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IMPACT OF THE AGE OF LAYING CHICKEN ON MECHANICAL STRENGTH OF EGGS

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ABSTRACT External and internal qualities of eggs are affected by a number of factors including the age of laying chicken. Understanding changes in quality is critical in industrial handling and processing of eggs. The aim of this study was to analyze mechanical strength of eggs laid by hens at 52 to 55 weeks of laying cycle. About 12000 white-shelled leghorn eggs from 6 flocks over 3 months period were used. Mechanical strength of eggs was measured in terms of the rupture force and energy using Universal Instron testing machine. Mean values of eggshells strength decreased from 34 to 31 N between 52 and 55 weeks, respectively. Eggshell thickness was in the range of 0.33 to 0.31 mm. The results showed that age of laying chicken significantly ($p<0.05$) influenced eggshell strength and eggshell thickness. Older hens laid weaker and thinner eggs. Thus, the age of laying chicken should be considered as a critical factor affecting egg handling and processing quality.

Keywords: Egg quality, chicken age, laying cycle, mechanical strength, shell thickness

INTRODUCTION

Chicken flocks typically have a laying cycle of about 12 months starting at 18-19 weeks of age. Their egg quality decreases as the birds age (Kröckel et al., 2005; Coutts and Wilson, 1990). Egg quality is based on characteristics of the egg that affect its acceptability to the consumer. The overall quality of a chicken egg is determined by its external and internal qualities. Egg shell quality, an important external quality of the egg, is related to its appearance. It is based on eggshell texture, egg specific gravity, shell breaking strength and shell thickness (Roberts, 2004). These factors affect initial consumer appeal and handling of the eggs. Internal egg quality is based on albumen quality, yolk quality and the presence of blood or meat spots (Jacob et al., 2000).

Eggshells are bioceramic materials constructed of columnar calcite crystals. They are brittle and can be broken on hitting a hard surface or another egg. Broken eggs cause economic loss in many ways. They cannot be sold as high quality eggs. They present cleanliness problems. Egg packs are routinely examined and the ones containing cracked eggs are rejected. This inspection results in rejected packs, accumulating at the front of a display, can make the display untidy and can lead to further egg damage. Furthermore, there is risk that egg display, the floor and the check-out counter become contaminated if a cracked egg releases its contents. Cracked egg itself can be contaminated and pose potential microbiological hazards and risks (Mertens et al., 2006; Widdicombe, 2008). Another consideration is that if an egg in a pack is cracked or leaked, the whole pack is discarded. Eggshell cracks can result from mechanical damage in the farm (during its laying or collection), at the grading station or in the supermarkets. Damage can also occur during transportation from the farm to the grading station or from the grading station to the supermarkets. Eggshell strength is an important parameter in handling the egg. A good quality shell requires about 26 to 35 N of force to break whereas a poor quality shell will break at about 23 N (Bell, 2001a). Eggs laid at the end of the laying cycle by older birds tend to be of poor quality. Thus, these eggs are more prone to cracks and leaks. Other factors affect eggshell strength. Larger eggs are generally weaker than smaller eggs since hens have a finite capacity to deposit calcium in the shell as the same amount of calcium is spread over a larger area (Butcher and Miles, 2003). Older hens lay bigger eggs than younger hens. Rodriguez-Navarro et al. (2002) compared two age populations and reported that the eggshells laid by aged hens had a lower breaking strength (less than half of those laid by young hens). Further, the authors reported that structural properties such as shell thickness of eggs laid by aged hens typically show greater variability. Shell strength is highly dependent on shell thickness. There has also been reported that specific gravity of eggs tend to decrease with the age of the hens (Peebles and Brake, 1987; Bennett, 1992). The specific gravity of eggs is correlated with their probability of cracking during processing. Age can also affect the surface characteristics of the eggs. Consumers prefer eggs with smooth surface than those with rough surface. In general, eggs with rough surface are weaker than eggs with smooth shells.

Age does not only affect external egg quality, it also affects internal egg quality. The albumen has a major influence on overall interior egg quality as thinning of the albumen can point to a quality loss. The most widely used and accepted method for estimating albumen quality is the Haugh Unit (HU) (Haugh, 1937). This method is based on the weight of an intact egg and the albumen height of the broken egg. When a freshly laid, good quality egg is broken onto a smooth flat surface, the yolk is generally in a central position surrounded by thick albumen. However, when a poor quality egg is broken, the yolk is normally displaced to one side with thinner surrounding albumen. As a result, a large area of the albumen is distorted and flattened to produce a wide area of liquid. Albumen thickness and quality is widely assessed in HU. Studies have suggested that the age of hens affects the HU of their laid egg. Silversides and Scotts (2001) reported that albumen height decreased when the hens' age increased. There are indications that HU value decreases at the rate of about 1.5 to 2 units for each increasing month after the onset of lay (Coutts and Wilson, 1990; Doyon et al. 1986). Currently, some farms in Quebec keep their flocks up to 74 weeks of age before renewing the flocks. There has not been any recent study on the quality of eggs laid by older hens. Estimating the age of the hens after which the egg quality becomes inacceptable for commercial handling will be beneficial to the poultry industry. This will reduce losses due to the breakage of the eggs during their collection and handling as well as during transportation. In addition, this can improve the ability of the industry to supply high quality eggs to consumers. The aim of this project was to monitor changes in internal and external qualities of egg laid by older hen flocks (at 71 to 74 week of age) in order to estimate the optimal age of the laying hens after which the flock might be renewed.

MATERIAL AND METHODS

Sample collection: About 10,000 intact white-shelled leghorn eggs collected from 6 flocks over a 13 week period were used in this study. The samples were collected from two grading stations namely, Ovale (Saint-Lambert-de-Lauzon, QC) and Nutri-Oeuf (Saint Hyacinth, QC). The eggs were collected over 4 week period for each flock corresponding to their 71 to 74 weeks of age in order to test the impact of the hens' age on the egg quality.

Quality measurements: Quality measurements were grouped into non destructive and destructive measurements. Non destructive measurements include specific gravity, cracks, leaks and surface characteristics. Destructive measurements include HU and measurement of shell thickness and strength. Cracks, leaks, surface characteristics and HU were performed in the grading stations. The remaining tests were performed at the laboratories in Macdonald Campus of McGill University.

Non destructive measurements:

Cracks, leaks and rough surface: Up to 720 eggs per grading station per visit were candled to detect cracks, leaks and rough surface.

Specific gravity: Specific gravity of 100 samples was determined by using gradational salt solutions with pre-designated densities namely, 1.07, 1.075, 1.08, 1.085 and 1.09. The samples were placed first in the solution having 1.06 as density. The eggs that sink were transferred to the next solution with higher density. This procedure stopped when all the eggs were either moved from the solution in which they float or passed to the next higher solution of higher density. Eggs that floated in a particular solution were given a specific gravity value equal to that of the solution.

Destructive measurements

HU: At each grading station, 100 eggs were selected randomly for the assessment of the HU. The HU is the correlation between the weight of the intact egg and the height of the albumen. Each sample were weighed with a calibrated balance (±0.01 mg) and broken carefully on a flat surface. HU was measured using a trigger mounted micrometer (±0.01 mm).

Eggshell strength: Eggshell strength of 100 eggs was assessed by the use of Instron Universal Testing machine (Instron, Model 4502, Massachusetts, USA). Two parallel stainless steel surfaces advancing at a constant rate of 0.4mm/min compressed the eggs at their equator. Data was recorded as the minimum force (N) needed to introduce crack into the shell.

Eggshell thickness: One hundred eggs were selected, broken out, rinsed and dried at room temperature for 3 days. Three pieces of shell of the dried samples were taken in order to measure shell thickness. The pieces were measured by an outside micrometer

(±0.01 mm) with rounded anvil (Starrett, 577M, The L.S. Starrett Co., Massachusetts, USA). Shell thickness was obtained from the average values of these three parts.

Statistical analysis: SAS System software (Vesion 9.2, SAS Institute, Inc., NC, USA) was used for statistical analysis. Duncan's multiple range test was used to estimate significant differences among the means at 5% probability level.

RESULTS AND DISCUSSIONS

Analysis of variance indicated that the effect of week was significant ($P<0.05$) on three quality attributes namely strength, thickness and HU as shown in Table 1. Farm only had a significant effect ($P<0.05$) on strength and thickness of eggshell. There was an interaction effect between farm and week on thickness and HU of the eggs. Since farm has a significant effect on the variation of data, further analysis was conducted to understand how the various quality traits changed with age of hens. Variations of the mean breaking force, shell thickness and the HU of eggs from the different farms through the 4 week study period are shown in Figures 1, 2 and 3, respectively. The breaking strength values were within the range generally accepted for good quality eggs (Bell, 2001a). In addition, the HU values were also within accepted range for good eggs. The variability of these factors between the farms was large. For example, the strength of the eggs laid in Farm 6 was between 30.27 and 35.57 N while the strength of those laid in Farm 2 was between 31.6 and 33.36 N. The thickness of the eggs laid in Farms 6 and 1 at week 71 were 0.31 and 0.35 mm, respectively. The corresponding values at week 74 were 0.33 and 0.32 mm. Figure 3 showed that the HU increased in Farms 1, 2, 3, 5 and 6 but decreased in Farm 4. The variations within the farms can be attributed to different practices and feed. Leeson et al. (1993) reported that the amount of dietary Ca and available P can strongly affect eggshell quality. However these variations did not show much difference between weeks. As a result, the average of the data at each week was calculated and analyzed in order to test the effect of week on egg quality.

The mean value of breaking force of the eggshells laid by hens aged 71, 72, 73 and 74 weeks varied between 33.5 and 31.04 N (Table 2). As expected, the maximum value was at the 71st week of age and the value decreased as the hens aged. The decrease was attributed to the larger sizes of eggs laid by older hens and their finite capacity to deposit calcium in the shell since the same amount of calcium was spread over a larger area (Butcher and Miles, 2003). The HU of the eggs laid by hens aged 71 weeks was 84.26 and it was 82.18 at 74th week of age. It decreased by about 2 units throughout the 4 weeks. This is in agreement with Coutts and Wilson (1990) who reported that the HU decreased by about 1.5 to 2 units for each month of lay. The HU is calculated from the weight of the intact egg and the height of the albumen. With age, the gelatinous structure of thick albumen changes its physical and chemical characteristics and breaks down into fluid leading to a decrease in HU.

Table 1 Effect of week, farm and their interaction on strength, thickness and HU

	Probability >F		
	Strength	Thickness	HU
Farm	< .0001*	< .0001*	< .0822
Week	< .0001*	< .0001*	< .0001*
Farm x Week	0.0963	< .0001*	< .0001*

*Model in which farm, week and farm x week: * significant at 5%*

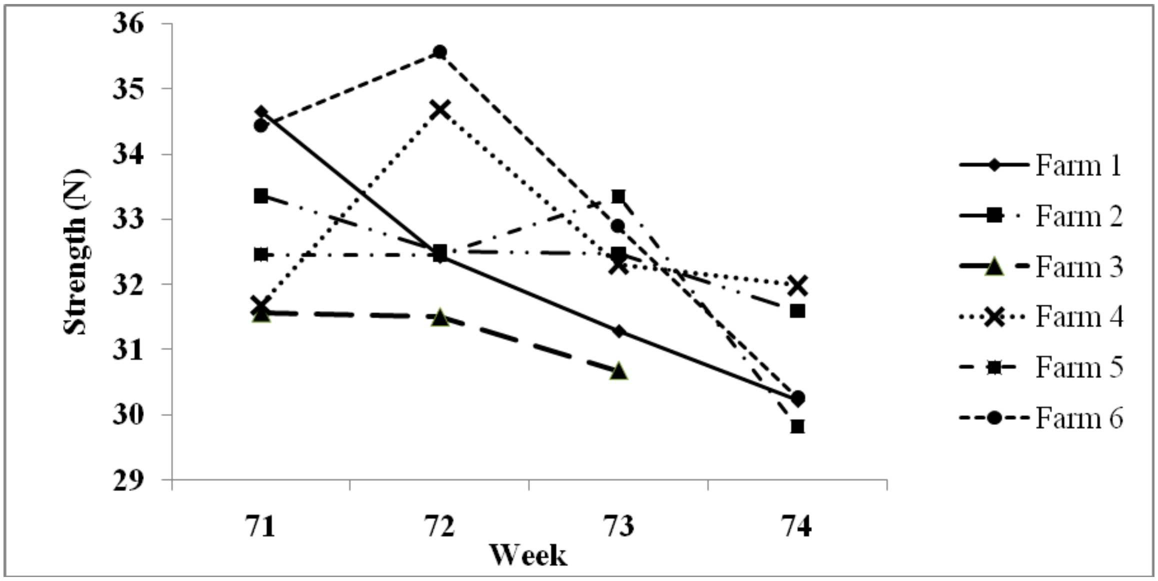

Figure 1 Variation of the strength within the farms through 4 week period

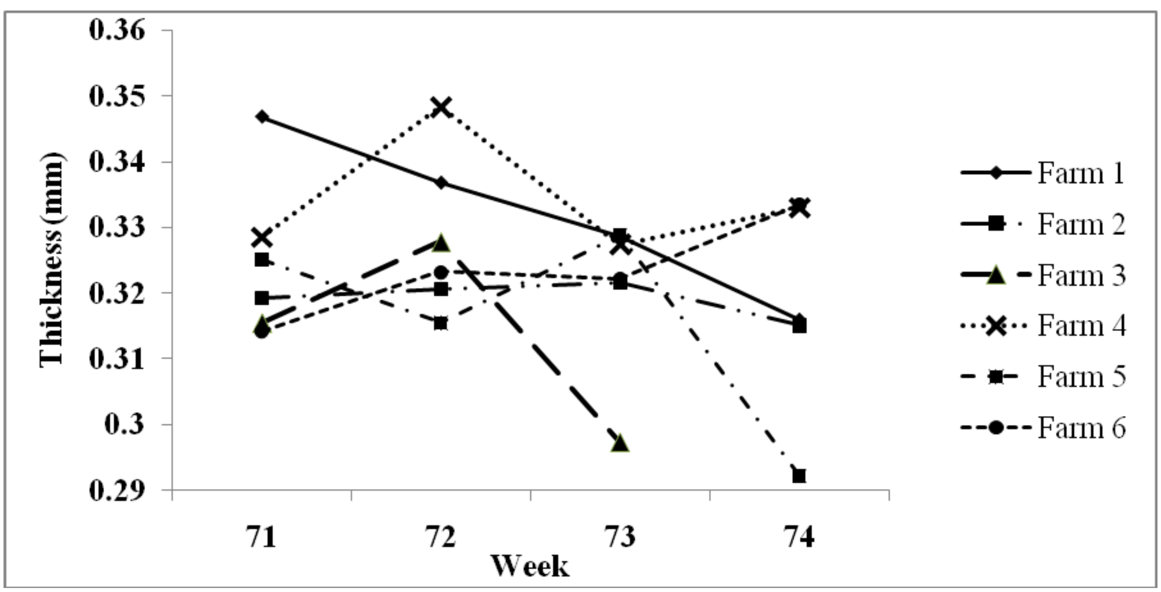

Figure 2 Variation of the thickness within the farms through 4 week period

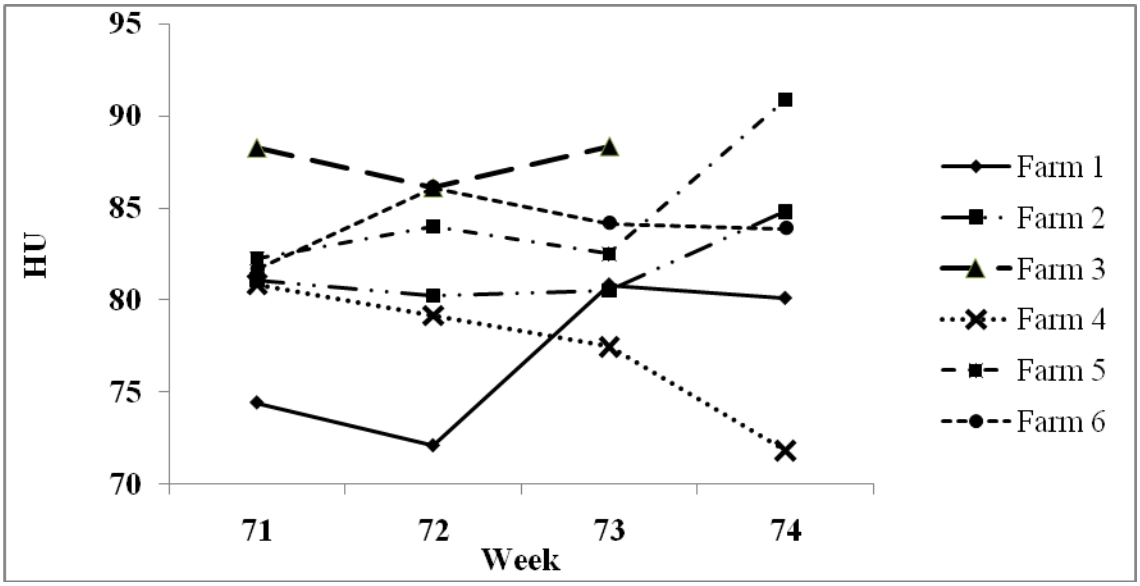

Figure 3 Variation of the HU within the farms through 4 week period

Table 2 Values of eggshell strength and thickness and HU (mean ± SEM) of eggs laid by hens at different age

Week	Eggshell strength (N)	Eggshell thickness (mm)	HU
71	33.5 ± 0.33[a]	0.33 ± 0.002[a]	84.26 ± 0.55[a]
72	33.1 ± 0.36[a]	0.33 ± 0.002[a]	81.88 ± 0.65[b]
73	31.92 ± 0.32[b]	0.32 ± 0.002[b]	80.98 ± 0.49[b]
74	31.04 ± 0.35[b]	0.32 ± 0.002[b]	82.18 ± 0.59[b]

[a,b] For the same column, means without a common superscript differed significantly ($P<0.05$) according to the Duncan's test

Mean separation analysis showed that there was no significant difference between the mean values of strength and thickness of eggs laid at 71 and 72 weeks. There was a significant drop in these quality traits after 72 weeks and for 73 and 74 weeks. This could be associated with several factors including defect in vitamin D metabolism or its expression in older hens (Garlich et al., 1984; Bar et al., 1999; Abe et al., 1982). Thus the flocks could be kept until 72 weeks of age without much loss in egg quality.

The distributions of specific gravity of the eggs at different weeks are shown in Figure 4. The result showed large variability in specific gravity. This could be due to the difference in the time of laying. Novo at al. (1997) reported that the specific gravity increased as the laid occurred later during the day. The highest percentage was obtained in the two groups of the eggs where the specific gravities were 1.08 and 1.085. In these two groups, the highest percentage was obtained at week 71st of age and the lowest one was obtained at week 74th of age. The specific gravity is an indirect indicator of the amount of the shell in relation to the size of the egg.

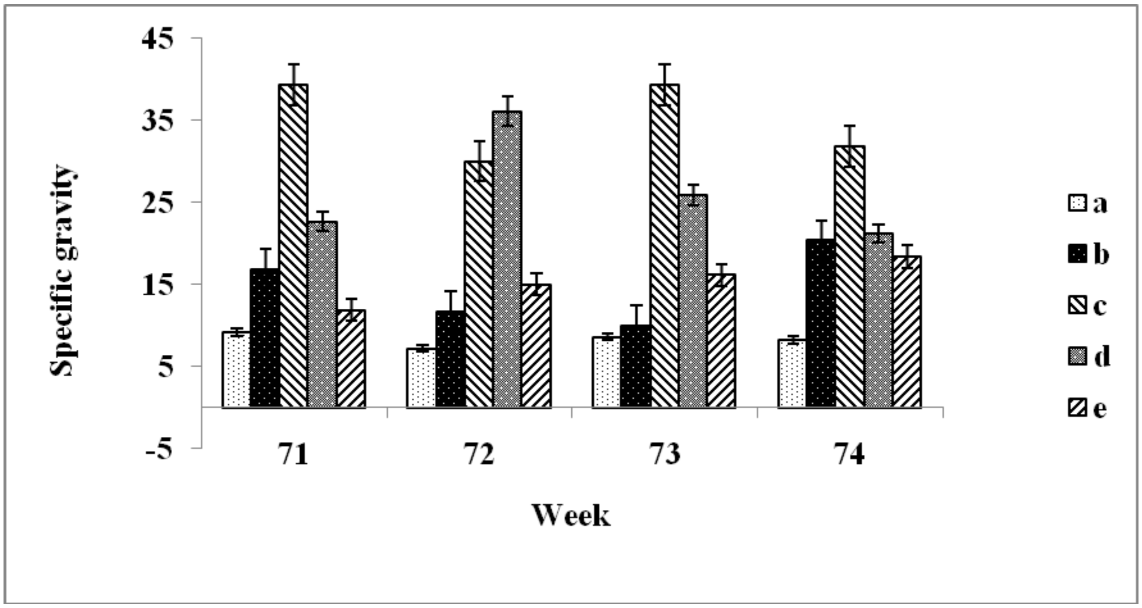

Figure 4 Relationship between the age of the laying hen and the specific gravity where a refers a, b, c, d and e refer to a specific gravity of 1.07, 1.075, 10.80, 1.085 and 1.09, respectively

The correlation coefficients between eggshell thickness, cracks, leaks, rough surface and eggshell strength are shown in Table 3. The correlation coefficients between eggshell strength and eggshell thickness, eggshell strength and cracks were 0.97 and -0.96, respectively. Cracks are highly related to eggshell thickness and strength (Hams et al., 1990). Charles and Strong (1998) reported that differences in percentage of cracks were primarily due to the difference in eggshell strength. However, the lowest correlation coefficient value was -0.51 which is the correlation coefficient between eggshell strength and leaks. This could be due to that the leaks are related to the vitelline membrane rupture strength rather than the strength of the eggshell. There was a negative correlation between the eggshell strength and leaks (-0.72). This is in agreement with Bell (2001a) who reported that eggs with rough surface are weaker than the normal eggs.

Table 3 Correlation coefficients between eggshell thickness, cracks, leaks, rough surface and eggshell strength

	Eggshell strength
Eggshell thickness	0.97
Cracks	-0.96
Leaks	-0.51
Rough surface	-0.72

The values of cracks, leaks, rough surface and specific gravity of eggs laid by hens at different age are shown in Table 4. An increase in the percentage of the cracks, leaks and rough surface and a decrease in the specific gravity value were observed throughout the 4 weeks of experiment. Although the cracks are highly correlated with the eggshell strength, the increase in the percentage of the cracks was not significant this could be due to the low amount of force applied to the eggs when taking samples. This force was lower than the force applied during handling the eggs within the grading station. The increase of the percentage of the rough surface was the highest within the egg surface quality traits with a value around 3%. This is in agreement with Coutts and Wilson (1990) who observed that the age has an impact on the production of rough surface eggshell. Concerning the specific gravity, the results showed that the difference between the mean is not significant. The specific gravity value was around 1.08. This value corresponds to an intermediate shell thickness since a specific gravity values of 1.09 and 1.07 correspond to a thick and thin eggshell, respectively (Bell, 2001b).

Table 4 Values of cracks, leaks, rough surface and specific gravity (mean ± SEM) of eggs laid by hens at different age

Week	Cracks (%)	Leaks (%)	Rough surface (%)	Specific gravity
71	4.33 ± 0.99^a	1.02 ± 0.27^a	3.54 ± 1.03^a	1.08 ± 0.001^a
72	4.47 ± 0.36^a	1.20 ± 0.33^a	5.81 ± 1.32^a	1.082 ± 0.0008^a
73	5.49 ± 0.90^a	1.20 ± 0.67^a	6.20 ± 2.44^a	1.081 ± 0.0008^a
74	4.91 ± 0.77^a	1.20 ± 0.59^a	6.81 ± 1.39^a	1.081 ± 0.001^a

[a,b] For the same column, means without a common superscript differed significantly (P<0.05) according to the Duncan's test

CONCLUSIONS

In this research, the impact of the age of the hen on the internal and external quality traits of the egg was investigated. The results presented above showed that the age affected significantly (P<0.05) the eggshell strength and thickness after the age of 72 weeks. At the same time, the HU decreased significantly (P<0.05) after the age of 71 weeks. At week 71, the eggshell strength, the eggshell thickness and the HU were 33.5N, 0.33 mm and 84.26, respectively. After four weeks, these quality traits became 31.04N, 82.18 and 0.32mm, respectively. No significant changes (P>0.05) have been observed in the percentage of cracks, leaks, rough surface. However there was an increase in the percentage of these quality attributes. Thus, the age of the laying hen is critical in order to maintain a good quality egg.

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REFERENCES

Abe, E., H. Horikawa, T. Masumara, M. Sugahar, M. Kubota, and T. Suda. 1982. Disorders of cholecalciferol metabolism in old egg-laying hens. Journal of Nutrition. 112: 436-446.

Bar, A., E. Vax, and S. Striem. 1999. Relatioships among age, eggshell thickness and vitamin D metabolism and its expression in the laying hen. Comparative Biochemistry and Physiology Part (A). 123: 147-154.

Bell, D. 2001a. Egg production and egg weight standards for table-egg layers. In "Commercial chicken meat and production" (Bell, D., W.Weaver, ed). Kluwer academic publishers. pp 1079-1107. Norwell, Massachusetts.

Bell, D. 2001b. Egg handling and egg breaking. In "Commercial chicken meat and production" (Bell, D., W.Weaver, ed). Kluwer academic publishers. pp 1098. Norwell, Massachusetts.

Bennett, C.D.2002. The influence of shell thickness on hatchability in commercial broiler breeder flocks. Journal of applied poultry research. 1: 61-65.

Butcher, G.D., and R.D. Miles. 2003. Concepts of eggshell quality. University of Florida. http://edis.ifas.ufl.edu/pdffiles/VM/VM01300.pdf

Charles, F., and J.R. Strong. 1988. Research note: relationship between several measures of shell quality and egg-breakage in a commercial processing plant. Poultry Science. 68: 1730-1733.

Coutts, J.A., and G.C. Wilson. 1990. Egg quality handbook. Queensland Department of Primary Industries, Australia.

Doyon, G., M. Bernier-Cardou, R.M.G. Hamiliton, F. Castaigne, and C.J. Randall. 1986. Egg quality. 2. Albumen quality of eggs from five commercial strains of White Leghorn hens during one year of lay. Poultry Science. 65: 63-66.

Egg regulations.2009. Regulations respecting the grading, packing, marking and inspection of eggs and international and interprovincial trade in eggs. Catalogue number: C.R.C., c. 284.

Garlich, J., J. Brake, C.R. Parkhurst, J.P. Thaxton, and G.W. Morgan. 1984. Physiological profile of caged layers during one production year, molt, and postmolt: egg production, egg shell quality, liver, femur, and blood parameters. Poultry Science. 63(2): 339-343.

Hams , R.H., A.F. Rossi, D.R. Milles, and R.B. Christmas. 1990. A method for estimating shell weight and correcting specific gravity for egg weight in egg shell quality studies. Poultry Science. 73: 599-602.

Haugh, R.R. 1937. A new method for determining the quality of an egg. U.S. Egg Poultry. 39: 27-49.

Jacob, J.P, R.D. Miles, and F.B. Mather. 2000. Egg quality. University of Florida, IFAS extension.

Kröckel, L., R. Poser, and F. Schwägele. 2005. Low Resolution Proton Nuclear Resonance Spectroscopy: Application for the determination of the internal quality of intact EGGS microbiological aspects. Fleischwirtschaft. 85(10): 108-112.

Leeson, S., J.D. Summers, and L. Caston. 1993. Response of brown-egg layers to dietary calcium or phosphorus. Poultry Science, 72: 1510-1514.

Mertens, K., F. Bamelis, B. Kemps, B. Kamers, e. Verhoelst, B. De Ketelaere, M. Bain, E. Decuypere, and J. De Baerdemaeker. 2006. Monitoring of eggshell breakage and eggshell strength in different production chains of consumption eggs. Journal of Poultry Science. 85: 1670-1677.

Ngoka, D.A., G.W. Froning, and A.S. Babji. 1983. Effect of temperature on egg yolk characteristics of eggs from young and old laying hens. Poultry Science. 62: 718-720.

Novo, R.P., L.T. Gama, and M. Chaveiro Soares. 1997. Effects of oviposition time, hen age, and extra dietary calcium on egg characteristics and harchability. Journal of Applied Poultry Research. 6: 335-343.

Peebles, E.D., and J. Brake, 1987. Eggshell quality and hatchability in broiler breeder eggs. Poultry Science, 66, 596-604.

Roberts, J. 2004. Factors affecting egg internal quality and egg shell quality in laying hens. Journal of Poultry Science. 41:161-177.

Rodriguez-Navarro, A., O. Kalin, Y. Nys, and J.M. Garcia-Ruiz. 2002. Influence of the microstructure on the shell strength of eggs laid by hens of different ages. British Poultry Science. 395-403.

Silversides, F.G., and T.A. Scott. 2001. Effect if storage and layer age on quality of eggs from two lines of hens. Journal of Poultry Science. 80:1240-1245.

Widdicombe, J., A. Rycroft, and N. Gregory. 2009. Hazards with cracked eggs and their relationship to egg shell strength. Journal of Science and Food Agriculture. 89: 201-205.