



Determination of Egg Yolk and Albumen Main Quality Characteristics by Image Processing Techniques

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Abstract: This study introduces tools to assess the internal quality characteristics of eggs through the analysis of color digital images, comparing classical methods with a video camera-based software product. Strong statistical relationships were found for key quality characteristics of hen and quail eggs. Video camera measurement software is an effective egg evaluation alternative applicable to production, quality control and research. Sufficiently fast and accurate means for the evaluation of key quality characteristics of eggs are proposed, which are suitable for automation in the poultry and food sector. Future directions include adapting of the software for other bird species, improving its capabilities, integrating of automation, providing user-friendliness and data security, and evaluating the cost-effectiveness of using this type of software product.

Keywords: Egg Quality Assessment, Video Camera Measurement, Digital Image Analysis, Automation in Agriculture, Poultry Farming, Statistical Relationship

Introduction

The study of the internal characteristics of avian eggs is essential for various scientific, zootechnical, nutritional and practical reasons. The data obtained from these studies help to obtain information about biology, agricultural practices and ensuring food safety (1, 15).

Measuring the size of the egg yolk and albumen, from a nutritional point of view, provides information about the composition of the egg and its quality characteristics. In cooking, the quality of the edible parts of the egg affects the type and quality of the food. From a consumer perspective, expectations regarding the characteristics of the yolk and albumen have directly and indirectly influence of the satisfaction with the purchase and consumption of this valuable food product, being a preferred source of animal protein for humans (14).

In industrial poultry farming, a detailed assessment of the quality of the given batch of eggs for consumption is made on the basis of a morphometric analysis of the constituent parts of the egg, especially the albumen and yolk (5), and sometimes for breeding (4). Poultry reproductive health assists farmers in monitoring and addressing potential technological and/or veterinary problems. Scientifically, researchers use morphometric analysis to understand reproductive biology and factors affecting egg size (5, 11).

Laboratory methods for determining the quality parameters of eggs, including measuring the size of egg yolk and egg white, have some limitations. Challenges include precision issues, invasive techniques affecting egg integrity, time-consuming processes, high costs, subjectivity in assessments, limited access to modern equipment, ethical considerations in studies involving fertilized eggs, potential environmental influencing factors.

Loffredi et al. (13) summarize that the main advantage of destructive analyzes of egg quality is its reliability, but it is slow, requires experienced operators and can be applied at the laboratory

level. In this context, there has been significant progress in the development of alternatives to classical laboratory practices, namely the application of semi- and fully automated systems for egg quality analysis (22, 23) and spectroscopy nondestructive analysis (1, 3, 12, 13). Computerized image analysis, spectroscopic examination, or a combination of both, using various regression models and artificial intelligence, may prove reliable for non-destructive determination of internal egg quality (9, 16, 19, 21, 24).

While progress continues, researchers and practitioners should keep these limitations in mind when conducting studies or applying measurements in different contexts. The use of image processing techniques to measure egg yolk and albumen dimensions offers significant advantages. These include minimization of the subjective factor, improved precision and accuracy through automated algorithms, increased efficiency, especially for large sample sizes, and the non-invasive nature of many methods preserving egg integrity.

The objectivity of the automated measurements and the possibility of digitization of the samples ensures consistency between different samples and observers, incl. sharing and storage. High-throughput capabilities enable rapid analysis of multiple samples. Advanced analytical functions, such as analysis of the shape and texture of the given component, offer sufficiently accurate data, and visualization tools help in interpreting the results.

The adaptability of image processing to different sizes and colors of eggs, together with its integration with modern technologies, improves the accessibility and usability of the obtained results. In the egg industry, image processing aids quality control by ensuring consistency and adherence to standards. Overall, image processing stands out as a powerful tool for precise, efficient and technologically integrated measurements of eggs and their components (8, 25). Egg quality can be assessed by image processing using both the main methods: destructive and non-destructive. The use of destructive methods provides the advantage of direct access to the main components determining the quality of the egg - albumen and yolk.

The aim of this development is to propose tools to determine basic internal characteristics of eggs by means of techniques for acquisition, processing and analysis of color digital images.

Hardware tools and method for analysis used in this study

On Fig. 1 is shown a schematic diagram of the experimental setup for obtaining color digital images and determining egg mass. It consists of two main modules. The first module is to determine the mass of the egg using a weight cell, an HX711 board for working with the weight cell and a single-board microcomputer. The second module consists of two wide-angle video cameras, through which two images of the studied object are obtained - from above and from the side. The two modules are connected to a personal computer, with software provision.

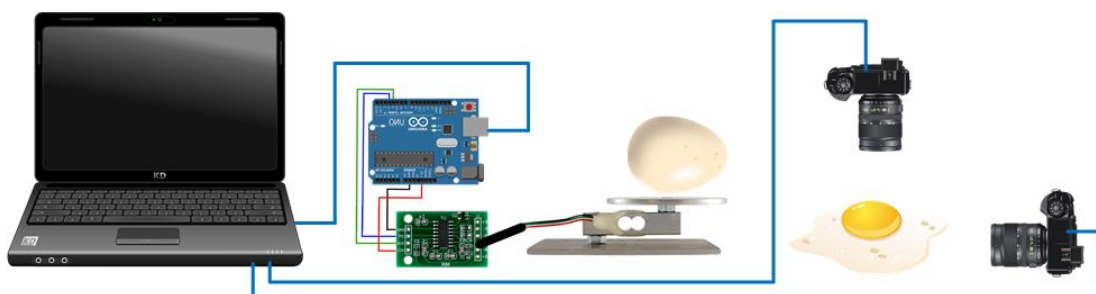


Fig. 1. Laboratory setup – principle schematic

On Fig. 2 is shown a schematic diagram of a destructive qualitative analysis of the internal components of an egg - yolk and albumen. The main elements of the albumen are dense and rare albumen, and due to the specifics of the chalazion layer, it is not subject to analysis. Marked are: the large (D_a) and small (da) diameters of dense albumen; yolk diameter (D_y); the heights of the yolk (h_y) and the solid albumen (h_a). These data were used to calculate the main characteristics of the examined eggs.

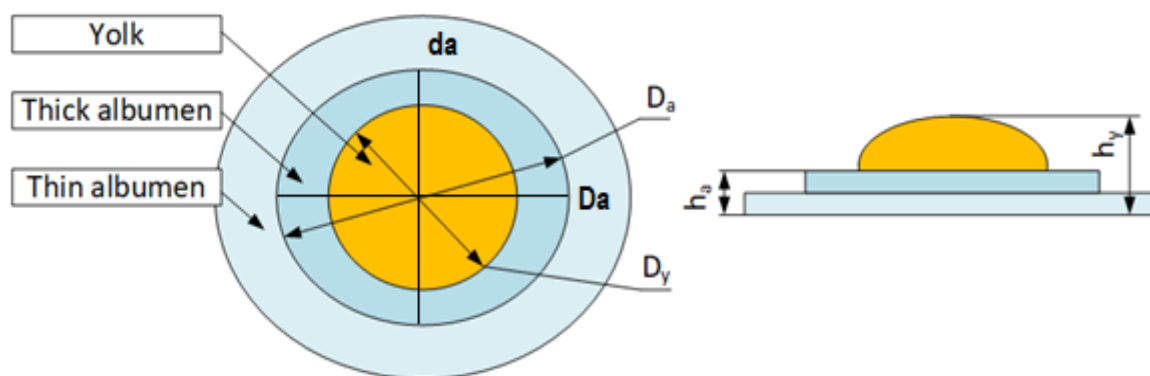


Fig. 2. Main characteristics of an avian egg – principle schematic

For the purpose of the study, 30 fresh hen and quail eggs obtained from commercial poultry facilities were used.

A Trust Exis video camera (Trust International BV, Dordrecht, The Netherlands) with a resolution of 640x480 pix was used to obtain color digital images. Egg images were obtained from a camera-to-object distance of 25 cm.

Used software application is Vividia AbleScope Viewer ver. 1.2.1.0 (Vividia Technologies, Woodruff, SC, USA) for image processing and measurement, designed for USB digital cameras, including microscopes, borescopes, dental cameras, and inspection cameras. Compatible with Windows operating systems, this software allows users to view, capture images and record videos in real time using video cameras connected to a USB interface. The app makes it easy to measure images on a PC screen, including a real-time calibration line option.

On Fig. 3 is shown a stage of the sizing procedure. A digital caliper with an accuracy class of 0.05 mm and a maximum measuring length of 150 mm was used. The sizing procedure involves loading the image with the gauge. Using the calibration software line, its markers are moved on the measuring scale. The setting size and units of measurement are recorded. A calibration file is saved that can be loaded when measuring on other images.

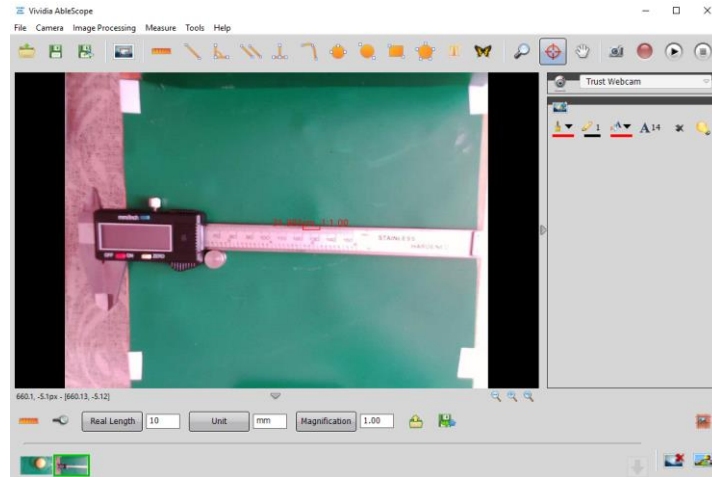


Fig. 3. Adjustment by size

Based on the digital technology used and the given software product, the following egg characteristics were determined: Shell surface area; Shell density; Albumen index; Hough unit; Yolk Index; Egg Quality Index.

Shell surface area S_s :

$$S_s = 4,835W^{0,662}, \text{ cm}^2 \quad (1)$$

where W is the mass of the egg (17).

Shell density D_s :

$$D_s = 1000 \frac{W}{S_s}, \frac{\text{mg}}{\text{cm}^2} \quad (2)$$

where W is the mass of the egg in g; S_s is shell surface area (17).

Albumen index AI is calculated as follows (18):

$$AI = \frac{\frac{h_a}{(Da + da)}}{2} 100 \quad (3)$$

where h is the height of the protein in mm; Da is the large diameter of the solid albumen in mm; da is the small diameter of the dense albumen in mm.

Hough unit HU , determined by the formula (7):

$$HU = 100 \log(h_a - 1,7W^{0,37}) \quad (4)$$

where h_a is the measured height of the solid albumen in mm; W is the mass of the egg in g.

Yolk Index YI :

$$YI = \frac{h_y}{D_y} 100, \% \quad (5)$$

where h_y is the yolk height in mm; D_y is the diameter of the yolk in mm.

Egg Quality Index EQI (15):

$$EQI = 100 \log_{10} \left(\frac{100 h_a \sqrt{h_y}}{\sqrt{0,5W - 5 + D_y^2 h_a}} \right) \quad (6)$$

where: W-egg weight; h_a -albumen height; h_y -yolk height.

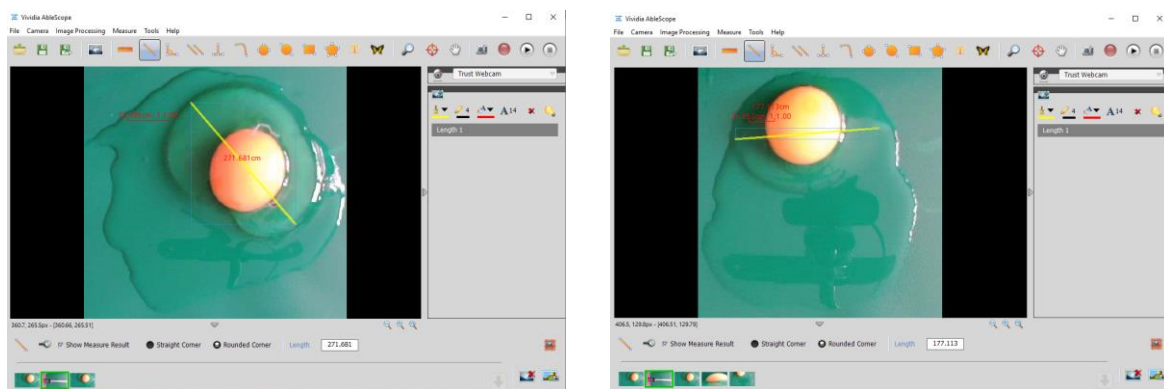
Sullivan et al. (20) prove that the p-value is not a sufficient criterion for comparing different measurement methods. The comparative analysis of the used measurement methods was made with more commonly used criteria for this purpose (Table 1): R- correlation coefficient, R^2 - regression coefficient and similarity level p-value (6). All calculations were made at the significance level $\alpha=0.05$.

Table 1. Measurement Criteria for Document Camera Measurement

Criteria	Range	Effect size	Comment
Coefficient of correlation R	-1 to 1	Small ± 0.2 Medium ± 0.5 Large ± 0.8	Quantifies the level of linear correlation between measurements.
Coefficient of regression R^2	0 to 1	Small 0.04 Medium 0.25 Large 0.64	The variance in one variable that can be accounted for by the other variable.
p-value	If $p \leq \alpha$ then the similarity between data is significant if $p < \alpha$ then the similarity between the data is highly significant		

Results of determination of main characteristics of eggs

On a Fig. 4 are shown images of the examined hen and quail eggs. The eggs are photographed from two points of view - from above and from the sides. In this way, by means of the image measurement program, the diameters and heights of the yolk and egg albumen can be determined, respectively.



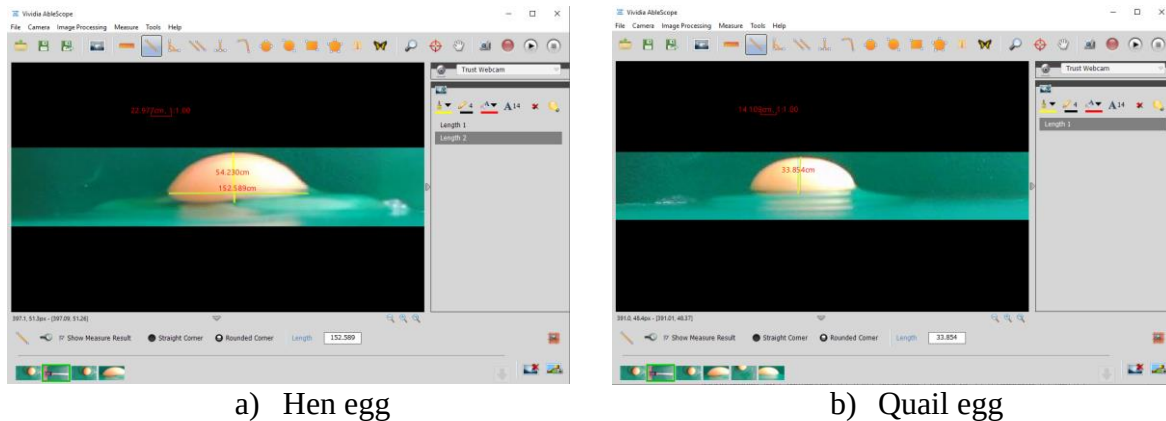


Fig. 4. Eggs from two points of view

Table 2 shows the results of measuring the main internal characteristics of eggs by a classic laboratory method and by the proposed system of measurement by color digital images. The obtained results show that the proposed image processing system tends to give smaller values for egg dimensions, weight, shell weight and various internal characteristics compared to the traditional laboratory method. These differences, although small, suggest that the image processing system may affect the quantification of egg characteristics. It is important to note that further validation and analysis is recommended to assess the accuracy and reliability of the image processing system in measuring egg characteristics. The results demonstrate the potential of this measurement approach, highlighting areas where corrections or additional calibration may be needed for accurate and consistent estimates.

Table 2. Results from measurements of egg characteristics

Measurement	Laboratory measurement		Image processing	
Eggs Dimensions	Hen	Quail	Hen	Quail
D, mm	57.47±1.15	33.95±1.14	53.36±0.78	29.03±1.38
d, mm	45.37±0.96	26.52±0.72	43.7±0.47	21.01±2.77
W, g	66.1±2.82	13.29±1.5	61.47±0.65	9.23±1.16
Ws, g	9.15±0.28	1.73±0.15	8.68±0.83	1.32±0.09
ha, mm	7.29±0.37	6.24±1.13	6.52±0.48	5.65±0.28
(Da+da)/2, mm	94.74±1.57	58.43±3.92	92.01±0.24	48.7±1.4
hy, mm	19.17±1.14	13.06±0.88	15.53±0.19	9.34±0.64
Dy, mm	44.41±1.79	30.17±2.41	39.82±1.67	26±0.37
H-Long axis of egg; D-short axis of egg; W-egg weight; W _s -Egg shell weight; h _a -thick albumen height; D _a -thick albumen diameter; h _y -yolk height; D _y -yolk diameter				

Table 3 presents the results of the calculation of the above egg quality indices based on the digital morphometric assessment.

A comparison of egg coefficients between traditional laboratory measurements and an image processing system shows small but noticeable differences in the various sizes and characteristics of hen and quail eggs. The image processing system tended to generate slightly lower values for shell surface area, shell density, albumen index, yolk index and egg quality index, especially for quail eggs, which is in relation to that reported by us difference in terms of the main morphometric parameters. The most distinct discrepancy is observed in Hough



Units, where the image processing system gives significantly lower values of the features involved in the calculation of Hough units and especially albumen height.

These differences highlight the potential impact of measurement method on the evaluation of egg characteristics, showing variation in external dimensions, shell properties and internal components. The results highlight the importance of thorough validation and verification when adopting innovative measurement approaches, ensuring the reliability and practical applicability of the proposed system.

The density D_s gives information about the thickness and compactness of the eggshell. Shell density is an important factor in evaluating egg shell strength and durability.

The albumen index is a measure of the quality of the egg albumen, and a higher index is usually desirable for certain applications where the physical properties of the egg albumen are important.

The yolk index presents information about the shape and quality of the yolk. A higher yolk index means a more rounded and desirable yolk shape, which corresponds to preserved quality characteristics of the perivitelline membrane.

Hough Unit is recognized as the standard for objectively quantifying the internal quality and freshness of eggs. Serving as a standard, this ratio provides an objective measure of "freshness" that is consistent with consumer preferences.

AQI is a complex index that takes into account multiple factors to provide a comprehensive assessment of egg quality. Includes a combination of the above features and possibly additional parameters.

Table 3. Egg quality indicators

Measurement	Laboratory measurement		Image processing	
Eggs	Hen	Quail	Hen	Quail
Dimensions				
S_s, cm^2	77.5±2.19	26.76±2.02	73.87±0.52	21.02±1.77
$D_s, \text{mg/cm}^2$	852.59±12.34	495.1±19.28	832.08±2.98	437.63±19.03
AI	1.93±0.1	2.68±0.51	1.85±0.13	2.36±0.14
HU	83.69±2.63	97.08±5.3	80.48±2	89.32±4.6
YI, %	43.18±2.49	43.45±3.45	39.07±1.7	35.92±2.49
EQI	100.54±3.98	114.6±12.21	91.54±5.68	73.15±7.33

Us-egg shell area; D_s -egg density; AI-albumen index; HU-Hough unit; YI-yolk index; EQI-Egg quality index

A comparative analysis of the used measurement methods was made. Its results are plotted in Table 4. The comparative analysis of methods for measuring hen and quail eggs shows strong and statistically significant relationships between the various criteria. Correlation coefficients (R) ranged from 0.93 to 0.97, indicating a high degree of association, while regression coefficients (R²) demonstrated strong predictive power, ranging from 0.81 to 0.95. p-values have a constant value of 0.00 highlighting the statistical significance of the results..

Table 4. Results from comparative analysis

Eggs	Hen			Quail		
Criteria	R	p-value	R ²	R	p-value	R ²
Characteristic						
H	0.90	0.00	0.81	0.91	0.00	0.82
D	0.97	0.00	0.95	0.91	0.00	0.84
W	0.97	0.00	0.95	0.98	0.00	0.95



Ws	0.95	0.00	0.91	0.92	0.00	0.84
ha	0.93	0.00	0.86	0.97	0.00	0.94
Da	0.96	0.00	0.92	0.93	0.00	0.86
hy	0.93	0.00	0.87	0.95	0.00	0.90
Dy	0.95	0.00	0.91	0.96	0.00	0.93
Ss	0.97	0.00	0.95	0.98	0.00	0.95
Ds	0.97	0.00	0.95	0.97	0.00	0.95
AI	0.95	0.00	0.89	0.97	0.00	0.95
HU	0.94	0.00	0.87	0.96	0.00	0.92
YI	0.93	0.00	0.87	0.96	0.00	0.93
EQI	0.97	0.00	0.95	0.97	0.00	0.93

H-Long axis of egg; D-short axis of egg; W-egg weight; W_s-Egg shell weight; h_a-thick albumen height; D_a-thick albumen diameter; h_y-yolk height; D_y-yolk diameter; Ss-egg shell area; Ds-egg density; AI-albumen index; HU-Hough unit; YI-yolk index; EQI-Egg quality index

On Fig. 5 are visualize the results for the coefficient of determination. In the comparative analysis of methods for measuring hens and quail eggs, some criteria stand out with extremely strong regression relationships. For hen eggs, characteristics such as weight ("W"), shell weight ("Ws"), shell area ("Ss"), shell density ("Ds"), and the egg quality index ("EQI") show a strong statistical relationship. Similarly, in quail eggs, the characteristics: weight ("W"), shell weight ("Ws"), shell area ("Ss"), shell density ("Ds"), albumen index ("AI") and Haugh unit ("HU") showed strong regression relationships, each with an R² of 0.95.

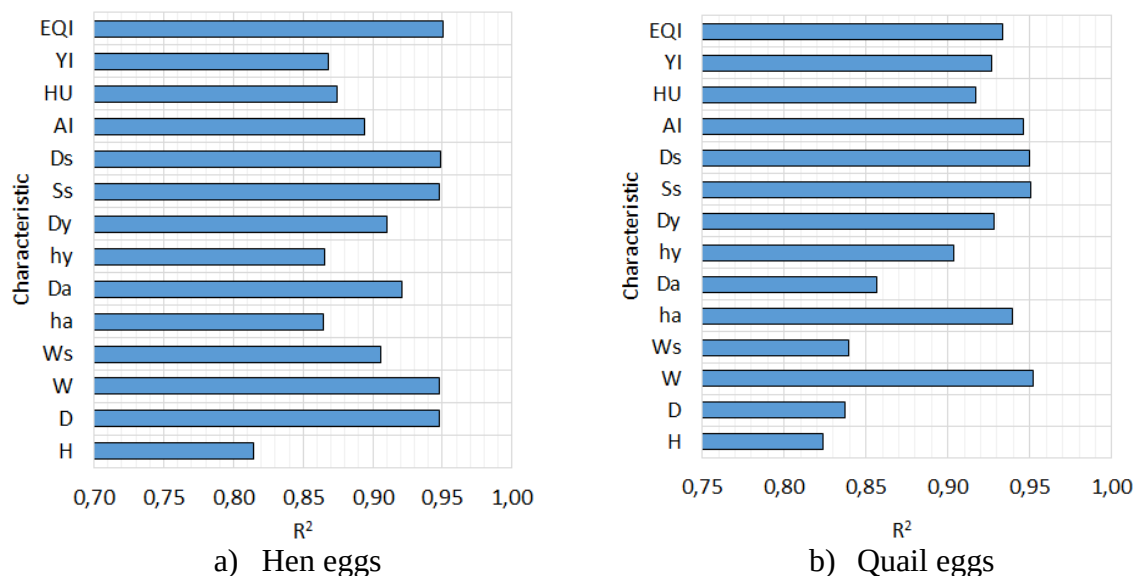


Fig. 5. Results for coefficient of determination

Discussion and recommendations

In this development, egg quality was analyzed by a destructive method. This is due to the fact that the dimensions of the egg albumen and yolk at the current level of development of science and technology cannot be determined by non-destructive methods. By such methods, at this time, the egg albumen to yolk ratio (9), yolk viscosity (10) and some criteria indirectly representing egg quality (13).



Although spectral analysis has a significantly higher accuracy than image processing, it has the disadvantage that the measurement is performed at only one point of the object (21). Similarly, hyperspectral analysis overcomes this disadvantage of measuring at only one point (24), but this type of analysis is characterized by obtaining large volumes of data and high cost of the equipment used. On the other hand, the disadvantages of spectral analysis can be overcome by using visual apparatus studies in combination with destructive analysis of the morphometric quality parameters of the eggs.

The use of ready-made software products for video camera measurement, instead of developing new algorithms for this purpose, has the advantage that a significant part of the factors affecting the measurement accuracy are reduced. This improves the results of (19). The measurement with a video camera and a ready-made software product is suitable for detailed laboratory measurements after breaking the egg, and not so directly on the production line.

By using a ready video camera measurement software product, the limitations and practicality of the image processing method for evaluating the internal characteristics of eggs have been removed. The reported shortcomings concerning the accuracy of some morphometric parameters can be overcome by using a more detailed recording technique, introduction of additional calibration of the measuring instrument, incl. and using a more accurate software product and last but not least developing and implementing corrective algorithms to minimize the software difference.

Conclusion and directions for future work

In this work, tools are proposed to determine basic internal characteristics of eggs by means of techniques for acquisition, processing and analysis of color digital images.

From the comparative analysis made between classical measurement methods and a software product for determining dimensions by video camera, it was found that for the fourteen investigated characteristics of hen's eggs, egg mass, shell mass, shell surface area, shell density and the index for egg quality show a strong statistical relationship. In quail eggs, the characteristics: egg mass, shell mass, shell surface area, shell density, protein index and Haugh unit can be determined with sufficient accuracy.

It has been proven that the use of a software product for measuring with a video camera is a sufficiently effective and automated alternative to traditional methods for measuring parameters characterizing the quality of eggs.

The results obtained can be used in production, quality control and research, providing a rapid and potentially accurate way to assess egg characteristics. It can also contribute to advances in technology and automation in the agricultural and food sectors.

Adaptation and testing of the video camera measurement software product for other bird species is needed. This will expand the application of the technology in poultry farming.

Further research should focus on improving the software, expanding its applicability, integrating it with automated systems, ensuring user-friendliness and data security, collaborating with industry stakeholders, and evaluating its cost-effectiveness.

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