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# Effect of Packaging Conditions on the Fruit Quality of Chinese Quince

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**Abstract** The respiration rate of Chinese quince was measured at 0, 5, 10, and 20°C to determine its tolerable range of storage temperatures. Based on the measured respiration rates, plastic films covering a wide range of gas permeabilities were used for packaging and storing individual Chinese quince at 0 and 10°C. Chinese quince can be categorized as low respiration fruit. Higher respiratory quotients were observed at higher temperature suggesting that the tolerable temperature range for storage is 0-10°C. Packages containing Chinese quince wrapped in highly gas-permeable polyolefin film PD 941 attained, with progressive decreases in volume, 9.5-10.2% $O_2$ and 1.3-1.8% $CO_2$ at 0°C, 8.1% $O_2$ and 2.4% $CO_2$ at 10°C. At these levels, PD 941 could preserve the fruit at acceptable quality levels for 152 and 50 days at 0 and 10°C, respectively. Less gas-permeable packages built up high $CO_2$ concentrations (above 15.8%) and low $O_2$ concentrations (less than 1.8%) causing free volume expansion and eventual dark discoloration of the fruit. The storage life realized by packaging with polyolefin film PD 941 could facilitate the availability of Chinese quinces in winter and spring for medicinal or ornamental purposes in the fresh state.

Keywords: *Pseudocydonia sinensis*, modified atmosphere packaging, plastic film, gas permeability, quality

## Introduction

Chinese quince fruits (*Pseudocydonia sinensis,* Koehne) have been widely used in Korea for tea, sugar preserves, and alcoholic drinks (1, 2). They may be used fresh or dried after slicing for long-term storage. They have been used as oriental medicinal ingredients for their pharmacological effects, including as a digestive aid, vomit sedative, and antispasmodic (1, 3). Fresh Chinese quince fruits are also used in household living rooms or in cars as an ornament and for its fragrance. Today, there is demand for fresh Chinese quince fruits year-round. However, there have been few studies on their storage and packaging. There is little information on postharvest handling and quality indices of the Chinese quince because of the scarcity of attention paid by researchers. Some post-harvest handling and quality indices, as well as information about optimum storage conditions for the western quince (*Cydonia oblonga*), which has climacteric respiratory behavior, have been reported (4, 5). The optimal storage conditions for the western quince were shown to be 0°C and 90% relative humidity, which provides a storage life of 2-3 months (4, 5). There are no reports about the post-harvest storage characteristics of Chinese quince. When compared to western quince, the flesh of the Chinese quince is much tougher and has a much higher content of total phenolics (6). The tougher flesh of Chinese quince makes it unpalatable for direct consumption even when cooked while the western quince can be consumed cooked or processed as jams or jellies. Interestingly, the phenolics found in Chinese quince have a stronger anti-influenza viral activity than those of western quince (6).

Chinese quince may have different post-harvest characteristics from those of western quince. Direct application of storage data of western quince to the Chinese quince may therefore be limited. Fundamental information such as fruit respiration rates and responses to storage temperature and packaging film needs to be established before designing storage and packaging of fresh Chinese quince (7-9). Therefore, this study was undertaken to investigate the respiration characteristics of fresh Chinese quince fruits and the extension of their shelf life by using low temperature and optimized packaging.

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## Materials and Methods

**Fruit source** Mature yellow Chinese quince fruits (*P. sinensis*, Koehne), weighing 420-540 g (average weight, 480 g), were purchased from a farm in Cheongdo-gun, Korea.

**Measurement of respiration rate** Respiration of Chinese quince at 0, 5, 10, and 20°C was measured in terms of $O_2$ consumption and $CO_2$ evolution by the closed system method (7). A single fruit was placed in a 1 L glass jar, and the gas concentrations of the jar's headspace were periodically analyzed with a Varian model 3800 gas chromatograph (Varian Inc., Palo Alto, CA, USA). Triplicate jar experiments were conducted to obtain an average respiration value. A thermal conductivity detector and an Alltech CTR I column (Alltech Associates, Inc., Deerfield, IL, USA) were used with helium as a carrier gas at a flow rate of 30 mL/min and a column temperature of 40°C.

Because oxygen was not separated from argon by the CTR I column, the $O_2$ concentration was calculated by subtracting from the chromatogram the area corresponding to 0.9% concentration of Ar in the air. The experimental data on the decrease in $O_2$ concentration (up to 10%) and the corresponding $CO_2$ increase were fitted by a simple linear regression (MS Excel®). The respective slopes of $O_2$ decrease and $CO_2$ increase were multiplied by the jar free volume and divided by sample weight to give respiration rates in $O_2$ consumption and $CO_2$ production rates, respectively. Even though the respiration rate may be described as a function of the $O_2$ and $CO_2$ concentrations, it was taken as a typical constant value from the fact that $O_2$ and $CO_2$ concentration changes in this range showed a linear slope (Fig. 1).

**Attributes of stored, packaged Chinese quince fruit** Individual Chinese quince fruits were packaged by heat sealing with plastic film (20×20 cm), and stored at 0 and 10°C. Free volume, as measured by immersing the package in water, was 402±67 mL. Humidity conditions were 85 (range 80-90%) and 70% (range 60-80%) at 0 and 10°C, respectively. Plastic films with a variety of gas permeabilities were selected for packaging materials. The films selected were polyolefins PD 941 film (20 μm thick) and PD 900 (50 μm thick); Both films were manufactured by Cryovac, Sealed Air Corp., Duncan, SC, USA. A polypropylene film of CPF 30 μm thick (ST Corp, Seoul, Korea) was also tested. The CPF film is widely used in industry for packaging a variety of foods, while PD 941 film and PD 900 are typical films used for fresh produce packaging. The film permeabilities to $O_2$ and $CO_2$ were measured by the quasi-isostatic method (10). A control package of perforated polyolefin film PY85 with 15 μm thickness (7200 perforations of 1 mm diameter on the total package surface area of 0.08 $m^2$, Cryovac, Sealed Air Corp.) was subjected to the same storage conditions for comparison with the other packages in the quality evaluation.

**Analysis of package atmosphere and fruit quality** During the storage period, three packages for each treatment were removed periodically, measured for $O_2$ and $CO_2$ concentrations using the gas chromatograph for the 1 mL gas samples taken from the headspace, and then opened to evaluate the quality attributes of the fruits. All the quality attribute values reported are the average of data from three packages. Weight loss was determined by weighing the package to the nearest 0.1 g and expressed as percentages of initial package weight. Maximum standard deviation of weight loss measurement was 1.7%. Ascorbic acid content of the juice was measured by the AOAC method (11) with an average standard deviation of 13 mg/100 g. Surface color of the fruits was measured at five locations of each fruit by using a color difference meter with a halogen lamp (Model JC 801; Color Techno System Corp., Tokyo, Japan). A reference white tile (X: 94.25; Y: 96.06; Z: 114.26) was used for calibration. Distance in Hunter color solid space from an initial surface color was calculated as $\Delta E = (\Delta L^2 + \Delta a^2 + \Delta b^2)^{0.5}$ to show the degree of color change during storage. A soluble solid of hand-extracted Chinese quince juice was measured using a hand refractometer (Model N1; Atago Co., Tokyo, Japan) with an average standard deviation of 0.8 °Bx. A pH meter (Model 520A; Orion Research Inc., Boston, MA, USA) was used to measure pH of the macerated quince juice (added with water twice the fruit weight) with an average standard deviation of 0.11. Titratable acidity was determined in citric acid concentration by titrating 100 mL diluted quince juice with 0.1 N NaOH until an end point of pH 8.1 was reached. Average standard deviation of the acidity measurement was 0.2%.

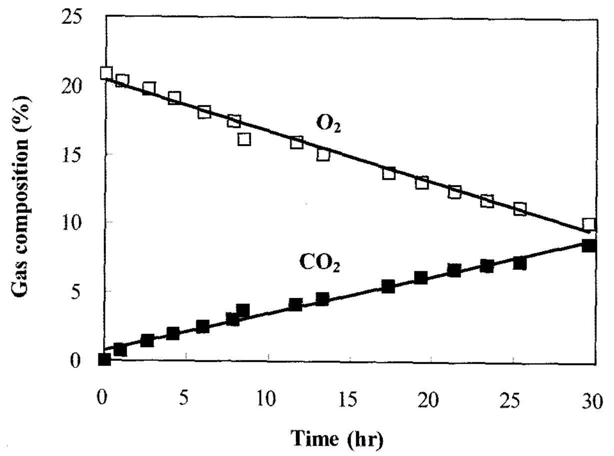


**Fig. 1. Representative data set of a closed system experiment for measuring respiration of Chinese quince at 10°C.** Quince weight: 403 g; jar free volume: 564 mL.

## Results and Discussion

**Respiration of Chinese quince** The respiration rates measured over $O_2$ concentrations of 10 to 21% and the corresponding $CO_2$ concentration changes (Fig. 1 and Table 1) suggest that Chinese quince may be categorized as a low respiration fruit or vegetable like apples, beets, citrus fruits, potatoes, and watermelons (0.1-0.3 mmol $CO_2$/kg·hr at 5°C) (12). Higher temperatures increased the levels of respiration and the respiratory quotient (RQ, the molar ratio of $CO_2$ produced relative to $O_2$ consumed) for the Chinese quince. Higher temperatures were reported to induce higher respiration rates and RQ in oranges with thick peels and/or wax coating (13). The higher temperature dependence of fruit respiration rates compared to that of the permeability of peel and/or wax coating likely accounts for higher $CO_2$ accumulation inside the fruits from resulting in higher rates of anaerobic respiration with high RQ.

Even though high RQs at high temperatures may result from a change in the respired substrate of sugars and organic acids, and different solubilities of $O_2$ and $CO_2$ in aqueous tissue (14), a greatly increased RQ may also result from an increase in anaerobic respiration, and may cause physiological disorders of the fruits (15-17). RQ values greater than about 1.3 were reported to produce

**Table 1. Respiration rates for Chinese quince at different temperatures**

| Temperature (°C) | Respiration rate[1)] (mmol/kg·hr) | | Respiration quotient |
|---|---|---|---|
| | $O_2$ consumption | $CO_2$ evolution | |
| 0 | 0.108±0.008 | 0.053±0.001 | 0.49 |
| 5 | 0.256±0.000 | 0.146±0.001 | 0.57 |
| 10 | 0.339±0.116 | 0.234±0.060 | 0.69 |
| 20 | 0.516±0.003 | 0.781±0.029 | 1.51 |

[1)]Mean±standard deviation.

high amount of ethanol with off-flavors for mandarin oranges, blueberries, and apples (13, 17, 18). Thus, in this context, long-term storage of Chinese quinces at high temperatures may pose a risk of anaerobiosis, which may result in physiological injury. Based on the RQ values in Table 1, storage temperatures of up to 10°C do not seem to pose any risk of anaerobiosis. The optimal temperature for storing quinces is known to be 0°C (4, 5), and our preliminary storage experiment where we stored Chinese quinces at 0°C did not reveal any symptoms of chilling injury. Therefore, the packaging and storage tests for Chinese quinces were undertaken at 0 and 10°C.

**The effect of different packaging materials on fruit quality** The plastic films used for packaging Chinese quince fruit covers a wide range of 0.67-5.49 and 1.93-29.10 mmol/atm·m$^2$·hr for $O_2$ and $CO_2$ permeances, respectively, at 0°C (Table 2). A 10°C increase in the storage temperature doubled the both $O_2$ and $CO_2$ permeances, which is typical for common plastic films (7, 19). Polypropylene CPF film had the lowest gas permeance and polyolefin PD 941 the highest value. The ratio of $CO_2$ permeance to $O_2$ permeance ranged from 2.88 to 5.70, which is the normal range of most plastic films (7, 19). These different degrees of gas permeability were thought to cover the range of available plastic films used for fresh produce packaging (19, 20), and, therefore, were used for packaging Chinese quince in this study.

The quality attributes of packaged quince were examined in correlation with the changes in package atmosphere (Fig. 2, 3). Less permeable polyolefin PD 900 and polypropylene CPF packages resulted in very high $CO_2$ concentrations even after short-term storage of less than 15 days at both temperatures, and they eventually ruptured due to free volume expansion after further storage. $CO_2$ accumulation above 15% under anoxic conditions for the PD 900 and CPF packages over 15 days of storage at 0°C caused significant decreases in ascorbic acid content and large color change after 32 days of storage (Fig. 2), and eventually resulted in severe physiological injury and discoloration after 103 days, at which the chemical and physical quality measurement was impossible and/or

**Table 2. Gas permeance of plastic films to $O_2$ and $CO_2$ at 0 and 10°C**

| Film thickness | Temperature (°C) | Permeance[1] (mmol/atm·m$^2$·hr) | | Permeance ratio ($\bar{P}_{CO_2}/\bar{P}_{O_2}$) |
|---|---|---|---|---|
| | | $O_2$ | $CO_2$ | |
| Polyolefin PD 941 (20 μm) | 0 | 5.49±0.34 | 29.10±0.45 | 5.30 |
| | 10 | 11.03±0.02 | 50.98±0.15 | 4.62 |
| Polyolefin PD 900 (50 μm) | 0 | 1.14±0.01 | 6.50±0.55 | 5.70 |
| | 10 | 2.23±0.17 | 10.09±0.42 | 4.52 |
| Polypropylene CPF (30 μm) | 0 | 0.67±0.04 | 1.93±0.10 | 2.88 |
| | 10 | 1.21±0.06 | 3.81±0.04 | 3.15 |

[1]Mean±standard deviation.

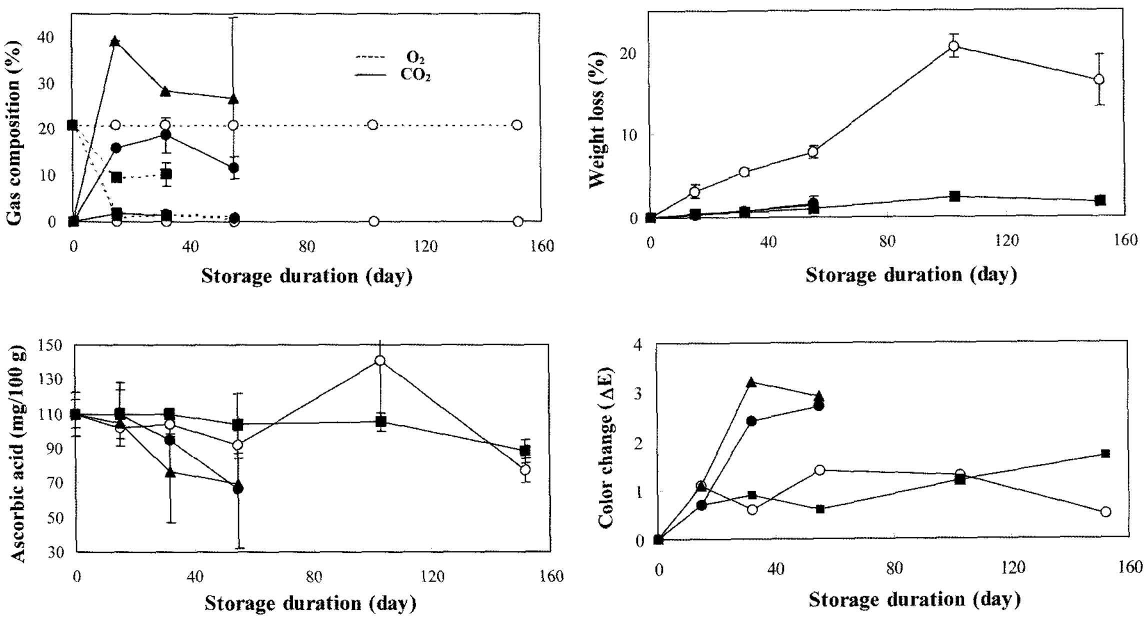


**Fig. 2. Changes in package atmosphere and fruit quality attributes at 0°C.** Vertical bars indicate the standard deviation. ○ : control; ■ : PD 941; ● : PD 900; ▲ : CPF.

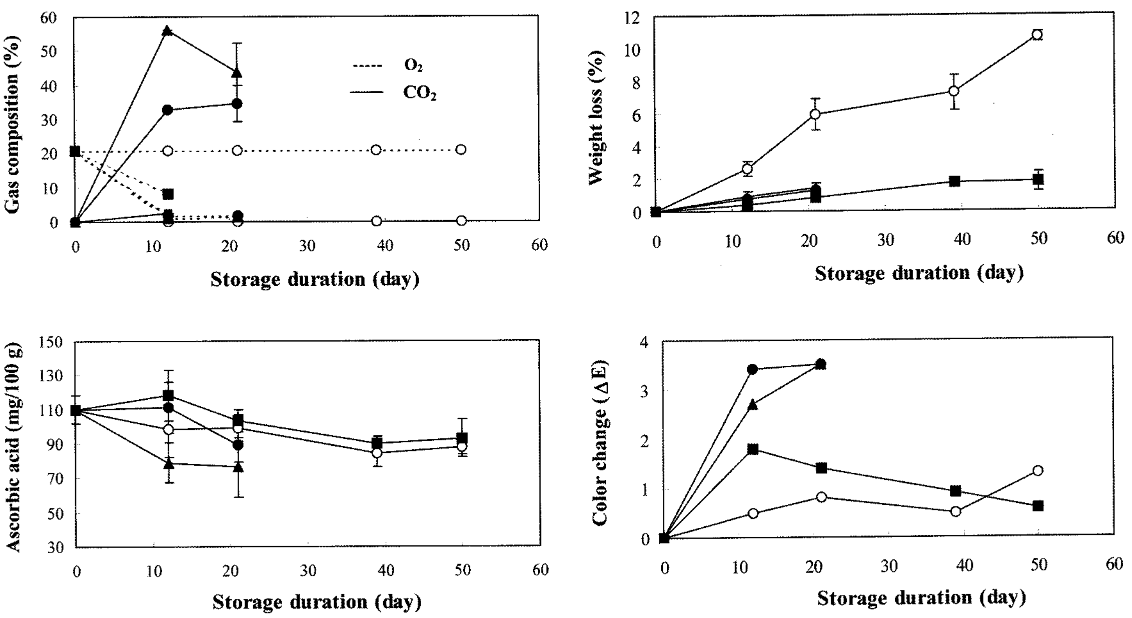


**Fig. 3. Changes in package atmosphere and quality attributes at 10°C.** Vertical bars indicate the standard deviation. ○ : control; ■ : PD 941; ● : PD 900; ▲ : CPF.

meaningless. At 10°C, the PD 900 and CPF film packages caused a more severe development of low $O_2$ and high $CO_2$ concentrations after 12 days (Fig. 3), which could damage the fruits physiologically (12). These two types of packages at 10°C showed some volume expansion and an appreciable loss of ascorbic acid up to 21 days, after which the fruit became darkened and discolored. Excessive anaerobic respiration to produce $CO_2$ gas under little presence of $O_2$ would be the mechanism causing the volume expansion and physiological color breakdown at both temperatures. The time for visual discoloration of fruit in the PD 900 and CPF packages was shorter with higher temperature (103 and 39 days at 0 and 10°C, respectively).

On the other hand, polyolefin PD 941 packages (high gas permeability) attained a modified atmosphere (MA) of moderately lowered $O_2$ and a slight accumulation of $CO_2$ (8.1-10.2% $O_2$, 1.3-2.4% $CO_2$, Fig. 2 and 3). The PD 941 packages progressively shrank in volume and the contact with the fruit surface became so tight as to make measurement of the package atmosphere impossible. The time taken for the PD 941 package to become tightly shrunken (55 and 21 days at 0 and 10°C, respectively) was shorter with higher temperature. Progressive decreases in the free volume of the flexible fresh produce package is a relatively common phenomena theoretically confirmed and observed experimentally, and depends on respiration and film's gas permeability (21, 22). The internal atmospheres of the PD 941 package established before the free volume depletion observed at 0 and 10°C are very different from those usually observed for fresh produce packaging with plastics (7, 23). The atmospheric characteristics associated with the free volume decrease is attributed to the low RQ (<0.7) of quince respiration and high $CO_2/O_2$ permeability ratio (>4.6) of the PD 941 film (Table 1, 2). Plastic film possessing a lower $CO_2/O_2$ permeability ratio may be employed to attain a higher $CO_2$ package atmosphere to a limited extent providing a beneficial MA effect (7). Furthermore, because the respiration of quinces follows a climacteric pattern, the interaction between produce respiration and gas permeation to build up the package atmosphere would be very complex and difficult to clearly understand even on a simple theoretical basis. The PD 941 package showed acceptable weight loss and ascorbic acid retention without noticeable color change for 152 and 50 days at 0 and 10°C, respectively (Fig. 2, 3).

All the non-perforated packages (PD 941, PD 900, and CPF) showed only slight weight loss, with little difference between packages. After 32 and 21 days at 0 and 10°C, respectively, the perforated control package exceeded 5% weight loss, which is the critical level of visual wilting and shriveling (24). The greater weight loss of the control packages compared with non-perforated plastic packages-which was observed particularly during the later storage period-seemed to have contributed to the higher ascorbic acid content due to a concentration effect.

Generally, the soluble solid content of Chinese quinces in most packages decreased (from 14.5 mostly to 12-13 °Bx), pH increased slightly (from 3.25 mostly to 3.3-3.5), and titratable acidity decreased with storage time (from 1.96 mostly to 1.1-1.4), with greater changes at higher temperatures (specific data not shown here). These observed trends of soluble solid content and pH change are different from the usual cases of fruit storage in which soluble solid content mostly consisting of soluble sugar increases and acidity declines with time (24, 25). The changes of soluble solid content and acidity, however, can be variable with the commodity depending on its reserve carbohydrate, sugar, and acid contents at harvest. Currently, there are no reports about the physiology and chemical quality changes of quinces stored at low temperature. Moreover, large variations among samples made it impossible to observe consistent and significant differences between treatments in changes of soluble solid, pH, and acidity.

Chinese quince fruits were best preserved at both temperatures by the PD 941 package (152 days at 0°C and 50 days at 10°C). The higher fruit quality achieved with this packaging is supported by its high ascorbic acid retention and small surface color change at the later storage periods (Fig. 2, 3). The storage lives observed in this study are much longer than the two to three months at 0°C known for quince (4, 5). At this stage, we cannot compare the Chinese quince with western quince with respect to its ability to tolerate prolonged storage. A more comprehensive study is thus required for a thorough understanding of the interactive mechanisms between respiration behavior and package permeation.

The relatively long storage life of the Chinese quince may make it possible for them to be available in winter and spring for use as a sweet-smelling ornament or for other purposes in the fresh state.

This study was conducted to obtain preliminary information about the storage and packaging of the Chinese quince. We described the attributes of the fruits themselves and the effects of various packaging materials and storage techniques on fruit quality. In the future, we plan to use these data to help design a modified atmosphere packaging system for Chinese quince.

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