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Quality of eggs coated with oil–chitosan emulsion: Combined effects of emulsifier types, initial albumen quality, and storage

Damir Dennis Torrico [a], Wisdom Wardy [a], Kennet Mariano Carabante [a], Kairy Dharali Pujols [a], Zhimin Xu [a], Hong Kyoon No [b], Witoon Prinyawiwatkul [a,*]

[a] School of Nutrition and Food Sciences, Louisiana State University Agricultural Center, Baton Rouge, LA 70803-4200, USA
[b] Department of Food Science and Technology, Catholic University of Daegu, Hayang 712-702, Republic of Korea

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ABSTRACT

Effects of mineral oil:chitosan (MO:CH at 25:75) emulsions prepared with four different emulsifiers (2 water- and 2 oil-miscible) as coatings on the internal quality (weight loss, Haugh unit, yolk index, and albumen pH) of coated eggs were evaluated during 5 weeks at 25 ± 2 °C and 20 weeks at 4 ± 2 °C. Eggs with two initial albumen qualities [Haugh unit (HU): $H = 87.8$ and $L = 70.9$] were used. At 25 ± 2 °C, Haugh unit, yolk index, and albumen pH of all coated eggs decreased with increased storage time. Coated H- and L-eggs maintained an *A*-grade up to 4 weeks and 1 week, respectively. Weight loss of all coated eggs remained below 1.35% after 5 weeks of storage at 25 ± 2 °C. All coated eggs maintained an *A*-grade with less than 2.5% weight loss during 20 weeks of storage at 4 ± 2 °C. Emulsifier types marginally affected the internal quality of coated eggs regardless of storage temperatures.

1. Introduction

The United States (US) is one of the major producers of eggs worldwide. According to the USDA Economics, Statistics, and Market Information System (USDA, 2013), the US production of table eggs in 2012 was 6.68 billion dozen compared to 6.60 billion dozen in 2011. Eggs are highly susceptible to internal quality deterioration mainly due to loss of moisture and, to a lesser extent, carbon dioxide through the eggshell pores, causing undesirable quality changes in albumen and yolk, and the overall weight loss (Stadelman, 1995b). In the US, eggs are required to be refrigerated at 7 °C or below to preserve the albumen and yolk quality, and to retard weight loss (Jirangrat, Torrico, No, No, & Printawiwatkul, 2010; Wardy et al., 2011). Refrigeration can effectively reduce by half the weight loss of eggs compared to room temperature storage, and refrigerated eggs can maintain a quality grade of *AA* for at least 4 weeks (Biladeau & Keener, 2009). However, in many countries (such as Thailand, Republic of Korea, and Brazil), refrigeration of eggs is not required by law (Hong et al., 2012; Mizumoto & Zylbersztajn, 2004) and may be seldom practiced. Therefore, coating is alternatively an effective method to preserve egg internal quality, and may help to reduce energy cost incurred by refrigeration of eggs during storage.

Coating materials have been applied to the eggshell surface for preserving the internal quality of eggs. These materials include synthetic polymers (Meyer & Spencer, 1973), polysaccharides (Bhale et al., 2003; Wardy, Pujols, Xu, No, & Prinyawiwatkul, 2014), proteins (Rhim, Weller, & Gennadios, 2004) and oils (Obanu & Mpieri, 1984; Waimaleongora-Ek, Garcia, No, Prinyawiwatkul, & Ingram, 2009). Our preliminary work demonstrated that an emulsion coating prepared from mineral oil (MO) and chitosan solution (CH) at a ratio of 25:75 was able to extend egg shelf-life longer than was chitosan solution coating alone. Additionally, the drying time of the emulsion on the eggshell is considerably reduced compared to MO alone.

In addition to emulsion coating materials, initial albumen quality of eggs, emulsifier types used in emulsion preparation, and egg storage conditions may affect internal quality of eggs; however, very few studies have been done in this area. Sabrani and Payne (1978) observed a significant interaction ($P < 0.05$) between age of hens (eggs from younger vs. older hens, having different initial albumen qualities) and coating material (linseed oil) on internal egg quality during 24 days of storage at 28 °C. From the published literature, there is no information available on the interaction between the emulsifier types used for preparing emulsion coating and the initial albumen qualities (expressed as Haugh unit) before coating and their combined effects on shelf-life of eggs during storage.

* Corresponding author. Tel.: +1 225 578 5188; fax: +1 225 578 5300.
E-mail address: wprinya@lsu.edu (W. Prinyawiwatkul).

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Therefore, the objective of this study was to evaluate the effects of MO:CH (25:75) emulsion coatings prepared with four different emulsifiers (2 water- and 2 oil-miscible) in preserving the internal quality of coated eggs (with two different initial albumen qualities before coating) during 5 weeks storage at 25 ± 2 °C and during 20 weeks of storage at 4 ± 2 °C.

2. Materials and methods

2.1. Materials

Mineral oil (viscosity = 34 mPa s; transparent, odourless and food-grade) was obtained from Ste Oil Company® Inc. (San Marcos, TX, USA). Chitosan (molecular weight = 223 kDa), acid soluble and white-coloured powder prepared from crab leg shell, was purchased from Biotech (Mokpo, Republic of Korea). Four emulsifiers included two oil-miscible types: (1) Tandem® 552K (a mixture of mono and diglycerides, polysorbate, water and propyl gallate; Caravan® ingredients, Lenexa, KS, USA), (2) Tween 80 (Polyoxyethylene-20-sorbitan monooleate, reagent grade; Amresco® Inc., Solon, OH, USA), and two water-miscible types: (3) TIC Pretested®Ticaloid®210 S Powder (gum acacia and xanthan gum; TIC Gums®, Inc., White Marsh, MD, USA), and (4) Eficacia XE (Acacia gum purified and instantised; Colloides Naturels International, Rouen Cedex, France). These emulsifiers were previously screened among others in their ability to form a stable emulsion between mineral oil (MO) and chitosan (CH) at a ratio of MO:CH = 25:75.

Faeces-free, white-shell eggs were obtained from two different batches of hens (52- and 54-weeks old Hyline W-36 hens; Cal-Maine Foods, Jackson, MS, USA). All eggs came from 2 different rows of the cage within the same facility. Five eggs from each row were randomly assigned to each treatment (a total of 10 eggs; 5 eggs per each of the two replicates). After collection from the farm and screening for defects and desirable weight range (50–70 g), eggs with two different initial albumen qualities (expressed as Haugh unit) before coating were selected: *H* = eggs from 52-weeks old hens with Haugh unit of 87.8, and *L* = eggs from 54-weeks old hens with Haugh unit of 70.9.

Chitosan solution was prepared at 2 g/100 mL concentration by dissolving chitosan in 1 mL/100 mL acetic acid (Kim, Youn, No, Choi, & Prinyawiwatkul, 2009). Four MO:CH emulsions were prepared at a fixed ratio of 25:75 by adding 1 g/100 g of each of the four different emulsifiers as described in following procedures: Emulsifiers Tandem® 552K and Tween 80 were added to MO and mixed using a hand blender (Model # 59780R, Hamilton Beach® Brands Canada, Inc., Picton, Ontario, Canada) at a low speed for 2 min at 25 °C; the mixture stood for 30 min at room temperature, and subsequently CH was added and mixed using the hand blender at a high speed for 6 min at 25 °C. Conversely, Tic Pretested®Ticaloid®210 S Powder and Eficacia XE were added to CH, mixed at a low speed for 2 min, stood for 30 min, and mixed with MO at a high speed for 6 min using a hand blender at 25 °C. The CH and all emulsions were prepared on the day of the coating experiment.

2.2. Coating treatment and storage of eggs

Eggs were individually weighed with a balance (TS400, Ohaus Corp., Florham Park, NJ, USA), coated with MO:CH (25:75) emulsion by using a sponge brush. Four coating treatments were evaluated throughout the storage periods: (1) TANDEM = coating with emulsion containing Tandem® 552K, (2) TWEEN = coating with emulsion containing Tween 80, (3) TIC = coating with emulsion containing TIC Pretested® Ticaloid®210 S Powder, and (4) EFICACIA = coating with emulsion containing Eficacia XE. Data for noncoated eggs were not reported in this study. After coating, all eggs were allowed to dry overnight, then placed in a small-end down position (Kim et al., 2009) on cardboard egg racks and stored at room temperature (25 ± 2 °C) and in a cold room at 4 ± 2 °C. Based on previous (Jirangrat et al., 2010) and preliminary studies which demonstrated that internal qualities of coated eggs would exhibit similar trends under refrigeration storage, only H-eggs were evaluated during refrigerated storage. For determination of weight loss, Haugh unit, yolk index, and albumen pH, two replicates (five eggs/replicate) per each treatment (ten eggs total/treatment) were taken weekly for up to 5 weeks at 25 ± 2 °C, and at 5-wk intervals for 20 weeks at 4 ± 2 °C.

2.3. Determination of weight loss, Haugh unit, egg grade, yolk index, and albumen pH

Weight loss (%) of the coated whole egg during storage was calculated as {[initial whole egg weight (g) after coating at day 0 − whole egg weight (g) after storage]/initial whole egg weight (g) after coating at day 0} × 100. The weight of whole eggs was measured with a balance (TS400S, Ohaus Corp., Florham Park, NJ, USA).

The height of albumen and yolk was measured with a tripod micrometre (Model S-6428, B.C. Ames Inc., Melrose, MA, USA). The yolk width was measured with a digital calliper (General Tools & Instruments, New York, NY, USA). The Haugh unit was calculated as $100 \log (H - 1.7\, W^{0.37} + 7.57)$, where *H* is the albumen height (mm) and *W* is the weight (g) of egg. Egg grade was based on the United States Standards for Quality of Individual Shell Eggs (USDA, 2000) and Haugh unit. The yolk index was calculated as yolk height/yolk width (Stadelman, 1995a). After measurement of Haugh unit and yolk index, the albumen was separated from the yolk. The thin and thick albumen were mixed thoroughly prior to measuring pH with a pH meter (IQ150, IQ Scientific Instruments, San Diego, CA, USA).

2.4. Statistical analysis

For internal quality of eggs, mean ± standard deviation values were reported based on ten measurements (two replicates; five eggs/replicate) per treatment. Data generated from the experiment at 25 ± 2 °C were carried out in a Complete Randomized Design (CRD) [6 × 4 × 2 factorial: 6 storage time periods, 4 types of emulsifiers (2 oil- and 2 water-based) and 2 initial albumen qualities before coating]. The Mixed model (PROC MIXED) was used to determine differences among main effects and all their interactions, assigning the egg replication as a random variable at $\alpha = 0.05$. When main effects were significant, the Tukey's Studentized Range test at $\alpha = 0.05$ was performed for post-hoc multiple comparisons. All analyses were done with the SAS software (SAS, 2003).

Multivariate Analysis of Variance (MANOVA) was used to determine if significant differences exist among coated eggs when all internal quality parameters are tested simultaneously. Descriptive discriminant analysis (DDA, Huberty, 1994) was used to determine internal quality parameters responsible for the underlying difference among coating treatments. Principal Component analysis (PCA) was also performed to visualize the relationship among egg quality variables (weight loss, Haugh unit, yolk index, albumen pH) and the four emulsifiers (TANDEM, TWEEN, TIC, EFICACIA).

3. Results and discussion

3.1. Internal quality of eggs affected by coating materials during room temperature storage (25 ± 2 °C)

3.1.1. Haugh unit

Throughout storage of eggs, changes in albumen quality may occur primarily due to storage conditions such as time,