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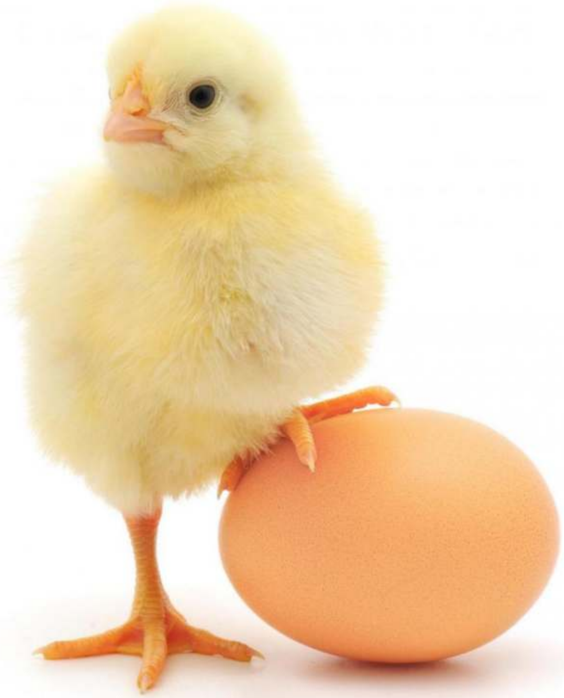

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Comparison of Quality Parameters in Hen's Eggs According to Egg Shell Color

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Abstract: The aim of this study was to evaluate some quality parameters of commercial hen's eggs according to egg shell color. A total of 5,424 eggs were purchased from 113 supermarkets situated in 14 cities from the east-center of Entre Rios, Argentina; 3,475 were white eggshell and 1,949 eggs were brown eggshell. The values of Egg Weight (EW), Eggshell Weight (ESW), Eggshell Thickness (EST), % eggshell (% ES) and Total Shell Surface Area (TSSA) were greater in brown eggs than in white eggs. There was a significant positive correlation between EW and ESW and EW and TSSA, but EW had negative correlations with % ES. There were no significant differences in yolk (Y) and albumen (Al) pH between brown eggs and white eggs. The range of Yolk Color (YC) was 2-11 for white eggs and 2-14 for brown eggs. However, in general, eggs had similar YC in a package. This is the first report about the quality of commercial hen's eggs from supermarkets in Argentina. Although eggs can belong to different hen's breeding systems and ages, there are some differences in the quality parameters studied between white and brown eggs.

Key words: Eggs, egg quality, color egg shell, supermarket

INTRODUCTION

The avian egg is considered to be a storehouse of nutrients such as proteins, lipids, enzymes and various biologically active substances, including growth promoting factors as well as defense factors against bacterial and viral invasion (Mine, 2007). Where eggs and eggs products provide a good source of nutrients, they also provide many desirable attributes as food ingredients. In relation to the production of desserts, several functional properties of eggs and eggs products are important - binding, foaming, thickening, color and flavor contribution and mouth feel improvement (Food and Environmental Hygiene Department, 2004).

The increasing consumer awareness of food safety issues has changed the public perception of a "good egg" from shell cleanliness and physical properties to that of microbial integrity (De Reu *et al*., 2006). Other consumers defined egg quality in physical and visual term (i.e. size of the air cell, color of the yolk, height of the albumen) and few consumers expressed concern about the microbial load contained on or within commercially processed eggs (Jones *et al*., 2002).

The nutrient content of eggs and weight of day-old chicks depend on the weight of the egg. This parameter can be determined without breaking the egg. Egg Weight (EW) is a direct proportion of albumen, yolk and shell. In addition, EW influences eggshell quality. It is known that large eggs have a higher number of cracks than small eggs (Sekeroglu and Altuntas, 2009).

The eggshell is a highly specialized structure that together with its membrane provides protection against physical damage and against microorganisms and small predators (Yoshinori *et al*., 2003). The eggshell color of brown eggs is a quality aspect that is important for the perception of the consumer. In general, a more homogeneous brown color is preferred over spotty or pale eggs. This aspect makes the shell color an important economic quality parameter (Wei and Bitgood, 1990). Brown eggs have been perceived by the consumer to be more natural or healthier than white eggs (Scott and Silversides, 2000). However, there are also regional preferences that can strongly influence the choice of genetic type for particular markets (Arthur and Sullivan, 2005).

The quality of eggshells is most commonly defined in terms of the amount of shell present and is assessed by measuring shell specific gravity, shell weight or shell thickness (Messens *et al*., 2005). Clean, intact eggshells are also required to ensure consumer satisfaction and dietary safety. Improving overall eggshell quality would have a significant economic impact on the industry (Yang *et al*., 2009).

Global egg production increased from 35.2 million tons in 1990 to 62.5 million tons in 2007 or by 78%. Egg production in the Americas increased from almost 8 million tons in 1990 to 11.9 million tons in 2007 or by 49.6%. Argentina is one of the five leading countries in egg production in the Americas (Windhorst, 2009).

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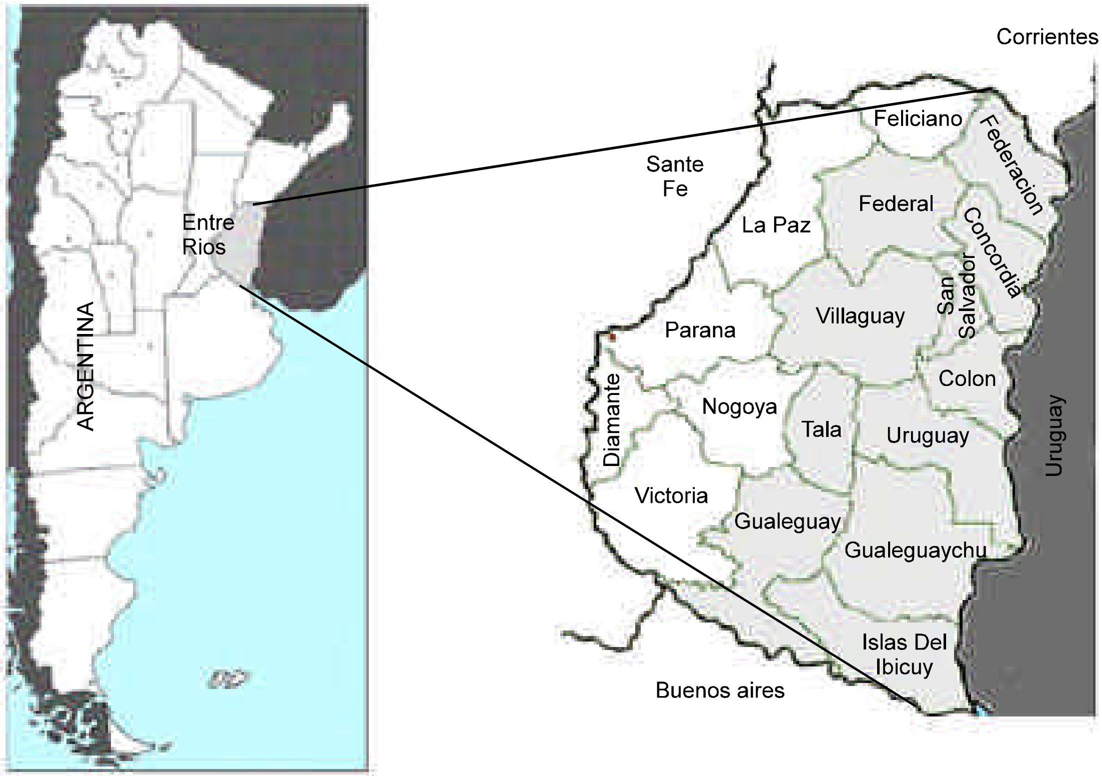

Fig. 1: Regions sampled from eggs sold in supermarkets in Entre Rios, Argentina, from March, 2007 to November, 2009. The counties sampled are in light gray

Argentina produces near 9 billion eggs and the per capita consumption is 211 eggs (Lamelas *et al.*, 2010). The most important egg layer breeds belong to Hy-Line, Lohmann and H&N in this country (Aho and Wright, 2010). Entre Rios is a northeastern province of Argentina, which produces 21% of egg production from the country (Schell *et al.*, 2009). There is not any study about egg quality in Argentina and Entre Rios. So the present work was conducted to evaluate some quality parameters of commercial hen's eggs sold at supermarkets according to egg shell color.

MATERIALS AND METHODS

Samples and egg packaging: A total of 5,424 eggs were purchased from 113 supermarkets, situated in 14 cities in the east-centre of Entre Rios, Argentina (Table 1). The samples were taken from 11 counties of Entre Rios, from March, 2007 to November, 2009 (Figure 1). From the totality of the eggs analyzed, 3,475 were white eggshell and 1,949 eggs were brown eggshell. They were grouped into six eggs each, but when the supermarket did not have this presentation; eggs were taken from 30-egg fiber carton. In that case, 4 samples of 6 eggs were used for this study. After purchased at the supermarkets, eggs were transported at room temperature to the INTA Poultry Health Laboratory (Concepcion del Uruguay, Entre Rios).

Table 1: Number (No.) of supermarkets sampled from different cities and counties in Entre Rios, Argentina, from March, 2007 to November, 2009

Counties of Entre Rios	Cities	No. supermarkets sampled
Colon	Colon	5
	San Jose	5
	Villa Elisa	12
Concordia	Concordia	17
Federacion	Federacion	6
Federal	Federal	5
Gualeguay	Gualeguay	9
Gualeguaychu	Gualeguaychu	12
Islas del Ibicuy	Villa Paranacito	3
San salvador	San Salvador	7
Tala	Rosario del Tala	3
Uruguay	Basavilbaso	5
	Concepcion del Uruguay	15
Villaguay	Villaguay	9
Total		113

Egg weight: Eggs were weighed individually in a sterile form with an electronic top-loading balance, scale 0.1 g (Precisa 3000 D, Zurich, Switzerland). According to the weights obtained, EW was classified in 1S (extra-large, $\geq$ 62 g), 1 (large, 54-61 g), 2 (medium, 48-53 g) and 3 (small, 42-47 g), based on Argentina's regulations (Anonymous, 1968).

Egg shell: Dirty surface was studied by macroscopic observation. Dirty eggs corresponded to type C eggs in Argentina, with less than 15% of dirty eggshell surface (Anonymous, 1968). The wet Eggshell Weight (ESW) was measured after eggs were broken and their contents (yolk and albumen) were separated with a spoon. Eggshell Thickness (EST) was measured on shells and the measurement included dried shell membrane. Thickness was measured at four points using a thickness meter, scale 0.01 mm (Schwyz, Argentina). These 4 values were averaged to obtain the mean of each eggshell thickness. Total Shell Surface Area (TSSA) was calculated in square centimeters, using the following equation: $3.9782 \times EW^{0.7056}$ (Peebles and McDaniel, 2004). The percentage of eggshell (% ES) was calculated using the following equation: (ESW/EW) x 100. ESW, % ES and EST were calculated in the 50%, 50% and 44% of eggs studied.

Egg components: yolk and albumen

Yolk Color (YC): Each egg was broken and YC was determined using a YC fan (DSM, ex-Roche, Basel, Switzerland) with color intensity ranging from pale yellow -scored 1- to deep orange- score 15- (Vuilleumier, 1969).

pH of the pool yolk-albumen, yolk and albumen: The eggs were broken and the eggshell was conserved to measure EST and the content from six eggs was pooled (mixture of yolk and albumen -YA-) or separated in pools of 6 Yolks (Y) or Albumens (Al). The pools were stomached (Stomacher 400 circulator, Seward, England) and then pH was measured in pH meter (OAKTON, Singapore) the same day.

Statistical analysis: Results were reported as range or mean ± standard error of the mean (SE). Differences in means were evaluated by a one-way Analysis of Variance (ANOVA) test. The results were only considered to be statistically different at $p<0.05$ (Rossman and Chance, 1998). Differences in the correlation coefficients between EW and ESW, EW and % ES and EW and TSSA were determined and significance tests were applied using OCTAVE, developed by the Group of Numerical Method, from the National Technological University of Concepcion del Uruguay, Entre Rios, Argentina, Projects 25D041.

RESULTS

Egg packaging: In terms of eggshell color, 64% were white and 36% were brown, but all eggs purchased from San Jose city were white. Eggs were packed in different packs (Table 2, Fig. 2), 6-egg fiber cartons (60.6%), 6-egg polystyrene bags (17.7%), 6-eggs wrapped in newspaper (10.2%), 30-egg fiber cartons (6.2%, in samples of 6 eggs) and 6-egg polystyrene foam cartons (5.3%). From 6-egg fiber cartons, 32.1% of the packs didn't have any label and only 24.8% of egg packs had a label with the brand and the EW categories (1 or 2). From these, 132 and 4 packs belonged to category 1 and 2, respectively. Only 15.9% of packs labeled with EW category 1 corresponded to those kinds of eggs. On the other hand, 22.7%, 25.8%, 9.1%, 16.7%, 4.5% and 5.3% of the packs labeled with this egg category had one, two, three, four, five or six eggs out of this EW category, respectively. From EW category 2, 25% of the packs corresponded to that kind of EW category. The others had one, two or five eggs out of this EW category (data not shown).

Table 2: Number (No) of samples according to egg packs purchased in different supermarkets of Entre Rios, Argentina

		No. of samples of 6 eggs, according to egg packs							
		6-Egg fiber cartons				6-eggs polystyrene foam cartons	30-egg fiber cartons[1]	6-eggs wrapped in newspaper	6-eggs in poly-styrene bags
Cities	No. of samples	Without label	With only label	With label and EWC	Total				
Basavilbaso	40	8	0	0	8	0	0	8	24
Concepcion del uruguay	120	64	16	16	96	0	8	16	0
Colon	40	12	15	13	40	0	0	0	0
Concordia	136	8	32	24	64	0	24	24	24
Federacion	48	28	4	0	32	0	0	0	16
Federal	40	4	16	4	24	0	0	8	8
Gualeguaychu	96	28	52	8	88	0	0	8	0
Gualeguay	72	0	53	15	68	0	0	4	0
San jose	40	8	0	8	16	0	0	0	24
San salvador	56	8	0	0	8	0	8	0	40
Rosario del tala	24	0	8	8	16	0	0	0	8
Villaguay	72	0	16	40	56	0	0	8	8
Villa elisa	96	8	0	0	8	48	16	16	8
Villa paranacito	24	0	24	0	24	0	0	0	0
Total	904	176	236	136	548	48	56	92	160
Percentage (%)	100	32.1	43.1	24.8	60.6	5.3	6.2	10.2	17.7

[1]Packs were considered from samples of 6 eggs. With label and EWC = With Label and Egg Weight Category

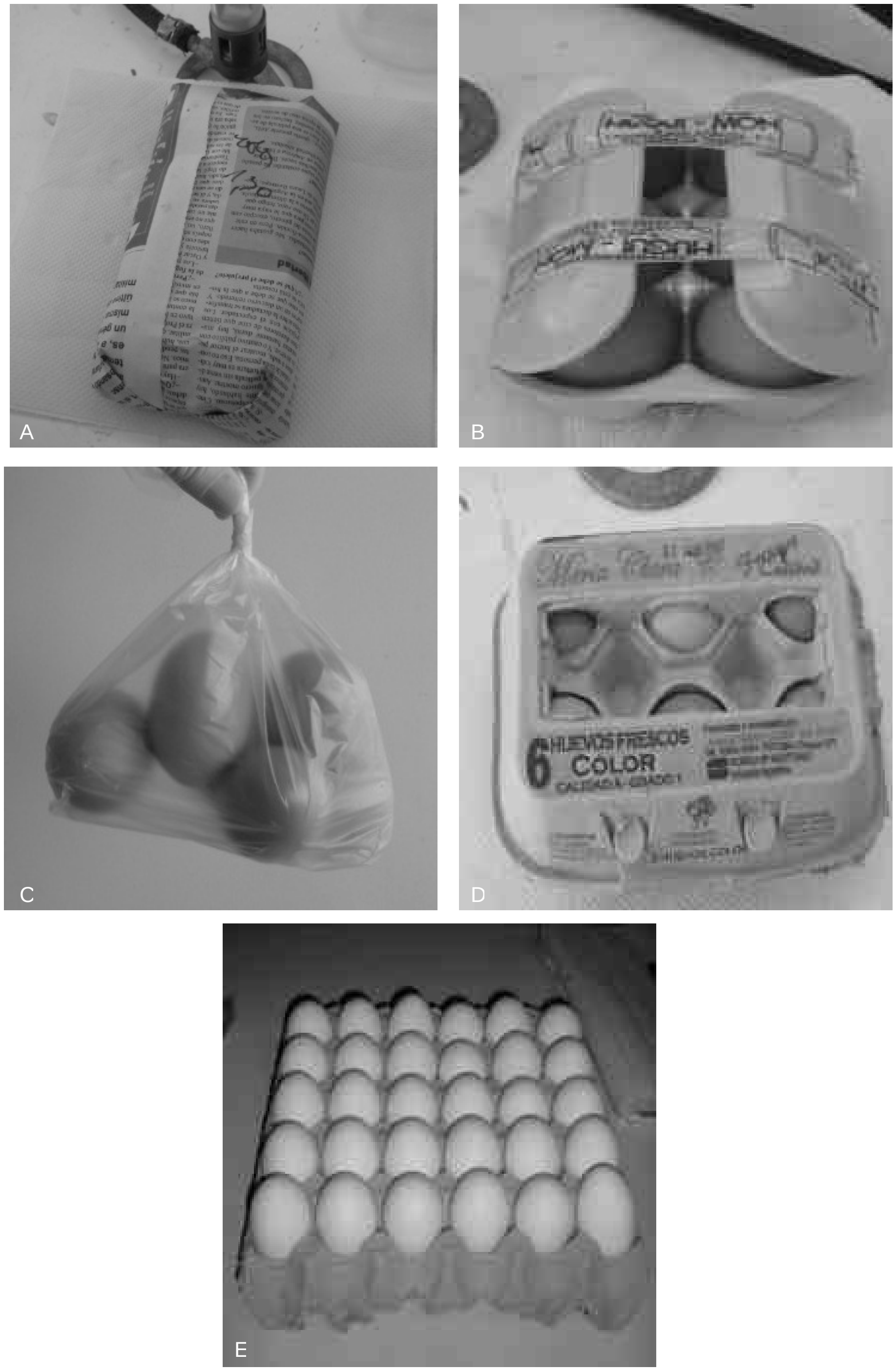

Fig. 2: Egg packs purchased in different supermarkets of Entre Rios, Argentina. A) 6-eggs wrapped in newspaper; B) 6-eggs in polystyrene foam cartons; C) 6-eggs in polystyrene bags; D) 6-eggs fiber cartons; E) 30-egg fiber cartons

From 6-egg polystyrene foam cartons, only 24 packs from the city of Villa Elisa were labeled with the brand and the detail of the individual EW (50 g each one). That EW didn't correspond to the real EW of the eggs. In general, EW was greater than 50 g (data not shown). On the other hand, the label didn't appear in the case of 6-eggs wrapped in newspapers, 6-egg polystyrene bags and 30-egg fiber cartons.

Table 3: Values of external egg quality characteristics in the total number of eggs studied according to egg shell color. Values represent means±SE. Eggshell weight, percentage eggshell (%) and eggshell thickness were calculated in the 50%, 50% and 44% of eggs studied

		Values according to eggshell color			
External egg quality characteristics	Total of eggs	Number of eggs	White eggshell	Number of eggs	Brown eggshell
Egg weight (g)	5,424	3,475	59.3±6.10^a	1,949	61.0±6.50^b
Eggshell weight (g)	2,712	1,764	6.7±0.70^a	948	7.0±0.80^b
Eggshell thickness (mm)	2,376	1,440	0.4±0.04^a	936	0.5±0.05^b
Percentage eggshell (%)	2,712	1,764	11.5±1.00^a	948	11.6±1.00^b
Total shell surface area (cm^2)	5,424	3,475	71.0±5.30^a	1,949	72.0±5.30^b

^{a,b}Means in the same row with different superscript are significantly different ($p<0.05$)

Table 4: Egg weight categories and number of eggs in different supermarkets of Entre Rios, according to eggshell (ES) color. 1S (>62 g), 1 (54-61 g), 2 (48-53 g) and 3 (42-47 g)

	Number of eggs, according to egg weight categories[1] and eggshell color											
	1S			1			2			3		
Cities of Entre Rios	White ES	Brown ES	Total	White ES	Brown ES	Total	White ES	Brown ES	Total	White ES	Brown ES	Total
Basavilbaso	133	8	141	74	14	88	9	2	11	0	0	0
Colon	31	31	62	89	58	147	23	6	29	1	1	2
Concepcion del uruguay	135	48	183	363	44	407	111	4	115	13	0	13
Concordia	243	179	422	264	75	339	42	6	48	3	4	7
Federacion	37	40	77	48	45	93	94	10	104	13	1	14
Federal	52	66	118	32	61	93	11	18	29	0	0	0
Gualeguay	9	23	32	152	121	273	73	39	112	12	3	15
Gualeguaychu	66	70	136	216	112	328	75	16	91	21	0	21
Rosario del tala	7	7	14	61	58	119	4	7	11	0	0	0
San jose	72	0	72	142	0	142	26	0	26	0	0	0
San salvador	75	119	194	31	87	118	2	22	24	0	0	0
Villa elisa	118	104	222	207	91	298	32	21	53	3	0	3
Villa paranacito	5	7	12	74	37	111	17	4	21	0	0	0
Villaguay	25	32	57	151	150	301	22	51	73	0	1	1
N° total	1,008	734	1,742	1,904	953	2,857	541	206	747	66	10	76
Percentage of TES[2]	58%	42%	32%	67%	33%	53%	72%	28%	14%	87%	13%	1%

[1]Egg weight class was classified in: 1S (extra-large, >62 g), 1 (large, 54-61 g), 2 (medium, 48-53 g) and 3 (small, 42-47 g).
[2]Percentage egg weight was measured on the total of each egg weight class; Percentage of TES = Percentage of total eggs sampled

Egg weigh and egg shell: A significant difference in the EW and egg shell parameters was observed between brown and white eggs, considering the total number of eggs (Table 3). The values of EW, ESW, EST, % ES and TSSA were greater in brown eggs than in white eggs.

In reference to EW, 32%, 53%, 14% and 1% belonged to 1S, 1, 2 and 3 EW categories, respectively (Table 4). Comparing eggshell color and EW categories, white eggshells were presented in 58%, 67%, 72% and 87% for 1S, 1, 2 and 3 egg categories, respectively. On the other hand, brown eggshells were in 42%, 33%, 28% and 13% to 1S, 1, 2 and 3 egg categories, respectively. Most of the sampled eggs from Basavilbaso, Concordia, Federal and San Salvador were class 1S. Relating eggshell color to EW, most eggs had a white eggshell in Basavilbaso and Concordia, but most of them were brown eggshell in Federal and San Salvador. Class 1 of EW predominated in Colon, Concepcion del Uruguay, Gualeguay, Gualeguaychu, Rosario del Tala, San Jose, Villa Elisa, Villa Paranacito and Villaguay and most of them were white eggshells. Federacion presented more number of eggs that belonged to the category 2, most of them were white eggshell.

EW was highly variable, between 36.2 and 92.1 g and 34 and 89.6 g for white and brown eggshell, respectively (Table 5). The Coefficient of Variation (CV) of sample of 6 eggs was 4.7% and 6.3% for EW of white and brown eggshell, respectively. However, the range was between 0.4% and 32.2% and 1.1% and 21.6% for white and brown eggshell, respectively. ESW was between 4.1 and 10.4 g and 4.9 and 9.6 g for white and brown eggshell, respectively. The % ES was between 7.5 and 16.9% and 7.7 and 17% for white and brown eggshell, respectively. On the other hand, EST was from 0.3 to 0.6 mm for both types of eggshell and TSSA was from 50 to 96.8 cm^2 and 47.9 to 95 cm^2 for white and brown eggshell, respectively (data not shown).

A detail of values of external egg quality characteristics, according to eggshell color, in different cities of Entre Rios is shown in Table 6. It was observed that there were only significant differences ($p<0.05$) in all parameters studied in Concepcion del Uruguay and

Table 5: Values of range and Coefficient of Variation (CV) of egg weight in sample of 6 eggs in different cities of Entre Rios, according to eggshell color

	Weight of white eggs			Weight of brown eggs		
		CV of sample of 6 eggs (%)			CV of sample of 6 eggs (%)	
Cities	Range (g)	Mean±SE	Range	Range (g)	Mean±SE	Range
Basavilbaso	48.7-76.9	6.0±1.7	3.2-11.0	51.2-65.3	6.2±1.8	4.6-7.7
Colon	46.4-66.8	3.9±1.2	2.0-6.2	41.6-69.8	5.2±1.9	1.4-7.9
Concepcion del Uruguay	40.4-80.4	4.7±2.2	1.4-11.3	51.7-86.5	7.6±4.4	3.3-21.6
Concordia	44.4-92.1	4.9±2.0	0.4-12.8	43.0-82.3	5.9±2.5	1.1-11.5
Federacion	42.4-80.1	5.0±1.9	1.7-8.7	34.0-80.9	7.2±4.0	2.8-17.9
Federal	50.4-78.0	6.0±3.2	2.2-13.9	48.2-78.4	7.6±3.1	1.3-14.9
Gualeguay	36.2-68.1	5.5±4.0	2.0-32.2	39.3-67.5	5.0±3.4	1.2-16.0
Gualeguaychu	40.0-73.4	5.2±2.4	1.2-13.2	50.0-89.6	6.0±3.6	2.5-21.3
Rosario del Tala	51.8-64.4	4.9±1.2	2.9-7.4	51.4-69.2	4.7±2.0	2.5-9.7
San Jose	47.1-68.0	4.2±1.6	1.5-9.4	N.D[1]	N.D	N.D
San Salvador	50.4-84.0	6.1±2.6	2.5-10.8	48.2-85.8	7.0±2.4	2.6-11.3
Villa Elisa	46.7-70.3	4.5±1.7	1.4-11.0	48.8-87.1	8.5±3.3	3.8-16.6
Villa Paranacito	48.5-74.4	5.4±3.0	2.0-14.3	51.2-76.0	6.3±3.2	2.7-13.9
Villaguay	49.7-65.7	4.0±1.2	1.4-6.0	46.7-66.1	4.5±2.1	1.6-12.5
Total	36.2-92.1	4.7±2.8	0.4-32.2	34.0-89.6	6.3±3.3	1.1-21.6

[1]N.D = No Detected

Table 6: Values of external egg quality parameters in different cities of Entre Rios, according to eggshell color. Values represent means ±SE

	Value of external egg quality parameters, according to eggshell color									
	Eggs weight (g)		Eggshell weight (g)		Eggshell thickness (mm)		% Eggshell		TSSA (cm^2)	
Cities	White eggshell	Brown eggshell	White eggshell	Brown eggshell	White eggshell	Brown eggshell	White eggshell	Brown eggshell	White eggshell	Brown eggshell
Basavilbaso	63.3±5.7^{a}	60.0±3.6^{b}	6.7±0.6	6.9±0.7	0.42±0.04^{a}	0.49±0.05^{b}	10.7±0.9^{a}	11.4±1.1^{b}	74.5±4.7^{a}	71.5±3.0^{b}
Colon	58.3±4.2^{a}	59.8±4.2^{b}	6.8±0.8	7.0±0.5	0.44±0.03	0.45±0.04	11.5±0.9^{a}	12.0±0.9^{b}	70.0±3.5^{a}	71.4±3.7^{b}
Concepcion del uruguay	58.3±6.4^{a}	63.4±7.2^{b}	6.6±0.8^{a}	7.4±0.8^{b}	0.39±0.05^{a}	0.44±0.05^{b}	11.4±1.1^{a}	11.8±0.9^{b}	70.2±6.2^{a}	72.8±5.7^{b}
Concordia	62.0±6.0^{a}	64.0±6.0^{b}	7.0±0.8^{a}	7.6±0.6^{b}	0.44±0.04^{a}	0.46±0.05^{b}	11.4±0.9^{a}	11.6±0.8^{b}	73.0±5.0^{a}	75.0±4.9^{b}
Federacion	55.4±7.8^{a}	60.7±6.2^{b}	6.6±0.7^{a}	7.1±0.7^{b}	0.43±0.04	0.43±0.03	12.0±1.2^{a}	11.5±0.9^{b}	67.4±6.6^{a}	72.0±5.2^{b}
Federal	62.9±7.0^{a}	61.0±6.0^{b}	7.0±0.7	7.1±0.8	0.42±0.03^{a}	0.45±0.03^{b}	11.3±1.0^{a}	11.6±0.8^{b}	73.8±5.8^{a}	72.3±4.8^{b}
Gualeguay	55.0±4.3^{a}	57.0±4.0^{b}	6.6±0.5	6.7±0.6	0.45±0.04	0.45±0.04	11.9±1.0	11.9±1.0	67.3±3.7^{a}	68.8±3.6^{b}
Gualeguaychu	58.0±5.0	59.0±6.0	6.7±0.7^{a}	7.4±0.9^{b}	0.41±0.05^{a}	0.45±0.06^{b}	11.8±0.9^{a}	12.1±1.2^{b}	69.8±4.4	70.5±5.2
Rosario del tala	57.2±3.6	57.4±4.0	6.4±0.5^{a}	6.9±0.5^{b}	0.41±0.02^{a}	0.43±0.02^{b}	11.1±0.7^{a}	12.0±0.8^{b}	69.4±2.4	69.5±2.6
San jose	59.2±4.3	ND[1]	6.9±0.7	ND	0.44±0.03	ND	11.6±1.0	ND	71.0±3.6	ND
San salvador	65.8±7.1	63.2±7.0	7.2±0.9^{a}	6.7±0.9^{b}	0.40±0.03	0.41±0.03	11.0±1.3	11.1±0.9	76.2±5.8^{a}	74.1±5.7^{b}
Villa elisa	59.7±4.2^{a}	63.3±8.2^{b}	7.0±0.7^{a}	7.2±0.9^{b}	0.45±0.03^{a}	0.47±0.05^{b}	11.7±0.9	11.5±1.3	71.3±3.6^{a}	74.1±6.7^{b}
Villa paranacito	56.7±3.4^{a}	57.0±4.2^{b}	6.3±0.5^{a}	6.7±0.6^{b}	0.40±0.03^{a}	0.42±0.03^{b}	11.2±1.1	11.5±1.1	68.6±3.0^{a}	70.0±3.0^{b}
Villaguay	57.6±3.4	57.5±3.9	6.4±0.5^{a}	6.8±0.5^{b}	0.44±0.05	0.45±0.04	11.0±0.7^{a}	11.5±0.8^{b}	69.5±3.0	69.4±3.4

[a,b]Means in the same row for each external egg quality parameter with different superscript are significantly different ($p<0.05$).

[1]ND = Not Detected. TSSA = Total Shell Surface Area (cm^2)

Concordia, but the other cities presented differences in some of them. A significant difference in EW was observed in 9 cities between brown and white eggs. EW was heavier in brown eggs than in white eggs in 7 cities and the contrary was observed in 2 cities. On the other hand, ESW showed a significant difference in 9 cities of Entre Rios in relation to eggshell color. Brown eggs were heavier than white eggs in relation to ESW in 8 out of these 9 cities.

EST showed a significant difference in 8 cities of Entre Rios in relation to eggshell color (Table 6). Brown eggs were heavier than white eggs in relation to EST in these cities. On the other hand, there was a significant difference in 9 cities for % ES, according to eggshell color. Brown eggshells were significantly heavier than white eggshells in 8 out of these 9 cities. The TSSA showed a significant difference in 10 cities of Entre Rios in relation to eggshell color. Brown eggs were heavier than white eggs in relation to this parameter in 7 cities.

In reference to the eggshell cleanliness, most of the eggs sold in supermarkets of Entre Rios had a clean eggshell (Table 7). The number of eggs with dirty surface was 1.12% and 1.74% for white and brown eggs, respectively.

Table 7: Percentage of eggs with a dirty eggshell, according to eggshell color

Eggshell color	Number of eggs	Number of eggs with dirty surface (%)
White	3,475	39 (1.12)
Brown	1,949	34 (1.74)
Total	5,424	73 (1.35)

Table 8: Correlation coefficients (r) between egg weight and other external quality parameters in different cities of Entre Rios, according to eggshell color

	Eggshell color					
	Egg weight in white egg			Egg weight in brown egg		
	Correlation coefficients					
Cities of Entre Rios	ESW	%ES	TSSA	ESW	%ES	TSSA
Basavilbaso	0.536**	-0.422**	0.999**	0.404	-0.572	0.999**
Colon	0.743**	0.205	0.846**	0.542**	-0.542**	0.838**
Concepcion del uruguay	0.710**	-0.201**	0.928**	0.735**	-0.324*	0.710**
Concordia	0.736**	-0.211**	0.968**	0.614**	-0.496**	0.978**
Federacion	0.693**	-0.579**	0.999**	0.638**	-0.366*	0.999**
Federal	0.690**	-0.533**	0.999**	0.750**	-0.056	0.999**
Gualeguay	0.407**	-0.417**	0.999**	0.478**	-0.391**	0.999**
Gualeguaychu	0.719**	-0.305**	0.999**	0.459**	-0.169	0.999**
Rosario del tala	0.550**	-0.127	0.999**	0.488**	-0.372*	0.999**
San jose	0.499**	-0.237**	0.999**	ND[1]	ND	ND
San salvador	0.485**	-0.458**	0.999**	0.799**	-0.074	0.999**
Villa elisa	0.505**	-0.227**	0.027	0.598**	-0.517**	0.848**
Villa paranacito	0.145	-0.432**	0.999**	0.166	-0.560**	0.999**
Villaguay	0.526**	-0.290**	0.999**	0.516**	-0.303**	0.999**

[1]ND = Not Detected. *p<0.05; **p<0.01. ESW = Eggshell Weight; %ES = %Eggshell; TSSA = Total Shell Surface Area

Table 9: Correlation coefficients (r) between total egg weight and other external egg quality parameters, according to different egg weight categories and Eggshell (ES) color

	Correlation coefficient according to egg weight categories and ES color							
	1S (>62 g)		1 (54-61 g)		2 (48-53 g)		3 (42-47 g)	
External egg quality	White ES	Brown ES	White ES	Brown ES	White ES	Brown ES	White ES	Brown ES
Eggshell weight	0.405**	0.438**	0.407**	0.384**	0.102	0.289**	0.200	ND[1]
%Eggshell	-0.293**	-0.410**	-0.046	-0.033	-0.269**	-0.013	-0.141	ND
Total shell surface area	0.915**	0.892**	0.636**	0.814**	0.493**	0.291**	0.520**	ND

[1]ND = Not Determined (low number of samples). **p<0.01

Correlative coefficients between EW and ESW, EW and % ES and EW and TSSA are shown in Table 8. In general, the correlations between EW and ESW and EW and TSSA were positive in both eggshell color, but there was a negative correlation between EW and % ES in both eggshell color. There was not a significant correlation between EW and ESW in the cities of Villa Paranacito (white and brown eggs) and Basavilbaso (brown eggs). In contrast, the correlative coefficient was statistically different (p<0.01) in both white and brown eggs for 11 of the 14 cities and in Basavilbaso and San Jose this difference was only observed in white eggs. Moreover, the correlation between EW and % ES was not significant in Colon and Rosario del Tala (white eggs), Basavilbaso, Federal, Gualeguaychu and San Salvador (brown eggs). In reference to the correlation between EW and TSSA, it was significant positive in 13 out of 14 cities studied.

When correlative coefficients between EW and ESW, EW and % ES and EW and TSSA were calculated according to different EW categories and eggshell color, the correlation was significantly positive between EW and ESW and EW and TSSA, but it was significantly negative between EW and % ES, independent of EW categories and eggshell color (Table 9). These coefficients did not show a significant difference between EW and % ES for eggs of EW category 1 and between EW and ESW for white eggshell of EW category 2. Furthermore, correlative coefficients could not be calculated for the category 3 of EW in brown eggs, because of the low number of samples.

Table 10: Values of internal egg quality parameters, according to eggshell color, considering the total number of eggs studied

	Values according to eggshell color			
Egg quality characteristics	N	WE	N	BE
Yolk color	1,728	6.4±1.4[a]	948	6.7±2.1[b]
pH pool yolk-albumen	540	7.6±0.4[a]	280	7.7±0.3[b]
pH pool albumen	83	8.9±0.4	61	9.1±0.4
pH pool yolk	83	6.3±0.5	61	6.5±0.5

[a,b]Means in the same row with different superscript are significantly different (p<0.05). WE = White Eggshell, BE = Brown Eggshell

Egg components: yolk and albumen: The means of YA, Y and Al pH were 7.6 (6.6-9.6), 6.3 (6.0-8.4) and 8.9 (8.0-9.6) for white eggs and 7.7 (6.1-8.3), 6.5 (5.8-7.1) and 9.1 (8.5-9.6) for brown eggs (Table 10). On the other hand, YC was an average of 6 for white eggs and 7 for

Table 11: Values of internal egg quality parameters in different cities of Entre Rios, according to eggshell color

	pH							
	Pool yolk-albumen		Pool albumen		Pool yolk		Yolk color	
Cities of Entre Rios	WE	BE	WE	BE	WE	BE	WE	BE
Basavilbaso	7.7±0.3	7.8±0.1	9.2±0.2	9.2±0.1	6.4±0.1	6.4±0.1	6.8±1.5	5.5±1.2
Colon	7.5±0.1[a]	7.6±0.1[b]	ND[1]	ND	ND	ND	5.5±0.8	5.4±0.7
Concepcion del uruguay	7.5±0.8	7.6±0.1	9.1±0.1	9.2±0.0	6.4±0.2	6.4±0.1	5.6±0.9	5.4±1.0
Concordia	7.6±0.1	7.6±0.2	ND	ND	ND	ND	6.6±1.5[a]	5.7±1.1[b]
Federacion	7.8±0.1	7.8±0.3	9.1±0.1	9.2±0.1	6.4±0.2	6.3±0.1	7.0±0.5[a]	6.5±0.6[b]
Federal	7.7±0.2	7.6±0.2	8.8±0.5	9.0±0.4	6.3±0.3	6.2±0.1	6.6±1.0[a]	8.6±3.0[b]
Gualeguay	7.9±0.3	7.8±0.5	9.2±0.3	9.4±0.1	6.6±0.4	7.0±0.9	6.6±0.8[a]	7.5±1.0[b]
Gualeguaychu	7.8±0.2	7.7±0.2	9.2±0.1	9.1±0.1	6.7±0.5	6.4±0.2	6.4±1.3[a]	5.6±1.7[b]
Rosario del tala	8.5±0.5	8.2±0.1	9.5±0.2	9.3±0.6	6.4±0.1	6.5±0.2	7.1±0.8	6.9±0.8
San jose	7.5±0.2	ND	9.0±0.0	ND	6.1±0.0	ND	6.0±1.0	ND
San salvador	7.7±0.2	7.8±0.4	9.2±0.1	9.2±0.2	6.4±0.1	6.5±0.3	7.5±1.2[a]	9.5±2.1[b]
Villa elisa	7.6±0.1	7.6±0.3	8.8±0.3	8.9±0.2	6.4±0.2	6.6±0.2	4.9±1.8[a]	8.6±2.4[b]
Villa paranacito	8.0±0.2	7.6±0.7	9.4±0.2	9.4±0.0	7.2±0.9	6.8±0.1	7.0±0.6[a]	6.2±0.6[b]
Villaguay	7.7±0.2	7.8±0.2	9.0±0.1[a]	8.9±0.2[b]	6.5±0.3	6.4±0.2	5.6±0.8	5.8±1.3

[a,b]Means in the same row with different superscript for each internal egg quality parameter are significantly different ($p<0.05$).
[1]ND: None Detected. WE = White Eggshell; BE = Brown Eggshell

Table 12: Values of range and Coefficient of Variation (CV) of yolk color in samples of 6 eggs in different cities of Entre Rios, according to eggshell color

	Yolk color white eggshell			Yolk color brown eggshell		
		CV sample of 6 eggs (%)			CV sample of 6 eggs (%)	
Cities	Range	Mean±SE	Range	Range	Mean±SE	Range
Basavilbaso	3.0-10.0	13.0±8.1	0.0-31.6	5.0-8.0	15.7±4.0	12.9-18.5
Colon	4.0-8.0	11.2±5.2	0.0-20.0	4.0-7.0	8.1±4.2	0.0-14.4
Concepcion del uruguay	4.0-8.0	11.2±5.2	0.0-20.0	4.0-7.0	8.1±4.2	0.0-14.4
Concordia	4.0-10.0	8.7±4.2	0.0-20.5	4.0-8.0	10.6±6.4	0.0-24.1
Federacion	5.0-8.0	3.6±4.0	0.0-12.2	5.0-8.0	5.1±3.3	0.0-8.2
Federal	6.0-10.0	5.6±4.1	0.0-12.3	4.0-14.0	7.6±3.1	4.9-10.0
Gualeguay	5.0-8.0	7.1±3.8	0.0-14.4	5.0-9.0	5.0±3.4	5.0-16.3
Gualeguaychu	3.0-10.0	10.4±4.1	0.0-19.4	4.0-11.0	7.3±1.9	0.0-15.3
Rosario del tala	4.0-8.0	8.0±7.0	0.0-21.1	4.0-8.0	8.9±5.0	5.7-19.0
San jose	2.0-8.0	11.8±9.8	0.0-40.4	N.D	N.D	N.D
San salvador	5.0-11.0	6.8±3.1	0.0-11.2	6.0-13.0	10.0±5.3	3.4-18.6
Villa elisa	2.0-9.0	18.7±7.7	5.0-37.3	4.0-13.0	15.2±6.8	7.7-27.9
Villa paranacito	6.0-8.0	7.6±1.6	5.7-11.0	5.0-7.0	7.8±1.2	6.6-9.1
Villaguay	4.0-7.0	9.2±5.7	0.0-19.4	2.0-8.0	10.3±7.5	0.0-31.0
Total	2-11	10.2±6.9	0.0-40.4	2-14	9.9±5.8	0.0-31.0

brown eggs, respectively. There were only a statistical differences in YC and pH of pooled YA between white and brown eggs ($p<0.05$). Brown eggs showed greater YC and pH of pooled YA than white eggs.

Table 11 shows details of values of internal quality parameters investigated. In general, there were not any differences in pH values between white and brown eggs. There was only a significant difference in the pH of YA in Colon city and of AI in Villaguay between white and brown eggs. The YC was significantly different in 8 cities of Entre Rios. YC was greater in white eggs than brown eggs for Concordia, Federacion, Gualeguaychu and Villa Paranacito. On the other hand, this value was greater in brown eggs than white eggs for Federal, Gualeguay, San Salvador and Villa Elisa.

The range of YC was 2-11 and 2-14 for white and brown eggs, respectively (Table 12). Villa Paranacito showed a low range, while Basavilbaso, Gualeguaychu and Villa Elisa showed a wide range in YC. The CV of sample of 6 eggs for this parameter was 10%, but the range was very wide from 0% to 40.4% for white eggs and from 0% to 31.0% for brown eggs. This characteristic was present in most of the cities studied.

DISCUSSION

We described some external and internal egg qualities of eggs sold in supermarkets according to egg shell color. Although a wide variety of eggs is available at retail, the consumer should be aware that the physical characteristics of these eggs are not completely the same (Jones *et al.*, 2010). On the other hand, egg cartons are the link with the consumer (Anonymous, 2009) and they came in several varying forms in our study. The marketing of eggs in cartons and other egg packs indicates that different areas of Entre Rios offer a wide variety of egg packaging. Similar results were found by Koelkebeck *et al.* (2001) in different states of the USA. Furthermore, the EW category of the packs was only true in less than 30% of the packs with label of this category. So the EW in the 6-egg fiber cartons should be better controlled before selling in the supermarkets of Entre Rios.

In reference to cleanliness, most eggs are clean when they are laid, but they can become contaminated with manure or other foreign material and cannot be marketed (Jacob *et al.*, 2008). Even with good farm-management practices and careful handling, a small percentage of dirty eggs will be produced. Producers must bear in mind that dirty eggs are covered with bacteria that will cause spoilage if they enter the egg. It is recommended that dirty eggs should be segregated from clean eggs, which should be packed in clean and cool packing materials. Whether conducted at the production or processing site, washing must be performed in a manner that minimize the chances of bacterial penetration of the shell (United State Department of Agriculture, 2000). Fortunately, the number of eggs which had dirty shells corresponds to the minor percentage sold to the public in our study. However, we don't know if those eggs were washed before packing.

It is known that EW is genetically linked to all three of the major components: shell, albumen and yolk. Zita *et al.* (2009) and Shi *et al.* (2009) reported that EW increased with the layer's age in all genotypes, nutrition and environment, which are also related to shell quality. On the other hand, Wall *et al.* (2010) demonstrated that EW was not affected by the laying hen's diet or genotype. Bell *et al.* (2001) compared traditional brown and white eggs and they found differences for egg retail age, but not for EW. We did not know about layer's age, nutrition and environment that related to eggs purchased from supermarkets, but we found that EW, ESW and EST were higher in brown eggs than in white eggs. Similar results were reported by Jones *et al.* (2010) in different types of eggs purchased from the same retail establishments in US cities. Furthermore, we reported that there was a low CV of EW for a sample of 6 eggs, so there was good homogeneity for the consumer. However, there was a wide range in the CV of EW.

EW is classified differently, depending on the country considered (Food and Agriculture Organization of the United Nations, 2003). Medium (49-56 g), large (56-65 g) and extra-large (65-70 g) classifications are the most commonly available in the USA (United State Department of Agriculture, 2000). Most of the eggs from supermarkets belonged to large (1) and extra-large (1S) in our study.

On the other hand, Sekeroglu and Altuntas (2009) reported that the correlation between EW and shell quality was inconsistent, ranging from negative to positive. We found the correlations between EW and ESW and, EW and TSSA were positive, while correlation between EW and % ES was negative.

The quality of eggshells can be assessed by measuring shell specific gravity, ESW or EST (Messens *et al.*, 2005). This characteristic has been difficult to ascertain due to the variable nature of the eggs (Jones and Musgrove, 2005). Generally, brown egg layers are believed to be heavier than white egg layers and they lay larger eggs with better albumen quality, but thinner shells. Scott and Silversides (2000) demonstrated that brown eggs were heavier than the white eggs, although the brown eggs had more shell and albumen than the white eggs. The results in our study are in accordance with these authors, although we found that EST was greater for brown eggshell than for white eggshell.

With reference to the internal egg quality, Biladeau and Keener (2009) demonstrated that the pH of AI increased or was maintained over time between 8.0 and 9.5 values and pH of Y between 5.9 and 6.3 for all eggs, which agrees with our results. Furthermore, Scott and Silversides (2000) showed that pH of AI is the same in both egg colors, white and brown; which was the same that we found.

YC has always been regarded as an important egg quality characteristic. In fact, consumers tend to associate the color of the yolk from golden yellow to orange with good health (Wall *et al.*, 2010). Because corn is used in the layers diet in many countries around the world, like Argentina, the consumer is most often receptive to eggs with a fair degree of yolk pigmentation. Yolk pigmentation is dependent on the accumulation of carotenoids, such as xanthophylls (Wall *et al.*, 2010). Corn contains much more xanthophylls than other cereals, although high levels of pigmentation can be achieved with natural ingredients, by including other products such as alfalfa and corn gluten meal (Leeson and Summers, 2005).

Consumer preferences for egg yolk pigmentation vary among countries and even between regions of the same country. For example, in the US, the preferred yolk coloration ranges from 7 to 10 in the DSM YC fan, whereas in some countries of Europe or Asia, the values preferred are higher (10 to 14) (Galobart *et al.*, 2004). Our study could find a significant difference in the YC according to eggshell color. The range of YC observed in our study was very wide, from 2 to 14, but the mean value was between 6 and 7.

On the other hand, Hernandez *et al.* (2002) studied the European consumer's perception and they found that it is important for the majority of consumers in the surveyed countries that all eggs in a package or those bought at the same time had the same or similar YC. So they considered homogeneity to be an indication of consistently good quality. We observed that the average of CV for YC in sample of 6 eggs was 10%, so there was a good homogeneity. However, the range of CV was very wide, so this could impact on the homogeneity of some packages of eggs.

This is the first report about the quality of commercial hen's eggs from supermarkets in Argentina according to egg shell color. There are some significant differences in the quality parameters studied between white and brown eggs. The variability in our results could be due to the fact that the eggs for the current study were purchased from different cities and they could belong to different hen's breeding systems and ages.

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