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Effects of combined hypobaric and atmosphere cold storage on the preservation of honey peach**

Li Wen-xiang[1,2] *and Zhang Min*[2]*

[1]Key Laboratory of Food Science and Safety, Ministry of Education, Southern Yangtze University, 214036 Wuxi, China
[2]School of Food Science and Technology, Southern Yangtze University, 214036 Wuxi, China

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A b s t r a c t. The physiological and biochemical changes of honey peach were investigated under combined hypobaric and atmosphere cold storage conditions. The freshness of honey peach was improved ($P \leq 0.05$) using hypobaric treatment over one week, but was not bettered when the hypobaric treatment time was shorter than 4 days, as compared with atmosphere cold storage. The best preservation effect was obtained by utilization of the sequential combination of hypobaric storage respectively at 10-20 kPa, 2±2°C for one week, at 20-30 kPa, 2±2°C for one week, and atmosphere cold storage.

K e y w o r d s: honey peach, preservation, hypobaric storage, atmosphere cold storage

INTRODUCTION

Peach is one of the four major local fruits in China. According to FAO statistics, the total planting area of peach in China was 908 000 ha in 2000 (51.9% of the total peach planting area of the world) and the yield was 3 830 000 t (28.5% of the total yield of the world). Both the planting area and outputs of peach in China, therefore, are the highest in the world (Wang and Wang, 2002; Zhang *et al*., 2001). The honey peach of Wuxi city in China is famous for its tender tissue, thin peel, abundant juice, high nutrient contents and special flavour. However, because of the tender tissue of cell wall and the fact that it was harvested in a high temperature and humidity season, the honey peach can easily be putrefied (Ma, 2003; Min *et al*., 2002). Therefore, there is a great necessity to develop effective preservation means of honey peach.

*Corresponding author's e-mail: min@sytu.edu.cn
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Previous studies on the storage of honey peach were focused on natural atmosphere cold storage (Fernadez-Trujillo *et al*., 1998c; Valers *et al*., 1997), modified atmosphere storage and controlled atmosphere storage (Aradhya, 1998; Bonghi, 1999; Fernadez-Trujillo *et al*., 1998a; Fernadez-Trujillo *et al*., 1998b; Zhang and Xiao, 2003), edible coatings (Cheng *et al*., 1996; Du *et al*., 1997), intermittent warming (Fernadez-Trujillo and Artes, 1997; Sung-bok *et al*., 1998;) and preservation chemicals (Bi *et al*., 1986; Yang, 1997), *etc*., but no researches have been reported on the hypobaric storage of the honey peach.

Hypobaric storage, also called vacuum storage or low-pressure storage, is an emerging storage technique based on cold storage. Lowering atmosphere pressure in a closed chamber is used to keep vegetables or fruits fresh (Liu, 2003). This can quickly remove the heat, reduce the oxygen level, and expel the harmful gas. The purpose of this study is to provide theoretical basis concerning the combination of vacuum cold storage and natural atmosphere cold storage, and to develop a new kind of practical storage technique.

MATERIAL AND METHODS

The scheme of the ZB-1.5M^3 hypobaric storage house used for the investigations is shown in Fig. 1.

Honey peach species named 'Zhaoyang' was obtained from the Department of Agriculture, Huishan District, Wuxi, China. The specifications of the peaches were: maturity degree of 80-90% (turning stage to red stage), average weight of 180 g or so per fruit, average hardness of 13.8×10^5Pa, and soluble solids content of 10.5%. The fruits were picked early in the morning, wrapped with PE foam bags, put in cardboard boxes, and immediately sent to the laboratory.

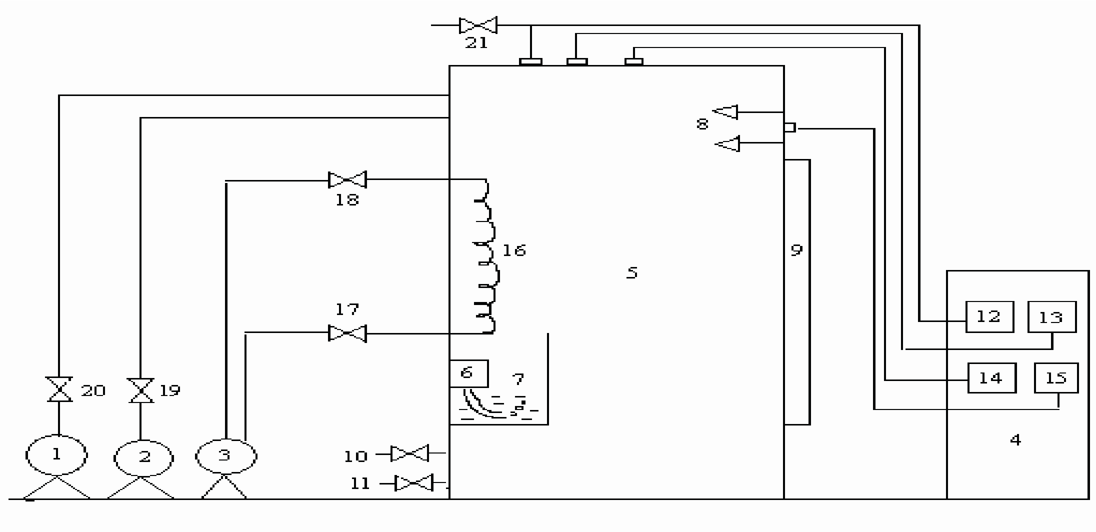

Fig. 1. Schematic diagram of the hypobaric house (Qihong Refrigeration Equipment Ltd., Wuxi, China): 1 - vacuum pump, 2 - pressure controller of moistener, 3 - compressor, 4 - automatic control panel, 5 - storage chamber, 6 - ozone disinfection device, 7 - cold water trough, 8 - spray nozzle, 9 - airtight door, 10 - vent valve, 11 - drain valve, 12 - vacuum pressure indicator and controller, 13 - ozone disinfection controller, 14 - temperature indicator and controller, 15 - relative humidity indicator and controller, 16 - evaporator, 17 - control valve, 18 - cather valve, 19 - pressure regulation valve, 20 - pressure regulation valve, 21 - bleed valve.

The honey peach was pretreated with seven different vacuum pressures (Table 1) over varying periods, and then subjected to natural atmosphere cold storage at 2±2°C. Samples were taken and analyzed every 5 days during the storage period. Each treatment was repeated twice and the corresponding test results were averaged. The experiment was continued until the fruits completely lost commercial value.

Weight loss was calculated by dividing the difference between the weight of the test sample (Ws) and that of the starting material (Wo) by Wo, and expressed in percentage (Yang and Zhang, 2000). The static-measuring method under room temperature (28±3°C) was adopted. Eight peach fruits were taken randomly and put into an airtight desiccator (inside diameter 260 mm) along with 10 ml 0.4N NaOH in a Petri-dish after weighing. The Petri-dish was taken out and titrated with 0.2 N oxalic acid ($C_2H_2O_4$) after 30 min. The volume of oxalic acid consumed was used to calculate the respiratory intensity (Yang and Zhang, 2000).

About 10 g (±0.01 g) of edible parts of six peach tissues were taken randomly and homogenized with 100 ml of 2% oxalic acid, and then centrifuged for 10 min at 13 000×g at 4°C. The vitamin C content in the supernatant was determined by the 2, 6-dichlorphenolindophenol sodium salt method (Yang and Zhang, 2000). About 10 g (±0.01 g) of edible parts of six peach tissues were taken randomly and mixed with 0.5 g sea sand, and homogenized in a mortar along with an addition of small amounts of distilled water. The whole homogenate was brought to the volume of 100 ml with distilled water and centrifuged at 6 000×g for 15 min. The titratable acidity in the supernatant was determined with 0.1 N NaOH (Yang and Zhang, 2000). The hardness of peach fruits was measured with a GY-1 type fruit hardometer. Three peach fruits were taken randomly; six replications were carried out for each peach. The results were averaged and expressed in $\times 10^5$k Pa (Yang and Zhang, 2000). About 20 g (±0.01 g) of edible parts of six peaches was taken randomly, mixed, and homogenized in a mortar. The

Table 1. Vacuum pressure/temperature/time at the hypobaric storage of honey peach

Treatment	Pressure/temperature/ storage time at hypobaric storage
A	Control (under atmosphere conditions)
B	10-20 kPa /2±2°C /24 h
C	10-20 kPa /2±2°C /4 days
D	10-20 kPa /2±2°C /7 days
E	10-20 kPa /2±2°C /7 days, then 20-30 kPa /3 days
F	10-20 kPa /2±2°C /7 days, then 20-30 kPa /7 days
G	10-20 kPa /2±2°C /7 days, then 20-30 kPa /until the end of experiment

T a b l e 2. Evaluation standard of honey peach

Scores	Freshness	Taste and flovour	Colour	Texture
8	Fresh and lustrous	Excellent fragrance and sweetness	Normal colour of matured fruits	Rich juice, tight and hard tissue
6	Fresh, and slightly lustrous	Good fragrance and moderate sweetness	Basically normal colour of matured fruits	Rich juice, a little loose and soft tissue
4	Slight water loss and dim luster	Light fragrance and low sweetness	Slight browning near the peach-pit or epidermises	Little juice, much loose and fairly soft tissue
2	Slight epidermis shrinking, complete luster loss	Weak abnormal odour	Obvious browning near the peach-pit or epidermises	Rare juice, soft tissue
0	Wilt and bad epidermis	Heavy abnormal odour	Serious browning near the peach-pit or epidermises	No juice, extremely soft tissue

mixture was subjected to filtration with a cellulose nitrate membrane filter (pore size 1 μm), and the soluble solid content of was determined on a WAY refractometer (Yang and Zhang, 2000). Four indexes (Table 2), *ie* freshness, taste and flavour, colour, and texture, were used to evaluate the sensory quality of honey peaches in the middle (14th day) and at the end of storage (30th day) (Yang, 1997).

The experimental design was completely randomized . Each test was repeated twice and the results were averaged. Data analysis was performed using the SAS statistical software package.

RESULTS AND DISCUSSIONS

The sensory quality of group B and C was found to be basically the same as group A. Nevertheless, groups D, E, F and G were significantly superior to group A in terms of taste, colour, and texture. Although group G was also good with regard to all four sensory attributes except freshness, it showed excessive water loss. Therefore, group F demonstrated the best preservation effects and was preferred in this experiment (Table 3).

The fruit hardness declined along with the extension of storage time showing a ‘first quick, and then slow’ decreasing trend. The decline of hardness under treatment B and C was not significant compared with treatment A. By contrast, the hardness under treatment D, E, and F declined more slowly than in treatment A ($P \leq 0.05$) during the storage period ranging between 5th-20th day, while treatment G declined more slowly than treatment A ($P \leq 0.05$) over the whole storage time. Therefore, hypobaric treatment was of significant benefit for the maintenance of fruit hardness (Fig. 2).

An earlier study (Orr and Brady, 1993) had indicated that the course of peach ripening could be divided into two typical phases, namely, slow softening phase in the earlier period and quick hardness losing phase in the latter period.

T a b l e 3. Assessment of sensory attributes of honey peaches in the course of hypobaric and subsequent atmosphere cold storage

Treatment	Freshness		Taste and flavour		Colour		Texture	
	(day)							
	14th	30th	14th	30th	14th	30th	14th	30th
A	8	6	8	4	8	5	6	1
B	8	6	8	4	8	5	6	1
C	8	6	8	4	8	5	6	2
D	7	5	8	5	8	6	7	4
E	7	5	8	6	8	7	8	5
F	6	5	8	7	8	8	8	6
G	4	2	8	6	8	8	8	6

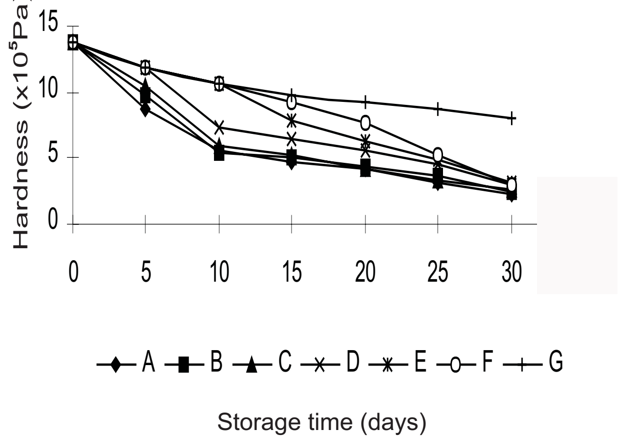

Fig. 2. The change of fruit hardness in the course of hypobaric and subsequent atmosphere cold storage.

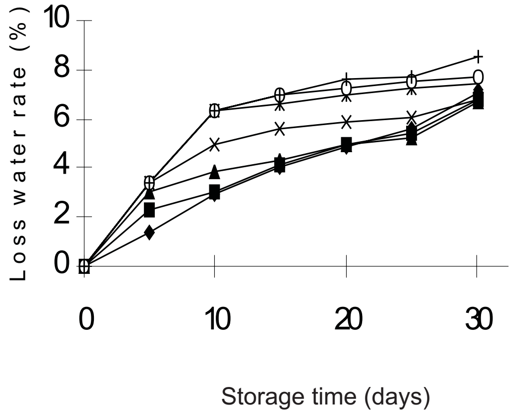

Fig. 3. The change of water loss rate in the course of hypobaric and subsequent atmosphere cold storage. Explanations as in Fig. 2.

The hardness declining of the honey peach used in this experiment, however, showed a 'first quick then slow' tendency. This could be mainly due to the difference of peach species and hardness measuring method. On the one hand, a species of fruits might have specific ripening courses; on the other hand, fruit hardness was usually measured without peel while in this experiment the hardness of wholesome peaches was determined. Because the honey peach used in this study is a soft tissue fruit that softens quickly after harvest, its hardness is not measurable on the third storage day in the ambient environment, and so was the case when it was stored for two weeks under atmosphere cold conditions. For this reason, the peach hardness was measured with peel, thus a great variance in the results exists as compared with that in the peeled state, but the changing tendency of hardness should be in rough similarity.

The changes of weight loss, as characterized by the water loss rate, increased with the extension of storage time. The water loss rate of group B, C, D was higher as compared with group A, respectively in the first 10, 15, and 25 days, and thereafter no significant difference was observed. The water loss rates in the case of group E, F, and G were all significantly ($P \leq 0.05$) higher as compared with treatment A, with the ultimate water loss rate of group G reaching as high as 8.55, a 16.96% increase over group A - 7.1% (Fig. 3).

Generally speaking, fruits and vegetables easily lose water under hypobaric storage conditions, and so is the case with the honey peach ($P \leq 0.05$). In order to improve the effects of hypobaric storage, necessary measures, like timely increasing of the environment humidity, should be adopted. The moistener used in this experiment, however, works following a procedure of 'bleeding, refrigerating, moistening' cycle, and provides insufficient and uneven humidity compensation. In high temperature seasons, this situation was especially worse so that an independent control system for the moistener is preferable for improvement in hypobaric storage effects.

The respiratory intensity showed a 'descending, steady, slight rising' change trend. Group B showed no significant respiratory intensity changes as compared with group A, but groups C, D and E showed significantly ($P \leq 0.05$) lower respiratory intensity as compared with group A in the first 5, 10, and 15 storage days, respectively, and groups F and G exhibited significantly ($P \leq 0.05$) lower respiratory intensity as compared with group A over the whole storage period. Group G demonstrated the lowest respiratory intensity with a minimum value (on the 10th day) being as low as 46.75% of that of group A. And at the end of this experiment, the respiratory intensity of group G was only 60.49% of that of group A (Fig. 4).

The V_C content of the peach of each group descended along with the extension of storage time. Group B showed the fastest V_C content descending rate. Both group C and D showed roughly similar V_C content decreasing rate with

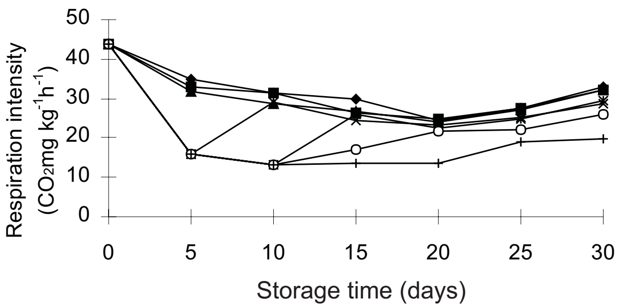

Fig. 4. The change of respiratory intensity in the course of hypobaric and subsequent atmosphere cold storage. Explanations as in Fig. 2.

group A. The descending rates of V_C content of groups E, F and G were significantly ($P \leq 0.05$) lower as compared with group A, and that of group G was the lowest of all (Fig. 5).

The soluble solids showed a 'rising-declining' changing tendency, which was different from the conclusion by Wu and Peng (2002) that the concentration of soluble solids tended to increase constantly over the whole storage period. This difference could be mainly due to diversity of peach species. In this experiment the descending rates of soluble solids content of groups B and C were not significantly different from that of group A, while that of groups D, E, F, and G were significantly ($P \leq 0.05$) slower as compared with group A (Fig. 6). This could be attributable to the lowering of the metabolic rate, which reduced pectin degradation and low molecular weight carbohydrate consumption.

The titratable acids of each group declined gradually. The decreasing rates of titratable acids of groups B and C were similar to that of group A, while those of groups D, E, F, and G were different as compared with that of A. At the end of this experiment, the titratable acids of group G were best retained (Fig. 7).

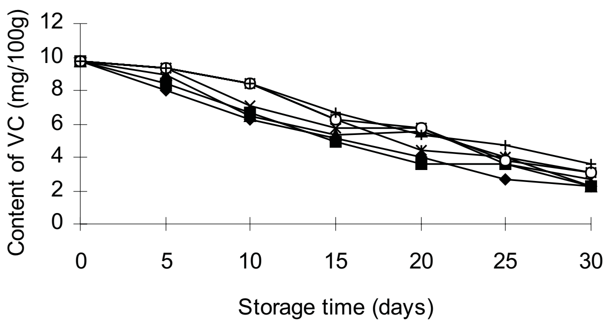

Fig. 5. The change of vitamin C content in the course of hypobaric and subsequent atmosphere cold storage. Explanations as in Fig. 2.

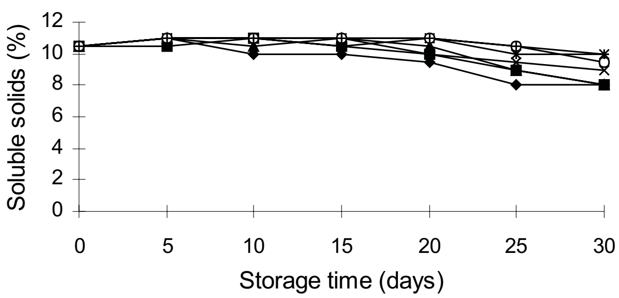

Fig. 6. The change of soluble solids content in the course of hypobaric and subsequent atmosphere cold storage. Explanations as in Fig. 2.

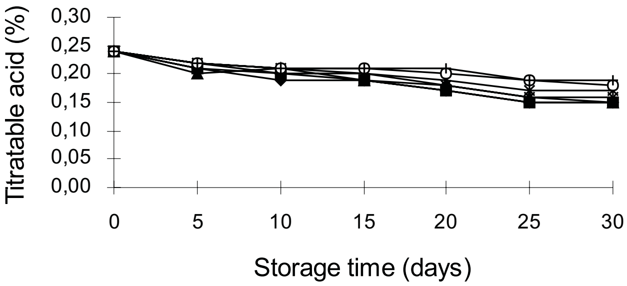

Fig. 7. The change of titratable acid content in the course of hypobaric and subsequent atmosphere cold storage. Explanations as in Fig. 2.

CONCLUSIONS

1. In the combination hypobaric and atmosphere cold storage process of this experiment, extension of hypobaric storage time from the 7th day on helped improve the sensory quality of the honey peach, in terms of peach freshness, taste and flavor, colour, and texture, compared to that observed if single atmosphere cold storage was used, while within the beginning 4 days, the sensory quality of honey peach was basically the same as that under single atmosphere cold storage. Optimum peach sensory quality was achieved under the sequential combination of hypobaric storage respectively at 10-20 kPa, 2±2°C for a week, at 20-30 kPa, 2±2°C for a week, and atmosphere cold storage.

2. The water loss rate increased, while the descending rate of hardness, V_C content, soluble solids, and respiratory intensity of honey peach decreased significantly ($P \leq 0.05$) with the extension of 10-20 kPa hypobaric storage time to more than 1 week; when the hypobaric storage time was less than 4 days, however, the water loss rate, and the descending rate of hardness, V_C content, soluble solids, and respiratory intensity remained similar, both as compared with atmosphere cold storage.

3. The declining rate of titratable acids was not significantly affected by the 10-20 kPa hypobaric storage extension whether within 4 days or longer than a week, as compared with atmosphere cold storage.

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