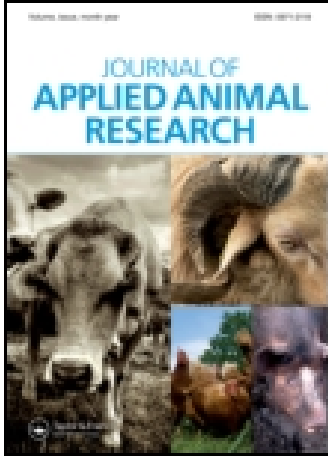


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Journal of Applied Animal Research

Publication details, including instructions for authors and subscription information:
<http://www.tandfonline.com/loi/taar20>

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Published online: 16 Jan 2014.

To cite this article: S. K. Mondal, Amit Kumar, P. P. Dubey, B. Sivamani & Triveni Dutt (2014) Estimation of variance and genetic parameters for pre-weaning weights of individual Landrace X Desi synthetic piglets, Journal of Applied Animal Research, 42:3, 338-344, DOI: [10.1080/09712119.2013.875901](https://doi.org/10.1080/09712119.2013.875901)

To link to this article: <http://dx.doi.org/10.1080/09712119.2013.875901>

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Estimation of variance and genetic parameters for pre-weaning weights of individual *Landrace X Desi* synthetic piglets

S. K. Mondal^a, Amit Kumar^{b*}, P. P. Dubey^b, B. Sivamani^b and Triveni Dutt^c

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(Received 23 August 2012; accepted 1 October 2013)

Variances and genetic parameters were estimated for birth weight (BW), 14 day body weight (14dW), 28 day body weight (28dW), 42 day body weight (42dW) and weaning weight or 56 day body weight (56dW) in the *Landrace X Desi* synthetic piglet population reared under sub-temperate agro climatic region of India. The data were analyzed using restricted maximum likelihood (REML) fitting six animal models with various combinations of direct and maternal effects. Estimates of genetic and permanent environmental correlations were obtained using bivariate analysis of an animal model and computed with the DFREML program. A log likelihood ratio test was used to select the most appropriate univariate model for each trait. The direct estimates of heritability were 0.43 ± 0.04 , 0.31 ± 0.04 , 0.35 ± 0.05 , 0.40 ± 0.06 , and 0.49 ± 0.06 for BW, 14dW, 28dW, 42dW, and 56dW, respectively and it increased with age from 14dW to 56dW. The permanent litter effect progressively decreased and was minimum at 56dW, ranged from 0.21 ± 0.06 to 0.34 ± 0.04 . Further, maternal genetic heritability was the highest, ranging from 0.16 ± 0.07 (model 5) to 0.18 (model 6), at age of weaning and the lowest for BW, from 0.04 ± 0.03 (model 5) to 0.06 (model 6). The presence of permanent litter effect was more important since it increased the accuracy of last three models (models 4–6) significantly over the first three models (models 1–3) without permanent litter effect. The selection of 56dW would be more reliable for genetic progress rather than the selection of BW. The direct additive genetic correlation (r_a) between BW and 56dW was -0.158 ± 0.29 which revealed that higher BW may not result for favorable changes in weaning weights which was in contradiction to many earlier reports.

Keywords: animal model; maternal effect; permanent litter effect; piglet; pre-weaning growth

1. Introduction

The growth of individual piglet is affected by both the offspring and dam performance during the suckling period. The maternal effects are strictly environmental for the offspring, but can contain both genetic and environmental components. The maternal environment represents mainly the sow's lactating potential and mothering ability which influences bearing, suckling, and raising her litter, antibody transmission and quality of the uterine environment. The genotype of the dam, therefore, affects the phenotype of the offspring through a sample of half her direct, additive genes as well as through her genotype for maternal effects on growth and fitness. If maternal effects are ignored, it can bias the estimate of genetic parameter for direct genetic effects. Hence, to achieve an optimum progress in a selection-based swine breeding program, both the direct and maternal components should be accounted for, especially if an antagonistic relationship between them exists (Roehe 1999; Chimonyo et al. 2006). Only a few reports (Zhang et al. 2000; Kaufmann et al. 2000; Solanes et al.

2004; Chimonyo et al. 2006) are available about direct additive genetic and maternal effects on body weights of individual piglets, estimated using DFREML-based software. Singh et al. (2010) and Dige et al. (2012) had analyzed growth traits of cattle and rabbits of different ages using different animal models. Simultaneously, for estimating genetic correlations authors (Karacaoren et al. 2006; De Haas et al. 2007) have efficiently used random regression models for longitudinal traits in cattle. The objective of the present study was to study the impact of maternal genetic effect and permanent litter effect for getting unbiased estimates of genetic parameters for pre-weaning growth traits among individual *Landrace X Desi* piglets. The aim behind this objective was to take decision for future swine breeding program by selecting breeding stock at an appropriate pre-weaning stage.

2. Materials and methods

2.1. Description of data and farm

In the current study, data on *Landrace X Desi* synthetic strain of pigs maintained at the Indian Veterinary Research

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Institute (IVRI), Izatnagar, Bareilly, UP, India, under All-India Coordinated Research Projects on swine improvement were collected for a period of 10 years (1996–2005) and analyzed. The Desi pigs are medium sized, black colored indigenous breed of pig having range of only 3–6 in litter size. The Landrace pigs were used as exotic breed for synthesizing the new synthetic population. For synthesizing the synthetic pig population, pigs of F₃ generation (62.5% Landrace inheritance and 37.5% indigenous inheritance) were mated with each other and selected over next nine generations. In the present study, a total of 1905 birth weight (BW) records of individual piglets were available which descended from 93 sire/boars (131 grand sire/boar) and 254 sows (195 grand sows/dams). For 14 day body weight (14dW), 28dW, 42dW, and 56dW, totally 1443, 1404, 1383, and 1326 records of individual piglets were available. Thus, the overall litter survivability at 14dW, 28dW, 42dW, and 56dW were 75.74, 73.70, 72.59 and 69.60%, respectively, as compared to litter size at birth. Maximum mortality was noticed in the first two week of growth in individual piglets.

The farm has a semi-arid climate with a high range temperature (4–47 °C). Summers are long, from early April to September, with the monsoon season in between followed by winter from October to March. Unlike large livestock, in crossbred synthetic population of pigs, the planned mating was practiced where farrowing was avoided during extreme summer (June, July, and August) and extreme winter (December and January) for minimizing mortality in piglets. Hence, season was classified only in two seasons and matting was planned to ensure farrowing during mild summer and mild winter months. The pregnant animals were given the dry concentrate mixture (16% crude protein and 3200 Kcal) for proper growth of the fetus as well as for its own body requirements. The creep ration (20% crude protein and 3000 Kcal) was offered to suckling piglets from 15th day to age of weaning. The piglets of each farrowing were mentioned in separate pen with their respective lactating sows. Data collected in the years 1996–2005 were divided into two periods: (1) 1996–2000 and (2) 2001–2005. The five different pre-weaning growth traits included for the analysis were body weights at birth (BW), 14th day (14dW), 28th day (28dW), 42nd day (42dW), and weaning or 56th day (56dW).

2.2. Statistical methods

(Co)variance components and genetic parameters were estimated by restricted maximum likelihood (REML) procedures using a derivative-free algorithm fitting six different animal models of DFREML, Version 3.0 β (Meyer 1998). Initially, the data were analyzed using least squares analysis of variance to identify the significant fixed effects (nongenetic factors) to be included in the animal models. For the growth traits, the model

included the fixed effects of period of birth (2 levels), season of birth (2 levels), sex of the piglet (2 levels), and litter size of sows (3 levels). The nongenetic factors significantly affecting the traits under study were included as the fixed effect in animal models and nonsignificant fixed effects were not included during execution of animal models. The age at the first farrowing was used as linear covariable in animal models under investigation. Six models which accounted for the direct and maternal effects were fitted as follows:

$$\mathbf{y} = \mathbf{X}\boldsymbol{\beta} + \mathbf{Z}_a\mathbf{a} + \boldsymbol{\varepsilon} \quad (1)$$

$$\mathbf{y} = \mathbf{X}\boldsymbol{\beta} + \mathbf{Z}_a\mathbf{a} + \mathbf{Z}_m\mathbf{m} + \boldsymbol{\varepsilon} \text{ with Cov}(\mathbf{a}_m, \mathbf{m}_o) = 0 \quad (2)$$

$$\mathbf{y} = \mathbf{X}\boldsymbol{\beta} + \mathbf{Z}_a\mathbf{a} + \mathbf{Z}_m\mathbf{m} + \boldsymbol{\varepsilon} \text{ with Cov}(\mathbf{a}_m, \mathbf{m}_o) = \mathbf{A}\boldsymbol{\sigma}_{am} \quad (3)$$

$$\mathbf{y} = \mathbf{X}\boldsymbol{\beta} + \mathbf{Z}_a\mathbf{a} + \mathbf{Z}_c\mathbf{c} + \boldsymbol{\varepsilon} \quad (4)$$

$$\mathbf{y} = \mathbf{X}\boldsymbol{\beta} + \mathbf{Z}_a\mathbf{a} + \mathbf{Z}_m\mathbf{m} + \mathbf{Z}_c\mathbf{c} + \boldsymbol{\varepsilon} \text{ with Cov}(\mathbf{a}_m, \mathbf{m}_o) = 0 \quad (5)$$

$$\mathbf{y} = \mathbf{X}\boldsymbol{\beta} + \mathbf{Z}_a\mathbf{a} + \mathbf{Z}_m\mathbf{m} + \mathbf{Z}_c\mathbf{c} + \boldsymbol{\varepsilon} \text{ with Cov}(\mathbf{a}_m, \mathbf{m}_o) = \mathbf{A}\boldsymbol{\sigma}_{am} \quad (6)$$

where, \mathbf{y} is the vector of records; $\boldsymbol{\beta}$, \mathbf{a} , \mathbf{m} , \mathbf{c} , and $\boldsymbol{\varepsilon}$ are vectors of fixed, additive direct genetic, maternal additive genetic, permanent environmental litter effect and residual effects, respectively; \mathbf{X} , \mathbf{Z}_a , \mathbf{Z}_m , and \mathbf{Z}_c are incidence matrices that relate these effects to the records; \mathbf{A} is the numerator relationship matrix between animals; and $\boldsymbol{\sigma}_{am}$ is the covariance between additive direct and maternal genetic effects.

Maternal across year repeatability for sow performance ($t_m = (1/4)h^2 + m^2 + c^2 + m_{am}h$) was calculated. The log-likelihood ratio tests (LRTs) were used to choose the most appropriate model for each trait. An effect was considered to have a significant influence when its inclusion caused a significant increase in log likelihood, compared with the model in which it was ignored. If two models were not differing significantly for LRT, the model with minimum sources of variations/effects was considered to be best. The most appropriate model for each trait as per LRT was subsequently used in the bivariate analyses for the estimation of genetic, phenotypic, permanent litter effect and residual correlations between the traits with starting values derived from single trait analyses.

3. Results and discussion

3.1. Estimation of variance components

The overall means (\pm SD) for 14dW, 28dW, 42dW, and 56dW were 0.79 ± 0.20 , 2.77 ± 0.65 , 4.89 ± 1.14 , $6.99 \pm$

1.68, and 9.14 ± 2.34 kg, respectively. Variance components and genetic parameters estimated by different models for growth traits are presented in Table 1.

3.1.1. Birth weight (BW)

The estimate of additive genetic variance and direct heritability was highest in animal model 1. The additive

genetic variance and estimate of direct heritability was reduced after inclusion of maternal genetic effect in model 2 which may be ascribed due to proper partitioning of phenotypic variance into additive genetic variance (σ_a^2) and maternal genetic variance (σ_m^2). Addition of the covariance between direct and maternal effect produced high and negative estimate of r_{am} (-0.34) in animal

Table 1. Estimates of (co)variance and genetic parameters for BW, 14dW, and 28dW.

Items	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Trait: BW						
σ_B^2	0.04	0.05	0.05	0.04	0.04	0.04
σ_e^2	0.02	0.02	0.02	0.02	0.02	0.02
h^2	0.43 ± 0.04	0.08 ± 0.02	0.15^e	0.10 ± 0.03	0.09 ± 0.03	0.10^e
m^2	–	0.50 ± 0.03	0.55^e	–	0.04 ± 0.03	0.06^e
r_{am}	–	–	-0.34	–	–	-0.19
c^2	–	–	–	0.38 ± 0.05	0.34 ± 0.05	0.34^e
t_m	0.11	0.21	0.49	0.41	0.40	0.41
Log L	2266.08	2401.32	2402.31	2413.26Φ	2413.58Φ	2413.65Φ
14dW						
σ_B^2	0.41	0.59	0.59	0.43	0.43	0.44
σ_e^2	0.29	0.23	0.23	0.30	0.23	0.23
h^2	0.31 ± 0.04	0.00	0.00^e	0.00	0.00	0.01^e
m^2	–	0.61 ± 0.03	0.62^e	–	0.00	0.04^e
r_{am}	–	–	-0.99	–	–	1.00
c^2	–	–	–	0.47 ± 0.05	0.47 ± 0.05	0.41^e
t_m	0.08	0.61	0.62	0.47	0.47	0.47
Log L	-31.59	94.62	94.93	116.23Φ	116.23Φ	115.23Φ
28dW						
σ_B^2	1.21	1.67	1.63	1.28	1.28	1.28
σ_e^2	0.79	0.62	0.59	0.63	0.64	0.61
h^2	0.35 ± 0.05	0.07 ± 0.06	0.12^e	0.06 ± 0.06	0.05 ± 0.06	0.11^e
m^2	–	0.55 ± 0.05	0.59^e	–	0.05 ± 0.06	0.09^e
r_{am}	–	–	-0.26	–	–	-0.56
c^2	–	–	–	0.45 ± 0.04	0.41 ± 0.06	0.39^e
t_m	0.09	0.57	0.55	0.47	0.47	0.45
Log L	-766.54	-658.11	-657.57	-642.16^{Φ}	-641.72^{Φ}	-641.56^{Φ}
42dW						
σ_B^2	2.43	3.00	2.96	2.55	2.57	2.57
σ_e^2	1.45	1.19	1.14	1.17	1.22	1.17
h^2	0.40 ± 0.06	0.15 ± 0.06	0.19^e	0.17 ± 0.06	0.14 ± 0.06	0.17^e
m^2	–	0.45 ± 0.05	0.47^e	–	0.14 ± 0.06	0.18^e
r_{am}	–	–	-0.15	–	–	-0.23
c^2	–	–	–	0.37 ± 0.05	0.25 ± 0.05	0.23^e
t_m	0.10	0.49	0.47	0.41	0.43	0.41
Log L	-1216.82	-1126.29	-1126.06	-1120.57^{Φ}	-1117.89^{Φ}	-1118.02^{Φ}
56dW						
σ_B^2	2.36	1.91	1.76	1.82	1.92	1.84
σ_e^2	4.60	5.55	5.45	4.80	4.86	4.85
h^2	0.49 ± 0.06	0.23 ± 0.05	0.28^e	0.29 ± 0.06	0.24 ± 0.08	0.27^e
m^2	–	0.43 ± 0.04	0.47^e	–	0.16 ± 0.07	0.18^e
r_{am}	–	–	-0.21	–	–	-0.14
c^2	–	–	–	0.34 ± 0.04	0.21 ± 0.06	0.21^e
t_m	0.12	0.49	0.46	0.41	0.43	0.43
Log L	-1559.42	-1469.52	-1468.73	-1467.15^{Φ}	-1463.30^{Φ}	-1463.17^{Φ}

Note: ^eIndicates that the approximation used to define standard errors of parameter estimates failed.

^ΦIndicates that log L of the model is significantly ($p < 0.05$) different from the rest of the models not bearing Φ . Also, models 4–6 with the highest log L in boldface were considered as best.

model 3. Also, the maternal genetic variance explained 55% of variation of BW and the direct estimate of heritability reduced to 0.15 (model 3). In model 4, the direct estimate of heritability was 0.10 ± 0.02 and the litter heritability (c^2) was 0.38 ± 0.04 . In model 5, the maternal component was partitioned in maternal heritability ($m^2 = 0.04 \pm 0.03$) and litter heritability (0.34 ± 0.05). Grandinson et al. (2002) estimated maternal and direct heritability for BWs of 0.15 and 0.04, respectively in Yorkshire piglets. The strong negative genetic correlation (-0.34) between direct and maternal genetic effects suggests an antagonistic association between direct and maternal genetic effects for BW. The negative genetic correlation (r_{am}) may be ascribed due to partitioning of nutrient requirement between sow and unborn piglets in a late stage of gestation. Our finding was in agreement with Roehe (1999) and Chimonyo et al. (2006) but in contradiction to Kaufmann et al. (2000) who reported a positive genetic correlation between direct and maternal genetic effects. In agreement with our findings, Chimonyo et al. (2006) reported direct heritability estimate of 0.09 ± 0.05 for BW in Mukota pigs using an animal model with maternal effect and litter effect. In agreement with our findings, Solanes et al. (2004) reported a very close estimate (0.10) of direct heritability using animal model 6 of the present investigation in Yorkshire individual piglets. Hermesch et al. (2001) and Kaufmann et al. (2000) estimated lower direct heritabilities of BW in piglets using an animal model with direct and maternal effects. On the contrary, Canario et al. (2010) reported higher heritability (0.32 ± 0.06) of BW in Landrace individual piglets with a low magnitude of permanent effects (0.007) of litters. In the present study, estimate of litter heritability (c^2) ranged from 0.34 ± 0.05 to 0.38 ± 0.03 . Solanes et al. (2004) and Chimonyo et al. (2006) reported lower estimates of environmental litter heritability (c^2) of 0.08 and 0.09, respectively, for individual BW of piglets using an animal model with direct and maternal effects. The high c^2 estimate indicated the importance of permanent litter environment and maternal care at birth of the piglets. Kaufmann et al. (2000) and Solanes et al. (2004) reported higher estimates of maternal heritability of 0.21 (Large White piglets) and 0.18 (Yorkshire piglets) for individual BW and concluded that maternal variance was higher than permanent environmental litter variance. Similar to our findings, Chimonyo et al. (2006) reported maternal heritability of 0.03 for BW of individual piglets in Mukota piglets. Estimates of t_m were similar for all the models except model 1, suggesting a consistent repeatability of sow performance across different models which include maternal effects. High estimates of t_m suggest scope of improvement in the BW through mass selection in *Landrace X Desi* piglets.

3.1.2. 14th-day body weight (14dW)

In the presence of either maternal genetic effect or permanent litter effect or both in animal models 2–6, any one of the above-mentioned effect engulfed all additive genetic variance of model 1 and direct estimate of heritability reduced to zero. Thus, it can be concluded that there was no scope of selection for body weights of two week old piglets, since virtually there was no genetic variation obtained due to genetic differences of piglets. Also, the log L values of models 1–5 differed significantly ($p < 0.05$) from model 1, suggesting that the estimate of variances and genetic parameters in model 1 for 14dW was biased. The maternal genetic effect in models 2 and 3 engulfed all the additive variance of model 1 and explained 61–62% of variation of 14dW in *Landrace X Desi* piglets. But, in the presence of permanent litter effect in models 4–6, it engulfed the additive genetic variance and maternal genetic variances of previous models (models 1–3). The environmental litter heritability ranged from 0.41 ± 0.05 (model 6) to 0.47 ± 0.05 (models 4 and 5) for 14dW and the maternal heritability ranged from 0 (models 4 and 5) to 0.04 (model 6) for 14dW in *Landrace X Desi* piglets. Hermesch et al. (2001) reported maternal heritability of 0.13 and direct heritability reduced to 0.04 after the inclusion of maternal effect in model for 14dW. The high c^2 estimate indicates the importance of permanent litter environment and strong maternal care during second week in piglets. Estimates of t_m ranged from 0.47 (models 4, 5, and 6) to 0.62 (model 3), suggesting consistent repeatability of sow performance across different models which include maternal effect or permanent litter effects.

3.1.3. 28th-day body weight (28dW)

Even after the inclusion of maternal effects or permanent litter effect or both in models, the additive genetic variance retained which indicated for the scope of genetic improvement for 28dW through mass selection. This may be ascribed because young piglets were depending wholly on suckling until the second week of age, and thereafter 15th day onwards to age of weaning these suckling piglets were offered creep ration. Similar to previously recorded body weights, the estimate of genetic variance (0.42 Kg^2) and direct heritability (0.35 ± 0.05) was highest in model 1. The maternal heritability ranged from 0.55 ± 0.05 to 0.59 in models 2 and 3. In models 5 and 6, the maternal heritability was found to be 0.05 ± 0.06 and 0.09, respectively, whereas, the litter heritability (c^2) was 0.41 ± 0.06 and 0.39, respectively. In the presence of maternal or permanent litter effect or both in models (2–6), the direct estimate of heritability reduced compared to model 1 and it ranged from 0.05 \pm 0.06 (model 5) to 0.12 (model 3). On the contrary,

Solanes et al. (2004) reported lower estimate of direct heritability (0.03) for three-week body weight of Large White piglets and revealed that maternal genetic effect and permanent litter effect were equally important with 18 and 21% variation of total phenotypic variation. Similar to our findings, Chimonyo et al. (2008) reported direct and maternal heritability 0.13 and 0.09, respectively, for three-week body weight of Mukota piglets, but on the contrary, they reported the environmental litter heritability of 0.02 only.

3.1.4. 42nd-day body weight (42dW)

Similar to earlier recorded pre-weaning growth traits, the additive genetic variance and direct heritability were highest in model 1 due to inflation of these estimates in the absence of maternal and/or litter effects in model. After the inclusion of maternal genetic effect or permanent litter effect or both in subsequent models (model 2–6), the direct estimate of heritability reduced and ranged from 0.14 ± 0.06 (model 5) to 0.19 (model 3). The maternal heritabilities were 0.45 ± 0.05 (model 2) and 0.47 (model 3) in the absence of permanent litter effect. But, in the presence of permanent litter effect, the maternal heritability reduced to 0.14 ± 0.06 (model 5) and 0.18 (model 6), whereas litter heritability (c^2) was 0.25 ± 0.05 (model 5) and 0.23 (model 6) for 42dW. The genetic correlations between direct and maternal genetic effects were strong and negative, ranging from -0.15 to -0.23 . Solanes et al. (2004) analyzed records of Large White piglets for six-week body weights using model 6 of our investigation and reported a lower estimate of direct heritability (0.06), maternal heritability (0.18), and litter heritability (0.21). Estimates of t_m were more consistent across models (except model 1) and ranged from 0.41 (models 4 and 6) to 0.49 (model 2), suggesting a consistent repeatability of sow performance across different models which include maternal genetic effect or permanent litter effects.

3.1.5. 56th-day body weight/weaning weight (56dW)

The estimates of direct heritability improved in comparison to early recorded pre-weaning traits especially in best fit models based on LRT (models 4–6). The estimate of permanent litter effect ranged from 0.21 ± 0.06 (models 5 and 6) to 0.34 ± 0.04 (model 4). Thus, it was noticed that the impact of permanent litter effect reduced at 56dW which was maximum at 14dW. The maternal heritability ranged from 0.47 (model 3) to 0.16 ± 0.07 (model 5), whereas the genetic correlation between maternal and direct genetic variance was negative and ranged from -0.14 (model 6) to -0.21 (model 3). Similarly, Solanes et al. (2004) reported genetic correlation between direct and maternal genetic effects of -0.14 for 56dW of Large White piglets. On

contrary, Tomiyama et al. (2010) reported that direct and maternal genetic correlation between 56dW was positive and high. Our result was in agreement with Zhang et al. (2000) who reported maternal and direct heritabilities, for an eight-week piglet weight, were 0.11 and 0.17, respectively. Solanes et al. (2004) used model 6 of our investigation and presented similar estimate of permanent litter effect (0.21) but had a lower estimate of direct heritability (0.12) and maternal heritability (0.09). Darfour-Oduro et al. (2009) reported that direct estimate of heritability increased for weaning weights of Indigenous Ghanaian piglets as compared to direct estimate of heritability for BW, but maternal heritabilities were always higher than direct heritabilities for both BW and weaning weights. Our finding, higher estimate of direct heritability at weaning age, was in agreement with the findings of Kaufmann et al. (2000), Solanes et al. (2004), and Chimonyo et al. (2006, 2008). In the present investigation, the permanent litter effects on weight progressively decreased with higher weights which was in contradiction to the report of Solanes et al. (2004) and Chimonyo et al. (2006, 2008) but was in agreement with the report of Kaufmann et al. (2000). In agreement with our findings, Chimonyo et al. (2006, 2008) reported that estimate of maternal heritability and direct heritability increased with advancement of age. In contradiction to our report, Kaufmann et al. (2000) and Solanes et al. (2004) reported that maternal effect decreased for body weights at weaning as compared to BW in Large White piglets. For 56dW, the estimates of t_m were more consistent across models (except model 1) and ranged from 0.41 (model 4) to 0.49 (model 2), suggesting a consistent repeatability of sow performance across different models which include maternal effect or permanent litter effect.

It was noticed that the presence of permanent litter effect in model increased the fitness and accuracy of model more efficiently than with the presence of maternal effect in model. Similarly, Satoh et al. (2002) concluded that largest biased estimates of direct additive genetic variance are observed when maternal genetic effect and litter environmental effects are ignored. For all traits under investigation, the log L values in models 4–6 were significantly ($P < 0.05$) higher than log L values of models 1–3, but simultaneously the log L values of models 4–6 did not differ significantly.

3.2. Correlation estimates

All the phenotypic correlations were moderate (0.229 for BW–56dW) to high (0.859 for 42dW–56dW) (Table 2). Estimates for direct genetic correlation between pre-weaning body weights of crossbred piglets at different ages ranged from -0.158 ± 0.29 for BW–56dW to 0.970 for 42dW–56dW. This may be ascribed because the

Table 2. Above the diagonal are direct additive genetic correlations (r_a) and permanent environmental correlations (r_c) (in parentheses); whereas below the diagonal are phenotypic correlations (r_p) and residual correlations (r_e) (in parentheses).

	BW	14dW	28dW	42dW	56dW
BW					
14dW	0.462 (0.607 ± 0.05)	-0.086 ± 0.09 (0.416 ± 0.08)	0.129 ± 0.49 (0.171 ± 0.09)	0.865 ± 0.09 (0.193 ± 0.09)	-0.158 ± 0.29 (0.153 ± 0.10)
28dW	0.344 (0.544 ± 0.05)	0.758 (0.763 ± 0.02)	0.761 ± 0.44 (0.757 ± 0.04)	0.666 ± 0.52 (0.570 ± 0.07)	0.592 ± 0.64 (0.493 ± 0.07)
42dW	0.229 (0.000 ± 0.00)	0.586 (0.626 ± 0.04)	0.813 (0.822 ± 0.02)	0.831 ± 0.20 (0.834 ± 0.03)	0.937 ± 0.18 (0.629 ± 0.06)
56dW	0.758 (0.511 ± 0.07)	0.505 (0.581 ± 0.05)	0.666 (0.633 ± 0.04)	0.859 (0.843 ± 0.02)	0.970 ± 0.05 (0.819 ± 0.03)

impact of common permanent litter effect was highest at 14dW and lowest at 56dW which diminished the genetic correlation between 14dW and 56dW. The permanent environmental correlations ranged from 0.153 ± 0.10 for BW–56dW to 0.834 ± 0.03 for 28dW–42dW. The permanent environmental correlations of BW with subsequent body weights reduced gradually with advancement of age which may be ascribed due to the lower magnitude of permanent litter environmental effect in piglets offered with creep ration. Further, the genetic correlation between 42dW and 56dW was highest because of the low impact of permanent litter effect at these ages compared to early recorded pre-weaning growth traits. The genetic correlation of BW with 56dW was lowest and negative (-0.158 ± 0.29) indicated that selection for better body weights at birth may not result in better body weights at weaning. In contradiction to our findings, Kaufmann et al. (2000), Ilatsia et al. (2008), Darfour-Oduro et al. (2009), and Pandey and Singh (2010) reported that selection to improve BW would be associated with favorable changes in 56dW because of positive genetic correlation between BW and 56dW. Estimates for residual correlations between pre-weaning body weights of piglets at different ages ranged from 0 for BW–42dW to 0.843 ± 0.02 for 42dW–56dW (Table 2). Hence, it could be concluded that the inclusion of permanent environment litter effect improved the accuracy of animal models. For all the pre weaning traits, moderate to high negative correlations were obtained between direct additive and maternal genetic variance. Some low genetic correlations between BW and other weight traits may be ascribed because of significant impact of maternal effect and/or permanent litter effect at early stage of growth.

References

- Canario L, Lundgren H, Haandlykken M, Rydhmer L. 2010. Genetics of growth in piglets and the association with homogeneity of body weight within litters. *J Anim Sci.* 88:1240–1247.
- Chimonyo M, Dzama K, Bhebhe E. 2006. Genetic determination of individual birth weight, litter weight and litter size in Mukota pigs. *Livest Sci.* 105:69–77.
- Chimonyo M, Dzama K, Bhebhe E. 2008. Genetic determination of mothering ability and piglet growth in indigenous Mukota sows of Zimbabwe. *Livest Sci.* 113:74–80.
- Darfour-Oduro K, Naazie A, Ahunu B, Aboagye G. 2009. Genetic parameter estimates of growth traits of indigenous pigs in Northern Ghana. *Livest Sci.* 125:187–191.
- De Haas Y, Janss LLG, Kadarmideen HN. 2007. Genetic correlations between body condition scores and fertility in dairy cattle using bivariate random regression models. *J Anim Genet Breed.* 124:277–285.
- Dige MS, Kumar A, Kumar P, Dubey PP, Bhushan B. 2012. Estimation of variance components and genetic parameters for growth traits in New Zealand White rabbit (*Oryctolagus cuniculus*). *J Appl Anim Res.* 40:145–148.

- Grandinson K, Lund MS, Rydhmer L, Strandberg E. 2002. Genetic parameters for the piglet mortality traits crushing, stillbirth and total mortality, and their relation to birth weight. *Anim Sci*. 52:167–173.
- Hermesch S, Luxford BG, Graser HU. 2001. Estimation of variance components for individual piglet weights at birth and 14 days of age. *Proc Assoc Adv Anim Breed Genet*. 14:207–210.
- Ilatsia ED, Githinji MG, Muasya TK, Okenoand TO, Kahi A. 2008. Genetic parameter estimates for growth traits of Large White pigs in Kenya. *S Afr J Anim Sci*. 38: 166–173.
- Karacaoren B, Jaffrézic F, Kadarmideen HN. 2006. Genetic parameters for functional traits in dairy cattle from daily random regression models. *J Dairy Sci*. 89:791–798.
- Kaufmann D, Hofer A, Bidanel JP, Kunzi N. 2000. Genetic parameters for individual birth and weaning weight and for litter size of Large White pigs. *J Anim Breed Genet*. 117:121–128.
- Meyer K. 1998. DFREML [Derivative Free Restricted Maximum Likelihood] Programme. version 3.0. Armidale (NSW): University of New England.
- Pandey A, Singh SK., 2010. Genetic and phenotypic correlation among body weight at various ages and among the reproductive traits in landrace desi and their cross-bred pigs. *Vet Sci Res*. 1:01–03.
- Roche R. 1999. Genetic determination of individual birth weight and its association with sow productivity traits using Bayesian analyses. *J Anim Sci*. 77:330–343.
- Satoh M, Hicks C, Ishii K, Furukawa T. 2002. Choice of statistical model for estimating genetic parameters using restricted maximum likelihood in swine. *J Anim Breed Genet*. 119:285–296.
- Singh RR, Dutt T, Kumar A, Singh M. 2010. Estimation of direct additive genetic and maternal variance for growth traits in *Vrindavani* cattle. *J Appl Anim Res*. 38:145–148.
- Solanes FX, Grandinson K, Rydhmer L, Stern S, Anderson K, Lundeheim N. 2004. Direct and maternal influences on the early growth, fattening performance, and carcass traits of pigs. *Livest Sci*. 88:199–212.
- Tomiyama M, Kanetani T, Tatsukawa Y, Mori H, Oikawa T. 2010. Genetic parameters for pre-weaning and early growth traits in Berkshire pigs when creep feeding is used. *J Anim Sci*. 88:879–884.
- Zhang S, Bidanel JP, Burlot T, Legault C, Naveau J. 2000. Genetic parameters and genetic trends in the Chinese x European Tiameslan composite pig line. I - Genetic parameters. *Genet Sel Evol*. 32:41–56.