Physical quality and composition of retail shell eggs

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ABSTRACT There are a number of specialty shell eggs available to consumers in the US retail market. A survey consisting of white and brown large shell eggs with various production and nutritional differences (traditional, cage-free, free-roaming, pasteurized, nutritionally enhanced, and fertile) was conducted to determine if physical quality and compositional differences exist. Identical brands of eggs were purchased from the same retail outlets on 3 occasions (replicates) in a single city. The average range of time from processing to purchase for all eggs was 7.67 to 25.33 d, with traditional white eggs in retail having the shortest time. Haugh unit values ranged from 66.67 (cage-free, docosahexaenoic acid, and n-3 enhanced) to 84.42 (traditional white). Albumen height followed a similar pattern. Egg weight was greater for brown eggs (61.12 vs. 58.85 g). Brown eggs also had greater static compression shell strength than white eggs (4,130.61 vs. 3,690.31 g force). Vitelline membrane strength was greatest for traditional brown eggs (2.24 g force). Percentage of total solids and crude fat was greatest in the cage-free, n-3-enhanced white eggs (25.07 and 11.71%, respectively). Although significant differences were found between white and brown shell eggs and production methods, average values for quality attributes varied without one egg type consistently maintaining the highest or lowest values.

Key words: shell egg, physical quality, composition, Haugh unit, shell strength

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INTRODUCTION

Consumers are becoming more aware of their food choices. As part of this trend, sourcing and production information is often desired for agricultural products. Furthermore, products associated with added health benefits are becoming more common in the marketplace. The US shell egg industry has begun to offer a diversified range of options to meet these consumer desires (AEB, 2008). The claims most often addressed on shell egg cartons are husbandry practices, hen nutrition, enhanced egg nutrition, and organic and fertile. Pricing for these products is typically at a premium but can vary from market to market. The pricing differences can be due to production-transportation costs or typical market pricing in the region. Hidalgo et al. (2008) conducted a study of retail eggs in Italy and determined that from a consumer point of view, the quality characteristics do not justify the increased prices for alternative eggs.

A variety of shell eggs are in the market, but there is no clear understanding of the overall physical and compositional quality of these different types of shell eggs. Bell et al. (2001), Koelkebeck et al. (2001), and Patterson et al. (2001) conducted a regional analysis of various shell eggs purchased in 115 stores in 38 US cities. They monitored egg age, egg weight (**EW**), albumen height (**AH**), Haugh unit (**HU**), and percentage of cracked eggs. The current study was undertaken to gain a more complete understanding of the physical and compositional quality of 8 types of traditional and specialty shell eggs purchased from the same retail establishments on 3 occasions (replicates) in a single US city. Egg age postprocessing, along with the physical quality factors of EW, AH, HU, shell thickness, shell weight, shell strength (**SS**), vitelline membrane strength (**VMS**), and vitelline membrane elasticity (**VME**), along with the compositional factors of percentage of solids, crude fat, protein, and ash, were monitored.

MATERIALS AND METHODS

On a single day, trips were made to 2 local grocery stores to purchase 2 dozen of each of the following egg types: traditional white; vitamin E, n-3 fatty acid, and enhanced white; pasteurized white; cage-free, docosahexaenoic acid (**DHA**), and n-3 fatty acid-enhanced white; fertile brown; free-roaming brown; cage-free and antibiotic-free brown; and traditional brown. All eggs were USDA grade A large eggs (USDA, 2008). This

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Table 1. Effects of egg type on egg retail age postprocessing, egg weight, albumen height, and Haugh unit values

Egg type	Retail age[1] (d)	Egg weight[2] (g)	Albumen height[2] (mm)	Haugh unit[2]
White shell				
Traditional	7.67[a]	60.53[BC]	7.28[A]	84.42[A]
Vitamin E and n-3	16.67[abc]	58.69[D]	6.32[BCD]	78.96[BC]
Pasteurized	24.00[c]	58.33[D]	6.79[AB]	81.99[AB]
Cage-free, docosahexaenoic acid, and n-3	22.33[bc]	57.86[D]	4.84[E]	66.67[E]
Brown shell				
Traditional	11.67[ab]	61.21[B]	6.60[BC]	79.08[BC]
Fertile	25.33[c]	60.65[BC]	6.26[BCD]	77.29[BCD]
Free-roaming	23.00[c]	63.41[A]	5.87[D]	73.88[D]
Cage-free and no antibiotics	16.67[abc]	59.22[CD]	6.12[CD]	76.70[CD]
SE	3.65	0.48	0.18	1.33

[a–c]Means within a column with similar superscripts are not significantly different ($P < 0.05$).

[A–E]Means within a column with similar superscripts are not significantly different ($P < 0.01$).

[1]n = 3 cartons (dozen).

[2]n = 36.

process was repeated on 2 other occasions for a total of 3 replicates. After purchase, eggs were stored at 4°C until analysis the following morning. All physical quality measurements were conducted on 12 individual eggs per treatment. Cracked eggs were excluded from sampling. All compositional measurements were conducted in triplicate from 4 pools (3 eggs/pool) for each egg type (treatment) composed of eggs that had been examined individually for physical quality measurements.

Egg retail age was defined as the time between the processing date (Julian date) printed on the carton and when eggs were purchased. Egg weight, AH, and HU (Haugh, 1937) were monitored with the aid of a computerized electronic measurement device (QCD Instrument, TSS, York, UK). Shell strength, VMS, and VME were recorded according to the methods of Jones et al. (2002) and Jones and Musgrove (2005) with a TA.XTplus Texture Analyzer (Texture Technologies, Scarsdale, NY) and Texture Expert software (Texture Technologies). Shell strength determinations were conducted utilizing a 5-kg load cell (calibrated with a 2-kg weight), 2 mm/s test speed, 0.001-kg trigger force, compression disc (TA-30, Texture Technologies), and egg holder (TA-650, Texture Technologies). Vitelline membrane testing methods include a 5-kg load cell, 3.2 mm/s test speed, 0.0001-kg trigger force, and 1-mm rounded end stainless steel probe (Texture Technologies). Shell thickness was recorded with a shell thickness gauge (25M-5 Thickness Measure, B. C. Ames Inc., Melrose, MA) at 3 locations around the equator of the shell. Shell weight was measured by rinsing shells and drying in a 100°C forced-air oven 18 to 24 h and included the shell membranes. Compositional analysis of percentage of moisture, ash, crude fat, and protein were determined according to the methods outlined by Jones (2007). Statistical analysis was conducted using the GLM model of SAS (SAS Institute, 2002). Means were separated by the least squares method.

RESULTS

The traditional white eggs had the lowest egg retail age (7.67 d) and fertile brown eggs were the oldest (25.33 d, $P < 0.05$) as seen in Table 1. Both of the traditional (white and brown) eggs were in the market the shortest amount of time. The more specialized eggs (fertile brown; pasteurized white; free-roaming brown;

Table 2. Effect of egg type on physical qualities of the shell and vitelline membrane[1]

Egg type	Shell weight (g)	Shell thickness (mm)	Shell strength (g force)	Vitelline membrane strength (g force)	Vitelline membrane elasticity (mm)
White shell					
Traditional	5.31	0.360	3,409.16[d]	2.06[ab]	4.02[a]
Vitamin E and n-3	5.27	0.359	3,749.23[cd]	2.03[ab]	3.87[ab]
Pasteurized	5.42	0.360	3,855.59[bc]	1.94[b]	4.14[a]
Cage-free, docosahexaenoic acid, and n-3	5.28	0.352	3,747.26[cd]	1.70[c]	3.15[bc]
Brown shell					
Traditional	5.98	0.388	4,314.34[a]	2.24[a]	4.23[a]
Fertile	6.01	0.397	4,074.60[abc]	1.70[c]	2.77[c]
Free-roaming	5.12	0.392	4,165.85[ab]	2.10[ab]	3.78[ab]
Cage-free and no antibiotics	5.59	0.372	3,968.23[abc]	2.07[ab]	4.05[a]
SE	0.07	0.004	134.97	0.08	0.29

[a–d]Means within a column with similar superscripts are not significantly different ($P < 0.05$).

[1]n = 36.

Table 3. Effect of egg type on egg proximate composition[1]

Egg type	Total solids (%)	Crude fat (% wet weight)	Protein (% wet weight)	Ash (% wet weight)
White shell				
Traditional	24.63[ab]	11.23[b]	13.14[abc]	0.90[a]
Vitamin E and n-3	24.22[bc]	10.61[c]	13.25[ab]	0.87[b]
Pasteurized	24.41[b]	10.77[c]	13.08[bcd]	0.88[b]
Cage-free, docosahexaenoic acid, and n-3	25.07[a]	11.71[a]	13.11[bcd]	0.91[a]
Brown shell				
Traditional	23.16[e]	10.02[e]	12.99[cd]	0.85[c]
Fertile	23.45[de]	9.93[e]	12.87[d]	0.86[bc]
Free-roaming	24.24[bc]	10.09[de]	13.39[a]	0.87[b]
Cage-free and no antibiotics	23.91[cd]	10.28[d]	13.05[bcd]	0.87[b]
SE	0.17	0.09	0.09	0.01

[a–e]Means within a column with similar superscripts are not significantly different ($P < 0.05$).

[1]n = 12 pools.

and cage-free, DHA, and n-3 white) were in retail the greatest length of time. The heaviest eggs on average were the free-roaming brown (63.41 g) and the lightest were the cage-free, DHA, and n-3 white; pasteurized white; and vitamin E and n-3 white (57.86, 58.33, and 58.69 g, respectively; $P < 0.01$). Albumen height and HU followed the same trend of differences between the egg types ($P < 0.01$). The highest HU was found for the traditional white (84.42) and the lowest for cage-free, DHA, and n-3 white (66.67).

Shell weight and shell thickness were not significantly different among the 8 types of eggs (Table 2). The traditional brown eggs had the greatest SS (4,314.34 g force) and the traditional white had the lowest (3,409.16 g force, $P < 0.01$). Vitelline membrane strength was greatest for the traditional brown (2.24 g force, $P < 0.05$). The cage-free, DHA, and n-3 white and fertile brown had the lowest average VMS values (1.70 g force). The most brittle (least elastic) VME were found in the fertile brown (2.77 mm, $P < 0.05$). There is no clear indication of egg retail age having a direct effect on VMS and VME in the current study.

The percentage of total solids ranged from 23.16 to 25.07% (Table 3). The lowest percentage of solids was found in the traditional brown and the highest in the cage-free, DHA, and n-3 white ($P < 0.05$). The cage-free, DHA, and n-3 white eggs also had the greatest average level of crude fat (11.71% wet weight) and the fertile brown had the least (9.93%, $P < 0.05$). The highest percentage of protein (13.39% wet weight) was found in the free-roaming brown and the lowest was in the fertile brown (12.87%, $P < 0.05$). Percentage of ash was greatest for the cage-free, DHA, and n-3 white and traditional white (0.91 and 0.90% wet weight, respectively) and lowest for the traditional brown (0.85% wet weight, $P < 0.05$).

All brown and white shell data were pooled and is presented in Tables 4, 5, and 6. There were no differences in egg retail age, AH, or HU in regard to shell color. Brown eggs purchased during this study were significantly heavier than the white eggs ($P < 0.05$, Table 4). The brown shell eggs had greater shell weights, shell thickness, and SS ($P < 0.05$, Table 5). There were no differences in VMS or VME. The white shell eggs had greater total solids, percentage of crude fat, and percentage of ash compared with the brown eggs ($P < 0.05$, Table 6).

Egg types were separated into cage-free and caged production based on carton labeling. The egg types determined to be cage-free were cage-free, DHA, and n-3; fertile; free-roaming; and cage-free and no antibiotics. The other half of the egg types were concluded to be from caged production. Eggs from caged production were in the retail market a shorter period of time than the cage-free eggs (15 and 21.83 d, respectively; $P < 0.05$; Table 7). Albumen height and HU were also greater for the caged production ($P < 0.0001$). Shell weight was greater for cage-free eggs (5.75 and 5.49 g, respectively; $P < 0.01$; Table 8). There was no difference between production type for shell thickness or SS. The vitelline membranes of the caged production eggs were stronger (2.07 and 1.87 g force, respectively; $P < 0.01$) and more elastic (4.06 and 3.43 mm, respectively) than the cage-free eggs. There were no differences in the proximate composition of eggs from the 2 production methods (Table 9).

Table 4. Effect of shell color on egg retail age, egg weight, albumen height, and Haugh unit values

Shell color	Retail age[1] (d)	Egg weight[2] (g)	Albumen height[2] (mm)	Haugh unit[2]
Brown	19.17	61.12[a]	6.21	76.76
White	17.67	58.85[b]	6.32	78.10
SE	2.51	0.30	0.11	0.84

[a,b]Means within a column with similar superscripts are not significantly different ($P < 0.05$).

[1]n = 12 cartons (dozen).

[2]n = 144.

Table 5. Effect of shell color on the physical qualities of the shell and vitelline membrane[1]

Shell color	Shell weight (g)	Shell thickness (mm)	Shell strength (g force)	Vitelline membrane strength (g force)	Vitelline membrane elasticity (mm)
Brown	5.93[a]	0.39[a]	4,130.61[a]	2.02	3.70
White	5.32[b]	0.36[b]	3,690.31[b]	1.93	3.80
SE	0.04	0.01	70.46	0.04	0.15

[a,b]Means within a column with similar superscripts are not significantly different ($P < 0.05$).

[1]n = 144.

Table 6. Effect of shell color on egg proximate composition[1]

Shell color	Total solids (%)	Crude fat (% wet weight)	Protein (% wet weight)	Ash (% wet weight)
Brown	23.69[b]	10.08[b]	13.07	0.86[b]
White	24.58[a]	11.10[a]	13.15	0.89[a]
SE	0.09	0.09	0.05	0.01

[a,b]Means within a column with similar superscripts are not significantly different ($P < 0.05$).

[1]n = 48 pools.

Table 7. Effects of type of production on egg retail age, egg weight, albumen height, and Haugh unit value

Production type	Retail age[1] (d)	Egg weight[2] (g)	Albumen height[2] (mm)	Haugh unit[2]
Cage-free	21.83[a]	60.29	5.78[B]	73.69[B]
Cage	15.00[b]	59.69	6.75[A]	81.11[A]
SE	2.20	0.31	0.10	0.78

[a,b]Means within a column with similar superscripts are not significantly different ($P < 0.05$).

[A,B]Means within a column with similar superscripts are not significantly different ($P < 0.0001$).

[1]n = 12 cartons (dozen).

[2]n = 144.

Table 8. Effect of production type on physical qualities of the shell and vitelline membrane[1]

Production type	Shell weight (g)	Shell thickness (mm)	Shell strength (g force)	Vitelline membrane strength (g force)	Vitelline membrane elasticity (mm)
Cage-free	5.75[A]	0.38	3,986.70	1.87[B]	3.43[B]
Cage	5.49[B]	0.37	3,832.08	2.07[A]	4.06[A]
SE	0.05	0.01	72.78	0.04	0.14

[A,B]Means within a column with similar superscripts are not significantly different ($P < 0.01$).

[1]n = 144.

Table 9. Effect of type of production on egg proximate composition[1]

Production type	Total solids (%)	Crude fat (% wet weight)	Protein (% wet weight)	Ash (% wet weight)
Cage-free	24.17	10.50	13.10	0.88
Cage	24.11	10.66	13.12	0.88
SE	0.10	0.12	0.05	0.01

[1]n = 48 pools.

DISCUSSION

The AH and HU values do not appear to be strongly linked with egg retail age for the types of eggs tested in the current study. The fertile brown had the greatest egg retail age and median AH and HU values. Previous studies have shown egg age and hen age to affect HU (Silversides and Villeneuve, 1994; Silversides and Scott, 2001; Jones et al., 2002; Jones and Musgrove, 2005). The pasteurized white eggs had an average egg retail age of 24 d and the second highest HU (81.99). Schuman et al. (1997) found HU scores to be greatly enhanced in all eggs exposed to a variety of immersion bath pasteurization temperature and dwell time schemes. The average HU values for all egg types were greater than 60, the minimum value for grade A classification by the USDA (USDA, 2000). In fact, all but the cage-free, DHA, and n-3 white had HU greater than 72, the minimum value for USDA grade AA.

Previous research examining the physical quality of US retail shell eggs had taken a more regional approach (Bell et al., 2001; Koelkebeck et al., 2001; Patterson et al., 2001). Bell et al. (2001) compared traditional brown and white and found differences for egg retail age and HU but not EW or percentage cracks. The average egg retail ages reported by Bell et al. (2001) were greater than those of the current study. Only 2 retailers were visited in the current study as opposed to 115 in Bell et al. (2001). The number of eggs present in the retail cases visited in the current study could be fewer, resulting in a greater turnover rate of product, but the data collected do not allow for a complete understanding of the differences in retail egg age between the 2 studies. Average HU was much lower for Bell et al. (2001). Unlike the current study in which 1 laboratory conducted all analyses on the same piece of equipment, multiple laboratories were involved in the regional analysis and could have an effect on the recorded values due to differences in available equipment and operators. Furthermore, all eggs were handled identically and stored in the same refrigerator before and during testing in the current study.

Egg weight was significantly different between the egg types and between white and brown shells. Patterson et al. (2001) found welfare-managed eggs to be heavier than their counterparts. That was also seen in the current study with the free-roaming eggs being the heaviest. Shell egg processing equipment is designed to allow for user input of many parameters, including EW, for customized packaging into cartons. There are minimum weight standards for shell eggs in cartons with the USDA grade shield but no guidance on maximum allowable weight (USDA, 2000). All eggs in the United States are not produced under the voluntary USDA grade shielding program (USDA, 2008), but all US eggs destined for retail must meet the state egg laws where they are marketed. Most states follow the USDA EW standards in their individual egg laws. Because the eggs for the current study were purchased at retail, there is no information available on how heavy the processing facility was packaging the eggs or the age of the flocks, which has been linked to EW, shell weight, and shell thickness. Furthermore, there was no information on the breed of hen producing the eggs, which has been directly linked to EW (Anderson, 2007). Therefore, although significant differences existed for EW between egg types and comparison groups, this could be due to the weights of eggs the processors were choosing to package into the cartons.

There were no differences in shell thickness or shell weight between the egg types in the current study. The work of Şekeroğlu and Altuntaş (2009) determined shell thickness to be greatest in medium eggs and lowest in extra-large eggs. Data collected in the current study did not demonstrate the same trend. The heaviest eggs (free-range brown, 63.41 g) have one of the greatest overall shell thicknesses (0.392 mm). Consequently, the smallest eggs (cage-free, DHA, and and n-3 enhanced; 57.86 g) had the thinnest shells (0.352 mm). The brown shell eggs had greater SS than the white shell eggs. These findings counter those of Şekeroğlu and Altuntaş (2009), who reported greater SS in medium eggs compared with larger eggs. In the current study, brown egg strains were heaviest and had greater static compression SS. Additionally, Hidalgo et al. (2008) found that caged eggs available in Italian retail had greater resistance to shell breakage. The current study did not detect a difference in SS between caged and cage-free eggs. There were differences among the eggs in VMS and VME. These differences were not clearly linked to shell color. When comparing the eggs based on production type, VMS and VME were greater for caged produced eggs.

The compositional characteristics of the eggs were also different among the types. Traditional brown and fertile brown eggs had the lowest percentage of total solids, crude fat, protein, and ash. They also had the greatest average shell weights (5.98 and 6.01 g, respectively). The retail egg age was very different for these 2 brown egg types (11.67 and 25.33 d, respectively), preventing an assumption that egg age was a factor in the proximate composition difference. When paired comparisons were conducted, the only proximate compositional differences noted were between shell color groups. The white shell eggs had significantly higher percentages of total solids, crude fat, and ash.

Although a wide variety of shell eggs are available in retail, the consumer should be aware that the physical and compositional characteristics of these eggs are not completely the same. Increasing consumer understanding of the quality variability of different types of shell eggs can help to prevent generalized negative bias toward eggs.

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