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Comparison of different eggshell thickness measurement methods

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Abstract: This study was conducted to examine how various methods affect the results of eggshell thickness measurements. Direct and indirect measurements were performed on 700 table eggs which were daily collected from the same flock. The shell thickness of the eggs was calculated according to a logarithm which uses egg weight. Eggs with a specific gravity of higher than 0.80 g/cm^3 were classified as thick-shelled, whereas the others were categorized as thin-shelled. After determining the shell thickness of the eggs by an ultrasound gauge, all of the eggs were broken, the shells were separated, and the shell thickness of each egg was measured with two micrometers (digital and manual). Values measured by the manual micrometer were considered as actual thicknesses. Lowest correlation was determined between the logarithm method and the others ($P > 0.05$). However, there was a significant correlation between ultrasound and micrometer measurements ($P < 0.05$). According to the results of the current study, ultrasound measurement may be accepted as a suitable method for determining the eggshell thickness without breaking the egg.

Key words: Eggshell thickness, egg weight, incubation, specific gravity, ultrasound

1. Introduction

The eggshell protects the embryo and provides gas exchange during incubation [1]. Therefore, an eggshell has to be resistant against the breaking forces until the chick hatches [2]. The thickness of the eggshell is measured to eliminate economic losses incurred due to quality deteriorations and incubation. Eggshell thickness is usually measured with or without membranes using specific instruments [3]. These methods are applicable to broken eggs, and it is impossible to use them in incubation studies. Therefore, researchers found new methods to estimate eggshell thickness indirectly. Ar et al. [4] determined eggshell thickness with a formula that uses the egg weight. Voisey and Hamilton [5] showed that egg shell thickness is closely related to egg specific gravity, and they used it to determine thickness [6]. In this method, eggs with a specific gravity of 1.080 g/cm^3 or lower have been classified as thin-shelled, whereas those with a specific gravity of 1.085 g/cm^3 or higher have been classified as thick-shelled. In recent years, ultrasound technology has started to be used for determining egg shell thickness. With this method, it is easy to determine thickness without breaking the egg. The most reliable results are obtained by measuring thickness using a micrometer after breaking the egg. However, particularly in incubation studies, egg shell thickness has to be determined without breaking the egg [7,8].

The comparison of eggshell quality measurement methods is not a new topic. Snapir and Perek [9] used specific gravity, breaking strength, shell thickness, shell weight per unit area, shell percentage, and their correlation to determine the best method for eggshell quality. Similarly, Leeson and Summers [10] compared Carter's [11] eggshell measurement logarithm with the conventional measurement method. All these comparisons were made to determine the most reliable, the easiest, and the fastest method.

The preferred method for determining the eggshell thickness may cause the measured value to be different from the actual value of the eggshell thickness. In this case, the results of the study will be revealed in the eggs with incorrect shell thickness values. This will cause the study to be incorrectly discussed. In this study, direct and indirect measurement methods were applied on the same egg groups, and the results were compared to determine which measurement method gave the most reliable results. It is expected that the findings of this study will help researchers to decide on the most proper method for determining eggshell thickness.

2. Material and methods

The current study was conducted on 700 eggs which were daily collected from Lohman Brown layer flock when they

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were 38–40 weeks old.. The hens were kept in 3-tier battery cages, and each cage contained three hens, each of which had a 705 cm^2 cage area. The hens were fed with peak laying feed (17% Crude Protein, 2800 kcal/kg ME, 0.38% methionine, 0.78% lysine, 3.60% calcium, and 0.45% phosphorus). Analyses were performed on 100 daily eggs per repetition. All the eggs were individually numbered and weighed; and then, they were plunged into salt solution with a gravity of 0.80 g/cm^3 which was prepared by using 122 g salt and 1 L water. The eggs floating in that solution were classified as "thin-shelled", and those sinking were classified as "thick-shelled" [6]. Shell thickness was measured with an egg shell thickness gauge (ORKA Tech. Ltd., Israel) that uses precision ultrasound to gauge thickness without breaking the egg and is accurate to within 0.01 mm. The shell thickness of each egg was measured on the blunted edge of the eggs. The eggs were then broken, and the shell thickness was measured on the same point as it was previously measured by an ultrasound gauge, firstly with membranes and then without membranes, using digital and manual micrometers. The shell thickness was also calculated with logarithm $L = 5.126 \times 10^{-3} \times W^{0.456}$, described by Ar et al. [4]. In this formula, L is pore length, which is used as shell thickness, and W is egg weight. The shell thickness values were grouped as thin-, medium-, and thick-shelled, described by Yamak et al., [12]. The lowest and the highest values of egg shell thickness were noted down.. Mean shell thickness values were also calculated. The difference between the thickest and the thinnest eggs was divided by 3 ($X_{max} – X_{min}$ / 3). This value was added to the mean value to determine the range of the thick shell group, and deducted from the mean egg shell thickness to determine the range of the thin shell group. The eggs were classified into 3 shell thickness groups (thin, medium, and thick) with this method. Data determined with specific gravity were used as thin- or thick-shelled.

Similarities between the shell thickness values, which were determined with different methods, were analyzed with the Pearson correlation test. Similarities between methods were compared with Paired t-test, and comparison with specific gravity was performed with the Wilcoxon rank test. The Spearman correlation test was administered to determine the similarities between egg shell thickness groups. Correlations were considered significant at $P < 0.05$. All analyses were performed with SPSS Software (Version 21).

3. Results and discussion

A total of 700 eggs were used for shell thickness measurement. Minimum, maximum, and mean values are given for different measurements in Table 1. The thinnest egg shell thickness value (0.209 mm) was determined using a digital micrometer (measured with membranes).

Table 1. Minimum, maximum, and mean values of egg shell thicknesses determined by different measurement methods.

Measurement method	Min.	Max.	Mean
DMMeb (mm)	0.210	0.476	0.354^{c}
DMWMeb (mm)	0.209	0.440	0.333^{d}
MMMeb (mm)	0.270	0.490	0.398^{a}
MMWMeb (mm)	0.230	0.450	0.364^{b}
Ultrasound gauge (mm)	0.270	0.460	0.398^{a}
Logarithm (mm)	0.300	0.390	0.336^{d}

DMMeb: Digital micrometer with membrane, DMWMeb: Digital micrometer without membrane, MMMeb: Manual micrometer with membrane, MMWMeb: Manual micrometer without membrane
Means with different superscripts along the same column were statistically different ($P < 0.01$)

Table 2. Ranges of egg shell thickness groups measured with different methods (mm).

Measurement method	Thin	Medium	Thick
DMMeb	< 0.268	0.268 > k > 0.446	> 0.446
DMWMeb	< 0.257	0.257 > k > 0.411	> 0.411
MMMeb	< 0.370	0.370 > k > 0.516	> 0.516
MMWMeb	< 0.293	0.293 > k > 0.439	> 0.439
Ultrasound gauge	< 0.336	0.336 > k > 0.462	> 0.462
Logarithm	< 0.310	0.310 > k > 0.370	> 0.370

DMMeb: Digital micrometer with membrane, DMWMeb: Digital micrometer without membrane, MMMeb: Manual micrometer with membrane, MMWMeb: Manual micrometer without membrane, k: eggshell thickness

Table 3. Number of eggs in different thickness groups.

Measurement method	Thin-shelled	Medium-shelled	Thick-shelled
DMMeb	20	675	5
DMWMeb	26	664	10
MMMeb	124	576	-
MMWMeb	37	652	11
Ultrasound gauge	37	663	-
Logarithm	1	697	2
Specific Gravity	345	-	355

DMMeb: Digital micrometer with membrane, DMWMeb: Digital micrometer without membrane, MMMeb: Manual micrometer with membrane, MMWMeb: Manual micrometer without membrane

Table 4. Coefficient of correlations between different egg shell thickness measurement methods.

	DMWMeb	MMMeb	MMWMeb	Ultrasound	Logarithm
DMMeb	0.940**	0.865**	0.837**	0.636*	0.051
DMWMeb		0.875**	0.875**	0.654*	0.022
MMMeb			0.909**	0.707**	0.025
MMWMeb				0.669*	0.020
Ultrasound gauge					–0.021

DMMeb: Digital micrometer with membrane, DMWMeb: Digital micrometer without membrane, MMMeb: Manual micrometer with membrane, MMWMeb: Manual micrometer without membrane
*P < 0.05, **P < 0.01

The thickest value (0.399 mm) was determined by an ultrasound gauge.

Differences were observed between different measurements on the same eggs. The highest correlations were observed between the methods which measured eggs with or without the membrane. However, differences were also found between the measurements of the digital and the manual micrometer: measurements of the digital micrometer resulted in a lower value than those of the manual micrometer. It is thought that this was related to the structures of the digital micrometer gauge and the eggshell. The flexible structure of the egg shell allows the gauge to compress more than the manual micrometer. Therefore, egg shell thickness measurements taken by the manual micrometer are considered the actual thickness values. Using micrometers is the most efficient method to determine the egg shell thickness, but it is impossible to use them in incubation studies. Therefore, the results of the measurement methods have to be evaluated to determine the closest measurements to the actual egg shell thicknesses. It is easy to calculate the egg shell thickness by using egg weight. However, the results showed that the values calculated from egg weight were the furthest values to the actual egg shell thicknesses (Table 1). On the other hand, determining the shell thickness with specific gravity does not give numeric values. Hence, it is not possible to discuss the shell thickness values obtained by specific gravity measurement. In this method, the eggs are only grouped as thin or thick-shelled. In a previous study, we showed that, to determine the effect of shell thickness on a specific trait, it is not enough to group eggs as thin- or thick-shelled [12].

All data measured with different methods were grouped as thin-, medium-, or thick-shelled according to the method described in the material and methods section of this study. The range of thickness groups of different measurement methods are given in Table 2. Thus, data obtained from specific gravity measurement have been compared with with the data obtained using other methods. The ranges of the groups changed due to the differences in minimum, maximum, and mean values obtained from measurement methods.

The number of eggs included in different shell thickness groups are given in Table 3. For the comparison of the egg shell thickness as thin or thick, the medium, or average thickness ranges of the eggs have to be determined. Therefore, it is important to group the eggs as thin-, medium-, or thick-shelled. With the specific gravity method, it was found that approximately half of the eggs were thin-shelled (345), and the other half of them were thick-shelled (355) (Table 3). It is not a realistic approach to definitely group the eggs as thin- or thick-shelled without regarding the factors affecting shell thickness [13]. Mean thickness values and ranges have to be determined before grouping. Actual measurement values showed that the eggs used in the study could be defined as medium-shelled eggs.

The coefficient of correlations between different measurement methods are given in Table 4. Specific gravity method was not included in the data, since this method did not determine numerical value. Significant coefficient of correlations was determined between most of the methods. However, the lowest and insignificant coefficient of correlations was determined between logarithm method and the other methods. As an expected result, highest correlations were found between the values of the same method which determined thickness with or without membrane. Similarly, significant correlations were found between micrometer measurements (Table 4). Particularly in incubation studies, eggshell thickness has to be measured without breaking the egg. Hence, correlations between the methods in which the egg is broken and those in which the egg is not broken are also important. A significant correlation was not calculated between logarithm method and the others. The highest correlation of the ultrasound method was determined with the manual micrometer measurement (0.707).

4. Conclusion

There are various eggshell thickness measurement methods used in the literature. Direct measurements which require the egg to be broken give the actual values. However, it is important to determine thickness without breaking it for incubation studies. Logarithm which uses egg weight did not give actual values. In addition, the correlation between logarithm method and all other methods was insignificant. On the other hand, specific gravity only groups eggs as thin or thick-shelled. The ranges of the mean thickness values have to be determined before grouping the eggs as thin- or thick-shelled. Determining the egg shell thickness by an ultrasound gauge is an easy method and highly correlated with the results obtained from the methods which directly measured the thickness by breaking the egg.

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