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Path Analysis of the Relationships Between Various Body Measures and Live Weight of American Bronze Turkeys Under Three Different Lighting Programs

Mehmet MENDEŞ[1] Ali KARABAYIR[1] Akın PALA[1]

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Abstract: In animal breeding and genetics, knowledge of causal effects may provide valuable information on selection. Different contributions of explanatory variables to the traits indicate that the breeder has to choose the variable with the largest contribution in a selection effort. In this study, direct and indirect effects of four explanatory variables (Shank Length, Breast Length, Breast Depth and Breast Circumference) influential on live weight at week 30 in American Bronze turkeys were investigated using path analysis. Results of the analyses indicated that the direct effects of shank length were the largest on live weight. In general, indirect effects of Breast Length and Breast Circumference through Shank Length were highest among all indirect effects. Shank Length is the most influential variable and must be included in the model in estimating the live weight at week 30.

Key Words: Lighting programs, causal effects, path analysis, American bronze turkey

Üç Farklı Aydınlatma Programında Yetiştirilen Amerikan Bronz Hindilerinde Değişik Vücut Ölçüleri ile Canlı Ağırlık Arasındaki İlişkilerin Path Analizi ile İncelenmesi

Öz: Hayvan ıslahı ve genetiğinde, sebep-sonuç ilişkilerinin bilinmesi seleksiyon hakkında önemli ipuçları verebilir. Sebep değişkenlerinin üzerinde durulan özelliklere katkılarının farklı olması, söz konusu özelliklere en fazla katkı yapan değişkenlerin belirlenmesini gerektirir. Bu çalışmada, Amerikan Bronz Hindilerinin tespit edilen dört özelliğinin (incik uzunluğu, göğüs uzunluğu, göğüs derinliği ve göğüs çevresi), 30. hafta canlı ağırlık üzerine doğrudan ve dolaylı etkileri iz katsayısı metodu (Path analizi) kullanılarak analiz edilmiştir. Analiz sonuçları, canlı ağırlık üzerine en fazla doğrudan etkiye sahip olan değişkenin incik uzunluğu değişkeninin olduğunu göstermiştir. Genel olarak, göğüs uzunluğu ve göğüs çevresi değişkenlerinin incik uzunluğu üzerinden olan dolaylı etkileri de daha yüksek bulunmuştur. Buradan hareketle, 30. hafta canlı ağırlığa en etkili değişkenin incik uzunluğu olduğu ve bunun modele dahil edilmesinin gerekli olduğu sonucuna varılmıştır.

Anahtar Kelimeler: Aydınlatma programı, sebep-sonuç ilişkileri, path analizi, Amerikan bronz hindi

Introduction

Main purpose of the animal breeding practices is to improve traits of economic value. Depending on the species, breeders try to improve traits such as meat, milk, egg and wool traits. These traits are closely related to explanatory variables such as age of dam, lighting program, sex, breed, breast length etc., depending on the species (Gürbüz et al. 1999, Şahiner and Görgülü 2000). Investigation of these relations may provide essential information to breeders in selection, crossbreeding and in other practices. Different explanatory variables may have different contributions on the trait. Those with a larger effect on the trait may be the most important to the breeder (İşci et al. 2004). These variables may have indirect effects on the traits through the other factors as well as direct effects. Lighting is one of the most important environmental factors that affect poultry performance as well other animal species. Different lighting programs affect the relationships among the variables (Hamilton and Kennie 1997, Yahav et al. 2000, Mendes et al. 2005a, Mendes et al. 2005b).

The causal effects needs to be investigated separately in different lighting programs to explain how the relationships among the variables change in different lighting programs. Determining the variables most effective or least effective on the traits in question may be beneficial in selection programs.

Explanatory variables may have direct or indirect effects on the traits (Li 1975, Düzgüneş et al. 1996, Keskin 1998). Usually, the direct effects are measured using correlation coefficient. However, indirect effects may confound the correlation coefficient. This may be because another unaccounted variable may be contributing to the correlation coefficient (Wright 1934, Wright 1960, Wright 1968, Sirali and Kayaalp 1995).

Using simple correlation coefficient between traits and explanatory variables may not explain the relationships in all aspects and may be inadequate in investigating the causal effects among the variables. In order to arrive at solid conclusions, correlation coefficient should be partitioned into components and analyzed just like in analysis of variance (Alvin et al. 1975, Gürbüz et al. 1999).

[1] Çanakkale Onsekiz Mart Üniversitesi Ziraat Fak. Zootekni Bölümü-Çanakkale

In many fields, such as agriculture, social sciences and medicine, path analysis is widely used to investigate direct and indirect causal effects between traits and explanatory variables. In this study, relationships between live weight at 30 week and four body measures (Shank Length, Breast Depth, Breast Length and Breast Circumference) were investigated via path analysis. Major purpose of this study was to determine the explanatory variable that is most effective on live weight at slaughter and to order the variables in terms of their contributions to the model.

Materials and Methods

The data were collected from 60 American Bronze turkeys. The birds were 15-week old at the beginning of the study. The study was carried out at the Üvecik Research Center of the Çanakkale Onsekiz Mart University. The animals were raised under intensive conditions with a lighting program of 23L: 1D in the first 55 days of the study. They were then allowed to go onto pasture. Three different artificial lighting programs in addition to day light were applied starting from 16th weeks of age. Group I (control), group II and group III were treated with lighting programs 23L: 1D, 18L: 6D and 12L: 12D, respectively. Each group had 10 male and 10 female turkeys. The starter and growth diets of the animals included 28% crude protein, 2900-3000 kcal/ME and 22% crude protein, 2800-2900 kcal/ME, respectively. Wheat and water were offered *ad libitum* to the turkeys when they returned back from the pasture under semi-intensive condition. The birds were weighed before slaughter at 30 weeks of age. Shank Length (X1), Breast Length (X2), Breast Depth (X3) and Breast Circumference (X4) were measured at 30 weeks of age also.

Path analysis was used to analyze the data. Path analysis provides a method to investigate direct and indirect effects. It is an extension of the ordinary multiple regression model. A regression is done for each variable in the model as a dependent on explanatory variables (Anonymous, 2004). The path coefficient from an explanatory variable (X) to a trait (Y) can be shown as below:

$$P_{Y.X_i} = b_i \frac{S_{X_i}}{S_Y}$$

where;

$P_{Y.X_i}$: Path coefficient, from X_i to Y (i=1, 2, 3, 4)

b_i : Partial regression coefficient,

S_{X_i} : Standard deviation of X_i,

S_Y : Standard deviation of Y

From here, indirect effects of X_i on Y through X_j are calculated as follows:

$$2r_{X_iX_j}(P_{Y.X_i})(P_{Y.X_j})$$

where $r_{X_iX_j}$ is the correlation coefficient between ith and jth independent variables and $P_{Y.X_j}$ is the path coefficient that indicates the direct effects of jth independent variable on the dependent variable. Coefficient of determinations can be partitioned into its components using path analysis as follows:

$$R^2 = P^2_{Y.X1} + P^2_{Y.X2} + P^2_{Y.X3} + P^2_{Y.X4} + 2r_{X1X2}P_{Y.X1}P_{Y.X2} + 2r_{X1X3}P_{Y.X1}P_{Y.X3} + 2r_{X1X4}P_{Y.X1}P_{Y.X4} + 2r_{X2X3}P_{Y.X2}P_{Y.X3} + 2r_{X2X4}P_{Y.X2}P_{Y.X4} + 2r_{X3X4}P_{Y.X3}P_{Y.X4}$$

where;

$P^2_{Y.X_i}$ and $2r_{X_iX_j}(P_{Y.X_i})(P_{Y.X_j})$ show direct and combined effects of explanatory variables (X1, X2, X3 and X4) in contributing to the variation of Y (Düzgüneş et al. 1987, Okut and Orhan 1993, Düzgüneş et al. 1996, Keskin 1998, Gürbüz et al. 1999).

Variance Inflation Factors (VIF) was calculated to measure whether there were any multicollinearity problems among the explanatory variables (Draper and Smith 1998).

Results

Descriptive statistics by lighting programs and sex are given in Table 1. The correlation coefficients between the traits and explanatory variables and those between the explanatory variables are given in Table 2. The correlation coefficient between Live Weight (Y) and Shank Length (X1) was large enough to be significant ($P< 0.05$) for male turkeys raised in the 23L: 1D lighting program and the Breast Circumference (X4) was highly correlated with Y ($P< 0.01$) for female turkeys in the same lighting program. In the 18L: 6D lighting program, male live weights had the highest correlation with X1 also. On the other hand, females had a conflicting result to the previous lighting program; X1 and X2 variables had the highest correlations with Y. In the 12L: 12D lighting program, Shank Length (X1), Breast Length (X2) and Breast Depth (X3) variables had the highest correlations with Y in males while in females, none of the correlations were large enough to be significant ($P>0.15$). There were no multicollinearity problems among the explanatory variables, since the VIF value was smaller than 10 in all cases (Draper and Smith, 1998) (Table 3).

Regression equations constructed for turkeys by lighting programs are given in Table 3. The coefficients in these equations are the path coefficients (Wright, 1960). Path coefficients for turkeys raised under 23L: 1D lighting program indicated that the X1 variable had the largest effect on live weight (Y) at slaughter for male turkeys. X3

Table 1. Descriptive statistics by lighting programs and sex

23L:1D Lighting program						
Sex	Male	Female	Male		Female	
Traits	$\bar{X} \pm S_{\bar{X}}$	$\bar{X} \pm S_{\bar{X}}$	Min	Max	Min	Max
Live weight (Y) (gr)	7642±352	5245±189	5420	8650	4150	6180
Shank Length (X1) (cm)	16.45±0.49	13.25±0.15	13.50	17.75	12.50	14.25
Breast Length (X2) (cm)	16.25±0.25	14.80±0.11	15.00	17.50	14.00	15.00
Breast Depth (X3) (cm)	6.03±0.19	5.78±0.10	5.25	7.00	5.25	6.25
Breast Circumference (X4) (cm)	72.90±1.51	63.00±0.78	65.00	79.00	60.00	66.00
18L:6D Lighting program						
Live weight (Y) (gr)	7721±386	5225±175	6100	9500	4250	6000
Shank Length (X1) (cm)	15.63±0.35	13.28±0.17	13.25	16.50	12.50	14.00
Breast Length (X2) (cm)	16.15±0.31	14.98±0.19	15.00	17.75	14.00	16.00
Breast Depth (X3) (cm)	5.58±0.10	5.40±0.12	5.00	6.00	4.50	5.75
Breast Circumference (X4) (cm)	72.30±1.05	65.20±1.23	65.00	76.00	60.00	74.00
12L:12D Lighting program						
Live weight (Y) (gr)	6298±228	5443±97.6	5700	7750	5110	5950
Shank Length (X1) (cm)	14.22±0.44	13.08±0.12	13.25	17.00	12.50	13.75
Breast Length (X2) (cm)	15.08±0.16	14.93±0.15	14.25	16.00	14.25	15.75
Breast Depth (X3) (cm)	5.11±0.37	5.40±0.17	4.25	5.75	4.50	6.00
Breast Circumference (X4) (cm)	64.11±0.74	62.60±0.31	62.00	69.00	61.00	64.00

Table 2 Correlation coefficients between traits by lighting programs and sex

Prog	23L:1D Lighting program										
Sex	**Male**						**Female**				
	Y	X1	X2	X3	X4		Y	X1	X2	X3	X4
X1	0.68*	1				X1	0.37	1			
X2	0.59	0.76**	1			X2	0.51	0.08	1		
X3	-0.01	0.07	-0.13	1		X3	-0.01	-0.51	0.05	1	
X4	0.58	0.89**	0.75**	0.19	1	X4	0.78**	0.19	0.71*	-0.21	1
18L:6D Lighting program											
X1	0.68*	1				X1	0.77**	1			
X2	0.35	0.49	1			X2	0.70*	0.41	1		
X3	0.18	0.03	0.19	1		X3	0.35	0.28	0.42	1	
X4	0.51	0.64*	0.46	0.38	1	X4	0.47	0.52	0.21	0.41	1
12L:12D Lighting program											
X1	0.98**	1				X1	0.22	1			
X2	0.90**	0.80**	1			X2	0.55	0.58	1		
X3	-0.79**	-0.81**	-0.64*	1		X3	-0.09	-0.19	-0.03	1	
X4	0.50	0.51	0.37	-0.79**	1	X4	-0.06	0.60	0.17	-0.36	1

*P< 0.05, **P < 0.01

Table 3. Path coefficients, standard error, standardized regression model, its R^2 and variance inflation factor (VIF) for 23L:1D, 18L:6D and 12L:12D lighting programs

	23L:1D Lighting program							
	Male				Female			
	Path Coef.	SE	VIF	R^2	Path Coef.	SE	VIF	R^2
X1	0.688**	0.726	5.1	68.5	0.415*	0.246	1.4	77.5
X2	0.199	0.555	3.0		-0.217	0.316	2.2	
X3	0.003	0.362	1.3		0.417*	0.256	1.5	
X4	-0.175	0.771	5.8		0.944**	0.322	2.3	
Y = 0,688 X1 + 0,199 X2 + 0,003 X3 - 0,175 X4					Y = 0,415 X1 - 0,217 X2 + 0,417 X3 + 0,944 X4			
18L:6D Lighting program								
X1	0.663**	0.459	2.1	68.7	0.528*	0.263	1.6	78.2
X2	-0.013	0.378	1.4		0.479*	0.247	1.4	
X3	0.147	0.364	1.3		-0.049	0.248	1.4	
X4	0.029	0.478	2.2		0.120	0.261	1.6	
Y = 0,663 X1 - 0,013 X2 + 0,147 X3 + 0,029 X4					Y = 0,528 X1 + 0,479 X2 - 0,049 X3 + 0,120 X4			
12L:12D Lighting program								
X1	0.689**	0.106	5.0	99.1	-0.040	0.572	2.5	54.4
X2	0.328*	0.079	2.9		0.598**	0.463	1.6	
X3	-0.025	0.120	6.5		-0.145	0.388	1.1	
X4	0.008	0.083	3.1		-0.186	0.494	1.9	
Y =0,689 X1 + 0,328 X2 - 0,025 X3 + 0,0075 X4					Y=0,040 X1 + 0,598 X2 - 0,145 X3 - 0,186 X4			

had the least contribution to the model. X4 had a negative effect on live weight, but this effect was not statistically significant. On the other hand, in females under the same lighting conditions, live weight was affected largely by X4.

Path coefficients for turkeys raised under 18L: 6D lighting program indicated that the Live weight of both male and female turkeys raised under this lighting program was affected mostly by the X1 variable. In studies related to lighting programs, this lighting program was reported to be the most optimum program (Mendes et al., 2005a). The path coefficients for turkeys raised under 12L: 12D lighting program indicated that the X1 variable had the largest effect on live weight at slaughter for male turkeys while X2 had the largest effect on live weight at slaughter for female turkeys.

Regression coefficients changed according to the lighting programs and gender (Table 3). The 18L: 6D lighting program seems to give the most pronounced relationships between the traits and the explanatory variables. The coefficients from tables 2 and 3 were also used to calculate the direct and indirect effects (Table 4). In Table 4, diagonal values are the path coefficients that measure the direct effects of each independent variable on the explanatory variables. Values off diagonal measure the indirect effects on the dependent variables. In male turkeys raised under 23L: 1D lighting program, only the path coefficient related to Shank Length (X1) was large ($P<0.01$). This indicated that one unit change in standard deviation in the X1 variable resulted in 0.688 unit change in standard deviation in the Y. Indirect effects of X4 (0.612) and X2 (0.523) on Y, through X1, was the highest among all indirect effects of X_i on Y. Indirect effects of X3 were close to zero. The largest direct contribution to female live weight was by X4 (0.944; $P<0.01$), X1 (0.415) and X3 (0.417). X1 and X3 had the same level of direct contributions ($P<0.05$). This implies that one unit change in standard deviation of Breast Circumference (X4) results in 0.944 unit change in standard deviation of Live Weight while that in Shank Length and Breast Depth results in 0.42 unit change in standard deviation of Live Weight. Effects of X2 (-0.217) were not large ($P=0.107$). In this lighting condition, the only coefficient that had large direct effects on both male and female turkeys was Shank Length (X1). X1 affected Live Weight largely through X3 while X2 and X3 had the largest effect on Live Weight through X4. X4 had the largest effect on Live Weight through X2.

In the 18L:6D lighting program, only the direct effects of X1 (0.663) were significant in male turkeys while direct effects of X1 (0.528) and X2 (0.479) were significant in female turkeys ($P<0.05$, Table 4). In male turkeys, one unit change in standard deviation of Shank Length resulted in 0.663 unit change in standard deviation of Live Weight while in females, that resulted in 0.528 changes in standard deviation of Live Weight. In addition, one unit change in standard deviation of X2 resulted in 0.479 unit change in standard deviation of Live Weight. In both genders, X2 and X4 had larger effects through X1 compared with X3.

In the 12L: 12D lighting program, direct effects of X1 (0.689) and X2 (0.328) in male turkeys was significant, while direct effects of X2 (0.598) was significant in female turkeys ($P<0.01$, $P<0.05$). In male turkeys, one unit change in standard deviation of Shank Length resulted in 0.689 unit change in standard deviation of Live Weight while that of Breast Length resulted in 0.328 unit change in standard deviation of Live Weight. In female turkeys, one unit change in standard deviation of Breast Length resulted in 0.598 unit change in standard deviation of Live Weight. Indirect effects of X2 and X3 through X1 were similar (0.551 and 0.558) in the male turkeys. Indirect effects of X1 and X2 through X3 and X4 were close to zero.

Direct and combined effects of the variables in contributing to the variation of Y are given in Table 5. In all lighting systems, Shank Length (X1) had the highest direct contribution to the variation in Y. Combined effects of X1 and X2 and combined effects of X1 and X4 on Y were the highest among the variable pairs. Regardless of the lighting program, Shank Length (X1) had the highest direct effects on live weight in both sex, while this was more obvious in males. This indicates that in estimating the live weight at 30 week, Shank Length is the most influential variable and must be included in the model. These findings are supported by Nestor et al., (2001) and Mendes et al. (2005a, 2005b).

Table 4. Direct and Indirect effects by lighting program

23L:1D									
Variables	Male				Variables	Female			
	X1	X2	X3	X4		X1	X2	X3	X4
X1	**0.688****	0.151	0.000	0.156	X1	**0.415****	0.033	0.213	0.179
X2	0.523	**0.199**	0.000	0.131	X2	0.033	**-0.217**	0.021	0.670
X3	0.005	0.026	**0.003**	0.033	X3	0.212	0.011	**0.417****	0.198
X4	0.612	0.149	0.000	**-0.175**	X4	0.079	0.154	0.088	**0.944****
18L:6D									
X1	**0.663****	0.006	0.004	0.019	X1	**0.528****	0.196	0.014	0.062
X2	0.325	**-0.013**	0.028	0.013	X2	0.216	**0.479***	0.021	0.025
X3	0.019	0.002	**0.147**	0.011	X3	0.148	0.201	**-0.049**	0.049
X4	0.424	0.006	0.056	**0.029**	X4	0.275	0.100	0.020	**0.120**
12L:12D									
X1	**0.689****	0.262	0.020	0.004	X1	**0.040**	0.245	0.041	0.097
X2	0.551	**0.328***	0.016	0.003	X2	0.023	**0.598****	0.004	0.032
X3	0.558	0.210	**-0.025**	0.006	X3	0.008	0.018	**-0.145**	0.067
X4	0.351	0.121	0.020	**0.008**	X4	0.024	0.102	0.052	**-0.186**

Table 5. Direct and combined effects of the explanatory variables in contributing to the variation of live weight (%)

Lighting Program	23L:1D		18L:6D		12L:12D	
Direct Effects	Male	Female	Male	Female	Male	Female
$P^2_{Y.X1}$	0.473	0.172	0.440	0.279	0.474	0.002
$P^2_{Y.X2}$	0.039	0.047	0.000	0.229	0.108	0.358
$P^2_{Y.X3}$	0.000	0.174	0.022	0.002	0.000	0.021
$P^2_{Y.X4}$	0.031	0.892	0.000	0.014	0.000	0.035
Combined Effects						
X1 and X2	0.207	-0.015	-0.009	0.207	0.361	-0.028
X1 and X3	0.000	-0.174	0.006	-0.014	0.028	-0.002
X1 and X4	-0.214	0.150	0.025	0.066	0.005	0.009
X2 and X3	-0.000	-0.009	-0.000	-0.020	0.011	0.005
X2 and X4	0.052	-0.293	-0.000	0.024	0.002	-0.038
X3 and X4	-0.000	-0.167	0.003	-0.015	0.000	-0.019

Conclusions

In all three of the lighting programs, changes of Shank Length in male turkeys resulted in significant changes in Live Weight. This statement was true for female turkeys also, with the exception of 12L: 12D lighting program. In addition, indirect effects of Breast Length and Breast Circumference through Shank Length were highest among all indirect effects. Shank Length can be the most influential variable and should be included in the model in estimating the live weight at week 30. It should be kept in mind that sample size is effective on the relationships between variables. Larger data sets give more reliable results.

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İletişim adresi:
Mehmet MENDEŞ
Çanakkale Onsekiz Mart Üniv. Ziraat Fak.
Zootekni Bölümü-Çanakkale