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RESEARCH ARTICLE

Determination of Egg Quality Characteristics of Different Poultry Species with Digital Image Analysis [1] [2] [3]

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Summary

The present study was aimed at the investigation of egg quality characteristics of different poultry species by digital image analysis. The material of the study was comprised of eggs of the Japanese quail *(Coturnix coturnix japonica)*, rock partridge (*Alectoris graeca*), ring-necked pheasant *(Phasianus colchicus)* and cross-chickens *(Denizli x Leghorn F1)*. Values pertaining to egg quality characteristics were obtained using the conventional method and digital image analysis. Egg length, egg width and shape index values measured by digital image analysis were shown to correspond closely with values measured using the conventional method, within an accuracy range of 98.44-98.54%. As regards internal egg quality characteristics, high error rates were determined for albumen height (32.24%) and yolk diameter (13.44%) values measured by digital image analysis, in comparison to values obtained with the conventional method. In result, it was demonstrated that egg quality characteristics could be determined by digital image analysis, in close correspondence with the conventional method, provided that devices equipped with measurement scales and images with reference points are used.

Keywords: *Conventional methods, Egg quality, Digital image analyses, Poultry species*

Farklı Kanatlı Türlerinde Yumurta Kalite Özelliklerinin Sayısal Görüntü Analizi İle Belirlenmesi

Özet

Bu çalışma, farklı kanatlı türlerinde yumurta kalite özelliklerinin sayısal görüntü analizi ile belirlenebilmesinin araştırılması amacıyla yürütüldü. Çalışmada bıldırcın (*Coturnix coturnix japonica*), kaya keklik *(Alectoris graeca)*, halkalı sülün *(Phasianus colchicus)* ve tavuk *(Denizli x Leghorn)* türlerine ait yumurtalar kullanıldı. Yumurta kalite özelliklerine ait değerler klasik metot ve sayısal görüntü analizi metotlarıyla belirlendi. Sayısal görüntü analizi ile yumurta boyu, yumurta eni ve şekil endeksine ait değerler bütün yumurtalarda klasik metot değerine genel olarak %98.44-98.54 oranları arasında yakın saptandı. İç kalite özelliklerinden ak yükseklik (%32.24) ve sarı çapı (%13.44) değerleri sayısal görüntü analizi ile klasik metottan yüksek hata oranında belirlendi. Sonuç olarak sayısal görüntü analiz metoduyla ölçüm skalasına sahip düzenekler ve referans noktasına sahip görüntüler kullanılarak yumurta kalite özellik değerlerinin klasik metoda oldukça yakın olarak belirlenebileceği ortaya konuldu.

Anahtar sözcükler: *Geleneksel metotlar, Yumurta kalitesi, Sayısal görüntü analizleri, Kanatlı türleri*

INTRODUCTION

Eggs not only constitute an important protein source for a balanced diet, but are also significant in terms of the reproduction and continuity of poultry species. In this context, the term "egg quality" refers to these two main features of eggs and their indicative criteria. Egg quality standards require that table eggs are clean such that their consumption does not pose any risk for human health and that they remain intact. On the other hand, the quality of hatching eggs bears significance for embryonic development. For, embryonic development depends on the presence of an egg shell of adequate thickness and porosity; the existence of an air-space at the blunt pole of the egg; the nutritional value (wholesomeness) of the egg yolk and the protection provided by the albumen [1,2]. Therefore, egg quality and the mainte-

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nance of this quality with minimal loss are of major importance for both table eggs and hatching eggs.

When determining egg quality characteristics, certain parameters are measured, which are indicative of the internal and external quality of the egg, using different devices [2-5]. The use of the conventional method for the determination of egg quality characteristics may result in human errors. Furthermore, errors may also occur due to the physical characteristics of the egg. To ensure that accurate and reliable data is obtained with the conventional method, in particular for data pertaining to the egg yolk and albumen, the person performing the measurement should act quickly. For, after the egg is broken out, the albumen expands rapidly. Furthermore, when measurements are performed using the conventional method, the risk of fatigue-induced errors increases proportionally with the number of eggs to be assessed. In this respect, there is a need for new measurement techniques to be introduced, which allow the measurers to rest; enable egg yolk and albumen measurements to be made within 2 min after the egg is broken out, before the expansion area enlarges; and enable the storage of the material used for measurements so that results can be confirmed in suspected cases.

For this purpose, computerized technologies used in a variety of fields have started to be used in the livestock sector. The theoretical and algorithmic assessment of information available in an image is referred to as digital imaging, which encompasses the location, orientation and size of the objects found in an image [6,7]. The digitization of the image involves the conversion of the optic image of the object, firstly into an analogue form and then into a digital form. The conversion of the light beams defining the object into electrical, analogue and digital signals creates the digital image [6,7].

Digital image analysis enables the classification, measurement and statistical analysis of the crude image without the need for it being renewed. Image analysis enables the determination of multiple parameters, including the length, area, angle, grey tone and colours of the object [6-13].

Software developed for digital image analysis calculates area and length measurements in pixels. The spatial calibration of these measurements requires that reference points in the image, of which the metric counterparts are known, are defined in the software [9-12,13].

The aim of the present study was to investigate the efficacy of digital image analysis in determining the characteristics of small-sized structures, such as the egg. The possibility of quality characteristics of intact eggs being determined within a shorter period of time with greater ease, and the images obtained being able to be stored, provide a major advantage in scientific research. The demonstration of the efficiency of digital image analysis will enable its automation.

MATERIAL and METHODS

The material of the study was comprised of eggs of the Japanese quail *(Coturnix coturnix japonica)*, rock partridge *(Alectoris graeca)*, ring-necked pheasant *(Phasianus colchicus)* and cross-chickens *(Denizli x Leghorn F_1)*, raised at the Alternative Poultry Unit of the Research and Practice Farm of Selcuk University, Faculty of Veterinary Medicine. Genotypes used for hybridization: Chicks of pure Leghorn lines were obtained from the Poultry Research Institute in Ankara, whilst roosters of the local Denizli breed, raised for both its eggs and meat, were obtained from Denizli province. Eggs were collected daily, and 120 eggs were used of each species, amounting to a total number of 480 eggs. Eggs with cracks, ripped albumen and poor image definition were excluded from the study. In the present study, two methods were used to determine egg quality characteristics. One was the conventional method; and the other, digital image analysis performed using software *(UTHSCSA Image Tool)* in the computer laboratory in the Faculty of Engineering. The eggs were individually numbered and weighed on an assay balance sensitive to ±0.02 g. Egg width and egg length were measured using a calliper, and imaged by means of devices equipped with measurement scales *(Fig. 1)*. The eggs, which were imaged, were kept at +4°C for one day

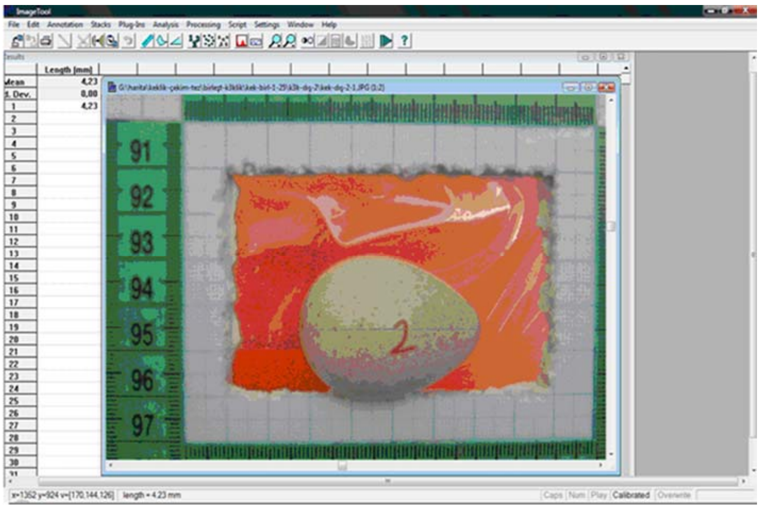

Fig 1. Computer screen showing the measurement of the egg width and length

Şekil 1. Yumurta eni ve boyu ölçüm pencere görüntüsü before broken out. After the eggs were broken out, the albumen and yolk were first evaluated by the conventional method and then imaged with a camera, on a flat glass surface with a measurement scale, from two different angles *(Fig. 2)*. The camera was fixed onto a tripod so that imaging could be performed at a distance of 20 cm. Three different images of the object were saved into a flash memory for the determination of different measurements. In total, 1440 images were taken of the 480 eggs used in the study, such that each area selected for digital image analysis was imaged twice. Subsequently, the images of each egg were assessed individually using the digital image software for the determination of egg quality characteristics. The pixel unit was converted into millimetres so that software measurements would be made in the metric system. For this purpose, first a range was defined, and then the original pixel unit was converted into the metric measurement unit *(Fig. 3)*. This process was repeated for each egg.

Ethics Committe Decisions of Veterinary Medicine Faculty of Selcuk University, the decision number: 2008/042. Without prejudice to the "Responsibilities of Researchers" indicated in the Instruction of the Ethics Board of Selçuk University Faculty of Veterinary Medicine (SÜVFEK), the project was approved unanimously to be "appropriate" in terms of research ethics.

Creation of Data

The parameters listed below, which are indicative of egg quality characteristics, were calculated using digital image analysis and the conventional method based on the indicated formulae [14,15].

Shape Index (%) = Egg Width (mm)/Egg Length (mm) X 100

Albumen Index (%) = Thick Albumen Height (mm)/(Long Diameter of External Thin Albumen (mm) + Short Diameter of External Thin Albumen (mm)/2) x 100

Haugh Unit = 100 log (H + 7.57 – 1.7 $W^{0.37}$)

H: Thick Albumen Height (mm)

W: Egg Weight (g)

Yolk Index (%) = Yolk Height (mm)/Yolk Diameter (mm) x 100

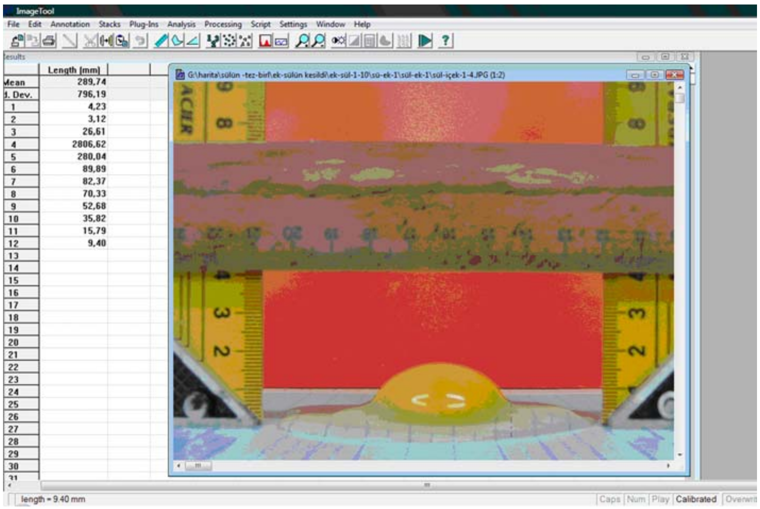

Fig 2. Computer screen showing the measurement of the height of the yolk and albumen

Şekil 2. Ak ve sarı yükseklik ölçüm pencere görüntüsü

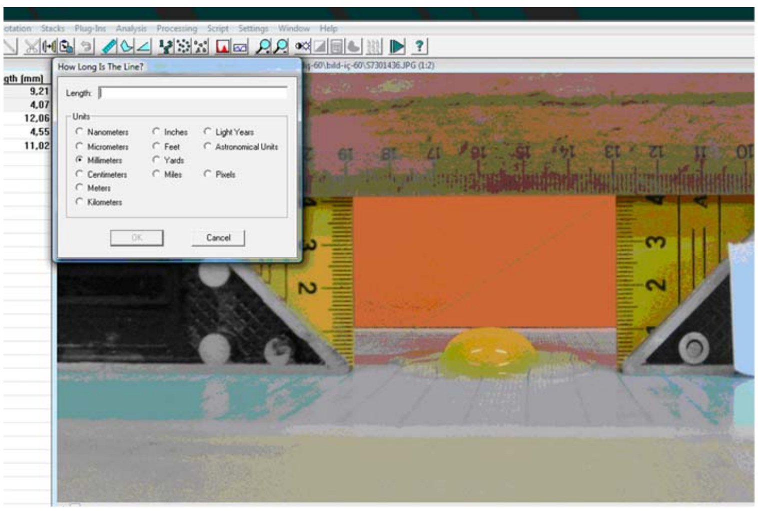

Fig 3. Computer screen showing the conversion of the measurement unit (spatial calibration) for the determination of yolk and albumen heights

Şekil 3. Yumurta yükseklik değeri için birim değiştirme pencere görüntüsü

Statistical Methods

Data pertaining to the external and internal egg quality characteristics obtained by the use of the conventional method and digital image analysis were assessed by the paired-sample t-test using the SPSS software [16].

The egg quality characteristics measured by digital image analysis were compared with the egg quality characteristics determined with the conventional method, and accuracy was calculated in percentage (Equation 1). The mean values of the egg quality characteristics were calculated so as to determine mean relative errors (Equation 2) [17].

$$P_{err} = \frac{|D_m - D_p|}{D_p} * 100\ \% \qquad (1)$$

$$A = \frac{1}{n} \sum_{i}^{n} P_{err} \qquad (2)$$

P_{err}, Percentile (%) error in data estimation

D_p, Value measured by the conventional method (measured value)

D_m, Value measured by digital image analysis (estimated value)

A, Mean relative error

RESULTS

Measurements of certain external and internal egg quality characteristics determined using the conventional method and digital image analysis in quail (n=93), partridge (n=79), pheasant (n=64) and chicken (n=88) eggs are presented in *Table 1, Table 2, Table 3* and *Table 4*, respectively.

The differences between the two methods for all measurements of quail egg internal and external quality characteristics were statistically significant (P<0.05 - P<0.01 - P<0.001). Egg length, egg width and shape index values measured by digital image analysis closely corresponded with the values obtained using the conventional method, at a mean accuracy rate of 98.62%. However, it was determined that, digital image analysis values for thick albumen height and yolk diameter differed from conventional method values at error rates of 37.06% and 21.27%, respectively. Furthermore, digital image analysis results differed from conventional method results at rates of 39.20% and 13.04% for albumen index and yolk index, respectively.

In partridge eggs, the differences between the two methods for the long diameter of the thick albumen, thick albumen height and Haugh unit were determined to be statistically insignificant (P>0.05); whilst the differences for the remaining egg quality characteristics were ascertained to be statistically significant (P<0.05 - P<0.01 - P<0.001). The results obtained with digital image analysis for external quality characteristics of the partridge egg were shown to correspond closely with results obtained with the conventional method at a mean accuracy rate of 98.55%. Furthermore, results obtained with digital image analysis in partridge eggs for diameters of the external thin albumen and thick albumen height were shown to correspond with results obtained using the conventional method at mean accuracy rates of 91.97% and 66.92%.

In the pheasant egg, differences between the results obtained for egg length, long diameter of the external thin albumen and yolk height with the two methods were shown to be statistically insignificant (P>0.05); whilst differences

Table 1. *Comparison of the two methods for certain external and internal quality characteristics of the quail egg (n=93, X±Sx)*
Tablo 1. *Bıldırcın yumurtalarının bazı dış ve iç kalite özelliklerinde iki metot karşılaştırması (n=93, X±Sx)*

Characteristics	Conventional Method	Digital image Analysis	P	Error (%)	Accuracy (%)
Egg length (mm)	31.70±0.13	31.46±0.14	0.000	1.07	98.93
Egg width (mm)	24.96±0.07	24.54±0.08	0.000	1.79	98.21
Long diameter of the external thin albumen (mm)	61.66±0.59	60.85±0.57	0.024	3.80	96.20
Short diameter of the external thin albumen (mm)	54.97±0.75	52.36±0.63	0.000	6.01	93.99
Long diameter of the thick albumen (mm)	41.94±0.36	43.95±0.38	0.000	6.05	93.95
Short diameter of the thick albumen (mm)	31.26±0.22	33.88±0.30	0.000	9.13	90.87
Thick albumen height (mm)	3.29±0.06	3.92±0.12	0.000	37.06	62.94
Yolk diameter (mm)	20.73±0.13	25.10±0.12	0.000	21.27	78.73
Yolk height (mm)	9.67±0.07	10.17±0.09	0.000	8.12	91.88
Shape index (%)	78.80±0.26	78.08±0.25	0.000	1.27	98.73
Albumen index (%)	5.72±0.13	6.96±0.21	0.000	39.20	60.80
Haugh unit	82.88±0.39	86.41±0.67	0.000	8.36	91.64
Yolk index (%)	46.74±0.36	40.55±0.35	0.000	13.04	86.96

Table 2. *Comparison of the two methods for certain external and internal quality characteristics of the partridge egg (n=79, X±Sx)*
Tablo 2. *Keklik yumurtalarının bazı dış ve iç kalite özelliklerinde iki metot karşılaştırması (n=79, X±Sx)*

Characteristics	Conventional Method	Digital Image Analysis	P	Error (%)	Accuracy (%)
Egg length (mm)	41.26±0.19	41.45±0.20	0.001	0.95	99.05
Egg width (mm)	31.12±0.09	30.78±0.10	0.000	1.57	98.43
Long diameter of the external thin albumen (mm)	88.26±1.14	84.83±1.17	0.000	6.69	93.31
Short diameter of the external thin albumen (mm)	73.55±1.11	69.61±0.98	0.000	9.38	90.62
Long diameter of the thick albumen (mm)	57.43±0.54	57.25±0.57	0.758	6.76	93.24
Short diameter of the thick albumen (mm)	43.33±0.30	44.50±0.34	0.001	5.43	94.57
Thick albumen height (mm)	4.15±0.09	4.48±0.16	0.070	33.08	66.92
Yolk diameter (mm)	29.90±0.18	32.08±0.14	0.000	7.55	92.45
Yolk height (mm)	13.61±0.10	13.23±0.16	0.028	8.30	91.70
Shape index (%)	75.53±0.36	74.36±0.34	0.000	1.84	98.16
Albumen index (%)	5.21±0.14	5.84±0.21	0.009	36.05	63.95
Haugh unit	80.34±0.62	82.07±0.95	0.136	10.41	89.59
Yolk index (%)	45.61±0.37	41.29±0.50	0.000	10.53	89.47

Table 3. *Comparison of the two methods for certain external and internal quality characteristics of the pheasant egg (n=64, X±Sx)*
Tablo 3. *Sülün yumurtasına ait bazı dış ve iç kalite özelliklerinde iki metot karşılaştırması (n=64, X±Sx)*

Characteristics	Conventional Method	Digital Image Analysis	P	Error (%)	Accuracy (%)
Egg length (mm)	45.02±0.20	45.00±0.21	0.653	0.87	99.13
Egg width (mm)	36.34±0.12	35.62±0.21	0.000	2.22	97.78
Long diameter of the external thin albumen (mm)	89.91±0.95	90.12±0.94	0.709	3.53	96.47
Short diameter of the external thin albumen (mm)	84.57±1.38	78.65±1.09	0.000	7.83	92.17
Long diameter of the thick albumen (mm)	62.57±0.60	64.68±0.61	0.000	4.15	95.85
Short diameter of the thick albumen (mm)	51.16±0.69	52.46±0.68	0.000	4.34	95.66
Thick albumen height (mm)	5.03±0.09	4.46±0.15	0.000	20.19	79.81
Yolk diameter (mm)	33.14±0.18	36.59±0.25	0.000	11.20	88.80
Yolk height (mm)	15.30±0.09	15.57±0.16	0.104	6.80	93.20
Shape index (%)	80.79±0.34	79.23±0.50	0.000	2.11	97.89
Albumen index (%)	5.79±0.11	5.30±0.19	0.005	19.01	80.99
Haugh unit	80.55±0.56	75.77±1.18	0.000	9.41	90.59
Yolk index (%)	46.22±0.32	42.72±0.58	0.000	10.01	89.99

between the results obtained for the remaining egg quality characteristics were significant ($P<0.05$ - $P<0.01$). Similar to the case with the quail and partridge egg, in the pheasant egg, digital image analysis results for egg length gave the highest correspondence rate with results obtained with the conventional method. Results obtained with digital image analysis for thick albumen height in the pheasant egg corresponded with results obtained with the conventional method at an accuracy rate of 79.81%, and therefore, achieved greater success in comparison to the results produced in quail, partridge and chicken eggs.

In the chicken egg, the differences between the two methods for the long diameter of the external thin albumen and yolk height were statistically insignificant ($P>0.05$); whilst differences for the other egg quality characteristics were significant ($P<0.05$-$P<0.001$). Similar to the results obtained in other poultry eggs, the results obtained with digital image analysis for egg length, egg width and shape index were shown to correspond closely, at an accuracy rate of 98.44%, with results obtained with the conventional method. However, the error rates for thick albumen height and yolk diameter values obtained with digital image analysis were very high.

DISCUSSION

External Quality Characteristics

The differences between the two methods for shape index results were statistically significant in quail, partridge, pheasant and chicken eggs ($P<0.001$). Shape index is a

Table 4. *Comparison of the two methods for certain external and internal quality characteristics of the chicken egg (n=88, X±Sx)*
Tablo 4. *Tavuk yumurtasına ait bazı dış ve iç kalite özelliklerinde iki metot karşılaştırması (n=88, X±Sx)*

Characteristics	Conventional Method	Digital Image Analysis	P	Error (%)	Accuracy (%)
Egg length (mm)	54.07±0.27	54.81±0.27	0.000	1.51	98.49
Egg width (mm)	40.89±0.16	40.60±0.16	0.000	1.13	98.87
Long diameter of the external thin albumen (mm)	113.81±1.05	113.79±1.10	0.977	3.39	96.61
Short diameter of the external thin albumen (mm)	102.08±1.21	95.33±1.01	0.000	8.01	91.99
Long diameter of the thick albumen (mm)	87.94±1.03	89.29±0.97	0.002	3.91	96.09
Short diameter of the thick albumen (mm)	70.01±1.02	71.00±0.89	0.030	4.77	95.23
Thick albumen height (mm)	4.74±0.07	5.46±0.21	0.002	38.64	61.36
Yolk diameter (mm)	38.17±0.27	43.35±0.27	0.000	13.72	86.28
Yolk height (mm)	16.24±0.11	16.38±0.19	0.355	7.18	92.82
Shape index (%)	75.70±0.31	74.17±0.31	0.000	2.03	97.97
Albumen index (%)	4.44±0.09	5.26±0.21	0.000	40.76	59.24
Haugh unit	69.78±0.70	73.31±1.68	0.047	20.73	79.27
Yolk index (%)	42.67±0.34	37.90±0.48	0.000	11.61	88.39

parameter calculated using the egg length and width. In quail, partridge, pheasant and chicken eggs, egg width values measured using the conventional method were greater than values obtained using digital image analysis. Egg width values being greater than egg length values led to shape index values being greater, although to a limited extent, when obtained with the conventional method compared to digital image analysis. Shape index values of the quail egg (78.80±0.26% and 78.08±0.25%) were lower than some values previously reported for this species [18-23] and yet similar to some other previously reported results [11,24-26]. In the chicken egg, the shape index value measured using digital image analysis (74.17%) was shown to correspond closely with the standard shape index (74%), whilst in the small-sized quail egg, the shape index value measured using the conventional method (78.80%) was shown to correspond closely with the standard shape index (80%). This difference observed with varying egg size could be due to variances in the quality of the egg images used for measurement. For, the images obtained with digital image analysis are processed without being improved. It was determined that the shape index values measured for the rock partridge egg in the present study were lower than values reported in certain previously conducted research [27-31]. On the other hand, shape index values of the ring-necked pheasant egg were greater than the values previously reported by Garip et al.[27] and Kuzniacka et al.[32]. It is considered that if maximum attention is shown to measurements of the egg width when using digital image analysis, satisfactory accuracy rates can be achieved.

Internal Quality Characteristics

Egg albumen is of great significance for the calculation of the albumen index and Haugh unit, which are both internal egg quality characteristics. These two values are calculated using the diameter and height of the egg albumen, which expands rapidly after the egg is broken-out. In the present study, thick albumen height values of poultry (quail, partridge, chicken) eggs, excluding the pheasant egg, measured using digital image analysis, were observed to be high. In result, this led to the albumen index and Haugh unit values measured using digital image analysis being greater than values measured with the conventional method in the quail (6.96±0.21% and 86.41±0.67), partridge (5.84±0.21% and 82.07±0.95) and chicken (5.26±0.21% and 73.31±1.68) egg. The thick albumen height values measured using digital image analysis being greater than the values measured using the conventional method could have arisen from the reference points used for height measurement in the two methods not being the same. The albumen index and Haugh unit values determined using both methods in the present study were greater than values reported in certain studies previously conducted in the rock partridge [26-38].

In the present study, the rate of accuracy of digital image analysis was calculated using the values measured with the conventional method as reference values. Accordingly, the internal egg quality characteristics with the lowest accuracy rates were determined to be thick albumen height and yolk diameter. Yolk diameter values measured using digital image analysis were high in all poultry eggs, which in result, led to the yolk index values calculated using digital image analysis being greater than the indices calculated using the conventional method. The yolk index values of the quail egg measured with the conventional method in the present study were observed to closely correspond with previously reported values [20,23,39]. Furthermore, the yolk index values of the pheasant egg measured using digital image analysis in the present study closely corresponded with the values previously reported by Garip et al.[27] and Kirikci et al.[33].

The differences determined between the two methods for the external and internal egg quality characteristics may have arisen from several factors, including the quality of the images used for measurements, the measurer not having used any reference points, and the skill of the measurer. The difference of the results obtained in the present study from other results, in the case of the application of the same methods, may have arisen from differences in the age of the flock from which the eggs were obtained, the laying period, season, lighting schedule, and the feed ration provided to the animals. In the case of the application of different methods, the differences observed may have arisen due to an error or multiple errors made in the application of the method.

In conclusion, the results of the present study demonstrated that external egg quality characteristics could be determined in close correspondence with the conventional method by digital image analysis. Furthermore, the opportunity to store the egg images used for measurements in digital image analysis enables suspected results to be checked for confirmation. It is considered that further studies are required for the digital image analysis method to be used commonly in practice.

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