Express Methods and Procedures for Determination of the Main Egg Quality Indicators

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Abstract **– The article considers the methods, procedures and results of experimental studies of the main egg quality indicators. The offered express methods and the automated installation provide definition of the weight, the form and density of egg. Based on the results of experimental studies of egg parameters, the express method of determining the volume of the egg through the area of the longitudinal section and the small diameter of the egg is substantiated. The express method for density determination by direct mass measurement and volume calculation gives minimal absolute error and provides a six time increase in performance, compared to the direct method.**

Keywords **– egg, weight, shape, volume, density, express method.**

1. Introduction

In accordance with the standard, the main qualitative indicators of the hatching egg are weight, shape and density [1].

The weight of eggs generally varies from 45 to 75 g and above. The relationship between egg weight and its nutritional value and its price is found [1], [2]. The weight of the egg is determined by scales or weighing mechanisms of egg sorting machines [1]. The productivity of mass determination using electronic scales is about 715 eggs / h.

The egg vulnerability depends on the shape of the egg [2]. Thus, it was found that irregularly shaped eggs are more prone to damage.

The shape is determined by the value of the shape index (IF), calculated as the ratio of the small diameter of the egg to the large, expressed as a percentage:

$$K1 = \frac{d}{D} \cdot 100\% \quad (1)$$

The value of the shape index depends on the breed of chickens: for egg direction K1 is between 73 and 80%, for chickens of meat direction K1 is between 76 and 80%. The productivity of the shape index determination using a mechanical measuring instrument (IM-1 indeximeter) is 800-1000 measurements per hour [3].

The shape of the egg can be determined through the shape factor (K2), which gives a more objective assessment of the shape [4]:

$$K2 = \frac{L^2}{S} \quad (2)$$

where, L is the perimeter of the longitudinal section of the egg, mm; S is the area of the longitudinal section of the egg, mm^2.

The density of the egg characterizes its freshness and the thickness of the shell, thus being an integral indicator of the quality of both hatching and marketable eggs. Fresh whole egg has a density of 1,085 - 1,1 gr/cm^3 and more. Hatching eggs should have the following density: for hens of egg direction of productivity - 1,08 gr/cm^3, for meat hens - 1,075 gr/cm^3. Low-density eggs reduce hatchability by up to 17%. The average density of an egg is defined as the ratio of the value of the volume to the weight of the egg. During storage, the density of eggs

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decreases. By the value of density, it is possible to determine the quality of the egg and its shelf life.

The volume of the egg is experimentally determined by the volume of water displaced. Theoretically, it is possible to calculate the approximate volume of an egg from its geometric parameters according to the formulas proposed by a number of authors [2], [5].

Egg density is determined by two methods. The first method is to determine the volume of the egg by immersing it in a container of water, where the volume of the displaced water determines the volume of the egg. Then the egg is weighed on a scale, and its density is calculated. The second method requires immersion in salt solutions with different concentrations. The density of the egg depends on the concentration of the solution, where the egg is in steady state. Both methods allow egg density determination without breaking it, as a result of which they are used in practice. Some studies have found a high correlation between shell thickness and egg density [7].

The main indicators of eggs vary depending on the breed, age and health of chickens, as well as under the influence of feeding rations and housing conditions. To obtain competitive products, it is necessary to conduct regular quality control of eggs. The instruments and devices used in the egg quality control laboratory have low productivity and accuracy. At present, mechanical devices are increasingly being replaced by automated and robotic systems.

Korean scientist Hyeon proposed the use of machine vision to determine the quality of the egg by the size of the air chamber of the egg [8], Figure 1.

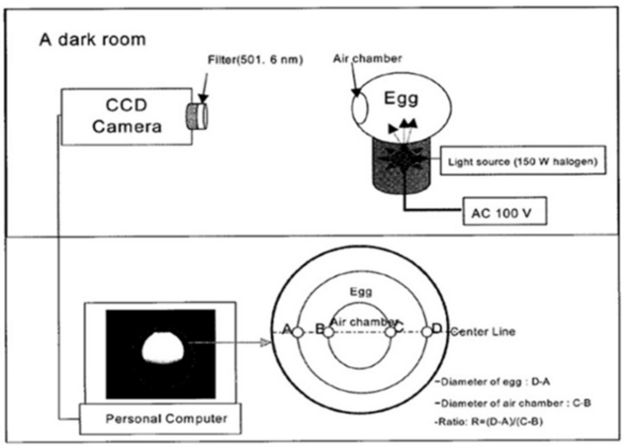

Figure 1. Determination of the eggs quality by the size of the air chamber using machine vision

The essence of the method is that the egg is placed in a dark room, where a camera is installed, which photographs the end side of the egg, illuminated by a halogen lamp. After that, the received image is transferred to a computer where measurements of small diameter of egg and the size of an air chamber of egg are made. Next, the proportionality coefficient is calculated and based on this, a decision is made on the egg freshness.

Indonesian scientist J Siswantoro proposes a method for determination of egg volume, based on the values of area, perimeter, small and large size of eggs, obtained from an egg 2D image and a neural network, Figure 2.

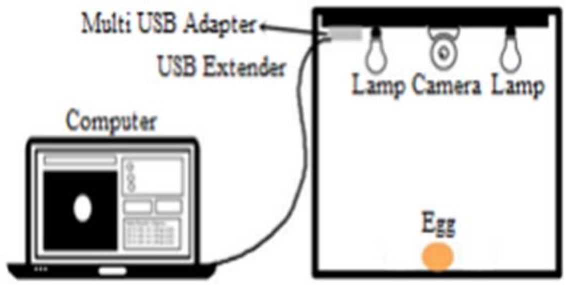

Figure 2. Device for determination of egg volume using a neural network

The values of the geometric parameters of the egg (area, perimeter, diameters) are used as a network input, then the volume of the egg is calculated [9].

The results of similar studies to determine the volume of the egg using a vision system that measures the small diameter and the area of the longitudinal section, integrated with an artificial neural network, are given in [10].

To study the geometric parameters of the egg a stationary automated installation "Technical vision system - Egg" is developed in the Kazakh National Agrarian University [4]. The block diagram of the automated installation "STZ - Egg" is shown in Figure 3. The program "STZ - Egg" is registered in the Ministry of Justice of the Republic of Kazakhstan as an object of copyright (Certificate №0610 from 03.03.18).

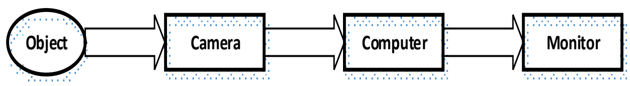

Figure 3. Block diagram of the automated installation "STZ - Egg"

The test object (egg) is installed on the work surface within the capture area of the camera. After that the camera captures the image of the work surface and transmits it to the computer. The program analyzes the image of the egg and the obtained egg parameters are displayed on the monitor [4]. This setting allows determination of the large (D) and small (d) diameters, area (S) and perimeter (L) of the longitudinal section of the eggs from different chicken breeds.

As a software development environment for automated installation, the LabVIEW graphical environment was used, which allows programming of various virtual instruments in a visual form and speed up of the software development process. The LabVIEW software development environment consists of two windows: a block diagram describing the program's logic and a front panel describing the program's interface. The interface of the program "STZ - Egg" is shown in Figure 4.

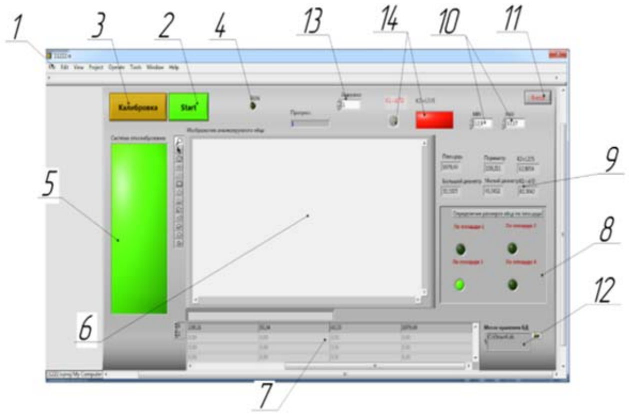

Figure 4. Interface of the program "STZ - Egg"

1. The main menu. Contains functions for closing the program, starting the program, minimizing the program window.
2. The Start button starts the camera and the program.
3. The calibration button enables or disables device calibration.
4. Program performance indicator (RUN) and progress indicator.
5. Indicator for the calibration accuracy.
6. Analyzed object image window.
7. Data table.
8. Area indicators.
9. Indicators of geometric parameters show the current values of large and small diameters, area, perimeter, shape index and shape coefficient.
10. Permissible range of form factor change.
11. The exit button provides the general exit from system.
12. Database storage path. Specifies the location where the data of the studied objects will be stored.
13. Delay controller. The value entered here defines the time interval in seconds, required to determine the parameters of one egg.
14. The shape coefficient indicators show that the shape of the egg conforms to the standard.

The program operation algorithm includes cycles of camera initialization, program start and stop, calibration, image capture and analysis, database formation and additional windows for program management [4].

2. Materials and Methods

Based on previous research, the relation between egg weight and its geometrical parameters is established. Using the value of the egg longitudinal section area, the weight is determined indirectly by the following equation:

$$m_k = 0{,}0399 \cdot S - 15{,}166 \quad (3)$$

where, m_k is the indirect value of the egg weight; S is the area of the egg longitudinal section;

Experimental verification of the algorithm and the program "STZ - Egg" on an automated installation showed that the duration of one cycle of measurements and classification of eggs was not more than 20 milliseconds.

The values of large and small egg diameters are almost equal to the one, measured with an electronic caliper. The duration of measuring the size of one egg by manual method is 13.6 seconds, while on an automated installation, with manual feeding and removal of eggs, is three seconds. The automated installation provides an increase in productivity of the labor, spent on measurement of geometrical parameters of eggs, with around 4,5 times. In addition, quantitative information about the area, perimeter and shape of the egg is obtained. Such information is not possible to be obtained by manual measurement.

An experiment was performed, in order to acquire the duration of egg processing from the moment of the object capturing by the camera till the moment of obtaining its geometrical parameters. Figure 5 shows the results of the egg size and shape determination and the duration of the individual processing procedures.

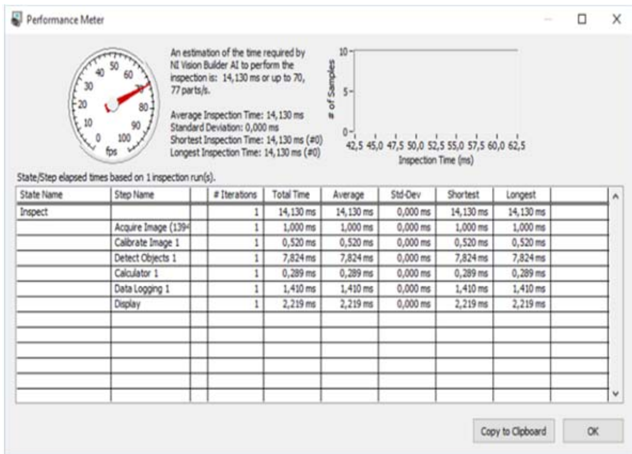

Figure 5. Duration of the procedures for determination of the parameters of one egg

The time spent on determination of the parameters of one egg was 14,130 ms.: to capture the image with a camera - 1,000 ms., to calibrate - 0.520 ms., to detect and determine the geometric parameters of the object - 7,824 ms., to calculate the coefficient and index of the form - 0,289 ms., to record data in MS

Excel - 1.41 ms., output data to the screen - 2,219 ms.

In order to justify and select methods for eggs volume and density determination, an experiment was performed using 80 chicken eggs of the cross "Loman White" with different weights [11].

The research was conducted in two stages. At the first stage, the egg weight, its small and large diameters and volume were measured by existing measuring instruments. Electronic scales DX-240h were used to measure the weight with an accuracy of 0.01 g. Measurements of egg diameters were performed using a caliper with an accuracy of 0.1 mm. The volume of eggs was determined according to Archimedes' law using a volumetric flask with a division value of 0.1 cm^3 filled with water [12]. Procedures for determining egg weight and volume are shown in Figure 6.

Figure 6. Determination of egg weight and volume by the direct method.

At the second stage, studies of the dimensional characteristics of eggs were carried out on a stationary automated installation. After that, the volume of each egg was calculated, according to the known formulas.

According to the Donald Hoyt formula [12], [6]:

$$V_x = k \cdot D \cdot d^2 \quad (4)$$

where, D is the large diameter, d is the small diameter, k is the volume coefficient equal to 0.509. A more accurate value of the volume coefficient is equal to k = 0.512.

The second method for calculating the volume is represented by the Simpson formula, which calculate the volume of an ellipsoid [5]:

$$V_S = 0.523 \cdot D \cdot d^2 \quad (5)$$

The third method is the calculation of volume by known weight [6]:

$$V_m = 0.913 \cdot m \quad (6)$$

where, m is the weight of the egg.

The automated installation "STZ - Egg" provides the possibility of additional measurement of the area and perimeter of the egg using a computer vision system. Using the values of the area and perimeter, we propose a number of new formulas for indirect assessment of the volume.

The first formula uses the area of the longitudinal section [12]:

$$V_s = Ks \cdot S\sqrt{S}, \text{ mm}^3 \quad (7)$$

where, Ks is the correction factor of the area, S is the area of the longitudinal section of the egg.

The second method use the perimeter and the longitudinal section area:

$$V_p = Kp \cdot S \cdot P, \text{ mm}^3 \quad (8)$$

where Kp is the perimeter correction factor, P is the perimeter of the longitudinal section of the egg.

The third method use the longitudinal section area and the small diameter:

$$V_{sd} = Ksd \cdot S \cdot d, \text{ mm}^3 \quad (9)$$

where Ksd is the correction factor for the area and the small diameter, S is the area of the longitudinal section of the egg, d is the small diameter of the egg.

3. Research and Analysis Results

The values of the correction factors: Ks = 0.028; Kp = 0.0018; Ksd = 0.641 are determined by statistical processing of the eggs experimental data. Considering the obtained average values of the correction coefficients and the presented above traditional methods for calculating the volume, its values are calculated both using traditional instruments, as well as automated installation. The volume measured by the direct method is taken as a standard. Egg volume is most accurately determined by the formula using the correction factor for area and small diameter, since the average value of the absolute error is 0.14 cm^3. As for the known formulas, the most accurate volume values were obtained by using the Hoyt formula with a correction factor k = 0.512. The absolute error in the determination of the volume was 0.55 cm^3. To confirm the reliability of the method of indirect determination of egg volume, a verification test was conducted on a sample of 10 eggs. The average error of the calculated volume value compared to the measured value was 0.361 cm^3. The values of the absolute error vary in the range between 0.05 cm^3 and 0.70 cm^3 [11].

Sixty chicken eggs of the cross "Loman White" of various weights, stored for no more than 3 days, were taken to be examined.

The experiment was carried out in several stages. First, all eggs were weighed on a laboratory scale DX-240 with an accuracy of 0.01 g.

After that, the volume of the egg was determined. Egg volume was determined using a volumetric flask with a division value of 0.1 cm^3 by the direct method according to Archimedes' law. The density of eggs was determined by the direct method in saline solutions of various densities in the range from 1.07 to 1.10 g/cm^3 with a division interval of 0.00025 g/cm^3. The density of the solution was measured using a hydrometer.

By sequentially immersing the eggs in salt solutions of different densities, the density of each egg is determined. The geometric parameters of the eggs (S, L, D, d) were determined on a stationary automated installation using the "STZ-egg" program.

To determine the volume in an indirect way, the following formula was used:

$$V_{sd} = 0.641 \cdot S \cdot d, \text{ cm}^3 \quad (10)$$

where, Vsd - egg volume; S is the area of the longitudinal section of the egg; d is the small diameter of the egg.

According to the weight and volume calculations results, the density values are determined by two methods:

a) using the experimentally measured weight and egg volume calculated by formula (9):

$$\rho_v = \frac{m}{V_{sd}}, \text{ gr/cm}^3 \quad (11)$$

The time to determine the indirect density values of 60 eggs using a scale and a stationary automated installation was 15 minutes. The productivity of the density determination process by this method is 240 eggs per hour.

b) through the volume of the egg measured by the direct method and the indirect value of the weight calculated by the formula (3):

$$\rho_m = \frac{m_k}{V}, \text{ gr/cm}^3 \quad (12)$$

The time spent on determining the density of 60 eggs in a direct way, considering the time spent on preparing the solutions, was 90 minutes. The productivity of the direct density determination process in saline solutions is 40 eggs per hour.

The experimental results of egg quality indicators were processed by variation statistics methods, using the Statistica 12 software and are shown in Table 1.

Table 1. Results of experimental studies of egg quality indicators

Parameter	Number of experiments	Mean value	Min	Max	Range	Variance	Error
M, g.	60	64,19	54,62	78,00	23,380	5,471	0,706
V, cm^3	60	59,24	50,10	71,80	21,700	5,130	0,662
ρ, g/cm^3	60	1,08	1,07	1,10	0,030	0,006	0,001
Mk,g.	60	64,69	56,10	77,25	21,150	4,698	0,606
Vsd, cm^3	60	58,4	50,57	72,22	21,648	5,174	0,668
ρ_v, g/cm^3	60	1,09	1,07	1,12	0,050	0,010	0,001
ρ_m, g/cm^3	60	1,09	1,05	1,13	0,080	0,022	0,003
$\rho-\rho_v$, g/cm^3	60	0,02	0,00	0,04	0,040	0,009	0,001
$\rho-\rho_m$, g/cm^3	60	0,03	0,00	0,06	0,060	0,012	0,002

4. Conclusion

1. The main indicators of an egg, which determine its incubation and commercial qualities are weight, shape and density. The existing technical approaches for determination of the shape and density have low productivity. The automated installation "STZ - Egg" provides determination of small and large diameters, area and perimeter of the longitudinal section of the egg, followed by the calculation of the index and egg shape coefficient with high productivity and sufficient accuracy. The automated installation provides a 30-fold increase in productivity, when measuring the geometric parameters of eggs.
2. The comparison of experimental data for manual determination of eggs volume using a volumetric flask and the data, obtained by calculation using three known formulas, shows that Hoyt's formula for volume calculation with a correction factor of 0.512 gives the most accurate volume values. The calculation error using this method is on average 0.55 cm^3.
3. The investigation of the indirect method for determination of the volume of an egg using the proposed new formula, which takes into account the longitudinal section area and the small diameter of the egg, was carried out. The results show that using correction factor of 0.641, the absolute error in volume determination by the indirect method, in comparison with manual measurements, does not exceed 0.36 cm^3. This confirms the possibility of using this method to calculate the values of the egg volume.
4. The experiment, carried out to determine the density of 60 eggs by two methods, showed that the indirect method for determination of the density by directly measuring the weight and calculating the volume, as a product of the area and the small diameter with a correction factor

equal to 0.641, provides a 6-fold increase in productivity, compared to the direct method and the method for calculation of the density using formula (12). The results of comparing the calculated density values showed, that the average absolute error in the density determination by the proposed indirect method is 0.02 g/cm^3 in comparison with the direct method.

5. The proposed express methods and procedures for determination of the main indicators of eggs quality, after additional research and determination of the values of the coefficients in formulas (3, 10), can also be used to determine the quality indicators of fruits and vegetables (apples, pears, apricots, potato tubers, tomatoes, onions, etc.).

References

[1]. Narushin, V. A., & Romanov, M. N. (2002). Egg physical characteristics and hatchability. *World's Poultry Science Journal*, *58*(3), 297-303.

[2]. King'ori, A. M. (2012). Poultry egg external characteristics: Egg weight, shape and shell colour. *Research Journal of Poultry Sciences*, *5*(2), 14-17.

[3]. Broussard, C. T., & Washburn, K. W. (1981). Factors affecting the hatchability of parabiotic chicks. *Poultry Science*, *60*(6), 1107-1114.

[4]. Alikhanov, D., Shynybay, Z., Moldazhanov, A., Kulmakhambetova, A., & Daskalov, P. (2017). Machine control system operation for automatic sorting of eggs into categories. In *Proc. of V-th International scientific congress "Agricultural machinery", Varna, Bulgaria* (Vol. 2, pp. 222-227).

[5]. Nikishov, A. A., & Ahmed, R. A. H. (2014). Incubatory qualities of white shell eggs of hens with the different ratio of weight and volume. *RUDN Journal of Agronomy and Animal Industries*, (1), 59-63.

[6]. Hoyt, D. F. (1976). The effect of shape on the surface-volume relationships of birds' eggs. The Condor, 78(3), 343-349.

[7]. WashburnK.W. (1981) Factors Affecting the Hatchability of Parabiotic Chicks. *Poultry Science*, 60(6), 1107-1114.

[8]. Kim, H. T., Ko, H. J., Kim, K. Y., Kato, K., Kita, Y., & Nishizu, T. (2007). Determination of egg freshness and internal quality measurement using image analysis. *Journal of Biosystems Engineering*, *32*(3), 166-172.

[9]. Siswantoro, J., Hilman, M. Y., & Widiasri, M. (2017, November). Computer vision system for egg volume prediction using backpropagation neural network. In *IOP Conference Series: Materials Science and Engineering* (Vol. 273, No. 1, p. 012002). IOP Publishing.

[10]. Soltani, M., Omid, M., & Alimardani, R. (2015). Egg volume prediction using machine vision technique based on pappus theorem and artificial neural network. *Journal of Food Science and Technology*, *52*(5), 3065-3071.

[11]. Moldazhanov, A. K., Alikhanov, J. M., Kulmakhambetova, A. T., & Shynybay, Z. S. (2017). Rationale And Choice Of Determination Of The Eggs Volume By The Calculated Method. *Series of Agricultural Sciences 3*(39), 126-131.

[12]. Hoyt, D. F. (1979). Practical methods of estimating volume and fresh weight of bird eggs. *The Auk*, *96*(1), 73-77.