



Classification of Chicken Eggs Based on Mass Using an Android-Based Digital Image System

Ifmalinda, N. Yandi, and Andasuryani

Department of Agriculture, Engineering and Biosystem, Andalas University, Padang 25163, INDONESIA

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CORRESPONDING AUTHOR

*E-mail: ifmalinda73@gmail.com

NOVELTY:

This research is novel in adapting advanced digital image processing techniques to a locally relevant five-grade egg classification system (pelor, bujang, remban, super, jumbo), offering the first validated smartphone-based solution tailored to smallholder poultry systems in West Sumatra.

A B S T R A C T

Chicken eggs are a widely consumed animal food commodity, along with other products such as chicken meat, beef, and milk. Chicken eggs are produced by laying hens, scientifically known as *Gallus gallus domesticus*. Manual grading of chicken eggs in West Sumatra relies on subjective sensory assessment, resulting in inconsistent classification outcomes. The development of a chicken egg grading application using Android-based digital images is a solution to this problem. This study presents the development and validation of an Android-based digital image processing system for automated mass-based grading of chicken eggs using the five-grade local classification system in Payakumbuh (pelor, bujang, remban, super, and jumbo). The image processing pipeline employed Otsu thresholding for segmentation, mean filtering for noise removal, and eccentricity-based shape determination to calculate egg volume, which was subsequently converted to Mass using a density constant of 1.0801 g/cm³. A total of 100 eggs were tested: 67 for correlation analysis and 33 for validation. The system achieved a mass correlation coefficient of $r = 0.9986$, a volume correlation of $r = 0.9976$, a mass RMSE of 0.4486 g, and a volume RMSE of 0.3972 ml. Out of 67 tested samples, 64 were correctly classified (95.5% accuracy). These results confirm that the developed application can reliably replace manual grading for small-scale poultry farmers, providing a practical and measurable digital innovation for the agricultural sector. These results indicate that Android-based image processing applications exhibit small errors, enabling the designed application to be implemented.

Contribution to Sustainable Development Goals (SDGs):

SDG 2 (Zero Hunger)

SDG 8 (Decent Work and Economic Growth).

SDG 9 (Industry, Innovation and Infrastructure)

SDG 12 (Responsible Consumption and Production)

1. INTRODUCTION

1.1. Research Background

Chicken eggs are a widely consumed animal food commodity, alongside other animal-based foods such as chicken, beef, and milk. Chicken eggs are a rich source of high-quality protein [1]. In 2018, the Food and Agriculture Organization (FAO) ranked Indonesia as the fourth-largest producer of chicken eggs in the world. The Central Statistics Agency [2] recorded that Indonesia

produced 5,155,998 tons of eggs in 2021, with West Sumatra Province accounting for 5.61% of this total.

The Indonesian Ministry of Trade states that chicken eggs are generally classified by mass and shell colour. Based on their Mass, chicken eggs are classified into very small, small, medium, large, and extra-large. In West Sumatra, particularly in Payakumbuh City, chicken eggs are classified into five local grades: pelor, bujang, remban, super, and jumbo. However, this classification process is currently performed manually by visual inspection and hand feel, which are inherently subjective, time-consuming, and prone to inconsistency. To address these



limitations, Android-based digital image processing offers a practical and portable alternative.

In general, digital image processing is the processing of 2-dimensional images using a computer [3]. Digital images can replace the human eye in assessing an object, providing more measurable, certain data. Prior studies have demonstrated its effectiveness in estimating the volume and Mass of fruits such as citrus [4] and apples [5]. Android-based implementations extend this capability to the farm level, enabling real-time grading without laboratory equipment [6].

1.2. Research Objective

This research aims to develop image processing for grading chicken eggs based on Mass using Android-based digital images.

1.3. Research Benefit

The benefit of this research is to simplify the classification of chicken eggs by Mass, achieve more precise classification results, and improve the quality of market chicken eggs.

1.4. Research Novelty and Contribution

While previous studies have explored image-based volume estimation for various agricultural commodities, no study has specifically developed an Android-based digital image processing application tailored to the five-grade local egg classification system of West Sumatra. This study is the first Android-based digital image processing application specifically designed for the five-grade local egg classification system of Payakumbuh, West Sumatra

2. MATERIALS AND METHODS

2.1 Time and Place

The research was conducted from March to May 2023 in Ompang Tanah Sirah Village, North Payakumbuh District, Payakumbuh City, West Sumatra Province, Indonesia.

2.2 Tools and Materials

The materials used in this study were chicken eggs. The tools used were an Android smartphone with a 48MP main camera, a laptop with an Intel Core i5-8300H processor and 8GB of RAM, calipers, a measuring cup, a digital scale, an image box with two 5W LED bulbs, and C+ software. and unity 3d.

2.3 Research Procedures

The image processing workflow is shown in Figure 1

2.3.1 Preliminary Research

This preliminary study was conducted to determine the mass range for each grade, as the classification of chicken eggs in West Sumatra, particularly in Payakumbuh City, has not yet been standardized. Furthermore, it aimed to determine the correlation among the volume, Mass, and specific gravity of chicken eggs. The study was conducted using a sample of 30 chicken eggs representing all grades.

From the preliminary research that has been carried out, the range of egg masses per grade was obtained as follows:

1. Pelor : < 45g
2. Bujang : 45g - 55g
3. Remban : 56g - 75g

4. Super : 76g - 85g
5. Jumbo : > 85g

The coefficient of determination obtained from the preliminary research conducted is 0.988, with the equation $y = 1.0515x - 1.6462$, yielding a correlation of 0.994. Since the correlation value is close to 1, it can be concluded that there is a strong correlation between the volume and Mass of chicken eggs. The density of a chicken egg must be known to estimate its Mass from the volume obtained by digital image processing. Preliminary research found the average density of chicken eggs to be $1.0801 \text{ g/cm}^3 \pm 0.0199 \text{ g/cm}^3$, consistent with values reported in the literature [7].

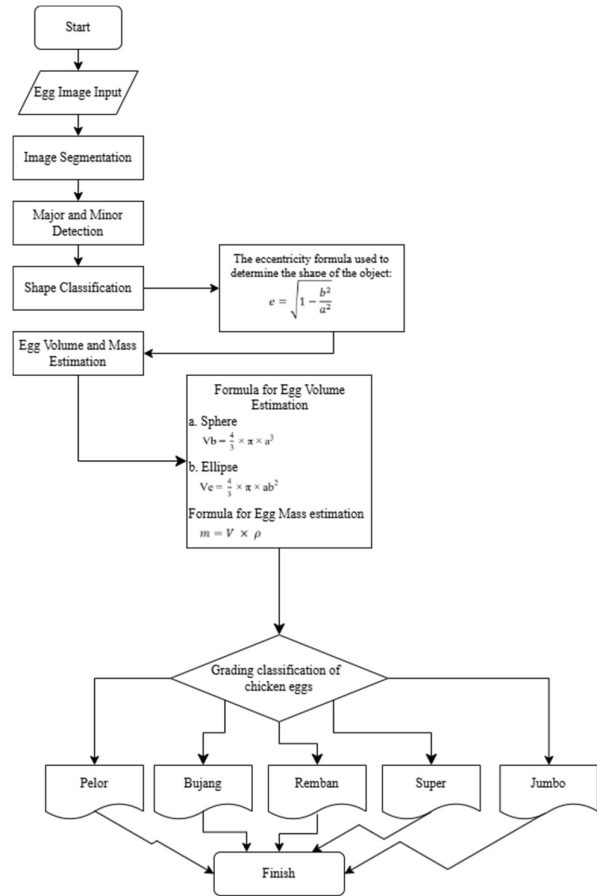


Fig. 1. The Workflow of Image Processing

2.3.2 Material Preparation

This study used the classification of chicken eggs found in Payakumbuh City, West Sumatra. The classification consists of five grades: jumbo, super, remban, bujang, and pelor eggs. The chicken eggs were sourced from several chicken farmers in North Payakumbuh District. A total of 100 freshly laid eggs were used, encompassing all five classifications. Sample size was determined based on the minimum requirement for regression analysis, which recommends at least 20 observations per predictor variable [8]. 67 samples were used for correlation observations and 33 for validation. Before testing, the eggs were washed with water to remove any dirt, then photographed with a smartphone. The samples were tested in Ompang Tanah Sirah Village, North Payakumbuh District, Payakumbuh City [9].

2.3.3 Manual processing

2.3.3.1 Manually Determining Object Shape

Shape determination identifies the appropriate formula for calculating an object's volume. The shape of an object is determined using its eccentricity value, which represents the ratio of the major axis radius to the minor axis radius. The major and minor axes are measured manually using a vernier calliper. Eccentricity value for a sphere is less than 0.3. Meanwhile, the eccentricity value for an ellipse is 0.3 to 0.7. According to Sahara et al. [10], the method for calculating eccentricity is by using the following equation:

$$e = \sqrt{1 - \frac{b^2}{a^2}}$$

Where :

a = radius value of the major axis (cm)

b = radius value of the minor axis (cm)

Iqbal et al. [5] established various criteria for determining eccentricity. These criteria are shown in Table 1.

Table 1. Egg Model Shape Criteria

Eccentricity	b/a ratio	Egg Shape
< 0.3	0.95-1.05	Ball
0.3 – 0.7	0.70-0.95	Ellipse

Source : Iqbal et al., 2011

2.3.3.2 Manual Measurement of Egg Mass and Volume

a) Mass measurement

Mass measurements were performed using a digital scale.

Each sample was weighed to determine its Mass.

b) Volume measurement

The volume of a chicken egg is measured using the equation proposed by Mohsenin (1986). Mohsenin stated that the actual volume and density of an object can be determined using the water displacement technique. The formula for calculating volume is as follows:

$$V \text{ (cm}^3\text{)} = \frac{m \text{ (g)}}{\rho \text{ (g/cm}^3\text{)}}$$

Where :

ρ = Density (g/cm³)

m = Mass (g)

V = Volume (cm³)

2.3.4 Image Data Processing

2.3.4.1 System Design

The Android smartphone application developed in this research is designed to classify chicken eggs based on the grades used in West Sumatra, particularly in Payakumbuh City, using digital image processing. This application will help chicken farmers determine egg grades simply by photographing the eggs. The chicken egg grading application was developed in C++. Images of chicken eggs are entered into the application, which then processes them to produce results for volume, Mass, and egg grade.

The application has five buttons: camera, gallery, sample, method, and exit. The camera button captures an image of the egg using the device's camera and proceeds to digital image processing. The gallery button retrieves an image from the device's gallery and proceeds to digital image processing. The sample button recalls previously saved results of digital image processing. The method button displays an explanation of the

working method of the digital image-based chicken egg classification application. The exit button closes the application.

Image processing of chicken eggs was performed in a series of sequential steps. The process began with image acquisition, where a 48 MP smartphone camera was positioned perpendicular to the egg surface at a fixed distance of 20 cm within a controlled imaging box. The imaging box was equipped with two 5W LED bulbs to provide uniform and diffuse illumination across the imaging area, effectively eliminating external light interference and shadows. This lighting setup ensured that each egg was captured under identical conditions throughout the experiment, minimizing variation caused by inconsistent illumination. Before measurement, the camera was calibrated by placing a reference object of known physical dimensions within the imaging frame. The pixel-to-centimetre scale factor was determined as the ratio of the reference object's physical size to its corresponding pixel dimensions, enabling the accurate conversion of all subsequent pixel-based measurements into real-world units [11].

After image acquisition, the image was thresholded to separate the egg from the background, producing a binary image for further analysis. The major and minor axes of the egg were then extracted by measuring the longest and shortest pixel dimensions of the segmented object. Using these axes, the shape of the egg was characterized through the eccentricity formula, which determined whether the object was better approximated as a sphere or an ellipse. Based on this classification, the egg volume was calculated using the corresponding geometric formula.

2.3.4.2 Data analysis

The data analysis carried out includes descriptive statistical analysis, as follows.

a) Correlation

Correlation is a measure that indicates the linear relationship between two variables, with values ranging from 0 to 1. The relationship is stronger when the correlation is close to 1, and weaker when it approaches 0 [12]. Pamungkas [13] states that the formula used to calculate the correlation value is as follows:

$$r_{xy} = \frac{n(\sum_{i=1}^n xy) - (\sum_{i=1}^n x)(\sum_{i=1}^n y)}{\sqrt{\{n(\sum_{i=1}^n x^2) - (\sum_{i=1}^n x)^2\} \{n(\sum_{i=1}^n y^2) - (\sum_{i=1}^n y)^2\}}}$$

Where :

r_{xy} = Correlation coefficient of x and y

x = Value of the independent variable

y = Value of the dependent variable

n = Number of data

$$R^2 = \frac{n(\sum_{i=1}^n xy) - (\sum_{i=1}^n x)(\sum_{i=1}^n y)^2}{\{n(\sum_{i=1}^n x^2) - (\sum_{i=1}^n x)^2\} \{n(\sum_{i=1}^n y^2) - (\sum_{i=1}^n y)^2\}}$$

Where :

R^2 = Coefficient of determination

n = Number of data

x = Value of the independent variable

y = Value of the dependent variable

b) Model Validation

Sudarwan (1998), as cited in Haryati [14], stated that a model is considered valid if its results reflect actual implementation. Validation is performed by comparing image-processing results

with manual measurements. The samples used constitute one-third of the total. The data used for the validation process include the manual measurement volume (Vs) relative to the image-processing volume (Va) and the manual measurement mass (Bs) relative to the image-processing mass (Ba). A correlation coefficient close to 1 indicates that the results of direct measurements and image processing are strongly related, suggesting that the measurements are accurate.

The Root Mean Square Error (RMSE) value indicates the accuracy of a dataset. The error rate in research data is proportional to the RMSE value [15]. Subakti [16] states that the formula for calculating the RMSE value is as follows:

$$RMSE = \sqrt{\frac{\sum_{i=1}^n (Y_{pred} - Y_{ref})^2}{N}}$$

Where :

RMSE = Root Mean Square Value Error

Y_{pred} = Predicted value

Y_{ref} = Actual value

N = Number of data

2.3.5 Research Output

An Android smartphone application was developed to determine the grade of chicken eggs. The application outputs the classification of chicken eggs along with their corresponding Mass.

3. RESULT AND DISCUSSION

3.1 Program Design Results

3.1.1 Main Menu Display

The application is designed with five buttons: camera, gallery, sample, method, and exit. The camera button captures an image of an egg using the device's camera. The gallery button retrieves an egg image from the device's gallery. The sample button recalls previously saved results of digital image processing. The method button displays an explanation of the working method of the digital image-based chicken egg classification application. The exit button closes the application. The main menu display is shown in Figure 2.

3.1.2 Image Acquisition of Eggs

The background used in the image is white cardboard. Images of chicken eggs can be uploaded to the application using either the

camera or gallery buttons. The image input process is shown in Figure 3.

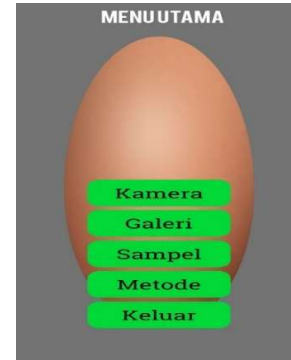


Fig. 2. Main Menu Display of Android Application

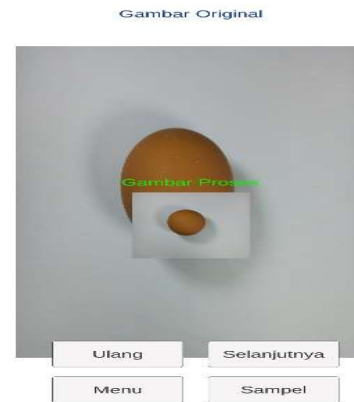


Fig. 3. Chicken Egg Image Input Process

3.1.3 Image Segmentation

Segmentation is performed using the Otsu thresholding method, which converts a grayscale image to a binary image. Nobuyuki Otsu introduced this approach in his article entitled 'A Threshold Selection Method from Gray-Level Histograms' [17].

After the image is input, it is converted to grayscale and thresholded to separate the egg object from its background. As a result, the egg appears white while the background appears black. At this stage, noise in the form of black dots on the object or white dots on the background may still be present, resulting in imperfect object shapes. Therefore, noise is removed using the mean filter, which replaces each pixel with the average of its neighbours. The segmentation process is shown in Figure 4.

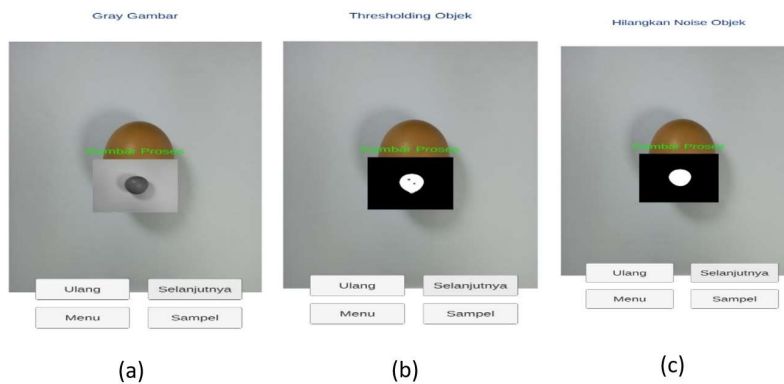


Fig. 4. Image Segmentation a) Grayscale, (b) Thresholding, (c) Noise Removal

3.1.4 Determining Major and Minor Axes Using Images

The major and minor axes of the egg determine the calculation of an object's volume. The line passing through both foci of the ellipse is called the major axis, and the midpoint of the segment connecting the two foci is called the center of the ellipse. The line passing through the center and perpendicular to the major axis is called the minor axis [18].

The major and minor axes are determined after the object has been separated from its background. The axes are then marked with straight lines passing through the center of the ellipse. Their values are obtained by converting the number of pixels per line to centimetres (cm). The process of determining the major and minor axes is shown in Figure 5.

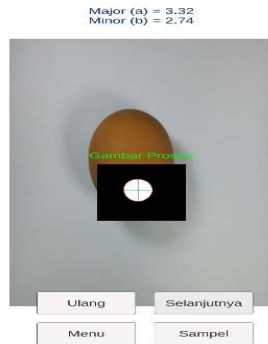


Fig. 5. Determining the Position of the Major and Minor Axes

3.1.5 Determining Object Shape Using Image Processing

Determining the shape of an object is necessary before calculating its volume, as it dictates which volume formula to use. The shape of an egg is determined by its eccentricity value, which represents the ratio of the major axis radius to the minor axis radius. An eccentricity value of less than 0.3 indicates a sphere, while a value between 0.3 and 0.7 indicates an ellipse [10].

3.1.6 Volume Prediction Using Image Processing

Venkatesh et al. [19] explained that the prediction of egg volume in digital images can be calculated using the following formula:

a) Ball shape

$$Vb = \frac{4}{3} \times \pi \times a^3$$

Where :

Vb = Volume of the sphere (cm³)

a = value of the radius of the major axis (cm)

b) Elliptical shape

$$Ve = \frac{4}{3} \times \pi \times ab^2$$

Where :

a = value of the radius of the major axis (cm)

b = value of the radius of the minor axis (cm)

Ve = Volume of ellipse (cm³)

3.1.7 Mass Prediction Using Image Processing

The Mass of an object is correlated with its volume through its density. To predict the Mass of a chicken egg from its volume, the egg's density is assumed to be constant. The density used is 1.0801 g/cm³, as obtained from preliminary research.

Mass prediction was calculated using the volume obtained through image processing. The egg's mass, measured with a digital scale, serves as the dependent variable (y-axis). In contrast, the volume obtained from image processing serves as the independent variable (x-axis). The correlation between these two variables was used to predict egg mass from digital images, using the density equation [4]. The final results produced by the application are shown in Figure 6.

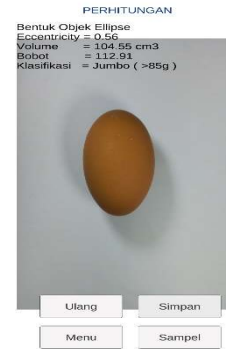


Fig. 6. Final Image Processing Result Display

3.2 Test Results

Testing of the Android-based digital image application for classifying chicken egg grades by Mass was carried out across five classifications: pelor, bujang, remban, super, and jumbo. Manual testing yielded 5 pelor eggs, 5 bujang eggs, 53 remban eggs, 2 super eggs, and 2 jumbo eggs. The highest volumes recorded in each classification were 41 ml for pelor, 52 ml for bujang, 70 ml for remban, 79 ml for super, and 105 ml for jumbo. The lowest volumes recorded were 29 ml for pelor, 48 ml for bujang, 51 ml for remban, 72 ml for super, and 90 ml for jumbo. The highest masses recorded in each classification were 43.0 g for pelor, 55.0 g for bujang, 74.3 g for remban, 85.3 g for super, and 111.2 g for jumbo. The lowest masses recorded were 31.5 g for pelor, 52.9 g for bujang, 55.2 g for remban, 77.9 g for super, and 96.8 g for jumbo.

The results obtained through the Android-based application were 5 pelor eggs, 5 bujang eggs, 52 remban eggs, 3 super eggs, and 2 jumbo eggs. The highest volumes recorded in each classification were 39.8 ml for pelor, 50.9 ml for bujang, 69.5 ml for remban, 78.8 ml for super, and 104.6 ml for jumbo. The lowest volumes recorded were 28.8 ml for pelor, 48.6 ml for bujang, 51.2 ml for remban, 70.2 ml for super, and 89.9 ml for jumbo. The highest masses recorded in each classification were 43.0 g for pelor, 54.9 g for bujang, 75.0 g for remban, 85.0 g for super, and 112.9 g for jumbo. The lowest masses recorded were 31.1 g for pelor, 52.5 g for bujang, 55.3 g for remban, 75.8 g for super, and 97.1 g for jumbo.

A comparison between manual classification and image-processing classification revealed differences. Of the 67 chicken eggs tested, 64 samples were correctly classified, and 3 were incorrectly classified. Three misclassifications were observed at the remban-to-super boundary. Possible sources of error include minor inconsistencies in egg placement orientation affecting axis detection, the constant-density assumption, which may slightly underestimate or overestimate Mass for eggs with unusually thick shells or large air cells, and residual background noise in eggs with non-uniform shell pigmentation. Future work should

investigate orientation-invariant detection methods and density estimation per grade.

3.3 Correlation

Correlation is a measure that indicates the strength of the linear relationship between two variables [12]. A correlation test was conducted to determine the strength of the linear relationship between manually measured volumes and masses of chicken eggs and the corresponding results obtained via Android-based digital image processing. Sugiyono [8] categorized the levels of relationship based on correlation value intervals into five levels, as shown in Table 2.

Table 2. Correlation Interval

No	Relationship Interval	Relationship Level
1	0.00-0.19	Very Low
2	0.20-0.39	Low
3	0.40-0.59	Currently
4	0.60-0.79	Strong
5	0.80-1.00	Very strong

Source: Sugiyono, 2016

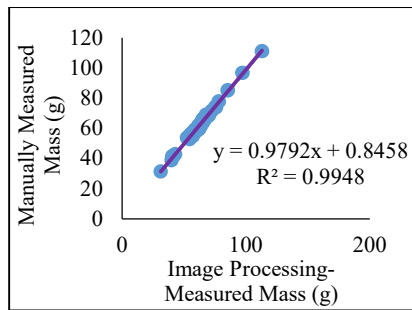


Fig. 7. Correlation Graph of Manual and Image Processing Mass
Based on Figure 7, the coefficient of determination (R^2) between the manually measured Mass and the Mass obtained through digital image processing is 0.9948, yielding a correlation value (r) of 0.9974. Based on the correlation intervals in Table 2, it can be concluded that the relationship between the manually measured Mass and the Mass obtained by digital image processing is very strong.

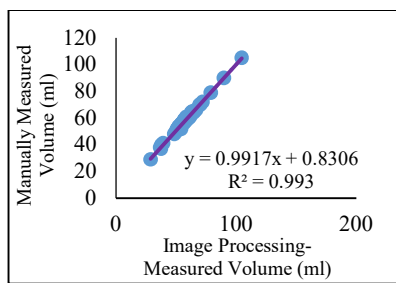


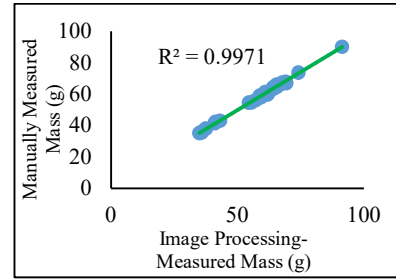
Fig. 8. Correlation Graph of Manual and Image Processing Volume

Based on Figure 8, the coefficient of determination (R^2) between the manually measured volume and the volume obtained through digital image processing is 0.9930, yielding a correlation value (r) of 0.9965. Based on the correlation intervals in Table 2, it can be concluded that the relationship between the manually measured volume and the digital image processing volume is very strong. These results are comparable to those reported by Omid

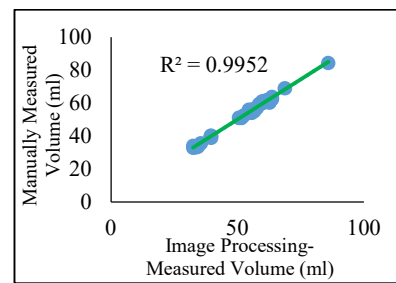
et al. [4] for citrus fruit mass estimation ($r = 0.987$) and Venekatesh et al. [19] for axi-symmetric fruit volume estimation ($r > 0.98$), confirming that the Otsu-based segmentation and ellipsoidal volume formula are effective for egg-shaped objects.

3.4 Validation

Validation is an index that indicates the accuracy of a measuring tool or instrument [20]. The sample test results used for validation are substituted into the regression equation (y) obtained from the correlation test to produce predicted values. The validation results of measurements using the Android-based digital image processing application are shown in Figure 9.



(a)



(b)

Fig. 9. Digital Image Processing Validation Graph for Mass and Volume: (a) Mass Validation, (b) Volume Validation

Based on Figure 8, the coefficient of determination for Mass is 0.9971 and for volume is 0.9952, yielding a mass correlation value of 0.9986 and a volume correlation value of 0.9976. Based on the correlation intervals described by Sugiyono [8], it can be concluded that both the mass and volume correlations indicate a very strong relationship. The Root Mean Square Error (RMSE) values of measurements obtained using the application are shown in Table 3.

Table 3. RMSE Values of Mass and Volume

Validation	MSE	RMSE
Mass	0.2012	0.4486
Volume	0.1577	0.3972

Source: Data Analysis

Based on Table 3, the RMSE value for Mass obtained through the Android-based digital image processing application is 0.4486, and the RMSE value for volume is 0.3972. These results indicate that the application produces a small margin of error, suggesting that the designed application is suitable for implementation.

4. CONCLUSION

4.1 Conclusion

This study successfully developed and validated an Android-based digital image processing application for classifying chicken eggs by Mass according to the local five-grade classification system of Payakumbuh City, West Sumatra. The application employs an Otsu thresholding segmentation pipeline combined with eccentricity-based shape determination and density-based mass estimation. Validation results demonstrate very strong agreement between image-derived and manually measured values, with mass correlation $r = 0.9986$, volume correlation $r = 0.9976$, mass RMSE = 0.4486 g, and volume RMSE = 0.3972 ml.

4.2 Suggestions

The primary limitation of the current system is the assumption of constant egg density, which may contribute to boundary-case misclassification. Additionally, image quality is sensitive to lighting conditions and egg orientation. Future research should explore AI-based deep learning approaches (e.g., convolutional neural network regression) for end-to-end mass prediction from raw images, as well as the use of a size reference object during image capture to improve pixel-to-cm calibration accuracy across diverse shooting conditions.

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