Effects of Type of Packaging Material on Postharvest Storage Quality of ‘Okubao’ Peach Fruit

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Abstract: The goal of this study was to compare the effects of modified atmosphere packaging (MAP), on the quality of ‘Okubao’ peach fruit. After harvest, peaches were subjected to MAP treatments by using 35 um anti-fogging cast polypropylene (CPP), 30 um polyethylene (PE) and 88 um antibacterial film and then kept at 0±0.1\degree C and 90± 5% for 49 days, while peaches stored for 35 days with unpackaged as control (CK). Physical and chemical changes [woolliness incidence, weight loss, healthy fruit index, color, flesh firmness, soluble solids contents (SSC), titratable acidity (TA), ascorbic acid, ethylene production and respiration rate, activities of polyphenol oxidase (PPO) and peroxidase (POD)] were recorded at harvest and every 7 days of storage. Fruit flesh firmness significantly decreased during storage for all treated fruits while MAP maintained firmer than control. Compared with CK, MAP-stored fruits showed significantly reduced incidence of woolliness and PPO, POD activities, as well as higher hue angles, SSC, TA, ascorbic acid contents and lower ethylene production and respiration rates. Peach could be stored for 28 days and 35 days by PE and antibacterial film, respectively, while stored successfully for up to 42 days using the CPP material. Peaches stored in CK maintained marketable for 21 days. These results showed that MAP resulted in a considerable improvement in keeping postharvest quality and providing longer storage, while CPP exerted the best effect.

Key words: ‘Okubao’ peach; packaging material; modified atmosphere packaging (MAP); quality.

1. Introduction

Peach is considered one of the most appreciated fruits by consumers due to sweet flavor, exquisite aroma and natural healthy compounds\textsuperscript{[1]-[3]}. However, due to the shelf life was only 5-7 days at room temperature and the demand of consumers for safe and high quality foods have increased, promising effective preservation method is necessary to improve storage quality and fulfill consumer demands\textsuperscript{[4]}.

The conventional method for slowing the ripening and prolonging the storage life of peach is cold storage, which, however, is limited due to chilling injury (CI) under unfavourable temperature\textsuperscript{[5]-[9]}. CI symptoms manifested primarily as woolliness are of commercial importance because shipping of peaches to distant markets and storage before selling require low temperatures\textsuperscript{[4],[10]}. Another relevant aspect to be taken into great account for maintaining the quality of horticultural commodities is the choice of the appropriate packaging system. Special film packages, with suitable permeability to CO\textsubscript{2} and O\textsubscript{2} are used to ensure an optimal equilibrium of these gases during storage and shipment\textsuperscript{[11] \[12]}. The mixture of gases in the package depends on the type of product, packaging materials and storage temperature.

Modified atmosphere packaging (MAP) has been used to supplement low temperature storage to protect the product from mechanical damage, reduce physiological disorders, prevention or retard senescence processes and associated biochemical and physiological changes, and inhibit decay in many fresh fruit and vegetable products with the aim of improving fruit quality and prolonging storage periods \textsuperscript{[13]-[15]}. For example, it is of crucial importance for broccoli to reduce weight loss and maintaining firmness and color through packaging. By the end of 14 days storage at 2\degree C, only the packaged broccoli were considered to be marketable, while unpackaged products became rapidly unmarketable at the same time because of weight loss and the accompanying flaccidity\textsuperscript{[15]}. The same result was also reported on carambolas. Carambolas held in low density polyethylene film at 10\degree C markedly retarded the decline in tissue firmness and the development of fruit colour, restricted water loss, and considerably suppressed the incidence of CI. Storage under MAP over the 5-6 weeks storage period...
effectively restricted water loss, lost less than 2% of their initial fresh weight. The CI symptoms were only noticeable after 40 days at 10°C for MAP fruit as compared to 20 days for non-MAP fruit[16].

Recently, some MAP treatments have been used in the effort to reduce respiration, decrease ethylene production, and slow deterioration through reduction of physiological disorders (chilling injury), and ultimately maintain good quality (appearance, texture and nutritive values) and extending the shelf life by maintaining high relative humidity and modify the concentrations of O2 and CO2 in the atmospheres surrounding the commodity [11], [13].

The use of the MAP technique has been tested in the storage of several peach and nectarines with success. Gao Hui, et.al[17] has been reported that polyethylene film can effectively maintain the quality by decreasing PG (polygalacturonase) and CX (cellulase) activities and decrease the respiration rate, ethylene production and decay, and slowed down the decrease in the flesh firmness and the increase in the relative membrane permeability. ZHU Lin, et al[18] explored the effects of different package treatments, and results showed that the package treatments had excellent effects for keeping flesh firmness, soluble solid contents(SSC) and TA values, for slowing down the rate of respiration, and prolonging the storage period for 35 days.

Meanwhile, GUAN Junfeng [19] suggested that polyvinyl chloride film (PVC) was a favorable strategy to extend the postharvest shelf life and retain good quality of peach fruits, be advantageous in retarding browning development, suppressing MDA content and PPO activity, but in maintenance of higher SOD activity, higher fruit firmness and better flavor. The effectiveness of modified atmospheres and packaging materials on honey peaches was studied by AN Jianshen, et al [20]. It showed conclusively that honey peach fruit could be stored for a period of 40 days under MAP condition by 0.015mm LDPE, which had minimal weight loss (<3%).

A lot of work has also been reported on the effect of MAP on the other fruits. Strawberries packaged under PVC polymeric film condition maintained better appearance and quality than unwrapped berries[21]. Blueberries stored in film with high gas permeance gave the highest scores for sensory texture and blueberry flavor[22]. MAP in “bag-in-box” Xtend® films (XF) effectively reduced the development of CI as well as other types of rind disorders in citrus fruit that are not related to chilling, such as rind breakdown, shriveling and collapse of the button tissue (aging) [23]. After 3 weeks of storage at 12°C plus 1 week at 20°C, modified atmosphere treatments were effective in reducing chilling injury in mango fruits. Fruits packed in Xtend® film or micro perforated polyethylene film dramatically reduced the development of red or green spots [24].

However, MAP may also have harmful effects include enhancement of decay due to excess humidity, initiation or aggravation of physiological disorders, off-flavors and increased susceptibility to decay [20] [25]. Therefore, the selection of packaging films with suitable barrier properties is of crucial importance to develop a gas composition able to maintain quality and assure a long shelf life to the packaged product. However, there is little information available regarding the effects of different MAP treatments on physiological changes in ‘Okubao’ peach. Moreover, the effects of MAP on alleviating CI and quality deterioration as well as the roles of PPO and POD activities remain unclear, and further research is needed to elucidate the physiological mechanisms involved. Thus, the effects of different MAP treatments on the storage period and fruit quality of ‘Okubao’ peach fruits were examined in this study, which was carried out with the aim of elucidating the effects of MAP treatments in cold storage so as to find the optimum packaging method, improving the limited storage ability and keeping good quality.

2. Materials and methods

2.1 Material and package treatments

Peaches were obtained at an optimum maturity from an orchard in Beijing, China and immediately transported to the laboratory where they were sorted for similar size, color and freedom from defects. The core temperature of peach fruit was forced-air cooled to reach stone temperatures of 3°C and randomly divided into 4 treatment groups. One group was stored unpackaged as the control (CK), other three MAP groups were achieved by 35 um anti-fogging cast polypropylene (CPP), 30 um polyethylene (PE) and 88 um antibacterial film, respectively. The film packages were sealed and all four treatments were stored at 0±0.1°C and 90±5% relative humidity under either CK for 35 days or MAP for 49 days. Physicochemical parameters and sensory evaluation were determined at harvest and at weekly intervals throughout storage. Three replicates were analyzed for each trial, with 5 peaches per replicate, for a total of approximately 100 kg in the experiments.

2.2 Quality evaluation

1) Sensory evaluation: A trained panel consisting of 5 people evaluated the sensorial quality of the samples. Visual quality was scored as 1 to 9, where excellent, freshly = 9; very good = 7; good, limit of marketability = 5; fair, limit of usability = 3 and poor, unusable = 1, where 6 is considered the minimum for salability[26].
2) Woolliness incidence (WI): The WI was estimated visually based on flesh browning area and calculated as the percentage of browned fruit on a scale where 0 = no browning; 1 = less than 1/4 browning; 2 = 1/4-1/2 browning; 3 = 1/2-3/4 browning; 4 = more than 3/4 browning.[27] [28]. The WI was expressed as follows: \[ \frac{(N_1 \times 1 + N_2 \times 2 + N_3 \times 3 + N_4 \times 4) \times 100}{(4 \times N)} \], where N = total number of fruits examined, and N1, N2, N3 and N4 were the number of fruits showing the different degrees of woolliness.

3) Healthy fruit incidence: The healthy fruit value was made by calculating the percentage of healthy fruit in relation to the total number of fruits in the samples at the time of evaluation, healthy fruits were those showing no signs of decay.

4) Weight loss: Weight loss was expressed as percent of fresh weight of initial weight. The mass of each replicate was detected using a digital scale with an accuracy of 0.01 g.

5) Color: External color was measure along the equatorial axes each fruit using CR-400 colorimeter, which provided L*, a* and b* coordinates. From these values, hue was calculated as \( h = \arctan \left( \frac{b^*}{a^*} \right) \).

6) Flesh firmness: Flesh firmness was determined on two opposite sides of each fruit in the equatorial region by a penetrometer (TR-FT327, Italy) equipped with a 5-mm diameter plunger tip, operating at room temperature after the skin was removed; results were read as Newton (N).

7) Soluble solids content (SSC) and titratable acidity (TA): SSC was determined in juice collected from three fruits per treatment with a hand-held refractometer (Atago Co.Ltd., Tokyo, Japan) at room temperature, and results expressed as %.

TA was examined by diluting 10 grams of flesh to a final volume of 100 ml with distilled water and then titrating 20 ml diluted juice to pH 8.1 with 0.05 mol·L-1 NaOH. Volume of NaOH was recorded and calculation convert to a percent malic acid basis.[29]

8) Ascorbic acid: Ascorbic acid content was determined by molybdenum blue colorimetric method according to the method of Li (2000).

9) Relative conductivity: Relative conductivity was determined according to the method of Li (2000).

10) Ethylene production and respiration rate:

Ethylene production was detected with a gas chromatography Agilent Technologies 7820A. 5 peaches were weighed and maintained hermetically for 2 hours in 2 L glass jar and then gas samples (1ml) of the effluent air were withdrawn from the headspace with a syringe and injected into the gas chromatography device. The results were expressed as ul·kg\(^{-1}\)·h\(^{-1}\), according to the method of Li et al. (2012).

Respiration rate was measured from the enclosed jars using an infrared CO2 analyzer as described by Zhao et al. (2005), and the respiration rate was expressed as mg CO2·kg\(^{-1}\)·h\(^{-1}\).

11) PPO and POD enzymes activities

2 grams of the fruit tissue was blended with 10 mL phosphate buffer and then was ground in ice-bath. The slurries were centrifuged at 12,000g for 20 min at 4°C and 2 mL supernatant was collected as enzyme-extracting solution. POD and PPO activities were exactly as described by Cao et al. (2007).

2.3 Statistical analysis

Statistical analysis was performed by statistical product and service solution (SPSS 19.0). Analysis of variance (ANOVA) was performed to determine the effect of the type of films on quality attribute and means were compared using least significant difference (LSD) test (\( P<0.05 \)).

3. RESULTS

3.1 Effects of MAP on the sensory evaluation during cold storage

Control fruits got lower scores compared with the MAP treatments with respect to sensory evaluation (Fig. 1). The peaches of CK were scored 5.5 as darkened and widespread shrinking on surface at 28 days of storage,
resulting in unmarketability. When after stored 35 days, peaches scored 2.5 became not edible, while the data of peach with PE, CPP and antibacterial film packages were 5.8, 6.3 and 6.1, respectively, PE stored peaches were unmarketable at this time. Consequently, the peaches can be stored maximally for 21 days with unwrapped controls. Compared different MAP treatments, CPP had better performance on keeping commercial sensory quality during cold storage than others do (p<0.05). The postharvest life of peaches was successfully raised to 28 days by PE, to 35 days by antibacterial film, and up to 42 days by CPP. Most probably, this result could be ascribed to the fast equilibrium of gas that was reached in the package[33].

3.2 Effects of MAP on the woulliness incidence and healthy fruit incidence during cold storage

![Graph](image)

**Fig.2 Effect of different MAP treatments on woulliness incidence and healthy fruit incidence of ‘Okubao’ peach during cold storage**

The results of WI showed that CPP package performed better than PE and antibacterial film packages, and especially better than CK (p<0.05) to reduce the severity of Cl symptoms (Fig. 2a). In our study, the woulliness incidence first occurred after 21 days in CK with 3.3%, but significantly increased up to 20.7% when stored for 28 days, while woulliness was observed only in PE fruit (5.6% woulliness index) and in antibacterial film fruit (3.9% woulliness index) at the same time. After 35 days of storage, CPP fruit firstly showed WI symptoms: the woulliness index was 12.7% compared with 37.3% in CK, 18.7% in PE and 16.3% in antibacterial film. The severities of the WI were increased after 49 days of storage for all treatments. The incidence of fruit flesh woulliness was lowered by MAP treatments made, whereas partially browning occurred in PE fruits, but the rates were not as high as in control fruits.

Control fruits got lower index compared with MAP treatments with regard to healthy fruit incidence. CPP got the highest index throughout the storage (Fig. 2b). Nevertheless, higher rates of deterioration in the control fruits caused these fruits to get lower healthy fruit incidence. When stored for 35 days, the lowest healthy fruit index was obtained in CK (27.5%) with CPP treatment resulted in the highest. Compared MAP treatments with respect to healthy fruit incidence, it would be of particular benefit to be able to use CPP to maintain quality and minimize the rate of perishability. The fact that CPP treatment gave the highest values in the trials is an important result in view of slower rate of softening and hence physiological disorder occurring in these fruits. Previous observation regarding the effectiveness of MAP treatments in significantly preventing product decay in grape fruit thus promoting a substantial shelf life prolongation, if compared to the unpackaged product have been reported elsewhere[34].

3.3 Effects of MAP on the weight loss during cold storage

![Graph](image)

**Fig.3 Effect of different MAP treatments on weight loss of ‘Okubao’ peach during cold storage**

Weight loss is one of the main indicators of fruit freshness. With prolonging storage periods, weight loss of peach increased drastically, while MAP treatments slowed down the increase (Fig. 3). The weight loss of peach
unpackaged was up to about 17% at 35 days of storage, while the peach with PE, CPP and antibacterial film packages were just 3.4%, 2.1%, 2.8% after stored 49 days, respectively. The results showed that weight loss of peach with MAP treatments was significantly (p<0.05) lower than that of the unpackaged. In addition, CPP package was the most effective in reducing weight loss of peach during storage among four treatments. The low weight loss trend in the MAP may be related to water vapor accumulation within the bags during the storage, consistent with Henriot R E [14] has suggested.

3.4 Effects of MAP on the fruit color during cold storage

![Fig.4 Effect of different MAP treatments on fruit color of ‘Okubao’ peach during cold storage](image)

The results showed that hue value of peach decreased in all samples with increasing storage time, while MAP treatment slowed down the decline (Fig. 4). The color value of peach unpackaged decreased significantly (p<0.05) faster than that of peach with MAP conditions and CPP package resulted in a higher color value compared with other three treatments during storage. The hue angle of CK fruit decreased from 35 h° to 30.4 h° after 35 days of storage, while the values of MAP-stored fruits were maintained roughly close to those found at harvest. After storage for 49 days, the decrease in hue index was remarkably slower in peach fruits stored in CPP when compared to PE and antibacterial film. This was well related to reduced senescence symptoms in fruit kept in CPP films.

3.5 Effects of MAP on the flesh firmness during cold storage

![Fig.5 Effect of different MAP treatments on flesh firmness of ‘Okubao’ peach during cold storage](image)

Fruit quality was correlated with firmness and color attributes [35]. Flesh firmness of the fruit rapidly decreased during the storage of all treatments (Fig.5). The control samples lost more than two third of their firmness when stored 35 days after harvest, the lowest flesh firmness was obtained. However, the firmness of the fruit positively affected from MAP storage in all storage periods which was determined to reach 29-35 N still acceptable by consumers at the end of the same storage period. This effect, was more drastic in the CPP samples than in the other treatments. During 49-day cold storage, the CPP-treated fruits still remained firmer with a firmness above 27N.

Our results showed that the highest firmness was determined for CPP-stored samples, followed by PE-treated samples and then antibacterial film samples under storage conditions. MAP treatments slow down fruit softening, compared to control treatment during the storage period. Similar results were obtained in several studies in which MAP was applied to peaches.
3.6 Effects of MAP on the soluble solids content and titratable acidity during cold storage

For all treatments, it can be seen that generally increases occurred in SSC at earlier storage, along with the consumption of respiration substrates, and then dropped at later storage (Fig. 6a). SSC of the peach fruit was so significantly different among the control, MAP-stored samples after 35 days of storage, the contents of peach with unpackaged, PE, CPP and antibacterial film packages were 8.9%, 9.4%, 10.6% and 9.6%, respectively. MAP increased SSC from initial values of 9.3%. After cold storage for 49 days, the SSC of the CPP and antibacterial film-stored peach maintained higher content than initial value with the exception of PE. In the trials, CPP application retarded the decrease in SSC.

When the results of TA analyses in peaches were considered, significant difference was detected between the CK and MAP treatments whatever the storage period; there was clear influence of MAP on the TA of ‘Okubao’ peaches. The lowest TA value in our research was obtained from control samples, whereas the highest TA value was obtained from CPP application with which deceased more slowly. The TA content of peach with unpackaged treatment were 0.096% at 35 days of storage, while that of peach with PE, CPP and K packages were 0.14%, 0.16% and 0.14% at 35 days of storage, respectively (Fig. 6b). When comparing peach fruit subjected to MAP for 49 days, the TA content of the CPP and antibacterial film-stored peach fruits were significantly higher than PE fruits, but the differences in TA content were disappeared among the treatments, the lower acidity in fruit kept in PE films (0.12%). The results showed TA content was affected significantly by storage time and different package treatments (p<0.05). In addition, CPP package was the most effective method.

3.7 Effect of MAP on the ascorbic acid during storage

It may be seen that the initial ascorbic acid values of peach decreased as the storage period was extended. The results showed that ascorbic acid content of peach decreased along the storage period (Fig. 7), while the different packages and storage time on the influence of ascorbic acid exerted extremely significant difference (p<0.05). Ascorbic acid content of peach with unpackaged, PE, CPP and antibacterial film packages were 1.2, 3.6, 3.1 and 2.4 mg·100g⁻¹ at 35 days of storage, respectively. At 49th day of storage, ascorbic acid content of peach with PE, CPP and antibacterial film packages were 1.3, 1.5 and 1.6 mg·100g⁻¹, respectively. The results showed that the loss of ascorbic acid value in fruits was retarded through MAP treatments.
3.8 Effect of MAP on the relative conductivity during storage

Although the relative conductivity values of fruits stored in all treatments significantly increased with the prolonging storage periods, the increase in MAP stored fruits were at quite lower rates compared to controls. The relative conductivity levels increased along the storage period and reached to high levels in control fruits as MAP peaches slowed down the substantial increase, and in this way, changes in membrane integrity were suppressed. Relative conductivity value in the trials reached the highest level after 21 days of storage, while peaches stored in CK remained higher values, determined as 62.7%, except that CPP raised to the highest content with 53.1%. CPP resulted in the better retention of membrane integrity.

3.9 Effect of MAP on the ethylene production and respiration rate during cold storage

The rate of ethylene production and respiration rate of the peach fruits exhibited a typical climacteric pattern in control and MAP-stored samples, whereas the MAP-treated samples reduced the ethylene production during storage (Fig. 9). Our results indicated that MAP-treated samples did completely suppress ethylene production, but rather continued to produce certain levels of ethylene.

The MAP-treated samples reduced the ethylene production during storage as seen in Fig. 9a. Our results indicated that MAP-treated samples did completely suppress ethylene production, but rather continued to produce certain levels of ethylene. The peak ethylene production rate of peach with unpackaged treatment was 0.088 uL·kg⁻¹·h⁻¹ and was higher than that of PE (0.049 uL·kg⁻¹·h⁻¹) at 7th day of storage, CPP and antibacterial film packages at 28th day and the data both were 0.014 uL·kg⁻¹·h⁻¹, while second ethylene production rate of peach in CK was 0.028 uL·kg⁻¹·h⁻¹ at 28 days of storage. The results showed that the ethylene production rate of peach was significantly affected by storage time and different package treatments (p<0.05). In addition, CPP package was the most effective in inhibiting ethylene production rate of peach during storage among four treatments.

As shown in Fig.9b, at 14 days of storage, the respiration rate of peach with unpackaged firstly reached the maximum 88.85 mg CO₂·kg⁻¹·h⁻¹ and 67 mg CO₂·kg⁻¹·h⁻¹ for the second climacteric peak. These values were higher than that of PE, CPP and antibacterial film packages which reached the peak value at 28th day storage and the data were 44.64, 36.06 and 37.94 mg CO₂·kg⁻¹·h⁻¹, respectively. The results showed a clear effect of MAP treatments in retarding respiration rate (p<0.05) and CPP package was the most effective method.

Similar to our results, certain report claimed that packaging films can achieve significant increase in shelf life through lowering the respiration rate and ethylene production and perception[11].
3.10 Effect of MAP on the PPO and POD activities during cold storage

![Graphs showing PPO and POD activities](image)

Fig. 10 Effect of different MAP treatments on PPO and POD activities of ‘Okubao’ peach during cold storage

The activity of PPO of peach increased during storage but MAP package treatments slowed down the increases significantly ($p<0.01$) (Fig. 10a). PPO activity of the control samples linearly increased as a function of the storage time. The PPO activity of peach with unpackaged treatment increased to 23.33 U·min$^{-1}$·g$^{-1}$ from the initial PPO activity was determined as 4.93 U·min$^{-1}$·g$^{-1}$, while that of PE, CPP and antibacterial film packages were 16.43, 13.11 and 13.63 U·min$^{-1}$·g$^{-1}$ respectively at 35 days of storage and 18.53, 16.67 and 17.37 U·min$^{-1}$·g$^{-1}$ at 49 days of storage, respectively. The results showed that CPP package was the most effective in inhibiting PPO activity of peach during storage among MAP treatments.

The POD activity of peach with unpackaged treatment increased in the first 28 days of storage simultaneously obtained the peak value, and then decreased while the POD activity of peaches applied with PE, CPP and antibacterial film packages increased in the first 42 days and peak of POD activity (Fig. 10b). The results showed that MAP treatments significantly ($p<0.01$) inhibited the activity of POD, and delayed the peak of the enzyme activity. In addition, CPP package was the most effective in inhibiting POD activity of peach during storage among MAP treatments. It was demonstrated that when an increase in the activities of PPO and POD occurs, accordingly, resulting in the occurrence of woolliness, that can discourage sensory acceptance.

4. Conclusions

During cold storage, peach with MAP treatments allowed a considerable extension of postharvest life and kept good fruit quality attributes since the storage life of ‘Okubao’ peach treated with unpackaged, PE, CPP and antibacterial packages were 21, 28, 42, 35 days respectively with the commercial sensory evaluation. It can be concluded that storing peaches in MAP, especially in CPP film will preserve the fruit color, flesh freshness and commercial quality without excessive loss of quality through significantly slowing down the respiration rate and ethylene production rate, and without risks of woolliness, senescence and decay development, probably due to inhibiting the activity of POD, PPO and delayed the peak of the enzyme activity.

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6. References


