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BODY MEASUREMENTS AS RELATED TO LIVE WEIGHT IN SWINE

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Introduction

Body measurements have a certain value in swine breeding and selection. Their usefulness arises from their relationship to the live weight of pigs. Winters (6),[2] stated that the weight of hogs can be calculated to a remarkable degree of accuracy by measurements.

Three body measurements, length from poll to tail head, heart girth, and flank girth, were compared with weight in a number of boars and barrows of imported, native, and crossbred pigs reared in Puerto Rico, which entered individual feeding trials.

The main objective of the study was to ascertain which measurement or measurements at weaning, with or without weight information, would be useful as an aid to selection for weight at 168 days of age. Although some work on the subject had been already reported in the United States, some differences were anticipated in this study because the pigs were reared under tropical conditions.

Winters (6), reported a formula for calculating weight at any age by measurements in inches: Heart girth $\times$ heart girth $\times$ length $\div$ 400 = weight in pounds. He stated that the formula is more accurate when used on hogs under 300 pounds than on heavier animals. He also presented a comparative table of the length, heart girth, and flank girth of boars and barrows of the Poland China and Minnesota No. 1 breeds at 24 weeks of age, and noted important sex differences in the measurements.

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The following persons contributed in one way or another to the progress of this study: Dr. R. E. Comstock, now of the North Carolina Institute of Statistics, initiated the work and directed the first feeding trial. Dr. W. W. Green, now of the University of Maryland, directed the second feeding trial and made suggestions for the better conduct of the work. Mr. Tomás Quiñones, who died in November 1948, was Swine Herdsman at La Plata, during the period covered in this study. His unceasing dedication to his work made possible the collection of most of the data presented here.

[2] Numerals in parentheses refer to Literature Cited, page 100-01.

Godbey et al (3), reported the coefficients of correlation of some measurements and weight at birth, and at 56, 112, and 168 days of age for 100 Berkshire barrows. They also reported the standard deviations and coefficients of variation of these measurements and weights.

González Chapel and Cabrera (4), showed that weaning weight could be used to some extent to predict the weight at 154 days of age of practically the same lot of pigs used in the present study.

Increasing the accuracy of the selection at an early age of pigs for breeding or subsequent rearing would, of course, reduce the cost of the selection and increase the efficiency of the herd management.

Procedure

The study reported here was conducted at the La Plata Animal Production Sub-station of the Agricultural Experiment Station, University of Puerto Rico, from March 1946 to August 1948. Four individual feeding trials were made during that period.

The following breeds and crossbreds were included in one or more of the different trials:

	Boars	*Barrows*		*Boars*	*Barrows*
Duroc Jersey	9	9	Landrace Large Black x Native	13	13
Natives	14	14	Tamworth x Duroc	4	4
Landrace Large Black x Duroc	11	11	Tamworth x Native	4	4
Duroc x Native	11	11			

A total of 132 pigs, 66 boars and 66 barrows, were considered. The source of the stock used was reported earlier (4).

The measurements were taken in inches and the weight in pounds by the same individual throughout the experiment.

The data were collected at weaning, (56 days), and at 84, 112, 140, and 168 days. Three measurements were made on each individual at each age and an average of the three was taken as representative of the measurement.

The same feed concentrate was given to the hogs and the same men took care of them throughout the trials.

The methods of multiple regression and analyses of variance outlined by Snedecor (5), were used in the study of the relationships. Capó's (1) design for the solution of normal equations was also used in the analysis of the data.

Experimental Findings

Measurements as related to breed and sex

Winters and Green (7), indicated that different strains of swine change body proportions at different ages. Winters (6), stated that swine change

form as they grow and, as weight increases, barrows and boars follow different paths of development in conformation.

The three measurements considered in this study differed significantly from each other at practically all ages in each of the four trials. Table 1 shows the average length, heart girth, and flank girth of all pigs in each of the trials, regardless of breed or sex.

Pigs of all breeds and both sexes had greater length than girth and greater flank girth than heart girth. From weaning to 168 days of age the

TABLE 1.—*Average measurements of length, heart girth, and flank girth of the pigs at different ages*

Age (days)	Measurements of—											
	Length in—				Heart girth in—				Flank girth in—			
	Trial 1	Trial 2	Trial 3	Trial 4	Trial 1	Trial 2	Trial 3	Trial 4	Trial 1	Trial 2	Trial 3	Trial 4
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
56	26.26	25.49	24.97	23.66	23.60	22.03	21.43	22.34	24.72	23.70	22.48	23.14
84	32.52	32.70	31.25	31.25	28.32	26.87	25.28	27.23	30.70	29.06	26.11	29.73
112	37.65	37.94	37.85	37.45	33.02	31.21	29.60	32.20	34.84	33.36	30.35	33.36
140	42.99	42.72	42.52	43.29	36.82	36.10	33.62	36.84	38.81	38.00	34.58	38.59
168	45.56	46.27	45.88	45.96	40.69	40.01	37.26	40.26	42.56	41.45	38.27	41.93

TABLE 2.—*Average length, heart-girth, and flank-girth measurements of boars and barrows used in these experiments, at different ages*

Age (days)	Boars			Barrows		
	Length	Heart girth	Flank girth	Length	Heart girth	Flank girth
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
56	25.63	22.53	23.72	24.65	22.01	23.14
84	32.50	26.92	28.93	31.32	26.59	28.28
112	38.39	31.69	33.15	37.11	30.89	32.26
140	43.61	35.91	37.41	42.07	35.42	37.14
168	46.60	39.67	40.95	45.25	38.99	40.62

pigs gained an average of 20.82 in. in length; 17.54 in. in flank girth, and 17.20 in. in heart girth. Most of the differences in measurements were probably caused by the initial difference at weaning, but this initial difference was observed in each of the four trials.

Table 2 contains a summary of the three measurements for the boars and the barrows, regardless of breed or trials.

The apparent over-all tendency was for the boars to have greater length and girth than the barrows at practically all ages; but statistical significance was found only in respect to length at the later ages in trials 1 and 2, and at

the earlier ages in trial 4. Some of these differences may have been produced by the initial difference at weaning.

The probable reason for the initial difference was explained in a previous report (4). The pigs selected to be barrows were castrated approximately 1 week before weaning and were chosen at random from the males selected for the individual feeding trials. The disturbance caused by castration, though temporary, may be partly responsible for the difference at weaning between the boars and the barrows.

Winters (6) reported that in a study of the effect of sex on the development of the pig at the Minnesota Agricultural Experiment Station, the boars and barrows followed different growth patterns. The boars gained weight faster for a time, but the barrows passed them later at a different time for each line of breeding. He further concluded that the effect of sex should be taken into account in a careful appraisal of data on growth and body form.

The average length of the different breeds at each of the trials is given in table 3.

The only statistically significant differences in length at 168 days of age were observed in trial 1 where the Landrace Large Black x Native proved to be longer than the Duroc and the Duroc than the Native. In trial 2 there were breed differences only at 112 days of age, the Landrace crossbreds being longer than the Native and Duroc x Native; the significance of the differences, however, disappeared at later ages. At 56 and at 112 days of age, in trial 3, the Durocs were significantly longer than the other breeds and the Tamworth x Native was the shortest. However, the significance of these differences disappeared at later ages. In trial 4 there were breed differences at 84 days of age; the Duroc crossbreds were longer than the Native and Landrace Large Black x Native, but the significance on these differences also disappeared at later ages.

The average heart girth of the different breeds at each of the trials is shown in table 4.

Significant differences were found in trial 1 at 140 and 168 days of age; the Durocs and Landrace Large Black x Native had greater heart girth than the Native. In trial 2 there were breed differences at 56 and 112 days of age; the Duroc x Native started with less heart girth than the other breeds but gained in the measurement until the significance of the differences disappeared at later ages. Significant differences were found at all ages in trial 3; from 56 to 140 days the Tamworth x Native was inferior to all other breeds in heart girth; the Durocs started with the best heart girth but at 140 and 168 days of age the crossbreds, with the exception of the Tamworth x Native, were better than the Durocs in this measurement. The only significant difference found in trial 4 was at 84 days of age when the Landrace

TABLE 3.—*Average length of the different breeds of swine used, at different ages*

Breed	Trial No.—			
	1	2	3	4
At 56 days of age				
	Inches	*Inches*	*Inches*	*Inches*
Duroc Jersey	25.64	—	26.66	—
Landrace Large Black x Duroc	—	26.05	24.35	24.65
Duroc x Native	—	24.51	24.73	24.00
Tamworth x Duroc	—	—	25.66	—
Native	26.56	25.51	—	22.47
Landrace Large Black x Native	26.78	26.23	25.16	23.22
Tamworth x Native	—	—	23.72	—
At 84 days of age				
Duroc Jersey	31.69	—	32.81	—
Landrace Large Black x Duroc	—	32.47	29.81	32.00
Duroc x Native	—	32.27	32.69	32.58
Tamworth x Duroc	—	—	31.56	—
Native	32.80	32.58	—	29.22
Landrace Large Black x Native	33.36	33.70	33.22	31.42
Tamworth x Native	—	—	28.34	—
At 112 days of age				
Duroc Jersey	37.32	—	42.44	—
Landrace Large Black x Duroc	—	39.83	36.50	38.85
Duroc x Native	—	36.31	38.60	36.89
Tamworth x Duroc	—	—	36.89	—
Native	37.89	37.23	—	36.00
Landrace Large Black x Native	37.81	39.42	37.30	37.14
Tamworth x Native	—	—	36.39	—
At 140 days of age				
Duroc Jersey	42.83	—	44.72	—
Landrace Large Black x Duroc	—	43.22	41.39	45.12
Duroc x Native	—	42.08	43.10	43.25
Tamworth x Duroc	—	—	42.39	—
Native	42.83	42.13	—	41.58
Landrace Large Black x Native	43.50	44.08	42.36	42.03
Tamworth x Native	—	—	40.75	—
At 168 days of age				
Duroc Jersey	45.88	—	47.58	—
Landrace Large Black x Duroc	—	47.03	44.52	48.00
Duroc x Native	—	46.41	46.19	46.03
Tamworth x Duroc	—	—	45.27	—
Native	44.10	45.18	—	45.00
Landrace Large Black x Native	46.97	47.40	45.86	44.79
Tamworth x Native[1]	—	—	—	—

[1] The Tamworth x Native was not represented at 168 days of age.

TABLE 4.—*Average heart girth of the different breeds of swine used, at different ages*

Breed	Trial No.—			
	1	2	3	4
At 56 days of age				
	Inches	*Inches*	*Inches*	*Inches*
Duroc Jersey	23.25	—	24.75	—
Landrace Large Black x Duroc	—	23.12	21.18	23.19
Duroc x Native	—	20.14	21.60	22.42
Tamworth x Duroc	—	—	20.48	—
Native	23.94	22.52	—	21.03
Landrace Large Black x Native	23.64	22.67	22.25	22.47
Tamworth x Native	—	—	19.37	—
At 84 days of age				
Duroc Jersey	27.67	—	26.47	—
Landrace Large Black x Duroc	—	27.33	24.88	28.31
Duroc x Native	—	26.23	26.29	28.14
Tamworth x Duroc	—	—	25.00	—
Native	28.09	26.72	—	25.22
Landrace Large Black x Native	29.62	27.53	26.72	26.89
Tamworth x Native	—	—	23.02	—
At 112 days of age				
Duroc Jersey	33.28	—	29.47	—
Landrace Large Black x Duroc	—	32.61	30.31	33.21
Duroc x Native	—	29.79	30.66	32.64
Tamworth x Duroc	—	—	29.16	—
Native	32.13	31.12	—	30.71
Landrace Large Black x Native	33.98	31.89	31.75	31.42
Tamworth x Native	—	—	26.77	—
At 140 days of age				
Duroc Jersey	38.07	—	32.27	—
Landrace Large Black x Duroc	—	36.70	34.58	37.62
Duroc x Native	—	35.21	33.22	37.36
Tamworth x Duroc	—	—	34.44	—
Native	35.57	35.70	—	35.54
Landrace Large Black x Native	36.83	37.36	35.27	36.17
Tamworth x Native	—	—	30.79	—
At 168 days of age				
Duroc Jersey	41.97	—	34.97	—
Landrace Large Black x Duroc	—	40.69	37.02	42.08
Duroc x Native	—	39.61	38.16	40.42
Tamworth x Duroc	—	—	36.38	—
Native	38.31	39.03	—	39.04
Landrace Large Black x Native	41.75	41.75	39.77	39.46
Tamworth x Native[1]	—	—	—	—

[1] The Tamworth x Native was not represented at 168 days of age.

Large Black x Duroc and Duroc x Native had greater heart girth than the Native and Landrace Large Black x Native.

The average flank girth of the different breeds at each of the trials is given in table 5.

Breed differences were observed in trial 1 at 168 days of age; the Durocs and Landrace Large Black x Native had greater flank girth than the Native. In trial 2 the only significant difference was found at 56 days when the Duroc x Native showed less flank girth than the other breeds, but the significance of the differences disappeared at the later ages.

There were breed differences in trial 3 at all ages; from 56 to 140 days of age, the Tamworth x Native was inferior to all other breeds in flank girth; the Durocs started with greater flank girth than the other breeds, but at 112, 140, and 168 days of age, the Landrace Large Black crossbreds and the Duroc x Native had flank girth exceeding that of the Durocs and Tamworth x Duroc. There were no significant differences in trial 4, although the tendency was for the Landrace Large Black x Duroc and the Duroc x Native to have greater flank girth than the Native and Landrace Large Black x Native.

VARIATION IN MEASUREMENTS

The standard deviations and coefficients of variation of the different measurements at the different ages were calculated using the data obtained from the 66 barrows considered. Although the barrows were of different breeds, it was thought that the information gathered might be of value to Puerto Rican swine producers. Most swine herds in Puerto Rico include several breeds or a mixture of breeds. The present insufficiency of pork production necessitates that emphasis be placed upon quantity rather than quality.

The coefficient of variation decreased from the 56- to the 168-day measurements. The information is summarized in table 6.

As shown in table 7, Goodbey, et al, (3), reported the mean and the coefficients of variation at 56, 112, and 168 days for weight, length, and heart girth of 100 Berkshire barrows.

Although Godbey et al (3) worked with Berkshire barrows, it is surprising how close their means are to those obtained in this study. However, the pigs considered here varied more in weight, length, and heart girth, probably because several breeds were represented and the information was collected from different trials.

Winters (6) reported the measurements shown in table 8 at 24 weeks for Poland China and Minnesota No. 1 boars and barrows.

The pigs studied here showed greater length and less girth at 168 days than those considered by Winters.

TABLE 5.—*Average flank girth of the different breeds of swine used, at different ages*

Breed	Trial No.—			
	1	2	3	4
At 56 days of age				
	Inches	*Inches*	*Inches*	*Inches*
Duroc Jersey	24.11	—	25.28	—
Landrace Large Black x Duroc	—	23.90	22.95	24.27
Duroc x Native	—	22.09	23.20	23.36
Tamworth x Duroc	—	—	20.60	—
Native	25.25	24.16	—	21.47
Landrace Large Black x Native	24.85	24.88	24.61	23.11
Tamworth x Native	—	—	19.45	—
At 84 days of age				
Duroc Jersey	29.44	—	26.56	—
Landrace Large Black x Duroc	—	28.83	25.92	30.50
Duroc x Native	—	28.56	27.63	30.83
Tamworth x Duroc	—	—	25.83	—
Native	31.11	29.52	—	28.19
Landrace Large Black x Native	31.99	29.19	28.00	29.14
Tamworth x Native	—	—	23.33	—
At 112 days of age				
Duroc Jersey	34.46	—	28.38	—
Landrace Large Black x Duroc	—	33.69	31.64	34.23
Duroc x Native	—	32.34	32.52	34.20
Tamworth x Duroc	—	—	29.14	—
Native	34.42	33.75	—	33.04
Landrace Large Black x Native	36.09	33.75	32.83	31.61
Tamworth x Native	—	—	27.70	—
At 140 days of age				
Duroc Jersey	39.47	—	30.44	—
Landrace Large Black x Duroc	—	37.26	36.66	39.15
Duroc x Native	—	37.00	35.54	39.72
Tamworth x Duroc	—	—	33.91	—
Native	37.90	38.13	—	36.08
Landrace Large Black x Native	39.21	39.86	37.19	38.39
Tamworth x Native	—	—	27.70	—
At 168 days of age				
Duroc Jersey	43.68	—	36.22	—
Landrace Large Black x Duroc	—	41.37	40.41	42.46
Duroc x Native	—	40.12	38.88	42.53
Tamworth x Duroc	—	—	35.61	—
Native	40.48	41.57	—	41.13
Landrace Large Black x Native	43.47	43.10	40.22	41.33
Tamworth x Native[1]	—	—	—	—

[1] The Tamworth x Native was not represented at 168 days of age.

TABLE 6.—*Standard deviations and coefficients of variation of measurements and weights at different ages for barrows of all breeds used in these experiments*

Measurements[1]	Mean	Standard deviation	Coefficient of variation
			Percent
56-day weight	29.05 lb.	6.224 lb.	21.43
56-day length	24.66 in.	2.011 in.	8.15
56-day heart girth	22.02 in.	1.958 in.	8.89
56-day flank girth	23.14 in.	2.406 in.	10.40
84-day weight	55.43 lb.	11.155 lb.	20.12
84-day length	31.32 in.	2.353 in.	7.51
84-day heart girth	26.60 in.	2.281 in.	8.58
84-day flank girth	28.29 in.	3.223 in.	11.39
112-day weight	88.83 lb.	15.504 lb.	17.45
112-day length	37.11 in.	2.645 in.	7.13
112-day heart girth	30.90 in.	2.815 in.	9.11
112-day flank girth	32.27 in.	3.465 in.	10.74
140-day weight	129.49 lb.	19.349 lb.	14.94
140-day length	42.07 in.	2.296 in.	5.46
140-day heart girth	35.43 in.	2.595 in.	7.33
140-day flank girth	37.14 in.	3.413 in.	9.19
168-day weight	173.04 lb.	21.731 lb.	12.56
168-day length	45.24 in.	2.001 in.	4.42
168-day heart girth	39.04 in.	2.749 in.	7.04
168-day flank girth	40.67 in.	3.430 in.	8.43

[1] 66 barrows at 56 days and 84 days; 65 barrows at 112 days; 62 barrows at 140 days; 50 barrows at 168 days.

TABLE 7.—*Mean and coefficients of variation at 56, 112, and 168 days for weight, length, and heart girth of 100 barrows, as follows, as reported by Godbey et al*

Measurement	Mean	Coefficient of variation
		Percent
56-day weight	31.86 lb.	19.90
112-day weight	96.31 lb.	17.56
168-day weight	174.52 lb.	10.93
56-day length	24.45 in.	6.30
112-day length	35.85 in.	5.91
168-day length	44.63 in.	3.93
56-day heart girth	21.50 in.	6.81
112-day heart girth	30.59 in.	6.83
168-day heart girth	38.19 in.	5.16

CORRELATION BETWEEN MEASUREMENTS AND WEIGHTS

The correlation between the measurements and the weights and between the different measurements are shown in tables 9 and 10.

Except for length and weight at 168 days of age, the correlations found in this study are much lower than those reported by Godbey et al (3) for length, heart girth, and weight at 56, 112, and 168 days of age. The reason for this may have been, again, that different breeds were represented.

TABLE 8.—*Length, heart girth, and flank girth measurements of Poland China and Minnesota No. 1 boars and barrows, as reported by Winters*

Breed and sex	Length	Heart girth	Flank girth
Poland China:			
Barrows	39.987	40.416	41.876
Boars	40.300	40.193	41.037
Minnesota No. 1:			
Barrows	42.280	43.293	43.500
Boars	41.360	39.827	39.720

TABLE 9.—*Correlation between length, heart-girth, and flank-girth measurements and weights at different ages of swine used in this study*

Age (days)	Length and weight	Heart girth and weight	Flank girth and weight
56	0.236	0.284	0.278
84	.376	.234	.132
112	.511	.497	.272
140	.546	.513	.504
168	.763	.531	.356

TABLE 10.—*Correlation between length, heart-girth, and flank-girth measurements at different ages of swine used in this study*

Age (days)	Length and heart girth	Length and flank girth	Heart girth and flank girth
56	0.663	0.677	0.884
84	.725	.687	.910
112	.544	.468	.911
140	.369	.318	.895
168	.391	.239	.808

ESTIMATES OF WEIGHT FROM MEASUREMENT

The weight of hogs at 168 days of age can be estimated with some accuracy from their length, heart girth, and flank girth. The equation to be used is: $Y = 7.058\,X_1 + 2.611\,X_2 - 0.420\,X_3 - 231.096$, wherein X_1 stands for the length in inches, X_2 for the heart girth in inches, and X_3 for the flank girth in inches. The multiple correlation coefficient upon which the equation

is based, 0.805, is highly significant statistically. Similar estimates could be made for other ages, but with less accuracy than at 168 days of age.

PREDICTION OF WEIGHT FROM MEASUREMENTS

The following tabulation shows the multiple correlation coefficients for the prediction of weight at 168 days of age by using different measurements and weight of weaning:

Measurements	*R*
Weaning weight + length + flank girth + heart girth	0.7120
Weaning weight + length + flank girth	.7052
Weaning weight + length	.7047
Weaning weight	.6516
Weaning length	.5989

The weight at 168 days of age can be predicted with some accuracy by using the weaning weight alone. The accuracy of the prediction is increased, however, when the value for length at weaning is added. No noticeable additional accuracy is attained by using either heart girth or flank girth at weaning, or both measurements. The equation for the prediction of weight at 168 days from the weight and length of the pigs at weaning is: $Y = 4.2919\ X_1 + 1.7175\ X_2 + 19.1073$, wherein X_1 is the length in inches and X_2 is the weaning weight in pounds.

Comstock, et al (2), stated that weaning weight is but a poor criterion of inherited ability to grow and that heavy weaning pigs gain more in the period from 56 days on, because they are heavier at the beginning of that period. This would be an important consideration in selecting breeding stock, but is of much less importance when the aim is to select fast-growing animals from a group of weaned pigs.

CONCLUSIONS

The crossbreds, Landrace Large Black x Duroc, Duroc x Native, and Landrace Large Black x Native, had greater length, flank girth, and heart girth than the Native and, in most cases, than the Duroc. The Tamworth crosses were inferior to the other breeds in these measurements. These results correspond to those obtained with weight data, reported by González Chapel and Cabrera (4).

If due consideration is given to the initial disadvantage of the barrows as compared with the boars, practically no difference in measurements was found between the sexes. The statistically significant differences observed could be well explained by the initial difference which was probably attributable to factors extraneous to the individuals themselves. However, the importance of sex as a factor influencing the growth and body form of swine has been well established at the Minnesota Agricultural Experiment Sta-

tion. The fact that the pigs in this study were fed individually may account, in part, for the better performance of the boars as compared with the barrows at the later age groups.

The variation within the measurements and within the weights was definitely higher than that found by Godbey et al (3), at Clemson Agricultural College, but that could be ascribed to the many breeds represented in this study.

The gain in length of the pigs of all breeds and sexes from weaning to 168 days of age corresponded more closely to the gain in weight than to the gain in heart or flank girth.

Accuracy in predicting the weight of hogs at 168 days of age from information obtained at weaning time can be increased appreciably by the use of the value for the length of the pigs at weaning. Heart-girth and flank-girth measurements add practically nothing to the accuracy of the prediction obtained from the values for weaning weight and weaning length. The use of the weaning weight for the 154-day weight prediction has been suggested already by González Chapel and Cabrera (4).

Summary

The length, heart girth, and flank girth of 66 boars and 66 barrows of different breeds and crossbreds were compared with their weight at weaning, and at 84, 112, 140, and 168 days.

There were important measurement differences between the breeds. Differences in measurement between the boars and the barrows could be explained by their initial difference at weaning.

It was found that accuracy in selecting pigs at an early age for breeding or subsequent rearing can be increased by using the length measurement along with the weight of the animals at weaning to predict weight at 168 days of age.

The use of heart or flank measurements does not increase the accuracy of the prediction.

The coefficients of correlation and variation for the different measurements are given for the ages studied.

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