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RELATIONSHIP BETWEEN STORAGE DURATION AND YOLK INDEX, ALBUMEN INDEX AND HAUGH UNIT OF PADJADJARAN QUAIL EGGS IN PEAK PRODUCTION PHASE

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ABSTRACT

Quail eggs represent a remarkably nutritious source of animal-derived protein that is economically accessible. However, the internal quality of these eggs is prone to deterioration during storage, largely due to physicochemical alterations. The Padjadjaran Quail is a domesticated strain developed through selective breeding and hybridization of the brown and black variants of the Japanese Quail (Coturnix coturnix japonica, exhibiting commendable egg production capabilities and superior quality. Research related to the internal quality of Padjadjaran Quail Eggs throughout extended storage periods remains relatively scarce. Consequently, the objective of this study was to explain the correlation between storage duration and the yolk index, albumen index, and haugh unit of Padjadjaran Quail eggs. The study was conducted over a span of 60 days at ambient temperature, utilizing 420 Padjadjaran Quail eggs sourced from hens in the peak production phase, at the Poultry Production Laboratory, Faculty of Animal Husbandry, Universitas Padjadjaran. The data were subjected to descriptive analysis, followed by correlation and regression assessments. The findings indicated a notable reduction in the average yolk index from 0.44 to 0.11, the albumen index from 0.12 to 0.01, and the haugh unit from 90.28 to 59.56. A highly significant correlation was established between the duration of storage and each respective parameter. The derived regression models were Y = 0.327 – 0.004X (yolk index), Y = 0.108 – 0.002X (albumen index), and Y = 91.698 – 0.536X (haugh unit).

Keywords : *Storage duration, quail eggs, yolk index, albumen index, haugh unit.*

Introduction

The species *Coturnix coturnix japonica*, commonly referred to as quail, has emerged as a viable alternative within the domain of poultry production, particularly esteemed for its efficacy in providing animal-derived protein. In the Indonesian context, the importance of this species is underscored by its escalating population, which reached 14,779,759 individuals in 2022, indicating a 5.2% increase relative to the preceding year (Directorate General of Livestock and Animal Health, 2022, 2023). Quail eggs are extensively consumed owing to their substantial nutritional profile, economical pricing, and widespread accessibility across both traditional and contemporary marketplaces.

Among the indigenous varieties, the Padjadjaran Quail is particularly notable, having been developed through a selective breeding program that incorporates male Japanese Quail of brown strain and female quail of black strain. The rigorous selection and purification process culminated in a final stock that exhibits significant potential as a premier local product (Anang et al., 2017). These eggs are cultivated and disseminated by the Quail Breeding Center situated within the Faculty of Animal Science at Universitas Padjadjaran. In light of the increasing consumer demands for superior egg quality and the necessity for clarity regarding storage stability, the examination of the performance characteristics of this specific variety is of paramount importance.

The optimal laying period for Padjadjaran Quail hens generally transpires between 12 to 20 weeks of age, wherein egg production attains an approximate average of 90% (Lokapirnasari, 2017). Nonetheless, as hens advance in age, physiological transformations significantly impact egg quality, particularly manifesting as a reduction in shell thickness. The diminishing thickness of eggshells, which correlates with the age of the hens, adversely influences the shelf life of the eggs by escalating water loss and degradation of quality (Perić et al., 2017; Drabik et al., 2021). Eggs produced by younger hens exhibit superior shell integrity and internal attributes, thereby facilitating an extended potential for storage (Maciel et al., 2015; Sokołowicz et al., 2018).

Throughout the storage period, the quality of eggs deteriorates as a consequence of evaporation and degradation of proteins (Sihombing et al., 2014). The loss of water and carbon dioxide via evaporation contributes to a reduction in internal egg pressure. As posited by Rocha et al. (2013), the albumen experiences amino acid hydrolysis, resulting in damage to the protein matrix, compromising the integrity of the vitelline membrane, and diminishing viscosity, which permits the albumen to migrate into the yolk. These alterations culminate in lower values for both the albumen and yolk indices (Argo et al., 2013), alongside a reduction in the height and weight of the albumen, ultimately leading to decreased haugh unit scores (Lestari et al., 2013).

Previous investigations, as elucidated by Carvalho et al. (2023), have established that prolonged storage durations adversely influence egg quality; however, the majority of extant research has predominantly concentrated on short-term storage intervals and generalized quail populations. There has been insufficient scrutiny directed towards specific strains, such as the Padjadjaran Quail, particularly during their peak production phase. Moreover, there exists a notable deficiency in exhaustive data analyzing the internal quality of quail eggs subjected to extended storage periods of up to 60 days. To address this lacuna in the literature, the present study endeavors to examine the correlation between storage duration and the internal quality of Padjadjaran Quail eggs procured from hens at their peak of production.

The anticipated outcomes of this investigation are poised to enhance the corpus of scientific knowledge within the domain of animal science by furnishing empirical evidence that may act as an academic reference pertaining to the interplay between storage duration and the internal quality of quail eggs derived from hens at their peak production phase. In addition, the results are expected to serve as a valuable resource for livestock practitioners, entrepreneurs engaged in quail egg production, and the general populace, providing guidelines for the appropriate storage of eggs at ambient temperature, thereby ensuring the preservation and safety of the quality of eggs marketed and consumed.

Materials and Methods

Research Materials

The study employed a total of 420 Padjadjaran Quail eggs which were procured from hens during their optimal production phase, specifically at 20 weeks of age. The eggs were acquired from the Quail Breeding Center located within the Faculty of Animal Science at Universitas Padjadjaran. Initially, 500 eggs were collected, and subsequently 420 eggs were carefully selected based on the criteria of shell integrity and weight uniformity.

The selection criteria encompassed the complete absence of discernible shell fissures and a weight coefficient of variation calculated at 8.1%.

Research Equipment

The equipment used in this study include vernier caliper 150 mm (0,01 precision; digital scale with 0-500 grams capacity (0,1 gram precision); egg tray; flat glass plate; tray container; dan spatula

Data collection procedure:

1. Egg Selection and Preparation
   A total of 500 eggs were initially obtained and examined. Eggs with visible cracks or outlier weights were excluded, yielding 420 eggs that met the criteria. These eggs were individually numbered and placed in egg trays.
2. Storage Conditions
   The eggs were stored at ambient room temperature for a total of 60 days. Data were collected at 3-day intervals throughout the storage period.
3. Sampling and Measurement
   On each data collection day, 20 eggs were sampled based on their assigned numbers. The eggs were weighed using the digital scale, then carefully cracked onto a flat glass plate. Measurements were taken for albumen height and average diameter, as well as yolk height and diameter, using a vernier caliper.

4. Data Recording and Analysis
   All measurements were recorded and subsequently analyzed using descriptive statistics, correlation analysis, and linear regression to assess the relationship between storage duration and internal egg quality.

Observed Variables

The internal quality parameters observed in this study were the yolk index, albumen index, and haugh unit. Each of these variables serves as an indicator of egg freshness and quality during storage.

1. Yolk Index

The yolk index is an indicator of egg freshness, calculated as the ratio between the height and diameter of the yolk. It reflects the firmness and shape retention of the yolk. The yolk index was measured by the yolk's height and diameter using a vernier caliper. The values obtained were then applied to the following formula:

$$Indeks\ Yolk = \frac{yolk\ height (mm)}{yolk\ diameter\ (mm)}$$

2. Albumen Index

The albumen index is the ratio of the height of the thick albumen to its average diameter. The albumen index was measured by the albumen's height, and diameter average using a vernier caliper. The measurement results were then applied to the following formula:

$$Albumen\ Index = \frac{albumen\ height\ (mm)}{average\ of\ albumen\ diameters\ (mm)}$$

3. Haugh Unit (HU)

The HU is a widely used measurement that combines albumen height and egg weight to evaluate egg freshness. Higher HU values indicate fresher eggs. The haugh unit was calculated by inputting the egg weight and the albumen height into the following formula:

$$HU = 100 \times \log(H + 7{,}57 - 1{,}7\ W^{0{,}37})$$

Notes:
H : Albumen height (mm)
W : Egg weight (g)

Statistical Analysis

Descriptive statistical analysis was conducted using Microsoft Excel to summarize the data related to the yolk index, albumen index, and Haugh unit. Additionally, inferential statistical analysis was conducted employing SPSS software, which incorporated Pearson Product-Moment Correlation to evaluate the intensity and orientation of the association between storage duration and each quality parameter of the egg, with a significance threshold established at $p < 0.05$. A simple linear regression model was applied to investigate the impact of storage duration on each parameter and to delineate predictive trends. The regression adhered to the structure of the linear equation:

$$Y = a + bx$$

Notes:
Y : Dependent Variable (Yolk Index/ Albumen Index/ Haugh Unit)
X : Independent Variable (Storage Duration)
a : Intercept
b : Regression Coefficient

Results and Discussion

Descriptive Analysis of Yolk Index, Albumen Index, and Haugh Unit of Padjadjaran Quail Eggs

Descriptive analysis was carried out to assess the internal quality of Padjadjaran Quail Eggs during storage based on yolk index, albumen index, and haugh unit. The results are presented in Table 1.

The yolk index is conceptualized as the proportional relationship between the height of the yolk and its diameter. This index serves as an indicator of the structural integrity of the yolk, with elevated values correlating with enhanced firmness and superior freshness (Purwati, 2015). At the commencement of the observation period (day 0), yolk index values exhibited a range from 0.35 to 0.48, culminating in a mean value of 0.44. This mean surpasses the conventional yolk index of fresh quail eggs, which is documented to range from 0.33 to 0.55, as articulated by Ayuti et al. (2021). The eggs utilized in this investigation were procured from hens during their apex production phase, which likely played a significant role in the comparatively high quality of the yolk at the onset of storage. By the conclusion of day 30, the yolk index experienced a decline to 0.16, signifying a reduction in yolk firmness and indicating a diminishment in freshness. This recorded value remained marginally higher than the yolk index of 0.13 noted by Carvalho et al. (2023). Extended storage led to further degradation, culminating in the lowest average value of 0.11 recorded on day 60, which denotes a substantial loss of yolk structure and freshness.

The albumen index, which serves as a measure of the viscosity and thickness of the egg white, is derived from the ratio of albumen height to its diameter (Djaelani, 2016; Trinitariyani, 2022). On day 0, the albumen index manifested a range from 0.08 to 0.19, with an average of 0.12. This average is lower than the findings of Karimudin (2021), who documented an average of 0.15 in quail eggs subjected to a diet of fermented bran, and Mulyadi et al. (2017), who reported values fluctuating between 0.16 and 0.17 by employing fermented shrimp waste feed. The lack of feed additives in this study may have significantly influenced the diminished albumen index values that were observed.

Table 1. Internal Quality of Padjadjaran Quail Eggs During Storage

Parameters	Storage Day					r	p-value
	0	15	30	45	60		
N	20	20	20	20	20		
Yolk Index	0.44±0.04	0.23±0.02	0.16±0.02	0.12±0.02	0.11±0.01	-0.894	0.000
Albumen Index	0.12±0.03	0.08±0.01	0.05±0.02	0.02±0.01	0.01±0.00	-0.983	0.000
Haugh Unit	90.28±3.60	83.76±1.64	77.04±3.13	66.02±1.74	59.56±1.80	-0.991	0.000

r = Correlation Coefficient; p-value < 0.05 = significant

The haugh unit serves as a metric for assessing overall freshness, employing a formula that incorporates both albumen height and egg weight. Elevated haugh unit values signify enhanced internal quality. On day zero, the values exhibited a range from 83.17 to 98.06, with an arithmetic mean of 90.28. This mean value surpassed the 81.10 documented by Ayuti et al. (2021) as well as the 87.62 reported by Silvia et al. (2020). Based on the grading standards established by the USDA (2000), the haugh unit on day zero qualifies for grade AA (haugh unit ≥ 72), thus denoting exceptional freshness. By the sixtieth day, the haugh unit value experienced a reduction to 59.56, categorizing it within grade B (haugh unit < 60). The descriptive statistics corroborate a persistent decline across all three internal quality parameters as the duration of storage prolongs.

Correlation between Storage Duration and Yolk Index, Albumen Index, and Haugh Unit of Padjadjaran Quail Eggs

Statistical correlation analysis was employed to investigate the association between storage duration and the internal quality parameters of Padjadjaran Quail eggs, which encompass the yolk index, albumen index, and haugh unit. All examined variables exhibited a negative correlation that was statistically significant, thereby indicating a uniform decline in internal quality as time progresses. The findings are presented in Table 1.

The yolk index demonstrated a correlation coefficient of r = -0.894 with a significance value of 0.00 (p < 0.05), denoting a highly robust relationship. The magnitude of this correlation substantiates that the quality of the yolk is adversely impacted by extended storage. Structural degradation in the vitelline membrane arises from osmotic pressure differentials between the albumen and yolk, resulting in the translocation of water into the yolk (Argo et al., 2013; Cornelia et al., 2014). This phenomenon compromises the integrity of the membrane and diminishes the yolk's capacity to preserve its shape and firmness. Proteolytic enzymes progressively dismantle structural proteins within the membrane, thereby further diminishing yolk stability (Hanusová et al., 2016). These alterations contribute to the overall reduction in yolk index, which is consistent with observations made by Sudjatinah & Sampurno (2019).

The albumen index revealed a correlation coefficient of r = -0.983 and a p-value of 0.00 (p < 0.05), indicating a very strong relationship. The deterioration of albumen quality is intricately connected to fluctuations in pH and alterations in albumen structure. Given that albumen possesses a high water content, it is particularly susceptible to degradation during storage (Nasution, 2017). The loss of carbon dioxide through the shell pores elevates the pH of the albumen, thereby disrupting the bicarbonate buffer system and compromising the gel matrix established by ovomucin (Dudusola, 2010; Lukito et al., 2012). Ovomucin operates as a fibrous glycoprotein that binds water. Any structural damage to ovomucin diminishes its water-holding capacity and facilitates moisture migration into the yolk, culminating in a reduced albumen index (Wilkanowska & Kokoszynski, 2012).

The correlation coefficient analysis revealed an exceptionally strong negative relationship ($r = -0.991$) between storage duration and haugh unit (HU), which was statistically significant ($p < 0.05$), thereby indicating that prolonged storage adversely influences HU values, corroborating findings by Silva et al. (2020). The pronounced correlation is ascribed to physicochemical transformations within the internal structure of the egg, initiated by the loss of CO_2 through shell pores, which enlarges the air cell, diminishes egg weight, and elevates albumen pH. The elevated pH disrupts the acid-base equilibrium, leading to the degradation of albumen proteins such as ovomucin. Given that ovomucin is responsible for maintaining the viscosity of the albumen, its degradation results in a reduction of albumen height, thereby decreasing HU (Kusumastuti et al., 2013; Sihombing et al., 2014). Jazil et al. (2013) also verified that prolonged storage contributes to the reduction of HU values.

Regression between Storage Duration and Yolk Index, Albumen Index, and Haugh Unit of Padjadjaran Quail Eggs

Simple linear regression was employed to investigate the correlation between the duration of storage and three internal quality metrics of Padjadjaran Quail eggs: yolk index, albumen index, and haugh unit. The findings revealed a uniform declining trend across all metrics, signifying a gradual deterioration in internal egg quality as time progressed.

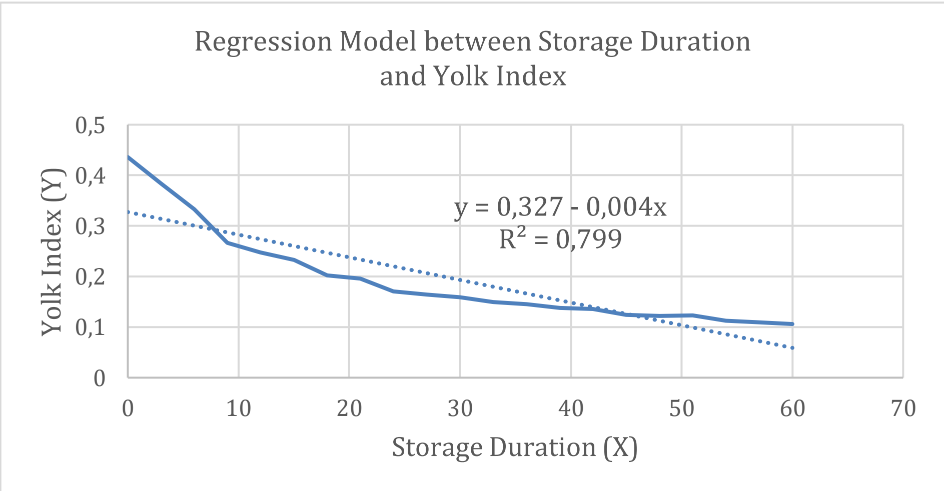

Illustration 1. Regression Model of Storage Duration and Yolk Index

The regression equation pertaining to the yolk index is expressed as $Y = 0.327 - 0.004X$ (Illustration 1). The y-intercept of 0.327 signifies the anticipated yolk index at the initial time point, prior to the influence of any storage conditions. The negative slope of –0.004 implies that the yolk index diminishes by 0.004 units on a daily basis, indicating a progressive reduction in yolk firmness over time. The coefficient of determination ($R^2 = 0.799$) reveals that 79.9% of the variability observed in the yolk index can be accounted for by the duration of storage, whereas the residual 20.1% may be subject to the effects of extrinsic variables such as temperature, humidity, and the quality of feed. These results are consistent with the findings of Ondrušiková et al. (2018), Sartika (2018), Sudjatinah & Sampurno (2019), and Wibawanti et al. (2017), which underscore the significance of environmental and nutritional determinants in maintaining yolk stability.

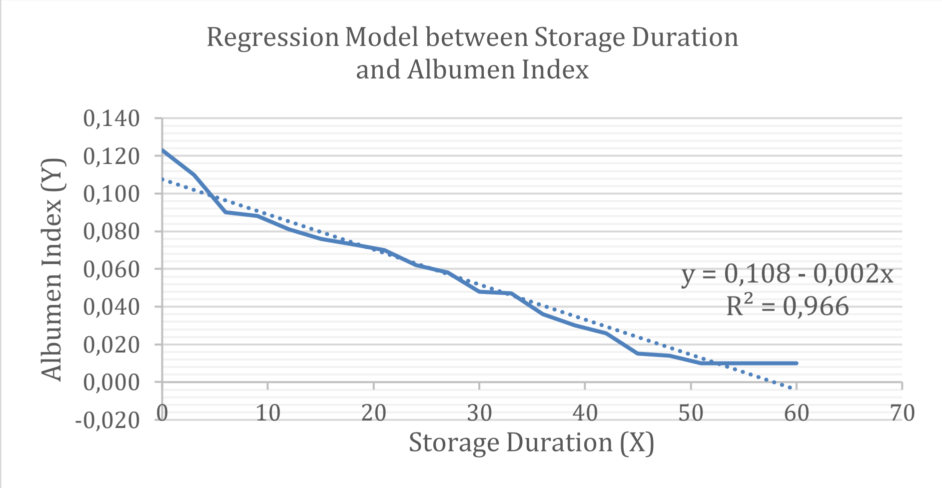

Illustration 2. Regression Model of Storage Duration and Albumen Index

The regression model for the albumen index is expressed as Y = 0.108 – 0.002X (Illustration 2). The intercept signifies the initial albumen index at the commencement of the storage period, whereas the negative coefficient indicates a marginal daily decline, which aligns with the progressive thinning of the albumen layer. The R^2 statistic of 0.966 implies that 96.6% of the observed variation can be accounted for by the duration of storage. The residual 3.4% may be attributed to factors such as nutritional intake, fluctuations in temperature, the health status of the hens, or the conditions of their housing, as articulated by Argo et al. (2013) and Nasution (2017).

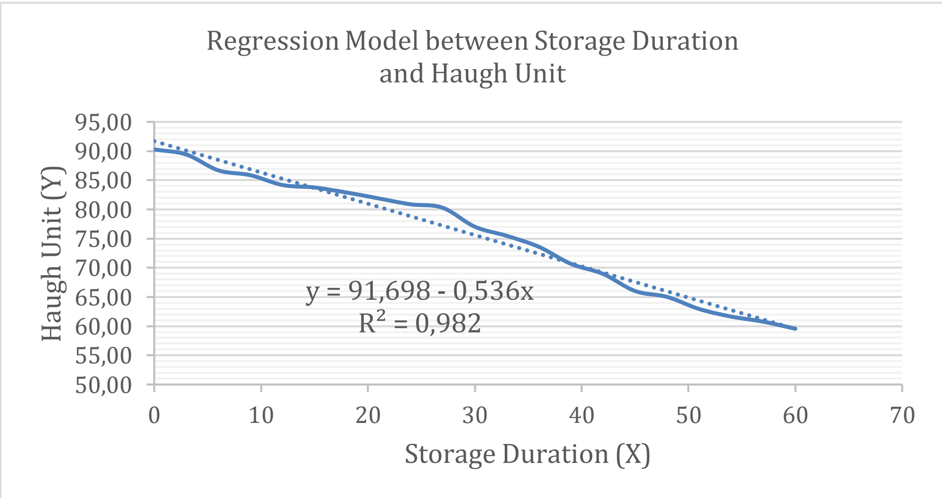

Illustration 3. Regression Model of Storage Duration and Haugh Unit

Concerning the haugh unit, the regression model is expressed as Y = 91.698 – 0.536X (Illustration 3). The initial parameter denotes the peak level of freshness at the zero-day mark. The gradient of –0.536 indicates a statistically significant daily decrement in the haugh unit, thereby denoting a continuous reduction in albumen height and overall freshness. The elevated R^2 value of 0.982 suggests that 98.2% of the variance in haugh unit is accounted for by storage duration, whereas the residual 1.8% could be attributed to variables such as moisture loss, alterations in albumen viscosity, egg mass, and protein concentrations. This assertion is corroborated by the findings of Amin et al. (2015), Bashir et al. (2015), and Lestari et al. (2013), who elucidate the impact of environmental changes and the structural attributes of eggs on haugh unit measurements.

Collectively, these findings substantiate that the duration of storage significantly influences the decline in internal quality of quail eggs. Continuous surveillance and optimal storage conditions are imperative to maintain the freshness and structural integrity of the eggs throughout the post-laying handling process.

Conclusion

1. The preservation period of 60 days resulted in a significant decrease in the yolk index from 0.44 to 0.11; the albumen index from 0.12 to 0.01; and the haugh unit from 90.28 to 59.56.
2. The duration of storage exhibited a robust correlation with the yolk index, albumen index, and haugh unit.
3. The regression models that explain the relationship between storage duration and each respective parameter are as follows: yolk index: Y = 0.327 – 0.004X; albumen index: Y = 0.108 – 0.002X; haugh unit: Y = 91.70 – 0.54X.

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