Wayamba Journal of Animal Science – ISSN: 2012-578X; P660-P667 2013
First Submitted May 16, 2013; Number 1368678125

ESTIMATES OF GENETIC PARAMETERS FOR GROWTH TRAITS IN PIG CROSSES OF NIGERIAN INDIGENOUS AND EXOTIC BREEDS AT BIRTH, WEANING AND MATURITY

V.M.O. Okoro[*1], U. E. Ogundu[1], I. C. Okoli[1], M. N. Opara[1], C.L. Okoro[2] , E. N. Nwachukwu[3] and S.N. Ibe[3]
[1] *Department of Animal Science and Technology, Federal University of Technology, Owerri.*
[2]*Department of Agriculture, Owerri Municipal Council, Owerri.*
[3]*Department of Animal Breeding and Physiology, Michael Okpara University of Agriculture, Umuahia*

[*]*Corresponding author: melavicong4real@yahoo.com*

Crossbreeding in pigs to exploit heterosis is employed in commercial pig production to achieve better average performance of crossbred animals than their purebred counterparts. This study was aimed at evaluating genetic parameters of growth traits such as bodyweight (BW), body length (BL), heart girth (HG) and height at withers (HW) in crosses of Nigerian Indigenous (NI), Large White (LW) and Landrace (LR) breeds of pigs, as well as establishing the effects of the crosses, parity and sexes on the growth traits at birth, weaning and maturity. At birth, the crosses LWxLR and LRxLW were significantly highest ($P<0.05$) for BW, HG and HW while LWxNI was the least ($P>0.05$). Parity 2 was significantly higher for HW than parity 1.Sex had no significant effect. At weaning, LRxLW was significantly highest for BW, HG and HW while LWxNI was least. Parity 2 was also significantly higher than parity 1 for HW only, while sex had no significant effect. At maturity, NIxLR was significantly highest for BW while only LRxNI was highest for BL. However, NIxLR cross was significantly highest for HG and HW. Parity 2 was significantly higher than parity 1 for BW only, while sex had no significant effect on the growth traits. Heritabilities for BW at birth, weaning and maturity ranged from 0.15±0.14 to 0.45±0.21 while the morphometric traits ranged from 0.14±0.18 to 0.90±0.104. Genetic correlation between BW and morphometric traits ranged from -0.96±0.366 to 0.99±0.656 at birth, weaning and maturity, while phenotypic correlation ranged from 0.0008±0.0024 to 0.145±0.128 at birth weaning and maturity. Environmental correlation between BW and morphometric traits ranged from -0.21±0.254 to 0.96±0.61. This suggests that heritabilities of crossbred pigs involving Indigenous pigs was low at birth and weaning, but high at maturity; hence selection for replacement stock could be achieved better using records at maturity (140 days). Genetic correlations between BW and morphometric traits were high at birth, weaning and maturity, while at weaning and maturity, environmental correlation was very low to medium. However, phenotypic correlation analysis of BW and morphometric traits showed very low association. Hence, genetic selection for BW could be achieved using the measure of any of the morphometric traits at any stage of growth.

Key words: Heterosis, Heritability, morphometric, genetic, phenotypic, environmental.

Swine breeding and genetics has advanced tremendously with rapid crossbreeding in order to exploit heterosis. Heterosis is the difference between crossbred animals and the average of their purebred counterparts (Ibe, 1998). Crossbreeding can be a very useful tool for the pork, lard and brittle producer to increase the efficiency and profit of an operation. With general use of breed and strain crossing in current swine production, it is important to estimate basic parameter values with which to evaluate and

identify superior crossing combinations. The results of most crossbreeding work have in general shown an advantage in the performance of crosses over that of their parents and one of the studies that supports the idea that breeds have different behaviour when used in crosses was presented by Schneider (1976), in studies involving Landrace and Poland China crosses. These results indicated that crossbred animals were superior to purebred animals in number of live piglets, vigour of the animals at birth, survival from birth to weaning and litter weight at weaning.The specific goal of this research is to establish the heritability estimates of body weight (BW), body length (BL), heart girth (HG), and height at withers (HW) traits of crossbred pigs at various stages of growth and to determine the biological relationships between the growth traits using genetic, phenotypic and environmental correlations. Statistical similarities and differences were also established between the breed crosses, parity and sex in pigs.

MATERIALS AND METHODS

Location of Experiment

This study was conducted at the Piggery Unit of the Federal University of Technology, Owerri Teaching and Research Farm. The University is located at Longitude $7^0 9'$ 12.91" E and Latitude $5^0 15'$ 46.89" N on an elevation of about 120 m above sea level. Owerri falls within the rainforest zone of Nigeria, with an average annual rainfall of about 1240 mm distributed over eight months (March to November) with its peak in June and July and dry spell usually in August. It has a humid climate and temperature that ranges from 28^0 C in the wet season to slightly over 35^0C in the dry season.

Experimental Animals and Mating

A crossbreeding involving three breeds of pigs, namely Nigerian Indigenous (NI), Large White (LW), and Landrace (LR) breeds of different lines was conducted. The matings were as follows:

1. NI (♂) x LW (♀); and 2. NI (♂) x LR (♀);
3. LW (♂) x LR (♀); 4. LW (♂) x NI (♀),
5. LR (♂) x NI (♀). 6. LR (♂) x LW (♀);

Three boars of each breed were mated to six sows per breed in a nested design to produce 41, 37 and 29 progenies per breed respectively (Table 1). Piglets generated from the crosses which comprised of 2 parities per cross, totaled 12 litters in the experiment. Data generated from cross, parity and sex, were replicated based on parities in order to estimate a reliable standard error of mean for crosses.

Table 1: Distribution of litters according to Breed of Sire

	Breed of Sire[a]		
Breed of Dam	LW	LR	NI
LW	*	16	13
LR	23	*	16
NI	18	21	*
TOTAL	41	37	29

[a] LW = Large White LR= Landrace NI= Nigerian Indigenous.
*No purebred mating.

Management of Experimental Animals

The parent animals were fed *ad libitum* on concentrates containing 17% crude protein (CP) and 2,480 Kcal/kg energy. The feeding regime was varied at the creep or starter, grower and breeder levels, with feed containing 24% CP, 16% CP and 18% CP respectively. Water was provided *ad libitum.* The compound feed (24% CP) was also used to flush the sows during the gestation period in order to provide enough nutrients for embryonic and foetal development. Prior to mating the animals, the boars and gilts were placed in separate pens, de-wormed using *Wormazin*® and provided with feed and water *ad libitum*. Animals infected with mange were treated with *ivoemectin*® injections subcutaneously. When heat was detected in the gilts for the first time, they were not mated until the second. Females were taken to the boar according to the mating design culminating to two parities per cross for all possible crosses. For the inseminated groups (NI x LW, NI x LR, LR x NI and LW x NI), semen were harvested, processed using cheese cloths to separate the gelatinous fraction and inseminated using pig catheters within the same day of collection.

After mating/insemination, the sows were removed from the pen to their own pens. On confirmation of pregnancy, the in-gilts were kept in pairs until about 14 days to parturition; they were then moved to farrowing pens until parturition occured. At this time, quantity and quality of diet were increased using starter ration and fresh clean water was also provided.

After parturition, the live piglets were retained with their dams to suckle the colostrum while still born and dead animals were removed and buried. Wood shavings were provided as litter materials for insulation, feeding of more quality diet ration continued and clean water was supplied to the dam. The dam was given antibiotics ( ) of 2 mls volume in order to reduce bacterial load to the suckling piglets, while the piglets were given iron injection (*Iron dextran*®) to prevent piglet anaemia two days after birth. Records on birth weight, litter size weight at birth, daily weight gain and morphometric measurements were taken. Notching of the piglets, for identification was done seven days after parturition and weaning was done at 56 days of age. Piglets were weaned and fed high-protein diet (starter ration) *ad libitum* from four weeks post birth, while *ivoemectin* was also administered to those with skin infections. At weaning, weaners were dewormed before putting them in the grower pens. They were fed and measurements taken until maturity age of 140 days.

Parameters Measured

The parameters measured were growth traits which includes.

1. Birth weight (measured using 5 kg weighing scale; Camry 22® China)
2. Weaning weight (56 days) (measured using 50 kg weighing scale; Salter England®)
3. Body weight at maturity (140 days) (measured using 200kg bridge weighing scale; Global Universal England®)
4. Morphometric measurements from birth to maturity (140 days) include
   i. Body length (BL) - Measured as the distance from the point of the scapular to the pin bone of the tail base, using a tailor's tape.
   ii. Heart Girth (HG) – Measured as the circumference of the animal's body taken immediately posterior to the shoulder, using a tailor's tape.
   iii. Height at Withers (HW) – Measured as the distance from the highest point on the dorsum of the animal to the ground surface, at the level of the front feet, using a tailor's tape.

Experimental Design and Statistical Analyses

The experimental design was:

A 2-factor factorial in a Randomized complete block design (RCBD) with cross and sex as main factors. The statistical model is in expression (1)

$Y_{ijkl} = \mu + C_i + P_j + S_k + (CPS)_{ijk} + e_{ijkl}$ … (1)

Where Y_{ijkl} = Single observation

μ = Overall mean

C_i = Effect of cross.

P_j = Effect of parity.

S_k = Effect of Sex.

$(CPS)_{ijk}$ = Interaction effect of cross, parity and sex.

e_{ijkl} = Random error assumed to be independently, identically and normally distributed with zero mean and constant variance i.e. iind$(0, \sigma^2)$;

Proc GLM of SAS (1999) was used in the analysis above. Significant means were separated using SNK method according to SAS (1999).

Estimates of variance and covariance components were obtained by using the MTDFREML software package (Boldman *et al*., 1995). An animal model using the Mixed Model Equation;

$\mathbf{y} = X\boldsymbol{\beta} + Z_1\boldsymbol{\alpha} + Z_2\mathbf{m} + \mathbf{e}$ was fitted,

where **y** is the data,

β are the fixed effects of Breed, sex and parity,

$\boldsymbol{\alpha}$ is the random vector of direct additive genetic effects,

m is a random vector of maternal additive genetic effects, and

e are the random, independently distributed errors;

X is the known incidence matrix relating observations to fixed effects ;
Z_1 and Z_2 are the known incidence matrices linking the α and **m** effects to **y**, respectively.
Genetic relationships between individuals were accounted for by including the additive genetic relationship matrix in the animal model equations according to Henderson (1984) below.

$$\begin{vmatrix} X'R^{-1}X & X'R^{-1}Z \\ Z'R^{-1}X & Z'R^{-1}Z+G^{-1} \end{vmatrix} \begin{vmatrix} \hat{\beta} \\ \hat{\alpha} \end{vmatrix} = \begin{vmatrix} X'R^{-1}Y \\ Z'R^{-1}Y \end{vmatrix}$$

Where R^{-1} = measure of correlation of errors
G = matrix of genetic relationship

$$G^{-1} = A^{-1}\underline{\sigma_e^2}$$
$$\sigma_\alpha^2$$

And A^{-1} = inverse of additive genetic relationship matrix, σ_e^2 is the residual variance, and $\sigma_{\tilde{a}}^2$
is the additive genetic variance.
The estimates of direct heritabilities were obtained by multiple-trait analysis using the multiple trait derivative free restricted maximum likelihood (MTDFREML) software according to Boldman *et al.*, (1995). The environmental, phenotypic and genotypic variances, covariances and correlation between the BW and morphometric traits were also estimated using the MTDFREML procedure, while the standard errors for heritability estimates and correlation estimates were done using single trait models. For the model fitted, maximization of the log-likelihood was implemented by the simplex method. The convergence criterion was set at 10^{-6} and the process was repeated until 2log likelihood remained unchanged in the first 6 decimal places.

RESULTS

The distribution of litters according to breed of sire is shown in table 1. A total of 41, 37 and 29 progenies were generated form NI, LW and LR sires respectively out of 2 parities each. Table 2, 3 and 4 show the mean effects of breed, parity and sex on BW, BL, HG and HW at birth, weaning and maturity. In all, LRxLW cross was significantly highest ($p<0.05$) for BW, HG and HW at birth, weaning and maturity, with NIxLW cross performing significantly best ($P<0.05$) at maturity. Parity 2 also performed significantly better than parity 1 from birth to maturity, while sex of the same animals had no significant effect on growth traits throughout the stages of growth. The mean, standard deviation, coefficients of variation and range of observed values at birth weaning and maturity are shown in table 5. At birth, BW records ranged from

Table 2. Mean effects of breed, parity and sex on BW, BL, HG and HW at birth

Fixed factors	Traits[1]	n	Birth Mean±SD BW (Kg)	Mean±SD BL (cm)	Mean±SD HG (cm)	Mean±SD HW (cm)
Breed	LWxLR	23	1.78±0.12^{a}	28.97±0.63	22.0±0.58^{a}	19.93±0.56^{a}
	LWxNI	18	1.05±0.04^{c}	22.28±0.81	18.58±0.65^{b}	15.67±0.53^{c}
	LRxNI	16	1.75±0.14^{a}	24.63±0.69	17.27±0.51^{b}	17.18±0.32^{b}
	LRxLW	21	1.94±0.08^{a}	29.38±1.02	22.69±1.29^{a}	19.42±0.45^{a}
	NIxLW	13	1.66±0.04^{ab}	25.08±0.99	17.11±0.96^{b}	16.67±0.41^{a}
	NIxLR	16	1.36±0.05^{b}	23.94±0.93	18.45±1.31^{b}	17.36±0.66^{b}
Parity	1	49	1.60±0.09	26.53±0.53	18.88±0.61	17.35±0.32^{b}
	2	58	1.61±0.07	25.64±0.83	20.39±0.65	18.39±0.43^{a}
Sex	Male	56	1.57±0.08	1.57±0.08	19.57±0.59	18.14±0.39
	Female	51	1.64±0.09	1.64±0.09	19.80±0.73	17.66±0.40

[1]=Large White (LW) x Landrace (LR) cross, 2=LW x Nigerian Indigenous (NI) cross, 3=LR x NI, 4=LR x LW, 5=WAI x LW, 6=NI x LR
^{abcd} means on the same row of the same fixed factor is significantly different ($P<0.05$).

Table 3. Mean effects of breed, parity and sex on BW, BL, HG and HW at weaning

Fixed factors	Traits[1]	n	Weaning Mean±SD BW (Kg)	Mean±SD BL (cm)	Mean±SD HG (cm)	Mean±SD HW (cm)
	LWxLR	20	5.70±0.32^{b}	45.20±1.16	33.60±1.29^{bc}	29.46±0.98^{b}
	LWxNI	10	3.17±0.13^{d}	45.40±1.34	34.86±2.42^{bc}	31.71±2.42^{ab}
Breed	LRxNI	14	6.47±0.46^{b}	43.29±1.39	30.11±1.84^{c}	28.78±1.53^{b}
	LRxLW	12	7.09±0.29^{a}	46.58±2.02	40.63±1.25^{a}	34.88±0.81^{a}
	NIxLW	13	4.49±0.39^{c}	49.54±0.98	36.75±2.78^{ab}	31.22±2.20^{ab}
	NIxLR	15	4.54±0.36^{c}	46.13±1.90	33.70±0.65^{bc}	34.70±0.63^{a}
	1	36	4.59±0.34^{b}	45.72±1.01	34.92±0.97	32.56±1.09
Parity	2	48	5.89±0.26^{a}	46.10±0.80	34.58±1.22	30.89±0.77
Sex	Male	45	5.16±0.24	46.04±0.81	34.97±1.05	31.16±0.87
	Female	39	5.53±0.32	45.82±1.04	34.42±1.24	32.25±0.98

[1]=Large White (LW) x Landrace (LR) cross, 2=LW x Nigerian Indigenous (NI) cross, 3=LR x NI, 4=LR x LW, 5=WAI x LW, 6=NI x LR

[abcd] means on the same row of the same fixed factor is significantly different (P<0.05).

Table 4. Mean effects of breed, parity and sex on BW, BL, HG and HW at maturity

Fixed factors	Traits[1]	n	Maturity Mean±SD BW (Kg)	Mean±SD BL (cm)	Mean±SD HG (cm)	Mean±SD HW (cm)
	LWxLR	20	24.55±1.61^{a}	61.54±1.03^{c}	44.85±1.56^{c}	42.69±0.84^{b}
	LWxNI	10	19.90±0.45^{c}	56.14±0.55^{d}	45.71±3.21^{c}	44.71±3.47^{b}
Breed	LRxNI	14	27.10±1.53^{b}	72.11±1.14^{a}	47.22±2.60^{bc}	43.11±1.57^{b}
	LRxLW	12	30.58±0.67^{a}	67.75±1.90^{ab}	52.75±1.25^{ab}	46.73±1.15^{b}
	NIxLW	13	21.88±0.99^{c}	57.22±1.21^{d}	53.33±1.23^{ab}	46.56±2.52^{b}
	NIxLR	13	30.14±0.97^{a}	69.38±2.00^{ab}	55.75±1.53^{a}	61.13±2.12^{a}
	1	36	23.84±0.86^{b}	64.40±1.66	49.12±1.68	47.64±1.62
Parity	2	46	29.45±1.02^{a}	63.59±1.11	49.92±1.21	46.45±1.57
Sex	Male	46	27.17±0.93	62.67±1.18	49.53±1.33	46.73±1.47
	Female	36	26.54±12.25	65.58±1.56	49.58±1.55	47.33±1.75

[1]=Large White (LW) x Landrace (LR) cross, 2=LW x Nigerian Indigenous (NI) cross, 3=LR x NI, 4=LR x LW, 5=WAI x LW, 6=NI x LR

[abcd] means on the same row of the same fixed factor is significantly different (P<0.05).

Hetzer and Bereskin, 1986; Adebambo, 1986) and estimation of genetic parameters for BW and morphometric traits (Johnson and Nugent, 2003; Oh et al, 1998; Hicks et al, 1998; tenNapel and Johnson, 1997, VanSteebergen et al, 1990; and Kuhlers and Jungst, 1983) in pigs had been documented previously. Adebambo (1986) reported a 154-day body weight (kg) of 57.85, 62.51, 30.53, 55.44 and 56.45 in LWxLW, HAxHA, NativexNative, LWxNative and HAxNative crosses of pigs, respectively with NativexNative cross being the least at age <1 in crosses of native and exotic pigs, although no significant difference was established. Also, Skorjanc *et al*. (2007) reported no significant sex effect (P>0.05) on pig body weight from birth to weaning in crosses of exotic pigs. However, no significant sex effect (P>0.05) on body weight of the pigs throughout the ages was recorded in this experiment. Although the males were heavier than the females, no significant difference was observed.

Heritability estimates in this study for BW and BL ranged from 0.15 to 0.45 from birth

Table 5: Descriptive statistics for growth traits.

Stage	Trait	n	Mean±SD	CV (%)	Minimum	Maximum
Birth	BW	107	1.607±0.682	42.43	0.39	3.50
	BL	107	26.05±6.096	23.40	13.00	38.00
	HG	107	19.42±1.29	44.22	8.50	23.00
	HW	107	17.71±0.45	35.05	10.20	20.25
Weaning	BW	84	5.331±1.693	31.76	2.50	10.00
	BL	84	45.941±4.93	10.72	35.00	57.00
	HG	84	34.94±2.42	41.11	18.30	42.00
	HW	84	31.79±2.22	36.30	20.30	35.26
Maturity	BW	82	28.84±4.604	48.40	15.30	33.00
	BL	82	62.62±7.617	22.16	30.00	78.00
	HG	82	49.94±1.56	40.35	20.50	56.05
	HW	82	47.49±1.78	32.41	30.65	62.00

Table 6: Estimates of Variance and Covariance (shown in bracket) components due growth traits using multiple trait analysis method of MTDFREML package.

[2]Stage of Growth	$\delta^2_{(BW)}$	$\delta^2_{(BL)}$	$\delta^2_{(HG)}$	$\delta^2_{(HW)}$	$\delta^2_{(BWerror)}$	$\delta^2_{(BLerror)}$	$\delta^2_{(HGerror)}$	$\delta^2_{(HWe}$
Birth	0.05	10.363	12.832	36.281	9.93	108.06	184.57	125.38
	(-0.693)	(-0.693)	(2.027)	(4.54)	(0.785)	(0.785)	(0.342)	(0.193
Weaning	1.468	11.671	5.17	15.32	15.31	121.71	142.54	123.95
	(0.222)	(0.222)	(1.949)	(2.848)	(-0.185)	(-0.185)	(0.124)	(-1.042
Maturity	6.589	0.7912	7.267	9.863	64.219	6.823	200.36	236.71
	(2.2114)	(2.114)	(4.689)	(7.81)	(1.155)	(1.155)	(-3.357)	(-4.77)

[2]$\delta^2_{(BW)}$: variance component due to Body Weight; $\delta^2_{(BL)}$: variance component due to Body Length. $\delta^2_{(HG)}$: Variance components due to Heart Girth; $\delta^2_{(HW)}$: Variance component due to Height at Withers.

Table 7: Estimates of heritabilities, genetic, phenotypic and environmental correlations for growth traits (with standard errors shown in brackets).

Stage	[3]Trait	h^2_{SF}	[4]Correlations		
			γ_G BW	γ'_P BW	γ'_E BW
Birth	BW	0.15(0.14)			
	BL	0.22(0.235)	-0.96(0.366)	0.0027(0.332)	0.50(0.411)
	HG	0.26(0.25)	0.99(0.656)	0.056(0.428)	0.76(0.003)
	HW	0.90(0.104)	0.85(0.216)	0.111(0.034)	0.96(0.61)
Weaning	BW	0.36(0.34)			
	BL	0.35(0.24)	0.65(0.609)	0.0008(0.234)	-0.38(0.466)
	HG	0.14(0.18)	0.85(1.119)	0.048(0.024)	0.03(0.25)
	HW	0.44(0.27)	0.99(2.313)	0.069(0.056)	-0.28(0.357)
Maturity	BW	0.45(0.21)			
	BL	0.42(0.24)	0.97(4.841)	0.145(0.128	0.43(0.301)
	HG	0.14(0.21)	0.93(1.156)	0.017(0.134)	-0.21(0.254)
	HW	0.16(0.16)	0.99(0.386)	0.026(0.012)	-0.32(0.254)

[3]= h^2_{SF}: heritability due to sire effect on body weight and body length, heart girth and height at withers. [4]= γ'_G - genetic correlation, γ'_P – Phenotypic correlation, γ_E = Environmental correlation

to maturity, while that for HW and HG ranged from 0.14 to 0.90. Johnson and Nugent (2003) reported a heritability estimate ranging from 0.19 to 0.27 in Landrace, Yorkshire, Duroc and Hampshire purebreds of pigs at 100d BW, 0.15 to 0.27

at 177d BW and 0.16 to 0.32 at 177d BL. The results from this study are within the range of the author, which is low. The values of 0.45 and 0.42 achieved for BW and BL at maturity of 140d is high, while that reported by Johnson and Nugent (2003) at 177d BW and BL was low. Meanwhile, Johnson et al (2002) earlier reported a range of 0.05 to 0.20 for Duroc and Hampshire breeds at 100d, while Kuhlers and Jungst (1992a) reported a realized heritability of 0.13±0.06 for 70d BW in Landrace. These are lower than the 0.36 reported for crossbred pigs at 56d BW in this study. The moderate to high estimates of heritability estimated at maturity in this study for BW and BL implies that direct selection for these traits would be more efficient than indirect selection. However, the moderate to high estimates of heritability in this study might be due to small population size used in the estimation as against large sizes used elsewhere.

Estimates of genetic correlation between BW and the three morphometric trait were closer to one (-0.96, 0.99, 0.85, 0.65, 0.85, 0.99, 0.93, 0.93 and 0.99) at birth, weaning and maturity. However, the phenotypic correlations were closer to zero (0.0027, 0.056, 0.111, 0.0008, 0.048, 0.069, 0.145, 0.017 and 0.026). The high and mostly positive genetic correlation between the BW and morphometric traits could be ascribed to the fact that longer, taller and stouter pigs would tend to be heavier and fatter than the reverse. While the lower phenotypic correlation could imply that visual and physical appraisal of these morphometric traits do not imply a direct relationship with the BW. Environmental correlation between the BW and morphometric traits were mostly negative and low at weaning and maturity, while at birth were all high and positive. This implies that at birth, environment played a major role in the relationship between the BW and morphometric traits, while at weaning and maturity, an inverse relationship exists which is low. Johnson and Nuggent (2003) reported a high and positive genetic correlation between BL and 177d BW for Landrace, Yorkshire, Duroc and Hampshire breeds of pigs. This is similar to the report of this study as a genetic correlation of 0.97 between 140d BW and BL was reported. High and positive genetic correlation of BW and morphometric traits indicates that improvement in these traits could be accomplished with a measure of either BL, HW or HG at 140d BW. Hicks et al (1998) reported low and negative phenotypic correlation (-0.02) between Average daily gain (ADG) and Carcass length (CCL); low and positive phenotypic correlation (0.04) for ADG and Average backfat thickness (ABF) in Japanese Large White pigs at 200lb BW. This is also similar to the findings of this study. The negative environmental correlation between BL and morphometric traits suggests that selection for BW alone is likely to have some negative effects on morphometric traits depending on the environment where such is carried out.

REFERENCES

1. Adebambo, O. A. (1986). Pig improvement and development in the tropics: the application of breeding and genetics. Proceedings of the International Seminar on Pig Production in the Tropics, University of Nigeria, Nsukka. February, 1986
2. Baas, T. J., Christian, L. L., and Rothchild, M. F. (1992). Heterosis and recombination effects in Hampshire and Landrace swine. I. Maternal traits. J. Anim. Sci. 70: 89-98.
3. Bereskin, B. and Hetzer, H. O. (1986). Genetic and Maternal effects on pig weights, growth and probe backfat in Diallel crosses of High and Low-fat lines of swine. J. of Animal Science. 63: 395-408.
4. Beretti, V., Superchi, P., Manini, R, Cervi, C and Sabbioni, A. C. (2009). Predicting liveweight from body measures in Nero Di Parma Pigs. Ann. Fac. Medic. Vet. Di Parma. 29: 129-140.
5. Boldman, K. G., L. A. Kriese, LS Van Vleck, C.P. Van Tassel, S. D., Kachman (1995). A manual for use of MTDFREML. A set of programs to obtain estimates of variances and

covariances. USDA-ARS: Washington.
6. Hicks, C. Tsutomu F. and Schinckel (1998). Estimates of genetic parameters for daily gain and carcass traits for Japanese Large White Swine. Purdue University 1998 Swine Day Report. http://www.ansc.purdue.edu/swine/swineday/sday98/psd27-98.htm
7. Ibe, S. N. (1998). An Introduction to Genetics and Animal Breeding. Longman Nigeria Plc.
8. Johnson Z. B. and Nugent III R. A. (2003). Heritability of body length and measure of body density and their relationship to backfat thickness and lion muscle area in swine. J. Anim. Sci. 81: 1943-1949.
9. Johnson, Z. B., Chewning J. J., and Nugent III R. A. (2002). Maternal effects on traits measured during postweaning performance test of swine from four breeds. J. Anim. Sci. 80: 1470 – 1477.
10. Kuhlers, D. L. and Jungst S. B. (1983). Estimates of genetic parameters for growth rate and backfat thickness of swine tested to 105 and 135 kg. J. Anim. Sci. 57: 879-884.
11. Kuhlers, D. L., and Jungst S. B. (1992a). Correlated responses in reproductive and carcass traits to selection for 70-day weight in Landrance swine. J. Anim. Sci. 70: 372-378.
12. Mbaga, S. H., Lym, C. M., Kifaro, G. C. and Lekule, F. P. (2005). Phenotypic characterization and production performance of local pigs under village settings in southern highland zone, Tanzania. Animal Genetic Resources 37: 83-90.
13. National Swine Improvement Federation (1997). Guidelines for Uniform Swine Improvement Programs. Washington D. C. USDA.
14. Nidup, K., Tshering, D., Wangdi, S., Gyeltshen, C., Phuntsho, T. and Moran, C. (2011). Farming and biodiversity of pigs in Bhutan. Animal Genetic Resources 48, 47-61.
15. Oh S. H., Lee D. H. and See M. T. (2002). Genetic correlations between growth and carcass traits. Livestock Production Science 65: 253-257.
16. SAS (1999). SAS Users Guide, Statistics Version 8, SAS Instutite Inc., Cary, North Carolina, USA.
17. Schneider, J. F. (1976). Heterosis, combining abilities and maternal ability estimated from single-crosses among four breeds of swine. Master's Thesis, Iowa State University, Ames, Iowa, pp. 107.
18. Skorjanc, D., Brus, M., and Potoka, M. C. (2007). Effect of birth weight and sex on preweaning growth rate of piglets. Arch. Tierz Dummerstorf. 50 (5) 476 – 486.
19. ten Napel, J., and Johson R. K. (1997). Genetic relationships among production traits and rebreeding performance. J. Anim. Sci. 75: 51-60.
20. Van Steenbergen, E. J., Kanis E., and Van Der Steen H. A. M. (1990). Genetic parameters of fattening performance and exterior traits of boars tested in central station. Livest. Prod. Sci. 24: 65-82.

