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PREDICTION MODEL OF ALBUMEN INDEX IN DUCK EGGS VIA EXTERNAL QUALITY CHARACTERISTICS IN CASE OF MULTICOLLINEARITY

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Abstract: This study used multiple regression analysis to estimate the relationships between duck egg albumen index and external quality traits of eggs. Egg albumen index was selected as the dependent variable, and egg weight, width, length, shape index and Haugh unit were determined as independent variables. In the multiple regression analysis, it was determined that the overall fit of the model was quite high, but there were multicollinearity problem among the independent variables. In order to solve this problem, Ridge regression method, which is widely used in the literature, was applied. In order to determine the albumen index, egg weight (X_1), width (X_1), length (X_3), shape index (X_4) and Haugh unit (X_5) variables were used, $\hat{R} = +\widehat{18.2029} + \widehat{0.1362}X_1 - \widehat{0.5736}X_2 - \widehat{0.1596}X_3 + \widehat{0.0262}X_4 + \widehat{0.1921}X_5 + \hat{e}$. The regression equation was obtained and found to be statistically significant (P<0.05). The model's fit was determined as R2=0.901, and Ridge regression method reduced the standard errors of the parameters, reduced the errors caused by multicollinearity problem and increased the accuracy of the model. The results show that Ridge regression method effectively solves the problem of multicollinearity and increases the accuracy of prediction, making it more reliable. This also reveals that Ridge regression method can be used effectively in poultry breeding and selection studies.

Keywords: Duck egg characteristics, Multiple regression, Multicollinearity problem, Ridge regression method

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1. Introduction

In recent years, duck egg production has shown a remarkable increase in both nutritional value and commercial value. Duck eggs are preferred for their high nutritional content and different gastronomic uses. In particular, the internal quality characteristics of duck eggs are among the elements that producers and consumers care about. Egg albumen index, as one of the internal quality characteristics of duck eggs, stands out as a critical parameter in determining whether the egg is fresh, its nutritional value and durability (Xu et al., 2021; Tuncer and Kılınç, 2019). In addition, the external quality characteristics of duck eggs are also of great commercial importance. External quality parameters such as egg shell color, shape and thickness are important factors affecting consumer preferences as well as market value (Zhao et al., 2020). The factors affecting duck egg production, as in other poultry animals, include many variables such as nutrition, genetic structure, environmental conditions and breeding methods (Güler and Erol, 2018). Each of these factors directly affects the internal and external quality parameters of eggs and therefore plays a decisive role in the market value of duck eggs. Quality analyses of eggs allow producers to obtain more efficient and high-quality products, while also ensuring that products that meet consumers expectations are offered to the market.

Modeling of factors affecting the quality parameters of eggs is usually done using statistical methods. Multiple regression analysis is a widely used method for such studies and is an effective approach to model the relationship between independent variables and dependent variables (Chen et al., 2019). However, when there are high correlations between independent variables, classical multiple linear regression analyses may lose their accuracy. Ridge regression method offers an important alternative to increase the reliability of the model for such cases. Ridge regression method adds a penalty term to the parameters of the model to solve multicollinearity problem, making the estimates more stable and reliable (Hoerl and Kennard, 1970; Liu and Zhang, 2022).

The aim of this study is to model the relationship between duck egg albumen index and external quality traits of the egg and to compare this relationship with the LSM (least square method) and Ridge regression method.

Since the LSM (least square method) is sensitive to multicollinearity problem, it is aimed to obtain more accurate and reliable estimates with Ridge regression method and to show that Ridge regression method is an effective method in the evaluation of duck egg quality.

2. Materials and Methods

In this study, 47 breeding eggs obtained from one-year-old Star-53 French-Peking duck flock were used. Egg quality analyses were performed in the Poultry Laboratory of the Animal Science Department of the Faculty of Agriculture of Çukurova University. The width and length of the eggs were measured with a digital caliper (± 0.01 mm). Egg weight was determined using an electronic scale with a sensitivity of 0.01 g. The eggs were broken one by one on a glass breaking bench and the dimensions of the yolk and albumen (height, width and length) were recorded using a digital caliper (± 0.01 mm). The egg albumen and yolk were collected in a separate petri dish and weighed using an electronic scale with a sensitivity of 0.01 g. The obtained data were used in the formulas (equations 1-3) below to calculate the shape index, albumen index and haugh unit values (Yannakopoulos and Tserveni-Gousi 1986; Kaya ve Aktan, 2011; Olawumi ve Chiristiana, 2017).

Shape Index =(Egg Width (mm))/(Egg Length (mm))x100 (1)

Albumen Index =(Albumen heigth (mm))/(Average of Albumen Width and Length (mm))x100 (2)

Haugh unit= 100 log (Albumen Height +7.57-1.7 x Egg Weight 0.37) (3)

In the study, an estimated model was established by determining one dependent (egg albumen index) and five independent (egg weight, width, length, shape index and Haugh unit) variables. In order to decide to what extent this model is compatible, a detailed examination of multiple regression analysis was performed with the help of SPSS 26 statistical package program, which is widely used in the literature.

In multiple regression analysis, there are various assumptions to determine the fit criterion of the model. One of these assumptions is that the independent variables are independent of each other, in other words, there is no relationship between the independent variables. If this assumption is not met, the problem of multicollinearity arises (Maxwell, 2000; Montgomery et al., 2001). The most commonly used methods for determining the problem of multicollinearity can be listed as follows. Simple correlation coefficient: If the relationship between explanatory variables (r≥075) is large, the existence of multicollinearity problem should be suspected. VIF (variance ıncreasing factor): It is a method used to determine the multicollinearity problem. It can be calculated with the help of the formula below (equation 4).

VIF: $$C_{ij} \quad \frac{1}{1-R_{ij}} \qquad (4)$$

Here Rij represents partial correlation. If the VIF (variance ıncreasing factor) value Cij ≥ 10, a multicollinearity problem occurs (Albayrak, 2005).

TV (tolerance value): It is found by subtracting the coefficient of determination from 1 (TV=1-R^2). As a result, a smaller TV (tolerance value) causes a larger VIF (variance ıncreasing factor) value. Therefore, a small TV(tolerance value) suggests that multicollinearity problem may exist (Albayrak, 2005).

Since it is not known exactly which of these methods is better, it is useful to consider the whole in determining the multicollinearity problem.

There are various suggestions in the literature to eliminate the multicollinearity problem (expelling the variable from the model, combining related variables, adding variables to the model, principal components and Ridge regression method, etc.). However, Ridge regression method, which is the most widely and reliably used in the literature, is recommended (Albayrak, 2005).

Ridge regression method, developed by Hoerl and Kennard (1970), is a more powerful alternative developed for situations where the classical LSM (least squares method) is ineffective when faced with a multicollinearity problem. Ridge regression method is based on the basic principles of the LSM (least squares method), but adds a small bias constant, the Ridge parameter (k), to the diagonal values of the variance and covariance matrix. Thanks to this addition, the model's estimation variances are reduced, while at the same time the estimations become slightly biased. As a result, Ridge regression method can produce two different results, such as unbiased estimates with high variance or biased estimates with low variance. This balance is generally a preferred method to increase the overall accuracy of the model (Albayrak, 2005). In order to determine the initial parameter k and the variance lag length in the appropriate model in Ridge regression method, the point at which the regression becomes stationary can be determined with ADF (augmetted Dickey Fuller) unit root tests, and the appropriate model variance lag length can be determined with the help of the VAR (vector auto regressive) model.

ADF(augmetted Dickey Fuller) unit root tests: A statistical test used to test whether time series data is stationary. A stationary time series is a series whose statistical properties (mean, variance) do not change over time. The ADF (augmetted Dickey Fuller) unit root tests whether the series contains a unit root. If there is a unit root, the time series is not stationary (there is a trend or tendency in the series). If there is no unit root, the time series is stationary. The mathematical expression of this model can be expressed as follows (equation 5).

$$\Delta Y_t = \alpha + \beta_t + \gamma Y_t - 1 + \sum_{i=1}^{p} \delta_i \Delta Y_{t-i} + \varepsilon_t \qquad (5)$$

Here,
Yt= Time series data,
ΔYt = Time series change,
α = Constant term,
β = Trend coefficient,
γ = Unit root coefficient,
δ_i= Lagged values coefficients,
p: Lag length,
ε_t= Error term,
(Dickey Fuller, 1979).
VAR (vector auto regressive) model: In econometric studies, when the relationships between independent variables are multi-sided and complex, it is often necessary to use simultaneous equation systems. In such systems, it is important to consider the interaction of each variable with other variables. One of the methods widely used in solving simultaneous equations is the VAR (vector auto regressive) model. The VAR (vector auto regressive) model allows modeling in time series analyses using the past values of each endogenous variable together with all other endogenous variables. The mathematical expression of this model can be shown as an equation with a lag length of p as follows (equation 6).

$$y_t = A_1 y_{t-1} + \cdots + A_p y_{t-1} + B_{x_t} + \varepsilon_t \qquad (6)$$

Here, y_t p×1 dimensional value vector, x_t d×1 dimensional deterministic variables, A_p p×p dimensional parameter matrices and the error terms vector (Johansen, 1995).

In the research, it was determined that there was a multicollinearity problem in the estimated model established with the help of simple correlation coefficient, VIF (variances increasing factor) and TV (tolerance value). It was aimed to eliminate this problem with the help of Ridge regression method, which is widely used in the literature.

3. Results and Discussion

In the data set obtained for the purpose of determining the internal and external quality of eggs, firstly, egg albumen and yolk index, albumen and yolk weights were tested in determining the dependent variables, the most appropriate R^2 ($R^2 > 0.75$) was found to be appropriate, and the hypothesis and estimated model were determined as follows (equation 7).

H_0: There is no relationship between egg albumen index and external egg quality characteristics.

H_1: There is a relationship between egg albumen index and external egg quality characteristics.

$$\hat{R} = \widehat{\beta_0} + \widehat{\beta_1} X_1 + \widehat{\beta_2} X_2 + \widehat{\beta_3} X_3 + \widehat{\beta_4} X_4 + \widehat{\beta_5} X_5 + \hat{e} \qquad (7)$$

$\hat{R}$= Egg albumen index
X_1 = Egg weight
X_2 = Egg width
X_3= Egg length
X_4= Shape index
X_5= Haugh unit

Afterwards, the multiple regression equation obtained by the LSM (least squares method) determined that the linear relationship between the egg albumen index and external quality characteristics was very strong at 98 %. This finding reveals that the changes in the albumen index are largely explained by the egg external quality characteristics. However, this strong relationship also brings up the problem of multicollinearity, and reveals that the Ho hypothesis is rejected and the regression relationships are statistically significant (P<0.01). This reported that the model is significant and the probability of the obtained results being random is low. In addition, while the parameter estimates and the significance levels of these parameters are given in Tables 1 and 2, the VIF (variances increasing factor) and TV (tolerance value) are given in Table 3 in order to determine the relationship between the independent variables and the risks of multicollinearity problem, and the distribution graphs of each independent variable are given in Figures 1, 2, 3, 4 and 5.

When Figures 1, 2, 3, 4 and 5 are examined, it is determined that the data are linear because the independent variables in the obtained data set (egg weight, width, length, shape index and Haugh unit) are moving around a certain line.

When Table 1 is examined, only the coefficients $\widehat{\beta_0}$, $\widehat{\beta_4}$ve $\widehat{\beta_5}$ are found to be significant (P<0.05).

In Table 2, the relationship between the independent variables is examined and it is observed that the VIF (variances increasing factor) value are high. While the VIF (variances increasing factor) value of the egg length, shape index and width values are high, the TV (tolerance value) of these variables are found to be low. The high VIF (variances increasing factor) value (VIF≥10) indicate the existence of a multicollinearity problem in the estimated model. In order to determine this problem precisely (equation 8);

$$\text{VIF,} \quad C_{ij} \quad \frac{1}{1-R_{ij}} \qquad (8)$$

with the help of the formula,

VIF, where Albumen index is the dependent variable (equation 9),

$$C_{ij} = \frac{1}{1-0.98} = \frac{1}{0.02} = 50 \qquad (9)$$

has been calculated.

In the estimated model where the egg albumen index is the dependent variable, it was determined that there was a multicollinearity problem since the condition ($C_{ij} \geq 10$) was met. For this purpose, in order to determine the appropriate lag length, the data set was first stabilized with ADF(augmetted Dickey Fuller) unit root tests using the Eviews package program, and then the appropriate lag number was determined with the VAR (vector auto regressive) model in the estimated model. Tables 3 and 4 are given.

Table 1. Parameter estimate and significance level of the multiple regression equation obtained by the LSM(least squares method)

	Regression Coefficient	Std. Error of the Estimate	t	P
	-207.778	80.870	-2.569	0.014
	2.193	1.703	1.288	0.205
	2.065	1.199	1.723	0.092
	0.832	1.132	0.735	0.467
	-0.221	0.071	-3.110	0.003
	1.051	0.352	2.983	0.005

Table 2. The relationship between the independent variables of the multiple regression equation obtained by the LSM (least squares method), VIF(variance increasing factor) and TV (tolerance value)

Correlation Matrix							
Variables	Egg Weight	Egg Width	Egg Length	Shape Index	Haugh Unit	TV	VIF
Egg Weight	1					0.03	27.58
Egg Width	0.879**	1				0.008	131.82
Egg Length	0.849**	0.554**	1			0.002	417.46
Shape Index	-0.416**	0.019**	-0.820**	1		0.004	274.15
Haugh Unit	0.102	0.263	-0.053	0.236	1	0.847	1.18

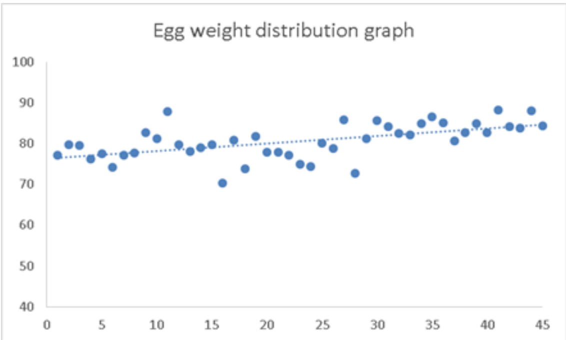

Figure 1. Egg weight distribution graph.

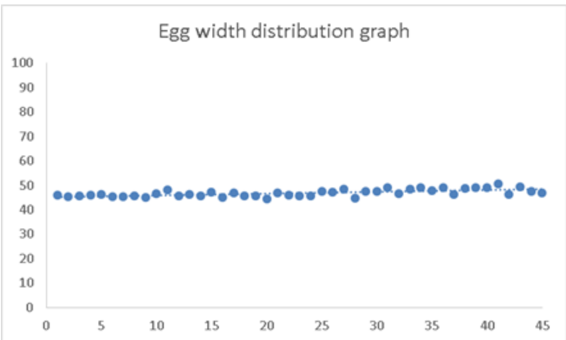

Figure 2. Egg width distribution graph.

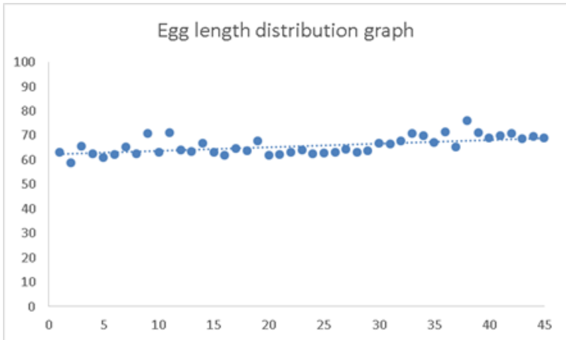

Figure 3. Egg length distribution graph.

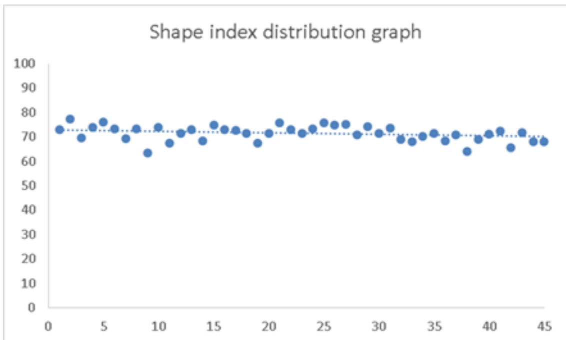

Figure 4. Shape index distribution graph.

When Tables 3 and 4 are examined, it is determined that the smallest value in terms of all comparison criteria except SC is the 5th lag value and the series are first degree stationary. In other words, it is determined that the effect of egg external quality characteristics on the albumen index is zero starting from the 5th lag length in the established estimated model. Thus, the Ridge regression method found in the literature was used to eliminate the multicollinearity problem that emerged in the established estimated model, and in the Ridge regression method, the initial k constant value was taken as 1 since it is first degree stationary, and in the VIF (variances increasing factor) value calculation, the appropriate lag length was taken as 5. In the multiple regression equation obtained with the Ridge regression method, the linear relationship between egg albumen index and external quality characteristics was re-examined, and it is given in Table 5, whether it is statistically significant or not is given in Table 6, and the parameter estimate, significance level, VIF (variances increasing factor) and TV (tolerance value) are given in Table 7.

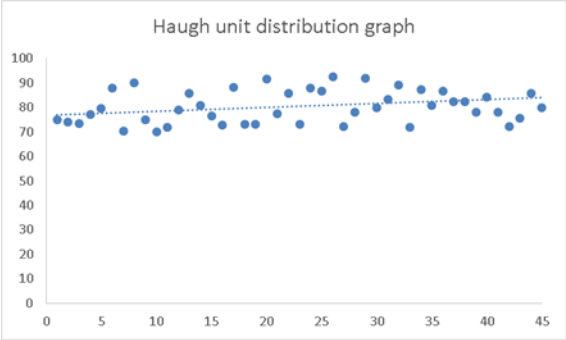

Figure 5. Haugh unit distribution graph.

Table 3. ADF (augmetted Dickey Fuller) unit root tests result

ADF-t statistics	Level		First Difference	
	t- statistics	Probability (p)	t- statistics	Probability (p)
Egg Albumen Index	-5.6947	0.076	-8.3776	0.001
Egg Weight	-2.1827	0.215	-7.4858	0.000
Egg Width	-2.2754	0.184	-6.8553	0.000
Egg Length	-2.3711	0.155	-7.6134	0.000
Shape Index	-5.8766	0.043	-6.9410	0.000
Haugh Unit	-5.6947	0.076	-8.3776	0.000

Table 4. VAR (vector auto regressive) model lag length result

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-466.26	NA	407.51	23.03	23.28	23.12
1	-395.07	118.07	74.71	21.32	23.07	21.95
2	-368.36	36.47	131.95	21.77	25.03	22.96
3	-321.53	50.26	107.44	21.24	26.44	22.98
4	-290.01	24.59	276.53	21.46	27.73	23.74
5	-191.15	48.22	62.93	18.39	26.17	21.22

LR= sequential modified LR test statistic (each test at 5% level) FPE= Final prediction error, AIC= Akaike information criterion, SC= Schwarz information criterion, HQ= Hannan-Quinn information criterion.

Table 5. Goodness of fit and standard error values of the multiple regression equation obtained by the Ridge regression method

R	R Square	Adjusted R Square	Std. Error of the Estimate
0.88	0.90	0.91	0.1003

Table 6. Variance analysis value of the multiple regression equation obtained from Ridge regression method

	Sum of Squares	df	Mean Square	F	Sig.
Regression	161.4982	5	32.2996	82.3397	0.000
Residual	16.0831	41	0.3922		
Total	177.5813	46			

Table 7. Parameter estimates, VIF (variances increasing factor) and TV (tolerance value) of the multiple regression equation obtained by the Ridge regression method

	Regression Coefficient	Std. Error of the Estimate	VIF	TV
$\widehat{\beta_0}$	18.2029	-	-	-
$\widehat{\beta_1}$	0.1362	0.0485	1.2082	0.3638
$\widehat{\beta_2}$	-0.5736	0.2322	1.5240	0.7649
$\widehat{\beta_3}$	-0.1596	0.1125	1.4120	0.2427
$\widehat{\beta_4}$	0.0262	0.0984	1.5049	0.3616
$\widehat{\beta_5}$	0.1921	0.0099	1.1405	0.8740

When Tables 5, 6 and 7 are examined, it is seen that there are significant differences between the parameters obtained from Ridge regression method and the LSM (least squares method). Ridge regression method, thanks to the penalty term added to the parameters, significantly reduces the standard errors of these parameters by limiting the size of the parameters. This increases the estimation accuracy of the model and provides more reliable results. In the LSM (least squares method), problems such as multicollinearity problem and overfitting may cause the standard errors of the parameters to increase. However, Ridge regression method effectively eliminates these problems and provides a more robust and reliable model. As a result, Ridge regression method has reduced the standard errors of the parameters and provided a more accurate and reliable regression model, and the estimated model is as follows (equation 10).

$$\hat{R} = \widehat{18.2029} + \widehat{0.1362}X_1 - \widehat{0.5736}X_2 - \widehat{0.1596}X_3 + \widehat{0.0262}X_4 + \widehat{0.1921}X_5 + \hat{e} \quad (10)$$

In the regression analysis results obtained with the LSM (least squares method) in Table 1, the regression parameters of the majority of the estimation equation (except for $\widehat{\beta_0}$, $\widehat{\beta_4} and \widehat{\beta_5}$) are insignificant (P>0.05). In addition, the standard error of the $\widehat{\beta_0}$ parameter is very high compared to the others, and these results are in accordance with the study of Akçay and Sarıözkan (2015).

When the relationship between the independent variables in Table 2 is examined, it is determined that there is a significant relationship between egg weight and egg length (88 %) and width (84 %). These results are similar to the reports of Akbaş et al., (1996), Kul and Şeker (2004), Gök et al., (2023).

Ridge regression method, which is frequently used in the literature, was preferred in order to prevent the multicollinearity problem detected in the estimated model in Tables 3 and 4. In the ridge regression analysis, the initially used k value was determined as 1 in accordance with literature recommendations, and the lag length was selected as 5 when calculating the VIF(variances increasing factor) value for the variables in the model. This application is parallel to the findings obtained in the study conducted by by Gök et al., (2022), Gök and Şahin (2023), Gök and Şahin (2023), Gök and Şahin (2024) Gök and Şahin (2024), Gök and Şahin (2025).

In Tables 5, 6 and 7, smaller parameter, VIF (variances increasing factor) (8.33) and TV (tolerance value) were found than the results obtained in the LSM (least squares method) in the Ridge regression method conducted to eliminate the multicollinearity problem. These results are equivalent to the studies of Albayrak (2005), Topal et al., (2010), Üçkardeş et al., (2012), Akçay and Sarıözkan (2015), Çiftsüren (2017), Yalçınöz and Şahin (2020), Tolun et al., (2023), Yavuz et al., (2023), Çetenak et al., (2024),Tolun et al., (2024).

4. Conclusion

In poultry farming, correct model selection is of great importance in determining egg yield and quality. Especially in cases where there are multiple linear correlations in the estimation of albumen index, which is one of the internal quality traits of eggs, the use of Ridge regression method as an alternative approach instead of the LSM (least squares method) provides more reliable results. This method helps to obtain more consistent and accurate results by reducing the estimation errors caused by high correlation between variables. Therefore, this study reveals that Ridge regression method can be used more effectively in poultry breeding and selection studies and emphasizes the points to be considered in model selection. Such models not only increase productivity, but also allow for a more accurate assessment of egg quality.

Author Contributions

The percentages of the authors' contributions are presented below. All authors reviewed and approved the final version of the manuscript.

	K.K.	İ.G.
C	50	50
D	50	50
S	50	50
DCP	50	50
DAI	50	50
L	50	50
W	50	50
CR	50	50
SR	50	50
PM	50	50
FA	50	50

C= concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because there was no study on animals or humans.

References

Akbaş Y, Altan O, Koçak C. 1996. Effects of hen's age on external and internal egg quality characteristics. Turk J Vet Anim Sci, 20: 455-460.

Akçay A, Sarıözkan S. 2015. Yumurta tavukçuluğunda gelirin Ridge regresyon analizi ile tahmini. Ankara Üniv Vet Fak Derg, 62: 69-74.

Albayrak SA. 2005. Çoklu bağlantı halinde en küçük kareler tekniğinin alternatifi yanlı tahmin teknikleri ve bir uygulama. Zonguldak Karaelmas Üniv Sos Bil Derg, 1: 105-126.

Çetenak T, Gök İ, Yavuz E, Şahin M. 2024. Statistical models and evaluation criteria used in poultry farming. BSJ Agri, 7(6): 710-719.

Chen Z, Liu Y, Wang J. 2019. Effects of feeding strategies on egg quality and production in ducks: A statistical approach. Poult Sci, 98(5): 2121-2130.

Çiftsüren MN. 2017. Yumurta iç ve dış kalite özellikleri arasındaki ilişkiyi belirlemede Ridge ve Lasso regülarizasyon yöntemlerinin karşılaştırılması. Yüksek Lisans Tezi, Yüzüncü Yıl Üniversitesi, Fen Bilimleri Enstitüsü, Zootekni Anabilim Dalı, Van, Türkiye, pp:86.

Dickey DA, Fuller WA. 1979. Distribution of the estimators for autoregressive time series with a unit root. J Am Stat Assoc, 74(366a): 427-431.

Gök İ, Şahin M, Tolun T. 2023. Determination of impact size by canonic correlation analysis of the factors affecting the buying or selling agricultural lands. Cumhuriyet Sci J, 44(2): 411-417.

Gök İ, Şahin M. 2023. Estimate of structural fractures in wheat culture and production in Türkiye by econometric analysis. BSJ Agri, 6(4): 411-415.

Gök İ, Şahin M. 2023. Investigation of vegetable production amount and the size of cultivation areas in Kahramanmaraş with the econometric model. BSJ Agri, 6(1): 8-15.

Gök İ, Şahin M. 2024. Analysis of the relationship lag between beef production amount and average meat price in Türkiye using the Koyck model. Turk Tarım Doğa Bilim Derg, 11(2): 342-346.

Gök İ, Şahin M. 2024. Econometric analysis of corn production in Türkiye. J Agric Fac Gaziosmanpaşa Univ, 41(2): 33-39.

Gök İ, Şahin M. 2025. General situation and production projection of chicken meat production in Türkiye. Osmaniye Korkut Ata Üniv Fen Bilim Enst Derg, 8(3): 1120-1128.

Gök İ, Yavuz E, Şahin M. 2022. Econometric analysis of factors affecting the buying or selling agricultural lands. BSJ Agri, 5(4): 455-463.

Güler F, Erol H. 2018. Ördek yumurtası üretiminde beslenme ve çevresel faktörlerin etkisi. J Anim Sci, 61(2): 190-202.

Hoerl AE, Kennard RW. 1970. Ridge regression: Biased estimation for non-orthogonal problems. Technometrics, 12(1): 55-67.

Johansen S. 1995. Likelihood based inference in cointegrated vector autoregressive models. Oxford Univ Press, Oxford, UK, pp: 54-59.

Kaya E, Aktan S. 2011. Japon bıldırcınlarında sürü yaşı ve kuluçkalık yumurta depolama süresi: 1. Koyu ak özellikleri üzerine etkileri. SDÜ Ziraat Fak Derg, 6(2): 30-38.

Kul S, Şeker İ. 2004. Phenotypic correlations between some external and internal egg quality traits in the Japanese quail (Coturnix coturnix japonica). Int J Poult Sci, 3(6): 400-405.

Liu Z, Zhang C. 2022. Ridge regression applications in agricultural production data modeling: Case studies in poultry farming. Int J Agric Res, 59(4): 345-356.

Maxwell SE. 2000. Sample size in multiple regression analysis. Psychol Methods, 5(4): 434-458.

Montgomery DC, Peck EA, Vining GG. 2001. Introduction to linear regression analysis, 3rd Edition. Wiley, New York, USA, pp: 672.

Olawumi S, Chiristiana B. 2017. Phenotypic correlations between external and internal egg quality traits of Coturnix quails reared under intensive housing system. J Appl Life Sci Int, 12(3): 1-6.

Tolun T, Gök İ, Şahin M. 2024. Modeling of some egg characteristics in henna partridges. BSJ Agri, 7(6): 729-742.

Tolun T, Yavuz E, Şahin M, Gök İ. 2023. Modeling egg curves in partridges. BSJ Agri, 6(1): 21-25.

Topal M, Eyduran E, Yağanoğlu M, Sönmez AY, Keskin S. 2010. Çoklu doğrusal bağlantı durumunda Ridge ve Temel Bileşenler regresyon analiz yöntemlerinin kullanımı. Atatürk Üniv Ziraat Fak Derg, 41: 53-57.

Tuncer S, Kılınç F. 2019. Yumurta akı indeksi ve dış kalite özellikleri arasındaki ilişkiler: Bir ördek yumurtası örneği. Turk J Vet Anim Sci, 43(6): 487-495.

Üçkardeş F, Efe E, Narinç D, Aksoy T. 2012. Japon bıldırcınlarında yumurta ak indeksinin Ridge regresyon yöntemiyle tahmin edilmesi. Akad Ziraat Derg, 1: 11-20.

Xu X, Zhang L, Song H. 2021. The impact of feed additives on egg quality and egg albumen index in ducks. Poult Sci, 100(3): 1430-1438.

Yalçınöz E, Şahin M. 2020. Yumurtacı tavuklarda yumurta verim eğrilerinin modellenmesi. KSÜ Tarım Doğa Derg, 23(5):

1373-1378.
Yannakopoulos AL, Tserveni-Gousi AS. 1986. Quality characteristics of quail eggs. Br Poult Sci, 27: 171-176.
Yavuz E, Abacı SH, Erensoy K, Şahin M. 2023. Modeling of individual egg weights of Lohmann-Brown layer hens. Turk J Vet Anim Sci, 47(3): 229-335.
Zhao X, Wang X, Li Y. 2020. Influence of genetic and environmental factors on egg shell quality in ducks. Anim Prod Sci, 60(7): 926-934.