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Original Article

Correlations between Breast Yield and Morphometric Traits in Broiler Pure Lines

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ABSTRACT

Broiler pure lines are valuable breeding species and morphometric traits are advantageous for the selection of breast yield since they could be applied practically and without any negative impact on welfare. In this study, live weight (LW), carcass weight and ratio (CW and CR), breast weight and ratio (BW and BR), abdominal fat weight and ratio (AFW and AFR), morphometric traits such as breast width, length and index (BWD, BL and BI) were investigated in broiler pure lines. The research material consisted of 3 dam (A1, A2 and A3) and 2 sire (B1, B2) pure lines of 42 days of age. LW, CW, BW, AFW, AFR, BR, BL, BWD and BI values were different between the two lines ($p<0.05$). LW, CW, BW and BI were higher in sire lines. The relationship between breast weight and index were also higher in sire and dam lines than the relationships between breast width and length separately (in sire lines: BWD: 0.73; BL: 0.79; BI: 0.79, in dam lines: BWD: 0.79; BL: 0.74; BI: 0.84). In addition, high r^2 values were determined in regression equations for BW estimation in dam and sire lines (0.836 and 0.857, respectively).

Because of the significant correlations between breast yield and its morphometric traits, it is seen that more feasible, ease of measurement, protection of breeding resources and welfare. It is thought that the use of breast index which shows a higher correlation compared to these traits will increase selection efficiency instead of using breast width and length separately.

INTRODUCTION

Current broilers achieved the same live weight by consuming 50% less feed according to their performance in the 1950s and genetic progress played an important role in this respect (Arthur & Albers, 2003; Thiruvenkadan & Prabakaran, 2017). While the early advances in broiler breeding were initially provided by cross-breedings, today's advances are largely a result of intensive selection supported by technology. In production, broiler performance is evaluated with feed utilization, live weight gain, liveability and slaughtering age. However, increasing consumer demand for breast meat also increased its value in the sector and roused the breeders to search for ways to optimize the amount of breast meat. Breast meat yield was the most important feature in broiler breeding and emphasized in several researches (Arthur & Albers, 2003; Melo *et al.,* 2003; Silva *et al.,* 2007). The low-fat content, tenderness and easy processing of the breast meat caused the price to increase compared to other carcass parts. In previous studies aimed at increasing the amount of breast meat, chickens produced from parents were slaughtered and parents who produce the chicks with high breast meat were selected. Recently, it was determined that breast meat yield was positively correlated with breast muscle sizes. For this reason, some breast features seen in technological imaging methods and morphometric measurements have begun to be applied in the selection for higher breast meat (Xu *et al.,* 2018). At the beginning, in the estimation of the breast yield, a needle probe was used to harm and decrease the welfare of the animal. Then, tomography (Bentsen & Sehested, 1989; Shivus & Katle, 1993; Baka *et al.,* 2003), magnetic resonance imaging (Mitchell *et al.,* 1991; Köver *et al.,* 1998; Scollan *et al.,* 1998) and real-time ultrasonic (RTU) methods were used (Wilson, 1992; Gaya, 2013). However, some factors as cost, motion limitation, inappropriate usage area limit the use of ultrasonographic methods in practical broiler breeding studies. Morphometric measurements may be used instead of these methods, because the amount of breast meat can be highly estimated (80-90%) without damaging the animals. High relationships were found between breast weight and body weight (0.83 and 0.80) and breast ratio (0.66 and 0.85), and the selection of breast weight and body weight and breast ratio were determined (Xu *et al.*, 2011). Breast width, length and depth were found to be strongly genetically and phenotypically correlated with breast weight, and the selection for these three parameters contributed to the development of breast yield (Xu *et al.,* 2018). Besides, Cahaner *et al.* (1985) stated that the abdominal fat level may be decreased by the selection applied to breast meat yield.

Breeding and selection process of broiler pure lines used in this study started with 3 pure dam lines (2 slow, 1 fast feathering) and 2 fast feathering sire lines in 2015. The objective was to improve growth performance traits (live weight and feed conversion ratio) and fertility of the sire lines and also to improve the egg production and hatching traits by maintaining the growth levels in the dam lines for 3 generations.

Morphometric measurements are advantageous for the selection of breast yield, as they do not negatively affect the animal welfare and are practicable in the broiler pure-lines. In this study, morphometric measurements of breast and the relationship between breast and general traits were investigated under routine broiler management conditions for 42 days.

MATERIAL AND METHOD

Housing

This study was conducted in Ondokuz Mayis University, Agricultural Faculty experimental farm between May-July 2018. All procedures were approved by Ondokuz Mayis University Ethical Committee for Experimental Animals (Project number: 2017/31; 30.06.2017). This study was conducted within the scope of *"Production of Parents and Hybrids by Reciprocal Crossing from Pure-lines Used in Local Broiler Breeding"* project.

Chickens were reared on floor system with 8-cm-thick wood shavings as litter material. The experimental housing used measured 40x9.0x3.5 m, were windowed, artificially lighted and ventilated containing heaters producing hot air automatically. Unit sizes were 1.8×2.2 m, containing one 15 kg capacity tube feeder and 5 nipple drinkers.

Chicken strain

The chicken–strains of the study consisted of 3 pure dam (A1: slow feathering, A2: fast feathering and A3: slow feathering) and 2 pure sire lines (B1: fast feathering, B2: fast feathering) used for broiler breeding. In 2015, the breeding process started by multiplying the dam and sire lines. In 2016, 2017 and 2018, two-stage selection program was directed to live weight trait for these chickens at 6 and 12 weeks of age. In addition, the feed conversion test was applied to males between 6 and 12 weeks that passed the first selection stage and were used as breeders. After the individual feed conversion test, an additional selection was applied between 10-12 weeks by adding the breast width and length.

Pedigree production was carried out in 50 dam lines and sire lines were composed of 35 families (1 male, 10 female), 25 of the families with high hatching egg yield during the 35 weeks of laying period in dam lines, high fertility rate and live weight in sire lines. 17-18 of the families with high live weight were provided to multiply the next generation. Some important pedigree data of pure lines are given in Table 1.

This study was carried out to execute the broiler performance in 90 male and female mixed pure-line chicks which were produced from the third generation of selection of sire and dam lines and some broiler traits of pure lines were examined for 42 days. A total of 90 animals from each line were randomly distributed in 15 units with 3 replications (n=30; 7.5 chicks per m^2). All birds were fed *ad libitum* with the same commercial diet based on corn and soybean meal in a 4-stage feeding program (Table 2). Optimal environmental conditions are ensured for all animals. The lighting was applied 24 hours for the first 3 days, 23 hours for the next 21 days and 18 hours until slaughtering age. The light intensity at the animal level in all compartments was 20-25 lux. At least 33-34 °C temperature was

Table 1 – Some pedigree data of dam and sire lines.

Lines		Selection criteria	Ages (week)	Population sizes	Selected families
A1, A3	Dams	The highest hatching egg yield; in [redacted]	24^{th}-35^{th}	50 pedigree family in each dam line (1[redacted]:10[redacted])	25 pedigree family in each dam line
		Average live weight; in [redacted],[redacted]	6^{th} and 12^{th}		
		Individual FCR test; in [redacted]	6^{th}-12^{th}		
		Individual breast width and length in [redacted],[redacted]	10^{th}-12^{th}		
A2		The highest hatching egg yield; in [redacted]	24^{th}-35^{th}		
		More than 10% of average live weight; in [redacted],[redacted]	6^{th} and 12^{th}		
		Individual FCR test; in [redacted]	6^{th}-12^{th}		
		Individual breast width and length in [redacted],[redacted]	10^{th}-12^{th}		
B1, B2	Sires	More than 10% of average live weight; in [redacted], [redacted]	6^{th} and 12^{th}	35 pedigree family in each sire line (1[redacted]:10[redacted])	17-18 pedigree family in each sire line
		Individual FCR test; in [redacted]	6^{th}-12^{th}		
		Individual breast width and length in [redacted],[redacted]	10^{th}-12^{th}		
		Fertility test; in [redacted]	25-34^{th} and 35-45^{th}		

provided in the house for the first 3 days and it was gradually decreased by 2-2.5 °C per week until 28 days of age. Temperature was kept constant at 21-22 °C for the last 2 weeks. Chicks were vaccinated against Newcastle, Gumboro and Infectious Bronchitis Disease and no health problems were observed.

Table 2 – Nutritional content of feeds used in the study.

Nutrients	Broiler chick starter (1-7. days)	Broiler chick (8-28. days)	Broiler chicken (29-35. days)	Broiler finisher (36-42. days)
Crude protein (%)	23	22	21	18
ME (Kcal/kg)	3000	3100	3100	3100
Crude cellulose (%)	4.0	4.0	4.0	6.0
Crude ash (%)	5.0	5.0	5.0	5.0
Ca (%)	1.0	0.95	0.80	0.80
Phosphorus (%)	0.50	0.50	0.45	0.60
Methionine (%)	1.0	0.45	0.40	0.40
Lysine (%)	1.35	1.20	1.10	1.0

Data collection

At the end of the study (day 42), all chickens were fasted for 10 hours before slaughtering, at which time live weights (LW) were determined in all animals and by which time the live weights (LW) were determined in all animals and breast width (BWD) and breast length (BL) were measured in 30 females and 30 males in each genotype with a 0.1 mm precision digital caliper. The largest distance between two points of the breast was BWD and the longest distance between two points from the front to the back through the sternum was determined as BL. Carcasses were chilled for 24 h at 4°C and cut into parts according to standard methods. Carcass weight (CW), ratio (CR, %), Breast weight (BW, g) and ratio (BR, %), abdominal fat weight (AFW, g) and ratio (AFR, %) were determined from cold carcass (Yamak *et al.,* 2017). Equation of breast index (BI), (BWD*BL) was used (Xu *et al.,* 2018).

Statistical analysis

Numerical data were analyzed statistically and calculated arithmetic means, standard errors of the mean as well as the coefficients of pearson correlation between BWD, BL, BI and LW, CW, CR, BW, AFW, BR, AFR in pure-line broiler chickens (males and females was analysed separately in dam and sire lines). The significance of the differences between the mean values of traits for males and females was determined by a one-factorial analysis of variance. The data obtained were tested as normal distribution, the values expressed as% were analyzed by transforming and the real value averages were given in the tables. Duncan multiple comparison test was used to compare the means (p<0.05) (Onder, 2018). Pearson correlation test was used to determine the relationships between variables and correlation coefficients are given in Table 4 and Table 5. BW was estimated by linear simple and multiple regression equations using LW, BWD and BL variables. Regression models of dam and sire lines were evaluated by the coefficients of determination (r^2) and standard error (S_y) of estimation (Table 6). The regression model used was:

$$Y_i = a + b_1x_1 + b_2x_2 + \cdots b_kx_k + S_y$$

where Y_i was the response variable (BW) of chicken; *a* was the regression constant; b_k was the regression coefficients of LW, BWD and BL and X_k was the explanatory variables (LW, BWD and BL). SPSS software was used in all analyzes (Version 22).

RESULTS

General and breast traits of broiler pure-lines are given in Table 3. Significant differences were found in traits such as CW and BR ($p<0.01$); LW, BW, AFW, AFR, BWD, BL and BI ($p<0.05$). Sire lines (B1 and B2) showed higher values for LW, CW, BW, BL, BWD and BI than dam lines (A1, A2 and A3).

The B2 line had a higher LW (2649.0 g), while the A1 line remained the lowest (2338.3 g). The same situation was observed in CW, but there was no significant difference between both lines for CR (74.0% and 75.5%). In dam lines A2 lines have the highest level of AFW (59.6 g) than A1 and A3 lines. AFW value of A2 line was similar to B1 and B2 lines (58.1 g and 53.7 g, respectively). AFR was lower in A1 line with 2.1% and higher in A2 line with 3.4% ($p<0.01$). There were significant differences in BW, BR, BL, BWD and BI breast traits between the lines ($p<0.05$; $p<0.01$). BW and BI were higher in sire lines and lower in A1line ($p<0.01$). The highest BR was observed in B2 line with 37.9%, followed by B1 (37.6%), A3 (36.8%), A1 (36.2%) and A2 (35.8%) lines, respectively. BWD and BL were lower in A1 and A3 lines (10.59-13.81 cm and 10.64-13.98 cm, respectively).

Table 3 – General and breast traits of broiler pure-lines.

Lines	General traits					Breast traits				
	LW (g)	CW (g)	CR (%)	AFW (g)	AFR (%)	BW (g)	BR (%)	BL (cm)	BWD (cm)	BI
A1	2338.3^b	1741.7^b	74.5	35.9^b	2.1^d	629.4^b	36.2^{bc}	13.81^c	10.59^c	146.48^b
A2	2364.7^b	1766.5^b	74.3	59.6^a	3.4^a	631.4^b	35.8^c	14.08^{bc}	10.86^{bc}	153.19^b
A3	2376.7^b	1750.0^b	74.0	38.5^b	2.2^{cd}	642.0^b	36.8^{abc}	13.98^c	10.64^c	148.98^b
B1	2618.5^a	1973.9^a	74.5	58.1^a	3.0^{ab}	742.2^a	37.6^{ab}	14.68^{ab}	11.41^a	167.03^a
B2	2649.0^a	1975.8^a	75.5	53.7^a	2.8^{bc}	748.2^a	37.9^a	14.94^a	11.33^{ab}	169.52^a
SEM	21.6	29.7	0.19	1.75	0.09	8.32	0.22	0.77	0.66	4.29
P values	**	*	NS	**	**	**	*	**	**	**
Male	2707.3	2016.3	74.5	46.5	2.3	732.7	36.3	14.77	11.30	166.87
Female	2231.6	1666.9	74.6	51.8	3.1	624.6	37.4	13.83	10.64	147.21
Gender	**	**	NS	NS	**	**	*	**	**	**
Line*Gender	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

LW:Live weight; CW:Carcass weight; CR:Carcass ratio; AFW:Abdominal fat weight; AFR:Abdominal fat ratio; BW:Breast weight; BR:Breast ratio; BL:Breast length; BWD: Breast width; BI: Breast index.

a, b, c: Means within columns with no common superscript letter differ significantly (*: $p<0.05$; **: $p<0.01$); SEM: standard error of means; NS: insignificant.

While the effect of gender on LW, CW and AFR was significant ($p<0.01$), it's not significant on CR and AFW ($p>0.05$). In males, LW and CW were higher (475.7 g and 349.4 g more) than females, whereas AFR was higher in females (3.1% vs 2.3%). BW, BL, BWD and BI were higher in males ($p<0.01$) and BR had higher value in females with a difference of 1.1% ($p<0.05$). Interactions between lines and gender were not significant for all traits and are thus not shown in Table 3.

Pearson correlation coefficients between morphometric measurements of breast and some variables in mixing of pure-lines were given in Table 4. Positive strong correlations were determined between BWD and BI; LW and CW variables in sire lines. Regardless of the correlations between AFW and BWD, BL, BI; AFR had also a low negative relationship with BWD (-0.41). In dam lines, the relationships between BWD, BL, BI and LW, CW, BW were higher than sire lines (0.74-0.89). The relationship between BI and LW, CW, BW were higher than that of BWD and BL. Unlike sire lines, there was no correlation between AFR and variables. There was no significant relationship between CR and morphometric traits on either line.

Pearson correlation coefficients between morphometric measurements of breast and some variables in dam and sire lines were given in Table 5. In dam lines, it is seen that males have moderate and high relationships between BWD and LW, CW, BW and females showed low-medium relations for these variables. In particular, the relationship between BI and LW, CW is high in males. In males of dam line, a moderate relationship was found between CR and BL, BI; 0.48 and 0.54, respectively.

The relationships between BWD and LW, CW were moderate and low in males of sire lines, high

Table 4 – Pearson correlation coefficients between morphometric measurements of breast and some variables in mixed gender of pure-lines.

Lines	Variables	Pearson correlation coefficients		
		BWD	BL	BI
	Weights, g			
	LW	0.70**	0.42*	0.72**
	CW	0.72**	0.44*	0.75**
	BW	0.73**	0.48*	0.79**
	TW	0.65**	0.42*	0.70**
Sire	AFW	-0.07	-0.19	-0.19
	Ratios in carcass, %			
	CR	0.16	0.14	0.19
	BR	0.19	0.23	0.27
	TR	0.21	0.17	0.26
	AFR	-0.41*	-0.35	-0.51*
	Weights, g			
	LW	0.81**	0.80**	0.89**
	CW	0.81**	0.81**	0.89**
	BW	0.79**	0.74**	0.84**
	TW	0.76**	0.79**	0.85**
Dam	AFW	0.26	0.19	0.25
	Ratios in carcass, %			
	CR	0.23	0.22	0.26
	BR	-0.11	-0.23	-0.19
	TR	0.20	0.34*	0.29
	AFR	0.00	-0.06	-0.03

LW:Live weight; CW: Carcass weight; BW: Breast weight; BR: Breast ratio; TW: Thigh weight; TR: Thigh ratio; AFW: Abdominal fat weight; AFR:Abdominal fat ratio; BL: Breast length; BWD: Breast width; BI: Breast index. Coefficients of correlation significant at *p=0.05, **p=0.01.

Table 5 – Pearson correlation coefficients between morphometric measurements of breast and some variables in dam and sire lines.

Lines	Variables	Pearson correlation coefficients					
		BWD		BL		BI	
	Weights, g	■	■	■	■	■	■
	LW	0.77**	0.48*	0.61**	0.48*	0.82**	0.60**
	CW	0.75**	0.48*	0.68**	0.42	0.86**	0.57*
	BW	0.56*	0.59*	0.48*	0.43	0.62**	0.64**
	TW	0.55*	0.37	0.55*	0.45	0.66**	0.50*
Dam	AFW	0.41	0.41	0.25	0.40	0.39	0.51*
	Ratios in carcass, %						
	CR	0.42	0.26	0.48*	-0.08	0.54*	0.12
	BR	-0.01	0.43	-0.05	0.19	-0.04	0.40
	TR	-0.25	-0.40	-0.14	0.01	-0.23	-0.28
	AFR	0.36	0.36	0.16	0.36	0.31	0.45
	Weights, g						
	LW	0.65*	0.77**	0.25	-0.10	0.51	0.66*
	CW	0.69*	0.75**	0.36	-0.04	0.60*	0.70*
	BW	0.78**	0.66*	0.50	0.04	0.73**	0.67*
	TW	0.51	0.79**	0.20	-0.13	0.40	0.67*
Sire	AFW	0.10	0.08	0.14	0.02	0.13	0.07
	Ratios in carcass, %						
	CR	0.37	0.27	0.36	0.30	0.41	0.50
	BR	0.72**	-0.11	0.57	0.26	0.74**	0.08
	TR	-0.30	0.27	-0.27	-0.32	-0.33	0.03
	AFR	-0.19	-0.32	-0.02	0.08	-0.12	-0.27

LW:Live weight; CW: Carcass weight; BW: Breast weight; BR: Breast ratio; TW: Thigh weight; TR: Thigh ratio; AFW: Abdominal fat weight; AFR:Abdominal fat ratio; BL: Breast length; BWD: Breast width; BI: Breast index; Coefficients of correlation significant at *p=0.05, **p=0.01

relationships were determined between BWD and BW, BR (0.78 and 0.72, respectively). There was no significant correlation between CR and morphometric traits ($p>0.05$), while a positive correlation was determined between BI and BR (0.74). About the BI and CW, BW there was the moderate-high relationship in both sex, but a positive correlation was determined between BI and LW (0.66) in females.

Table 6 – Regression equations for estimating of breast weight (g) using morphometric traits.

Lines	Number	Regression equations	S_y	r^2
Dam	1	$Y = 0.245X_1 + 56.90$	34.6	0.828
	2	$Y = 9.837X_2 – 417.85$	51.3	0.621
	3	$Y = 7.663X_3 – 434.90$	56.0	0.549
	4	$Y = 0.211X_1+1.920X_2 - 69.66$	34.3	0.836
	5	$Y = 0.238X_1 + 0.307X_3 + 29.21$	35.1	0.828
	6	$Y = 6.616X_2 + 4.050X_3 – 638.42$	45.8	0.708
	7	$Y = 0.206X_1 + 1.910X_2 + 0.258X_3 – 92.27$	34.8	0.836
Sire	8	$Y = 0.282X_1 + 3.71$	37.0	0.815
	9	$Y = 12.097X_2 – 629.25$	58.6	0.538
	10	$Y = 5.928X_3 – 132.44$	75.5	0.231
	11	$Y = 0.238X_1 + 3.326X_2 – 258.80$	35.7	0.836
	12	$Y = 0.265X_1 + 1.573X_3 – 185.53$	36.5	0.829
	13	$Y = 11.074X_2 + 4.533X_3 – 1184.02$	50.7	0.669
	14	$Y = 0.208X_1 + 3.960X_2 + 2.006X_3 -550.21$	34.1	0.857

Y: Breast weight (BW); X_1: Live weight (LW); X_2: Breast width (BWD); X_3: Breast length (BL); *Sy*: Standart error of estimation; r^2: Coefficients of determination.

The regression equations for BW prediction were determined by using LW and BWD and BL, which are the morphometric traits of the breast (Table 6). There were no multi linearity observed between variables, because VIF values were under threshold of 10 (Onder & Abaci, 2015), and are not given in the table. 3 traits constituted independent variables of regression equations: LW (X_1), BWD (X_2) and BL (X_3). The calculations used the data on dams (equations 1 to 7) and sires (equations 8 to 14). The BW estimation for dam lines was determined by equation 4 *(Y = 0.211X1 + 1.920X2 - 69.66)* with the highest r^2 value (0.836) and the lowest *Sy* (34.3), and equation 7 had similar $r^2$and S_y (0.836; 34.8). This was followed by equations 1 and 5 and had the same r^2 value (0.828). For sire lines, the highest r^2 and S_y values were obtained in the 14th equation (0.857; 34.1) and the lowest r^2 in the 10th equation (0.231).

DISCUSSION

The selection efficiency in pure lines largely determines the performance of future broiler hybrids. The feed conversion ratio, carcass parts such as breast and abdominal fat level are important traits for poultry breeding. As expected from general traits, CW and BW were closely related to LW and the differences in lines of these traits were similar and were higher in sire lines and males. These results confirm previous findings for general traits in broiler pure-lines, possibly because of the selection for egg production in dam lines that caused lower live weight and the selection for growth traits in sire lines increased live weight and body mass gain (Berri *et al.,* 2001; Schmidt *et al.,* 2009). Similarly, Schmidt *et al.* (2006), when applied selection for live weight, sire lines showed higher LW than dam lines. Besides, Havenstein *et al.* (2003a), Siegel *et al.* (2006) and Schmidt *et al.* (2009) indicated that the growth traits of males were better than females. In females, BR was higher (37.4%) than males (36.3%), this was due to the high BW/CW ratio (Havenstein *et al.,* 2003b).

For the abdominal fat, Havenstein *et al.* (2003b) indicated that abdominal fat content in males was 0.24%, and 0.30% in females at 43 days of age in 1957. They also reported that these values increased to 1.29% in males and 1.50% in females in 2001 (Havenstein *et al.,* 2003b). In addition, depending on the direction of selection, significant differences were determined between both lines for abdominal fat and also positive correlations were determined between live weight and abdominal fat. In the present study, females had significantly more AFR than males in all lines with a higher AFR (3.4%) in A2 line. AFR of B1 and B2 lines were similar and this is in agreement with previous studies. The higher abdominal fat deposition in A2 line may be explained by the fact that both the dam line and the result of intensive selection applied in the direction of live weight were unlike the A1 and A3 lines. It was also known that the egg production at 52 weeks of age in the A2 line is lower than A1 and A3 (data not shown). The fact that the AFR value in B1 and B2 lines are higher than A1 and A3 is seen as an obvious result of the selection applied for live weight.

Schmidt *et al.* (2006) determined BWD (6.88-7.38 cm), BL (12.10-12.83 cm) in dam lines and (11.41-11.33 cm), (14.68-14.94 cm) respectively in sire lines. In the present study, the overall results showed the higher values of BWD and BL whether in sire or dam lines. This discrepancy in results may be because of genotype, selection intensity and duration of the selection and breeding process. In addition, some previous studies have shown that correlation coefficients between BW and BL, BWD were weaker (Argentao *et al.,* 2002; Gaya *et al.,* 2011), while in this study the correlation between BW and BL, BWD was higher. Lariviere *et al.* (2007) reported similar findings that there was a strong correlation between BW and BWD. However, the relationship of BW with BL (0.82) and BWD (0.74) was lower than BI (0.87). Therefore, BI (0.79) may be used in the prediction of breast meat yield in sire lines rather than BWD (0.73) and BL (0.48) separately.

Cahaner *et al.* (1985) stated that there is a positive relationship between body weight and abdominal fatness. In our study, it was observed that selection applied in the direction of live weight increased the amount and rate of abdominal fat in sire lines and partially in A2 line. In this way, AFW and AFR were A2: 59.6 g; 3.4%; B1: 58.1 g; 3.0%; B2: 53.7; 2.8%; A3: 38.5 g; 2.2%; A1: 35.9 g; 2.1%, respectively. However, it may be said that there is a significant negative correlation between BI and AFR (-0.51), and a moderate decrease in abdominal fatness can be achieved in selection by BI values. In dam lines, higher correlations were found between LW, CW, BW and morphometric traits compared to sire lines. Strong correlations were determined between BI and LW, CW and BW: 0.89, 0.89 and 0.84, respectively. These correlations may be explained by the fact that breast and carcass ratios are higher in dam lines than sire lines. In order that, it could be reasoned that the use of BI instead of the separate use of BWD and BL allows a higher estimate of the amount of breast meat in dam lines. There was no significant correlation between BR, AFR and morphometric traits. In dam lines, the stronger correlations were observed between LW, CW, TW and BWD, BL, BI in males than females, but no relation was observed with TWD trait. In addition, the presence of a moderate relationship (0.51) between AFW and BI in females indicates that abdominal fatness will increase following selection for BI. However, it could be reasoned that AFR may be reduced in future generations with high heritability of breast yield. In sire lines, the correlations between BW, BR and BWD were determined (0.78 and 0.72, and BI 0.73 and 0.74, respectively) in males.

In the multiple regression models for dam and sire lines, BW was estimated by using LW, BWD and BL variables, r^2 and S_y values were shown in Table 6. Melo *et al.* (2003) used LW, BWD and BL explanatory variables in the estimation of BW and r^2 values were determined 0.85, 0.30 and 0.63 respectively. Phenotypic correlations between morphometric traits and BW and regression equations including these traits show a higher relationship and r^2 than BWD in estimation of BW (Melo *et al.,* 2003; Bochno *et al.,* 2000). In our study, 0.828 and 0.815 r^2 values were slightly lower in dam and sire lines in the estimation of LW and BW in equations 1 and 8, respectively. The r^2 values of BWD (equations 2 and 9; 0.621 in dams, 0.538 in sires) were higher and r^2 values of BL in our dam and sire lines (equations 3 and 10; 0.549 in dams; 0.231 in sires) has remained less accurate in estimation compared to the study of Melo *et al.* (2003). In our study, although LW shows high r^2 and low *Sy* in simple linear regression equations (1 and 8), this situation is also observed in multiple linear regressions. Therefore, it is important to note that only equations including LW are not sufficient to predict BW, but other independent variables should be considered. Therefore, the use of equation 7 ($Y = 0.206X_1 + 1.910X_2 + 0.258X_3 – 92.27$; $r^2 = 0.836$; S_y: 34.8) for dam lines and the equation 14 ($Y = 0.208X_1 + 3.960X_2 + 2.006X_3 – 550.21$; $r^2 = 0.857$; S_y: 34.1) for sire lines with high r^2 and low S_y values will provide more accurate estimation.

CONCLUSION

Breast yield has been one of the most important features of broiler chickens since the beginning of breeding and selection process. In the selection studies applied in the direction of this yield, the breast weight was determined directly by slaughtering and the carcass portion. However, this method has many disadvantages such as labor force, welfare and the destruction of breeding material which led to the search for new methods. It is seen that there are significant relationships between breast and thigh yields and some morphological characteristics, ease of measurement, protection of breeding material and suitable for animal welfare. In the present study, it is thought that the use of BI (BWDXBL) which shows a higher correlation with these traits will increase the efficiency of selection rather than using the BWD and BL separately. In addition, when BWD and BL were used separately in the regression equations, r^2 values were low and the determination coefficient values were insufficient. In multiple regression equations involving LW, BWD and BL as explanatory variables, BW could be estimated with r^2 and minimum S_y. At the same time, it is considered that BI (BWDXBL) that has a negative correlation with abdominal fatness in sire lines, it may be used to improve breast traits on one hand and reduce abdominal fat on the other hand. Furthermore, it is thought that correlation coefficients and r^2may be strengthened if the breast depth can be determined indirectly without affecting animal welfare.

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REFERENCES

Argentao C, Filho TM, Marques J, Souza E, Eler J, Ferraz J. Genetic and phenotypic parameters of growth and carcass traits of a male line of broilers raised in tropical conditions. Proceedings of the 7th World Congress on Genetics Applied to Livestock Production; 2002 Aug 19-23; Montpellier. France. p.333–336.

Arthur JA, Albers GAA. Industrial perspective on problems and issues associated with poultry breeding. In: Muir WM, Aggrey SE, editors. Poultry genetics breeding and biotechnology. Wallingford: CAB International; 2003.

Baka G, Romvári R, Milisits G, Süti Z, SzabóA, Locsmándi L, et al. Non-invasive body composition measurement of broiler chickens between 4 – 18 weeks of age by computer tomography. Archiv für Tierzucht Dummerstorf 2003;46:585-595.

Bentsen HB, Sehested E. Computerised tomography of chickens. British Poultry Science 1989;30:575-585.

Berri C, Wacrenier N, Millet N, Le Bihan-Duval E. Effect of selection for improved body composition on muscle and meat characteristics of broilers from experimental and commercial lines. Poultry Science 2001;80:833-838.

Bochno R, Rymkiewicz J, Szeremeta J. Regression equations for in vivo estimation of the meatcontent of duck carcasses. British Poultry Science 2000;41:313-317.

Cahaner A, Krinski M, Nitsan Z. The response to one cycle of divergent selection for abdominal fat in broilers raised under different conditions. Poultry Science 1985;64:1813-1820.

Gaya LDG, Mourão GB, Ferraz JBS, Mattos EC, Costa AMMA, Filho TM, et al. Estimates of heritability and genetic correlations for meat quality traits in broilers. Scientia Agricola 2011;68:620-625.

Gaya LDG. Genetic variability in ultrasound records of breast muscle in a broiler breeding program. Natural Science 2013;5:1-4.

Havenstein GB, Ferket PR, Qureshi MA. Growth, livability, and feed conversion of 1957 versus 2001 broilers when fed representative 1957 and 2001 broiler diets. Poultry Science 2003a;82:1500–1508.

Havenstein GB, Ferket PR, Qureshi MA. Carcass composition and yield of 1957 versus 2001 broilers when fed representative 1957 and 2001 broiler diets. Poultry Science 2003b;82:1509–1518.

Kövér G, Romvári R, Horn P, Berényi E, Jensen JF, Sorensen P. In vivo assessment of breast muscle, abdominal fat and total fat volume in meat type chickens by magnetic resonance imaging. Acta Veterinaria Hungarica 1998;46:135-144.

Lariviere JM, Michaux C, Verleyen V, Hanzen C, Leroy P. Comparison of non-invasive methods to predict breast muscle weight in slow-growing chickens. Proceedings of the 18th European Symposium on the Quality of Poultry Meat and of the 12th European Symposium on the Quality of Eggs Products; 2007 Sept 2-5; Prague. Czech Republic. p.262–263.

Melo JE, Motter MM, Morao LR, Huguet MJ, Canet Z, Miquel CM. Use of in-vivo measurements to estimate breast and abdominal fat content of a free-range broiler strain. Animal Science 2003;77:23-31.

Mitchell AD, Wang PC, Rosebrough RW, Elsasser TH, Schmidt WF. Assessment of body composition of poultry by nuclear magnetic resonance imaging and spectroscopy. Poultry Science 1991;70:2494–2500.

Onder H, Abaci S. Path analysis for body measurements on body weight of Saanen kids. Kafkas Üniversitesi Veteriner Fakültesi Dergisi 2015;21(3):351-354.

Onder H. Nonparametric statistical methods used in biological experiments. Black Sea Journal of Engineering and Science 2018;1(1):1-6.

Schmidt GS, Figueiredo EAP, Ledur MC. Genetic gain for body weight, feed conversion and carcass traits in selected broiler strains. Revista Brasileira de Ciência Avícola 2006;8:29-32.

Schmidt CJ, Persia ME, Feierstein E, Kingham B, Saylor WW. Comparison of a modern broiler line and a heritage line unselected since the 1950s. Poultry Science 2009;88:2610-2619.

Scollan ND, Caston LJ, Liu Z, Zubair AK, Leeson S, Mcbride BW. Nuclear magnetic resonance imaging as a tool to estimate the mass of the pectoralis muscle of chickens in vivo. British Poultry Science 1998;39:221–224.

Siegel PB, Blair M, Gross WB, Meldrum B, Larsen C, Boa-Amponsem K, et al. Poult performance as influenced by age of dam, genetic line, and dietary vitamin E. Poultry Science 2006;85:939–942.

Silva SR, Pinheiro VC, Guedes CM, Mourão JM. Prediction of carcass and breast weights and yields in broiler chickens using breast volume determined in vivo by real-time ultrasonic measurement. British Poultry Science 2007;47(6):694-699.

Svihus B, Katle J. Computerised tomography as a tool to predict composition traits in broilers. Comparisons of results across samples and years. Acta Agriculturae Scandinavia, Animal Science 1993, 43:214-218.

Thiruvenkadan A, Prabakaran R. Recent approaches in poultry breeding. Approaches in Poultry, Dairy and Veterinary Sciences 2017;2(2).

Wilson DE. Application of ultrasound for genetic improvement. Journal of Animal Science 1992;70:973-83.

Xu TS, Liu XL, Huang W. Estimates of genetic parameters for body weight and carcass composition in pekin ducks. Journal of Animal and Veterinary Advances 2011;10:3123-8.

Xu Y, Hu J, Zhang Y, Guo Z, Huang W, Xie M, et al. Selection response and estimation of the genetic parameters for multidimensional measured breast meat yield related traits in a long-term breeding Pekin duck line. Asian-Australasian Journal of Animal Sciences 2018;31(10):1575-1580.

Yamak US, Sarica M, Boz MA, Ucar A. Effect of production system (barn and free range) and slaughter age on some production traits of guinea fowl. Poultry Science 2017;0:1–7.