

Effects of Various Eggshell Treatments on the Egg Quality during Storage

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ABSTRACT : The combined effects of washing, sanitization and coating of eggshell on the physical and microbiological quality during storage were evaluated at 4° and 30°C. The interior qualities of the eggs were assessed by weight changes, yolk index, albumen index, Haugh unit value, and microbial contamination of egg shell and egg white during 30 days of storage in untreated, washed, or sanitized and mineral oil-coated eggs. The results suggest that these changes were faster in higher temperature (30°C) than lower temperature (4°C) storage, and washed eggs deteriorated faster than untreated eggs. The sanitized and coated eggs maintained the best quality during storage in all parameters measured. The shelf-life of washed, sanitized and coated eggs could be extended 4-5 fold compared to that of washed or untreated eggs. (*Asian-Aust. J. Anim. Sci.* 2003, Vol 16, No. 8 : 1224-1229)

Key Words : Sanitized and Coated Egg, Weight Change, Yolk Index, Albumen Index, Haugh Unit

INTRODUCTION

Eggs are one of the most important human nutrition sources (Kinoshita et al., 2002), and the consumer's demand for fresh and hygienic eggs is continuously increasing with the economic growth. Consequently, there are many investigations concerning the improvement of preservation or quality of eggs. Recently, in many countries, the hygienic eggs have been produced by introducing the washing technology of egg. However, the cuticle, which is one of the natural physical defenses of the egg, is damaged during the washing process, resulting in deterioration of egg quality (Lee et al., 1996; Chang et al., 1999). The preservation of the egg is greatly influenced by the temperature and humidity of the storage condition, and 4-5°C and 75-85% humidity are suggested as the best condition (Stadelman and Cotterill, 1977; Han, 1982).

The sanitizing effect on eggshell surface of various washing solutions has been investigated. Jenkins and Pennington (1919) first reported the increased bacterial contamination by scrubbing eggshell with sandpaper or rough cloths during washing, and there were many reports on the effects of washing method or washing temperature on egg preservation (Stadelman and Cotterill, 1977) thereafter. Egg-washing chemicals, such as Rocoal (QAC), sodium hypochlorite, 0.1 N NaOH and 0.1 N H₂SO₄ are also used to sanitize or to improve preservation of the eggs. Chlorine is the most widely used egg-washing chemical. However, it was observed that if chlorine content was higher than 50 ppm in a washing solution, the chlorine

reacted with specific amino acids existing in cuticle layer, deposited over the surface of the shell, causing the change of the color of the white eggshell (Song, 1983).

The coating method of the eggshell with oil was first used by Dutch farmers as early as 1807, and it was reported that coating the egg with mineral oil greatly improved the shelf-life of the eggs (Spamer, 1931). Swanson et al. (1958) suggested that coating the egg within several hours after laying is most effective, and Lee (1979) and Xie et al. (2002) reported that the low temperature and adequate humidity are necessary after oil treatment to maintain good quality. Tanabe and Ogawa (1979) studied the effects of washing and coating materials on interior quality of chicken eggs, and reported that coating with vegetable oil or mineral oil was more effective than with sucrose-fatty acid ester emulsion to keep interior quality of eggs for 13 weeks. Tanabe (1978) also studied the combined effect of washing, oiling and holding on interior quality of egg. However, there are no reports on the effect of disinfectant along with coating on the preservation of eggs.

The objectives of this study were to investigate the combined effects of washing, sanitization and coating of eggshell on egg quality during storage at two temperatures (4° and 30°C).

MATERIALS AND METHODS

Materials

Fresh laid eggs (Dekalb Warren species) were purchased from the Live-stock Experiment Station of Seoul National University, and superior grade (about 60 g) were used to minimize the experimental error during storage. 4% K-sorbate was purchased from the market and light mineral oil was purchased from Sigma Chemical Co. (St. Louis, MO, USA).

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Treatment of eggs

Three hundred eggs were randomly divided into 3 experimental groups: untreated eggs (U) as a control group, washed eggs (W) and washed, sanitized and mineral oil-coated eggs (WSC). W and WSC group eggs were washed with 40°C tap water for 2 min using kitchen scrubber and blow-dried for 1 min. WSC group eggs were then immersed for 3 min into 4% K-sorbate solution at 45°C, blow-dried and coated with mineral oil for 1 min. All treated eggs were stored in a RH 85% desiccator which was placed in 30°C incubator or 4°C refrigerator for up to 30 days.

Determination of egg qualities

Batches of 10 eggs were used to measure the weight loss, yolk index, albumen index and Haugh unit. Yolk index which indicates the spherical nature of egg yolk, and albumen index and Haugh unit which represent the thickness of egg white were determined as follows: Eggs were broken and contents of the eggs were poured onto a horizontal glass. Height and diameter of the egg yolk and egg white were measured with an egg height measurer and a callipers (Mitutuyo, Tokyo, Japan), respectively. Yolk index and albumen index were determined by the method suggested by Nam and Kim (1998). The diameters of egg yolk and egg white were the average of the maximum and minimum diameter. Haugh unit was determined using the procedure suggested by Brant et al. (1951).

Scanning electron microscopy of eggshell surface

Eggshell samples from each group were prepared for the scanning electron microscopy (SEM) test. The eggs were broken, eggshells were cut into squares of 1 cm² and dipped in Karnovsky's fixative (Electron Microscopy Science, Fort Washington, PA, USA). The fixed shell samples were snap-frozen by dipping in liquid nitrogen and broken into small pieces. Samples were then fixed by osmium tetroxide, dehydrated with graded ethanol, and washed with hexamethyldisilazane (Electron Microscopy Science, Fort Washington, PA, USA). Samples were coated with gold and observed by using a Hitachi S-570 scanning electron microscopy (Instruments, Hitachi, Ltd, Tokyo, Japan) at 20 kV and 4,000-fold magnification.

Microbial enumeration in eggshell and egg white

The changes of microorganisms in eggshell surface and egg white during storage were examined according to the method described by Mallmann et al. (1953). Each stored egg was placed in Whirl-Pak bag (Nasco Whirl-Pak, Fort Atkinson, WI, USA) containing 25 ml of 0.1% peptone solution and hand-shaked for 1 min to release bacteria from the eggshell surface. Eggs were taken out from the plastic bags and sprayed with 70% ethanol on the shell to clean egg

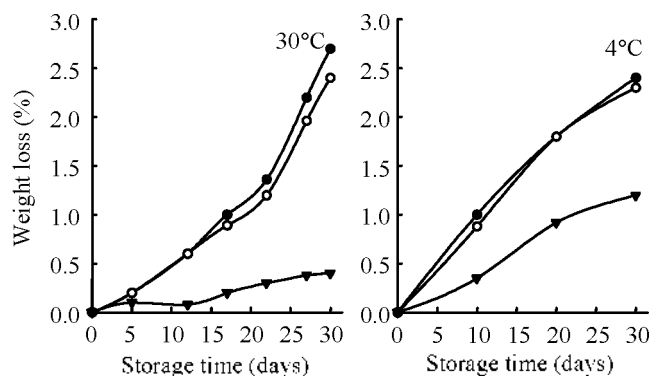


Figure 1. Influence of egg coating treatment on weight loss during 30 days of storage at 30 and 4°C (RH 85%).

○—unwashed egg, ●—washed egg, ▼—washed, sanitized and coated egg.

surfaces. After the eggs were broken, 1.0 g of egg white was mixed with 50 ml of 0.1% peptone solution. The samples of shell shaking solutions as well as the egg white solutions were diluted, plated on Plate Count Agar (PCA) (Oxoid, Basingstoke, UK) and incubated at 30°C for 2-3 days, and the colonies were counted.

RESULTS AND DISCUSSION

Changes in egg weight during storage

The change in egg weight during storage is mostly due to the evaporation of moisture through the thousands of pores contained in an eggshell surface, and it is an indicator of the deterioration of egg quality. As shown in Figure 1, weight losses of U and W groups increased as storage time increased at both temperatures (4° and 30°C). There were about 2.5% weight losses of initial weight after 30 days of storage at 30°C, and W group showed a slightly greater weight loss than the U group. However, at 4°C storage, the percentages of weight losses were more rapid within day 0 to 20 than those between day 20 to 30. In contrast, the weight losses at 30°C storage were more rapid between day 20 to 30. The percentages of weight loss of WSC group eggs were much lower than those of the other groups. The greater weight loss in W group may be due to the damage of the cuticle layer, which is another protective covering in eggshell. The cuticle acts as a layer that impedes evaporation or bacterial penetration by closing the pores within the shell. The smallest weight loss in WSC group may be attributed to the fact that the coating blocks the pores on the shell, preventing the evaporation of moisture and gases. Imai (1981) reported that the beneficial effect of coating on weight loss was marked both at 3°C and at room temperature. Homler and Stadelman (1962) also reported similar results.

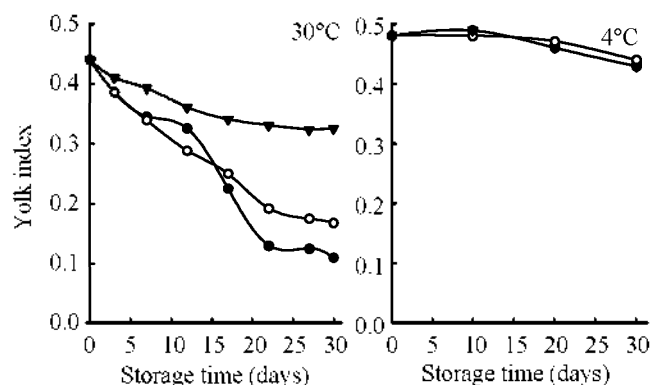


Figure 2. Influence of egg coating treatment on yolk index during 30 days of storage at 30° and 4°C (RH 85%).

○ unwashed egg, ● washed egg, ▼ washed, sanitized and coated egg.

Indexes of egg quality

General indexes determining the egg quality are yolk index, albumen index and Haugh unit. These indexes are higher in fresh eggs than stored eggs, and the longer the storage time, the lower these indexes. Yolk index decreased as storage time increased in all treatment eggs at both temperatures, but the reduction was greater at 30°C than 4°C. U and W groups showed more reductions in yolk index than WSC group. The yolk index decreased to below 0.3 after 12 and 17 days of storage in W and U groups, respectively (Figure 2). However, yolk index stayed above 0.3 after 30 days of storage at 30°C in WSC group. These results are similar to those of Imai (1981) who reported coating of eggs was effective in maintaining interior quality such as yolk index and Haugh unit compared with uncoated eggs during storage at 3°C and at room temperature. Meanwhile, Wong et al. (1996) reported that yolk index decreased to 0.2 after 10 days of storage at 25°C in normal eggs. On the other hand, at 4°C storage, yolk index stayed above 0.4 in all eggs during 30 days of storage. These results are similar to those of Lee (1979) who found no differences of yolk index at 0°C between untreated and coated eggs. Ahn et al. (1981) also observed no changes in yolk index of untreated eggs at 4°C.

In Figure 3, the changing pattern of albumen index during storage of the eggs was similar to that of yolk index; it decreased as the storage time increased, and the reduction was greater at 30°C than those at 4°C storage. At 30°C storage, albumen index decreased rapidly up to 17 days of storage and then decreased slowly in all treatments. After 7 days of storage, the albumen index was lower in W group than in U group, indicating a faster deterioration of the W group. However, the albumen index dropped slowly in WSC group eggs than the other group eggs. It took 15 days for an albumen index value to become below 0.05 in WSC group, while it took 7 days in U and W groups, suggesting

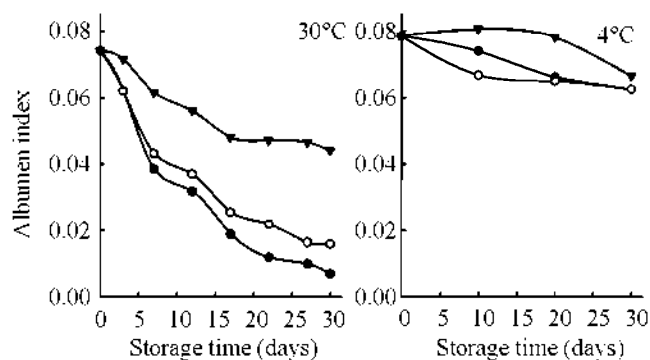


Figure 3. Influence of egg coating treatment on albumen index during 30 days of storage at 30° and 4°C (RH 85%).

○ unwashed egg, ● washed egg, ▼ washed, sanitized and coated egg.

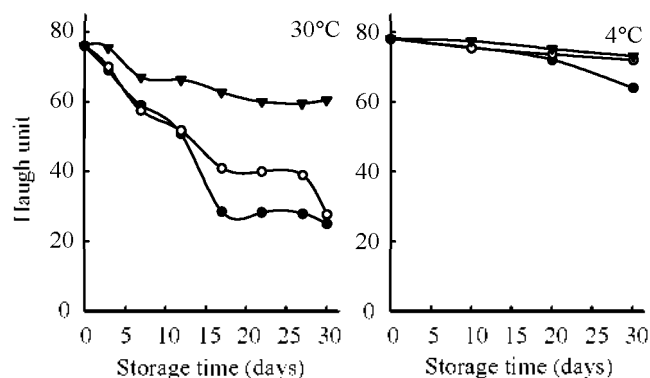


Figure 4. Influence of egg coating treatment on Haugh unit during 30 days of storage at 30° and 4°C (RH 85%).

○ unwashed egg, ● washed egg, ▼ washed, sanitized and coated egg.

more than 2-fold increase in shelf-life of WSC group eggs in comparison to that of the other eggs. In contrast, at 4°C storage, all groups of eggs maintained an albumen index value over 0.06 after 30 days of storage, yet WSC group showed the highest albumen index value followed by W group and lastly U group.

Haugh unit

Haugh unit value determines the changes of the interior quality of eggs, and this value decreases as the interior quality of the eggs becomes poor. Haugh unit values, also, decreased with an increase in storage time at both temperatures (4° and 30°C), and a greater decrease in Haugh unit values were found at 30°C than at 4°C (Figure 4). U and W groups showed a faster rate of decrease in Haugh unit until 17 days of storage at 30°C and then leveled off thereafter. The egg yolks were disintegrated in W group after 27 days of storage; therefore, it was impossible to measure Haugh unit after 30 days of storage.

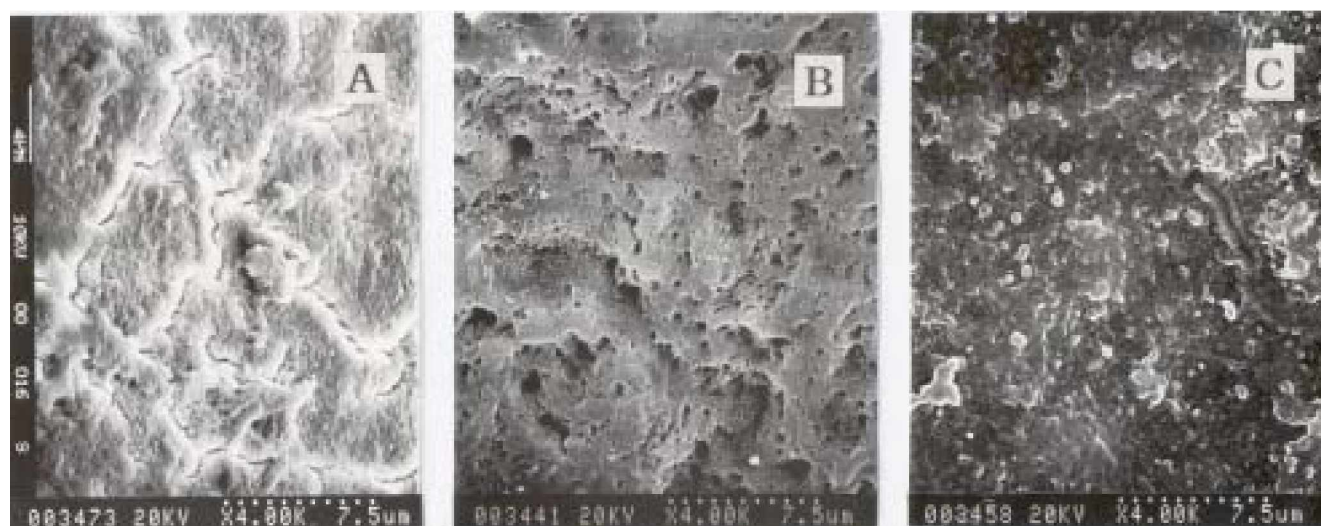


Figure 5. Scanning electron micrographs of eggshell surface ($\times 4,000$). A: Unwashed egg, B: Washed egg, C: Washed, sanitized and coated egg.

W group showed a more rapid decrease and lower Haugh unit value than U group, while WSC group exhibited a constant rate of decrease in Haugh unit. These results were similar to those of Tanabe (1978) who reported that Haugh unit of egg oiled before washing was higher than that of egg unoiled and washed, and egg oiled after washing. Homler and Stadelman (1962) reported that Haugh unit values of oil-coated and non-coated eggs after 21 days of storage at 22°C were 45.28-57.15 and 45.40-49.28, respectively. Meanwhile, in our study, Haugh unit value of washed, sanitized and coated eggs after 21 days of storage at 30°C was 62. Therefore, these results suggest that the combined effects of washing, sanitization and coating were more effective than single effect of coating on the preservation of egg.

Haugh unit is used to grade an egg's quality in the USA. An egg with Haugh unit value over 72 is graded as AA, A with Haugh unit value over 60, B with over 32, C with a value below 31. WSC group maintained a Haugh unit value of about 60 even after 30 days of storage, while it took 7-10 days in W or U groups. After 30 days of storage, WSC group maintained grade A, while the grades of the other groups dropped to C. Ahn et al. (1981) reported that U group became grade B after 7 days of storage at $25\text{-}30^{\circ}\text{C}$.

In contrast, at 4°C storage, Haugh unit value stayed over 72 (AA grade) after 20 days of storage in all groups. WSC and U groups maintained AA grade, while W group became A grade after 30 days of storage. Homler and Stadelman (1962) also reported higher Haugh unit value in coated eggs than in untreated eggs.

Microstructural changes in eggshell surface

As shown in Figure 5, U group appeared to have rough and uneven surfaces with subtle cracks (Figure. 5A). This

might be attributable to the irregular distribution of the cuticular layer. In contrast, W group was characterized by smooth surfaces and cut forms of cuticle layer in one direction (Figure. 5B). It is reasoned that the hand washing process removed large parts of cuticle layer, resulting in smooth surfaces and the cracks, which were observed in U group, disappeared in W group. The removal of the cuticle layer allowed penetration of microorganisms into the eggs, resulting in a shorter storage time for W group than that of U group. Basic features of WSC group appeared to be similar to those of W group. The eggs had smooth surfaces and did not show any signs of cracks (Figure. 5C). However, the surfaces of eggs of the WSC group were covered with a mucous substance and the coated oil residues covered the eggshell surface and prevented the intrusion of bacteria, and thus improved the quality of the eggs during storage.

Microbial enumeration in eggshell and egg white

The spoilage of eggs during storage is mainly caused by microorganisms. The occurrence of microorganisms depends on the surrounding environments, the state of handling, the conditions of storage and washing state (Gentry and Quarles, 1972).

Total viable cell counts on eggshell of all groups stored at 30°C were 2.8×10^2 at day 0 (Figure 6). In U group, total viable cell counts increased dramatically to 7.7×10^3 at day 4 and to 6.7×10^5 at day 21, reaching the highest count, and then decreased to 3.3×10^5 at day 30. In W group, total viable cell counts markedly decreased until day 10, because of washing process, yet it increased to the similar level of U group, reaching peak point at day 21. In WSC group, the viable cell counts were negligible until 17 days of storage and increased to 3.1×10^1 at day 21 and remained similar level until 30 days of storage. The washing, sanitizing and

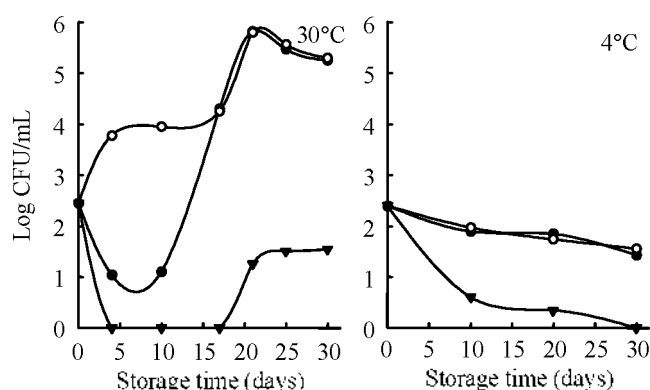


Figure 6. Influence of egg coating treatment on egg shell viable cell counts during 30 days of storage at 30° and 4°C (RH 85%). ○ unwashed egg, ● wshed egg, ▼ washed, sanitized and coated egg.

coating process blocks the growth of the microorganisms in eggs. Consequently, the shelf-life of washed, sanitized and coated eggs could be extended 4-5 fold compared to that of washed or untreated eggs. In contrast, storing at 4°C reduced the viable cell counts continuously during storage in all treatment eggs, and there was almost no microbial growth in WSC group.

These results indicate that coating process not only blocked the penetration of the microorganisms, but also inhibited their growth. On the other hand, Imai (1981) reported that coating of eggs did not increase the bacteriological stability of shell eggs, but was effective in the reduction of weight loss and in maintaining interior quality. These differences between our study and Imai's study indicate that the combined treatment of washing, sanitization and coating is more effective than single effect of coating on the preservation of egg.

The viable cell counts in egg white were less than 1×10^1 in all 3 treatment eggs during 30 days of storage (data not shown). These results indicate that eggshell and inner membrane of eggs completely prevented the microbial penetration and the nutritional state of egg white was not adequate for microbial growth, and the defense mechanism of egg white such as lysozyme prevented microbial growth in egg white.

CONCLUSIONS

This study examined the physical quality and microbiological changes of eggs with 3 different kinds of treatment; untreated, hand washed, or washed, sanitized and oil-coated. The changes in internal quality of the eggs, i.e., weight changes, yolk index, albumen index, Haugh unit values, and microbial contamination of eggshell and egg white during storage were measured for 30 days at 4° and 30°C. The results showed that these changes were faster in

higher temperature (30°C) than lower temperature (4°C), and that washed eggs deteriorated faster than untreated eggs. The washed, sanitized and coated eggs maintained the best quality during the 30 days of storage in all parameters measured. Consequently, the shelf-life of washed, sanitized and coated eggs could be extended 4-5 fold compared to that of washed or untreated eggs.

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