# The Effect of Storage and Strain of Hen on Egg Quality[1]

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**ABSTRACT** Eggs from 31-wk-old ISA-White and ISA-Brown hens were sampled immediately after lay and after periods of storage of 1, 3, 5, and 10 d at room temperature. Longer periods of storage resulted in lower albumen weight and albumen height and higher albumen pH. Eggs from ISA-Brown hens had more albumen and shell than those from ISA-White hens, likely due to differences in selection history rather than due to pleiotropic effects of eggshell color. Within each line and storage period, the egg weight was more closely associated with albumen weight than with yolk or shell weight. The albumen height of eggs from ISA-Brown hens was lower than that of ISA-White hens at all storage times, but the albumen pH was not affected by the strain. Albumen height and albumen pH were statistically unrelated in fresh eggs, but the association became larger as the storage period increased, suggesting that albumen height measures factors that are present when the egg is laid and changes during storage, whereas albumen pH measures only the effect of storage.

(*Key words*: egg quality, layer strain, storage, egg components)

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## INTRODUCTION

Albumen quality is often measured as a function of the height of the inner thick albumen, for example the Haugh unit (Haugh, 1937), or more correctly as the height alone (Silversides and Villeneuve, 1994). The influence of genetics on albumen height has been known for many years (Johnson and Merrit, 1955), and there are minor effects of nutrition in specific cases (Monsey et al., 1977; Benabdeljelil and Jensen, 1990). The major factor in determining albumen height is egg storage time and conditions. The effects of storage on egg quality can also be measured by the increase in albumen pH.

The characteristics of the albumen are not the only measures of egg quality. The advent of the egg breaking industry has greatly increased the importance of the relative proportion of the egg components (Ahn et al., 1997). Breakers separate the yolk and albumen because they have very different qualities, they are used for different markets, and they have different commercial values. The proportion of yolk and albumen is largely determined by the age and strain of the hen (Akbar et al., 1983; Ahn et al., 1997).

Eggshell color has always received more attention from the consumer than it deserves. There is little or no direct relation between shell color and nutritional content of the egg, but eggshell color does give an indication of the breeding history of the hen. White eggs are produced commercially by lines derived principally from the White Leghorn breed, whereas brown eggs are produced by hens derived from a number of dual-purpose breeds, including Barred Plymouth Rock, Rhode Island Red, Rhode Island White, Australorp, New Hampshire, and probably others. These dual-purpose breeds were the chickens kept in farm flocks in the last century, and brown eggs have been perceived by the consumer to be more natural or healthy than white eggs.

Intense selection of brown egg lines lagged behind that of white egg lines by many years, and for a period brown-shelled eggs deserved a premium price because they cost more to produce. Recently however, selection of brown egg lines has produced hens that rival white egg lines in the cost of production. Currently available brown egg lines compare favorably to white egg lines for production levels (unpublished observations), and they are kept industrially in the same way as white egg lines.

Washburn (1990) summarized research that described differences in the eggs produced by white and brown egg lines, but much of the research that he described is old. There is a paucity of recent literature describing quality or compositional differences between white and brown eggs. Albumen quality and the proportion of egg components are characteristics that respond to selection, and it could be expected that the old literature is no longer valid.

This research investigated differences in fresh and stored eggs of hens from two lines of commercial layers, one a brown egg line and one a white egg line.

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## MATERIALS AND METHODS

Eggs were obtained from ISA-Brown and ISA-White hens that were included in a laying trial at the Pacific Agri-Food Research Centre at Agassiz, British Columbia. Eggs were collected over 4 d when the hens were 31 wk old. Approximately 150 eggs were collected for each strain for each storage time. Eggs that were laid overnight were not used for the experiment. Fresh eggs were collected and measured within 2 h of being laid. Samples of eggs were stored for periods of 1, 3, 5, and 10 d at room temperature. High and low temperatures in the storage area were noted twice daily and averaged 20.2 C over the 10-d period.

At sampling, eggs were weighed and broken onto a flat surface where the height of the inner thick albumen was measured with an electronic albumen height gauge.[4] The yolk was separated from the albumen and weighed. The pH of the albumen was measured immediately with a pH meter.[5] The shells were dried at room temperature for 3 d, at 60 C for 3 d, and then weighed. The weight of the albumen was calculated as the difference between the weight of the egg and the weight of the yolk plus shell.

### *Stastical Analysis*

All data were analyzed with the SAS statistical package (Littell et al., 1991). An ANOVA using the general linear models procedure included the main effects of storage time and strain of hen and the interaction between these factors. When the effect of storage time was significant, the means were separated using Duncan's test. Correlation coefficients (r) were calculated with the PROC CORR procedure of SAS to determine the relative importance of the three egg components in determining egg weight. The PROC REG procedure was used to investigate the effect of storage time on albumen height and albumen pH. The correlation coefficients between albumen quality (albumen height and albumen pH) and egg weight, albumen weight, and shell percentage were calculated. Probabilities of less than 0.05 were considered significant for all analyses.

## RESULTS

The effect of storage time was statistically significant for all measures except eggshell weight (Table 1). The principal changes with storage appeared to be decreases in albumen and egg weights. For an unknown reason the fresh eggs were smaller than those that were stored for 1 and 3 d and had smaller yolks and shells than the stored eggs. The fresh eggs had less albumen than those stored for 1 d, but thereafter storage was associated with lower albumen weight. Storage of 1 to 10 d did not affect shell and yolk weights. When measured as a percentage of the egg, albumen weight decreased with storage, and shell and yolk weights increased because the egg weight loss was principally a loss in albumen weight. With storage, albumen height decreased and albumen pH increased.

The main effect of strain was significant for all measures except albumen pH. Eggs from ISA-Brown hens were heavier than those from ISA-White hens and had more shell and albumen but less yolk. This difference between strains was reflected in the percentages of the components. The albumen pH of eggs from the two strains was nearly identical, but the albumen height of eggs from ISA-White hens was greater. The interactions between storage time and strain were significant for albumen pH and albumen height. The albumen pH of fresh eggs was lower for eggs from ISA-Brown than those from ISA-White hens (Table 2), but after storage the albumen pH of eggs from both strains of hens was similar. The albumen height of eggs from ISA-Brown hens was lower at all storage times, but the difference between strains was less for fresh eggs and for those that had been stored for 10 d than it was for other periods of storage.

Correlation coefficients between the three components of the egg and the total egg weight (Table 3) show that the albumen weight was closely associated with egg weight overall and at each storage period. The correlation coefficients between egg weight and yolk and shell weights were lower than that between egg weight and albumen weight.

Overall, albumen height was negatively correlated with albumen pH (r = –0.82 for ISA-Brown and –0.81 for ISA-White; Table 4). However, there was no association between these two measures of albumen quality in fresh eggs from either strain of hen. As storage time increased, the correlation coefficients between albumen height and pH increased (except at 10 d for eggs from ISA-White hens), but the highest correlation coefficient (10 d storage of eggs from ISA-Brown hens) was only –0.35. The linear regressions of albumen height on storage time produced $R^2$ values of 0.43 and 0.47, and values of albumen pH on storage time were 0.79 and 0.82 for eggs from ISA-Brown and ISA-White hens, respectively.

There was a low but significant correlation between albumen height and egg weight in eggs from both strains (r = 0.15). When calculated at each storage time, the correlation coefficients between albumen height and egg weight were low and variable, and most were not significant. Similar, but lower, correlation coefficients were found between albumen pH and egg weight, and the correlation between these measures overall was not significant for either strain. Albumen height was more closely associated with albumen weight than it was with egg weight, but even when all eggs were measured together correlation coefficients were only 0.27 and 0.29. The statistical relationships between albumen height and albumen weight at each storage time were generally lower than the relationships overall. The correlation between albumen pH and albumen weight was low overall and inconsistent among individual storage times.

[4]Queensboro Instruments, Ottawa, ON, Canada K2A 2J3.
[5]Model 360i, Corning Incorporated, Corning, NY 14831.

**TABLE 1. The effect of storage time and layer strain on egg components and albumen quality**

| | Weight (g) | | | | % of egg | | | Albumen | |
|---|---|---|---|---|---|---|---|---|---|
| Item | Egg (1,497)[1] | Shell (1,499) | Yolk (1,462) | Albumen (1,460) | Shell (1,497) | Yolk (1,460) | Albumen (1,460) | pH (1,499) | Height (mm) (1,499) |
| Storage time | | | | | | | | | |
| Fresh | 56.84[c] | 5.897[b] | 13.57[b] | 37.35[b] | 10.38[b] | 23.92[e] | 65.71[a] | 7.34[e] | 9.16[a] |
| 1 d | 58.57[a] | 5.99[a] | 14.37[a] | 38.18[a] | 10.25[c] | 24.59[d] | 65.16[b] | 8.54[d] | 7.67[b] |
| 3 d | 57.70[b] | 5.99[a] | 14.40[a] | 37.33[b] | 10.39[b] | 24.98[c] | 64.63[c] | 9.09[c] | 6.50[c] |
| 5 d | 56.68[c] | 5.94[ab] | 14.36[a] | 36.35[c] | 10.48[b] | 25.40[b] | 64.11[d] | 9.29[b] | 5.62[d] |
| 10 d | 56.34[c] | 5.98[a] | 14.47[a] | 35.86[c] | 10.62[a] | 25.74[a] | 63.64[e] | 9.37[a] | 4.75[e] |
| SEM | 0.23 | 0.03 | 0.07 | 0.18 | 0.04 | 0.09 | 0.10 | 0.01 | 0.05 |
| ISA-Brown | 58.50 | 6.13 | 14.10 | 38.22 | 10.49 | 24.17 | 65.34 | 8.74 | 6.25 |
| ISA-White | 55.97 | 5.79 | 14.35 | 35.85 | 10.36 | 25.65 | 63.99 | 8.72 | 7.22 |
| SEM | 0.15 | 0.02 | 0.04 | 0.11 | 0.02 | 0.05 | 0.06 | 0.01 | 0.03 |
| Source of variation | | | | | ($P$) | | | | |
| Storage time | <0.01 | 0.33 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Strain | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 0.54 | <0.01 |
| Storage × strain | 0.64 | 0.55 | 0.91 | 0.46 | 0.18 | 0.77 | 0.44 | 0.02 | 0.03 |

[a–e]Means of storage times with different superscripts are different at $P < 0.05$.

[1]The number of observations is given in parentheses.

Albumen height had a negative association with eggshell percentage for both strains and at each storage time. However, at no time were the correlation coefficients very high, and they were not significant for any storage times. The correlation between albumen pH and shell percentage was positive, lower than that with albumen height, and not significant for most storage times.

## DISCUSSION

With storage, the albumen weight of these eggs decreased, causing a lower egg weight. Yolk and shell weights were not changed by storage. This result agrees with those of many authors, most recently Ahn et al. (1999), who have found that shell weight does not change with storage. It may not agree with the literature for yolk weight, which could be expected to increase with a longer period of storage as amino acids move through the vitelline membrane from the albumen (Heath, 1977).

With storage, albumen pH increased and albumen height decreased, as expected (Li-Chan and Nakai, 1989). Albumen height and pH are used to determine albumen quality, and these two measures were associated statistically when all eggs were considered together. Among fresh eggs there was no relationship between albumen height and pH, but the statistical association became larger with longer periods of storage. As well, the $R^2$ values for the regressions of albumen pH on storage time were much higher than those for albumen height on storage time. Albumen quality is determined by factors present before an egg is laid and by storage time or storage conditions. These data suggest that albumen pH measures primarily the freshness of the egg, whereas albumen height measures the freshness of the egg and differences that are present when the egg is laid.

Several investigators have compared the eggs of white and brown egg-laying strains (Curtis et al., 1985, 1986; Washburn, 1990). Generally, brown egg layers are believed to be heavier than white egg layers, and that they lay larger eggs with better albumen quality but thinner shells. These differences between white and brown egg layers are not due to a direct relationship with shell color but, rather, due to differences in the genetic origins of the hens. The data reported here are in clear conflict with many of these beliefs. The brown eggs were heavier than the white eggs, likely because the hens weighed more (unpublished observations). Although the brown eggs had more shell and albumen than the white eggs, they had less yolk. The albumen pH was the same, but the albumen height of the brown eggs was much less. Significant interactions between storage time and strain for both albumen height and pH appear to be caused by one mea-

**TABLE 2. The effect of egg storage and strain of hen on albumen quality**

| Storage time | n | | Albumen pH | | Albumen height (mm) | |
|---|---|---|---|---|---|---|
| | ISA-Brown | ISA-White | ISA-Brown | ISA-White | ISA-Brown | ISA-White |
| Fresh | 135 | 165 | 7.31[e] | 7.37[e] | 8.67[a] | 9.57[a] |
| 1 d | 167 | 132 | 8.55[d] | 8.53[d] | 7.22[b] | 8.24[b] |
| 3 d | 161 | 139 | 9.09[c] | 9.10[c] | 5.98[c] | 7.11[c] |
| 5 d | 128 | 172 | 9.30[b] | 9.29[b] | 4.98[d] | 6.09[d] |
| 10 d | 153 | 147 | 9.38[a] | 9.36[a] | 4.40[e] | 5.12[e] |
| SEM | | | 0.01 | 0.01 | 0.07 | 0.07 |

[a–e]Means of storage times with different superscripts are different at $P < 0.05$.

**TABLE 3. Correlation coefficients (r) between egg components and egg size in fresh eggs and after storage[1]**

| Storage time | ISA-Brown | | | | ISA-White | | | |
|---|---|---|---|---|---|---|---|---|
| | n | Albumen | Yolk | Shell | n | Albumen | Yolk | Shell |
| Total | 723 to 744 | 0.96 | 0.62 | 0.65 | 737 to 755 | 0.95 | 0.67 | 0.67 |
| Fresh | 134 to 135 | 0.96 | 0.65 | 0.69 | 164 to 165 | 0.96 | 0.73 | 0.70 |
| 1 d | 163 to 167 | 0.97 | 0.66 | 0.57 | 130 to 132 | 0.96 | 0.75 | 0.66 |
| 3 d | 157 to 161 | 0.96 | 0.67 | 0.71 | 136 to 139 | 0.96 | 0.73 | 0.66 |
| 5 d | 123 to 128 | 0.96 | 0.57 | 0.71 | 165 to 172 | 0.94 | 0.70 | 0.69 |
| 10 d | 147 to 153 | 0.95 | 0.66 | 0.67 | 142 to 147 | 0.94 | 0.67 | 0.66 |

[1]All correlation coefficients are significant at $P < 0.01$.

sure for each strain; a longer period of storage might be needed to observe whether these interactions were truly important.

These data describe eggs of only two lines from a single company, and the conclusions reached cannot be applied to all layer strains. However, most comparisons in the literature between white and brown egg layers are old, and it is reasonable to believe that brown egg layers have changed over time (as have white egg layers). A market exists for brown-shelled eggs, and primary breeders would be expected to select for improved egg production to supply the market with efficient layers. Each trait added to a selection index decreases the progress that is possible for an individual character (Legates and Warwick, 1990), and increased selection pressure on one trait decreases the pressure that is possible for others. White egg layers have had high egg production for many years, and it is likely that breeders have given emphasis to secondary traits such as yolk weight and albumen quality in their programs. In the past, production by brown egg layers has been lower than that of white egg layers, but this is not necessarily true today. To obtain the same egg production as white egg lines, breeders of brown-egg layers have likely placed relatively more emphasis on egg production than on secondary characteristics.

Egg weight is genetically linked to all three of the major components: shell, albumen, and yolk. Washburn (1990) summarized literature to show that the link between egg weight and albumen weight is higher than those between egg weight and shell or yolk weight. Fletcher et al. (1981, 1983) showed that as egg size increases, so does the percentage of albumen. The data presented here demonstrate that within a strain, variation in egg weight is determined largely by variation in albumen weight. Selection for albumen weight as an individual trait should be possible because the heritability is moderate to high (Washburn, 1979). The heritability of shell strength (Hunton, 1982) or thickness (Poggenpoel, 1986) is also moderate to high, but that for yolk weight is lower (Washburn, 1979). Selection for egg weight, ignoring the importance of the con-

**TABLE 4. Correlation coefficients (r) between measures of albumen quality and egg weight, albumen weight, and shell percentage[1]**

| Storage time | ISA-Brown | | | | ISA-White | | | |
|---|---|---|---|---|---|---|---|---|
| | Albumen pH | Egg weight | Albumen weight | Shell % | Albumen pH | Egg weight | Albumen weight | Shell % |
| Total | | | | | | | | |
| Albumen height | –0.82** | 0.15** | 0.27** | –0.23** | –0.81** | 0.15** | 0.29** | –0.17** |
| Albumen pH | | –0.04 | –0.14** | 0.13** | | –0.05 | –0.18** | 0.11** |
| Fresh | | | | | | | | |
| Albumen height | –0.03 | 0.17* | 0.24** | –0.22* | –0.04 | 0.12 | 0.19* | –0.09 |
| Albumen pH | | –0.10 | –0.03 | 0.07 | | 0.19* | 0.18* | –0.10 |
| 1 d | | | | | | | | |
| Albumen height | –0.16* | 0.27** | –0.34** | –0.33** | –0.10 | 0.12 | 0.16 | –0.23** |
| Albumen pH | | –0.10 | –0.12 | 0.13 | | –0.06 | –0.10 | 0.14 |
| 3 d | | | | | | | | |
| Albumen height | –0.26** | 0.14 | 0.18* | –0.05 | –0.21* | 0.18* | 0.22* | –0.05 |
| Albumen pH | | –0.21** | –0.18* | 0.08 | | –0.20* | –0.23** | 0.10 |
| 5 d | | | | | | | | |
| Albumen height | –0.31** | 0.23** | 0.27** | –0.17 | –0.33** | 0.14 | 0.20* | –0.10 |
| Albumen pH | | –0.38** | –0.42** | 0.16 | | –0.06 | –0.14 | 0.36** |
| 10 d | | | | | | | | |
| Albumen height | –0.35** | 0.05 | 0.11 | –0.18* | 0.04 | 0.16 | 0.23** | –0.11 |
| Albumen pH | | 0.04 | –0.05 | 0.38** | | 0.03 | –0.01 | 0.01 |

*$P < 0.05$.

**$P < 0.01$.

[1]Table 3 provides the number of samples measured for each strain and at each storage time.

stituents, should result in greater albumen weight because of the higher correlation with egg weight, as has been found in selected (Akbar et al., 1983) or in modern versus old, commercial (Tharrington et al., 1999) strains.

Hunton (1982) summarized 1968 North American random-sample tests and showed that the shells of brown egg layers were thinner than those of white egg layers. Breeders of brown egg lines might have been forced to apply selection pressure to this trait, and the data presented here suggest that they have been successful.

These data demonstrate that eggs from different lines can differ in characteristics whose importance depends on the ultimate use of the egg. The percentage of albumen and yolk is important to the egg breaking industry, with the yolk being more valuable. Breakers would pay more for these brown eggs than these white eggs because of the greater egg weight, yet they would obtain less yolk. If albumen quality measurements are used to measure the effects of storage, then these brown eggs will be penalized unfairly in relation to the white eggs if albumen height rather than albumen pH is used as the measure.

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