Asian-Aust. J. Anim. Sci.
Vol. 24, No. 2 : 279 - 284
February 2011

www.ajas.info

Effects of Storage Temperature and Time on the Quality of Eggs from Laying Hens at Peak Production

Y. H. Jin, K. T. Lee, W. I. Lee and Y. K. Han*
Department of Food Science and Biotechnology, Sungkyunkwan University, Suwon 440-746 Korea

ABSTRACT : The objective of this study was to evaluate the effects of storage temperature and time on the quality parameters of eggs from laying hens at peak production. A total of 576 eggs were obtained from Lohmann Light-Brown hens, which were collected 3 times when the hens were 26, 27, and 28 weeks old. The fresh eggs were collected and measured within 2 h of being laid. Samples of 48 eggs each were stored in chambers for 2, 5, or 10 d inside a refrigerator (5°C), at room temperature (21°C), and at a high temperature (29°C). As the storage temperature and time increased, egg weight, percentage of albumen, Haugh unit (HU), and yolk color significantly ($p<0.001$) decreased. In addition, egg shell weight, shell percentage, and albumen weight significantly ($p<0.001$) decreased with storage time. Yolk weight, yolk percentage, and albumen pH significantly ($p<0.001$) increased with increasing storage temperature, and yolk pH significantly ($p<0.001$) increased with increasing storage time. When the storage temperature was increased to 29°C, egg weight loss dramatically increased from 1.74 to 3.67% at 5 and 10 d of storage time, respectively. With the exception of the 5°C storage temperature, HU dramatically decreased according to storage time and temperature, decreasing from 91.3 to 72.63 at 21°C and from 87.62 to 60.92 at 29°C during 10 d of storage; however, this decline was not found at 5°C. A rapid increase in albumen alkalinity was observed even after just 2 d of storage regardless of the storage temperature. Interactions between storage time and temperature were significant ($p<0.001$) with respect to egg weight loss, egg shell weight and percentage, albumen weight and percentage, yolk weight and percentage, albumen and yolk pH, HU, and yolk color. The results of the current study indicated that eggs from laying hens at peak production had significant deterioration of internal quality with increasing storage temperature and time. The results suggest that egg weight loss, albumen pH, and HU are parameters that are greatly influenced by the storage temperature and time of eggs from hens at peak laying. (**Key Words :** Egg Quality, Storage Time, Storage Temperature, Haugh Unit, Peak Laying)

INTRODUCTION

Unlike external quality, the internal quality of eggs starts to decline as soon as they are laid by hens. Thus, although factors associated with the management and feeding of hens can play a role in internal egg quality, but egg handling and storage practices also have a significant impact on the quality of eggs reaching consumers. Albumen quality is not only an important indicator of egg freshness, it is also significant for the egg processing industry. Albumen quality is a standard measure of egg quality, and it is influenced by genetic factors (Johnson and Merritt, 1955) and environmental factors such as storage temperature and time (Samlli et al., 2005). The unit (HU) proposed by Haugh (1937), is calculated from the height of the inner thick albumen and the weight of an egg, and is considered to be a typical measure of albumen quality. Silversides and Scott (2001) reported that quality measurements based on the albumen height of fresh eggs are biased by the strain and age of the hens. However, albumen pH is not affected by hen age or strain and can be used to measure egg freshness without this bias. The albumen height of eggs is at a maximum when the eggs are laid and decreases with increasing storage time. Silversides and Villeneuve (1994) reported that pH is a useful means for describing changes in albumen quality over time during storage. Significant increases in yolk pH were observed with increasing storage time (Samli et al., 2005). Bird age is the most important factor affecting the egg quality of freshly laid eggs. Initial albumen quality decreases rapidly with advancing flock age (Williams, 1992). Most of the changes in egg quality in terms of HU, albumen height, albumen pH, yolk index, specific gravity, and air cell size are attributed to moisture loss by evaporation through the shell pores and the escape of CO_2 from albumen (Hinton, 1968; Shenstone, 1968;

* Corresponding Author : Y. K. Han. Tel: +82-31-290-7904, Fax: +82-31-299-4144, E-mail: y.k.han@skku.edu
Received June 8, 2010; Accepted August 13, 2010

Robinson, 1987).

In this study, freshly laid eggs were stored at different temperatures to investigate the effects of storage time and temperature and their interaction on egg quality in peak laying hens.

MATERIALS AND METHODS

The eggs used in this study were obtained from one hundred twenty-eight, 24 to 29 week old Lohmann Light-Brown hens, which were included in a laying trial at the experimental facilities of the Department of Food Science and Biotechnology at Sungkyunkwan University. The average laying rate was 96.6±8.36% (mean±SD). The hens were fed a mashed diet and all nutrient levels met or exceeded the nutrient requirements suggested in the Lohmann Brown Management Guide (Lohmann Tierzucht GmbH, 2008). All hens were housed in windowless and environmentally controlled rooms and offered feed and water *ad libitum*. The cages were made of galvanized metal wire (approximately 25×35×50 cm) and placed in double-decker rows providing 430 cm^2/hen. Each cage had a nipple waterer. A wire egg collector was installed in front of the cages. The room temperature was kept at 21-23°C and the light cycle consisted of 16 h of light (incandescent lighting, 10 lx) and 8 h of darkness. All procedures used in this experiment were approved by the Animal Ethics Committee of Sungkyunkwan University and according to the guidelines for the care and use of animals in research (Korean Ministry of Food, Agriculture, Forestry, and Fisheries, 2008). A total of 576 eggs were collected in 3 collections when the hens were 26, 27, and 28 weeks old. The fresh eggs were collected and measured within 2 h of being laid. The total 576 eggs were used in 12 treatments (4 storage periods×3 storage temperatures) with 48 eggs examined in each. The samples of 48 eggs each were stored for 2, 5, or 10 d in chambers in a refrigerator (5°C), at room temperature (21°C), and at high temperature (29°C). Relative humidity was regulated at 50 to 60% for all treatments. Yolk colour and Haugh units were measured using an egg multi tester EMT-5200 (Robotmation Co. Ltd., Tokyo, Japan). Haugh units were calculated from the recorded egg weights and albumen heights using the formula: $HU = 100 \log_{10} (H-1.7 W^{0.37}+7.56)$, where HU = Haugh unit, H = height of the albumen (mm), and W = egg weight (g). The yolks were separated from the tester tray (yolk, albumen, and tray) using a Teflon spoon. Before the yolk weight was determined, the chalaza was removed with a spatula. The shells were weighed without drying. Albumen weight was calculated by subtracting the weight of the tester tray. In each of the 576 collected eggs, pH values of the albumen and yolk were measured using a pH meter (Corning Pinnacle 540, Switzerland).

The data were analyzed as a randomized block design (Snedecor and Cochran, 1989), using the appropriate General Analysis of Variance procedures of STATISTIX (1996). The model included the main effects of the storage times and temperatures and the two-way interactions between these factors. Significant differences between means were determined by the Least Significant Difference (LSD) method at a level of $\alpha = 0.05$. To investigate the effects of storage time and temperature on albumen pH and HU and on egg quality parameters among the eggs separated into three storage times and three storage temperatures, STATISTIX software was used.

RESULTS AND DISCUSSION

The results of the effects of storage time and temperature are presented in Table 1, 2, and 3. With several exceptions, both storage time and temperature significantly affected almost all parameters of internal egg quality. As storage temperature and time increased, egg weight, percentage of albumen, HU, and yolk color significantly ($p<0.001$) decreased. In addition, egg shell weight, shell percentage, and albumen weight significantly ($p<0.001$) decreased with storage time. Yolk weight, yolk percentage, and albumen pH significantly ($p<0.001$) increased with increasing storage temperature, and yolk pH significantly ($p<0.001$) increased with increasing storage time.

Egg weight was not significantly decreased by storage for 0 to 10 d at 5°C and 21°C, but it was significantly ($p = 0.028$) decreased by storage at 29°C. However, when considered as a percentage of weight loss, egg weight significantly ($p<0.001$) decreased with increasing storage time and temperature. When the storage temperature was increased to 29°C, loss of egg weight dramatically increased from 1.74 to 3.67% at 5 and 10 d of storage time, respectively. These results are in agreement with those of Samli et al. (2005), who reported significant ($p<0.001$) egg weight reductions of 2.08 and 3.11%, respectively, within 5 and 10 d of storage at 29°C. Similar weight losses were also reported by Akyurek and Okur (2009). There was no difference in shell weight from 0 to 10 d of storage at 21°C, whereas at the storage temperatures of 5 and 29°C there were significant ($p<0.001$) decreases in shell weight with increasing storage time. These results are in agreement with those of Samli et al. (2005) who found that shell weight changed significantly ($p<0.05$) with storage time and temperature. In contrast, Silversides and Scott (2001) reported that changes in shell weight were unclear within 10 d of storage. Albumen weight also decreased with storage time, whereas yolk weight increased with storage time and temperature. When considered as percentages of the egg,

Table 1. Effects of storage temperature and time on egg quality

Storage temperature (°C)	Storage time (d)	n	Egg		Egg shell	
			Weight (g)	Loss (%)	Weight (g)	%
5	0	48	59.25	-	7.65[a]	13.50[a]
	2	48	59.16	0.15[c]	7.78[a]	13.27[a]
	5	48	59.08	0.28[b]	7.02[b]	12.43[b]
	10	48	58.92	0.55[a]	7.12[b]	12.46[b]
	SEM		0.589	0.018	0.122	0.182
	p		0.977	<0.001	<0.001	<0.001
21	0	48	59.79	-	7.51	13.19
	2	48	59.59	0.33[c]	7.45	12.86
	5	48	59.38	0.67[b]	7.57	12.86
	10	48	59.08	1.18[a]	7.60	13.14
	SEM		0.588	0.033	0.119	0.168
	p		0.853	<0.001	0.818	0.356
29	0	48	59.35[a]	-	7.89[a]	13.24[a]
	2	48	58.89[a]	0.77[c]	7.78[a]	13.26[a]
	5	48	58.32[ab]	1.74[b]	7.32[b]	12.49[b]
	10	48	57.17[b]	3.67[a]	6.81[c]	12.30[b]
	SEM		0.535	0.060	0.091	0.116
	p		0.028	<0.001	<0.001	<0.001
Source of variation						
SEM	Storage time		0.329	0.023	0.065	0.091
	Storage temperature		0.285	0.020	0.056	0.079
p-value	Storage time		0.118	<0.001	<0.001	<0.001
	Storage temperature		0.034	<0.001	0.196	0.231
	Time×temperature		0.766	<0.001	<0.001	<0.001

[a-c] Different letters indicate significant differences among the means in each column with the same storage temperature.

Table 2. Effects of storage temperature and time on albumen and yolk quality

Storage Temperature (°C)	Storage time (d)	n	Albumen		Yolk	
			Weight (g)	%	Weight (g)	%
5	0	48	35.54	62.66	13.48[c]	23.84[b]
	2	48	36.48	62.18	14.36[a]	24.55[a]
	5	48	35.40	62.66	14.06[ab]	24.91[a]
	10	48	36.17	63.14	13.91[b]	24.40[ab]
	SEM		0.451	0.317	0.147	0.254
	p		0.277	0.207	<0.001	0.029
21	0	48	35.60	62.41	13.87[b]	24.40
	2	48	36.52	62.00	14.74[a]	25.14
	5	48	36.14	62.22	14.43[a]	24.92
	10	48	35.67	61.48	14.79[a]	25.54
	SEM		0.491	0.361	0.196	0.327
	p		0.511	0.297	0.004	0.100
29	0	48	36.89[a]	61.76[a]	14.86[bc]	25.00[c]
	2	48	36.37[a]	61.76[a]	14.64[c]	24.98[c]
	5	48	36.06[a]	61.39[a]	15.30[b]	26.12[b]
	10	48	32.61[b]	58.86[b]	15.96[a]	28.44[a]
	SEM		0.513	0.341	0.192	0.305
	p		<0.001	<0.001	<0.001	<0.001
Source of variation						
SEM	Storage time		0.280	0.196	0.104	0.171
	Storage temperature		0.243	0.170	0.090	0.148
p-value	Storage time		<0.001	<0.001	<0.001	<0.001
	Storage temperature		0.230	<0.001	<0.001	<0.001
	Time×temperature		<0.001	<0.001	<0.001	<0.001

[a-c] Different letters indicate significant differences among the means in each column with the same storage temperature.

Table 3. Effects of storage temperature and time on albumen and yolk pH, Haugh units, and yolk colour

Storage Temperature (°C)	Storage time (d)	n	pH		Haugh units	Yolk color
			Albumen	Yolk		
5	0	48	8.09[c]	5.82[b]	88.79	7.27[c]
	2	48	8.31[b]	5.89[b]	87.76	7.63[ab]
	5	48	8.77[a]	6.02[a]	89.15	7.38[bc]
	10	48	8.76[a]	5.93[ab]	87.63	7.85[a]
	SEM		0.052	0.042	0.760	0.097
	p		<0.001	0.011	0.405	<0.001
21	0	48	7.95[d]	5.65[c]	91.30[a]	7.23[a]
	2	48	8.77[c]	5.87[b]	83.44[b]	6.73[b]
	5	48	9.18[b]	5.92[b]	75.67[c]	6.63[b]
	10	48	9.50[a]	6.09[a]	72.63[d]	6.90[b]
	SEM		0.038	0.042	0.788	0.104
	p		<0.001	<0.001	<0.001	<0.001
29	0	48	8.01[c]	5.93	87.62[a]	7.29[a]
	2	48	9.45[b]	5.98	73.01[b]	6.73[b]
	5	48	9.72[a]	5.93	61.85[c]	6.58[b]
	10	48	9.71[a]	5.93	60.92[c]	6.56[b]
	SEM		0.026	0.045	1.086	0.104
	p		<0.001	0.462	<0.001	<0.001
Source of variation						
SEM	Storage time		0.023	0.025	0.513	0.063
	Storage temperature		0.020	0.021	0.445	0.054
p-value	Storage time		<0.001	<0.001	<0.001	<0.001
	Storage temperature		<0.001	0.287	<0.001	<0.001
	Time×temperature		<0.001	<0.001	<0.001	<0.001

[a-c] Different letters indicate significant differences among the means in each column with the same storage temperature.

albumen weight decreased and yolk weight increased with storage temperature and time. These results are in agreement with those of Silversides and Scott (2001), who reported that measuring components as proportions of the whole egg removed any inconsistencies, and longer periods of storage resulted in greater percentages of shell and yolk and a lesser percentage of albumen. In contrast, Akyurek and Okur (2009) reported that albumen and yolk weights did not change within 10 d of storage at any temperature.

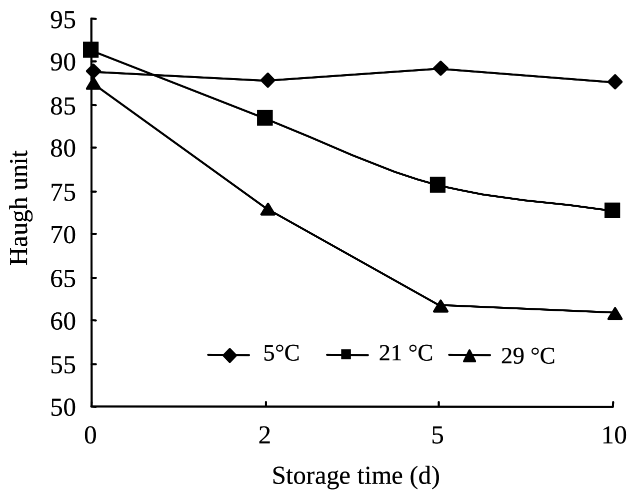

Figure 1. Effects of storage time and temperature on Haugh unit.

With the exception of storage at 5°C, dramatic reductions in HU were observed according to storage time and temperature. HU decreased from 91.3 to 72.63 at 21°C and from 87.62 to 60.92 at 29°C during 10 d of storage, whereas at 5°C no decline was found. These results are in agreement with Samli et al. (2005) who reported that storage time and temperature adversely affected HU ($p<0.001$). Similar results were demonstrated by other researchers (Tona et al., 2004; Akyurek and Okur, 2009). Figure 1 shows the changes in HU with storage time and temperature.

Significant increases in albumen and yolk pH values were observed with increasing storage temperature and time. A rapid increase in albumen alkalinity was observed, even after just 2 d of storage, regardless of the storage temperature. Albumen pH increased from 8.01 to 9.72 at the storage temperature of 29°C. A highly significant interaction between storage time and temperature was observed for albumen pH ($p<0.001$). Most of the increase occurred during the first 5 d of storage. This rapid increase

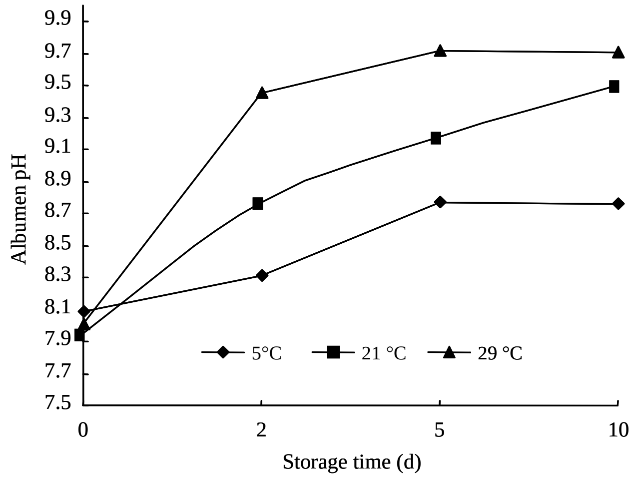

Figure 2. Effects of storage time and temperature on albumen pH.

was followed by progressive delays at 5°C and 29°C, and a slower rate of increase at 21°C throughout the remainder of the storage period. These findings are in agreement with results reported by other researchers (Scott and Silversides, 2000; Samli et al., 2005; Akyurel and Okur, 2009). In contrast, Walsh et al. (1995) reported that neither storage time nor temperature influenced albumen pH. The increase in yolk pH was not as large as the increase in albumen pH, and yolk pH did not differ during 10 d of storage at 29°C. In contrast, Samli et al. (2005) showed that yolk pH differed from 5.75 to 6.08 during 10 d of storage at 29°C. The present results are in agreement with those of other researchers (Samli et al., 2005; Akyurel and Okur, 2009) who also found that increases in yolk pH were significantly affected by storage time, but not by temperature. In addition, a highly significant interaction between storage time and temperature was observed for yolk pH ($p<0.001$).

Significant changes in yolk color occurred even after 2 d of storage depending on the storage temperature and time ($p<0.001$). Maria Elena et al. (2006) reported that for storage time, color did not diminish at 4°C, while at 20°C there was an average reduction of 9.91 to 8.33 at 30 days of storage. This could be attributed to dilution of the egg yolk. Jones (2006) stated that as the internal temperature of an egg increases, the protein structures of the thick albumen and vitelline membrane breakdown faster. These effects of storage are expected (Heath, 1977; Ahn et al., 1999) as some ingredients from the albumen pass through the yolk membrane and are lost through the shell. This may partly explain why storage and time caused negative effects on the yolk color. As the membrane degenerates during storage, water enters the yolk causing dilution of the pigment, and after prolonged storage time, albumen proteins may enter the yolk decreasing the yolk color. No recent data were found regarding the relationship between yolk color and storage temperature or time.

Interactions between storage time and temperature were significant ($p<0.001$) with respect to egg weight loss, egg shell weight and percentage, albumen weight and percentage, yolk weight and percentage, albumen and yolk pH, HU, and yolk color (Tables 1, 2 and 3). Figure 1 and 2 clearly show the two-way interaction of storage temperature and time on HU and albumen pH. Deteriorations in albumen quality were clearly shown during storage at 21 and 29°C as the eggs were stored from 2 to 10 d. This finding implies that reductions in egg quality occurred by storage time in a nonlinear manner. Albumen pH differed even at the 5°C storage temperature. The importance of storage time and temperature on measures of egg composition and quality was investigated using regression analysis (Table 4). The regression results of the storage conditions on egg weight, percentage of albumen, yolk weight and percentage, HU, and albumen pH were significant in both storage conditions with low R^2 values, whereas the results for albumen weight, shell weight and

Table 4. Regression analysis coefficients (a, b) of eggs by storage time and temperature [1]

	Time			Temperature		
	a	b	R^2	a	b	R^2
Egg weight	58.32***	-0.13**	0.01	57.06***	0.04*	0.01
Albumin weight	36.37***	-0.13***	0.02	36.02***	-0.01	0
Albumin %	62.30***	-0.10***	0.02	63.09***	-0.07***	0.07
Yolk weight	14.24***	-0.07***	0.03	13.65***	0.05***	0.12
Yolk %	24.47***	0.17***	0.08	23.96***	0.07***	0.08
Shell weight	7.70***	-0.06***	0.07	7.39***	0	0
Shell %	13.22***	-0.07***	0.05	12.96***	0	0
Haugh units	86.07***	-1.42***	0.20	92.61***	-0.69***	0.33
Colour	7.12***	-0.01	0	7.75***	-0.04***	0.17
Albumen pH	8.36***	0.11***	0.39	8.31***	0.03***	0.18
Yolk pH	5.84***	0.02***	0.04	5.90***	0	0

[1] Regression coefficients and coefficients of determination are based on 571 observations.
* p<0.05. ** p<0.01. *** p<0.001.

percentage, yolk color, and yolk pH were not significant.

CONCLUSIONS

The data from the current study indicate that eggs from laying hens at peak production can have significant reductions of internal quality with increased storage temperature and time. There were significant interactions between egg quality and both storage temperature and time. Haugh units were adversely affected by length of storage and increased storage temperature. A rapid increase in albumen pH was observed even after just 2 d of storage regardless of the storage temperature. Interaction effects between storage temperature and time were also significant in terms of egg weight loss, shell weight and percentage, albumen weight and percentage, yolk weight and percentage, albumen and yolk pH, HU, and yolk color. The results indicate that egg weight loss, albumen pH, and HU are parameters that are greatly influenced according to the storage temperature and time of eggs from hens at peak laying.

REFERENCES

Ahn, D. U., J. L. Sell, C. Jo, M. Chamruspollert and M. Jeffrey. 1999. Effects of dietary conjugated linoleic acid on the quality characteristics of chicken eggs during refrigerated storage. Poult. Sci. 78:922-928.

Akyurek, H. and A. A. Okur. 2009. Effect of storage time, temperature and hen age on egg quality in free-range layer hens. J. Anim. Vet. Adv. 8:1953-1958.

Haugh, R. R. 1937. The Haugh unit for measuring egg quality. US Egg Poult. Mag. 43:522-555, 572-573.

Heath, J. L. 1977. Chemical and related osmotic changes in egg albumen during storage. Poult. Sci. 56:822-828.

Hinton, H. R. 1968. Storage of eggs. In: Egg Quality. A study of the Hen's Egg. T.C. Carter. Ed. Oliver and Boyd, Edinburgh, Scotland. pp. 251-261.

Johnson, A. S. and E. S. Merritt. 1955. Heritability of albumen height and specific gravity of eggs from white Leghorns and Barred Rocks and the correlations of these traits with egg production. Poult. Sci. 34:578-587.

Jones, D. R. 2006. Conserving and monitoring shell egg quality. Proceedings of the 18th Annual Australian Poultry Science Symposium. pp. 157-165.

Korean Ministry for Food, Agriculture, Forestry and Fisheries 2008. Guidelines for the Care and Use of Animals in Research. Korean Ministry for Food, Agriculture, Forestry and Fisheries, Seoul, Korea.

Lohmann Tierzucht GmbH, 2008. Layer Management Guide Lohmann Brown Classic.

Maria Elena, C. J., S. G. Leonor, M. B. Eduardo, C. D. Silvia, A. G. Avila, F. M. Benjamin, R. P. Miriam and P. G. R. Fernando. 2006. Shrimp head meal in laying hen rations and its effects on fresh and stored egg quality. INCL. 31: http://www.scielo.org.ve/scielo.php?pid=S0378-18442006001100009&script=sci_arttext.

Robinson, D. S. 1987. The chemical basis of albumen quality. In: Egg Quality-Current Problems and Recent Advances (Ed. R. G. Wells and C. G. Belyavin). Butterworths, London. pp. 179-191.

Samli, H. E., A. Agna and N. Senkoylu. 2005. Effects of storage time and temperature on egg quality in old laying hens. J. Appl. Poult. Res. 14:548-533.

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

Shenstone, F. S. 1968. The gross composition, chemistry and physicochemical basis of organization of the yolk and white. In: Egg Quality. A study of the Hen's Egg (Ed. T. C. Carter). Oliver and Boyd, Edinburgh, Scotland. pp. 26-58.

Snedecor, G. W. and W. G. Cochran. 1989. Statistical Methods. 7th ed. The Iowa State University Press. Ames, Iowa.

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.

STATISTIX. 1996. Statistix for Windows, User's Manual. Analytical Software. Tallahassee, Florida.

Tona, K., O. Onagbesan, B. De Ketelaere, E. Decuypere and V. Bruggeman. 2004. Effects of age of broiler breeders and egg storage on egg quality, hatchability chick quality, chick weight and chick posthatch growth to 42 days. J. Appl. Poult. Res. 13: 10-18.

Walsh, T. J., R. E. Rizk and J. Brake. 1995. Effects of temperature and carbon dioxide on albumen characteristics, weight loss, and early embryonic mortality of long stored hatching eggs. Poult. Sci. 74:1403-1410.

Williams, K. C. 1992. Some factors affecting albumen quality with particular reference to Haugh unit score. World's Poult. Sci. J. 48:5-16.