Genetic parameters for white blood cells, haemoglobin and growth in weaner pigs for genetic improvement of disease resilience

S. Hermesch[1] & B. G. Luxford[2]

[1] Animal Genetics and Breeding Unit, a joint venture of NSW Department of Primary Industries and University of New England, University of New England, Armidale, NSW 2351, Australia
Susanne.Hermesch@une.edu.au (Corresponding Author)
[2] Rivalea Australia, PO Box 78, 2646, Corowa, Australia

Summary

This study aimed to estimate genetic parameters for white blood cells and haemoglobin levels in weaner pigs and estimate their genetic correlations with multiple growth traits. Five weight measurements were collected on 2,025 Large White pigs. A proportion of these pigs (813 pigs) also had total and differential white blood cells and haemoglobin recorded at an average age of 36.4 days. Haematological variables included total white blood cells (WBC), and counts of lymphocytes (LLYM), neutrophils, monocytes, eosinophils (LEOS), basophils and haemoglobin (HbL). In addition, haemoglobin was recorded on farm with the HemoCue Hb 201+ analyser (HbF). Genetic parameters were estimated using an animal model and fitting common litter effect as an additional random effect for most traits. Heritabilities for total and differential blood cells varied from 0.11 ± 0.09 for LLYM to 0.46 ± 0.10 for LEOS. Both haemoglobin measures were heritable with estimates of 0.15 ± 0.08 for HbF and 0.30 ± 0.14 for HbL. Growth traits were moderately heritable including growth from weaning to five weeks of age which covered only a short time period of ten days. These heritability estimates demonstrated that white blood cells, haemoglobin and growth recorded in weaner pigs may be used to describe disease resilience. Genetic correlations between white blood cells or haemoglobin and growth traits were variable and a better understanding of factors affecting genetic correlations between white blood cells or haemoglobin and growth is needed.

Keywords: disease resistance, hemoglobin, innate immunity, heritability, performance

Introduction

Genetic improvement of health of livestock remains challenging because specific information about health status of individual animals is often limited on farms. Growth may be used as a proxy for health status of animals because many sub-clinical diseases lead to reduced growth rate. Further, repeated growth measures together with some information about infection challenge may be used to describe disease resilience which has been defined as the ability of animals to maintain productivity when facing infection challenges (Albers *et al*., 1987). Disease resilience may offer a more practical approach for genetic improvement of health status of pigs because it uses measures of productivity and makes use of the mechanisms of both disease resistance and disease tolerance (Hermesch, 2014; Doeschl-Wilson & Lough, 2014).

A number of immune traits including total and differential white blood cells have been shown to be moderately to highly heritable (e.g. Henryon *et al*., 2006; Clapperton *et al*., 2008; Clapperton *et al*., 2009). In particular, Flori *et al*. (2011) found high heritabilities for multiple

immune traits following vaccination against *M. hyopneumniae*. These results support the observation that "heritability tends to rise as one goes from general disease category to specific disease resistance to specific immune response with antibody responses sometimes being highly heritable." (Bishop *et al*., 2002). Phenotypes to measure immune responsiveness in pigs are currently being developed in Australia (Harper *et al.*, 2018). However, it may not always be feasible to implement a specific immune challenge for pigs on farms. Instead, immune parameters may be recorded in weaner pigs following the challenging weaning process for genetic improvement of disease resilience.

It was the aim of this study to estimate genetic parameters for total and differential white blood cells and haemoglobin recorded in weaner pigs at five weeks of age and to estimate their genetic correlations with multiple growth traits.

Material and Methods

Data

Weight measurements were collected on 2,025 Large White pigs from January 2013 to November 2014 at the piggery of the University of Queensland in Gatton, Australia. A proportion of these pigs (813 pigs) also had white blood cells and haemoglobin recorded. Blood samples of pigs were collected at five weeks (at 36.4 ± 3.69 days) into vacutainers with anticoagulants (EDTA) and stored at 1 to 4^{o} C until haematology analyses (0.72 ± 1.04 days later) using a calibrated automated haematology analyser (Cel-Dyn® 3700, www.abbottdiagnostics.com). The haematology variables from these haematology analyses included total white blood cells (WBC), and counts of lymphocytes (LLYM), neutrophils (LNEU), monocytes (MONO), eosinophils (LEOS) and basophils (BASO) as well as haemoglobin (HbL). Further, haemoglobin was recorded on farm (HbF) with the HemoCue Hb 201+ analyser (HemoCue® 2012) on 1152 animals.

Pigs were weighed at weaning (at 26.8 ± 2.4 days) and at five, nine, 12 and 17 weeks of age. This study presents genetic parameters for average daily gain from a) birth until five and 17 weeks of age (ADGb-5, ADGb-17), b) from weaning to five weeks (ADGw-5) and c) from five to 17 weeks of age (ADG5-17).

Outliers exceeding four standard deviations from the mean were eliminated from the analyses for all traits. The distribution of traits was evaluated with the univariate procedure (SAS, 2014). Traits with a skewness or kurtosis number of smaller than -1.0 or greater than 1.0 were log transformed using a log to the base of 10. The log-transformed traits were LNEU, LLYM and LEOS.

Methods

Genetic parameters were estimated with ASReml (Gilmour *et al*., 2009) using an animal model and fitting common litter as an additional random effect for most traits. Estimates of common litter effect were not fitted for LNEU, LEOS and ADG5-17 because the low and non-significant estimates (0.02 ± 0.05). Significant fixed effects were weekly weaning batch (fitted for all traits, 47 levels), sex (fitted for all traits except LLYM, 2 levels), age at weaning (fitted for HbF, HbL, LEOS) and time period from collection of blood samples until haematology analyses (fitted for MONO, BASO).

Results and Discussion

Heritability estimates

Estimates of heritability for total and differential blood cells varied from 0.11 ± 0.09 for LLYM to 0.46 ± 0.10 for LEOS (Table 1). Most estimates of heritabilities from this study were similar to the range of estimates (0.22 to 0.30) presented by Henryon *et al*. (2006) for differential white blood cells recorded in pigs at 52 days of age. Flori *et al*. (2011) found higher heritabilities for these traits (range: 0.38 to 0.80). However, standard errors of these estimates were also larger (0.20 and 0.21). Jointly, these studies demonstrate that total and differential blood cells are heritable traits that can be used for pig breeding. All of these studies collected blood samples in weaner pigs between 36 and 57 days of age thereby providing early selection criteria for pig breeding.

The measure of haemoglobin recorded on farm with a handheld device (HbF) had a lower heritability of 0.15 ± 0.08 than the lab measure (HbL: 0.31 ± 0.14). The residual variance was twice as high in HbF in comparison to HbL indicating larger measurement errors. However, additive genetic variances were similar for both traits and these two measures of haemoglobin were genetically the same trait (genetic correlation of 0.99). The heritability for HbF found in this study was higher than the estimate of 0.04 ± 0.02 presented by Hermesch and Jones (2012) for the same trait. These results demonstrate that haemoglobin levels in weaner pigs have genetic variation. Handheld on-farm measures may be used to record haemoglobin provided that operators are trained and accuracy of measurements are evaluated through repeated records.

All growth traits were moderately heritable including ADGw-5 which covers only a short time period of ten days from weaning to 5 weeks. Variation in gut fill contributes to measurement errors in weight and longer test periods are required to measure growth accurately (Arthur *et al*., 2008). High variability was also observed for ADGw-5, however, the heritability estimate of 0.26 ± 0.08 for ADGw-5 demonstrates genetic variation in the ability of weaner pigs to cope with the weaning process. Colditz and Hine (2016) suggested to use husbandry practices such as weaning that provide physical and social stressors to animals for characterisation of resilience phenotypes. The genetic variation found for ADGw-5 supports the notion to use growth shortly after weaning for genetic improvement of resilience of pigs.

Estimates of genetic correlations

Estimates of genetic correlations between total and differential white blood cells were moderate to high ranging from 0.29 ± 0.26 to 0.91 ± 0.09 (Table 2). Differential white blood cells had higher genetic correlations with WBC and lower genetic correlations with LEOS. A result that was also found by Flori *et al*. (2011).

Total WBC had no significant genetic correlation with early growth traits while genetic correlations with later growth traits tended to be higher. Estimates of genetic correlations for WBC with ADG5-17 or ADGb-17 were 0.46 ± 0.36 and 0.49 ± 0.30 (Table 3). In comparison, genetic correlations between WBC measured at start or end of the test period (Clapperton *et al*., 2008) or in SPF versus non-SPF pigs (Clapperton *et al*., 2009) varied from -0.69 ± 0.39 and 0.03 ± 0.30. The large range of estimates and their level of uncertainty indicates that information about these genetic associations is still limited. Further studies are required to gain a better understanding of factors affecting genetic associations between WBC and growth.

Early growth measures had negative genetic correlations with haemoglobin levels varying from -0.66 ± 0.22 between HbF and ADGb-5 to -0.09 ± 0.27 between HbL and ADGb-5 (Table 3). Estimates of genetic correlations were higher between later growth traits and haemoglobin levels with estimates ranging from -0.19 ± 0.29 to 0.36 ± 0.23. Similarly, the genetic correlation between HbF and growth until 21 weeks of age was -0.26 ± 0.20 in the study by Hermesch and Jones (2012). At the phenotypic level, Perri *et al*. (2016) found lower haemoglobin levels in larger weaner pigs and highlight the larger iron requirements of pigs with higher growth rate. The higher haemoglobin requirements of faster-growing pigs may influence estimates of genetic correlations between these traits, and the genetic correlation between haemoglobin and growth may be affected when haemoglobin is measured, i.e. at the start or the end of the growth period. These aspects need to be considered when genetic correlations between haemoglobin and growth are evaluated.

Conclusions

Genetic analyses demonstrated that white blood cells, haemoglobin and growth recorded in weaner pigs were heritable and may be used to describe disease resilience. Genetic correlations between these traits were variable and a better understanding of factors affecting genetic correlations between white blood cells or haemoglobin and growth is needed.

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Table 1. Mean, standard deviation (sd), phenotypic variance ($\hat{\sigma}_P^2$), heritability ($\hat{h}^2$) and common litter effect estimates ($\hat{c}^2$) both with standard errors (se) for traits investigated.

Trait[1]	N	Mean	sd	$\hat{\sigma}_P^2$	$\hat{h}^2$	se	$\hat{c}^2$	se
WBC	811	16.82	4.71	21.2	0.26	0.12	0.07	0.05
LLYM	812	0.854	0.186	0.0326	0.11	0.09	0.10	0.05
LNEU	806	0.792	0.173	0.0288	0.32	0.09		
MONO	813	1.59	0.60	0.3322	0.18	0.11	0.12	0.05
LEOS	810	-0.56	0.229	0.0494	0.46	0.10		
BASO	813	0.328	0.181	0.0289	0.12	0.08	0.08	0.04
HbF	1152	110.3	13.38	155.8	0.15	0.08	0.11	0.04
HbL	812	114.0	10.05	80.7	0.31	0.14	0.06	0.05
ADGw-5	1780	189.9	125.10	8648	0.26	0.08	0.13	0.03
ADGb-5	1889	298.7	45.23	1682	0.27	0.08	0.17	0.03
ADG5-17	1105	844.4	87.67	6598	0.27	0.08		
ADGb-17	1246	679.2	63.92	3694	0.22	0.09	0.04	0.04

[1] Trait abbreviations: WBC: white blood cells, LLYM: lymphocytes (log transformed), LNEU: neutrophils (log transformed), MONO: monocytes, LEOS: eosinophils (log transformed), BASO: basophils, HbF: haemoglobin recorded on farm, HbL: haemoglobin recorded in laboratory, ADGb-5: growth from birth to five weeks,ADGw-5: growth from weaning to five weeks, ADG5-17 growth from five to 17 weeks; ADGb-17: growth from birth to 17 weeks.

Table 2. Genetic & litter correlations (first & second row above diagonal) and residual & phenotypic correlations (first & second row below diagonal) with standard errors (± se) between total and differential white blood cells.

Trait[1]	WBC	LLYM	LNEU	MONO	LEOS	BASO
WBC		0.80 ± 0.23	0.91 ± 0.09	0.56 ± 0.29	0.64 ± 0.20	0.60 ± 0.32
		0.99 ± 0.15		0.42 ± 0.33		0.24 ± 0.41
LLYM	0.64 ± 0.04		0.41 ± 0.38	0.45 ± 0.52	0.59 ± 0.31	0.77 ± 0.50
	0.68 ± 0.02			0.28 ± 0.30		0.02 ± 0.35
LNEU	0.63 ± 0.04	0.00 ± 0.07		0.32 ± 0.23	0.43 ± 0.21	0.32 ± 0.23
	0.69 ± 0.02	0.07 ± 0.04				
MONO	0.47 ± 0.06	0.03 ± 0.06	0.51 ± 0.07		0.29 ± 0.26	0.36 ± 0.39
	0.48 ± 0.03	0.12 ± 0.04	0.43 ± 0.04			0.95 ± 0.20
LEOS	0.16 ± 0.08	0.09 ± 0.08	0.18 ± 0.08	0.23 ± 0.08		0.19 ± 0.20
	0.30 ± 0.04	0.19 ± 0.04	0.25 ± 0.04	0.23 ± 0.04		
BASO	0.32 ± 0.06	0.01 ± 0.06	0.37 ± 0.06	0.51 ± 0.05	0.03 ± 0.08	
	0.36 ± 0.04	0.09 ± 0.04	0.35 ± 0.04	0.53 ± 0.03	0.07 ± 0.04	

[1] Trait abbreviations: WBC: white blood cells, LLYM: lymphocytes (log transformed), LNEU: neutrophils (log transformed), MONO: monocytes, LEOS: eosinophils (log transformed), BASO: basophils.

Table 3. Genetic & litter correlation (first & second row) and residual & phenotypic correlation (third and fourth row) between white blood cells (WBC), haemoglobin and growth traits with standard errors (± se).

Trait[1]	WBC	ADGw-5	ADGb-5	ADG5-17	ADGb-17
WBC		-0.06 ± 0.30	0.26 ± 0.31	0.46 ± 0.36	0.49 ± 0.30
		-0.17 ± 0.29	0.41 ± 0.32		0.00 ± 0.65
		-0.09 ± 0.08	-0.16 ± 0.08	-0.17 ± 0.08	-0.16 ± 0.08
		-0.09 ± 0.04	0.01 ± 0.04	0.01 ± 0.05	0.01 ± 0.05
HbF	-0.33 ± 0.40	-0.66 ± 0.22	-0.25 ± 0.30	-0.18 ± 0.27	-0.19 ± 0.29
	-0.06 ± 0.37	-0.70 ± 0.13	-0.27 ± 0.20		ne[2]
	0.12 ± 0.07	-0.24 ± 0.06	-0.26 ± 0.06	-0.12 ± 0.06	-0.12 ± 0.06
	0.02 ± 0.04	-0.39 ± 0.03	-0.25 ± 0.03	-0.14 ± 0.04	-0.14 ± 0.04
HbL	-0.30 ± 0.35	-0.24 ± 0.28	-0.09 ± 0.27	0.14 ± 0.25	0.36 ± 0.23
	0.06 ± 0.55	-0.80 ± 0.24	-0.36 ± 0.31		-0.78 ± 0.92
	0.19 ± 0.09	-0.42 ± 0.08	-0.41 ± 0.08	-0.25 ± 0.08	-0.27 ± 0.09
	0.04 ± 0.05	-0.42 ± 0.04	-0.30 ± 0.04	-0.13 ± 0.05	-0.12 ± 0.05

[1] Trait abbreviations: WBC: white blood cells, HbF: haemoglobin recorded on farm, HbL: haemoglobin recorded in laboratory, ADGb-5: growth from birth to five weeks, ADGw-5: growth from weaning to five weeks, ADG5-17 growth from five to 17 weeks; ADGb-17: growth from birth to 17 weeks.
[2] ne: could not be estimated