satisfactory. The commodity ratios of 1# and 2# reached 90%, while that of C.K was only 33%, which demonstrates that MAP and coating can effectively extend the shelf-life of strawberry.

3) Change in permeability of the cell membranes

With an extension of storage time after harvesting, the integrity of strawberry cells gradually changed so that the permeability of the cells increased. The effects of MAP & Ozone and Coating on the permeability of the cell membranes of strawberries are shown in Fig. 5. Through the treatments of 1#, 2#, 3#, 4#, the ratio of permeability obviously increased, in contrast to the C.K, after eight days. The permeability of 1#, 2#, 3# after 8 days is 62, 57 and 58%, respectively, while that of C.K is 85%; this shows that the treatments of 1#, 2#, 3# can effectively inhibit the increase in permeability and so the shelf-life of strawberry increases.

4) Change of soluble sugar (reducing sugar)

The change of soluble sugar in strawberry during storage periods is shown in Fig. 6. Due to the maturation of strawberry, the sugar content basically increased during the first two days, decreasing thereafter. From the figure, the amount of change of 1# soluble sugar was the smallest, with a level of 40 mg g^{-1} or so.

5) Change in acid content

Acid content is one of the most important factors relating to flavour. The effects of MAP and Ozone and Coating on the acid content of strawberries are shown in Fig. 7.

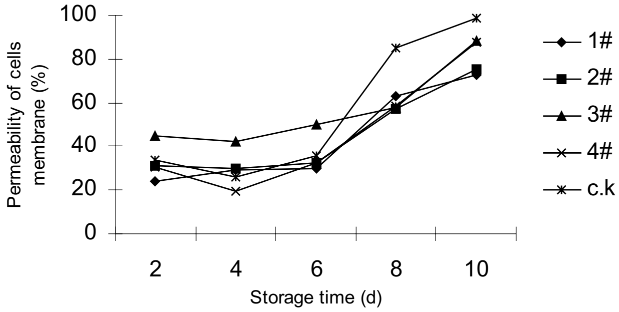

Fig. 5. Effects of MAP and Ozone and Coating on strawberry permeability of cell membranes.

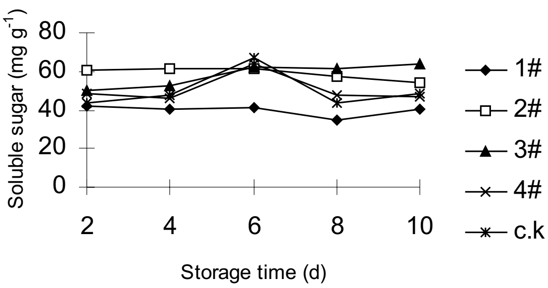

Fig. 6. Effects of MAP and Ozone and Coating on soluble sugar content in strawberries.

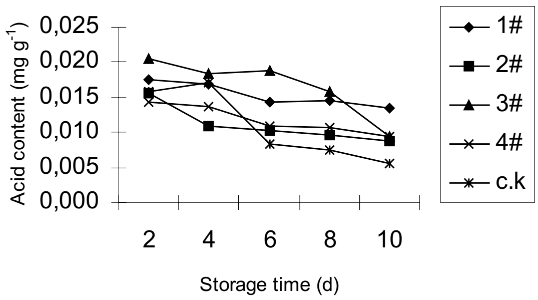

Fig. 7. Effects of MAP and Ozone and Coating on the acid content in strawberries.

With the extension of storage time, the acid content decreased gradually; consequently, the quality of the strawberries decreased. The change in the acid content was relatively higher in 3# and the highest in C.K. However, MAP and Ozone and Coating of 1# and 2# retain the acid content well.

6) Change in Anthocyanin content

As the pigments are broken down and the transmission of the photosynthesis electrons decreases, the change in the content of anthocyanin is often considered to be one of the indices of aging. The effects of MAP and Ozone and Coating on the content of anthocynin in strawberries are shown in Fig. 8. From the figure, it can be seen that the anthocyanin content decreased continuously. The decrease of anthocyanin can be effectively delayed through the treatment with MAP+Ozone+Coating. Of all the different treatments, the effects of 1# and 2# were the best, while 3# and C.K were the worst.

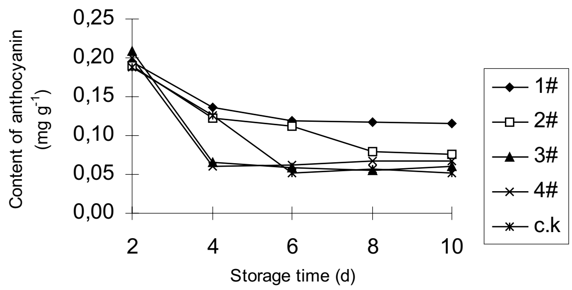

Fig. 8. Effects of MAP and Ozone and Coating on strawberry anthocyanin content.

Organoleptic analysis

The organoleptic analysis of strawberries during storage periods is as shown in Table 1. From the table, it is found that storage time of strawberries after 1# and 2# treatment can be extended to 8-10 days, compared with only 2-4 days' storage time for C.K and C.K'.

CONCLUSIONS

1) The optimum concentration of ozone for strawberry was 4.3 mg m^{-3}.

2) The best coating ingredient was 1# and 2# (1#: polyvinyl alcohol 134 (2%), monostearatacylglycerol (0.5%), phytic acid (0.05%), sorbitol (0.05%); sodium alginate (0.1%); absolute alcohol (8%); 2#: polyvinyl alcohol 134 (1%), soluble starch (1%); glucose (1%); sucrose (1%); sodium alginate (0.1%), sorbitol (0.05%)).

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APPENDIX

The optimum concentration of ozone for strawberry in storage

1) Determination of the optimum ozone concentration and MAP conditions for strawberry

The strawberry test variety was the Fengxiang, a variety widely planted in Southern China. Fresh strawberries were

T a b l e 1. Organoleptic analysis of strawberries during storage periods

Coating treatment number		Storage time (days)				
		2	4	6	8	10
1	Colour	Almost the same of fresh sample	Slightly changed	Slightly changed	Slightly changed	Changed
	Taste	"	"	"	"	Slightly changed
2	Colour	"	Almost the same of fresh sample	"	"	"
	Taste	"	"	"	"	"
3	Colour	"	Slightly changed	"	"	Changed
	Taste	"	"	"	"	"
4	Colour	"	"	"	"	"
	Taste	"	"	"	"	"
C.K	Colour	Slightly changed		Changed	Changed	"
	Taste	Slightly changed, acidic	Almost changed	"	"	"
C.K'	Colour	Slightly changed changed	Rotten			
	Taste	Changed, some alcohol flavour	"			

picked from a local farm (Suzhou, Jiangsu province, China), then dipped into 0, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0 mg m^{-3} ozone water (Shanghai Ozone generator, China) for 1 min, respectively. The samples were packaged with 2.5% O_2 + 10% CO_2 according to preliminary trial and stored at 4°C.

2) Establishment of multiple assessments for the storage of strawberries

As all the storage parameters are not equally important to strawberry preservation, we should set up the importance distributed collection of each storage parameter's weight which is responsible for the balance of each storage parameter. For the purposes of this study, we selected 20 experts – who had been engaged in the field of fruit and vegetable storage for more than one year – to judge the importance of the effects of storage on the browning index, respiration, ascorbic acid content, the soluble sugar content and the acid content of strawberry:

$$a_1= [0.9,0.1,0.0,0.0,0.0];\ a_2= [0.6,0.3,0.1,0.1,0.0];$$

$$a_3= [0.7,0.25,0.2,0,0.05];\ a_4= [0.5,0.2,0.1,0.1,0.1];$$

$$a_5= [0.4,0.2,0.2,0.1,0.1]$$

where: a_1, a_2, a_3, a_4 and a_5 represent the importance of the browning index, respiration, ascorbic acid content, sugar content, and acid content, respectively. According to some experts' analysis, the performance of browning index, respiration, vitamin C content, sugar content and acid content account for 30, 20, 20, 10 and 10% respectively. Therefore, the multiple storage assessment for strawberry storage is:

$$b = (0.3, 0.2, 0.2, 0.1, 0.1)\ (a_1,a_2,a_3,a_4,a_5) =$$

$$(0.58, 0.18, 0.08, 0.03, 0.03) \quad \text{(A-1)}.$$

The synthetic index of quality 'b' is very useful as an exclusive index in the optimization of parameters.

3) The optimum concentration of ozone for strawberry storage

For optimizing the concentration of ozone for strawberry, the multiple assessments mentioned above have to be used for the index of the tests. The result is shown in Table A-1. In each index, the first column is the caculated value (No. unit).The second column is the first column subjection function calculation value (no unit), namely for: $Y= (x- x_{min})/(x_{max}- x_{min})$ or $y=1- (x- x_{min})/(x_{max}- x_{min})$, through the treatment, it can clearly know the testing result of each index, then multiply by the heavy and then can be synthesized to evaluate the index. From the table, an ozone concentration curve fitted and optimum ozone concentration were obtained as shown in Fig. A-1. It can be seen that the optimum concentration of ozone for preserving strawberries was 4.3 mg m^{-3}.

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Table A-1. Assessment of synthetic index for strawberry storage

Ozone concen-tration (mg m^{-3})	Browning index (a_1)		Respiration (a_2)		Ascorbic acid (a_3)		Soluble sugar content (a_4)		Acid content (a_5)		Synthetic index(b)
	calcu-lated	y	calcu-lated	y	calcu-lated	y	calcu-lated	y	calcu-lated	y	Calculated by (A-1)
0	2.236	0.000	0.522	0.000	65.444	0.000	5.822	0.447	0.243	0.004	0.014
1.0	1.600	0.279	0.431	0.446	75.822	0.981	6.082	0.602	0.262	0.365	0.447
2.0	1.923	0.000	0.506	0.000	66.796	0.000	5.080	0.000	0.242	0.000	0.449
3.0	1.313	0.527	0.362	0.855	66.930	0.014	6.742	1.000	0.246	0.070	0.563
4.0	1.000	0.797	0.378	0.760	75.997	1.000	5.996	0.551	0.258	0.292	0.733
5.0	1.000	0.797	0.338	1.000	68.212	0.154	6.006	0.557	0.280	0.714	0.726
6.0	0.765	1.000	0.389	0.691	66.962	0.018	6.081	0.602	0.295	1.000	0.769

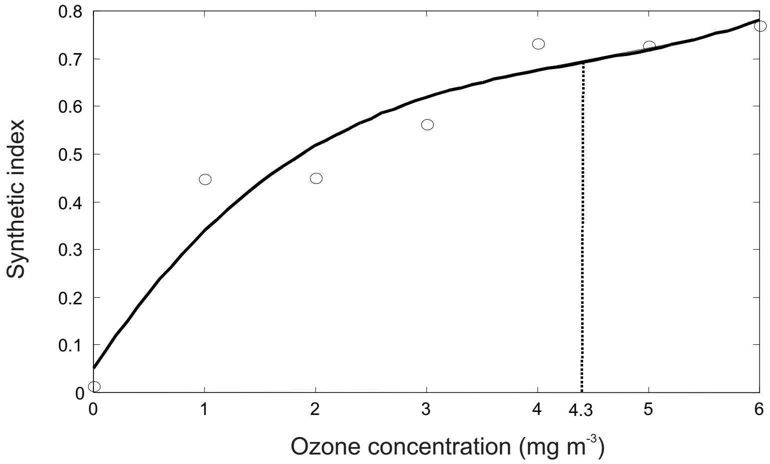

Fig. A-1. The ozone concentration curve fitted and the optimum ozone concentration.

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