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Araştırma
(Research)

Prediction of Internal Quality Characteristics by Regression Equations Using External Quality Characteristics of Egg in Cream Coloured Laying Hens

Sezai ALKAN[1*]

[1]Ordu University, Faculty of Agriculture, Department of Animal Science, Ordu/TÜRKİYE

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Sorumlu yazar: Sezai ALKAN, e-posta: sezaialkan61@gmail.com

Abstract

Objective: This study was conducted to predict egg weight, eggshell weight, shell thickness, eggshell surface area, egg shape index, egg yolk height, egg yolk diameter, egg yolk, egg yolk weight, albumen weight using various egg characteristics as independent variables.

Materials and Methods: In this study, Lohmann Sandy eggs obtained from a commercial free range egg production enterprise in Ordu province were used. The eggs used in this study were collected at 24, 28, 32, 36, 40, 44, 48 and 52 weeks of age and calculations were made using a total of 30 eggs in each of these weeks. During the research, an electronic scale sensitive to 0.01 g was used for weighing the eggs, a caliper sensitive to 0.01 mm was used for measuring egg length, width, and yolk diameter, a flat glass-covered table was used for breaking the eggs, a tripod micrometer sensitive to 0.01 mm was used for measuring yolk and albumen height, and a micrometer sensitive to 0.01 mm was used for measuring shell thickness. In the study, regression equations were developed using eggs obtained at 24, 28, 32, 36, 40, 44, 48 and 52 weeks of age.

Results: In the study, egg weight was significantly and positively correlated with egg length and egg width and the correlation values were 0.569 and 0.859 for egg length and egg width, respectively. At the same time, a high phenotypic correlation was found between egg weight and white weight (0.957) and a highly significant correlation was found between egg weight and yolk weight (0.610). A highly significant and positive correlation was found between albumen index and albumen height (0.893), while significant and negative correlation was found between albumen index and albumen width (-0.575).

Conclusion: Based on the findings, the examined traits can serve as selection criteria for improving egg weight. Furthermore, the identified correlations between internal and external egg quality traits suggest that these parameters can be improved through selection.

Keywords: Egg quality, Free range system, Lohmann Sandy, Phenotypic correlation, Regression equation

Krem Rengi Yumurtacı Tavuklarda Yumurtanın Dış Kalite Özellikleri Kullanılarak İç Kalite Özelliklerinin Regresyon Eşitlikleriyle Tahmin Edilmesi

Öz

Amaç: Bu çalışmada, çeşitli yumurta özelliklerini bağımsız değişken olarak kullanarak yumurta ağırlığı, yumurta kabuğu ağırlığı, kabuk kalınlığı, yumurta kabuğu yüzey alanı, yumurta şekil indeksi, yumurta sarısı yüksekliği, yumurta sarısı çapı, yumurta sarısı ve ak ağırlığının tahmin edilmesi amaçlanmıştır.

Materyal ve Yöntem: Bu çalışmada Ordu ilinde serbest sistemde yumurta üretimi yapan ticari bir tavuk işletmesinden elde edilen Lohmann Sandy tavuklarına ait yumurtalar kullanılmıştır. Çalışmada kullanılan yumurtalar 24, 28, 32, 36, 40, 44, 48 ve 52 haftalık yaşlarda toplanmış ve bu haftaların her birinde toplam 30 adet yumurta kullanılarak hesaplamalar yapılmıştır. Araştırma sırasında yumurtaların tartılmasında 0,01 grama duyarlı elektronik terazi, yumurta uzunluğu, genişliği ve yumurta sarısı çapının ölçülmesinde 0,01 mm'ye duyarlı kumpas, yumurtaların kırılmasında düz cam kaplı masa, yumurta sarısı ve ak yüksekliğinin ölçülmesinde 0,01 mm'ye duyarlı üçayaklı mikrometre ve kabuk kalınlığının ölçülmesinde 0,01 mm'ye duyarlı mikrometre kullanılmıştır. Araştırmada 24, 28, 32, 36, 40, 44, 48 ve 52 haftalık yaşlarda elde edilen yumurtalar kullanılarak regresyon denklemleri geliştirilmiştir.

Araştırma Bulguları: Çalışmada, yumurta ağırlığı, yumurta uzunluğu ve yumurta genişliği ile önemli ve pozitif fenotipik korelasyon göstermiş olup korelasyon değerleri yumurta uzunluğu ve yumurta genişliği için sırasıyla 0,569 ve 0,859 olarak hesaplanmıştır. Aynı zamanda, yumurta ağırlığı ile ak ağırlığı arasında (0.957) ve yumurta ağırlığı ile yumurta sarısı ağırlığı arasında önemli ve pozitif fenotipik korelasyon (0.610) belirlenmiştir. Yine albumen indeksi ile albumen yüksekliği arasında önemli ve pozitif fenotipik korelasyon (0,893) bulunurken, albumen indeksi ile albumen genişliği arasında önemli ve negatif korelasyon (-0,575) bulunmuştur.

Sonuç: Bu çalışmada elde edilen sonuçlara göre, incelenen özellikler yumurta ağırlığını iyileştirmek için seleksiyon kriteri olarak kullanılabilir. Ayrıca, iç ve dış yumurta kalite özellikleri arasında belirlenen korelasyonlar üzerinde durulan parametrelerin seleksiyon yoluyla geliştirilebileceğini göstermektedir.

Anahtar kelimeler: Yumurta kalitesi, Serbest sistem, Lohmann Sandy, Fenotipik korelasyon, Regresyon denklemi

Introduction

Lohmann Sandy hens are known for their robust build, high egg production and adaptability. These hens are characterized by medium-sized bodies, a sandy or light brown plumage and strong legs. Known for their adaptability to various production environments, Lohmann Sandy hens excel in both conventional cage systems and alternative housing systems, making them a versatile choice for poultry producers worldwide. The body weight of Lohmann Sandy hens varies depending on their age. The body weight of an adult Lohmann Sandy hen is approximately 1400-1500 grams in 20 weeks. Their endurance and adaptability allow them to be easily raised in different geographical locations. Lohman Sandy pullets generally start laying at 18-20 weeks and their average annual egg production varies between 300-330 eggs. Egg production varies according to the genetic characteristics of the hens, care-feeding status, climatic conditions (temperature, humidity, etc.) and the level of stress they face. Under standard care-feeding and environmental conditions, Lohmann Sandy hens consume an average of 105 to 110 grams of feed per day. The egg color of Lohmann Sandy hens is white and cream-beige and they reach 50% egg production at an average age of 140-150 days. Peak egg production (97-98%) is reached at an average age of 23 weeks.

Egg quality is generally categorized into external and internal characteristics. Assessing certain traits, such as egg weight and various shape parameters, often requires breaking the eggs, which compromises their structural integrity. Research has highlighted those factors like egg weight, shell weight, shell thickness, yolk weight, albumen weight, albumen index, yolk index, and Haugh units are critical determinants of egg quality (Khurshid et al., 2003; Abanikannda et al., 2007; Alkan et al., 2010; Alkan et al., 2015).

A positive correlation between egg length, width, and weight has been consistently observed, enabling the estimation of egg weight from its dimensions (Farooq et al., 2001; Alkan et al., 2008; Alkan et al., 2015). This relationship suggests that egg weight can be inferred not only from external attributes, such as egg width, egg length, and shell thickness, but also from internal characteristics, including yolk width, yolk height, albumen height, and the Haugh unit. To achieve accurate predictions of egg weight based on these relationships, it is essential to determine the correlations and regression coefficients among the various external and internal components.

In this study aimed to predict several egg parameters, including egg weight, shell weight, shell thickness, shell surface area, shape index, yolk height, yolk diameter, yolk weight, and albumen weight, by utilizing a range of egg characteristics as independent variables.

Materials and Methods

The present study utilized Lohmann Sandy eggs obtained from a commercial free-range egg production facility located in Ordu province. The eggs were collected at specific intervals corresponding to the ages of 24, 28, 32, 36, 40, 44, 48, and 52 weeks, with 30 eggs sampled during each of these time points. Measurements were conducted using precise instruments: an electronic scale with an accuracy of 0.01 g for weighing, a caliper sensitive to 0.01 mm for determining egg length, width, and yolk diameter, and tripod micrometer with 0.01 mm sensitivity for yolk and albumen height measurements. Eggshell thickness was measured using a micrometer with the same level of precision, while egg breaking tests were performed on a flat, glass-covered surface.

Egg quality traits were assessed using established methodologies as described by Yannakopoulos and Tserveni-Gousi (1986), Peebles (2004), Narushin (2005), and Alkan et al. (2008). Data was analyzed using the SPSS statistical software package (SPSS Inc., 2008).

The following formulas were employed to calculate various egg quality parameters:

Shell surface area = 3.9782 x W^{7056}, where W is the egg weight in grams.

Shape Index (%) =100*(Egg width/Egg height)

Shell Ratio (%) =100*(Shell weight/Egg weight)

Albumen Index (%) =100*Albumen height/ [Albumen length Albumen width) /2]}

Albumen Weight (g)=Egg weight- (Yolk weight Shell weight)

Albumen Ratio (%) =100*(Albumen weight/Egg weight)

Yolk Index (%) =100*(Yolk height/Yolk diameter)

Yolk Ratio (%) =100*(Yolk weight/Egg weight)

Yolk/Albumen Ratio (%) =100*(Yolk weight/Albumen weight)

Haugh Unit=100 log [Albumen height-(1.7*Egg weight0.37) +7.57]

Egg Volume (cm^3) = [0.6057- (0.0018*Egg width)] *Egg length*(Egg width)2

Regression is a statistical method used to study the relationship between one dependent variable (often denoted as Y) and one or more independent variables (often denoted as X). The goal of regression analysis is to understand how the dependent variable changes as the independent variables change.

Results and Discussion

Prediction of egg weight from egg length and width

During the study, the following equations were developed to predict egg weight from egg length and width at 24, 28, 32, 36, 40, 44, 48 and 52 weeks.

Regression equation at 24th week;

Y =-103.135 + 0,971 * Egg length + 2.487 * Egg width (R^2=0,970)

Regression equation at 28th week;

Y =-107.662 + 1,105 * Egg length + 2.44 * Egg width (R^2=0,976)

Regression equation at 32nd week;

Y =-87.183 + 0,627 * Egg length + 2.588 * Egg width (R^2=0,878)

Regression equation at 36th week;

Y =16.971 + 0,599 * Egg length + 0.137 * Egg width (R^2=0,400)

Regression equation at 40th week;

Y =-106.683 + 1,189 * Egg length + 2.294 * Egg width (R^2=0,948)

Regression equation at 44th week;

Y =-126.013 + 1,111 * Egg length + 2.836 * Egg width (R^2=0,962)

Regression equation at 48th week;

Y =-139.061 + 0,937 * Egg length + 3.370 * Egg width (R^2=0,892)

Regression equation at 52nd week;

Y =-95.637 + 0,269 * Egg length + 3.265 * Egg width (R^2=0,724)

The general regression equation used to predict egg weight is given below:

Y =-18.084 + 0,815 * Egg length + 0.758 * Egg width (R^2=0,487)

where; Y = predicted egg weight.

Egg weight can be accurately estimated using egg width and length due to the strong relationship between these traits and egg weight. In the current study, the regression model explained 48.70% of the variation in egg weight. Similarly, Alkan et al. (2008) reported that egg length and width significantly influenced the weight of Japanese quail eggs, with a regression coefficient of 82.60%. The relationship between egg weight, width and length is well established and can be effectively modeled using various mathematical approaches. From simple volumetric approaches to sophisticated empirical models, these methods allow accurate estimation of egg weight from easily measurable dimensions. Consequently, these models are valuable in egg quality control processes and further scientific research on egg quality traits.

Prediction of eggshell weight from egg weight

The following equations were developed to predict eggshell weight from egg weight at 24, 28, 32, 36, 40, 44, 48 and 52 weeks.

Regression equation at 24th week;

Y=1,595+0,076* egg weight (R^2=0,246)

Regression equation at 28th week;

Y=1,526+0,076* egg weight (R^2=0,523)

Regression equation at 32^{nd} week;

Y=0,987+0,082* egg weight (R^2=0,473)

Regression equation at 36^{th} week;

Y=1,536+0,079* egg weight (R^2=0,454)

Regression equation at 40^{th} week;

Y=1,734+0,073* egg weight (R^2=0,237)

Regression equation at 44^{th} week;

Y=2,020+0,067* egg weight (R^2=0,290)

Regression equation at 48^{th} week;

Y=1,525+0,076* egg weight (R^2=0,522)

Regression equation at 52^{nd} week;

Y=6,072+0,006* egg weight (R^2=0,004)

The general regression equation used to predict eggshell weight is given below.

Y=2,016+0,068* egg weight (R^2=0,420)

where; Y = predicted eggshell weight

In this study, the adjusted R^2 value for the fitted model was 42.00%. Alkan et al. (2008) reported that egg length and width significantly influenced the eggshell weight in Japanese quails, with a regression coefficient of 50.70%. Similarly, Fajemilehin (2008) found a significant and positive correlation between egg weight and dimensions such as length and width in Guinea fowls, with regression coefficients of 7.40% for egg length, 8.20% for egg width, and 8.40% for egg weight. In general, there is a positive correlation between shell weight and surface area; that is, as surface area increases, shell weight tends to increase. The relationship between eggshell weight and surface area is a critical factor in understanding eggshell quality and strength. Mathematical models and empirical data help to predict and optimize this relationship. Usually, there is a direct relationship between the weight of the shell and its surface area. If the shell has a larger surface area, it usually contains more material and is therefore heavier.

Prediction of eggshell thickness from egg weight

The following equations were developed to predict eggshell thickness from egg weight at 24, 28, 32, 36, 40, 44, 48 and 52 weeks.

Regression equation at 24^{th} week;

Y=0,488-0,002* egg weight (R^2=0,067)

Regression equation at 28^{th} week;

Y=0,384-0,000* egg weight (R^2=0,001)

Regression equation at 32^{nd} week;

Y=0,396+0,000* egg weight (R^2=0,019)

Regression equation at 36^{th} week;

Y=0,396+0,001* egg weight (R^2=0,143)

Regression equation at 40^{th} week;

Y=0,391+0,000* egg weight (R^2=0,008)

Regression equation at 44^{th} week;

Y=0,407+0,000* egg weight (R^2=0,019)

Regression equation at 48^{th} week;

Y=0,392+0,000* egg weight (R^2=0,005)

Regression equation at 52^{nd} week;

Y=0,649-0,004* egg weight (R^2=0,055)

The general regression equation used to predict eggshell thickness from egg weight.

Y=0,478-0,001* egg weight (R^2=0,044)

where; Y = predicted eggshell thickness.

The eggshell is a complex structure that protects the egg and supports the development of the embryo. Shell surface area is a measure of the overall dimensions of the egg and is often related to the physical dimensions of the egg, such as its width and length. The shell accounts for about 10% of the total weight of the egg. Eggshell thickness is a critical characteristic that affects egg preservation and gas exchange. Generally, it can vary in different parts of the egg. In general, eggs with a larger surface area can have thicker or thinner shells. The relationship between eggshell thickness and eggshell surface area is an important factor in egg durability, hatching success and overall quality. Typically eggshell thickness decreases as surface area increases, indicating that larger eggs may be more fragile. Understanding and optimizing this relationship is critical for quality control and improvement in egg production. In this study, the regression coefficients were 4.40% for egg weight and 4.40% for egg surface area. However, Farooq et al. (2001) and Khurshid et al. (2003) also reported a significant relationship between eggshell thickness and egg width.

Prediction of eggshell surface area from egg weight

The following equations were developed to predict eggshell surface area from egg weight at 24, 28, 32, 36, 40, 44, 48 and 52 weeks.

Regression equation at 24^{th} week;

Y=22,825+0,832* egg weight (R^2=1,000)

Regression equation at 28^{th} week;

Y=24,985+0,795* egg weight (R^2=1,000)

Regression equation at 32^{nd} week;

Y=23,176+0,826* egg weight (R^2=1,000)

Regression equation at 36th week;

Y=23,938+0,812* egg weight (R^2=1,000)

Regression equation at 40th week;

Y=24,787+0,798* egg weight (R^2=1,000)

Regression equation at 44th week;

Y=25,325+0,789* egg weight (R^2=1,000)

Regression equation at 48th week;

Y=25,210+0,791* egg weight (R^2=1,000)

Regression equation at 52nd week;

Y=25,792+0,782* egg weight (R^2=1,000)

The general regression equation used to predict eggshell surface area from egg weight.

Y = 24.505 + 0.802 * egg weight (R^2=1,00)

where; Y = predicted eggshell surface area.

This value indicates how well the model explains the variance of the dependent variable. In the given case, the R^2 value is given as 1.00, i.e. 100%. This indicates that egg weight explains the entire variance in eggshell surface area. That is, on the data set in this model, egg weight fully explains the shell surface area. An R^2 value of 1.00 indicates that the model perfectly explains the eggshell surface area in the data set. This indicates that egg weight is the sole determinant of the variation of shell surface area and other factors do not affect this relationship. Generally, this relationship is positively correlated, i.e. the greater the surface area, the greater the egg weight. This indicates that this model is quite robust and reliable for predicting eggshell surface area in practical applications. Using egg weight information, we can make precise predictions about the shell surface area. Usually, eggs with larger surface area are heavier, but this relationship can change in a nonlinear way. Alkan et al. (2008) identified a strong correlation between eggshell surface area and egg weight in Japanese quails, with a regression coefficient of 99.40%. Similarly, studies by Farooq et al. (2001), Khurshid et al. (2003), and Gulnavaz (2002) reported a significant relationship between eggshell thickness and egg width.

Prediction of egg shape index from length and width

The following equations were developed to predict egg shape index from egg length and width at 24, 28, 32, 36, 40, 44, 48 and 52 weeks.

Regression equation at 24th week;

Y=0,742-0,013* egg length+0,018*egg width (R^2=0,981)

Regression equation at 28th week;

Y=0,761-0,014* egg length+0,018*egg width (R^2=0,985)

Regression equation at 32nd week;

Y=0,736-0,014* egg length+0,020*egg width (R^2=0,980)

Regression equation at 36th week;

Y=0,745-0,014* egg length+0,019*egg width (R^2=0,985)

Regression equation at 40th week;

Y=0,789-0,014* egg length+0,018*egg width (R^2=0,993)

Regression equation at 44th week;

Y=0,777-0,013* egg length+0,017*egg width (R^2=0,988)

Regression equation at 48th week;

Y=0,751-0,013* egg length+0,018*egg width (R^2=0,989)

Regression equation at 52nd week;

Y=0,771-0,013* egg length+0,017*egg width (R^2=0,989)

The general regression equation is used to predict egg shape index from egg length and width.

Y = 0.748- 0.014 * egg length + 0.018 * egg width (R^2=0,987)

where Y = predicted egg shape index

Egg shape index plays an important role in various practical applications because it can have an impact on egg quality, fragility, hatching success and even marketing characteristics. Egg shape index is an important factor affecting embryo development and hatching success. Round or overly long eggs can adversely affect gas exchange or temperature distribution during embryonic development, which can reduce hatching success. Egg shape index also has an impact on the physical strength of the egg. Generally, rounder eggs can be more advantages in terms of shell durability because they allow the shell to better resist pressure. Longer eggs can be more fragile during transportation, which can create problems in logistics and marketing. Egg shape index can affect the risk of egg breaking during storage and transportation. Round and symmetrical shaped eggs tend to be less damaged during packaging and transportation. Eggs with elongated or irregular shapes require more care during transportation and may require special packaging solutions. Egg shape index is an important parameter affecting the physical properties, quality and marketing value of eggs. It plays a critical role in both hatching success and consumer preference. Therefore, egg producers and researchers should carefully monitor egg shape index and try to optimize it. Understanding the shape index can be an important step in improving the efficiency and quality of egg production. The egg shape index was predictable with better accuracy from egg width and length. Regression coefficient of the fitted model was 98.70%.

Prediction of yolk height from egg weight

Following equations were developed to predict height of yolk from egg weight at 24, 28, 32, 36, 40, 44, 48 and 52 weeks.

Regression equation at 24th week;

Y=14,509+0,099*egg weight (R^2=0,140)

Regression equation at 28th week;

Y=17,935+0,039*egg weight (R^2=0,014)

Regression equation at 32nd week;

Y=7,691+0,294*egg weight (R^2=0,284)

Regression equation at 36th week;

Y=7,691+0,294*egg weight (R^2=0,284)

Regression equation at 40th week;

Y=11,211+0,117*egg weight (R^2=0,199)

Regression equation at 44th week;

Y=16,727+0,062*egg weight (R^2=0,079)

Regression equation at 48th week;

Y=18,795+0,027*egg weight (R^2=0,011)

Regression equation at 52th week;

Y=15,893+0,076*egg weight (R^2=0,123)

The general regression equation used to predict the height of yolk from egg weight.

Y=19,973+0,010*egg weight (R^2=0,001)

where Y = predicted height of yolk

This regression equation expressed a linear model that predicts the height of the yolk (dependent variable) using egg weight (independent variable). The very low R^2 value (0.1%) indicates that egg weight is hardly effective in predicting yolk height. In other words, yolk height is a highly variable trait that cannot be explained by egg weight and depends on other factors. Many factors can affect the height of the yolk. These factors may include the shape of the egg, genetic characteristics of the laying hen, nutritional status, age of the egg and other biological variables.

Prediction of yolk diameter from egg width

Following equations were developed to predict diameter of yolk from egg width at 24, 28, 32, 36, 40, 44, 48 and 52 weeks.

Regression equation at 24th week;

Y=28,200+0,188*egg width (R^2=0,022)

Regression equation at 28th week;

Y=8,871+0,705*egg width (R^2=0,154)

Regression equation at 32nd week;

Y=-2,965+0,994*egg width (R^2=0,346)

Regression equation at 36th week;

Y=4,224+0,828*egg width (R^2=0,499)

Regression equation at 40th week;

Y=-5,218+1,025*egg width (R^2=0,245)

Regression equation at 44th week;

Y=-3,142+0,997*egg width (R^2=0,422)

Regression equation at 48th week;

Y=-39,894+0,000*egg width (R^2=0,000)

Regression equation at 52nd week;

Y=18,074+0,496*egg width (R^2=0,135)

The general regression equation is used to predict the diameter of yolk from egg width.

Y=5,145+0,790*egg width (R^2=0,474)

where Y = predicted diameter of yolk

Yolk width could be reliably estimated from egg width, with the regression model demonstrating a coefficient of 55.20%. By measuring the width of the egg, a reasonable estimate of the diameter of the yolk can be made. Yolk diameter is an important criterion in determining the nutritional value and quality characteristics of the egg. Egg yolk contains nutrient-important components, and the size of the yolk affects its total nutritional value. Estimation of yolk diameter can be used to assess the nutritional value and commercial value of the egg. Egg producers can perform quality control and classify eggs by estimating yolk diameter based on egg width. Estimating the yolk diameter from the width of the egg is a simple and quick method. Width measurement is a widely used metric when assessing the physical properties of eggs and the model is therefore easy to use in practice. The yolk diameter generally increases with egg width. This model provides practical benefits in applications such as quality control and grading in egg production.

Prediction of yolk weight from egg weight

Following equations were developed to predict weight of yolk from egg weight at 24, 28, 32, 36, 40, 44, 48 and 52 weeks.

Regression equation at 24th week;

Y=9,002+0,066*egg weight (R^2=0,043)

Regression equation at 28th week;

Y=-0,379+0,262*egg weight (R^2=0,421)

Regression equation at 32nd week;

Y=-0,631+0,270*egg weight (R^2=0,446)

Regression equation at 36th week;

Y=2,308+0,236*egg weight (R^2=0,389)

Regression equation at 40th week;

Y=-3,649+0,315*egg weight (R^2=0,503)

Regression equation at 44th week;

Y=6,669+0,165*egg weight (R^2=0,287)

Regression equation at 48th week;

Y=10,668+0,094*egg weight (R^2=0,211)

Regression equation at 52th week;

Y=5,711+0,178*egg weight (R^2=0,372)

The general regression equation used to predict weight of yolk from egg weight:

Y =-1.122 + 0.280 * egg weight (R^2=0,552)

where Y = predicted weight of yolk

Yolk weight could be predicted with greater accuracy based on egg weight, with the fitted model yielding a regression coefficient of 55.20%. The yolk is rich in protein, fat and other nutrients. Estimating the weight of the yolk provides information about the nutritional value of the egg. Egg producers can perform quality control and grade eggs by estimating yolk weight based on egg weight. By measuring the weight of the egg, a reasonable estimate of the weight of the yolk can be made. This is particularly useful when it is difficult or inconvenient to weigh the components of the egg separately.

The phenotypic correlations between external and internal egg quality traits

The phenotypic correlations between external and internal egg quality traits of Lohmann Sandy hens are given in Table 1.

The phenotypic correlation between egg weight and egg shape index was found to be significant (0.311) in this study. Understanding this relationship is important for various reasons, including optimizing breeding programs, improving egg quality, and enhancing the efficiency of egg production. Eggs with certain weights and shapes may be more resistant to breaking during handling and transport, affecting their marketability and shelf life. Generally, larger eggs tend to have higher egg shape index values, implying they are relatively rounder. This is because as egg weight increases, both dimensions (length and width) tend to increase, but the width may increase more proportionally, resulting in a rounder shape. Studies investigating the relationship between egg weight and egg shape index have produced mixed results. While numerous studies on hens have reported a negative, though often statistically insignificant, correlation between egg weight and shape index, this suggests that heavier eggs tend to be longer (Tebesi et al., 2012; Begli et al., 2010; Nowaczewski et al., 2008; Kul and Seker, 2004; Rozycka and Wezyk, 1985). Conversely, research by Bernacki and Heller (2003) on Guinea hens found that heavier eggs had a higher shape index, indicating a rounder, more spherical shape.

In the present study, egg weight exhibited a significant positive correlation with both egg length and egg width, with correlation coefficients of 0.569 and 0.859, respectively. This positive relationship demonstrates that an increase in egg length is associated with an increase in egg weight. The relationship between egg weight and its dimensions, specifically egg length and egg width, is an important area of study in poultry breeding. Understanding how these dimensions correlated with egg weight helps in improving breeding practices, optimizing egg production, and enhancing quality control measures. Egg weight is inherently related to its physical dimensions. Egg width more directly affects the total volume of the egg and therefore its weight. The width represents the diameter of the egg and even a small increase in width can result in a significant increase in total volume and weight. Eggs are usually oval in shape and therefore the width more directly determines the central volume of the egg and thus its total mass. Length is less directly related to the shape of the egg. Egg length was also reported to significantly affect egg weight by Momira et al. (2003). However, the relationship between egg weight and egg width was significant. This may be attributed to the fact that the yolk covers the width area and therefore the eggs are heavier. Understanding these relationships helps in selecting hens that produce eggs of desirable size and shape.

Table 1. The phenotypic correlations between external and internal egg quality traits of Lohmann Sandy hens

Traits	SW	YW	YH	YWDT	AH	AWDT	AL	EWDT	EL	ST	AI	YI	SI	SFA	SR	HU	EWL	AW	Y/A	YR	AR
EW	,061	,610**	,350	,477**	,190	,351	,122	,845**	,421*	, -234	,037	, -034	,245	1,00**	, -641**	, -003	,808**	,957**	, -437*	, -332	,592**
SW		,035	,177	,022	, -079	,159	,217	,231	,392*	, -178	, -126	,151	,289	,064	,675**	, -102	,100	, -048	,024	, -110	, -227
YW			,482**	,686**	,275	,045	, -061	,518**	,517**	,099	,232	, -064	, -120	,609**	, -443*	,136	,62**	,369*	,439*	,530**	, -234
YH				,380*	,662**	, -185	,000	,408*	,164	, -195	,572**	,686**	,164	,347	,188	,583**	,375*	,226	,147	,188	, -072
YWDT					,193	,042	,087	,367*	,546**	, -020	,145	, -405*	, -239	,476**	, -319	,062	,523**	,322	,228	,308	, -097
AH						, -217	, -158	,228	,004	, -269	,893**	,483**	,168	,184	, -113	,977**	,177	,136	,078	,108	, -004
AWDT							,622**	,380*	,239	, -080	, -575**	, -208	,039	,352	-,084	, -246	,377*	,379*	, -324	, -347	,315
AL								,148	,287	,052	, -492**	, -052	, -156	,120	,135	, -146	,232	,141	, -177	, -169	,093
EWDT									,392*	, -344	,037	,113	,408*	,843**	, -377*	,068	,902**	,788**	, -379*	, -308	,453*
EL										,122	, -103	, -241	, -674**	,417*	, -407*	, -092	,749**	,331	,094	,194	,025
ST											, -226	, -202	, -407*	, -235	,003	, -225	, -190	, -289	,402*	,409*	, -325
AI												,435*	,125	,032	, -085	,877**	, -007	, -023	,191	,227	, -122
YI													,325	, -036	,174	,507**	, -029	, -035	, -034	, -054	,000
SI														,247	,104	,138	, -022	,297	, -413*	, -450*	,350
SFA															, -640**	, -008	,804**	,957**	, -438*	, -334	,593**
SR																,009	, -468**	, -672**	,256	,091	, -516**
HU																	, 016	, -039	,139	,149	, -098
EVL																		,724**	, -224	, -126	,336
AW																			, -664**	,558**	,798**
Y/A																				,972**	, -946**
YR																					, -873**

*:P<0,05, **:P<0,01; EW: Egg weight, SW: Shell weight, YW: Yolk weight, YH: Yolk height, YWDT: Yolk width, AH: Albumen height, AWDT: Albumen width, AL: Albumen length, EWDT: Egg width, EL: Egg length, ST: Shell thickness, AI: Albumen index, YI: Yolk index, SI: Shape index, SFA: Shell surface area, SR: Shell ratio, HU: Haugh unit, EWL: Egg volume; AW: Albumen weight, Y/A: Yolk/albumen, YR: Yolk ration, AR: Albumen ratio

Breeders can use these correlations to predict egg weight from easily measurable dimensions (length and width), aiding in quality control and selection processes. Producers can use the relationships between weight and dimensions to standardize egg sizes and improve packaging and storage practices.

In this study, a non-significant positive relationship was found between egg weight and eggshell weight (0.061). The positive value of this value indicates that the eggshell weight tends to increase slightly as the egg weight increases. This finding indicates that there is almost no relationship between egg weight and eggshell weight, and even if there is a relationship, it is very weak. This may be because the eggshell weight may be shaped independently of the egg weight. For example, the total weight of an egg may depend more on the amount of liquid it contains, whereas the weight of the shell may be determined more by genetic or environmental factors. Egg weight has an indirect relationship with eggshell quality. Therefore, most researchers have reported that eggshell thickness has a direct relationship with egg weight Choi et al. (1983); Stadelman (1995 a). Some researchers mentioned a positive correlation between egg weight and shell thickness (Stadelman, 1995 b; Nowaczewski et al. 2008; Kul and Seker (2004). When it is stated that there is a positive correlation between egg weight and shell thickness, this implies that heavier eggs tend to have a thicker shell. Larger and heavier eggs may need thicker shells to preserve the contents and protect them from cracking. The shell provides the mechanical strength of the egg. So, it makes sense for a heavier egg to have a thicker shell. During the development of the egg, the internal pressure of the egg increases as the embryo grows. Eggs with thicker shells tend to break less during storage and are generally considered to be of better quality. A thick shell can increase the resistance to this pressure. This relationship between egg weight and shell thickness can be considered when packing and transporting eggs. Eggs with thicker shells are more durable and less likely to be damaged. In this study, a high phenotypic correlation was found between egg weight and white weight (0.957) and a highly significant correlation was found between egg weight and yolk weight (0.610). The findings obtained in this study are consistent with the reports of Obike and Azu (2012), Tebesi et al. (2012), and Kul and Seker (2004) who found highly significant correlations between egg weight and albumen weight and yolk weight. These results indicate that as albumen and yolk weight increase, egg weight also increases. Therefore, selection for egg weight will always select for eggs with larger albumen and yolk weights, which are necessary for embryo development.

Yolk weight was significantly correlated with yolk width (0.686). A value of 0.686 indicates a medium to high correlation strength. In this case, we can say that as the yolk width increases, the yolk weight generally increases. From a biological point of view an increase in the width of the yolk may indicate that the yolk is larger and therefore contains more substances. Therefore, as the width increases, the weight also increases. From a practical point of view this relationship can be used to assess egg quality or size. For example, you can make an estimate of the weight of the yolk by measuring the width. Yolk width likely represents a substantial portion of the yolk, potentially contributing positively to yolk weight. A non-significant negative correlation was observed between yolk weight and yolk index (−0.064), aligning with findings from Obike and Azu (2012) and Nwagu et al. (2010). Additionally, a significant negative correlation (−0.405) was identified between yolk index and yolk diameter. This outcome is expected, as yolk diameter plays a crucial role in determining the yolk index. Conversely, the relationship between yolk index and yolk height was strongly positive and significant (0.686). Furthermore, the yolk index showed a significant positive correlation with albumen height (0. 483), suggesting that improvements in yolk diameter, yolk height, and albumen height would enhance the yolk index. Since yolk index is a key indicator of egg freshness, these improvements could also lead to fresher eggs. In this study, a highly significant positive correlation was observed between albumen index and albumen height (0. 893), whereas a significant negative correlation was found between albumen index and albumen width (−0.575).

Conclusion

Regression equations are a powerful tool for predicting internal egg quality characteristics based on the external quality characteristics of hen eggs. These equations can help producers develop strategies to optimize internal quality, ensuring that consumers receive more consistent and higher-quality eggs. Therefore, regression analysis plays an important role in the fowl egg industry for both producers and consumers. Producers can make informed decisions to improve egg quality and production efficiency by using regression models. Further research and refinement of these models could lead to even more accurate predictions and better management practices in Lohmann Sandy fowl egg production. Phenotypic correlation is a measure of the relationship between two or more phenotypic traits. Understanding the phenotypic correlations among egg quality characteristics is essential for enhancing the effectiveness of selection programs and optimizing the production of high-quality eggs. According to this result, these traits should be used as selection criteria to improve egg weight. Also, poultry researchers will study egg quality traits as well as the activities of breeders engaged in breeding and breeding of Lohmann Sandy hen eggs.

Conflict of Interest

The author declares no conflicts of interest.

Kaynaklar

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