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Effects of modified atmosphere package on preservation of strawberries

M. Zhang[1]*, *G. Xiao*[1], *J. Peng*[1], *and V.M. Salokhe*[2]

[1]School of Food Science and Technology, Southern Yangzte University, 214036 Wuxi, China
[2]Agriculture, Aquatic Systems and Engineering Program, Asian Institute of Technology, Pathumthani 12120, Thailand

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A b s t r a c t. Effects of Modified Atmosphere Package (MAP) on the preservation of strawberries was studied in this experiment. The results show that the optimum gas composition of MAP tests for strawberry was 2.5% O_2+16% CO_2. The composite membrane of LDPE & PVC was superior to single LDPE and PVC membranes. The storage tests show that MAP could inhibit the respiration and weight loss of strawberries. Furthermore, it also can retard soluble sugars, titrable acidity and anthocyanin decrease. In addition, the dynamic change of gas composition in package was studied.

K e y w o r d s: modified atmosphere package, strawberry, preservation

INTRODUCTION

Strawberry (*Fragaria ananassa* Duch.) is a highly perishable fruits due to high respiration, weight loss and fungus attack. The shelf-life of fresh produce 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 respiration rate (Day, 1990). Consequently, the most commonly used method for shelf-life extension is low temperature. But storage quality can be further improved by altering the gas atmosphere surrounding the fresh strawberry (Church,1994; Holcroft and Kader,1999). The respiration rate of fruits and vegetables usually decreases with increasing CO_2 and/or decreasing O_2 concentration (Holcroft amd Kader, 1999). Furthermore, high CO_2 concentration can inhibit the generation of C_2H_4 because it can influence the enzyme's activity, thus the permeability of cells membrane does not increase quickly. MAP is often used to maintain elevated CO_2 and reduced O_2 concentrations inside consumer-packaged produce containers (Exama *et al*., 1993).

The aim of the present work was to evaluate the effects of MAP on respiration rate, browning index, acidity, anthocyanin content, etc. Based on this study, an optimum MAP technology for strawberry can be attained.

MATERIALS AND METHODS

Equipment

The gas system for modified atmosphere package is shown in Fig. 1. The volume of precise cylinder is 1 l.The mixing cylinder is 10 l.The system accuracy is ±0.5%. A DDS-11A Type Electrical Conductivity Measuring Apparatus was used for determining the permeability of strawberry. The vacuum pressure used was 0.1 MPa.

Determination of optimum gas composition for strawberry

The testing variety of strawberry was Fengxiang, a widely planted variety in Southern China. Strawberries were picked directly from a local farm (Suzhou, Jiangsu province, China), which did not receive any postharvest treatment.

In order to attain the optimum gas composition for strawberry, two elements and quadratic orthogonal combination design were adopted (Wu, 2002).

Suppose that y is the comprehensive assessing index related to browning change during strawberry storage:

$$y = b_0 + b_1 x_1 + b_2 x_2 + b_{12} x_1 x_2 + b_{11} x_1{}^2 + b_{22} x_2{}^2 \quad (1)$$

Where $b_0, b_1, b_2, b_{12}, b_{11}, b_{22}$, are coefficients of the Eq. (2), x_1 and x_2 are the codes of 2 levels. There exists the following transformation:

$$x_1 = \frac{z_1 - 4}{2} \qquad x_2 = \frac{z_2 - 12}{10}, \qquad (2)$$

*Corresponding author's e-mail: min@sytu.edu.cn

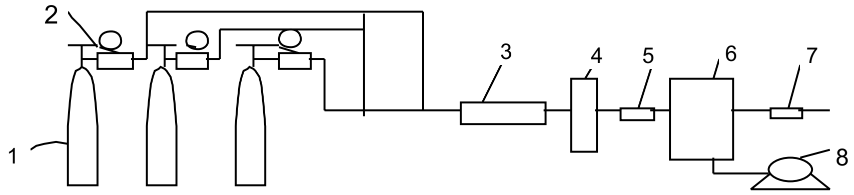


Fig. 1. Gas schemes of modified atmosphere package: 1 – gas bottle, 2 – pressure decreasing valve, 3 – three way valve, 4 – precise cylinder, 5 – filling valve, 6 – mixing cylinder, 7 – filling valve, 8 – vacuum pump.

where z_1 represents the O_2 concentration (2~6%), z_2 is the CO_2 concentration (2~22%). Three levels were chosen for z_1 (2,4,6) and z_2 (2,12,22).

Table 1 was the experimental design of optimum gas composition for strawberry. Except gas composition, the other storage conditions were the same as previously mentioned.

In order to compare the effectiveness of preservation among the stored strawberries, an index of commodity rate was adopted in the test. The rate of commodity was defined as the ratio of the number of strawberries in groups of browning grade 0 and 1 and the number of total stored strawberries.

T a b l e 1. Experimental design of optimum gas composition for strawberry

Element	Number								
	1	2	3	4	5	6	7	8	9
$x_1(O_2)$	1(6%)	1(6%)	–1(2%)	–1(2%)	1(6%)	–1(2%)	0(4%)	0(4%)	0(4%)
$x_2(CO_2)$	1(22%)	–1(2%)	1(22%)	–1(2%)	0(12%)	0(12%)	1(22%)	–1(2%)	0(12%)

Procedure for package and storage

Strawberries were sorted by size and appearance. Diseased, damaged and extremely large or small ones were discarded. Acceptable strawberries were selected at random and sixteen to twenty strawberries were placed into a LDPE & PVC package (25×36 cm size). After the initial gas composition, 2.5% O_2 and 16% CO_2, was drawn into packages, then it was stored at 6°C. Two control samples were set up: i) C.K (check experiments) was packaged only with air and stored at 6°C, ii) C.K' was without packaging and stored at 6°C.

The experiments were repeated twice. Samples were picked up every other day and evaluated in terms of several physicochemical qualities as detailed below. The ripeness of selected strawberries suitable for the tests was strictly controlled according to good texture and bright red color.

Browning index was determined organoleptically as follows: 0 – no browning change; 1 – a spot of browning divergence lines, but doesn't emerging browning; 2 – obvious browning divergence lines, and emerging obvious browning ribbon, whose width is smaller than one-fifth of fruit flesh; 3 – emerging obvious browning ribbon, whose width is smaller than one-third of fruit flesh; 4 – obvious browning, whose width is larger than one-fifth of fruit flesh.

Weight loss was calculated according to weights of each package before and after storage (Zhang, 2001; Zhang, 2002). Weight loss was expressed as a percentage of the initial weight of strawberries. Respiration rate was measured using a standard method, which uses NaOH to titrate to calculate released CO_2 concentration. A traditional method, Fehling's Test (Zhang, 1999), was adopted for measuring the change of reducing sugar content. Titrable acidity was expressed as percentage of malic acid. The pH value used in acid determination was measured by pH-meter. Anthocyanin content was measured by spectrophotometry method.

The permeability was measured by the electrical conductivity ratio of pre-heated and post-heated samples. The term permeability of cell membrane was defined as the rate of pre-heated sample's electrical conductivity ratio and post-heated sample's electrical conductivity ratio. The procedure is as follows. Firstly, strawberry samples of 10 g were cut into pieces of 0.8×0.8×0.4 cm size, then washed in deionized water. After absorbing water, 50 ml distilled water was added and kept at constant temperature of 30°C for 10 min, then the electrical conductivity was determined by a DDS-11A measuring apparatus. At last, the specimen was dipped into boiling water for 15 min and then the electrical conductivity was determined again.

Statistical analysis

The tests were repeated twice. Since there was no significant difference between the two experiments, the results were pooled and averaged. Data on the optimum gas composition for strawberry were processed by SAS'RSREG software.

RESULTS AND DISCUSSION

Effects of MAP on storage of strawberry

Weight loss

Part of respiration and transpiration of a fresh produce can be expressed by the change of its weight loss (Zhang, 2001). Weight loss will take place with the extension of storage time. The result during MAP storage is shown in Table 2. Overall, weight loss was greater in C.K and C.K'. It showed that modified atmosphere could inhibit water transpiration. Therefore, it can extend the shelf-life of strawberry.

Respiration rate

The respiration of strawberries was obviously increased after harvest (Fig. 2), which was intensely related with the biological reactions. Therefore, it can affect the quality of strawberries during the storage periods. The results showed the respiration was inhibited to a different extent after packaging. Contrasting with C.K and C.K', the effect of modified atmosphere was the best, whose changing amplitude was the smallest.

Reducing sugars

The change of reducing sugar of strawberry during the storage periods was shown in Fig. 3. Due to the maturation of strawberry, the sugar content was basically rising during the first two days (from 47.68 to 52.36 mg g^{-1}), then it decreased. From the figure, the changing amplitude of reducing sugar in MAP treatment was the smallest, keeping at the level of 50 mg g^{-1} or so.

Acid content

The acid content is one of the important factors which determine the flavour. With the extension of storage time, the acid content decreased gradually (Fig. 4). Consequently, the quality of strawberries decreased. The change in acid content was relatively higher in C.K and C.K'. It means the MAP treatment can keep the flavour retained. The mechanism is that low oxygen and high carbon dioxide can inhibit the activity of some enzymes, therefore, it can retard organic acid degradation.

The change of permeability of cells membrane

With the extension of storage time, the cell integrality of strawberries was gradually changing so that the permeability of cells increased (Zhang, 1999). Through the treatments of MAP, the ratio of permeability obviously retarded contrasted with the C.K and C.K' after five days (Fig. 5). The

Table 2. Effects MAP treatments (LDPE & PVC composite membrane) on the weight loss

Storage time (d)	2	3	4	5	6	7
MAP treatments	0.2164	0.6141	0.6238	1.3168	1.5676	2.2543
C.K	0.2669	0.5103	1.7853	2.2150	2.8821	3.3568
C.K'	1.2832	2.6136	3.2650	8.2231	12.2821	24.5699

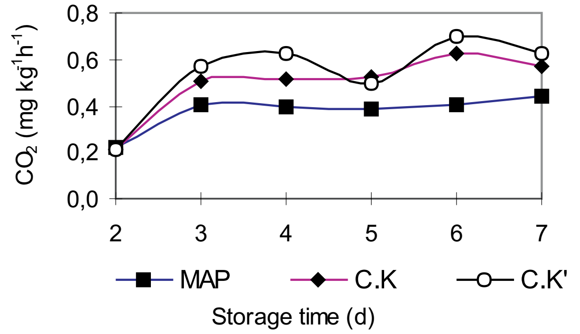


Fig. 2. Effects of MAP (LDPE & PVC composite membrane) on the respiration of strawberry.

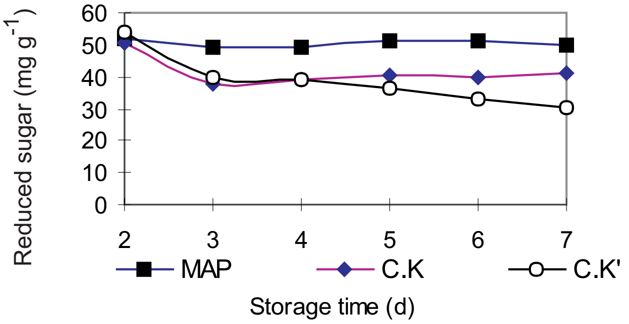


Fig. 3. Effects of MAP (LDPE & PVC composite membrane) on the reducing sugar content of strawberry.

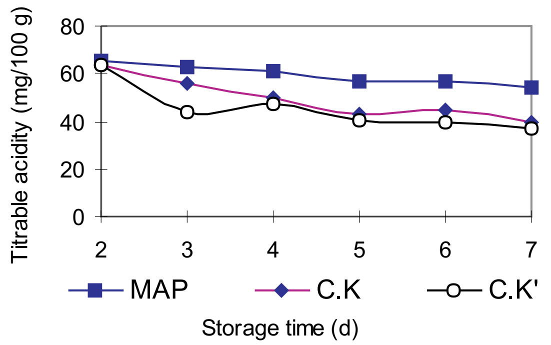


Fig. 4. Effects of MAP (LDPE & PVC composite membrane) on the acidity content of strawberry.

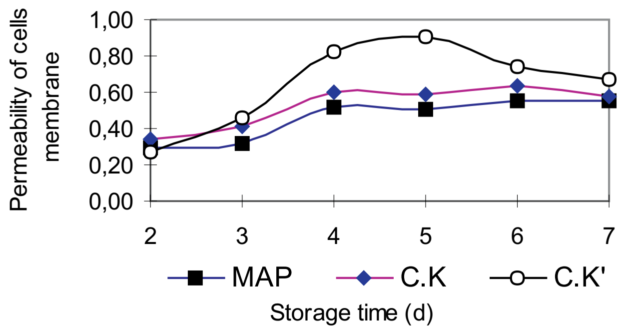


Fig. 5. Effects of MAP (LDPE & PVC composite membrane) on permeability of cells membrane of strawberry.

results showed that the treatments of MAP can effectively inhibit the permeability increasing. Therefore, the shelf-life of strawberry was increased accordingly.

Anthocyanin content

As the pigments are broken during the storage, the change of anthocyanin content is often considered as one of the indices of aging. From Fig. 6, it can be seen that the anthocyanin content was continuously decreasing during storage. Through the treatments of MAP, the trend of anthocyanin decrease can be effectively improved.

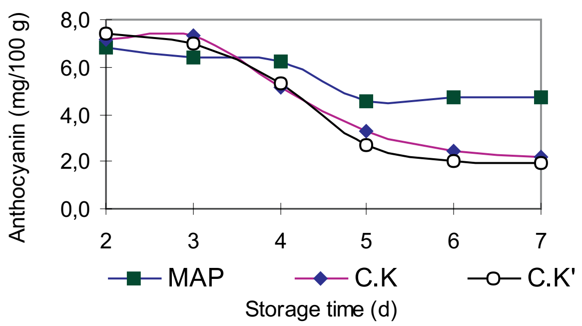


Fig. 6. Effects of MAP (LDPE & PVC composite membrane) on the anthocyanin content of strawberry.

The optimum gas composition for strawberry

According to the experiment design of optimum gas composition for strawberry (Table 1), the optimum results were shown in Table 3.

Therefore, according to calculation, the regression equation was:

$$y = 0.616 - 0.05x_1 - 0.103x_2 + 0.004x_1x_2 - 0.029x_1^2 + 0.186x_2^2 \quad (3)$$

For assessing significance of the regression equations:

$$L_{yy} = 5.059 - 9\cdot 0.721^2 = 0.380, \quad (4)$$

$$U = b_1 l_{x1y} + b_2 l_{x2y} + b_{12} l_{x1x2y} + b_{11} l_{x1'y} + b_{22} l_{x2'y} = 0.401, \quad (5)$$

$$R = \sqrt{\frac{U}{L_{yy}}} = 0.973 \quad (6)$$

where L_{yy} is dispersion quadratic sum, U is regression sum of squares; R is diphase correlation coefficient.

When α=0.05, N_1=5, N_2=3, look F distribution table, F_α=9.01, $R_\alpha = \sqrt{\frac{5F\alpha}{3+5F\alpha}} = 0.968$, due to $R>R_\alpha$, so the effect of regression is very significant.

Solving the Eq. (3), the optimum parameters were x_1=–0.840, x_2=0.285.

According to the Eq. (2), the related optimum O_2 composition z_1=2.32; the related optimum CO_2 composition z_2=15.85.

Therefore, 2.5% O_2+16% CO_2 used in the tests can effectively inhibit strawberry's browning.

Effects of different packaging materials to the storage of strawberry

In this paper, three packaging materials were used: I) LDPE, II) PVC, III) LDPE and PVC composite polymer. After inflating with 2.5% O_2 and 16% CO_2, the strawberries were stored at 6°C in order to understand the shelf life of strawberry in cooled shelf in supermarket. The results are shown in Fig. 7.

Due to the permeability of the high molecular polymer is different, how to control the gas composition and relatively humidity in-package is very important for the storage tests of strawberry. In order to adjust O_2 and CO_2 concentration in-package, it needs to select different packaging

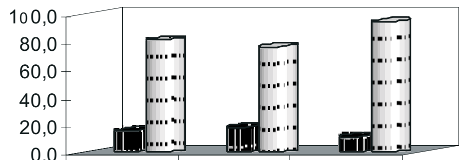
T a b l e 3. The testing results of optimum gas composition for strawberry

No.	x_1'	x_2'	y	x_1y	x_2y	x_1x_2y	x_1'y	x_2'y	yy
1	0.333	0.333	0.625	0.625	0.625	0.625	0.208	0.208	0.391
2	0.333	0.333	0.911	0.911	–0.911	–0.911	0.304	0.304	0.830
3	0.333	0.333	0.521	–0.521	0.521	–0.521	0.174	0.174	0.272
4	0.333	0.333	0.822	–0.822	–0.822	0.822	0.274	0.274	0.676
5	0.333	–0.667	0.446	0.446	0.000	0.000	0.149	–0.297	0.199
6	0.333	–0.667	0.939	–0.939	0.000	0.000	0.313	–0.626	0.881
7	–0.667	0.333	0.892	0.000	0.892	0.000	–0.595	0.297	0.796
8	–0.667	0.333	0.922	0.000	–0.922	0.000	–0.614	0.307	0.849
9	–0.667	–0.667	0.406	0.000	0.000	0.000	–0.271	–0.271	0.165
Σ			6.485	–0.300	–0.616	0.015	–0.058	0.371	5.059

materials for storage. The results (Fig. 7) showed that the browning index and commodity rate of LDPE & PVC was obviously superior to that of single PVC and LDPE.

Gas change in the package

Since strawberry is still alive after harvest, it also respires. It is necessary to achieve proper gas composition in the package, so it is very important to study the gas change in the package of MAP. In order to understand the shelf life of strawberry in cooled shelf in supermarket, the strawberries were stored at 6°C. The results (Fig. 8) show that O_2 concentration was quickly rising while CO_2 concentration decreased at first 12 h, which may be resulted by the difference concentration between in-package and out-package. Then, with the extension of storage time, because of respiration, the O_2 concentration decreased while CO_2 concentration risen. After 18 h, the change of O_2 and CO_2 was very small, which manifested the gas reaching a balance. It can also reflect that MAP can inhibit respiration of strawberry.



	LDPE	PVC	LDPE&PVC
browning index	15,63	18,23	11,22
ratio of commodity	81,22	76,24	94,62

Fig. 7. Effects of different packaging materials to the storage of strawberry.

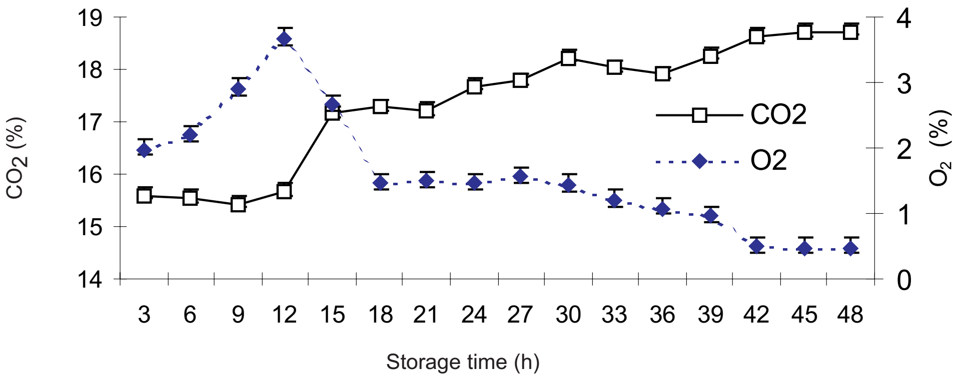


Fig. 8. Change of gas composition in-package during storage (LDPE & PVC composite membrane). The related conditions as follows: 1) thickness of the composite membrane – 28 mm, 2) stored temperature – 6°C, 3) at atmosphere.

CONCLUSIONS

1. The optimum gas composition of MAP for strawberry is 2.5% O_2 + 16% CO_2.
2. The composite membrane of LDPE and PVC is superior to the membrane of LDPE and PVC, which can effectively control the gas and humidity change in-package.

3. The shelf-life of strawberry after harvest can be extended to 4~6 days by MAP treatments. Therefore, this technology is very promising.

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