Effects of Storage Time and Temperature on Egg Quality in Old Laying Hens

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Primary Audience: Commercial Egg Producers, Managers, Researchers

SUMMARY

The aim of the present study was to examine the effects of storage time and temperature and their interaction on the quality parameters of eggs obtained from aged laying hens. Eggs from 50-wk-old Bovans White hens were sampled immediately after being laid and subjected to storage periods of 2, 5, and 10 d at 5, 21, and 29°C. Extension of the storage time up to 10 d and temperature up to 29°C resulted in significant deterioration of egg quality. Albumen height, Haugh unit, pH of albumen and yolk, specific gravity, and air cell size have been found to be the most important parameters and were greatly influenced by storage time and temperature. In a 10-d storage period Haugh units were 76.3, 53.7, and 40.6 when stored at 5, 21, or 29°C, respectively. The size of air cell (distance between eggshell and membrane) exceeded 4 mm when eggs were stored 2 d at greater than 21°C. Rapidly increased pH in albumen with 2 d storage time was observed, regardless of storage temperature. Likewise, pH during a 5-d storage period continued to increase from 7.47 to 9.2 at 29°C. Interaction effects between storage time and temperature were also significant for egg weight loss, specific gravity, air cell size, Haugh unit, albumen height, and pH. The results of the present study suggested that Haugh unit, pH of albumen, and air cell size were the most important parameters influenced by the storage period and storage temperature in laying hens.

Key words: Egg quality, storage time, temperature, old hens, Haugh unit, air cell

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DESCRIPTION OF PROBLEM

For many years the most important external and internal egg quality traits have been shown to be egg weight, egg shape, shell thickness, breaking strength, specific gravity, air cell, albumen height and weight, and yolk index. Albumen quality is influenced by genetic factors [1]. Environmental factors such as temperature, humidity, the presence of CO_2, and storage time are also of prime importance in terms of the maintenance of egg quality. Albumen quality is not only an important indicator for egg freshness, but it is also important for the egg breaking industry because albumen and yolk have different markets [2, 3, 4, 5]. Storage time and temperature appear to be the most crucial factors affecting albumen quality or Haugh unit (HU). The HU, as described by Haugh [6], is calculated from the height of the inner thick albumen and the weight of the egg and could be considered to be a measure of visual appearance because it

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describes the appearance of the egg when it is broken onto a flat surface [7].

Visual appearance of the albumen has also been used extensively to describe egg quality [8, 9]. Excess loss of water from the egg through evaporation at a rate that is influenced by the temperature and relative humidity during the long-term storage conditions has generally been reported to be detrimental to table and hatching egg quality [10, 11, 12]. Some researchers have reported a decline in hatchability by as much as 5% per day after 7 d of storage [13].

It has been reported [14] that pH is a useful tool for describing the changes in albumen quality over time during storage, but its measurement is time consuming. Albumen pH increases with the loss of CO_2 from the egg. An increase in pH and dry matter has been reported by extending the storage time from 2 to 30 d. Decreases in viscosity and changes in taste and flavor have also been reported in aging eggs [15].

In healthy flocks, bird age is the most important factor affecting albumen quality of freshly laid eggs. Initial albumen quality rapidly decreases with advancing flock age. Forced molting is beneficial in restoring albumen quality in aged hens [7]. However, the economic consequences of this practice depend on local circumstances. Oiling of eggs within 24 h of lay has been reported to be effective in retarding albumen deterioration but does not replace the need for cool storage [7].

Although genetic and environmental factors [2, 16] are also major factors affecting egg quality, nutritional factors [17] have only minor effects. Within the bounds of accepted commercial practice, albumen quality is largely unaffected by the nutrition of a hen [7]. Albumen quality might be related to the protein source of the laying hen consumed within the diet. Increased laying hen productivity has been reported to lead to a reduction in eggshell quality and an improvement of albumen quality. Thus, considering the most productive group, the shell is thinner and less colored, and Haugh units and percentage of dry matter in the albumen are higher [18]. The specific gravity and compression fracture strength of the eggs are also changed by storage time [19].

Many attempts have been made to determine egg quality. The problem has been to find a factor that is rapidly measured and associated with the difference in quality [8]. A number of studies have been conducted concerning the effects of storage time on egg quality. However, the interaction of time and temperature is not fully known. Therefore, the aim of the present study was to examine effects of storage period and temperature and the interaction between storage times and temperatures on egg quality in aged laying hens.

MATERIALS AND METHODS

Eggs were obtained from Bovans White [20] hens that were included in a laying trial at experimental unit of Department of Animal Science (Trakya University). In the current experiment, 400 laying hens at the age of 50 wk were used. They were randomly confined in the commercial compact type wire cages (50 × 44 × 46 cm) equipped with nipple drinkers and trough feeders. Laying hens were housed in battery cages with 4 hens per cage and fed a compound feed that was prepared according to NRC recommendations [21]. Laying hens were maintained in the experimental room with windows and received additional artificial light to provide 16 h of light and 8 h of dark.

We collected a total of 350 eggs at once for the present experiment when the hens were 50 wk old. Fresh eggs were collected and measured within 2 h of being laid. Each of 35 sampled eggs was stored in chambers for 2, 5, or 10 d in a refrigerator (5°C), at room temperature (21°C), and hot at high temperature (29°C). Humidity was 55 to 60% for all treatments. Thus, 350 eggs were collected and used in 10 treatments (3 storage periods × 3 storage temperatures plus 1 group of fresh eggs) with 35 eggs examined in each. For sampling, each egg was weighed and broken, and the height of the thick albumen and egg yolk were measured within a tripod micrometer. The albumen and yolk were separated, and only yolk was weighed. In each of 350 collected eggs the pH of the albumen and yolk was measured by pH meter [22]. Haugh units were calculated from the HU formula [$HU = 100 \log (H - 1.7W^{0.37} + 7.57)$]. Egg yolk width was measured by using a compass. The yolk indices were then calculated as follows: yolk index = yolk height/yolk width. Air cell (distance between eggshell and membrane, mm) and

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

Storage time (d)	Storage temperature (°C)	n	Egg weight		Shell		Specific gravity (g/cm^3)	Air cell (mm)
			Fresh (g)	Loss (g)	Weight (g)	Thickness (μm)		
	Fresh eggs	35	62.38	—	7.764^{a}	298^{abc}	1.086^{a}	3.18^{e}
2	5	35	61.83	0.17^{d}	6.836^{b}	308^{abc}	1.085^{a}	3.66^{e}
	21	35	63.85	0.32^{d}	6.908^{b}	292^{c}	1.082^{b}	4.28^{d}
	29	35	62.88	0.41^{cd}	6.916^{b}	298^{abc}	1.082^{b}	4.56^{d}
5	5	35	61.94	0.32^{d}	7.092^{b}	293^{bc}	1.082^{b}	4.00^{d}
	21	35	63.67	0.65^{c}	6.875^{b}	305^{abc}	1.078^{c}	4.69^{c}
	29	35	61.49	1.30^{b}	6.750^{b}	313^{a}	1.071^{d}	5.81^{b}
10	5	35	62.78	0.42^{cd}	6.968^{b}	312^{a}	1.080^{bc}	4.24^{cd}
	21	35	61.69	1.03^{b}	6.444^{c}	296^{abc}	1.074^{d}	5.69^{b}
	29	35	61.96	1.94^{a}	6.784^{b}	307^{abc}	1.063^{e}	7.82^{a}
SEM			0.270	0.046	0.039	1.829	0.001	0.103
Source of variation			*P*					
Storage time			NS	<0.001	<0.05	0.467	<0.001	<0.001
Storage temperature			NS	<0.001	<0.05	0.192	<0.001	<0.001
Time × temperature			NS	<0.001	<0.05	0.041	<0.001	<0.001

[a–e]Different letters indicate significant differences among the means in each column ($P < 0.05$).

eggshell thickness (mean of 3 different sides of eggs, μm) were measured with same micrometer [23]. To measure the specific gravity (SG) of the egg, saline solutions used varied in SG from 1.060 to 1.100 in increments of 0.005.

Data for fresh and stored eggs together were subjected to Duncan's multiple range test. The data without fresh eggs were analyzed using the SAS statistical package [24]. An ANOVA using a general linear model included the main effects of storage time and storage temperature of eggs and the two-way interactions between these factors. Although all interactions were significant a further ANOVA used only main effects.

RESULTS AND DISCUSSION

Results of the effects of storage temperature and time are presented in Tables 1 and 2. Storage time and temperature significantly affected almost all parameters of internal and external qual-

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

Storage time (d)	Storage temperature (°C)	n	Albumen			Yolk		
			Haugh units	Height (mm)	pH	Weight (g)	Yolk index	pH
	Fresh eggs	35	91.37^{a}	8.56^{a}	7.47^{h}	17.97^{b}	44.09^{b}	5.75^{de}
2	5	35	80.11^{b}	6.65^{b}	7.99^{g}	18.49^{ab}	46.21^{b}	5.90^{c}
	21	35	72.82^{c}	5.80^{c}	8.52^{d}	19.36^{a}	44.07^{b}	5.90^{cd}
	:29	35	64.84^{d}	4.85^{d}	8.70^{c}	19.26^{a}	41.11^{cd}	5.99^{bc}
5	5	35	76.20^{bc}	6.16^{bc}	8.44^{e}	18.33^{ab}	48.48^{a}	6.20^{a}
	21	35	60.09^{de}	4.41^{de}	9.17^{a}	19.33^{a}	43.13^{bc}	5.69^{e}
	29	35	55.68^{e}	3.89^{e}	9.20^{a}	18.80^{ab}	38.25^{e}	5.85^{cd}
10	5	35	76.27^{bc}	6.18^{bc}	8.26^{f}	18.50^{ab}	40.77^{cd}	5.86^{cd}
	21	35	53.74^{e}	3.76^{e}	8.94^{b}	19.34^{a}	39.02^{de}	6.08^{ab}
	29	35	40.57^{f}	2.81^{f}	9.11^{a}	19.25^{a}	32.73^{f}	6.07^{ab}
SEM			1.092	0.113	0.029	0.111	0.398	0.018
Source of variation			*P*					
Storage time			<0.001	<0.001	<0.001	0.548	<0.001	0.023
Storage temperature			<0.001	<0.001	<0.001	0.011	<0.001	0.060
Time × temperature			<0.001	<0.001	<0.001	0.936	<0.01	<0.001

[a–h]Different letters indicate significant differences between the means in each column ($P < 0.05$).

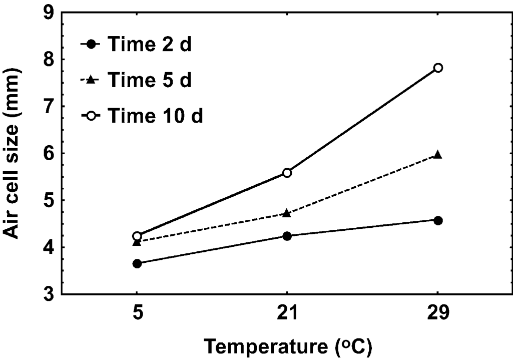

FIGURE 1. Effects of storage time and temperature on egg cell size.

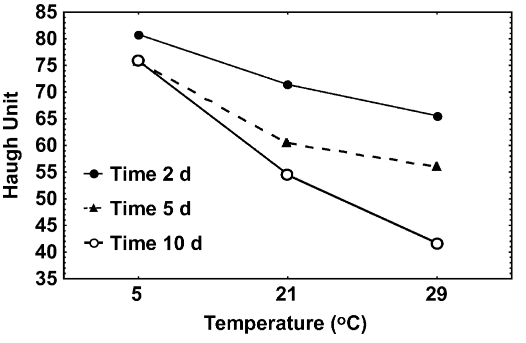

FIGURE 2. Effects of storage time and temperature on Haugh units.

ity parameters investigated in the present study. Egg weight, shell weight, specific gravity, albumen height and HU, and yolk index significantly ($P < 0.001$) decreased with increased storage time and temperature. Albumen and yolk pH were also significantly ($P < 0.001$) increased by increased storage time and temperature. Egg weight was not significantly decreased by storage for 0 to 10 d at 5°C. However, during storage at 21°C, egg weight loss significantly increased to 0.65 and 1.03 g at 5 and 10 d of storage time, respectively. When storage temperature was increased to 29°C, loss of egg weight dramatically increased to 1.30 and 1.94 g at 5 and 10 d of storage time, respectively. Concomitant decreases in weight of albumen and yolk were also observed with increased storage time and temperature. These results are in agreement with those of Walsh et al. [10], who reported significant ($P < 0.001$) egg weight decreases of 0.36 and 0.57 g, respectively, within 7 and 14 d of storage. Similar weight losses have also been reported by Silversides and Villeneuve [14]. In contrast, Scott and Silversides [12] reported that for an unknown reason egg weight did not differ within 10 d storage.

Dramatic deteriorations were also observed in albumen height, HU, and yolk index due to storage time and temperature. These results are in agreement with those of Scott and Silversides [12], who reported a significant ($P < 0.05$) decrease from 9.16 to 4.75 mm in albumen height in eggs aged 10 d. Similar results were also demonstrated by other workers [5, 10]. The HU decreased from 91.4 to 76.3 at 5°C during 10 d of storage, whereas at 21 and 29°C storage this decline was further extended to 53.7 and 40.6, respectively. Storage at temperatures greater than 5°C also caused considerable deterioration in yolk index. At 21°C the yolk index decreased from 44.1 to 39.0 and at 29°C to 32.7 during 10 d of storage. Significant increases in pH of albumen and yolk were also observed with increased storage time and temperature.

A rapid alkalinity increase in albumen, even after 2 d of storage time, was observed, regardless of temperature difference and extended from 7.47 to 9.2 at 29°C during 5 d of storage. These findings are in agreement with the results reported by other researchers [5, 12, 14]. In contrast, Walsh et al. [10] reported that neither temperature nor storage time influenced albumen pH. The increase in pH observed in yolk was not as large as in albumen, and it differed from 5.75 to 6.08 during 10 d of storage at 29°C.

Significant ($P < 0.001$) physical changes occurred in specific gravity and size of the air cell depending upon the increased temperature and storage time. Specific gravity was 1.086 in the fresh eggs, whereas it declined to 1.063 due to increased storage time and temperature. In addition, air cell size increased with increased storage time and temperature. Air cell size exceeded 4 mm in 2 d when they were kept over 21°C. However, this critical size (4 mm) could not be maintained up to 5 d unless the eggs were stored at 5°C. No recent data were found with regard to the relation of air cell size and storage time or temperature.

Interaction effects between storage time and temperature were significant with respect to egg

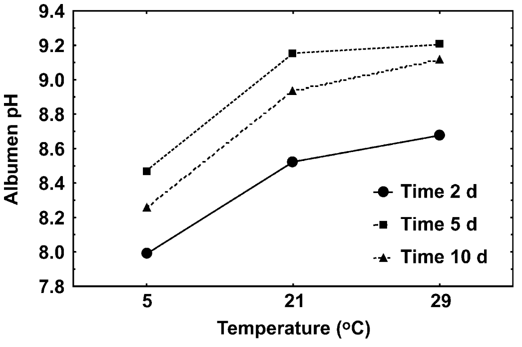

FIGURE 3. Effects of storage time and temperature on albumen pH.

weight loss, specific gravity, air cell size, HU, albumen height, and pH (Tables 1 and 2). Figures 1, 2, and 3 clearly show the two-way interaction of storage time and temperature on air cell size, HU, and albumen pH. The deterioration in albumen quality was clearly pronounced during storage at 21 and 29°C as the eggs aged from 2 to 10 d. In contrast, air cell size increased from below 4 mm to between 4 and 6 mm at 21 and 29°C in 2 and 5 d storage, and when kept at 29°C for 10 d it increased to around 8 mm. This finding implies that the deterioration of egg quality was increased by storage time in a nonlinear manner. Therefore, one should bear in mind that deterioration of internal egg quality is a function of storage time and temperature. Indicators of egg quality deterioration were not likely to be affected equally by storage time and temperature. Figures 1, 2, and 3 clearly show that albumen pH is the most sensitive parameter in measuring internal egg quality because it indicates a difference even at 5°C storage. Under storage temperature up to 29°C, the air cell size of eggs stored 10 d increased rapidly according to storage time and temperature. Similar interaction effects also occurred for HU and albumen pH (Figures 1, 2, and 3).

Most of these changes in egg quality in terms of albumen height, HU, albumen pH, yolk index, SG, and air cell size were attributed to water loss by evaporation through the pores in the shell and the escape of carbon dioxide from albumen [11, 25, 26]. The net effect of these changes is a progressive loss in egg weight and a continual decline in albumen quality [7].

CONCLUSIONS AND APPLICATIONS

1. Eggs from 50-wk-old laying hens had significant deterioration of quality with increased egg storage time and temperature.
2. Haugh units drastically decreased from 91.4 to 76.3, 53.7, and 40.6 during storage at 5, 21, and 29°C.
3. Air cell size of the stored eggs exceeded 4 mm in 2 d when stored at greater than 21°C.
4. A rapid increase in pH of albumen, even during 2 d of storage, was observed regardless of storage temperature.
5. Interaction effects between storage time and temperature were also significant in egg weight loss, specific gravity, air cell size, HU, albumen height, and pH.
6. The results suggested that HU, pH of albumen, and air cell size were parameters greatly influenced by storage period and temperature of eggs from aged laying hens.

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