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RESEARCH ARTICLE

Prediction of the length and width of quail eggs using linear regression analysis

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Lineer regresyon analizi ile bıldırcın yumurtası boyu ve eninin tahmini

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Öz

Amaç: Bu çalışma, bıldırcın yumurta boyu ve yumurta eni değerlerinin tahmini için bıldırcın yumurta ağırlık değeri kullanarak regresyon eşitliklerini ve belirlenen regresyon eşitliğinin hata oranını belirlemek amacıyla yapılmıştır.

Gereç ve Yöntem: Yumurta toplama işlemi denklem oluşturmak (Haziran-Ağustos) ve denklem doğruluk oranı (Eylül-Ekim) için farklı zamanlarda yapılmıştır. Yumurtaların sayısal ölçüm değerleri ortalama ve standart sapma kullanılarak özetlenmiştir. Bıldırcın yumurtasının boyu ve eni bağımlı değişkenleri sırayla ağırlık bağımsız değişkeni kullanılarak Lineer Regresyon Analizi ile modellenmiştir.

Bulgular: Bıldırcın yumurta boyu ve eni bağımlı değişkenler için oluşturulan eşitlik (1) ve (2), yumurta boyu ve eninin tahmini için oldukça yüksek performansa sahip olduğu saptanmıştır. Her iki denklemle elde edilen R^2 değeri 0.99 olup yumurta ağırlık değişkeninin bıldırcın yumurta boyu ve eni değişkenlerindeki toplam değişimi açıklama oranı %99 olarak bulunmuştur. Önerilen yumurta boyu regresyon denklemi ile Rahn and Paganelli (1988) denklemi arasında ortalama farkının testi istatistiksel olarak anlamlı bulunmamıştır (P=0,939).

Öneri: Önerilen bıldırcın yumurta eni regresyon denkleminin Rahn and Paganelli (1988) denkleminden daha başarılı olduğu ve ortalama farkın istatistiksel olarak anlamlı olduğu belirlenmiştir.

Anahtar kelimeler: Coturnix japonica, yumurta ağırlığı, denklem, yumurta boyu ve eni

Abstract

Aim: This study was aimed at establishing regression equations for the estimation of egg length and egg width values using egg weight values in quail eggs, and at determining the error rate of the regression equations established.

Materials and Methods: Quail eggs were collected twice, between June and August to be used for the establishment of equations, and between September and October to be used for the assessment of the accuracy of the equations established. The numeric measurements of the eggs are presented as means and standard deviations.

Results: Equations were established for the estimation of the dependent egg length and egg width variables using the independent egg weight variable with linear regression analysis. It was determined that equations (1) and (2) established for the estimation of egg length and egg width, respectively, both performed very well. The R^2 value was 0.99 for both equations, which demonstrated that the egg weight variable had a share of 99% in describing the total change in the egg length and egg width variables. The mean difference between the regression equation established in this study for the estimation of egg length and the Rahn and Paganelli (1988) equation was found to be statistically insignificant (P=0.939).

Conclusion: In result, the regression equation established in this study for the estimation of quail egg width was ascertained to perform better than the Rahn and Paganelli (1988) equation, and the mean difference between these two equations was statistically significant.

Keywords: Coturnix japonica, egg weight, equations, egg length and width

Introduction

Despite its importance, record keeping is generally perceived as a burden by staff working at animal production units. The most common records kept at egg production units are the number of eggs produced and total egg weight. Apart from egg weight, egg length and egg width are also important parameters for hatching egg and table egg production units. This is due to egg shape being a quality trait highly valued by consumers (Artan and Durmus 2015). Eggs are kept in cartons, as a protective packaging material, after being collected, while being stored and during sales exposition, and eggs of abnormal size and shape are observed not to maintain their eggshell quality in these cartons. For example, when placed in cartons, very large eggs may suffer from eggshell fractures, and very small eggs may undergo yolk displacement because of exposure to excessive tremor during transport (Seydim and Dawson 1999).

Parameters used to define the quality of hatching and table eggs include eggshell, yolk and albumen values. In this context, egg quality traits are classified under two groups, namely, external and internal quality traits. Excluding egg weight and some egg shape characteristics, the detection of some other external and internal egg quality traits requires the breaking out of eggs, thus, the impairment of egg integrity (Alasahan and Gunlu 2012, Sogunle et al. 2017). Therefore, in poultry species with low annual breeding ratios, the detection of these traits reduces the annual number of broods and puts flock sustainability under risk. On the other hand, in poultry species with a breeding pattern distributed throughout the year, broken eggs constitute the primary disadvantage to holding profitability (Moosanezhad Khabisi et al. 2012).

Table eggs are important as a food product and hatching eggs are important for the continuation of the existence of poultry species. At facilities, where both types of eggs are produced, quality traits need to be determined. Egg length-width and the surface cleanliness of the eggshell are quality traits that can be assessed at the first instance for the sake of food safety and animal health. Based on the requirements of the Turkish Food Codex in force, egg shape index is the main egg shape trait of interest. To determine whether the eggs produced meet the egg shape index requirement stipulated in the legislation, the length and width of the eggs need to be measured. However, holdings with high egg production numbers may tend to use carton measurements instead of specific egg length and width measurements. Therefore, the risk of encountering eggshell fractures is high in eggs purchased without checking the content of the carton.

The conventional way of determining egg quality traits, at holdings and in scientific research, is calliper measurement (Duman et al. 2016). Furthermore, egg quality test devices may be preferred to be used in large-scale projects. These devices are capable of determining whole egg weight, dry eggshell weight, eggshell resistance to impact, albumen height, Haugh unit, eggshell thickness, vitelline membrane resistance to laceration, and yolk colour. Another method used for eggshell quality assessment is digital image analysis. This method is based on imaging, the saving of the images taken, and the performance of measurement on these images using image analysis software. However, although egg quality test devices and digital image analysis software are advantageous with respect to the accuracy of results and schedule management, they are also rather costly. On the other hand, the individual error rate of calliper measurement varies with the experience level of the measurer.

Several studies have pointed out to the significance of egg shape characteristics for consumer preferences and hatchability results (Kamanli et al. 2010, Alasahan and Copur 2016, Hristakieva et al. 2017). Thus, although it may be perceived as a burden by staff working at animal holdings, it is considered that keeping records for at least egg shape characteristics would be useful in view of the correlation of these characteristics with egg quality. Accordingly, based on the correlation between egg weight and egg shape characteristics, data belonging to eggs laid by small birds have been used to establish equations for the prediction of egg shape characteristics (Rahn and Paganelli 1988, Narushin 2005). However, some studies suggest that these equations do not produce accurate results for large eggs. Thus, it is important that separate specific equations be established for each poultry species, so that egg weight values can be used for the prediction of egg shape characteristics. The use of equations specific to each species would compensate for the error rate associated with calliper measurements performed either inattentively or at the wrong level of the egg.

This study was aimed at establishing regression equations

Table 1. Descriptive statistics for egg weight, egg length and egg width (n=3551)

Egg Weight mean ± sd	Egg Length mean ± sd	Egg Width mean ± sd
11.579±1.047	32.499±1.439	23.995±1.032

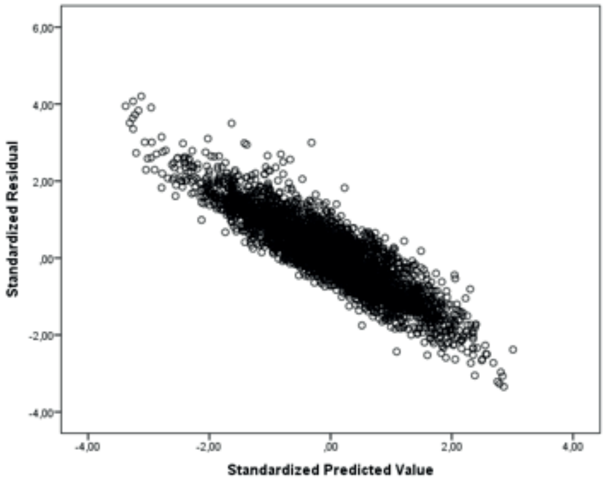

Figure 1. The distribution of the residual values against the predicted values used in the detection of the heteroscedasticity problem for the dependent length variable and the independent weight variable.

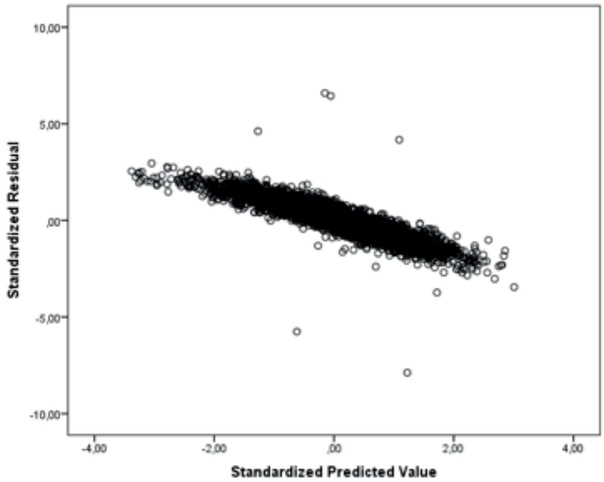

Figure 2. The distribution of the residual values against the predicted values used in the detection of the heteroscedasticity problem for the dependent width variable and the independent weight variable.

for the determination of egg length and egg width values, used for the calculation of egg shape characteristics (shape index and elongation) with the egg weight value. Furthermore, it was aimed to compare the newly established regression equations with equations previously established for small bird eggs in terms of associated error rate.

Materials and Methods

Eggs laid by Japanese quails with yellow plumage (Coturnix japonica), raised at the Alternative Poultry Research and Application Unit of Mustafa Kemal University, Faculty of Veterinary Medicine, constituted the study material. Eggs were collected at two different time points for the establishment of equations and the testing of the accuracy of the equations established. For the establishment of equations, 3551 eggs were collected throughout a 3 month-period, from the beginning of June to the end of August. Another 1000 eggs were collected during a 1 month-period, between the 1st of September and the 30th of October, for the detection of the accuracy of the equations established.

The eggs used in this study were collected on a daily basis. Within one hour of collection, each egg was measured for weight, length and width. Egg weight values (g) were measured using an electronic balance with 0.01 g precision, and egg length (mm) and width (mm) values were measured with a digital calliper.

The weight, length and width values of the 3551 eggs collected for the establishment of equations were compiled in an excel document. The statistical analysis of the data was performed using an R version 3.5.0 programming language and the Minitab Version 17.0 software package. Numerical measurements were expressed as mean values and standard deviations. The egg length and egg width variables were modelled using the egg weight variable and linear regression analysis. Due to the linear regression models not meeting the constant variance hypothesis, the Box-Cox transformation was used.

Equation; $y=\beta_1 〚(x)〛^{(\beta_2)}+\varepsilon$

Furthermore, with an aim to test the validity of the equation, apart from the data set of the 3551 eggs, a new data set of 1000 observations was established, and the error rates of our equation and the equation previously developed by Rahn and Paganelli (1988) were determined. The mean error rate difference was analysed using the t-test in separate groups. The statistical significance was set at 0.05 in all tests.

Egg length = 14,7 x (egg weight)^{0,341}

(Rahn and Paganelli (1988) equation)

Egg width = 11,3 x (egg weight)^{0,327}

(Rahn and Paganelli (1988) equation)

Results

Establishment of the regression equation

Table 2. The regression equation developed for the dependent length and width variables and the independent weight variable

	$\hat{\beta}$	se($\hat{\beta}$)	R^2
Egg weight*	13.04938	0.0059	0.999
Egg weight**	8,01571	0.0043	0,999

* The dependent length variable and the independent weight variable
** The dependent width variable and the independent weight variable

Table 3. Descriptive statistics for egg weight, egg length and egg width

	Weight mean ± sd	Length mean ± sd	Width mean ± sd
Measured values	11,68±1,22	32,66±1.66	23,82±1,01
Proposed equation	------	32,62±1,28	24,10±1,13
RP equation	------	33,95±1,22	25,21±0,87
		Error (%)*	
	Proposed Equation mean ± sd	RP Equation mean ± sd	P-value
Length Estimation	-4,077±0,354	-4,067±3,767	0,939
Width Estimation	-1,241±4,173	-5,974±4,053	<0.001

*Comparison of the two equation for length and width of quail egg (n=1000)

The descriptive statistics for the weight, length and width of the 3551 eggs, collected for the establishment of equations, are presented in Table 1.

Constant variance is one of the assumptions of linear regression. The Breusch-Pagan test confirmed that the regression equation developed for the dependent egg length variable and the independent egg weight variable suffered from heteroscedasticity. According to this test, the p value was 0.319 and the assumption of constant variance assumption was invalid. Figure 1 supports this finding, and it was determined that a problem of decreasing variation existed.

The regression equation obtained using the Box-Cox transformation is as shown in equation (1).

Egg length =13.04938x(egg weight)$^{0.373272}$ (1)

The regression equation developed for the dependent width variable and the independent weight variable presents with the problem of heteroscedasticity (p=0.656). Figure 2 supports this finding.

The regression equation obtained using the Box-Cox transformation is as shown in equation (2).

Egg width=8.01571x(egg weight)$^{0.448338}$ (2)

Equations (1) and (2) perform very well in the estimation of the egg length and width values. The R^2 value was calculated as 0.99 for both equations. Thus, the weight variable describes the total change in the length and width variables at a rate of 99%.

Determination of the rate of accuracy

The means and standard deviations of the measurements, proposed equation and RP equation values of the 1000 eggs (collected in addition to the 3551 eggs used for the development of the estimation equation) are presented in Table 3. The relative error rate of the proposed equation was compared to the relative error rate of the equation established by Rahn and Paganelli (1988) (Table 3). Accordingly, the mean difference between the equation established in the present study for the prediction of egg length and width and the equation established by Rahn and Paganelli (1988) was found to be statistically insignificant. Thus, it was found that both equations had similar error rates (p=0.939).

The proposed equation for egg width is more successful than the equation proposed by Rahn and Paganelli (1988). For, the mean value was closer to zero and the mean difference between it and the equation established by Rahn and Paganelli (1988) was statistically significant (p<0.001).

Discussion

In the present study, the linear regression model was used for the prediction of the length and width of yellow japanese quail eggs. The coefficient of determination (R^2 value), which was used to assess the usefulness of the regression equation developed to estimate egg length and width, separately, was 0.999. This R^2 value implies that the share of the egg weight variable in describing the total change in the egg length and egg width variables was 99%. Uckardes et al. (2012) reported the R^2 value of the equation they established with the ridge regression method for the estimation of the albumen index of japanese quail eggs using egg weight, egg length, egg width, Haugh unit and shape index values as 0.787. This value is lower than the R^2 value determined in the present study. This difference may have arisen from different sample sizes and numbers of variables (Montgomery et al. 2012, Weisberg 2005). Seker (2004) and Orhan et al. (2016) suggested that egg weight could be used for the estimation of albumen weight and yolk weight. This suggestion is in agreement with the result of the present study demonstrating egg weight to have a share of 99% in the estimation of egg length and egg width values. In another study conducted by Rafhert et al. (2011), the internal quality traits of Japanese quail eggs were estimated on the basis of external quality trait variables using the principal component regression analysis. This study showed that the internal quality traits of eggs could be estimated with better accuracy using external quality trait variables, which is in agreement with the result of the present study demonstrating that egg weight can be used for the prediction of egg length and egg width values at an accuracy rate of 99%.

In the present study, following the establishment of the regression equations for the egg traits investigated, the error rate of the proposed equations in comparison to that of the RP equation was detected on the basis of the egg length and egg width measurements (Table 4). Accordingly, the error rates determined for the estimation of egg length using the proposed equation (32.62 mm) and the RP equation (33.95 mm) were found to be close to each other, and the estimated value obtained with the use of the proposed equation (32.62 mm) was observed to be closer to the egg length measurement (32.66 mm). On the other hand, the egg length values reported by Sari et al. (2016), Kumari et al. (2008) and Narinc et al. (2015) (34.80 mm, 33.00 mm and 33.93 mm, respectively) were observed to be closer to the values estimated with the RP equation (El-Tarabany et al. 2015). Mean egg weight estimations close to RP equation results were determined to be higher than the measurement results of the present study.

In the present study, the egg width estimation obtained with the proposed equation (24.10 mm) was closer to the egg width measurement (23.82 mm). The egg width values determined by measurement and the use of the proposed equation in the present study were found to be close to the egg width values reported by Daikwo et al. (2013) (23.20 mm), Ojedapo (2013) (24.30 mm), and Olawumi and Christiana (2017) (24.00 mm). On the other hand, the egg weight and egg width values determined by measurement and the use of the proposed equations in the present study were found to be lower than those reported by Alkan et al. (2010), Hanusova et al. (2016), Kumari et al. (2016) and Copur Akpinar et al. (2017). It should always be considered that egg weight is positively correlated with egg shape traits.

Conclusions

Record keeping is very important for poultry holdings. Thus, record keeping should not be limited to scientific research, and should be applied as routine practice in each poultry house. In this context, a regression equation was established in the present study for the prediction of egg shape traits with linear regression analysis at minimum error rates using the mean egg weight value (11.58 g). The equation developed in the present study was determined to have a low error rate particularly in the estimation of the egg width value. It is considered that, on the basis of the correlation between egg weight and egg shape traits, the conduct of further studies for the establishment of separate regression equations for different mean egg weight values would be a rational approach to minimize equation error rates.

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