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Some Physical, Morphological, and Mechanical Characteristics of Turkey (*Meleagris gallopavo*) Eggs

■**Author(s)**

Galic A[I]
Pliestic S[I]
Janjecic Z[I]
Bedekovic D[I]
Filipovic D[I]
Kovacev I[I]
Copec K[I]

[I] University of Zagreb Faculty of Agriculture, Svetosimunska 25, 10000 Zagreb, Croatia.

■**Mail Address**

Corresponding author e-mail address
Zlatko Janjecic
University of Zagreb Faculty of Agriculture,
Svetosimunska 25, 10000 Zagreb, Croatia.
Tel: +385-1-2393951
Email: zjanjecic@agr.hr

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ABSTRACT

The physical, morphological, and mechanical characteristics of eggs play an important role in the processes of embryo development and hatching. Some physical, morphological, and mechanical characteristics of turkey (*Meleagris gallopavo*; Zagorje breed) eggs collected during two laying cycles from same turkey hens were determined in this study. The average values of length, width, geometric mean diameter, weight, surface area, volume, sphericity, eggshell thickness, and eggshell density were determined as 66.61 mm, 46.84 mm, 52.66 mm, 77.74 g, 8712.42 mm^2, 76553.49 mm^3, 79.31%, 0.354 mm and 3.13 g cm^{-3}, respectively. Eggs collected during second laying cycle were, on average, larger and heavier in comparison with those collected during first cycle. Average albumen, yolk and eggshell percentages of the eggs collected during two laying cycles were 58.11%, 29.50% and 12.39%, respectively. The highest breaking strength was obtained when the eggs were loaded along the X-front axis and the least breaking strength was required along the Z-axis. The average breaking strength, absorbed energy and firmness in loading along the *X*-front axis were found to be 73.80 N, 9.75 N mm and 280.30 N mm^{-1}, respectively.

INTRODUCTION

Turkeys (*Meleagris gallopavo*) were domesticated in Mexico between years 200 B.C. and 700 A.D. and were taken to Europe immediately after the discovery of America. The first certain arrival of domestic turkeys in Spain was in 1511 (Schorger, 1966) and their diffusion through Europe was very rapid with an annual rate of 40-50 km (Crawford, 1992). The first written evidence of the existence of turkeys in Croatia appears in the year 1561, precisely in the Zagorje region (Kodinetz, 1940).

Zagorje is a region in northern Croatia with many hills, meadows, and orchards and with favorable climate for turkey breeding. Breeding in this limited geographical area during the past four and a half centuries, with a very small influence from outside, has resulted in specific traits, which characterize the Zagorje as a distinctive turkey breed. Zagorje turkeys have been traditionally reared in an outdoor system over the centuries, which means that the birds are kept free for most of their lives, moving freely through meadows, orchards, groves, or other habitats rich in vegetation and fauna. Adult Zagorje turkeys are provided with a solid shelter (poultry house) only during the night or unfavorable weather conditions. Zagorje poults are also reared outdoors until formation of caruncles (Muzic *et al.*, 1999).

Zagorje turkey became known in Europe in the 1930s, when 40,000-50,000 birds were annually exported to many European countries. However, this activity ceased at the beginning of the World War II, when the Zagorje turkey fell into oblivion, in the economic, rearing, and scientific sense. In past years in Croatia there has been a growing interest in the consumption of animal products, including turkey meat, derived from systems alternative to than intensive-indoor production (Muzic *et al.*, 2003), and there is an increasing number of family farms that rears turkeys in numbers, varying between a few dozen to a few hundred birds. Muzic *et al.* (1999) measured the body weight of 753 traditionally-reared Zagorje turkeys between 9 and 11 months of age and obtained 6.8 kg and 3.9 kg average body weight in males and females, respectively. Zagorje turkey hens lay eggs only in one short period during the year, from early March to late May. In that case, up to 25 eggs per one hen can be expected.

Turkey eggs can be utilized as food, but due to the small demand and high price, they are used almost exclusively for hatching (Kokoszynski, 2017). The physical characteristics of the egg play an important role in the processes of embryo development and successful hatching (Narushin and Romanov, 2002). The egg morphological characteristics, such as weight and percentage of main components and their correlations, are also very important because they influence egg quality, reproductive soundness, and embryonic development (Oblakova, 2006; Popoola *et al.* 2015). The morphology and composition of turkey eggs are determined by the bird origin and breeding programs (Faruga *et al.*, 1996). The weight of turkey eggs and the percentages of egg components vary considerably among the various strains or breeds. Both egg size and the weight of its main components are influenced by genetic and nongenetic factors (Sainz *et al.*, 1983). The mechanical characteristics of eggs are given by their strength under various loads in terms of several parameters, such as breaking strength, deformation, firmness and toughness (Abdallah *et al.*, 1993; De Ketelaere *et al.*, 2002; Polat *et al.*, 2007). Eggshells must be strong enough to prevent cracking in order to preserve the embryo until hatching (Altuntas & Sekeroglu, 2008). It mechanically protects the embryo against impacts and serves as a barrier against bacterial infection (Onagbesan *et al.*, 2007). The breaking strength of eggs depends on various factors, such as breeding conditions (Lichovnikova & Zeman, 2008), egg shape (Nedomova *et al.*, 2009) and other parameters.

The objective of this study was to investigate some physical, morphological, and mechanical characteristics of turkey eggs. These characteristics are, namely, dimensions, weight, geometric mean diameter, surface area, volume, sphericity; eggshell thickness, shape index, and weight, and percentages of egg components, yolk to albumen ratio, breaking strength, deformation, specific deformation, absorbed energy and firmness.

MATERIALS AND METHODS

Turkey eggs used in this study were collected from a family farm located near Zagreb, capitol of Croatia (latitude 45° 52′ N, longitude 16° 06′ E), with annual production of about 50 birds. On this farm, adult turkeys are reared in a free-range system and fed only maize grits, free from chemical products and medicines. Turkeys spend only the night in a closed shed, and during the day they remain in a fenced meadow. The size and housing system of this farm are typical in that part of Croatia. Eggs were collected from May 1st till May 31st of the year 2015 and again in same period in 2016, ie 10 eggs per hen in each cycle, from the same five turkey hens hatched in March, 2014. A total sample of 100 eggs was evaluated, consisting of 50 eggs collected during each laying cycle.

Egg physical characteristics

The length (L) and width (W) of the collected eggs were measured using an electronic digital caliper, with accuracy of 0.01 mm. The geometric mean diameter (D_g), surface area (*SA*), volume (*V*), sphericity (ø), and shape index (*SI*) were calculated using the following equations:

$$D_g = (LW^2)^{1/3} \quad (1)$$

$$S = \pi D^2_g \quad (2)$$

$$V = \pi/6\ (LW^2) \quad (3)$$

$$ø = [(LW^2)^{1/3}/L] \times 100 \quad (4)$$

$$SI = (W/L) \times 100 \quad (5)$$

where *L* is length in mm, *W* is width in mm, D_g is geometric mean diameter in mm, ø is sphericity in %, *S* is surface area in mm^2, *V* is volume in mm^3 and *SI* is shape index in % (Mohsenin, 1970; Anderson *et al.*, 2004; Polat *et al.*, 2007; Altuntas & Sekeroglu, 2008).

Eggshell thickness was determined as the average of three measurements randomly taken on the three different parts of the eggshell in each egg using an electronic digital micrometer with accuracy of 0.001 mm. Eggshell density (*SD*) was calculated using the following equation:

$$SD = (SW/S\text{x}ST) \quad (6)$$

where *SD* is eggshell density in g cm^{-3}, *SW* is eggshell weight in g, *S* is surface area in mm^2, and *ST* is eggshell thickness in cm (Curtis *et al.*, 1985).

A total sample of 100 eggs was used for the determination of mentioned physical characteristics.

Morphological characteristics

To evaluate the egg weight, eggs and egg components were separately weighed on a precision electronic balance reading to 0.01 g. The yolks of the eggs broken to measure breaking strength were separated from the albumen. Before yolks were weighed, the chalazae were carefully removed from the yolk using forceps, and the yolks were rolled on a paper towel to remove adhering albumen. The eggshells were carefully washed and dried for 48 h in an oven at 21 °C, and then weighed. Albumen weight was determined by subtracting yolk and eggshell masses from the original egg mass. Using the individual weight of each egg and its components, albumen percentage (albumen mass/egg weight x 100), yolk percentage (yolk mass/egg weight x 100), eggshell percentage (eggshell mass/egg weight x 100) and yolk to albumen ratio (yolk mass/albumen mass) were calculated.

Mechanical characteristics

A commonly-used technique for the measurement of eggshell strength is the compression of an egg between two plates. To measure the forces required to break the egg, a universal testing machine (Figure 1) was used to compress the egg. The egg was placed on the fixed plate, loaded at the compression speed of 0.33 mm s^{-1}, and pressed with a moving plate connected to the load cell until the egg was broken (Nedomova *et al.*, 2009). The forces were measured by a data acquisition system, which included dynamometer HBM (Hottinger Baldwin Messtechnik, Darmstadt, Germany), an amplifier HBM DMC 9012 A and a personal computer.

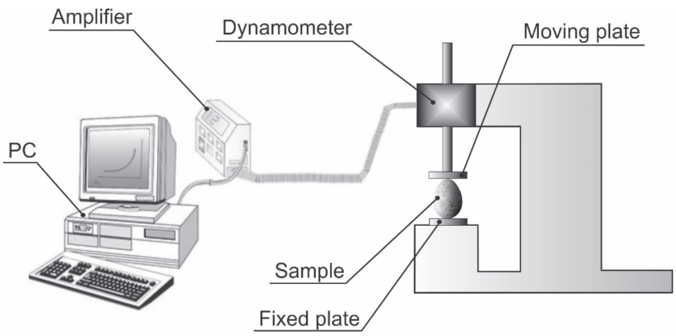

Figure 1 - Schematic presentation of the universal testing machine used to measure breaking strength

Two compression axes (*X* and *Z*) of an egg were used to determine the breaking strength, specific deformation, absorbed energy, and firmness. The *X*-axis was the loading axis through the length dimension in two directions, front (force F_{xa}) and back (force F_{xb}), while the *Z*-axis (force F_z) was the transverse axis containing the width dimension (Figure 2). The series of fifteen eggs was tested for each orientation.

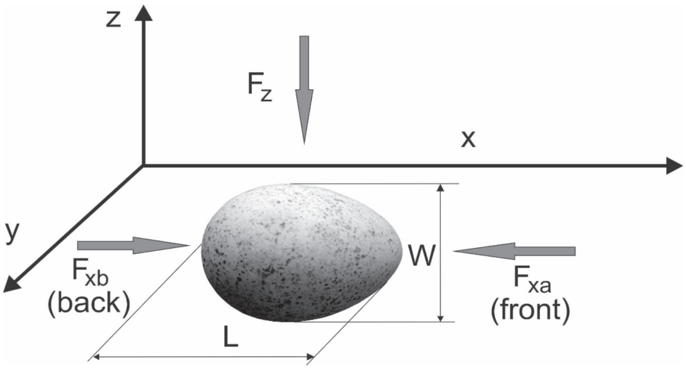

Figure 2 - Characteristic dimensions of eggs and compression directions: length (*L*), width (*W*) and forces applied in three directions (F_{xa}, F_{xb}, F_z)

The specific deformation was obtained using the following equation:

$$\mathcal{E} = (1 - L_f/L) \times 100 \quad (7)$$

where $\mathcal{E}$ is the specific deformation in %, L_f is the deformed egg length measured in the direction of the compression axis in mm, and *L* is the undeformed egg length measured in the direction of the compression axis in mm (Altuntas & Sekeroglu, 2008).

Energy absorbed (E_a) by an egg at the moment of breaking was calculated using the following equation:

$$E_a = (F_r\ D_r)/2 \quad (8)$$

where E_a is the absorbed energy in Nmm, F_r is the breaking strength in N and D_r is the deformation at the breaking point in mm (Polat *et al.*, 2007; Altuntas & Sekeroglu, 2008).

Firmness (*Q*) is regarded as a ratio of compressive force to deformation at the breaking point of egg and was obtained using the following equation:

$$Q = F_r/D_r \quad (9)$$

where *Q* is the firmness in N mm^{-1}, F_r is the breaking strength in N and D_r is the deformation at the breaking point in mm (Altuntas & Sekeroglu, 2008).

The obtained data were submitted to analysis of variance, and the LSD test was used to compare the means. The differences were considered significant if $p<0.05$.

RESULTS AND DISCUSSION

Physical characteristics

The physical characteristics of the turkey eggs collected during two laying cycles are presented in Table 1. Eggs collected during second laying cycle were, on average, 2.57% longer and 4.61% wider in comparison to eggs collected during first cycle. Egg length values varied over a wider range than egg width values, which is in agreement with results of Mroz *et al.* (2014).

Table 1 – Physical characteristics of Zagorje turkey eggs collected during two laying cycles (standard deviation in parentheses).

	1st cycle	2nd cycle
Length (mm)	65.76ᵃ (1.98)	67.45ᵃ (2.11)
Width (mm)	45.78ᵃ (1.24)	47.89ᵃ (1.38)
Geometric mean diameter (mm)	51.64ᵃ (0.86)	53.68ᵃ (0.98)
Weight (g)	72.40ᵃ (4.47)	83.08ᵇ (5.75)
Surface area (mm^2)	8375.09ᵃ (278.31)	9049.75ᵇ (329.09)
Volume (mm^3)	72117.61ᵃ (3587.34)	80989.37ᵇ (4075.13)
Sphericity (%)	79.01ᵃ (2.17)	79.61ᵃ (2.30)
Shape index (%)	69.69ᵃ (3.31)	71.05ᵃ (3.83)
Eggshell thickness (mm)	0.339ᵃ (0.020)	0.368ᵇ (0.028)
Eggshell density (g cm^{-3})	3.24ᵃ (0.21)	3.02ᵃ (0.19)

Values followed by the same letter are not significantly different ($p<0.05$)

The obtained average length of 66.61 mm and average width of 46.84 mm were close to those determined in the eggs of Ethiopian turkeys, of 65.0-mm length and 47.0-mm width (Adeyeye, 2009) and slightly higher than average length and width of Nigerian turkey eggs, of 62.4 and 46.1 mm, respectively (Popoola *et al.*, 2015). Anandh *et al.* (2012) divided eggs from Beltsville Small White and Board Breasted Bronze turkeys into three groups according to weight: below 60 g, 61-69 g and above 70 g, and obtained average lengths of 56.5, 62.0, and 64.4 mm, and average widths of 43.0, 46.5 and 48.3 mm, respectively. According to higher length and width values of the eggs collected during second laying cycle, their average geometric mean diameter was 3.95% higher in comparison with the eggs collected during first cycle.

Marsden & Martin (1949) classified turkey eggs in seven groups as a function of weight, from very small (64 g) to very large (106 g). According this classification, Zagorje turkey eggs, with average weight of 77.74 g, belong to group of small to medium-small turkey eggs. Eggs from second laying cycle were significantly heavier compared with those collected during first cycle, and this is in agreement with findings of Moran and Reinhart (1979), who reported that eggs laid by older turkey hens were heavier than those laid by younger hens (86.0 *vs*. 83.1 g). Mroz & Orlowska (2009), Anandh *et al.*, (2012), and Nestor and Noble (1995) also reported positive relationship between turkey hen age and egg weight. The average egg weight of Zagorje turkeys (77.74 g) was higher than that determined in Bronze turkeys, of 67.4 to 70.3 g (Ozcelik *et al.*, 2009); in Nigerian turkeys, of 69.22 g (Popoola *et al.*, 2015); and in Ethiopian turkeys, of 70.9 g (Adeyeye, 2009), as well as the average weights of three above-mentioned weight groups of turkey eggs reported by Anandh *et al.* (2012), of 55.61, 65.28, and 72.55 g. On the other hand, higher turkey egg weights were reported by Hristakieva *et al.* (2017) in North-Caucasian Bronze turkeys, of between 79.01 g and 88.23 g in eggs from 34-week-old hens, and 84.30 g and 85.61 g in eggs of 46-week-old hens. The average egg weight obtained in Zagorje turkeys was also lower than average weight of Heavy Meat turkey eggs, of 84.67-88.97 g (Hristakieva *et al.*, 2009); Canadian turkey eggs, of 89.0-89.1 g (Ghane *et al.*, 2015); and Poland turkey eggs, of 89.86-101.40 g (Mroz *et al.*, 2014).

The average surface area of Zagorje turkey eggs collected during second laying cycle (90.50 cm^2) was close to those reported in North-Caucasian Bronze turkey eggs (90.87-91.86 cm^2) by Hristakieva *et al.*, (2017a); however, the average surface area of Zagorje eggs collected during first cycle was significantly lower (83.75 cm^2). Average volume of Zagorje turkey eggs collected during two laying cycles (76.56 cm^3) was close to average volume (76.17 cm^3) of the heaviest (70 g) egg weight group determined by Anandh *et al.* (2012).

Egg shape index is defined as the ratio between its width and length. This parameter is important due to the role of egg shape in the direction of turning during incubation, which determines embryo movements for nutrient utilization (Hristakieva *et al.*, 2017b). According to Sarica & Erensayin (2004), eggs can be characterized according to shape index (SI) as sharp, normal (standard) and round for SI values of <72, 72-76, and >76, respectively. Zagorje turkey eggs presented 70.37% average SI, and therefore, may be characterized as sharp. The obtained SI of Zagorje turkey eggs is compared with that of North-Caucasian Bronze turkey eggs, of 71.57-74.25% (Hristakieva *et al.*, 2017a), Heavy Meat turkey eggs, of 72.33-73.32% (Hristakieva *et al.*, 2009) and eggs of turkeys from India, of 75.0-76.1% (Anandh *et al.* 2012).

Average eggshell thickness of Zagorje turkey eggs was 0.354 mm, which is similar to that determined (0.356 mm) in Poland turkey eggs of same weight class of 70-80 g (Mroz *et al.*, 2014), but lower compared with North-Caucasian Bronze turkey eggs, of 0.38-0.39 mm (Hristakieva *et al.*, 2017a) and of Heavy Meat turkey eggs, of 0.43-0.44 (Hristakieva *et al.*, 2009).

The average eggshell density of Zagorje turkey eggs was 3.13 g cm^{-3}, which is higher than that reported by Hristakieva *et al.* (2017a) in North-Caucasian Bronze turkey eggs (2.10-2.31 g cm^{-3}).

Morphological characteristics

The weight of egg components, percentages of egg components and yolk to albumen ratio (Y/A) of turkey eggs collected during two laying cycles are presented in Table 3. Average albumen, yolk, and eggshell percentages of the Zagorje turkey eggs collected during two laying cycles were 58.11%, 29.50% and 12.39%, respectively. These values are close to results reported by Ghane *et al.* (2015), who determined average albumen, yolk, and eggshell percentages of 57.05%, 30.55%, and 12.55% in Canadian turkey eggs, respectively, and by Applegate *et al.* (2005), of 60.70%, 27.97% and 11.33% in fertile commercial turkey eggs. The eggs collected during second laying cycle were, on average, 14.75% heavier relative to the first cycle, which was associated with higher albumen, yolk and eggshell weights, as previously found by Siopes & Neely (1997). Eggs collected during second laying cycle presented, on average, 2.31% higher yolk percentage and 1.67% lower albumen percentage compared with those collected during first cycle. Applegate & Lilburn (1996) reported that yolk percentage increased from 28.2% to 34.0% and albumen percentage decreased from 60.2% to 53.3% in the eggs of 36-week-old relative to 55-week-old turkey hens. Mroz *et al.* (2014) observed that turkey eggs weighing 95 g and 110 g had 3.05% and 4.86% lower yolk content and 3.16% and 5.21% higher albumen content compared with eggs weighing 80 g.

Table 2 – Weight of egg components, percentages of egg components and yolk to albumen ratio (Y/A) of Zagorje turkey eggs collected during two laying cycles (standard deviation in parentheses)

	1st cycle	2nd cycle
Albumen weight(g)	42.68^{a} (1.94)	47.59^{b} (2.23)
Yolk weight(g)	20.51^{a} (0.74)	25.46^{b} (0.85)
Eggshell weight(g)	9.20^{a} (0.21)	10.03^{b} (0.24)
Albumen percentage (%)	58.95^{a} (0.97)	57.28^{a} (0.97)
Yolk percentage (%)	28.34^{a} (0.90)	30.65^{b} (0.90)
Eggshell percentage (%)	12.71^{a} (0.43)	12.07^{b} (0.43)
Y/A ratio (%)	0.481^{a} (0.024)	0.536^{b} (0.024)

Values followed by the same letter are not significantly different ($p<0.05$)

The average yolk to albumen ratio of the Zagorje turkey eggs collected during the two laying cycles was 0.509. Eggs collected during second laying cycle presented, on average, 11.43% higher Y/A ratio in comparison with those collected during first cycle. This is in accordance with results of Applegate and Lilburn (1996), who determined an increase of the Y/A ratio from 0.53 to 0.62 in 36- and 55-week-old hens, respectively. Similar changes in the relative proportion of egg components as a function of turkey hen age were reported by Moran & Reihart (1979) and Reidy *et al.* (1994).

Mechanical characteristics

Average values of mechanical characteristics of Zagorje turkey eggs collected from two laying cycles are presented in Table 3. The highest breaking strength values in both laying cycles was determined in loading along the *X*-front axis, and the lowest, along the *Z*-axis. Significantly higher breaking strength values were determined for the eggs collected during second laying cycle in all three directions evaluated.

Table 3 – Mechanical characteristics of turkey eggs collected during two laying cycles (standard deviation in parentheses)

	Direction	1st cycle	2nd cycle
Breaking strength (N)	*X*-front	69.53^{a} (13.73)	78.07^{b} (10.64)
	X-back	42.77^{a} (8.91)	49.69^{b} (8.05)
	Z	39.92^{a} (7.85)	46.21^{b} (6.57)
Deformation (mm)	*X*-front	0.28^{a} (0.05)	0.25^{b} (0.03)
	X-back	0.34^{a} (0.07)	0.30^{b} (0.04)
	Z	0.45^{a} (0.07)	0.39^{b} (0.05)
Spec. deformation (%)	*X*-front	0.43^{a} (0.08)	0.37^{b} (0.06)
	X-back	0.53^{a} (0.11)	0.44^{b} (0.09)
	Z	0.98^{a} (0.16)	0.81^{b} (0.10)
Absorbed energy (N mm)	*X*-front	9.73^{a} (3.48)	9.76^{a} (3.35)
	X-back	7.27^{a} (2.71)	7.45^{a} (2.85)
	Z	8.98^{c} (2.16)	9.01^{a} (2.03)
Firmness (N mm^{-1})	*X*-front	248.32^{a} (25.05)	312.28^{b} (33.58)
	X-back	125.80^{a} (29.71)	165.63^{b} (23.43)
	Z	88.71^{a} (23.83)	118.49^{b} (25.72)

Values followed by the same letter are not significantly different ($p<0.05$)

There is a lack of technical information and data in the scientific literature about mechanical characteristics of turkey eggs and, therefore, the results obtained in this study were compared with those obtained in other poultry species. The average breaking strength for chicken eggs has been reported to range between 27.27-29.38 N (Altuntas & Sekeroglu, 2008), 30.9-37.8 N (De Ketelaere *et al.*, 2002), 33.35-35.32 N (Pavlovski *et al.*, 2003), 34.92-36.43 N (Nedomova *et al.*, 2009) and 34.45-53.49 N (Trnka *et al.*, 2012). The average breaking strength for duck eggs has been reported to range between 24.81-37.11 N (Okruszek *et al.*, 2006).

In comparison with those values, the turkey eggs tested in this study presented higher eggshell strength and, on average, higher strength was required to break the eggs (43.07-73.80 N), depending on the direction of the applied force. Comparatively, goose eggs present higher breaking strength (74.17-105.32 N); however, they are larger than turkey eggs, with average length of 78.26 mm and width of 53.62 mm (Zhang *et al.*, 2017). Nedomova *et al.* (2014) also reported higher breaking strength in goose eggs (63.80-101.92 N) loaded at the same compression speed of 0.33 mm s^{-1} as in the present study. On the other hand, much higher breaking strengths are obtained in large eggs, such as ostrich eggs 531.52-904.54 N (Nedomova *et al.*, 2013), whereas small eggs, such as those of Japanese quails (weighing 10.58-14.25 g) have much lower breaking strength, of 6.2-11.4 N (Polat *et al.*, 2007). These results demonstrate the strong influence of egg weight on egg breaking strength.

The deformation and specific deformation values of eggs compressed along the *Z*-axis were significantly higher than for those compressed along the both *X*-axes. The same relation was also observed by Altuntas & Sekeroglu (2008) in Lohmann chicken eggs, while Polat *et al.* (2007) determined the highest deformation value along the *X*-front axis in Japanese quail eggs.

The absorbed energy was determined as a function of breaking strength and deformation on the surface of egg. The highest absorbed energy was determined when load was applied along the *X*-front axis, while the least energy was determined along the *X*-back axis in eggs from both laying cycles. There were no significant absorbed energy differences between two laying cycles. The average absorbed energy values determined in Zagorje turkey eggs (7.36-9.75 N mm) are higher than the values of 3.29-3.53 N mm observed in Lohmann chicken eggs (Altuntas & Sekeroglu, 2008), of 2.80-5.10 N mm in Hisex Brown chicken eggs (Nedomova *et al.*, 2009) and of 3.41-7.88 N mm in Japanese quail eggs (Polat *et al.*, 2007), but lower than the values of 8.68-19.99 N mm reported for goose eggs (Nedomova *et al.*, 2014) and much lower than those observed in ostrich eggs, of 90.59-217.19 N (Nedomova *et al.*, 2013).

The firmness values determined along the *Z*-axis were significantly lower than those determined along both *X*-axes. This also indicated that lower force was required to break the eggs along the *Z*-axis. The firmness values for eggs compressed along *X*-front axis were significantly higher than along *X*-back axis. Significantly higher firmness was determined in the eggs collected during second laying cycle in all three directions relative to the first cycle. The average firmness values of the evaluated Zagorje turkey eggs were 103.60-280.30 N mm^{-1}, depending on applied direction. Similar values were observed in Lohmann chicken eggs (124.64-133.02 N mm^{-1}) by Altuntas & Sekeroglu (2008) and Hisex Brown chicken eggs (158.59-269.90 N mm^{-1}) by Nedomova *et al.* (2009), but much higher values were observed for ostrich eggs (932.50-1484.10 N mm^{1}) by Nedomova *et al.* (2013).

CONCLUSIONS

Average length, width, geometric mean diameter, weight, surface area, volume, sphericity, eggshell thickness, and eggshell density of Zagorje turkey eggs were determined as 66.61 mm, 46.84 mm, 52.66 mm, 77.74 g, 8712.42 mm^2, 76553.49 mm^3, 79.31%, 0.354 mm, and 3.13 g cm^{-3}, respectively. Average albumen, yolk and eggshell percentage of the eggs collected during two laying cycles were 58.11%, 29.50%, and 12.39%, respectively. Average breaking strength, absorbed energy, and firmness when loading along the *X*-front axis were 73.80 N, 9.75 N mm and 280.30 N mm^{-1}, respectively.

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