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Volume and Surface Area Calculation based on Measurements of Egg Diameter, and Correlation with Other Inner and Outer Features for Three Purposes of Breeding Chickens

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ABSTRACT

A completely randomized experimental design for the three purposes to use egg diameter for volume and surface area calculation, and correlation with other inner and outer features of breeding hens, was performed. Eggs from light breeds (3 554), heavy breeds (1 011), and turquino breeds (2 537), 2-3, 7-8, and 10-11 months of laying, respectively, were used (totaling 7 102 eggs). The values for volume calculation (Kv) were 0.531 and 0.527, for heavy and turquino breeds. The values for the surface area calculation (Ks) ranged between 2.885 and 2.866, for heavy and light breeds, respectively. The volumes achieved for heavy and turquino breeds were 52.46-57.11 mm3, respectively. Surface area ranged between 64.23 and 71.71 mm2. The yolk, white, and Haugh indexes showed significant differences ($P < 0.05$) for the three purposes, due to storage time before incubation. The results proved that the eggs studied for the three purposes of breeding chickens, generally have satisfactory inner and outer characteristics that guarantee incubation efficiency.

Key words: *eggs, breeding chickens, volume calculation, surface area calculation*

INTRODUCTION

The poultry industry plays an important role as a source of protein to satisfy the public´s demands, and new increases have been foreseen in the next years (FAO, 2012).

World population will go from 7.2 billion to 9.6 billion, by 2050, when meat and milk demands will grow 73 and 58%, respectively, regarding the 2010 levels (FAO, 2011).

In developing countries like Cuba, poultry activities is a way to increase and improve human nutrition, because birds are highly productive, with fast breeding and high nutritional efficiency. Besides, the genetic selection and highly developed husbandry practices have increased meat and egg production efficiency (Boerjan, 2004 and Summer, 2004). Because of demand increases in poultry productions, and due to the expansion of markets, companies are seeking enhanced production (Gil de los Santos *et al*., 2007; Ananikannda *et al.*, 2007), and Afolabit *et al.*, 2012). According to Iqbal *et al*., 2012), there are different methods to calculate egg volume and surface area, that can ensure incubation efficiency.

The aim of this paper is to calculate volume and surface area based on egg diameter measurements; as well as correlation with other outer and inner features in three purposes of breeding chickens.

MATERIALS AND METHODS

The eggs were collected at the hatchery for light breeding chickens, No. 19, Chile Libre; and at hatchery No. 31, Angola Libre, whose target is heavy breeding chickens, located on km 2 and km 3, respectively north of Camaguey city, on Camino de la Matanza. Also included was hatchery No. 14, Fabricio Ojeda, for turquino breeding chickens, on Callejón del Ganado, La Mosca, south of Camaguey city, all from the National Poultry Company. A completely randomized design was used.

The samples were 2-3; 7-8; and 10-11 months of laying, with a total number of 7 102 eggs, distributed in light (3 554), heavy (1 011), and turquino (2 537) breeding chickens.

A 0.01 g accuracy scale was used for egg measurements, and the volumes were estimated by dipping the egg in a 1 000 mL Erlenmeyer. A caliper gauge was used to determine the smallest diameter (SM) between the egg poles, and the greater diameter (GD) in the equator.

The variables observed were egg weight, greater diameter (GD), shell thickness, porosity, height, and yolk and white diameters.

GD and SD measurements were made to determine the coefficient for the theoretical volume (Kv), and coefficient for surface area (Ks), according to Narushin (2005), with these expressions:

$Kv = 0.6057 - 0.0018 * (SD)$

$Ks = 3.155 - 0.0136 * (GD) + 0.0115*(SD)$

Calculation of the theoretical volume (Vt) and surface area (S) were made by these expressions:

$Vt = Kv * (GD) * (SD)^2$

$S = Ks * (GD) * (SD)$

Shell thickness was measured in two spots of the egg: the equator and the pole mean, using a micrometer to achieve the mean value.

Porosity was measured by submerging a square cm of the egg in a cobalt chloride solution at 10%, until the shell turned pink. Then the pores were counted using a micro stereoscope.

For the Haugh indexes of white and yolk, the following equations were applied (López 1997):

- Yoke index (YI) = yolk height/yolk diameter.
- White index (WI) = white height/white diameter.
- Haugh units = 100 log (H + 7.75 - 1.5 * W 0.37).

Variance analysis and Tukey´s multiple mean comparison was performed to the variables studied (P< 0.05), using SPSS (version 18.0, 2012).

RESULTS AND DISCUSSION

The purposes had significant differences, the highest for the heavy, and the lowest for the turquino breeding chickens. These results are slightly higher than the reports by Narushin (2005). The variation coefficient is low, below the reports by the same author (1.41%).

Moreover, Ks had significant differences, between 2 866 and 2 885 for heavy and light chickens, respectively, with a slightly better behavior, above 2 854, according to Narushin (2005). The variation coefficient (4.44%) was also above the value reported by the same author (1.27%) (Table 1).

The values for the egg volume values had significant differences, above the turquino chickens (57.11 cm), and below in the heavy chickens 52.46 cm^3). They were below 62.11 cm^3, the lowest value reported by Sánchez (2014), when analyzing animals at the egg production line.

The results achieved were within 52.0-70.4 cm^3, coinciding with the values published by Narushin (2005). The turquino chickens were slightly above the range reported by Guerra (2006), whose volumes (calculated by water displacement) had values of 44.87-54.61 cm^3 for the normal types of eggs (round ovoid and small ovoid eggs) in light chickens. The other two types of breeding chickens had values matching the author´s range, but higher than 40.33 and 41.13 cm^3, reported by Vargas (2008).

The values observed in turquino chickens were also higher than the 43.66 cm^3 reported by Batista (2010) for the same type of chickens, and also higher than 53.78 cm^3, for Leghorn layers.

Analysis of the indicator for the three types of chickens revealed that turquino´s were higher; however, size was not the same, indicating the age of parent as the possible factor, also reported by Guerra (2006).

Egg surface area had significantly different figures, between 64 and 68 cm^2 (the highest for turquino, with 71.71 cm^2, and the lowest for the heavy chickens, with 64.23 cm^2). The results from this paper matched the reports by Guerra (2006), thus indicating a seeming correspondence in the behavior of these indicators for the purposes studied.

The surface area values achieved were similar to reports by Vargas (2008) and Sánchez, ranging between 66.66 and 71.16 cm^2. The latter was lower than the 74.26 cm^2 reported by Narushin (2005), and higher than the 57.78 cm^2 ± 2.87, according to reports by Iqbal *et al*. (2012).

Table 3 shows the results of variance analysis of thickness and porosity of the shell for the purposes studied. Significant differences were observed in the purposes for each indicator, which suggested that they had some effects on the results of the parameters analyzed.

Thickness had differences between the heavy (less thick), in relation to the turquino and light chickens, which were similar. These values matched others by Smith *et al*. (1998), and reported by Castañeda *et al*. (2991) (0.33-0.36) in similar working conditions.

The heavy chickens had similar values to the reports by Afolabi *et al*., (2012), between 0.34 and 0.38 mm.

Porosity had a different behavior among the purposes (the light chickens had the highest values, 160 pores/cm^2). These figures were higher than the 120 and 150 pores/cm^2 achieved by López *et al*., (1997), and Guerra (2006), which were only observed in heavy chickens, whose values were 149 pores/cm^2.

Regarding shell thickness, the three purposes had adequate conditions. These favorable values, along with porosity indexes, pointed to normal gas exchange between the egg and the environment, during incubation, without affecting normal embryonic development.

The mean yolk index showed that the purposes had different behaviors for $P < 0.05$ (Table 4). This indicator had been influenced by the storage time of eggs before incubation, especially if it occurred at room temperature, as Sardá (1992) noted, when he found yolk indicators in fresh eggs, of 0.49 mm, and at 4 or 5 days in optimum storage conditions, 0.42. This value is close to the ones presented in this paper, and also similar to reports by Peruzzi *et al*. (2012) (0.35-0.34%) in similar conditions. However, these results were above the 0.13 and 0.20 mm observed by Afolabi *et al*. (2012). The difference may be influenced by egg freshness, because they are known to reduce height and increase yolk diameter overtime (Guerra, 2006). Furthermore, Mróz *et al* (2004) reported values of 0.42-0.48 mm that coincide with the ones achieved in this paper, except for light hens.

No significant differences were observed among the purposes for the white (0.07-0.11 mm). These results were reported as optimum by López *et al*. (1997), and were higher than the ones reported by Sardá (1992), but in storage conditions at room temperature, for 7 days. López (1991) highlighted that this indicator is one of the most important ones in terms of internal quality, which is more quickly affected than the yolk index, particularly when the storage conditions are not the ideal ones; it was later demonstrated by Sardá (1992).

Table 4 also describes the Haugh units, with significant differences among the purposes studied. It does not coincide with the results reported by Brenes (1993), whose values ranged between 85 and 87%, except for the breeding chickens. Likewise, Stephenson *et al*. (1999) reported values of 83.1-86.1%.

The value of Haugh units tends to decrease due to egg weight increase at the laying curve, in relation to the equation for the estimation of those units. In this paper, the purposes had significant differences. The heavy and turquino breeds had low values, but the light breed did not, according to criteria by Guerra (2006), who observed minimum values of 87%, by studying 3 of the six types of eggs. Although they are slightly inferior to the values found in this experiment, they are superior to reports by Monira *et al*. (2003).

CONCLUSIONS

The results of this study proved that the eggs studied for the three purposes of breeding chickens had satisfactory inner and outer characteristics that guaranteed incubation efficiency.

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Table 1. Results of volume (Kv) and surface area (Ks) coefficient calculations for the purposes studied (Kv)

Purposes or breeding hens	Kv		Cov (%)	Ks		Cov (%)
	Mean	ET		Mean	ET	
Light	0.530[a]	0.000068	0.84	2.885 [a]	0.002637	4.44
Turquino	0.527[b]			2.884[b]		
Heavy	0.531[c]			2.866[c]		
General	0.529			2.881		
Significance	*			*		

Different superscript letters on the parameters indicate significant differences for P < 0.05, acording to Tukey

Table 2. Results of volume and surface area calculations for the study purposes

Purpose Breeding chickens	V (mm^3)			S (mm^2)			Sig.
	Mean	E:T	Cov (%)	Mean	E:T	Cov (%)	
Light	52.68[a]	0.266	24.548	67.63[a]	0.529	23.939	
Turquino	57.11 [b]			71.71[b]			*
Heavy	52.46 c			64.23 c			

Different superscript letters on the parameters indicate significant differences for P < 0.05, acording to Tukey

Table 3. Results of other outer characteristics of shell, for the purpose

Characteristic	Breeding chickens Light	Breeding chickens Turquino	Breeding chickens heavy	ET	Sig
Shell thickness (mm)	0.36[a]	0.36 [a]	0.33[b]	0.0008	*
Porosity pores/cm^2	160 [a]	158[b]	149[c]	0.22	*

Different superscript letters on the parameters indicate significant differences for P < 0.05, acording to Tukey

Table 4. Results of inner egg quality for the purposes studied

Characteristic	Breeding chickens Light	Breeding chickens Turquino	Breeding chickens Heavy	ET	Sig
White index	0.41[a]	0.42[b]	0.43[c]	0.064	*
White index	0.08	0.07	0.07	0.001	ns
Hatcheries Haugh	86.3 [a]	69.4[b]	73.3[c]	0.17	*

Different superscript letters on the parameters indicate significant differences for P < 0.05, acording to Tukey