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RESEARCH NOTE

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Chitosan Coating Effects on Respiration Rate and Internal Gas Composition of 'Fuji' Apple and 'Satsuma' Mandarin

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Abstract Effects of chitosan coating on respiration rate and internal gas composition of 'Fuji' apple and 'Satsuma' mandarin were investigated and compared to wax emulsions and two commercial coating materials. Chitosan coating reduced respiration rate significantly ($p<0.05$) in 'Fuji' apple and 'Satsuma' mandarin compared to uncoated and other coating materials. Chitosan coating on 'Fuji' apple showed the highest CO_2 and the lowest O_2 concentration in the internal gas composition at 5°C but showed no differences compared to other coating materials at 20°C. 'Satsuma' mandarin showed significantly high CO_2 concentration in chitosan coating at 20°C but there were not significant differences among coating materials in CO_2 and O_2 composition at 5°C.

Keywords: edible coating, chitosan, 'Fuji' apple, 'Satsuma' mandarin, respiration, internal gas composition

Introduction

An edible coating is defined as a thin, edible film that can be deposited onto the surface of food and that can extend the shelf life of coated food by acting as a barrier to moisture and gas transmission.

Chinese applied wax coatings to oranges and lemons in the 12th and 13th centuries. Hot melt paraffin waxes have been used to coat citrus fruits in the United States since the 1930s, and various waxes have been used for coating fresh fruit and vegetables (1). In 1982, Lowings and Cutts (2) reported that a sucrose fatty acid ester mixture, which was tasteless and odorless, could be used for preserving fruits. Sucrose fatty acid ester mixtures were commercialized in 1983 and were used under the names of 'Semperfresh (SPE)' and 'Pro-long (TAL)' and have been approved as coatings on various fruits to extend their shelf life and to reduce quality changes. Park *et al.* (3) reported that the SPE coatings delayed weight loss of 'Fuji' apples and 'Shingo' pears and retarded the respiration rate of apples during storage. And SPE increased shelf-life and quality of apricots (4), tomatoes (5), cherry (6), and apple (7,8).

Several attempts have been made to develop other materials that do not impart a waxy taste and are water-washable. Chitosan is a natural cationic polysaccharide derived from chitin. It can form a semi-permeable coating, which can modify the internal atmosphere, which will delay ripening and decrease transpiration rates in fruits and vegetables such as strawberries (9), mango (10), citrus (11), tomatoes (12), and Indian jujube (13).

Even though some edible coatings have been successfully applied to fresh produce, others have adverse affects on quality. Modification of internal gas composition by edible coatings can increase disorders associated with high CO_2 and low O_2 (14-17). Several representative problems associated with edible coatings are anaerobic fermentation, rapid weight loss, level elevation of core flush, and increased incidence of decay (18). The success of edible coatings for fruits and vegetables mainly depends on the selection of appropriate films or coatings that can give a desirable internal gas composition (19).

An effective edible coating leads to a reduction in respiration rate by limiting exposure to ambient O_2 and increasing internal CO_2. Many previous studies reported on coatings that were effective in retarding the quality change by reduced respiration rate or modified internal gas composition. However, little evidence was found to relate respiration rate changes to internal gas composition in coated fruits. The objective of this study was to determine effective coating material for edible coating of apples and mandarin. Korean 'Fuji' apple and 'Satsuma' mandarin were coated with different concentration levels and conditions of chitosan and wax emulsions. Respiration rate and internal gas composition were monitored during short-term storage at 5 and 20°C for the fruits coated by commercial coating materials.

Materials and Methods

Fruits Apples ('Fuji') were purchased from Andong, Gyeongbuk, Korea and 'Satsuma' mandarins (*Citrus unshi* MARK.) were obtained from Seogwipo, Jeju, Korea. The fruits were selected carefully to ensure uniformity in maturity, size, color, and physical appearance. Samples were sanitized in chlorinated water.

Coating materials ***Chitosan***: Chitosan was purchased from Biotech Co., Ltd., Mokpo, Korea. Chitosan samples derived from red crab shell had viscosity of 15 cp and degree of deacetylation above 95%. Chitosan was dissolved in diluted lactic acid (2%, v/v) to obtain 0.5 and

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1.5%(w/v) solution. The pH of solutions was adjusted to 5.2 with 0.1 N NaOH. Tween 80 was added to the solution at 0.1%(v/v) to improve wettability (20).

Wax emulsions: Two wax emulsions with different ratios of bees wax to coconut oil (A, 35 g beeswax: 15 g coconut oil; B, 45 g beeswax: 5 g coconut oil) were used. Sodium oleate (4 g) was dissolved in 500 mL water at 70°C. Hot wax mixture, 45 g bees wax and 5 g coconut oil, was added to the aqueous solution at 70°C with stirring at 1,300 rpm for 10 min. The stirring was continued for 1 hr more and then was left to cool (20).

Commercial coating materials: Semperfresh™ (SPE), sucrose ester based fruit coating, was obtained from Agricoat Industries Ltd. (Berkshire, UK) and diluted to 0.8 and 1.2%(v/v) for coating. Coseal coating wax, carnauba based wax, was purchased from Coseal Co., Ltd. (Gunsan, Jeonbuk, Korea).

Treatments Samples were dipped for 10 sec in each coating material. Chitosan was used for coating apples with concentrations of 0.5 and 1.5%(w/v) after adjusting pH to 5.2. SPE was used for coating apples in 0.8 and 1.2%(v/v) solutions and compared with the chitosan coatings. 'Satsuma' mandarins were coated with a 1.5%(w/v) chitosan solution and 2 kinds of beeswax emulsions and compared to Coseal wax. All coated samples were dried by fan for 3 hr. An untreated lot dipped in water served as the control. Samples were stored in an environment chamber at 5 and 20°C, 80% relative humidity (RH).

Respiration rate The respiration rate experiments were conducted in respiration chambers, constructed from glass jars. There were 2 apples and 2 'Satsuma' mandarins in jars with volume of 4.5 and 1.2 L, respectively, for each coating treatment. A rubber stopper was placed in the jar cover for gas sampling. Headspace gas (0.5 mL) was taken by needle after 24 hr for apples and 12 hr for mandarin and measured by gas chromatograph (GC) (Column, CTR-1, 50°C; injector, 50°C; detector, 150°C; carrier gas, He; flow rate, 20 mL/min, Model 163; Hitachi, Tokyo, Japan). Experiments were replicated 3 times for each treatment and observations were taken at 5 or 20°C.

Internal gas composition A cylindrical plug of tissue was removed from central region of fruits using a borer. Tapered glass tubes were inserted into the holes in the samples. Glass tubes were cylindrical in shape with 2 different diameters, bigger one for insert in fruits and smaller for sampling gas, of 1.3 and 0.5 cm, respectively. Glass tube was attached to fruits using silicone. The tapered end of the glass tube was sealed by a robber septum (21) (Fig. 1). The gas (0.5 mL) was taken from glass tube after 0, 6, 12, and 24 hr and analyzed for compositions by GC, as described in the measurement of respiration rate. Experiments were replicated 5 times for each treatment and observations were taken at 5 and 20°C.

Statistical analysis The data were analyzed using the Statistical Analysis System (SAS). Analysis of variance was used to determine statistical relationships among treatments. Significance was determined at p=0.05 level for all analysis. Treatment means were compared by Duncan's multiple comparison test.

Results and Discussion

Respiration rate The respiration rates of apples coated and uncoated are shown in Fig. 2. The respiration rates of uncoated apples were 4.76 and 20.75 mg CO_2/kg · hr at 5 and 20°C, respectively. Coated apples had lower respiration rates than those of uncoated. The respiration rates of apple coated with 0.5% chitosan were 2.60 and 15.57 mg CO_2/kg · hr at 5 and 20°C, respectively. The lowest respiration rates of 1.98 and 13.29 mg CO_2/kg · hr were shown for 1.5% chitosan coating at 5 and 20°C and were significantly (p<0.05) different from other coating treatments. Chitosan showed better coating effects than SPE in restricting respiration rate.

The respiration rates of 'Satsuma' mandarins, coated and uncoated, are showed in Fig. 3. The respiration rates of uncoated 'Satsuma' mandarins were 15.13 and 55.62 mg CO_2/kg · hr produced at 5 and 20°C, respectively, and higher than those of coated 'Satsuma'. The respiration rates were 14.57 and 54.07 mg CO_2/kg · hr for beeswax-A coated 'Satsuma' mandarins at 5 and 20°C, respectively, and were 13.84 and 53.71 mg CO_2/kg · hr for beeswax-B coated 'Satsuma' mandarins at 5 and 20°C, respectively. The

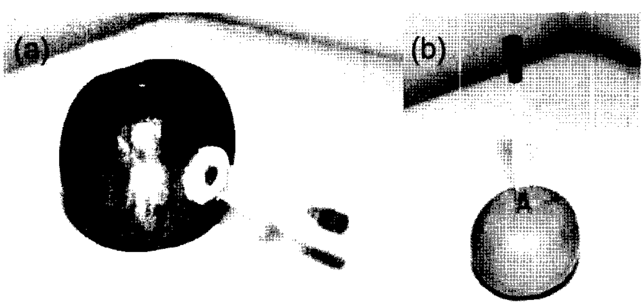

Fig. 1. Photograph of 'Fuji' apple (a) and 'Satsuma' mandarin (b) for internal gas composition.

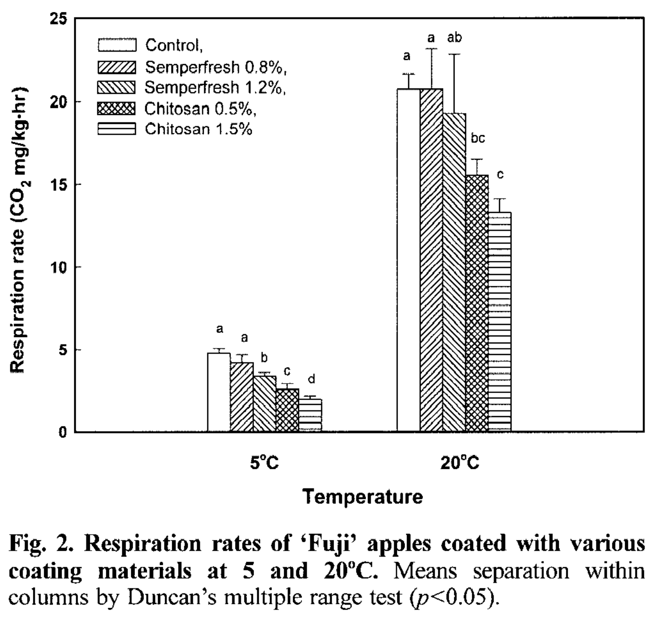

Fig. 2. Respiration rates of 'Fuji' apples coated with various coating materials at 5 and 20°C. Means separation within columns by Duncan's multiple range test (p<0.05).

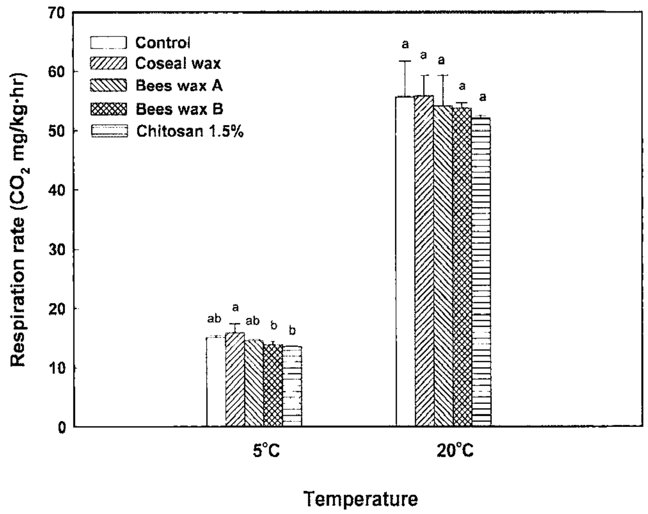

Fig. 3. Respiration rates of 'Satsuma' mandarins coated with various coating materials at 5 and 20°C. Means separation within columns by Duncan's multiple range test ($p<0.05$).

respiration rates were 13.45 and 52.10 mg CO_2/kg·hr for chitosan coated 'Satsuma' mandarins at 5 and 20°C, respectively. Cohen *et al.* (22) showed that the respiration rates of mandarin treated with the various wax formulations were lower than those of unwaxed mandarins. Ben-Yehoshua (14) found that the respiratory activity of waxed 'Shamouti' and 'Valencia' oranges declined during storage.

Edible coating on the surface of fruits and vegetables can provide an alternative to modified atmosphere storage. It can decrease respiration of fruits and vegetables by suppressing entrance of O_2.

Park (1) reported O_2 permeability of chitosan film is lower than that of SPE film. Hence apples coated with chitosan are suppressed respiratory activity and have lower respiration rate compared to that of apples coated with SPE. Chitosan can be effective coating material for extending shelf life of fresh fruits and vegetables by reducing respiration.

Internal gas composition Internal gas composition of fruits and vegetables is an indicator of quality change during storage (23). Internal O_2 and CO_2 compositions of coated and uncoated apple samples are given in Fig. 4. Required equilibrium times (when gas composition of the inside of the glass tube is constant) need to be determined by periodically monitoring gas changes inside the glass tubes. Equilibrium times can be expected to vary with variety, ripeness, temperature, and harvesting season for various fruits. In our study, internal gas compositions were observed and 12 hr were sufficient to achieve equilibrium conditions in the glass tubes attached to the fruits. After 24 hr, when complete equilibrium condition was constant, the internal CO_2 concentrations of uncoated apples were 1.61 and 5.85% at 5 and 20°C, respectively. SPE and chitosan coating treatments showed higher internal CO_2 level in comparison to the control. The internal CO_2 concentrations of apples coated with chitosan 1.5% were 3.43 and 8.64% at 5 and 20°C, respectively, and were the highest CO_2 concentration. Internal O_2 concentrations of uncoated apples were 20.6 and 15.62% at 5 and 20°C, respectively. Coated apples had lower internal O_2 levels than uncoated. Chitosan 1.5% coating (8.64 and 12.55%) also appeared to be the best effective gas barrier to O_2 ingress.

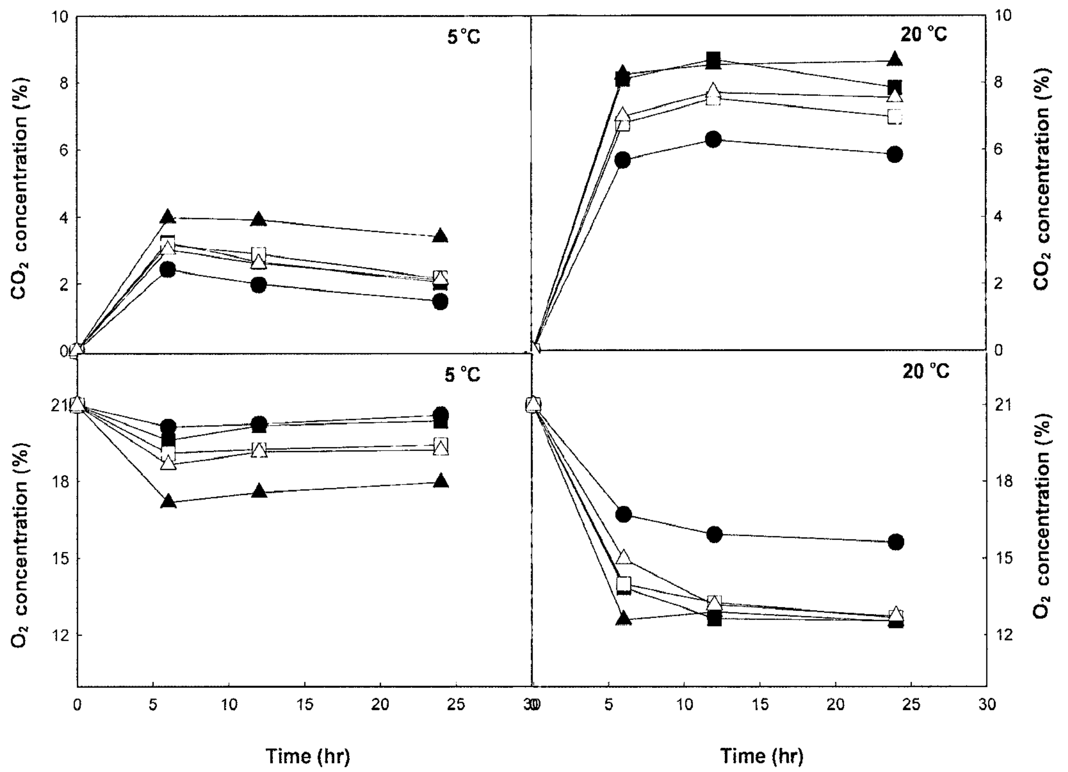

Fig. 4. Changes in internal gas compositions of 'Fuji' apples coated with various materials. ○, Control; □, Semperfresh 0.8%; ■, Semperfresh 1.2%; △, chitosan 0.5%; ▲, chitosan 1.5%.

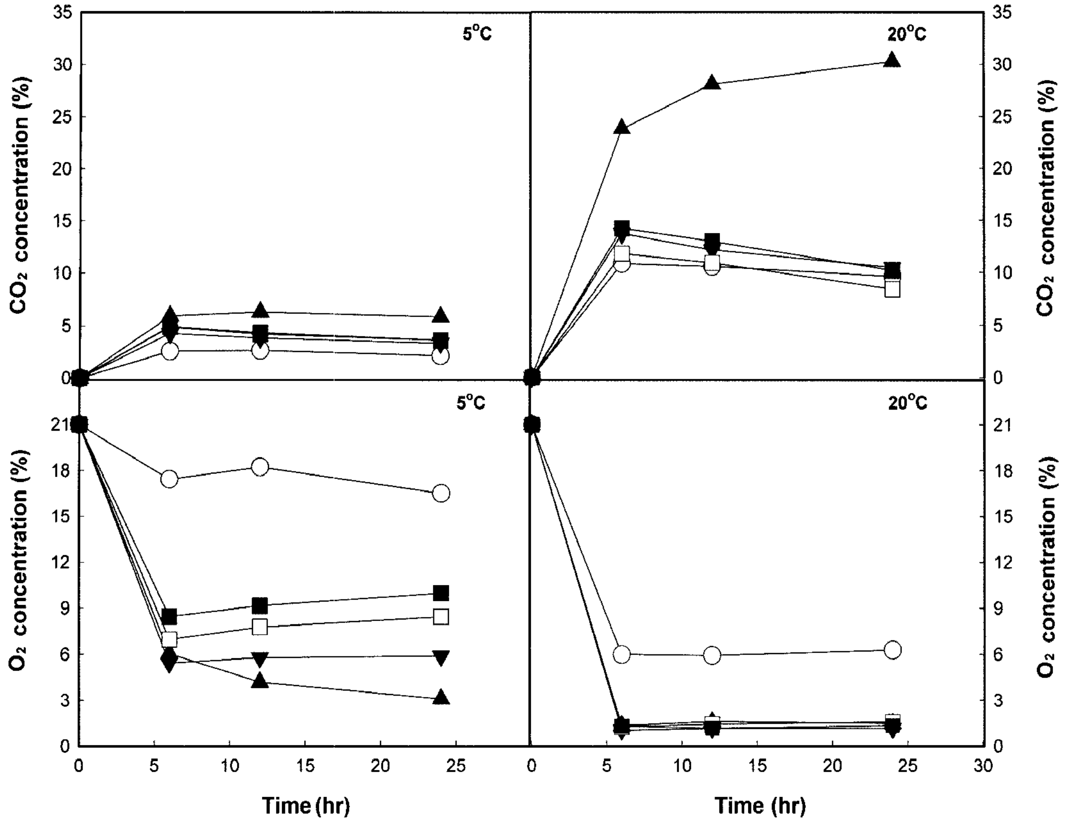

Fig. 5. Changes in internal gas compositions of 'Satsuma' mandarins coated with various materials. ○, Control; ▼, Coseal wax; □, beeswax A; ■, beeswax B; ▲, chitosan 1.5%.

In 'Satsuma' mandarin (Fig. 5), coating treatments also resulted in higher internal CO_2 levels and lower internal O_2 levels compared to uncoated fruit. After 24 hr, the internal CO_2 concentrations of uncoated 'Satsuma' mandarins were 2.13 and 9.64% at 5 and 20°C, respectively. Beeswax coating did not have significant effect on the internal CO_2 levels of 'Satsuma' mandarins. Chitosan coating had higher internal CO_2 concentrations compared to the control. Internal CO_2 concentrations of 'Satsuma' mandarins coated with chitosan solution were 5.84 and 30.26% at 5 and 20°C, respectively, and markedly higher than uncoated 'Satsuma' mandarins. However, in the case of the storage at 20°C, high concentration of CO_2 can lead to increase incidence of decay or flesh browning (18). Coated 'Satsuma' mandarins had lower O_2 concentrations than uncoated fruit at both temperatures. Although there were no significant differences among the internal O_2 concentrations between various coated fruit at 20°C, the internal O_2 levels of 1.5% chitosan coating were the lowest among all treatments (3.09 and 1.48% at 5 and 20°C, respectively). Chitosan coatings had significant ($p<0.05$) effect on the internal gas composition among all treatments. El Ghaouth *et al.* (24) reported that chitosan coating decreased the O_2 and raised the CO_2 concentrations within tomato fruit stored at 20°C, with a greater effect at the higher coating concentration.

Both of apples and 'Satsuma' mandarins coated with chitosan 1.5% had lower respiration rate and higher internal CO_2 concentration than those of coated fruits with other coating materials. Low O_2 and high CO_2 concentrations inside the coated fruits resulted from increased resistance to gas diffusion in the fruits peel (18). Chitosan coating on surface of the fruit may be effective for the reduction of permeability of peel to O_2 and CO_2, resulting in increased internal CO_2 and decreased internal O_2 inside the fruit, thereby restricting entrance of O_2 and reducing respiration rate and delaying ripening of fresh fruits and vegetables (25-27).

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