Prediction of live broiler weight based on body measurements

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ABSTRACT

Two strains of broiler type chickens (WL and VC) that varied in body conformation were used to determine the relationship of egg weight, body weight and shank length at various ages to live weight at broiler age (BW_7). Response for fast growth was observed in the VC strain. Larger skeleton as a response was observed in the WL strain. Differences between strains become very prominent as the birds advanced in age. Measurements of body weight at 5 weeks plus sex effect used as estimators of final weight (BW_7) gave the highest values of R^2 (0.910 and 0.818 in WL and VC strains, respectively). Measurements of body weight at 3 weeks (BW_3) showed a significant positive linear relationship, but had a small effect on final weight.

The results indicate that selection response for heavy birds at 54 days of age by measuring their shank length at an age younger than 5 weeks is not recommended for these two strains.

Within a strain, the r^2 or R^2 increase values were always higher for body weight as a predictor of final weight than shank length at the same age and sex. Thus, body weight is the simplest and most accurate parameter to be used as a critierion for growth selection from 5 weeks of age onward.

The effect of egg weight on final weight (BW_7) was not significant for the two strains.

INTRODUCTION

Primary breeders in the broiler industry have carefully undertaken selection programs to produce grandparent and parent stocks to be used in the production of commercial broiler chicks. One of the most important traits under selection is rapid growth. Selection is usually done when birds reach 8 weeks of age. Raising chicks up to 8 weeks prior to selecting them is costly.

Lerner (6) reported the correlation coefficients between 4 week shank length and 8 week body weight as 0.778 and 0.740 for males and females, respectively. Also. Knos and Mardsolen (5), Ablanalp and Kosin (2), Rizak and El-Ibiary (9) and Chhabra and Desai (3) reported that body weight and shank length are highly associated traits. All these reports indicate that long legged birds yield more weight and possibly more meat. Nir and Ascarelli (8) studied the relationship between the final weight and growth at younger ages. Their results indicated that the correlations of 42 day weight with 5 day weight and 14 day weight were, 0.342 and 0.621, respectively.

The correlation of egg weight and body weight has been reported to be the highest in the first week and then decreases gradually and by 10 weeks of age the correlation has almost disappeared (10). Moris et al (7) found a strong positive relationship between

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the weight of the chick at 1 day of age and egg weight for both sexes with no significant differences in the weight of the sexes.

The following study was conducted to formulate a prediction equation of final weight using early measurements of body weight and shank length and egg weight.

MATERIALS AND METHODS

The experimental populations used in this study were obtained from Indian River Poultry farms and two strains were used; strain one (designated WL by supplier) is a dominant white strain selected for large skeleton and is characterized by an angular body shape and has an estimated inbreeding coefficient (F) of 18-20%. Strain two (designated VC by supplier) is characterized by heavy flesh, had a calculated inbreeding coefficient (F) of 10%.

Two experiments were conducted at approximately two and one-half year interval.

In experiment 1: there were 308 and 349 eggs set from WL and VC strains, respectively. All the eggs were individually numbered and weighed, and were set in the incubator (hatch-0. Matic, Robbins) in alternating tray for each strain. There were 44 males and 64 females from WL strain and 81 males and 104 females from VC strain used throughout the experiment. All the chicks were individually wing banded and body weight (BW_1) and shank length (SL_1) were recorded at one day of age to the nearest 0.1 gram and .01 cm, respectively. When shank length was measured, the left leg was held so that the tarsal joint and joint between the tarsometatarsus and the midle toe both form right angles. A vernier caliper was used to measure the distance between the center of the foot pad and the posterior surface of the tarsal joint. Thus, the measurement included the length of the tarsometatarsus, the thickness of the distal head of the tibiotarsus plus the soft tissues and skin. All chickens were brooded and reared in one large pen intermingled on the floor using conventional management procedures. They were fed, ad libitum, a Colorado State University standard broiler starter ration. At 5 weeks of age, body weight and shank length were recorded and designated as BW_5 and SL_5. Body weight was recorded at the age of 54 days and was designated as BW_7.

Experiment 2: There were 323 and 291 eggs from WL and VC strains respectively. All eggs were handled, hatched and reared in the same way as in experiment 1. The numbers of birds at the end of the experiment were 26 males and 54 females from WL strain and 58 males and 74 females from VC strain. In this experiment, measurements of body weight and shank length were extended to include the following:

BW_1	Body weight at 1 day
SL_1	Shank length at 1 day
BW_2	Body weight at 2 weeks
SL_2	Shank length at 2 weeks
BW_3	Body weight at 3 weeks
SL_3	Shank length at 3 weeks
BW_5	Body weight at 5 weeks
SL_5	Shank length at 5 weeks
BW_7	Body weight at 54 days
SL_7	Shank length at 54 days
Egg Wt.	Hatching egg weight.

The growth weight data from the experiments were analyzed separately for each strain and sex using the following simple linear regression model:

$$Y_i = B_o + B_1X_1 + E_i$$

where Y_i is the i^{th} observation for BW_7. X_i is the i^{th} observation of the independent variable (body weight or shank length) at a given age younger than 54 days. B_o is the intercept, B_1 is the slope of the regression of Y_i on X_i, and E_i is random error assumed N $(0,\sigma^2_e)$.

Another analysis (11) was performed for the growth data of each strain. However, the sex effect was included in the model. This analysis was used to utilize the stepwise regression in order to construct a prediction equation for both sexes. The following multiple regression model was used:

$$Y_{ij} = B_o + B_1X_i + B_2Z + B_3X_i1Z + E_{ij}$$

Y_{ij} is the i^{th} observation for BW_7 of the j^{th} sex, j = 1,2 X_{ij} is the i^{th} observation of the independent variable (body weight or shank length) at a given age of the j^{th} sex, j = 1,2 Z is ad dummy variable (sex) and Z = 0 if males and Z = 1 if females, B_1 is the slope of the regression of Y_{ij} *on* X_i for males and for females the slope $B = (B_1 + B_3)$, B_2 is the difference between male and female intercepts, B_3 is the difference between the slopes of the two sexes, E_{ij} random error distributed with N $(0,\sigma^2)$.

RESULTS AND DISCUSSION

As early as 2 weeks of age response to selection for fast growth was observed in the VC strain (Table 1). Larger skeleton as a response to selection was observed in the WL strain. Differences between strains become very prominent as the birds advanced in age. There were no significant differences in the mean of egg weight between the two strains in experiment 2.

Table 1 — Mean and standard error of egg weight and body measurements in the two experiments

	Variables	No. Birds	WL	No. Birds	VC
			Strains		
Exp. 1					
	Egg wt. (g)	108	65.86 ± 0.679***	185	62.11 ± 0.396
	BW_1 (g)	108	45.41 ± 0.345***	185	41.68 ± 0.304
	BW_5 (g)	108	1015.43 ± 12.99	185	1028.42 ± 11.31
	BW_7 (g)	108	1940.77 ± 24.66	185	1997.58 ± 20.87
	SL_1 (cm)	108	2.66 ± 0.011	185	2.64 ± 0.009
	SL_5 (cm)	108	8.26 ± 60.051***	185	8.02 ± 0.039
Exp. 2					
	Egg wt. (g)	81	60.80 ± 0.479	134	60.99 ± 0.381
	BW_1 (g)	81	42.92 ± 0.34	134	43.07 ± 0.31
	BW_2 (g)	81	248.83 ± 3.71	134	267.01 ± 2.53***
	BW_3 (g)	81	464.33 ± 6.08	134	489.72 ± 4.31***
	BW_5 (g)	81	1093.53 ± 17.28	134	1213.28 ± 11.73***
	BW_7 (g)	80	2040.39 ± 42.92	133	2302.45 ± 28.63***
	SL_1 (cm)	81	2.64 ± 0.019	134	2.63 ± 0.008
	SL_2 (cm)	81	4.84 ± 0.033	134	4.77 ± 0.020
	SL_3 (cm)	81	6.03 ± 0.034	134	5.98 ± 0.026
	SL_5 (cm)	81	8.54 ± 0.047**	134	8.38 ± 0.037
	SL_7 (cm)	80	11.08 ± 0.091*	133	10.87 ± 0.062

* Significant difference (P ≤ .05) between the two stains.
** Significant difference (P ≤ .01) between the two stains.
*** Significant difference (P ≤ .001) between the two stains.
! Differences approach significance at (P ≤ .10) between the two strains.

Experiment 1: Prediction equations were formulated for BW_7 from the knowledge of each independent variable that showed a significant relationship with BW. The prediction equation and coefficient of determination (r^2) for each sex seperately are given in Table 2. The dependence of BW_7 on BW_5 and SL_5 was highly significant ($P < .01$) in the

Table 2 — Prediction equation for body weight at 54 days of age (BW_7) and the coefficient of determination (r^2 in WL and VC strains (Experiment 1)

Strain	Sex	Independent Variable	Prediction Equation	r^2
WL	Male	**Shank Length**		
		SL_1	$\hat{Y}_{BW_7}$ = 819.4 + 508.5 SL_1	0.126*
		SL_5	$\hat{Y}_{BW_7}$ = -180.8 + 273.7 SL_5	0.486**
		Bodi Weight		
		BW_5	$\hat{Y}_{BW_7}$ = 842.9 + 1.2 BW_5	0.696**
	Female	**Shank Length**		
		SL_1	$\hat{Y}_{BW_7}$ = 606.1 + 441.0 SL_1	0.103**
		SL_5	$\hat{Y}_{BW_7}$ = -167.9 + 242.6 SL_5	0.468**
		Body Weight		
		BW_1	$\hat{Y}_{BW_7}$ = 1316.5 + 10.1 BW_1	0.062*
		BW_5	$\hat{Y}_{BW_7}$ = 578.0 + 1.3 BW_5	0.777**
VC	Male	**Shank Length**		
		SL_5	$\hat{Y}_{BW_7}$ = 285.7 + 234.3 SL_5	0.283**
		Body Weight		
		BW_5	$\hat{Y}_{BW_7}$ = 1261.8 + 0.88 BW_5	0.414**
	Female	**Shank Length**		
		SL_1	$\hat{Y}_{BW_7}$ = 607.4 + 456.6 SL_1	0.097**
		SL_5	$\hat{Y}_{BW_7}$ = 207.0 + 206.0 SL_5	0.263**
		Body Weight		
		BW_5	$\hat{Y}_{BW_7}$ = 824.3 + 1.0 BW_5	0.531**

* Significant at ($P < .05$). ** Highly significant at ($P < .01$).

two strains and on SL_1 in the WL and VC females only (table 2). There was a significant ($P<.05$) linear relationship between BW_7 and SL_1 in males and BW_7 and BW_1 in WL females. It was noted that, within a strain, the r^2 values were always higher for body weight than shank length at the same age and sex, except in one single case where r^2 for BW_1, was lower than the one for SL_1 in WL females. Most of the variation in BW_7 were explained by BW_5 variable with a maximim r^2 value of 0.777.

The results of multiple regression analysis of BW_7 and the prediction equation are shown in Table 3 for strain WL and VC. Multiple regression analysis using stepwise procedures was used to analyze these data.

Sex has been used as a dummy variable in the equations along with the main continuous variable plus the ineraction between the two. Regression coefficients of BW_7 on SL_1, SL_5, BW_5 and sex were highly significant ($P<.01$) in the two strains and also on sex by SL interaction in the WL strain only, (table 3). The power of determination of the studied independent variables on BW_7 was different in the two types of regressional analysis (simple and multiple regression analysis). For example, when sexes were combined in one analysis, SL_1 caused an increase in the BW_7 of explained variability of 0.039 and 0.021 in WL and VC, respectively, whereas in the simple regression analysis, the same variable had higher values of r^2, 0.126 and 0.103 in WL males and females respectively, and 0.097 in VC females. But when the measurementes of body weight and shank length were taken at 5 weeks of age in WL strain and only the body weight at the same age in the VC strain, the r^2 values were lower than the R^2 increase for the same variable. This means that more precision was obtained by combining the sex in one analysis which mean that variability within groups was reduced.

Experiement 2: Coefficent of the regression lines of body weight on shank length for the period 1 to 54 days of age inWL and VC males and females are presented in Table

Table 3 — Prediction equation for BW_7, R^2 increase due to sex or interaction, multiple R and R^2 coefficients by strain (Experiment 1)

Strain	Indipendent variable Xi	Prediction equation [(1)]	R^2 increase (sex or interaction)	R	R^2
WL	**Shank Length**				
	SL_1	$Y_{BW_7} = 926.1 + 468.9\ SL_1 - 393.8Z$	0.653	0.832	0.693
	SL_5	$Y_{BW_7} = -172.4 + 272.7\ SL_5 - 29.5\ SL_5Z$	0.137	0.905	0.818
	Body Weight				
	BW_5	$Y_{BW_7} = 807.9 + 1.2\ BW_5 - 207.4\ Z$	0.097	0.954	0.910
VC	**Shank Length**				
	SL_1	$Y_{BW_7} = 1272.3 + 366.9\ SL_1 - 431.5Z$	0.651	0.820	0.672
	SL_5	$Y_{BW_7} = 430.4 + 217.1\ SL_5 - 309.0Z$	0.651	0.863	0.746
	Body Weight				
	BW_5	$Y_{BW_7} = 1166.9 + 0.9.6\ BW_5 - 276.8Z$	0.145	0.904	0.818

(1) All the variables in the eqations are statistically significant

Table 4 — Average slope[1] and standard deviation of the regression equations of body weight on shank lenght in two strains for the period from 1 to 54 days of age (Experiment 2)

Strain	No. Birds	Sex	Slope gm/cm		Standard Deviation
WL	26	Male	255.4	±	29.4a/
	54	Female	231.4	±	28.8c/
VC	58	Male	288.2	±	21.8b/
	74	Female	269.5	±	20.39d/

[1] Regression coefficcient averaged over individual slopes. (All regression coefficients are significantly different from zero (P < .05)

a/ and c/ Significant difference (P < .01) from b/, d/, respectively.

4. A significant ($P < .05$) positive linear relationship was found between body weight and shank length during the period of 1 to 54 days of age for both strains and sexes. Significant differences were found between the slopes of regression lines of the two strains, Slopes of VC males and females were significantly ($P < .01$) higher than slopes of WL males and females, respectively from 1 to 54 days of age. Test of dependence of BW_7 on SL and body measurements at different ages for males and females in each strain are given in Table 5. In the first degree regression SL_2, SL_3, SL_5, SL_7, BW_2, BW_3 and BW_5 in WL males, and SL_5, SL_7, BW_2, BW_3 and BW_5 in VC males exhibited a highly significat ($P < .01$)positive relationship with BW_7. The females in the two strains were only slightly different than the males in regards to SL_1, SL_2 and SL_3 variables. In WL females, the regression of BW_7 on SL_5, SL_7 and BW_2, BW_3 and BW_5 were significant ($P < .01$) and significant ($P < .05$) for SL_1, whereas in the VC females the regression of BW_7 on SL_2, SL_3, SL_5, SL_7 and BW_2, BW_3 and BW_5 were highly significant ($P < .01$) and on SL_1 being significant only at the ($P < .05$) level.

T-tests were made between males and females for each strain to test if there were any differences in the regression coefficient showing a significant linear relationship. Comparisons were also made between the same sex of the two strains. There were no significant differences ($P > .05$) in the slope of the regression lines. However, there were some inconsistencies in the results of the two sexes in the two strains with respect to SL_1, SL_2, SL_3 in both strains. Therefore, the data of both sexes from each strain were combined

Table 5 — Body wieght (BW_7) expressed as a function[a] of body measurement in 26 males (Top) and 54 females (Bottom) of WL strain and in 58 males (Top) and 74 females (Bottom) of VC strain (Esperiment 2)

Indipendente Variable	Strain WL	Strain VC
	MALES	
Shank Length		
SL_1	25.1 ± 272.1**	281.0 ± 329.7
SL_2	599.9 ± 161.2 **	196.1 ± 142.7
SL_3	569.4 ± 149.5**	109.4 ± 126.8
SL_5	594.2 ± 137.8**	344.8 ± 96.0**
SL_7	427.4 ± 100.9	351.8 ± 59.8**
Body Weight		
BW_1	7.1 ± 29.0	13.7 ± 7.9
BW_2	5.8 ± 1.3**	2.9 ± 1.1**
BW_3	4.3 ± 0.82**	2.2 ± 0.64**
BW_5	1.8 ± 0.31**	1.3 ± 0.25**
	FEMALES	
Shank Length		
SL_1	844.2 ± 352.1*	569.0 ± 272.9*
SL_2	213.8 ± 146.6	361.0 ± 114.4**
SL_3	226.3 ± 158.9	330.0 ± 82.0**
SL_5	353.6 ± 92.7**	336.8 ± 54.4**
SL_7	256.4 ± 46.7**	347.5 ± 37.5**
Body Weight		
BW_1	2.8 ± 12.1	4.3 ± 7.7
BW_2	3.1 ± 1.3*	4.5 ± 0.81**
BW_3	2.7 ± 0.70**	3.0 ± 0.51**
BW_5	1.7 ± 0.20	1.8 ± 0.14**

[a] Regression coefficient (mg/cm on SL; gm/gm on Bw) ± standard error
* Regression coefficient is significantly different from, zero (P < .05)
** Regression coefficient difference is highly significant from zero (P < .01)

in one analysis in order to overcome this reversal. The same procedures of multiple regression analysis used in Experiment 1 was also applied in Experiment 2. The prediction equations with R and R^2 (coeficient of determination), and R^2 increase which is the additional amount of total variability explained by sex are given in Table 9.

The variables SL_1, SL_2,SL_5, SL_7 and BW_2, BW_3 and BW_5 showed highly significant linear relationship with BW_7 in the two strains with SL_1 being significant at ($P < .05$). SL_3 was highly significant along with one of the main variables in the equation. This indicates that the regression lines of the two sexes have different intercepts (Table 6), when the interaction is significant as shown with the variables SL_5 and BW_3 in WL strain, the regression lines of both sexes are not parallel. R^2 and r^2 from multiple and simple regression analysis (Table 6, 7) respectively, were higher for the prediction equations pertaining to body weight than the shank length at the corresponding age. Judging from these values, one may conclude that the independent variables of body weight at a given age had a higher level of determination of BW_7 versus the shank length.

In general, the measurements taken on younger birds (3 weeks of age and under) would explain more of the variability in the final weight (BW_7) if the analysis were made separately for each sex. On the other hand, sexes would be more advantageous in explaining the variability in BW if they were combined in one analysis when the measurements were taken on older birds (over 3 weeks of age).

When the results of the two experiments were compared for the same variables (SL_1, SL_5, BW_1, BW_5) they were similar in VC strain for all the variables in both sexes but in WL only BW_1 of males and SL_1 of females were similar. In WL the relationships between BW_7 and SL_1 of males and BW_7 and BW_1 of females were not the same in the two

Table 6— Prediction equation for body weight at 54 days, multiple-R, R-square coefficient and R^2 increase for sex or interaction by strain (Experiment 2)

Strain	Indipendent variabile Xi	Prediction equation [1] prediction	R^2 increase sex or interaction	Multiple R	R^2
WL	**Body weight**				
	BW_2	$Y_{BW_7} = 1240.3 + 4.3\ BW_2 - 383.3Z$	.330	.187	.471
	BW_3	$Y_{BW_7} = 537.2 + 3.7\ BW_3 - 0.74BW_3Z$	.000	.743	.553
	BW_5	$Y_{BW_7} = 270.4 + 1.8\ BW_5 - 221.6Z$	.065	.852	.726
	Shank length				
	SL_1	$Y_{BW_7} = 485.2 + 707.6\ SL_1 - 436.8Z$	.330	.610	.372
	SL_2	$Y_{BW_7} = 515.5 + 374.9\ SL_2 - 414.8Z$	.330	.645	.416
	SL_3	$Y_{BW_7} = -80.1 + 394.0\ SL_3 - 368.6Z$	.330	.650	.423
	SL_5	$Y_{BW_7} = -1575.8 + 446.1\ SL_5 - 32.1SL_5Z$	.000	.722	.522
	SL_7	$Y_{BW_7} = -1727.3 + 340.9\ SL_7 -$	.000	.747	.559
VC	**Body weight**				
	BW_2	$Y_{BW_7} = 1514.9 + 3.8\ BW_2 - 394.0Z$	.457	.752	.566
	BW_3	$Y_{BW_7} = 1219.7 + 2.6\ BW_3 - 349.8Z$	.457	.769	.591
	BW_5	$Y_{BW_7} = 486.7 + 1.6\ BW_5 - 185.6Z$	.059	.860	.740
	Shank length				
	SL_1	$Y_{BW_7} = 1393.3 + 438.1\ SL_1 - 412.5Z$	.457	.689	.474
	SL_2	$Y_{BW_7} = 1165.6 + 268.6\ SL_2 - 388.2Z$	.457	.705	.497
	SL_5	$Y_{BW_7} = -382.0 + 339.3\ SL_5 - 266.8Z$	.475	.777	.604
	SL_7	$Y_{BW_7} = -1709.0 + 370.0\ SL_7$	0.000	.842	.709

(1) All variables in the equations are statistically significant

experiments. The results of both experiments indicate that, within a strain, the r^2 values were always higher for body weight than shank length for the same age and sex.

According to these findings, there were some differences in the results from one strain to another and from one experiment to the other. These differences could be due to changes in the genetic association between BW_7 and each of the independent variables and among these independent variables, themselves. In order to confirm this statement, further detailed studies involving estimates of genetic parameters should be made. The effect of individual egg weight on the final weight of the chick hatched from it was not significant in the two experiments and this may mean that both variables are controlled by independent genes as suggested by Festing and Nordskog (1967).

The results of this investigation showed that body weight at 5 weeks (BW_5) appear to be the simplest and most accurate parameter to be used as a criterion for growth selection. Among the shank measurements, SL_5 gave the highest correlation with the final weight but not as high as body weight at the same age.

Table 7 — Coefficient of determination (r^2) in males (top) and females (bottom) of WL and VC strains (Experiment 2)

Independent variable	r^2 WL	r^2 VC
	Males	
Shank length		
SL_2	.366**	—
SL_3	.377**	—
SL_5	.436**	.187**
SL_7	.428**	.382**
Body weight		
BW_2	.442**	.111**
BW_3	.532**	.179**
BW_5	.539**	.341**
	Females	
Shank length		
SL_1	.100*	.057*
SL_2	—	.121**
SL_3	—	.184**
SL_5	.219**	.347**
SL_7	.367**	.544**
Body weight		
BW_2	.105*	.298**
BW_3	.221**	.313**
BW_5	.591**	.705**

* Significant ($P < .05$)

** Highly significant ($P < .01$)

— No significant correlation

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« التنبؤ بوزن طيور اللحم باستعمال القياسات الجسمية »

د. على حسين كانون

المستخلص

استخدمت فى هذه الدراسة سلالتين من دجاج اللحم مختلفتين فى تكوينهما الجسمى وذلك لدراسة العلاقة بين الوزن الحى عند التسويق ووزن الجسم وطول الساق فى اعمار مختلفة ونتج عن عملية الانتخاب استجابة فى معدل النمو فى السلالة VC وكبر حجم الهيكل العظمى فى السلالة WL وكانت الفروق بين السلالتين جلية واضحة بتقدم العمر. كان لوزن الجسم عند الاسبوع الخامس من العمر بالاضافة الى تأثير الجنس، واللذين استعملا كتقدير للوزن النهائى (BW 7) اكبر قيمة لمعامل التقدير R 2 (0,910 و 0,818) فى WL و VC على الترتيب. ولقد اظهر وزن الجسم عند الاسبوع الثالث من العمر علاقة خطية موجبة ومعنوية بالرغم من تأثيره البسيط على الوزن النهائى. ولقد أظهرت النتائج بأن عملية الانتخاب للطيور الثقيلة الوزن فى عمر التسويق (54 يوم) مبنية على أساس قياس طول الساق فى عمر اقل من الاسبوعالخامس، غير مجدية داخل كل سلالة وبين السلالتين. ومن الملاحظ أيضا بأن قيمة معامل التقدير لوزن الجسم داخل كل سلالة كان ادق من استخدام طول الساق عند نفس العمر والجنس وذلك بالنسبة لوزن الجسم عند عمر التسويق ونستخلص من ذلك بأن استعمال وزن الجسم عند الاسبوع الخامس من العمر أو فى اعمار اكبر، كدليل لنمو الجسم، يعتبر اكثر كفاءة من اية ادلة اخرى.