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Viscosity changes of chitosan solution affect physico-functional properties and consumer perception of coated eggs during storage

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ABSTRACT

Effects of storage of chitosan (CH) solution on physico-functional properties and consumer perception of CH-coated eggs were evaluated during 5- and 15-weeks storage at 25 °C and 4 °C, respectively. Seven treatments [CH0 (freshly-prepared), CH1 (stored for 1-week at 25 °C), CH1R (1-week, 4 °C), CH3 (3-weeks, 25 °C), CH3R (3-weeks, 4 °C), CH5 (5-weeks, 25 °C), CH5R (5-weeks, 4 °C)] were applied on eggshell. After 5-weeks storage, CH-solution viscosity decreased by 2.56 and 4.6 times, respectively, at 4 °C and 25 °C while pH slightly increased. CH0 preserved grade-A quality for 4-weeks vs. 1-week for noncoated eggs at 25 °C. After 5-weeks, weight loss (%) of coated eggs at 25 °C (6.04–5.59) was lower than that of noncoated eggs (7.44) but higher than that of all eggs at 4 °C (2.93–2.46). Albumen pH increased while emulsion capacity decreased with increased storage time; however, both were insignificantly affected by CH viscosity. Consumers perceived CH0- and CH1R-eggshell to be glossier than noncoated eggs after 5-weeks. Purchase intent was higher for CH-coated eggs (72–77.3%) than for noncoated eggs (61.3%). Overall, viscosity changes of CH-coating solution had lesser impact on quality of CH-coated eggs than did storage temperature/time of eggs.

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1. Introduction

The use of polysaccharides in the food industry as biodegradable edible coatings has received increased attention over the past decade. Amongst biopolymers, chitosan (CH), a partially deacetylated derivative of chitin, has been noted for its inherent film-forming, antimicrobial, and oxygen barrier properties (Butler, Vergano, Testin, Bunn, & Wiles, 1996; Kim, No, & Prinyawiwatkul, 2007; No, Park, Lee, & Meyers, 2002), and has been successfully applied as a coating to improve food quality and to extend food shelf-life. Commercial applications of CH are influenced by its viscosity in solution. CH viscosity was significantly affected when it was subjected to physical (e.g., heating, autoclaving, ultrasonication) and chemical (e.g., ozone) treatments, and decreased with an increase in treatment time and temperature (No, Kim, Kim, Kim, & Meyers, 1999). No, Kim, Lee, Park, & Prinyawiwatkul (2006) reported that, a decrease in CH viscosity with increased storage time corresponded to a decrease in antibacterial activity against gram-positive (*Listeria monocytogenes* and *Staphylococcus aureus*) and gram-negative (*Salmonella* Enteritidis and *Escherichia coli*) bacteria during 15-weeks storage at 4 °C and 25 °C, and solutions stored at 25 °C possessed similar or weaker antibacterial activity compared to 4 °C.

Eggs contribute an inexpensive source of high quality protein for the human diet but are highly perishable as pores in the shell allow for mass exchange with the surrounding environment (Stadelman, 1995b). CH solution has been used as a fast-drying coating to modify the internal atmosphere and successfully extend the shelf-life of eggs (Bhale et al., 2003; Caner & Cansiz, 2008; Kim, Youn, No, Choi, & Prinyawiwatkul, 2009; No, Prinyawiwatkul, & Meyers, 2005; Torrico et al., 2010; Wardy, Torrico, Prinyawiwatkul, No, & Saalia, 2010). To effectively utilise CH as a coating material to preserve internal quality of eggs, factors that may influence its barrier and coating properties on eggs need to be elucidated.

Functionality of CH as an edible coating may also be affected by its initial viscosity and viscosity and pH changes during storage. Due to the time-consuming nature of CH solution preparation, especially from high molecular weight CHs, it would be practical to prepare CH-solutions in bulk and to store them for commercial applications (No et al., 2006). Effects of storage time and temperature of CH solution on its effectiveness as an edible coating to extend egg shelf-life have not been reported in the literature.

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The objective of this work was to evaluate the effects of storage time and temperature of CH solution on physico-functional properties and consumer perception of CH-coated eggs during storage at 25 °C and 4 °C.

2. Materials and methods

2.1. Materials

α-CH (molecular weight of 1110 kDa, acid soluble and white-coloured powder prepared from crab leg shell) was purchased from Kitto Life (Seoul, Korea). White-shelled unwashed, faeces-free eggs within the weight range of 50–70 g per egg (to reduce variation) were obtained from Cal Maine Foods (Jackson, MS, USA).

2.2. Preparation of CH-solutions and storage tests

CH powder was dried at 60 °C for 4 h in a forced-air oven, and dissolved in 1 mL/100 mL acetic acid at 1 g/100 mL concentration with continuous stirring for 5 h at room temperature. CH-solutions were prepared, stored in screw-capped glass bottles at 25 ± 2 °C and 4 ± 2 °C for 5 weeks, and taken weekly for pH and viscosity determination. Viscosity in centipoise (cP) units was measured at 24 ± 0.5 °C with a viscometer (model DV-II+, Brookfield Engineering Labs Inc., Middleboro, MA, USA) at 20 rpm using an RV-I spindle, with data gathered in Wingather V2.1 software (Brookfield Engineering Labs Inc.). Triplicate measurements (20 readings each) were recorded. The rate of decline of viscosity expressed in percentage was calculated as [(the difference in viscosity between the start and end of storage) × 100]/the number of weeks. pH was measured in triplicate (3 readings each) using a pH meter (Accumet® AP61, Fisher Scientific, Pittsburgh, PA, USA). To simplify the experiment, CH-solutions after 0, 1, 3 and 5 weeks of storage, exhibiting different viscosities, were selected as coating materials.

2.3. Experimental design and storage of eggs

Each egg was weighed with a balance (Model TS400S, Ohaus Corp., Florham Park, NJ, USA) and randomly assigned to one coating treatment [control uncoated, CH0 (freshly-prepared), CH1 (chitosan solution stored for 1-week at 25 °C), CH1R (1-week, 4 °C), CH3 (3-weeks, 25 °C), CH3R (3-weeks, 4 °C), CH5 (5-weeks, 25 °C), and/or CH5R (5-weeks, 4 °C)]. CH solution was applied to the surface of each egg using a sponge brush. After coating, eggs were left to dry on racks in the horizontal position at room temperature. Upon drying, the coated eggs were placed small end down (Kim et al., 2009) on egg racks and stored at 25 ± 2 °C and/or 4 ± 2 °C. Quality measurements were done on twelve eggs per treatment weekly for 5 weeks at 25 °C and at intervals of 5 weeks for 15 weeks at 4 °C.

2.4. Measurement of physico-functional quality

2.4.1. Haugh unit, yolk index, weight loss and albumen pH

The weight (W) of the egg (g) was measured using a balance (Model TS400S, Ohaus Corp., Florham Park, NJ, USA). The height of yolk (mm) and albumen (H, mm) was measured using a tripod micrometer (Model S-6428, B.C. Ames Inc., Melrose, MA, USA). The Haugh unit was calculated as 100 log ($H - 1.7W^{0.37} + 7.57$) (Haugh, 1937). The rate of decline of the Haugh unit was calculated as the difference in Haugh unit between the start and end of storage divided by the number of weeks. Egg grade was based on the United States Standards for Quality of Individual Shell Eggs (USDA, 2000). A digital caliper (General Tools & Instruments, NY, USA) was used to measure the yolk width (mm), and the yolk index computed as [yolk height (mm)/yolk width (mm)] (Stadelman, 1995a).

Weight loss (%) of whole eggs during storage was calculated as {[initial whole egg weight (g, with or without coating) at day 0 − whole egg weight (g, with or without coating) after storage]/initial whole egg weight (g, with or without coating) at day 0} × 100. The albumen pH was measured using a pH meter (Accumet® AP61, Fisher Scientific, Pittsburgh, PA, USA).

2.4.2. Emulsion capacity (EC)

EC of egg yolk was determined following the method of Waimaleongora-Ek, Garcia, No, Prinyawiwatkul, & Ingram (2009). Red-coloured oil was used to enhance view of emulsion collapse, and was prepared by adding 0.3 g of biological stain (Oil Red O, 19819-6; Sigma–Aldrich, St. Louis, MO, USA) to a litre of soybean oil (Great Value®; WalMart, AR, USA). Fifteen grams of yolk (from a pool of three eggs) was mixed with 20 mL of soybean oil and 10 mL of vinegar and emulsified at high speed using a hand blender (Hamilton Beach, Model 59780; Southern Pines, NC, USA) for 2 min. Then, 2 g of the resulting emulsion was taken and emulsified with 9 mL of 0.1 mol/L NaCl solution and 30 mL of red-coloured oil at low speed for 2 min. Additional red-coloured oil was dispensed from a burette at a speed of 0.1 mL s^{-1} while stirring at low speed until the emulsion broke. The breakpoint at which phase inversion occurred was considered as EC (Prinyawiwatkul, Beuchat, McWatters, & Phillips, 1997). EC was expressed as mL of soybean oil added per g of egg yolk. Three measurements from each of the three replicates (three eggs were used for each replicate) were made for each treatment.

2.4.3. Shell colour

Colour of the eggshell was measured using a portable Minolta spectrophotometer (Model CM-508d, Minolta Camera Co. Ltd., Osaka, Japan) with 2° standard observer and D_{65} illuminant during 5 weeks storage at 25 °C and 4 °C. Results were recorded as L^* (lightness), a^* (+ for redness and − for greenness) and b^* (+ for yellowness and − for blueness), and expressed as whiteness index ($WI = 100 - [(100 - L^*)^2 + a^{*2} + b^{*2}]^{1/2}$) and the magnitude of colour differences between stored eggshell and their day 0 (reference) values ($\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$) where $\Delta L^* = L^*_{\text{treatment}} - L^*_{\text{reference}}$; $\Delta a^* = a^*_{\text{treatment}} - a^*_{\text{reference}}$; $\Delta b^* = b^*_{\text{treatment}} - b^*_{\text{reference}}$. Three measurements from each of three replicates were made at the same randomly selected locations weekly for each treatment and averaged.

2.5. Sensory analysis and consumer purchase intent

75 consumers were recruited from Baton Rouge, Louisiana, USA to participate in the sensory discrimination of the seven CH-coated eggs (CH0, CH1, CH1R, CH3, CH3R, CH5, CH5R) compared with the control noncoated eggs after 5 weeks of storage at 25 °C. Consumers were first presented with a labelled control egg, followed by unlabelled coated eggs and one unlabelled control (to determine the "noise" level). The unlabelled eggs were independently compared to the labelled control for specified attributes. For surface smoothness and glossiness, consumers were asked to indicate whether the unlabelled coated and control eggs were perceived as "more," "the same," or "less" in the specified attribute compared with that of the labelled control, and whether they were "sure" or "unsure" about their decision; in this case, as the direction of a given attribute was of interest, the bipolar R-index was used. For surface odour, colour and overall difference, consumers were asked if the unlabelled coated and unlabelled control eggs were "different from" or "the same as" the labelled control, and whether their decision was "sure" or "unsure"; in this case, as the direction of a given attribute was not relevant, the unipolar R-index was used (Bhale et al., 2003; Bi & O'Mahony, 2007). Afterwards, these

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