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The Impact of Different Egg Weights on External Egg Quality Characteristics in Turkish Native Geese of the Kars Region

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THIS aims to assess the impact of varying egg weights on the external egg quality traits of Turkish native geese from the Kars region. A carefully selected set of 250 incubation eggs was utilized, with a focused subset of 60 eggs chosen for a detailed analysis of shell characteristics. Precise egg weight measurements were conducted, followed by categorization into three distinct weight classes: 'light' (<136 g), 'medium' (136-164 g), and 'heavy' (>164 g). Measurements of egg length, width, and other parameters provided the basis for subsequent analyses. Key parameters, including eggshell weight, thickness, density, volume, ratio, and pore number, were calculated and subjected to rigorous statistical analysis. Results revealed statistically significant differences among groups in various aspects, such as egg weight, width, length, volume, and surface area (*P<0.001*). Similar statistically significant differences were observed for eggshell weight, thickness, and density (*P<0.001*). The eggshell volume also exhibited significant variations among groups (*P<0.001*). Eggshell ratio and pore number displayed noteworthy differences between groups, particularly in the comparison between the 'light' and 'heavy' groups (*P=0.003*). Additionally, a significant negative correlation was identified between egg weight and shell thickness. In conclusion, this comprehensive investigation of egg and eggshell characteristics across different weight categories of Turkish native geese elucidates substantial variations and underscores the intricate interplay between these attributes.

Keywords: Egg weights, External egg quality, Turkish native geese.

Introduction

Geese possess significantly distinct and remarkable performance characteristics, setting them apart from other poultry species. These unique attributes include their ability to efficiently digest feed with high cellulose content, herbs and even wild plants. Furthermore, geese display a natural resilience against challenging weather conditions and various disease agents, making them highly valuable for poultry farming endeavours. In addition to their exceptional traits, geese offer compelling economic advantages due to their low maintenance and minimal shelter requirements. Their robustness reduces housing and rearing costs, rendering them an appealing choice for farmers seeking cost-effective solutions. Moreover, geese exhibit high feed conversion efficiency, enabling them to yield meat and eggs with remarkable efficacy [1–4].

Geese farming, a distinctive sector within agriculture, holds remarkable global importance, even though it might not currently play a significant role in the Turkish economy. Geese meat serves as an alternative product, and its demand is increasing in several countries. In Türkiye, geese farming is predominantly practiced in rural areas across various regions, particularly thriving in Kars, Muş, Erzurum, Ağrı, Ardahan, as well as Southeastern Anatolia, Western Black Sea, Inner Aegean, Eastern Anatolia, Central Anatolia, and the Lake District. Despite its relatively small scale in Türkiye, geese farming plays a crucial role in sustaining local economies by offering supplementary income and livelihood

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opportunities for communities. Moreover, the practice contributes to preserving traditional agricultural knowledge and cultural heritage, passing down essential skills from one generation to the next. Geese meat’s unique taste and nutritional benefits make it a sought-after choice for consumers seeking dietary diversity. With shifting consumer preferences towards healthier and more sustainable food options, geese meat has become an appealing alternative to conventional poultry products. The demand for geese meat has notably increased in recent years, both domestically and internationally, as consumers appreciate its distinct flavor and recognize its potential health advantages. This growing interest has encouraged improvements in geese farming practices and exploring opportunities to expand its market presence [5–7].

The Kars region and its surrounding areas benefit from a favorable climate, geographical characteristics, cost-effective production methods, and traditional preservation techniques that allow for the extended storage of goose meat throughout winter. Furthermore, the widespread local consumption of goose meat contributes to a thriving goose farming industry in Kars. Geese are extensively raised in this area, and apart from their valuable meat, their edible organs and feathers also contribute significantly to the economy. Geese stand out for their egg-laying activities, starting in early March and lasting until mid-June. Throughout this period, geese produce a substantial quantity of eggs, which serve as valuable resources for both consumption and commercial purposes [6,8,9].

The average egg weight in geese exhibits a noteworthy pattern, characterized by an increasing trend up to the breeding age of 3-4 years, followed by a gradual decline in subsequent periods. In parallel, concerning different phases of the egg-laying period, the initial stages witness the highest average egg weight, which then experiences a rapid reduction until approximately the 50th day, eventually stabilizing. In the context of Kars province, the Turkish native geese manifest an intriguing variation in the average egg weight, commencing at a relatively modest level of around 155 grams during the first year, and subsequently escalating to approximately 168 grams by the age of 3. Furthermore, upon examining geese with diverse body colors, it is discerned that those with a gray hue exhibit the most favorable average egg weight, while the overarching mean average egg weight in Turkish native geese is established at 163.74 grams [10,11].

Goose eggs are primarily considered as hatchery eggs due to their limited production. This aspect underscores the crucial need to focus on both augmenting egg production and enhancing egg quality. Eggs are a direct outcome of the well-regulated and healthy functioning of the reproductive organs in geese. However, physiological or morphological abnormalities and injuries can lead to egg deformities, thereby influencing the overall reproductive performance. Considering this, prioritizing the health and proper care of the reproductive organs in geese becomes a critical step in elevating egg quality and maximizing productivity. Specific gravity, shell weight, and shell thickness are extensively employed as standard criteria for evaluating egg quality. These measurements serve as invaluable tools in fostering the optimal and responsible production of goose eggs, resulting in the acquisition of eggs with superior quality [11,12].

Certain studies [10,12–14] have been conducted on some external egg quality traits in geese raised in Kars and its surrounding areas, Türkiye. However, research focusing on the effects of different egg weights on external egg quality remains limited. Therefore, the present study aims to determine the impact of varying egg weights on external egg quality traits in Turkish native geese of the Kars region.

Material and Methods

Location

Kars province is situated at geographical coordinates 40°36’18”N and 43°5’48”E, with an elevation of 1760 meters above sea level. Positioned in the eastern region of Türkiye, Kars province shares its border with Armenia.

Egg Collection

In this research, the eggs under examination were sourced from a select group of native Turkish geese, aged between 30 to 35 weeks and exhibiting an average weight ranging from 3 to 4 kg. The breeding flock of geese was reared using established industry practices within a specialized poultry production facility. For this study, a total of 250 incubation eggs were carefully selected and included. To ensure accurate data collection, any soiled eggs were meticulously cleaned and carefully dried prior to the commencement of measurements. Specifically, 60 eggs were meticulously chosen to assess the shell characteristics in detail.

Physical Properties of Eggs

Accurate measurements of egg weights (EW) were performed with a high precision of ± 0.1 g immediately upon reaching the total egg count, ensuring the acquisition of reliable data. Subsequently, the eggs were meticulously categorized into three distinct groups based on weight classes, following the classification method [15]: "light" (<136 g), "medium" (136-164 g), and "heavy" (>164 g). Egg length (L) and width (W) were precisely measured using a digital calliper with a remarkable accuracy of 0.01 mm, allowing for a comprehensive assessment. Various parameters were then calculated using established formulas to enable further analysis of egg characteristics. These parameters included the geometric mean diameter (Dg), surface area (S), volume (V), shape index (SI), sphericity (Sp), elongation (E), and specific gravity (SG), all of which were obtained with utmost care and precision, thus providing valuable insights into the physical properties of the eggs [16–22].

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

S (mm^2) = πD_g^2

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

SI (%) = (W/L) x 100

Sp (mm) = $[(LW^2)^{1/3} / L] \times 100$

E (mm) = L / W

SG (g/cm^3) = (EW / V)

To assess the shell characteristics, our research involved the creation of groups, each containing 20 eggs selected randomly. The precise measurement of eggshell weight (SW) was carried out with an accuracy of 0.1 g. Additionally, the thickness of the eggshell (ST) was determined by measuring three different points on each egg (sharp end, blunt end, and equator) using an electronic digital micrometer with an accuracy of 0.001 mm, and then the average of these measurements was recorded.

Essential parameters like shell density (SD), shell volume (SV), shell specific gravity (SSG), shell ratio (SR) and pore number (PN) were computed using the established formulas cited in the relevant literature [18–21,23,24].

SD (g/cm) = (SW / S x ST)

SW (cm^3) = ST x S

SSG (g / cm^3) = SW / SV

SR (g) = (SW / W) x 100

PN = 304 x $W^{0.767}$

Statistical Analysis

The distribution of different groups based on varying egg weights was assessed for normality using the Shapiro-Wilk test. As the data exhibited a normal distribution, parametric tests were employed for group comparisons. Multiple group comparisons were conducted using one-way ANOVA, and pairwise comparisons were performed using Tukey's honestly significant difference (HSD) test. Pearson correlation coefficients were calculated to explore the relationships between variables. The results were presented as mean ± standard error of the mean (SEM). Statistical significance was set at P<0.05 for result evaluation. The data analysis was conducted using SPSS® software (version 26.0, Chicago, IL, USA).

Results

The egg weight was measured as 125.56 g for the light group, 152.13 g for the medium group, and 174.92 g for the heavy group. The differences in egg weights between the groups were found to be statistically significant (P<0.001), indicating that the groups were distinct in terms of egg weight. The egg width and length for the light group were measured as 53.51 mm and 78.77 mm, respectively. For the medium group, the measurements were 56.94 mm in width and 84.32 mm in length. Lastly, for the heavy group, the measurements were 59.52 mm in width and 88.15 mm in length. The results showed a statistically significant increase in egg size from the light group to the medium group and from the medium group to the heavy group (P<0.001), indicating notable variations in egg size among the groups (Table 1).

Furthermore, the study assessed the geometric diameter of the eggs, which was found to be 60.86 mm for the light group, 64.89 mm for the medium group, and 67.83 mm for the heavy group. A statistically significant difference was observed in the geometric diameter among the groups (P<0.001). The egg volume and surface area showed a statistically significant increase from the light group to the medium group and from the medium group to the heavy group (P<0.001), highlighting substantial variations in these parameters among the groups. On the other hand, the egg shape index, elongation, and sphericity parameters did not show statistically significant differences among the groups (P>0.05). Similarly, there were no statistically significant differences in egg-specific gravity among the groups (P>0.05), leading to the conclusion that egg-specific gravity was not a significant variable in this study (Table 1).

The eggshell weight was measured as 11.32 g for the heavy group, 14.28 g for the medium group, and 17.46 g for the light group, indicating highly significant differences (P<0.001) and distinct variations in eggshell weight among the groups. Similarly, eggshell thickness showed significant differences (P<0.001) across the groups, with measurements of 0.53 mm for the light group, 0.50 mm for the medium group, and 0.46 mm for the heavy group (Table 2).

Moreover, there were significant variations in eggshell density among the groups (P<0.001), with values of 4.45 g/cm^3 for the light group, 5.45 g/cm^3 for the medium group, and 6.43 g/cm^3 for the heavy group. The trend was consistent when examining eggshell volume, with statistically significant differences (P<0.001) observed between the light, medium, and heavy groups. However, no statistically significant difference (P>0.05) was found in eggshell specific gravity between the light and medium groups, while a significant difference (P=0,003) was observed between the light and heavy groups. Regarding the eggshell ratio, the light group had a value of 9.18%, the medium group had 10.37%, and the heavy group had 11.94%. The eggshell ratio displayed statistically significant differences (P<0.01) among the groups, particularly between the light and heavy groups (P=0.003). Lastly, when considering the pore number, the light group had 12151 pores, the medium group had 14061 pores, and the heavy group had 15682 pores. The differences in pore number among the groups were statistically significant (P<0.001), indicating distinct variations in pore number among the groups (Table 2).

A study on native Turkish geese examined correlations between egg external quality characteristics, as shown in Table 3. Notably, egg weight had a significant negative correlation with shell thickness (r = -0.709, *P<0.01*). Egg weight also positively correlated with shell density, volume, ratio, specific gravity (*P<0.05*), and pore number (*P<0.01*). Similarly, egg width correlated positively with shell weight, density, volume, ratio, and pore number, but negatively with shell thickness (r = -0.609, *P<0.01*). Egg length was positively correlated with shell weight, density, volume, pore number (*P<0.01*), and ratio (*P<0.05*), but negatively with shell thickness (r = -0.584, *P<0.01*). Geometric diameter correlated positively with shell weight, density, volume, ratio, and pore number, while negatively with shell thickness (*P<0.01*). Egg volume positively correlated with shell weight, density, ratio, and pore number, but negatively with shell thickness (*P<0.01*).

Discussion

The northeastern region of Türkiye, particularly encompassing the provinces of Kars and Ardahan, holds a significant and noteworthy position within the country's native goose farming landscape. This prominence can be attributed to a combination of factors, including the region's distinctive natural environment and climatic conditions, as well as the prevalent tradition among the local populace of incorporating goose meat into their culinary preferences. Consequently, the breeding of geese has emerged as a thriving endeavour in this area. It's worth noting that commercial goose farming in Türkiye, both on a nationwide scale and more specifically in the northeastern Anatolia region, is largely characterized by the operation of small, family-run enterprises, with only a limited presence of larger commercial ventures. Furthermore, it is pertinent to highlight that a substantial proportion of Türkiye's goose population consists of indigenous genotypes, underlining the unique genetic diversity that this region contributes to the country's goose farming heritage [5,6,25]. Limited research [10,12–14,26,27] has been conducted on the egg characteristics of domestically raised Turkish geese within the region. Nevertheless, our extensive literature review revealed a lack of studies examining the influence of varying egg weights among Turkish native geese on the overall external egg quality. To address this gap, our study aimed to categorize Turkish native geese into three distinct groups based on egg weights (light, medium, heavy), thereby investigating the potential correlations with external quality attributes. Furthermore, a key focal point of our research was the application of mathematical formulas previously documented in scholarly works [18–21] to compute diverse external quality parameters, consequently making a valuable contribution to the existing body of knowledge.

In our study, we determined the egg weights for the light, medium, and heavy groups as 125.56 g, 152.13 g, and 174.92 g, respectively. The egg widths and lengths were measured as follows: 53.51 mm and 78.77 mm for the light group, 56.94 mm and 84.32 mm for the medium group, and 59.52 mm and 88.15 mm for the heavy group. The results obtained from our analysis indicate that the categorization based on egg weight in Turkish native geese directly influences egg size. In the context of egg characteristics in native geese within Türkiye, previous studies have reported egg weight, length, and width as 124.11 g, 78.39 mm, and 53.23 mm, respectively [28]. In the Kars region, the average egg weight of native geese has been reported as 144.20 g [13], 144.51 g [12], and 148.43 g [14]. Furthermore, another study documented the egg weight, length, and width of Turkish native geese as 163.74 g, 8.67 cm, and 5.70 cm, respectively [10]. In the case of different goose breeds raised in the Kars region, egg weight was reported as 144.2 g [26] and 156.19 g [27]. In our study, without categorization into groups, we determined the total egg weight, length, and width as 152.54 g, 84.15 mm, and 56.90 mm, respectively. Our findings were higher than those reported in some studies [12–14,28], yet lower than the data from another study [10]. Such variations may be attributable to factors such as breeding age and variations in feeding practices. This divergence in egg metrics highlights the intricate interplay between biological and environmental factors affecting egg characteristics within the native geese population. Our study demonstrated that egg weight categorization significantly influences egg size in Turkish native geese. The results indicated that lighter eggs were associated with smaller dimensions, while heavier eggs exhibited larger dimensions. This finding underscores the importance of considering egg weight as a factor that directly contributes to variations in egg size within the population of native geese.

The assessment of egg characteristics assumes a pivotal role within the realm of modern poultry farming and egg production. The utilization of measurements such as egg geometric diameter, surface area, and volume holds paramount significance in objectively gauging egg quality [19,29,30]. In consonance with our study, we embarked upon the determination of egg external quality attributes, including geometric diameter, surface area, and volume, by stratifying eggs into distinct weight categories. The findings derived from our investigation unveiled a direct correlation between egg weight and these dimensions. Specifically, the geometric diameter and volume were observed to increase across the weight categories: 60.86 mm and 118.29 cm^3 for the light group, 64.89 mm and 143.23 cm^3 for the medium group, and 67.83 mm and 163.59 cm^3 for the heavy group. Our statistical analysis substantiated pronounced disparities in geometric diameter, surface area, and volume among the different weight-based groups. This observed trend echoes the results obtained in a previous study conducted on Pekin ducks [19]. The characterization of egg attributes in native Turkish geese extends to earlier research encompassing native geese populations in Türkiye. The reported egg surface area varied between 112.73 cm^2 and 119.19 cm^2, while the egg volume ranged from 113.86 cm^3 to 123.84 cm^3 [28]. Turning our focus to Turkish native geese, it's worth noting that previous studies reported egg volumes of 126.47 cm^3 [12] and 126.4 cm^3 [22], accompanied by egg surface areas and volumes of 136.9 cm^2 and 142.8 cm^3, respectively [18]. In our comprehensive investigation, we discovered that the average geometric diameter, surface area, and volume were 64.81 mm, 132.21 cm^2, and 143.34 cm^3, respectively. What's particularly intriguing is that our findings stood apart from the established literature [12,22,28], except for a specific study [18], consistently showcasing notably higher average values for geometric diameter, surface area, and volume. This divergence could potentially be attributed to a multitude of factors, including but not limited to feeding practices, phenotypic variations, and genetic differences, underscoring the intricate interplay between these factors and egg metrics.

Within our study, we have delved into the assessment of shell characteristics across different weight categories, providing a comprehensive insight into the multifaceted realm of eggshell quality in native Turkish geese. Our investigation of shell weight unveiled measurements of 11.32 g, 14.28 g, and 17.46 g for the heavy, medium, and lightweight groups, respectively. Turning our attention to shell thickness, our measurements revealed values of 0.53 mm, 0.50 mm, and 0.46 mm for the light, medium, and heavy groups, in that order. Correspondingly, our analysis of shell volume and shell ratio unveiled measurements of 53.95 cm^3, 65.92 cm^3, 77.36 cm^3, and 8.99%, 9.37%, 9.94%, respectively. As we scrutinized these parameters closely, a discernible pattern emerged. We observed an upward trend across all parameters, except for shell thickness, as the egg weight increased. This noteworthy correlation accentuates the significant role of egg weight in influencing shell weight, thickness, volume, and ratio. In turn, these insights contribute substantively to our comprehension of eggshell quality dynamics within the realm of native Turkish geese. One of the most intriguing findings of our study was the intriguing inverse relationship between egg size and shell thickness. Specifically, we observed that as egg size expanded, shell thickness underwent a proportional reduction, thereby revealing a compelling negative correlation across multiple parameters. This novel observation clearly establishes that in the context of native Turkish geese, larger egg sizes align with thinner eggshells, an aspect that holds implications for optimizing commercial breeding practices. Earlier research endeavours have documented a spectrum of shell attributes in native Turkish geese: ranging from a shell weight of 11.23 g to 11.32 g, shell thickness spanning 0.46 mm to 0.47 mm [28], to a shell weight of 20.37 g, shell ratio of 14.68%, and shell thickness of 0.72 mm [12]. Further contributing to this body of knowledge, another study recorded a shell weight of 14.79 g, shell ratio of 9.28%, and shell thickness of 0.51 mm [18] in native Turkish geese. Synthesizing our findings, the collective average values encompassed 14.36 g for shell weight, 0.50 mm for shell thickness, 65.74 cm^3 for shell volume, and 10.44% for shell ratio. This study extends the frontiers of understanding eggshell quality in native Turkish geese through a meticulous evaluation of shell attributes across diverse weight categories. By shedding light on the intricate interplay between egg weight and shell characteristics, our results underscore the multifaceted nature of eggshell quality. In addition to enriching our comprehension, these findings have practical implications. The nuanced relationship between egg size and shell thickness holds practical implications for the poultry industry, particularly in refining commercial breeding strategies. As such, precision management of egg size and shell thickness emerges as a pivotal consideration in the realm of commercial production processes. In the broader context, our study serves as a significant stepping stone towards the holistic understanding and enhancement of eggshell quality in native Turkish geese. Subsequent research endeavours could delve deeper into the nexus between shell characteristics and egg contents, thereby contributing to a more nuanced grasp of the genetic dimensions within the framework of Turkish native geese.

Conclusion

In conclusion, our comprehensive examination of egg and eggshell parameters in different weight groups of native Turkish geese has revealed significant variations, illuminating the intricate interplay between egg characteristics and shell attributes. The correlation between egg weight and shell thickness highlights the trade-off between size and shell thickness, which carries implications for both biological understanding and practical poultry management. These findings underscore the importance of considering egg weight and size as vital determinants of eggshell quality. While egg-specific gravity did not prove significant in this study, variations in eggshell density and volume among weight groups suggest nuanced relationships. This study enhances our grasp of the complex interactions shaping eggshell quality, guiding more informed poultry production practices.

Conflicts of interest

The authors report no conflicts of interest.

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Availability of Data and Materials

Datasets analyzed during the current study are available in the author (B. Boğa Kuru) on reasonable request.

Author Contributions

BBK and TK: Study design, data collection, draft writing. Statistical analysis. Article writing and editing, supervision. All authors have read, reviewed, and approved the final draft.

TABLE 1. External quality characteristics of eggs of different weights.

Parameters	Light	Medium	Heavy	P value	Total
No.	56	134	70	-	260
Weight (g)	125.56 ± 1.15[a]	152.13 ± 0.65[b]	174.92 ± 0.96[c]	***	152.54 ± 1.17
Width (mm)	53.51 ± 0.21[a]	56.94 ± 0.13[b]	59.52 ± 0.19[c]	***	56.90 ± 0.16
Length (mm)	78.77 ± 0.45[a]	84.32 ± 0.24[b]	88.15 ± 0.33[c]	***	84.15 ± 0.27
Geometric diameter (mm)	60.86 ± 0.22[a]	64.89 ± 0.12[b]	67.83 ± 0.15[c]	***	64.81 ± 0.17
Surface area (cm^2)	116.45 ± 0.85[a]	132.33 ± 0.48[b]	144.60 ± 0.65[c]	***	132.21 ± 0.70
Volume (cm^3)	118.29 ± 1.28[a]	143.23 ± 0.79[b]	163.59 ± 1.10[c]	***	143.34 ± 1.13
Shape index (%)	68.03 ± 0.40	67.61 ± 0.25	67.60 ± 0.36	NS	67.70 ± 0.18
Elongation	1.47 ± 0.009	1.48 ± 0.006	1.48 ± 0.008	NS	1.48 ± 0.004
Sphericity (%)	77.34 ± 0.30	77.02 ± 0.19	77.01 ± 0.27	NS	77.08 ± 0.14
Specific gravity (g/cm^3)	1.06 ± 0.004	1.06 ± 0.003	1.07 ± 0.004	NS	1.07 ± 0.002

[a-c]: Different letters in the same line are statistically different. ***: *P<0.001*, NS: Not significant.

TABLE 2. Shell characteristics of eggs of different weights

Parameters	Light	Medium	Heavy	P value	Total
No.	20	20	20	-	60
Shell weight (g)	11.32 ± 0.23[a]	14.28 ± 0.25[b]	17.46 ± 0.59[c]	***	14.36 ± 0.40
Shell thickness (mm)	0.53 ± 0.003[a]	0.50 ± 0.003[b]	0.46 ± 0.006[c]	***	0.50 ± 0.002
Shell density (g/cm^3)	4.45 ± 0.08[a]	5.45 ± 0.08[b]	6.43 ± 0.22[c]	***	5.44 ± 0.13
Shell volume (cm^3)	53.95 ± 1.02[a]	65.92 ± 0.88[b]	77.36 ± 1.12[c]	***	65.74 ± 1.37
Shell specific gravity (g/cm^3)	0.21 ± 0.002	0.21 ± 0.001	0.22 ± 0.008	NS	0.21 ± 0.003
Shell ratio (%)	9.18 ± 0.06[a]	10.37 ± 0.09[ab]	11.94 ± 0.31[b]	**	10.44 ± 0.12
Pore number (n)	12151 ± 151[a]	14061 ± 123[b]	15682 ± 137[c]	***	13965 ± 203

[a-c]: Different letters in the same line are statistically different. **: P<0.01, ***: P<0.001, NS: Not significant

TABLE 3. Pearson correlation coefficients between external egg quality characteristics

Parameters	Shell weight	Shell thickness	Shell density	Shell volume	Shell specific gravity	Shell ratio	Pore number
Weight	0.882**	-0.709**	0.833**	0.992**	0.300*	0.431**	0.988**
Width	0.840**	-0.609**	0.772**	0.964**	0.248	0.413**	0.947**
Length	0.701**	-0.584**	0.639**	0.868**	0.133	0.279*	0.858**
Geometric diameter	0.847**	-0.663**	0.776**	0.996**	0.222	0.392**	0.980**
Surface area	0.847**	-0.667**	0.775**	0.997**	0.220	0.391**	0.980**
Volume	0.846**	-0.669**	0.773**	0.997**	0.218	0.389**	0.978**
Shape index	0.090	0.089	0.090	0.021	0.123	0.129	0.013
Elongation	-0.092	-0.085	-0.092	-0.023	-0.123	-0.130	-0.014
Sphericity	0.090	0.089	0.090	0.021	0.123	0.130	0.013
Specific gravity	0.211	-0.236	0.322*	0.023	0.405**	0.218	0.148

*: Correlation is significant at the 0.05 level (2-tailed), **: Correlation is significant at the 0.01 level (2-tailed).

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