Effect of Testing Temperature on Internal Egg Quality Measurements

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ABSTRACT The objective of this study was to determine the effect of egg testing temperature on quality measurements of shell eggs. The quality measurements compared included 3 Haugh unit (HU) devices (electronic Haugh, tripod Haugh, and Haugh meter), egg weight, albumen height, albumen width, albumen index, yolk width, yolk height, yolk index, percentage of thin albumen, and vitelline membrane strength at 3 temperatures of 5, 13, and 23°C from 2 strains of laying hens (Hyline W36 and Bovans White) at 2 storage times. The HU measurements averaged 72.44 at time zero and 59.99 at 7 wk. At 7 wk for all devices, HU values decreased 6 units with increased temperature ($P < 0.05$). The electronic Haugh and tripod Haugh devices gave equal measurements for all testing conditions. The Haugh meter gave equal values at 5°C for fresh eggs but lower HU at higher temperatures and 7 wk storage. Thus, it is recommended that egg testing temperature be reported when HU are measured. Coefficient of variation generally increased for all HU methods with increasing temperature. Although there was a proportionately different amount of thin albumen detected between the strains of laying hens, no significant difference was seen in HU. From the evaluated methods for measuring quality, the electronic Haugh, which electronically measures albumen height and calculates HU, provided the lowest coefficient of variation, was sensitive to quality loss, and gave the highest quality measurement (5°C).

Key words: egg quality, testing temperature, Haugh unit, albumen quality

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INTRODUCTION

Internal egg quality relates to the functional characteristics of an egg. Many methods have been developed to quantify interior egg quality; however, the effect of testing temperature has not been fully investigated. Testing temperature is sometimes unreported or given as a general range, such as room temperature (Keener et al., 2000; Kirunda and McKee, 2000). This could impact results and also makes it difficult to compare studies.

Haugh units (**HU**) are the standard method for determination of interior egg quality. The rate of quality loss as measured by HU is a nonlinear function (Haugh, 1937). Several researchers have questioned the validity of the Haugh method and its correction for egg weight. For example, Eisen et al. (1962) compared a direct albumen height measurement and calculated HU and found a bias in the HU regression. They reported that the correction for egg weight results in an overestimation of albumen height in smaller eggs and an underestimation of albumen height in larger eggs. Although its validity has been questioned, Wesley and Stadelman (1959) found that the HU correlates well with the physical appearance of the broken-out egg and is significantly correlated to other quality measurements including thin albumen diameter, yolk centering, shape of thin albumen, shape of thick albumen, percentage of outer thin albumen, percentage of thick albumen, and total percentage of thin albumen. Silversides et al. (1993) determined that the egg weight correction in the HU method was unnecessary when measuring the quality of fresh eggs at room temperature. Also, they suggest that comparing HU from different flocks was inaccurate. They suggested measuring the albumen height to determine egg quality.

In the development of methods to measure albumen height, Wilgus and VanWagenen (1936) compared thick albumen height to a thick albumen height corrected for the weight of the egg. They found that the r^2 were equal and that the uncorrected measurement of the albumen height was simpler. However, recent studies by Silversides and Scott (2001) found that the albumen height is biased by the strain and age of hen.

Heiman and Carver (1936) reported that the albumen index (defined in the Materials and Methods section) was better than other quality measurements because egg weight does not influence albumen index. Sauter et al.

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(1953) found that the albumen index is closely correlated with quality loss as determined by candling. One of the major disadvantages of the albumen index is that the rate of quality loss is a nonlinear function, similar to HU.

Vitelline membrane strength has become increasingly important for food safety reasons (Messens et al., 2005). The strength of the vitelline membrane decreases with increasing egg age. This may allow nutrients in the yolk to become available to any microorganisms that are present in the albumen. Kirunda and McKee (2000) found that membrane strength values are significantly related to yolk index and HU.

Wesley and Stadelman (1959) found that the yolk index (defined in the Materials and Methods section), although correlated to other interior quality measurements including percentage of outer thin albumen, percentage of thick albumen, and total percentage of thin albumen, was not as accurate as the HU in giving a complete picture of overall egg quality. Their findings were similar to those of Sharp and Powell (1930), who found that the height of the thick albumen decreases more rapidly than the yolk index with storage.

Little attention has been given to the influence of variables such as egg testing temperature and age on these quality measurements. Spencer et al. (1956) found that the amount of time between breakout and measurement can impact the quality values. They found that the albumen quality, as measured by HU and albumen height, declined linearly with the logarithm of elapsed time from breakout. Additionally, the laying hen strain and the age of the egg influenced the rate of loss. Stadelman et al. (1954) observed a linear decrease of −1.15 HU per 10°C increase in testing temperature. The objective of this research was to determine the effects of egg testing temperature, storage time, and bird strain on interior egg quality measurements.

MATERIALS AND METHODS

Experimental Design

A 2 × 2 × 3 × 3 × 12 (2 storage times, 2 laying hen strains, 3 temperatures, 3 replicates, and 12 eggs or replicates) experimental design was used to compare the effect of testing device, temperature, and laying hen strain on internal egg quality measurements. The measurements evaluated included egg weight, albumen height, albumen width, albumen index, HU, yolk height, yolk width, yolk index, percentage of thin albumen, and vitelline membrane strength. At each storage time, 12 eggs from each temperature-strain combination were evaluated using each method, with the exception of vitelline membrane strength, which used 20 eggs. Ninety dozen Grade A large eggs from Hy-Line W36 and Bovans White laying hens were collected from the North Carolina State University Poultry Research Farm and transported in an air-conditioned van to the laboratory within 48 h from lay and placed in refrigerated storage at 5°C. Two testing periods, at time zero and after 7 wk of storage at 5°C, were used. Seven weeks was selected as the maximum length of refrigerated storage corresponding to approximately 45 d after packaging. This corresponds to the "use by date," which is generally recognized as 45 d. Testing temperatures of 5, 13, and 23°C were selected based on refrigeration temperature (5 to 7°C); room temperature (20 to 23°C), and a midpoint temperature (13°C). Twenty-four hours prior to testing, a set of eggs were removed from the cooler and placed into incubators on open plastic flats at each temperature for equilibration. A set of eggs consisted of 150 eggs or 5 flats. Unpublished data (results not shown) found that 24 h of equilibration at 23°C did not statistically influence egg quality. Prior to testing, all eggs were candled and cracked eggs removed.

Because of instrumental limitations, vitelline membrane measurements were only taken at 5°C. Each method except percentage of thin albumen and vitelline membrane measurements was performed on the same egg to eliminate egg-to-egg variation. Approximately 5 min was required to complete all measurements on each egg. The eggs were removed randomly from the incubator as tested, and all testing was done in a room at 23°C.

Egg Weight

Eggs were weighed to the nearest 10th of a gram prior to testing. After weighing, the eggs were broken out onto a glass break-out table for albumen height, albumen width, albumen index, HU, yolk height, yolk index, and yolk width measurements.

Eggs used for vitelline membrane and percentage of thin albumen measurements were not weighed.

Albumen Height

A tripod micrometer (B.C. Ames Co., Waltham, MA) and an electronic height gauge that is part of the Technical Services and Supplies QDC Egg Quality System (TSS, York, UK) were used to measure albumen height. For each method, measurements of the albumen height were done on the thick albumen, not touching the yolk and avoiding the chalazae. The micrometer placement was approximately 6 mm from the yolk and the edge of the thick albumen. The tripod micrometer measures the height using a spring dial. The electronic height gauge measures the albumen height by conduction. When the probe contacts the albumen, the height is recorded electronically. A visual check was used to insure that the thick albumen was not ruptured during this measurement procedure.

Haugh Units

Three HU methods were compared. The first method evaluated used the Technical Services and Supplies QDC Egg Quality System. This instrument is connected to a computer equipped with software to automatically record egg weight (in grams) and albumen height (in

Table 1. Egg quality parameter measurements taken at different storage times and temperatures

	Egg weight (g)	Electronic albumen height (EAH) (mm)	Tripod albumen height (TAH) (mm)	Albumen width (mm)	Percentage of thin albumen	Yolk height (mm)	Yolk width (mm)	Membrane strength (g)	Membrane rupture deformation (mm)
Storage time (ST)									
Zero	62.53	5.91[a]	5.79[a]	82.39[b]	18.27[b]	18.87[a]	41.47	2.29[a]	2.3
7 wk	61.84	4.56[b]	4.24[b]	85.44[a]	21.96[a]	17.95[b]	40.99	1.85[b]	1.4
Strain (S)									
Hy-Line W 36	62.32	5.28	5.47	82.95[b]	21.34[a]	18.22[b]	41.45	1.96[b]	1.6
Bovans White	62.05	5.19	4.98	84.89[a]	18.89[b]	18.60[a]	41.00	2.18[a]	2.1
Testing Temperature (TT), °C									
5	61.62	5.33[a]	5.12[a]	82.24[b]	19.95	19.37[a]	40.31[b]	2.07	1.85
13	62.71	5.39[a]	5.15[a]	83.68[b]	19.66	18.31[b]	41.14[a]		
23	62.23	4.99[b]	4.78[b]	85.54[a]	20.72	17.55[c]	42.23[a]		
CV, °C									
5		18.8	18.8	7.7	27.8	5.7	5.2	27.7	2.9
13		23	24.8	9.2	30	5.8	4.7		
23		22.1	24.2	9	4.8	6.8	4.4		
Interaction									
ST × S	NS	*	**	*	NS	**	NS		
ST × TT	NS	**	*	**	NS	**	*		
S × TT	NS	NS	NS	NS	NS	**	NS		
ST × S × TT	NS	NS	NS	NS	NS	NS	NS		

[a–c]Means within a section, in a given column, followed by the same letter do not differ significantly ($P < 0.05$).

*$P < 0.05$; **$P < 0.01$.

millimeters) and calculate HU (Haugh, 1937). The second method was a standard tripod micrometer. This device measured the albumen height in millimeters. The albumen height (H), along with egg weight (W), measured previously, was used in the following HU equation; G was the gravitational constant of 32.2.

$$HU = 100\log\left\{H - \left[\sqrt{G}\,(30W^{0.37} - 100)/100\right] + 1.9\right\} \quad [1]$$

The third method tested was a Haugh Meter (B.C. Ames Co.). The Haugh meter is a spring micrometer that is adjusted manually for egg weight and displays HU directly. Egg weight adjustments are done by converting individual egg weight into ounces per dozen.

Albumen Index

Albumen index is defined as height of the albumen divided by the width of the albumen (Heiman and Carver, 1936). Albumen height measurements were recorded using the standard tripod micrometer. The albumen width was determined by averaging the minimum and maximum of the broken-out egg with dial calipers (Bel-Art Products, Pequannock, NJ).

Percentage of Thin Albumen

Percentage of thin albumen was measured by taring a screen, approximately 8 × 8 in., with 3-mm openings, and a beaker on a scale. The entire contents of 1 egg were broken out onto the screen, and the egg weight was recorded. The contents were allowed to drip for 1 min. After 1 min, the thick white and yolk were gently rolled off of the screen, which was then placed back on the scale, and the percentage of thin albumen was determined using Equation 2.

$$\text{Percentage of thin albumen} = (\text{weight loss}/\text{weight of entire contents}) \times 100. \quad [2]$$

Yolk Index

The yolk index was determined by measuring the width of the yolk with dial calipers and the height of the yolk using a standard tripod micrometer. The measurements were taken with the yolk in the natural position when the egg was broken out (Funk, 1948).

$$\text{Yolk index} = \text{height yolk}/\text{width yolk} \quad [3]$$

Vitelline Membrane Strength

Vitelline membrane strength was measured using the TA-XT2i Texture Analyzer (Texture Technologies Corp., Scarsdale, NY) with a 5-kg load cell, and a sensitivity of 0.1 g (or texture analyzer trigger force). Pressure was applied at a rate of 3.2 mm/second with the instrument set at 10 g full scale. A 1 mm in width, rounded-end, stainless-steel probe was used to apply direct pressure to the membrane. Care was taken to avoid contact with the germinal disc or the chalazae (Lyon et al., 1972). The force at rupture and the deformation at rupture were recorded.

Statistical Analysis

All data were analyzed using the GLM procedure of SAS with the main effects being laying hen strain, stor-

Table 2. Egg quality method measurements taken at different storage times and temperatures

		Electronic haugh	Haugh meter	Tripod haugh	Albumen index	Yolk index
Storage time (ST)						
Zero		74.32[a]	69.60[a]	73.38[a]	0.07[a]	0.46[a]
7 wk		62.73[b]	57.75[b]	59.57[b]	0.05[b]	0.44[b]
Strain (S)						
Hy-Line W 36		69.01[a]	63.61[b]	66.96[c]	0.06	0.44[b]
Bovans White		68.04[ac]	63.75[b]	65.99[cd]	0.06	0.45[a]
Testing temperature (TT), °C						
5	0 wk	73.8[a]	71.8[abc]	73.3[ac]	0.65[a]	0.48[a]
	7 wk	65.8[dbec]	60.8[defgh]	62.4[degi]		
13	0 wk	76.6[ajk]	68.0[bcl]	75.3[a]	0.66[a]	0.44[b]
	7 wk	62.4[egm]	57.5[fgm]	59.1[gm]		
23	0 wk	72.5[alno]	68.9[ino]	71.5[alo]	0.58[b]	0.41[c]
	7 wk	60.1[hipm]	55.1[mq]	56.7[hmq]		
CV, °C						
5	0 wk	10.9	10.9	10.7	22.2	7.1
	7 wk	10.8	13.0	11.7		
13	0 wk	9.7	12.4	9.8	30.2	6.2
	7 wk	12.0	14.1	13.7		
23	0 wk	10.9	13.1	11.7	28.1	6.7
	7 wk	13.1	15.1	14.1		
Interaction						
ST × S		*	**	**	*	NS
ST × TT		**	NS	*	**	**
S × TT		NS	NS	NS	NS	NS
ST × S × TT		NS	NS	NS	NS	**

[a–q]Means within a section followed by the same letter do not differ significantly ($P < 0.05$).

*$P < 0.05$; **$P < 0.01$.

age time, egg testing temperature, HU measuring device, and replicate. Mean differences were separated via the PDIFF option, which uses the Tukey least squares method. A significance level of $P < 0.05$ was used for all comparisons. The MEANS procedure was used to determine the CV for the quality measurements.

RESULTS AND DISCUSSION

Tables 1 and 2 display the results for this study. These results include a comparison of 5 egg quality measurements and 9 egg quality parameters taken at 3 testing temperatures on fresh and 7-wk-old eggs from 2 hen strains. For all results, replicate was not found to be significant and therefore was excluded from further discussion. To compare the precision of the measurements and parameters, the CV was determined. The CV are shown in Tables 1 and 2. As expected, egg quality decreased with storage time.

Various egg quality parameters are included in Table 1. Egg weight averaged 62 g with no influence from storage time. In addition, there was no difference in egg weight between the laying hen strains or testing temperatures.

Egg quality parameter measurements included electronic (**EAH**) and tripod albumen height (**TAH**). Initially, values were 5.91 and 5.79, respectively, and decreased to 4.56 and 4.24, respectively, at 7 wk. There was not a significant difference in EAH and TAH for the laying hen strain, but increasing testing temperature showed reduced height. The CV of the EAH and TAH measurements were comparable with the lowest CV (18.8) seen at 5°C.

Albumen width and percentage of thin albumen increased with storage time with a slight increase with temperature. Also, the CV for albumen was notably small (~8); however, the laying hen strain significantly influenced these results. This result is similar to Silversides and Scott (2001), who found that the amount of albumen in ISA-White hens was greater than eggs from ISA-Brown hens. Because of this strain difference, it would be difficult to recommend albumen width or percentage of thin albumen as an egg quality measurement.

Yolk height decreased approximately 10% with temperature increasing from 5 to 23°C with only a slight decrease with storage time. For yolk width, minimal change was observed with either temperature or storage time. Both yolk height and yolk width had the lowest CV for all the measurements (4 to 7), but percentage decreases in yolk height and width with storage were significantly less than those observed in the albumen and HU.

Membrane strength and deformation were very sensitive to storage time and testing temperature, but instrument limitations prevented measurement at temperatures >5°C. Specifically, the membrane became considerably weaker (>80% decrease) at 13°C, and it was not possible to measure a change in force at rupture of deformation, although it was observed to be extremely sensitive to temperature and age effects. Since these data were incomplete, vitelline membrane measurement was excluded from further discussion.

Albumen index and yolk index showed minimal decreases with storage time and temperature. The CV for albumen index is especially high (~27). Wesley and Stadelman (1959) found that the yolk index is not as accurate as the HU in giving a complete picture of overall egg quality.

In the egg industry, the standard for interior egg quality is determined by HU. Therefore, a major component of this research was a comparison of the 3 HU devices for 2 bird strains, at the 2 storage times, and 3 testing temperatures. There was no detectable difference in HU with bird strain. For fresh eggs, the electronic Haugh and tripod Haugh gave equal values for all temperatures. The Haugh meter was equivalent for fresh eggs at 5°C, but gave lower values with increasing temperature. At 7 wk of storage, all 3 HU measuring devices showed a similar decrease in egg quality of 6 HU with increasing temperature. This suggests that the influence of testing temperature becomes more pronounced as egg storage time increases. Previous research (Stadelman et al., 1954) found a 1.15 HU decrease for every 10°C increase in temperature. The average HU measurements decreased from 72.44 at time zero to 59.99 at 7 wk of storage, suggesting that it is sensitive to egg quality changes. The CV for all HU measuring devices was low, within the range of 10 to 14, with the electronic Haugh having the lowest average CV of ~11. The CV for the HU at 0 wk of storage for all 3 devices is consistently lower than the CV for HU at 7 wk of storage. This suggests that the rate of quality loss in individual eggs varies more than the initial quality. In summary, the HU measuring devices show a higher sensitivity for assessing egg quality as compared with the other egg quality method measurements, and the CV were low. However, eggs stored 7 wk were influenced more by temperature effects. Thus, it is recommended that egg testing temperature be reported when HU are measured. Overall, the electronic HU measuring device had a consistently lower CV compared with the other 2 HU measuring devices and produced consistently higher values.

Several significant interactions were found, as indicated in Tables 1 and 2. Albumen height measurements had significant storage × strain and storage × testing temperature interaction. For both methods, electronic and tripod micrometer, Hy-line W36 was lower than Bovans White at the initial testing and higher after 7 wk of storage. These interactions further highlight the strain effect on albumen height and their different response to storage and testing temperature. In addition, these interactions suggest that the albumen height is more sensitive to increased temperature in aged eggs than fresh eggs.

Yolk height measurements have significant storage × testing temperature interactions. After 7 wk of storage, testing temperature had a larger effect on yolk height than at time zero. This suggests that the vitelline membrane is more sensitive to temperature changes after storage, similar to the albumen effect documented in the Haugh measurements. Yolk height also had significant laying hen strain × testing temperature interactions. Here again, this suggests that eggs from each laying hen strain respond differently with increasing testing temperature. The storage × strain × testing temperature interactions were not significant except yolk index. There was no clear explanation for this observed interaction.

Summary and Conclusions

Strain differences were detected in albumen width and percentage of thin albumen, yolk height, yolk index, and vitelline membrane strength measurements, but no strain difference was found in albumen height or HU. Yolk height, yolk width, and yolk index had the lowest CV, but these measurements showed minimal change with storage. In general, all measurements and parameters tested showed lower egg quality at higher testing temperatures and increased storage time. It should be noted that the largest quality loss (39%) was observed for vitelline membrane deformation at 5°C, but instrument limitations and a large decrease (>80%) in membrane strength with increasing temperature prevented additional measurements for this recently developed method.

The electronic Haugh and tripod Haugh gave equal values for all storage times and testing temperatures. The Haugh meter gave equal values at 5°C for fresh eggs but lower HU at higher temperatures and 7 wk storage. The average HU decreased from 72.44 at time zero to 59.99 at 7 wk storage, suggesting that it is sensitive to egg quality changes. The Haugh unit measurements on fresh eggs showed no effect from temperature, but eggs tested after 7 wk storage showed a decrease of 6 HU with increased temperature. Thus, it is recommended that egg testing temperature be reported when HU are measured. CV generally increased for all HU methods with increasing temperature and storage time. From the evaluated methods for measuring quality, the electronic Haugh, which electronically measures albumen height and calculates HU, provided the lowest CV, was sensitive to quality loss and gave the highest quality measurement (5°C).

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