**Effect of Plasticizer Concentration and Solvent Types on Shelf-life of Eggs Coated with Chitosan**

**SU HYUN KIM, HONG KYOON NO, SOON DONG KIM, AND WITOON PRINYAWIWatKUL**

**ABSTRACT:** Effects of plasticizer concentrations (0, 0.5, 1.0, 1.5, and 2.0% glycerol) and solvent types (1% acetic and 1% lactic acid) on internal quality of eggs coated with 2% chitosan solution were evaluated during 5 wk of storage at 25°C. In comparison of plasticizer concentrations, eggs coated with chitosan dissolved in acetic acid containing 2% glycerol showed significant reduction in weight loss compared with the noncoated eggs during 5 wk of storage. At 2% glycerol, the Haugh unit and yolk index values suggested that chitosan-coated eggs can be preserved for at least 3 wk longer than the control noncoated eggs during 5 wk of storage at 25°C. Use of acetic acid rather than lactic acid as a chitosan solvent was more advantageous in view of shelf-life extension of eggs.

Keywords: chitosan-coated egg, Haugh unit, plasticizer, shelf-life, yolk index

**Introduction**

Eggs have long been consumed in a daily diet throughout the world (Cook and Briggs 1986). During storage of eggs, weight loss and interior quality deterioration are encountered. The movement of carbon dioxide and moisture through the shell governs quality changes in albumen and yolk and weight loss of eggs (Stadelman 1986b). To overcome these problems, considerable attention has been given to the development of coating materials from synthetic polymers (Rhim and others 1996; Obanu and Mpieri 1984). Films and coatings can act as a barrier for moisture, gas, and aroma transfer (Wan and others 2005).

Chitosan is a natural biopolymer derived by deacetylation of chitin, a major component of the shells of crustacea such as crab, shrimp, and crawfish. Chitosan has been documented to possess a film-forming property for use as edible films or coatings (Butler and others 1996; Cho and others 2002; Xie and others 2002; Rhim and others 2004), and oils (Knight and others 1972; Obanu and Mpieri 1984). Films and coatings can act as a barrier for moisture, gas, and aroma transfer (Wan and others 2005).

Chitosan coating decreased weight loss and increased shelf-life of eggs. Yolk and albumen quality of chitosan-coated eggs could be preserved, respectively, at least 2 and 3 wk longer than observed for the control noncoated eggs at 25°C (Bhale and others 2003; No and others 2005).

In preparation of edible films, plasticizer is often incorporated into films to induce flexibility, and glycerol is one of the most widely used plasticizers (Wan and others 2005). Studies have shown that the concentration, composition, size, and shape of the plasticizer affect the properties of films (Sothornvit and Krochta 2001; Thomazine and others 2005). Chitosan coating decreased weight loss and increased shelf-life of eggs. Yolk and albumen quality of chitosan-coated eggs could be preserved, respectively, at least 2 and 3 wk longer than observed for the control noncoated eggs at 25°C (Bhale and others 2003; No and others 2005).

**Materials and Methods**

**Materials**

Chitosan [molecular weight (Mw) = 440 kDa], acid-soluble and white-colored powder prepared from crab leg shell, was purchased from Kittto Life (Seoul, Korea). Unwashed, feces-free, brown-shell eggs (51.3 to 60.8 g with an average weight of 56.3 g) were obtained from a local poultry farm (Daegu, Korea) and immediately used for this experiment.

**Preparation of chitosan coating solutions and treatment of eggs**

Part I for evaluation of plasticizer effect, chitosan coating solutions were prepared in 1% (v/v) acetic acid at 2% (w/v) concentration with glycerol at a level of 0, 0.25, 0.5, 0.75, and 1.0 mL/g of chitosan (i.e., 0, 0.5, 1.0, 1.5, and 2.0% v/v). The viscosity of these chitosan solutions measured with a Brookfield viscometer, model LVDV-II+ (Brookfield Engineering Labs., Stoughton, Mass., U.S.A.) at 25 ± 0.3°C ranged 100 to 105 cP. Part II for comparison of effect of solvent types, chitosan solutions were prepared in 1% (v/v) acetic acid and/or lactic acid at 2% (w/v) concentration with 2% (v/v) glycerol. The measured viscosity of these chitosan solutions was 103 and 109 cP respectively. All solutions were freshly prepared before being applied to eggshells.

Eggs were weighed individually, coated with chitosan solutions using a sponge brush, and allowed to dry under a fan for 15 min. Noncoated eggs and eggs coated with 1% acetic and/or lactic acid were used as the control groups. All eggs (50 eggs/treatment) were...
placed in cardboard egg racks and stored in an incubator at 25 °C for 5 wk. Ten eggs per treatment were taken at 1-wk intervals for determination of weight loss, Haugh unit, and yolk index.

**Determination of weight loss**

For both control (noncoated or 1% organic acid-coated) and chitosan-coated eggs at various concentrations of glycerol, weight loss (%) of the whole egg during a 5-wk storage was calculated as [(initial whole egg weight (g) before coating at day 0 – whole egg weight (g) after storage)/initial whole egg weight (g) before coating at day 0] × 100.

**Determination of Haugh unit and yolk index**

The height of albumen and yolk was measured with a tripod micrometer (Model S-6428, B.C. Ames Inc., Melrose, Mass., U.S.A.), and the yolk width was measured with a digital caliper (CD-20B, Mitutoyo, Japan). The Haugh unit was calculated using the Haugh unit calculator converting egg weight and albumen height values to Haugh units. The yolk index was calculated as yolk height/yolk width (Lee and others 1996).

**Scanning electron microscope**

Shell surface of noncoated eggs (control) and eggs coated with chitosan dissolved in 1% acetic acid containing 2% glycerol was observed using a Scanning Electron Microscope (JSM-6335F, Joel, Japan) after gold coating with a carbon coater (108-CA, Joel, Japan).

**Statistical analysis**

Data were analyzed using ANOVA, followed by the Duncan's multiple-range test using the SPSS (Statistical Package for Social Sciences, SPSS Inc., Chicago, Ill., U.S.A.) software package. Mean ± standard deviation values were reported based on 10 measurements (eggs) per treatment.

**Results and Discussion**

**Effect of plasticizer on weight loss**

The weight loss of control (noncoated and 1% acetic acid-coated) and chitosan-coated eggs at various concentrations of plasticizer (glycerol) during 5 wk of storage at 25 °C is shown in Table 1. For all eggs, the weight loss significantly (P < 0.05) increased with increasing storage periods, ranging from 7.74% to 10.21% after 5 wk. During 5 wk of storage, significant differences in weight loss were not observed between noncoated and 1% acetic acid–coated eggs, as also observed by No and others (2005), except at 4 wk. Without exception, there were no significant weight losses observed among chitosan-coated eggs at 0, 0.5, 1.0, and 1.5% glycerol throughout the 5 wk of storage. Compared with the noncoated eggs, chitosan-coated eggs with 2% glycerol significantly prevented weight loss throughout the 5 wk of storage period. These eggs also showed less weight loss than chitosan-coated eggs without glycerol after 4 and 5 wk of storage.

In our present study, weight loss of noncoated and chitosan-coated eggs without glycerol was 10.21 and 9.38%, respectively, after 5 wk of storage at 25 °C. Under the same storage conditions, No and others (2005) also similarly observed that the corresponding weight loss was 10.45 and 8.57% to 11.52%, respectively. On the other hand, Bhale and others (2003) reported that weight loss of noncoated and chitosan-coated eggs without plasticizer was 7.84 and 6.69% to 7.17%, respectively, after 5 wk of storage at 25 °C. Differences in weight loss among these studies may be due to differences in chitosan products used, initial egg quality (egg grade, Haugh unit, yolk index), and egg size (Mueller 1958).

Weight loss of eggs during storage is caused by the evaporation of water and loss of carbon dioxide from the albumen through the shell (Obanu and Mpieri 1984; Stadelman 1986b). Characteristics of chitosan film, made by dissolving chitosan in 1% acetic acid, vary depending on the amount of plasticizer (Rhim and others 1998), and, therefore, may affect its efficacy as a coating material on eggs. The shell of chitosan-coated eggs showed minimal surface porosity (Figure 1), which contributed to less weight loss during storage. This study shows that chitosan coating, especially with 2% glycerol, may offer a protective barrier against transfer of carbon dioxide and moisture through the eggshell, thus minimizing weight loss and extending the shelf life of eggs (Lee and others 1996).

**Effect of plasticizer on Haugh unit**

The Haugh unit is an expression relating egg weight and height of the thick albumen, and used for measurement of the albumen quality. The higher the Haugh value, the better the albumen quality of the eggs (Stadelman 1986a).

Changes in the Haugh unit of control and chitosan-coated eggs at various concentrations of glycerol during 5 wk of storage at 25 °C are noted in Table 2. Overall, the Haugh unit decreased with increasing storage periods. The loss of albumen quality is largely attributed to the initial albumen quality and the movement of water from albumen to yolk (Mueller 1959). During 5 wk of storage, significant differences in the Haugh unit were not observed between noncoated and 1% acetic acid–coated eggs. Compared with the noncoated eggs, chitosan-coated eggs, irrespective of glycerol concentrations, generally had higher Haugh units during 5 wk of storage. These results support previous observations by Lee and others (1996), Bhale and others (2003), and No and others (2005), who reported that chitosan

**Table 1 – Effect of plasticizer concentrations on weight loss (%) of chitosan-coated eggs during a 5-wk storage at 25 °C**

<table>
<thead>
<tr>
<th>Coating</th>
<th>1 wk</th>
<th>2 wk</th>
<th>3 wk</th>
<th>4 wk</th>
<th>5 wk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Noncoated</td>
<td>2.23 ± 0.26a</td>
<td>3.77 ± 0.73bc</td>
<td>6.24 ± 0.73bc</td>
<td>7.38 ± 0.58bc</td>
<td>10.21 ± 2.29d</td>
</tr>
<tr>
<td>1% acetic</td>
<td>2.22 ± 0.23a</td>
<td>3.93 ± 0.39a</td>
<td>6.45 ± 0.89a</td>
<td>8.56 ± 0.84a</td>
<td>9.74 ± 1.00ab</td>
</tr>
<tr>
<td>Chitosan</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glycerol (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.0</td>
<td>1.85 ± 0.36a</td>
<td>3.53 ± 0.39abc</td>
<td>5.62 ± 0.88abc</td>
<td>7.27 ± 0.56bc</td>
<td>9.38 ± 1.82bcd</td>
</tr>
<tr>
<td>0.5</td>
<td>1.72 ± 0.19a</td>
<td>3.17 ± 0.39a</td>
<td>5.32 ± 0.88a</td>
<td>7.11 ± 1.24a</td>
<td>8.04 ± 1.41ab</td>
</tr>
<tr>
<td>1.0</td>
<td>1.72 ± 0.34a</td>
<td>3.54 ± 0.82abc</td>
<td>5.16 ± 0.88a</td>
<td>7.12 ± 1.06a</td>
<td>8.98 ± 1.31abc</td>
</tr>
<tr>
<td>1.5</td>
<td>1.69 ± 0.22a</td>
<td>3.28 ± 0.72abc</td>
<td>5.09 ± 0.62a</td>
<td>6.87 ± 1.46ab</td>
<td>8.29 ± 1.21abc</td>
</tr>
<tr>
<td>2.0</td>
<td>1.65 ± 0.21a</td>
<td>2.97 ± 0.38a</td>
<td>5.01 ± 0.60a</td>
<td>6.14 ± 0.51a</td>
<td>7.74 ± 1.16a</td>
</tr>
</tbody>
</table>

*Means ± standard deviations of 10 measurements. Chitosan was dissolved in 1% acetic acid.

**Means with different superscripts within a column indicate significant differences (P < 0.05).**

All means among storage periods in each row were significantly different (P < 0.05) from one another; superscript letters not shown.
coating was effective in preserving the albumen quality of eggs. Among chitosan-coated eggs, those with plasticizer (glycerol) added at 2% glycerol showed higher Haugh units than did the nonplasticized eggs after 4 and 5 wk of storage.

After 2 wk of storage, the Haugh unit decreased from an initial value of 94.22 to 57.98 for noncoated eggs. The Haugh unit (60.71) of chitosan-coated eggs at 2% glycerol after 5 wk of storage was similar to that of noncoated eggs after 2 wk of storage. However, the Haugh unit (49.68) of chitosan-coated eggs without glycerol after 5 wk of storage was comparable to that (48.86) of noncoated eggs after 3 wk of storage. This implies that chitosan coating with 2% glycerol is more effective in preserving the albumen quality of eggs than chitosan coating without glycerol. In this study, chitosan coating with 2% glycerol could preserve the albumen quality of coated eggs for at least 3 more weeks compared with the noncoated eggs (Table 2).

Effect of plasticizer on yolk index

A yolk index value, calculated as yolk height/yolk width, is an indication of freshness of eggs (Stadelman 1986a). A decrease in a yolk index value during storage indicates a progressive weakening of the vitelline membranes and liquefaction of the yolk caused mainly by diffusion of water from the albumen (Obanu and Mpieri 1984).

Table 3 shows changes in yolk index of control and chitosan-coated eggs at various concentrations of glycerol during 5 wk of storage at 25°C. Overall, the yolk index decreased with increasing storage periods, as also observed for the Haugh unit (Table 2). During 5 wk of storage, significant differences in the yolk index were not observed between noncoated and 1% acetic acid–coated eggs, except for 1 wk. Compared with the noncoated eggs, chitosan-coated eggs, irrespective of glycerol concentrations, showed significantly higher yolk index during 2 to 5 wk of storage. Among chitosan-coated eggs, those with 2% glycerol generally showed higher yolk index.
than the ones with other concentrations of glycerol during 5 wk of storage.

The yolk index of chitosan-coated eggs without glycerol in our present studies decreased by 0.23 (from 0.51 to 0.28) after 5 wk of storage (Table 3). According to previous reports, yolk index of 2% chitosan-coated eggs without plasticizer dropped by 0.16 to 0.27 (from an initial value of 0.48) (No and others 2005) and 0.07 to 0.09 (from 0.38) (Bhale and others 2003) after 5 wk of storage at 25 °C, and by 0.21 (from 0.51) after 30 d of storage at 20 °C (Lee and others 1996). The discrepancies found among these studies may be due to differences in chitosan products used, initial egg quality (egg grade, Haugh unit, yolk index), egg size, storage temperature, and storage period (Mueller 1958).

The yolk index (0.35) of chitosan-coated eggs with 2% glycerol after 5 wk of storage was similar to that (0.36) of noncoated eggs after 2 wk of storage. This suggests that chitosan coating with 2% glycerol helps preserve the yolk quality of coated eggs for at least 3 wk longer than observed for noncoated eggs.

Results from Tables 1 to 3 collectively indicated that chitosan-coated eggs with 2% glycerol reduced weight loss and preserved the quality of albumen and yolk for at least 3 wk longer than observed for the noncoated eggs. Therefore, the subsequent study on the effects of solvent types (acetic vs lactic) on weight loss, Haugh unit, and yolk index of chitosan-coated eggs was done at a fixed 2% glycerol (v/v) level.

### Effect of solvent types on weight loss

For comparison of solvent types effect, chitosan solutions were prepared in 1% (v/v) acetic and/or lactic acid at 2% (w/v) concentration with 2% (v/v) glycerol and applied to eggs for coating. During 5 wk of storage, no significant differences in weight loss were observed among noncoated and 1% acetic and lactic acid–coated eggs, except at 4 wk (Table 4). For chitosan-coated eggs at 2% glycerol, significant differences in weight loss were not observed between acetic and lactic acid after 5 wk of storage. However, chitosan-coated eggs, regardless of solvent types, significantly preserved quality compared to control eggs.

### Effect of solvent types on Haugh unit and yolk index

During 5 wk of storage, significant differences in the Haugh unit were not observed between 1% acetic and lactic acid–coated eggs, except at 2 wk (Table 5). In comparison of chitosan-coated eggs, however, acetic acid had higher Haugh unit than lactic acid after 4 and 5 wk of storage. For yolk index, there were no significant

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### Table 2 — Effect of plasticizer concentrations on Haugh unit of chitosan-coated eggs during a 5-wk storage at 25 °C

<table>
<thead>
<tr>
<th>Coating</th>
<th>0 wk</th>
<th>1 wk</th>
<th>2 wk</th>
<th>3 wk</th>
<th>4 wk</th>
<th>5 wk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>94.22 ± 6.72</td>
<td>94.22 ± 6.72</td>
<td>94.22 ± 6.72</td>
<td>94.22 ± 6.72</td>
<td>94.22 ± 6.72</td>
<td>94.22 ± 6.72</td>
</tr>
<tr>
<td>1% acrylic</td>
<td>94.22 ± 6.72</td>
<td>94.22 ± 6.72</td>
<td>94.22 ± 6.72</td>
<td>94.22 ± 6.72</td>
<td>94.22 ± 6.72</td>
<td>94.22 ± 6.72</td>
</tr>
</tbody>
</table>

### Table 3 — Effect of plasticizer concentrations on yolk index of chitosan-coated eggs during a 5-wk storage at 25 °C

<table>
<thead>
<tr>
<th>Coating</th>
<th>0 wk</th>
<th>1 wk</th>
<th>2 wk</th>
<th>3 wk</th>
<th>4 wk</th>
<th>5 wk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.51 ± 0.04</td>
<td>0.51 ± 0.04</td>
<td>0.51 ± 0.04</td>
<td>0.51 ± 0.04</td>
<td>0.51 ± 0.04</td>
<td>0.51 ± 0.04</td>
</tr>
<tr>
<td>1% acrylic</td>
<td>0.51 ± 0.04</td>
<td>0.51 ± 0.04</td>
<td>0.51 ± 0.04</td>
<td>0.51 ± 0.04</td>
<td>0.51 ± 0.04</td>
<td>0.51 ± 0.04</td>
</tr>
</tbody>
</table>

### Table 4 — Effect of solvent types on weight loss (%) of eggs coated with chitosan containing 2% glycerol during a 5-wk storage at 25 °C

<table>
<thead>
<tr>
<th>Coating</th>
<th>1 wk</th>
<th>2 wk</th>
<th>3 wk</th>
<th>4 wk</th>
<th>5 wk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>2.23 ± 0.26</td>
<td>2.23 ± 0.23</td>
<td>2.09 ± 0.17</td>
<td>1.65 ± 0.21</td>
<td>1.38 ± 0.34</td>
</tr>
<tr>
<td>1% acrylic</td>
<td>2.23 ± 0.23</td>
<td>2.09 ± 0.17</td>
<td>1.65 ± 0.21</td>
<td>1.38 ± 0.34</td>
<td></td>
</tr>
<tr>
<td>1% lactic</td>
<td>2.23 ± 0.23</td>
<td>2.09 ± 0.17</td>
<td>1.65 ± 0.21</td>
<td>1.38 ± 0.34</td>
<td></td>
</tr>
</tbody>
</table>
differences between 1% acetic acid and lactic acid–coated eggs during 5 wk of storage (Table 6). In comparison of chitosan-coated eggs at 2% glycerol, acetic acid had higher yolk index than lactic acid after 4 and 5 wk of storage, as also observed for Haugh unit (Table 5).

Table 5 indicates that acetic acid is more effective in preserving the quality of albumen and yolk than lactic acid as a chitosan solvent for chitosan-coated eggs at 2% glycerol. Acetic acid has often been used as a solvent for the production of chitosan films (Canel and others 1998). Chitosan films made with acetic acid have greater tensile strength, and lower water vapor and oxygen permeability than those made with lactic acid (Rhim and others 1998; Park and others 2002).

Conclusions

Chitosan coating containing glycerol was effective in preserving the internal quality of eggs. Chitosan coating with 2% glycerol increased the shelf life of eggs by at least 3 wk at 25 °C compared with that of noncoated eggs. Use of acetic acid rather than lactic acid as a chitosan solvent was more advantageous in view of shelf-life extension of eggs. Further investigations are needed to focus on various types of plasticizers, since different types of plasticizers may influence mechanical and permeation properties of chitosan film or coating, and, thus, affecting the internal quality of coated eggs.

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