Effects of Extended Storage on Egg Quality Factors

D. R. Jones[1] and M. T. Musgrove

Russell Research Center, Egg Safety and Quality Research Unit, USDA-Agricultural Research Service, Athens, Georgia 30604

ABSTRACT Eggs were collected from a single inline processing facility weekly for 3 wk (replicates). The eggs were stored at 4°C and 80% RH. Sampling began the day after collection and continued each week for 10 wk. During analysis, 24 eggs were examined for egg weight, albumen height, Haugh units (HU), shell strength, and vitelline membrane strength for each replicate. Egg weight decreased ($P < 0.0001$) from approximately 61 to 57 g after 10 wk of storage. Eggs from the second replicate were significantly ($P < 0.0001$) heavier than the other replicates by an average of 3 g. On average, albumen height decreased with extended storage ($P < 0.0001$) from 7.05 to 4.85 mm. Albumen height was approximately 0.2 mm higher for the eggs in replicate 2 compared with the other replicates ($P < 0.01$). Haugh unit values decreased during cold storage from 82.59 to 67.43 ($P < 0.0001$). There were no differences between replicates for HU values. No differences were detected for shell strength between replicates or during extended storage. A significant difference ($P < 0.05$) was found in detectable vitelline membrane strength between replicates, but this difference was less than 0.05 g. The elasticity of the vitelline membrane decreased during storage ($P < 0.01$) remaining low after 6 wk. Extended cold storage led to decreases in egg weight, albumen height, and HU. However, average HU values were still within the range for grade A. Shell strength was not affected by extended storage. Vitelline membrane elasticity also decreased, which could lead to yolks more easily rupturing as consumers crack the eggs. The results indicated that although the physical quality factors monitored in this study decreased during storage, egg quality was still acceptable beyond current recommended shelf life guidelines.

(*Key words*: egg quality, storage, Haugh unit, vitelline membrane, shell strength)

2005 Poultry Science 84:1774–1777

INTRODUCTION

The physical appearance of an egg makes the first impression upon the consumer. If the product does not meet perceived expectations, consumer confidence diminishes. The structural quality of the shell egg is important to the processor because eggs that are structurally sound will arrive to the consumer in the best condition. Furthermore, high interior quality is of importance to egg products manufacturers because it allows for better separation of components without crossover contamination, especially when producing albumen products. Much of the cited literature on egg quality was conducted some time ago, and updated research is needed to assess today's industry (Scott and Silversides, 2000).

Haugh units (HU; Haugh, 1937) are the standard for quantifying interior egg quality. It has been recorded that HU decrease during storage (Kahraman-Dogan et al., 1994; Jones et al., 2002). Silversides and Villeneuve (1994) reported that changes in albumen quality during storage are described equally well by albumen height and HU.

Vitelline membrane characteristics have been seen as not only physical quality factors but also as microbial quality contributors in the egg (Gast and Beard, 1990; Humphrey et al., 1991; Humphrey, 1994). Smolinska and Trziszka (1982) state that the selective properties of the vitelline membrane depend on length and conditions of storage. The strength of the vitelline membrane has been found to decrease during prolonged cold storage (Jones et al., 2002). Cunningham and Ylander (1980) have also reported vitelline membrane strength to be decreased in mottled yolks. Trziszka and Smolinska (1982) have also concluded that chemical changes in the vitelline membrane manifest themselves as physical changes such as membrane strength.

Carter (1970) stated that the eggshell derives its ability to absorb energy from 2 sources: the material it is made from and its shape. Shell quality is affected by genetic selection (Petersen, 1965). Anderson et al. (2001) found no differences in shell strength among closed, random-bred control strains. The modern commercial strain used in the study did produce eggs with significantly greater shell

Received for publication February 8, 2005.
Accepted for publication July 20, 2005.

[1]To whom correspondence should be addressed: drjones@saa.ars.usda.gov.

Abbreviation Key: HU = Haugh units.

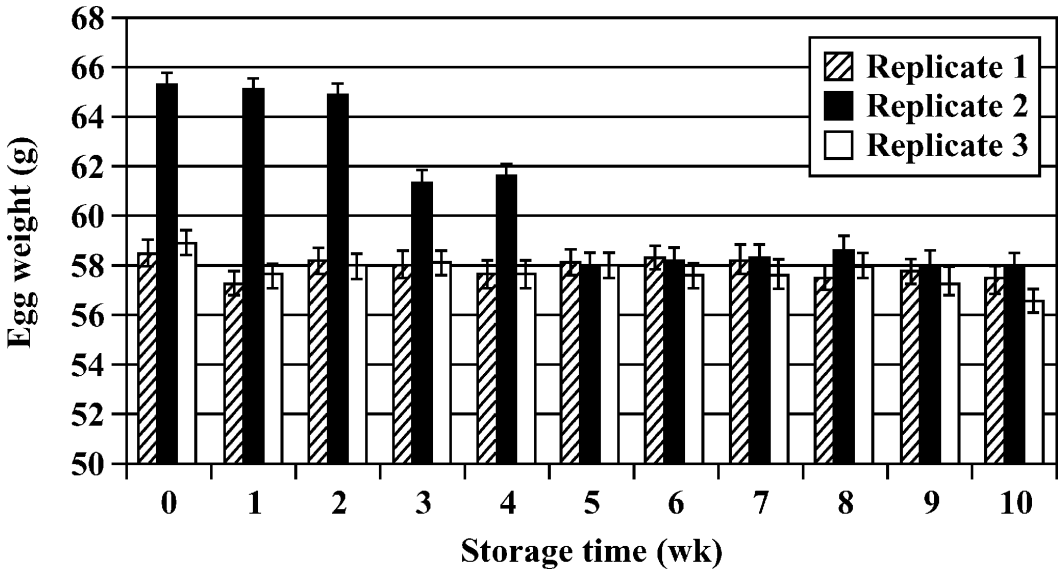

Figure 1. Effects of extended cold storage on egg weight ($P < 0.0001$).

strength. A negative correlation has been found between eggshell strength and hen productivity (Oosterwoud, 1987). Conversely, the current commercial strain in the Anderson et al. (2001) study was the strain with the greatest egg production rate, daily egg mass, and egg weight (Jones et al., 2001). Poor shell quality will result in a greater number of cracked eggs, which will result in greater losses for the producer. In 1965 it was estimated that 5 to 7% of shell eggs produced in the United States were cracked (Petersen, 1965).

Many of the regulations governing the production and marketing of shell eggs were developed based on egg quality concerns. Before many of the advances that exist today in laying hen management practices, egg production was a seasonal event. Therefore, eggs had to be stored for extended periods to maintain supply in the marketplace. Much of the research that examined the role of extended storage on egg quality was conducted during this time, such as that of Bauermann et al. (1969). Since then, processing technology, layer management practices, and genetic selection have changed. The current study was undertaken to examine the effects of extended cold storage on quality factors of shell eggs produced and processed with current technology and storage regulations.

MATERIALS AND METHODS

Processed large shell eggs were collected after placement into retail cartons from an inline operation producing USDA shielded eggs. Forty-five dozen large eggs were collected in a single day, representing a replicate, for 3 wk consecutively. The eggs were placed in cardboard half cases and stored in a 4°C cold room with 80% RH until the sampling time. Initial sampling period was conducted 1 d

Table 1. Effects of extended cold storage on albumen height, Haugh units, shell strength, and vitelline membrane strength and deformation at rupture

Weeks	Albumen height (mm)	Haugh unit value	Shell strength (g force)	Vitelline membrane strength (g force)	Deformation at rupture (mm)
0	7.05^{w}	82.59^{W}	3,650.26	2.36	0.66^{a}
1	6.65^{w}	80.62^{W}	3,872.30	2.36	0.63^{ab}
2	5.84^{x}	74.63^{X}	3,743.51	2.43	0.67^{a}
3	5.58^{xyz}	73.17^{XY}	3,831.75	2.40	0.56^{ab}
4	5.60^{xy}	73.14^{XY}	3,850.44	2.29	0.31^{b}
5	5.49^{xyz}	72.69^{XY}	3,750.05	2.35	0.50^{ab}
6	5.29^{yz}	71.07^{XYZ}	3,709.38	2.33	0.30^{b}
7	5.26^{yz}	70.83^{XYZ}	3,751.48	2.34	0.29^{b}
8	5.25^{yz}	71.05^{XYZ}	3,892.05	2.37	0.36^{ab}
9	5.06^{yz}	69.35^{YZ}	3,658.25	2.30	0.30^{b}
10	4.85^{z}	67.43^{Z}	3,580.59	2.31	0.39^{ab}
SEM	0.11	0.93	100.32	0.03	0.09

^{a,b}Means within a column with like letters are similar ($P < 0.05$).

$^{w\text{-}z}$Means within a column with like letters are similar ($P < 0.01$).

$^{W\text{-}Z}$Means within a column with like letters are similar ($P < 0.001$).

Table 2. Effects of replicate on albumen height, Haugh units, shell strength, and vitelline membrane strength and deformation at rupture

Replicate	Albumen height (mm)	Haugh unit value	Shell strength (g force)	Vitelline membrane strength (g force)	Deformation at rupture (mm)
1	5.54[b]	72.88	3754.31	2.33[b]	0.40
2	5.77[a]	73.78	3712.37	2.38[a]	0.53
3	5.57[ab]	73.32	3794.24	2.33[b]	0.43
SEM	0.06	0.48	51.79	0.02	0.05

[a,b]Means within a column with like letters are similar ($P < 0.05$).

after collection and each subsequent week for the designated time frame. A random 24 egg sample was selected from each replicate for analysis throughout the 10 wk. Cracked eggs within the sample were excluded from analysis.

Egg weight, albumen height, and HU (Haugh, 1937) were recorded with a TSS QCD system (Technical Services and Supplies, Dunnington, York, UK). Shell and vitelline membrane strengths were measured utilizing a TA-XT2plus texture analyzer (Texture Technologies, Scarsdale, NY). A 5-kg load cell was used for both testing methods. Shell strength was determined utilizing, a 3 in. diameter aluminum compression disc (TA-30, Texture Technologies) attached to the unit along with an egg holder with posts that could rotate (TA-650, Texture Technologies). The egg was aligned so that the disc came into contact with the apex of the large end of the egg. A test speed of 2 mm/s and a trigger force of 0.001 kg were used. For vitelline membrane strength and deformation measurements, the methods of Jones et al. (2002) were followed utilizing a trigger force of 0.0001 kg. Care was taken to ensure measurements were not made near the chalazae because Lyon et al. (1972) have identified this part as the strongest section of the vitelline membrane.

Data were analyzed with the general linear model operation of SAS software (SAS Institute, 1999). Replicate and week were the main effects. When significant differences occurred ($P < 0.05$), means were separated by the least squares method.

RESULTS AND DISCUSSION

Egg weights remained fairly constant throughout storage for replicates 1 and 3 with the heaviest average egg weight being 58.94 g and the lowest being 56.61 g. There was a distinct decrease in egg weight during the first 5 wk of storage for the second replicate from an average weight of 65.29 g to 58.03 g. For these reasons, there was a significant ($P < 0.0001$) interaction between replicate and week of storage (Figure 1). These data demonstrate the variable nature of physical characteristics of shell eggs. The eggs for this study were collected postprocessing from an inline facility; therefore, they were a random assortment of the large eggs being produced by the flocks of various ages in that complex of one million birds.

Albumen height and HU decreased significantly ($P < 0.001$ and $P < 0.0001$, respectively) during storage (Table 1). Albumen height was the greatest during wk 0 (7.05 mm) and the lowest at wk 10 (4.85 mm). Silversides and Scott (2001) also found that albumen height decreased as eggs aged. The HU initially were 82.59 and decreased to 67.43 by wk 10. The decline in albumen height and HU resembles the trend reported by Silversides and Villeneuve (1994). According to USDA-Agricultural Marketing Service guidelines (USDA, 2000), grade A determinations begin when HU are less than 72. In the current study, this level was not reached until after 6 wk of cold storage. Jones et al. (2002) reported a decline to grade A in HU values at 6 wk in control eggs for a study conducted at refrigerated temperatures. On average, the eggs remained grade AA well past the current 30-d recommended shelf life for grade A retail shell eggs. There was a significant ($P < 0.05$) difference among replicates for albumen height. The difference among the 3 replicates was 0.23 mm (Table 2).

There were no differences during storage or among replicates for shell strength. During storage, gram force values ranged from 3,892.05 to 3,580.59 g (Table 1). Among the replicates, average recorded forces were 3,794.24 to 3,712.37 g (Table 2). Lin et al. (1996) have speculated that the nonhomogenous and irregular shape of the egg causes difficulty in accurate assessment of stress or strain. For this reason, in the current study special care was taken to ensure the force was applied at the apex of the large end of the intact egg for each measurement. The most common method of assessing shell quality in the past has been specific gravity determination. Harms et al. (1994) report the sensitivity of the specific gravity solutions used in this method can lead to inaccurate measurements of shell quality. The use of rheological instrumentation and specific placement of the egg to ensure uniform application of force decreases some of the testing variability.

Vitelline membrane strength was not significantly different during the storage period (Table 1). Gram force strength of the membrane was measured as 2.43 to 2.29 g. Jones et al. (2002) found a difference in vitelline membrane breaking strength during extended cold storage. The forces they reported ranged from 2.17 to 1.67 g. Although equipment from the same manufacturer was used for both studies, different machine models were used. This difference might have contributed to some of the differences. Funk (1944) reports a 2.3% decrease in vitelline membrane strength when eggs are held at 0°C for 70 d. In the current study, vitelline membrane strength decreased 6% during storage. The current study used 4°C storage conditions and a much

more precise method of membrane strength determination. In the Funk and current studies, eggs were processed within 24 h of being laid. The eggs used in the Jones et al. (2002) study were from an offline processing facility, which could account for the differences in results. It has also been stated that the strength of the vitelline membrane decreases during storage due to the yolk absorbing water (Oosterwoud, 1987). There was a significant ($P < 0.05$) difference among replicates with replicate 2 having a mean vitelline membrane strength of 2.38 g compared with replicates 1 and 3, which were both 2.33 g (Table 2). The difference was statistically obvious due to the low degree of variability in recorded strengths; however it is doubtful that a consumer would notice such a small difference when cracking eggs in the home.

Deformation at rupture did differ ($P < 0.05$) during storage. The greatest elasticity (0.66 mm) was recorded initially. The lowest deformation distance was found at 7 wk of storage, 0.29 mm (Table 1). The replicates were statistically the same with deformation distances of 0.53 to 0.40 mm (Table 2). Fromm and Matrone (1962) reported that the elasticity of the vitelline membrane increased with egg age. In the current study and that of Jones et al. (2002), the opposite was found to be true. The differences between these studies could be due in part to analytical methods used and egg storage conditions. The more recent studies held eggs for prolonged periods at 4 to 7°C compared with 25°C for the earlier work. A decrease in yolk viscosity during storage reported by Hidalgo et al. (1996) follows the current study and previous research findings of decreased yolk elasticity.

There was a decrease in egg weight during long-term cold storage, but this decrease was more pronounced for one replicate compared with the other two. Albumen height and HU decreased as storage time increased. Even after 10 wk of cold storage, average HU were well within the guidelines for grade A eggs. Shell strength and vitelline membrane strength did not significantly change over time. Vitelline membrane deformation or elasticity did decrease as cold storage progressed, which could contribute to an increased incidence of yolk breakage as consumers crack eggs into skillets or attempt to separate the components for cooking. The findings of this study demonstrated that when shell eggs were refrigerated, current shelf life or sell-by requirements could be extended beyond 30 d without compromising physical quality factors or decreasing consumer satisfaction.

ACKNOWLEDGMENTS

The authors thank Patsy Mason, Julie Northcutt, Kathy Orr, and Susan Akins for their technical assistance with this project.

REFERENCES

Anderson, K. E., J. B. Tharrington, P. A. Curtis, and F. T. Jones. 2001. Shell characteristics of eggs from historic strains of Single Comb White Leghorn chickens and the relationship of egg shape to shell strength. Int. J. Poult. Sci. 3:17–19.

Bauermann, J. F., J. Bezpa, R. M. Grover, and O. F. Johndrew, Jr. 1969. The effects of pre-cooling and warm packing on interior egg quality. Poult. Sci. 48:866–870.

Carter, T. C. 1970. Why do egg shells crack? World's Poult. Sci. J. 26:549–561.

Cunningham, F. E., and D. M. Ylander. 1980. Ultrastructure of vitelline membranes from normal and mottled egg yolks. Poult. Sci. 59:2449–2455.

Fromm, D., and G. Matrone. 1962. A rapid method for evaluating the strength of the vitelline membrane of the hen's egg yolk. Poult. Sci. 41:1516–1521.

Funk, E. M. 1944. Effects of temperature and humidity on the keeping quality of shell eggs. Res. Bull. 382. Univ. Missouri, Columbia, MO.

Gast, R. K., and C. W. Beard. 1990. Production of *Salmonella enteritidis*-contaminated eggs by experimentally infected hens. Avian Dis. 34:438–446.

Harms, R. H., A. G. Abdallah, and D. R. Sloan. 1994. Errors in measuring and calculating eggshell quality. Poult. Sci. 73:599–602.

Haugh, R. R. 1937. The Haugh unit for measuring egg quality. US Egg Poult. Mag. 43:552–555, 572–573.

Hidalgo, A., M. Lucisano, E. M. Comelli, and C. Pompei. 1996. Evolution of chemical and physical yolk characteristics during the storage of shell eggs. J. Agric. Food Chem. 44:1447–1452.

Humphrey, T. J. 1994. Contamination of egg shell and contents with *Salmonella enteritidis*: A review. Int. J. Food Microbiol. 21:31–40.

Humphrey, T. J., A. Whitehead, A. H. L. Gawler, A. Henley, and B. Rowe. 1991. Numbers of *Salmonella enteritidis* in the contents of naturally contaminated hens' eggs. Epidemiol. Infect. 106:489–496.

Jones, D. R., K. E. Anderson, and G. S. Davis. 2001. The effects of genetic selection on production parameters of Single Comb White Leghorn hens. Poult. Sci. 80:1139–1143.

Jones, D. R., J. B. Tharrington, P. A. Curtis, K. E. Anderson, K. M. Keener, and F. T. Jones. 2002. Effects of cryogenic cooling of shell eggs on egg quality. Poult. Sci. 81:727–733.

Kahraman-Dogan, H., L. Bayindirli, and M. Ozilgen. 1994. Quality control charts for storage of eggs. Food Qual. 17:495–501.

Lin, J., V. M. Puri, and R. C. Anantheswaran. 1996. Strains in eggshell during cooling of eggs—Measurement and prediction using the finite element method. Trans. ASAE 39:1005–1012.

Lyon, C. E., G. W. Newell, and R. D. Morrison. 1972. Vitelline membrane strength and egg yolk mottling. Poult. Sci. 51:480–487.

Oosterwoud, A. 1987. Effect of egg handling on egg quality. Poult. Sci. Symp. 20:283–291.

Petersen, C. F. 1965. Factors influencing egg shell quality—A review. World's Poult. Sci. J. 21:110–138.

SAS Institute. 1999. A User's Guide to SAS. Version 8.2. Sparks Press Inc., Cary, NC.

Scott, T. A., and F. G. Silversides. 2000. The effect of storage and strain of hen on egg quality. Poult. Sci. 79:1725–1729.

Silversides, F. G., and T. A. Scott. 2001. Effect of storage and layer age on quality of eggs from two lines of hens. Poult. Sci. 80:1240–1245.

Silversides, F. G., and P. Villeneuve. 1994. Is the Haugh unit correction for egg weight valid for eggs stored at room temperature? Poult. Sci. 73:50–55.

Smolinska, T., and T. Trziszka. 1982. The vitelline membrane: dynamics of cholesterol metabolism in hens' eggs. Food Chem. 8:215–223.

Trziszka, T., and T. Smolinska. 1982. Chemical characterization of the vitelline membrane of hens' eggs. Food Chem. 8:61–70.

USDA. 2000. United States standards, grades, and weight classes for shell eggs. AMS 56.210. AMS, USDA, Washington, DC.