SOURCES OF VARIANCE IN PRE-WEAN GROWTH TRAITS OF MARINDUKE PIG (*Sus domesticus*)

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Abstract- The pre-wean growth is a complex trait that gauges the success or failure of the succeeding post-wean growth until a final product is produced. This study evaluates the variance components to identify the critical source of variance in pre-wean growth traits of Marinduke pig, the indigenous pig in the island province of Marinduque, Philippines. The pre-wean growth as measured on birth weight (BW_0), weaning weight at 49 day-old (BW_{49}), weight gain (BWG), and average daily gain (ADG) were evaluated from 62 piglets. The mean and variability *e.g.* standard deviation and coefficient of variation, correlation and regression, analysis of variance, and variance partitioning were instituted. Result shows that the pre-wean growth trait specifically the BW_0 was dependent on the maternal effect (37.74%) or the influence of the dam's phenotype on the phenotype of her progeny. The BW_{49} (42.20%), BWG (46.23%) and ADG (47.58%) were found due to the effect of litter size. A management protocol that shall provide better nutrition and welfare is required to sustain the physiological requirements thereby ensuring better and uniform pre-wean growth in Marinduke pig.

Index Terms - Growth traits, Marinduke pig, Philippines, Swine breeding, Variance components

I. INTRODUCTION

Three pig species, namely; *Sus philippensis*, *Sus ahoenobarbus*, and *Sus scrofa* are known to exist as protein foods of Filipinos in the Neolithic period [1, 2]. The *S. philippensis* (warty pig) and *S. ahoenobarbus* (Palawan bearded pig) are the endemic wild pigs in the Philippines. The *S. scrofa* is a domestic pig species grown in the country since early civilization. These three pig species are presumed to have shared evolutionary path producing the Philippine native pig. This is a scientific guess in the absence of factual and empirical information but provides interesting idea necessary for elucidating the nature of the current genetic property of the Philippine native pig. It is speculated that several evolutionary forces like inter-specific hybridization, fixation, isolation, and formation of sire-lines have contributed to the existing genotype of domestic pig [1, 2, 3, 4, 5, 6]. The recent qualitative study using microsatellite markers shows a low genetic diversity in the sampled 23 native pigs from three locations, namely; Ilocos, Tarlac, and Quezon in the Philippines [6]. Similarly, the Taoyuan pigs in Taiwan have low genetic diversity [5]. These reports show that the Philippine native pig and Taoyuan pig are both genetically pure and distinct genetic resources.

Several variants of native pig are known to exist in the Philippines [6]. The Marinduke pig is the classic example in the island province of Marinduque, Philippines ($13^o24'$N $121^o58'$E). There are three variants of Marinduke pig with distinct visual phenotypes to include the pure black pig, black with white-feet pig, and multi-color pig that must be documented as part of the Philippines' commitment to conserve animal genetic resources (FAO Global Plan of Action for Animal Genetic Resources http://dad.fao.org/). The information about these pig variants is necessary in elucidating the complexity of domestication, magnitude of genetic improvement and required strategy for genetic conservation. Relatively, the population of Marinduke pig is declining based on the shipment of live piglets to other provinces having an average negative change of 27.85% from 2012 to 2014 (http://marinduquevet.ph/?page_id=438). The extraction rate for lechon processing (3,565±1,209 piglets being shipped monthly from 2012 to 2014) coupled with relatively low reproductive efficiency (8.3±1.9 piglets born; in this paper) and low growth rate (0.14kg/d; in this paper) of Marinduke pig are believed to aggravate the decline in pig population.

The Marinduke pig is popular and preferred in the processing of lechon (roast whole pig). The lechon has become part of the Filipino culture associated to festivities and thanks-giving [7]. Having this niche market, support system and innovation that shall improve their availability for the lechon are necessary. Their slow growth performance is one of concerns to be addressed. Growth as defined here refers to compositional change based on time-related accretion of body mass. The pre-wean growth is mostly associated with the nursing ability or maternal influences which are dependent on genetics and non-genetic functions [8]. Hence, this paper evaluates the pre-wean growth of Marinduke pig to identify its critical source of variation.

II. MATERIALS AND METHODS

Data Source

The pre-wean growth of Marinduke pig was evaluated on relative change in body weight from birth to weaning using the pooled data from two variants, namely: Marinduke black pig and Marinduke white-feet pig. The pre-wean growth traits, namely; birth weight (BW_0), weaning weight at 49 day-old (BW_{49}), weight gain (BWG), and average daily gain (ADG) were measured from 62 piglets (66 at birth) born on May 2014 (27 piglets) and November 2014 (39 piglets). The piglets were progeny of full-sib parents; 2 sires and 4 dams with two litters each dam. Relatively, the piglets belong to two sire families with two full-sib litters and four half-sib litters each sire family. The

sires and dams were progeny of the unrelated foundation stock maintained at the Livestock Farm of Marinduque State College (MSC), Philippines (13°20'52.2"N, 122°06'03.2"E). The Marinduke pigs are fed with composite of commercial feeds (BAI Reg. No. M-174, Lipa Agricultural Development Corp., Philippines) and forages e.g. *Trichanthera gigantea*, grasses, and legumes; and managed in consonance to Republic Act 8485 and Republic Act 10631 (The Animal Welfare Laws of the Republic of the Philippines) as certified by the MSC Ethics Review Committee.

The BW_0 of piglets was taken (Fuji Sun weighing scale, 0.05 kg graduation) and recorded at farrowing time specifically after removing the fetal membrane and treating the umbilical cord with iodine solution (Betadine®, Mundipharma Distribution GmbH, Philippines). After weighing; each piglet was assigned with identification code through notches in both ears. The right ear contains the litter number while the left ear contains the individual number within litter. The ear notch wounds were treated with iodine solution. The piglet was placed in the ventral area of the dam while in lay down position and trained to suckle colostrum. There was closed monitoring of the health condition of dam and piglets within 24 hr post-partum. Iron administration was performed within 48 hr of birth. All piglets in a litter were treated with the same procedure as described. The dam nursed her piglets until the weaning age.

Moreover, we practiced scattering of a handful of creep feed in the pig pen to train piglets eat solid food starting at 7th day old. The creep feeding was employed continuously until weaning to stimulate post-weaning feed consumption [9]. The weaning process commences from transferring the dam to the breeding herd and leaving the piglets in the pen. There were 62 piglets at weaning time. The BW_{49} of piglets was taken (Fuji GT weighing scale, 0.2 kg graduation) and recorded at weaning.

Data Format

The birth weight (BW_0) and weaning weight at 49 day old (BW_{49}) were encoded in a column format in Microsoft Office Excel ver. 2007. The weight gain (BWG) was computed as the difference of BW_{49} minus BW_0. The average daily gain (ADG) was a quotient of BWG in proportion to the weaning age (49 d). The data were expressed in kg except ADG, kg/d. The independent variables, namely; sire, dam, sex ratio, litter size, and sex of piglet were encoded correspondingly with the pre-wean growth traits data. There were two sires and four dams with corresponding identification code each. The sex ratio of piglets in a litter was composed of 1:1 (equal male to female ratio), >1:1 (more males than females), and <1:1 (less males than females). The litter size was categorized into ≤ 8 (5 to 8 piglets per litter; 6.8±1.3) and ≥ 9 (9 to 11 piglets per litter; 9.8±1.0). The sex of piglet refers to their biological sex of either male or female. The data file was linked to the Statistical Analysis System (SAS) software ver 6.12 (SAS Institute, Cary, USA) for statistical analyses.

Data Analysis

The mean and measures of variability such as standard deviation and coefficient of variation of pre-wean growth traits were calculated in PROC UNIVARIATE PLOT NORMAL. The skewness value as a measure of normality distribution was considered. The association among the pre-wean growth traits with litter size were determined in PROC CORR. The phenotypic variance of pre-wean growth traits was partitioned into variance components of sire, dam, sex ratio, litter size, and sex of piglet in PROC NESTED. The model was $\sigma^2_{Pijklmn} = \sigma^2_{si} + \sigma^2_{dj} + \sigma^2_{rk} + \sigma^2_{ll} + \sigma^2_{xm} + e_{ijklmn}$ where $\sigma^2_{Pijklmn}$ as the phenotypic variance, σ^2_{si} as variance between-sire, σ^2_{dj} as variance between-dam, σ^2_{rk} as variance between-sex ratio, σ^2_{ll} as variance between-litter size, σ^2_{xm} as variance between-sex of piglet, and e_{ijklmn} as the residual variance. The variance due to sire, dam, sex ratio, litter size, and sex of piglet were partitioned further to measure the magnitude of differences between-factors and with-in factor [10]. The model was $Y_{ij} = \mu + \alpha_i + e_{ij}$; where Y_{ij} is the j^{th} measurement on the i^{th} factor, μ is the overall mean, α_i is the between-factors effect, and e_{ij} is the residual (within-factor effect). The significance of the main effect and interaction effect of the independent variables were tested in PROC GLM.

III. RESULTS

Pre-wean Growth Performance

The pre-wean growth as measured on birth weight (BW_0), weaning weight (BW_{36} to BW_{56}), weight gain (BWG) and average daily gain (ADG) of native pigs varies considerably in different countries (Table 1). Relatively, the Marinduke pig was observed to have similar pre-wean growth performance with the native pigs in other countries (Table 2). The Marinduke pig had mean BW_0 of 0.84±0.15 kg and capable to grow into 7.74±1.52 kg achieving a BWG of 6.89±1.56 kg at the rate of 0.14±0.03 kg/d within the 49 d pre-wean period. However, its positively skewed data indicated that the majority of them had pre-wean growth performance below the mean while few was sufficiently heavy at weaning ($p>\alpha$). Relevant analysis shows that the amount of heterogeneity (coefficient of variation) in weight at birth and weaning was 17.49% and 19.65%, respectively. The heterogeneity had increase to 22.57% and 22.64% for the BWG and ADG, respectively indicating wide variability among the piglets of Marinduke pig.

Table 1. The pre-wean growth performance of different breeds of native pig.

Breed	BW0	BW36-56	BWG	ADG	Author
Hurrah (Nepal)	0.72	6.72	6.00	0.122	[11] Pokharel et. al., 2013
Nigerian hybrid	0.91	6.72	5.81	0.119	[12] Oluwole et al. 2014
Ghungroo (India)	0.96	7.07	6.11	0.109	[13] Banik et al., 2013
Nigerian	0.90	6.70	5.80	0.104	[14] Nwakpu, 2013
Kadon (Thailand)	0.58	6.10	5.52	0.092	[15] Vasupen et al., 2008
Niang Megha (India)	0.64	5.47	4.83	0.086	[13] Banik et al., 2013
Nigerian	1.34	4.48	3.14	0.056	[16] Ogah, 2010
Nigerian	0.93	4.03	3.10	0.055	[17] Ajayi & Akinokun, 2013
Nigerian	0.85	3.36	2.51	0.051	[18] Nwakpu & Ugwu, 2009
Mean	***0.87 (0.22)***	***5.63 (1.36)***	***4.76 (1.44)***	***0.088 (0.03)***	

BW0= birth weight, kg; BW36-56= weaning weight at 36 to 56 day old, kg; BWG= weight gain, kg; ADG= average daily gain, kg/d; some values were re-computed. Listed based on growth rate (ADG).

Table 2. The descriptive statistics of pre-wean growth traits of Marinduke pig.

Parameter	BW0	BW49	BWG	ADG
Observation	66	62	62	62
Mean, kg	0.842	7.737	6.892	0.141
Minimum, kg	0.693	6.217	5.336	0.109
Maximum, kg	0.990	9.257	8.448	0.172
Standard deviation	0.147	1.520	1.556	0.032
Coefficient of variation	17.491	19.649	22.575	22.636
Skewness	0.532	0.475	0.541	0.504
Pr < W	0.015	0.041	0.024	0.012

BW0= birth weight, BW49= weaning weight at 49 d/o, BWG= weight gain, ADG= average daily gain

Association Within Pre-wean Growth Traits

The heavy weight piglet at birth (>0.8kg) was found to belong into small litter size that ranges from 5 to 8 piglets per litter (r = -0.2559). This negative correlation of BW_0 with litter size in this study did not affect the survivability of the piglets until weaning (r = -0.3155). On the other hand, the light weight piglets at birth (<0.8 kg) had relatively fast growth rate similar to the piglets that were heavier at birth (r = -0.2768), an indication of compensatory growth performance (Table 3).

Table 3. The phenotypic correlation of pre-wean growth traits with litter size in Marinduke pig.

Parameter	LS_B	LS_W	BW0	BW49	BWG	ADG
LS_B		0.0001	0.0381	0.6933	0.5711	0.5594
LS_W	0.9664**		0.0099	0.3985	0.2914	0.2880
BW0	-0.2559*	-0.3155**		0.1406	0.0265	0.0294
BW49	0.0511	0.1091	-0.1893		0.0001	0.0001
BWG	0.0733	0.1361	-0.2818*	0.9955**		0.0001
ADG	0.0756	0.1371	-0.2768*	0.9922**	0.9963**	

LS_B = litter size at birth, LS_W = litter size at weaning, BW0= birth weight, BW49= weaning weight at 49 d/o, BWG= weight gain, ADG= average daily gain; the values below the diagonal line were the correlation coefficient (with asterisk was significant at α of 1%** or 5%*) while values above were the p-values.

Sources of Variance in Pre-Wean Growth Traits

The variation in pre-wean growth traits was primarily associated to the dam and litter size effects (Table 4). The dam effect contributed 37.74% to differences in BW_0 and 24.59% in BW_{49}. The litter size effect was relatively low at BW_0 (22.27%) but high at BW_{49} (42.20%). Further analysis shows that the variation in weight was associated largely on individual differences or "residual effect" under a particular independent factor. The between-factor effect also called the "treatment effect" measures the extent of variation in pre-wean growth traits that is associated on level of independent factors e.g. sex ratio and litter size. The presence of significant interaction effect indicates the potential influence of other factors to the variation in pre-wean growth traits.

Table 4. Variance component, functions of variance component, and significance value in pre-wean growth traits of Marinduke pig.

	BW0		BW49		BWG		ADG	
Variance Source	Variance	Percent	Variance	Percent	Variance	Percent	Variance	Percent
Sire	-0.0048	0	-0.4994	0	-0.5601	0	-0.0002	0
Dam	0.0134	37.74	0.7195	24.59	0.8358	26.89	0.0004	31.11
Sex ratio	-0.0090	0	0.1930	6.60	0.1580	5.08	-0.0000	0
Litter size	0.0079	22.27	1.2348	42.20	1.4371	46.23	0.0006	47.58
Sex of piglet	0.0041	11.67	0.2438	8.33	0.1866	6.00	0.0001	5.71
Residual	0.0100	28.32	0.5349	18.28	0.4910	15.79	0.0002	15.59
Total	0.0354	100	2.9259	100	3.1084	100	0.0013	100
Functions of variance components								
t_{HS}	-0.1356		-0.1707		-0.1802		-0.1538	
t_{FS}	0.2429		0.0752		0.0887		0.1538	
c^2	0.3785		0.2459		0.2689		0.3077	
p-value								
Sire	.		.		.		.	
Dam	*0.0080***		*0.0001***		*0.0001***		*0.0001***	
Sex ratio	*0.5202*		*0.4558*		*0.4824*		*0.6339*	
Litter size	*0.0017***		*0.0001***		*0.0001***		*0.0001***	
Sex of piglet	*0.4430*		*0.8305*		*0.7171*		*0.7377*	
Interaction effect	*0.9057*		*0.0241**		*0.0117**		*0.0080***	
CV	*14.2293*		*11.6375*		*12.2039*		*12.2583*	
R^2	*49.0897*		*73.5477*		*77.9612*		*77.8851*	
Intercept	*0.8583*		*7.4000*		*6.5300*		*0.1320*	
SEE	*0.0489*		*0.4027*		*0.3761*		*0.0077*	

BW0 = birth weight, BW49 = weaning weight at 49 d/o, BWG = weight gain, ADG = average daily gain; t_{HS} = half-sib correlation, t_{FS} = full-sib correlation, c^2 = combination of maternal and common environmental effects and dominance effect; CV = coefficient of variation, R^2 = coefficient of determination, SEE= standard error of estimate; **= significant at α of 1%, *= significant at α of 5%

IV. DISCUSSION

The birth weight (BW_0) is a complex trait and the most important determinant for the succeeding post-natal growth. Studies involving large data set (40,000 piglets) were unanimous in disclosing its complex nature and functions in different pig breeds [19, 20, 21,22, 23]. The inverse relationship of BW_0 with litter size is of paramount importance. Reduction in BW_0 from 43 g per piglet to 56 g per piglet in crossbreds (landrace x large white) and 95 g per piglet in purebred large white selected for increase litter size were observed [19, 24]. Relevant evaluation shows a negative association (r = -0.30 and -0.15/-0.20, respectively) with litter size in hyperprolific Czech large white and F_1 of Nigerian pigs and large white or landrace [23, 25]. This study in Marinduke pig adheres on the negative association (r = -0.2559) of BW_0 with litter size indicating that these traits was independent on data set ($p<0.05$, Table 3). The main effect of litter size shows that the heavier piglets at birth (0.91±0.02 kg > population mean of 0.84±0.15 kg) belong to the litter size of 6.8±1.3 piglets, which was below the population mean of 8.3±1.9 piglets ($p<0.05$, Table 4).

The measures of variability, namely; range, variance, standard deviation and coefficient of variation were positively correlated between BW_0 and litter size [23]. It shows that a variation in BW_0 (CV from 15% to 24%) was associated to prolificacy but with increased proportion (3% to 15%) of small piglets (<1.0 kg) in landrace and large white [24]. Thus, several management options (e.g. cross-fostering, split suckling, etc) were reviewed to mitigate the negative effects of large litter size and overcome the potential risk to welfare of pigs and economic performance [26]. Relatively, it is presumed that any or combination of the management options well do considering the non-additive nature of gene regulating the expression of CV_{BW0}. Its low heritability (<0.05) confirms the non-additive effect indicating low influence to the succeeding generations [23]. The repeatability estimate of BW_0 was moderate (0.33 in large white to 0.42 in crosssbred landrace x large white) while CV_{BW0} was low, <0.15 [24]. Observation in this study similarly shows that the repeatability estimate due to litter size effect was 0.43 indicating that a substantial variation between piglets within-litter do exists. This finding reiterates the necessity to select for a dam possessing genetics capable of producing uniformly-sized piglet (≈1.0kg).

The influence of litter size and BW_0 with BW_{49} was not established in this study. However, there was 2% increased in CV of weaning weight (Table 2). This finding disagrees with report that shows negative correlation (-0.348) between litter size and weaning weight and positive correlation (0.168) between birth weight and weaning weight in Yorkshire and F_1 of Yorkshire x Landrace [19, 21].

V. CONCLUSION

The maternal effect was identified as the critical source of variance in BW_0 (37.74%). The variation in BW_{49} (42.20%), BWG (46.23%) and ADG (47.58%) was due to the litter size effect. However, the existence of interaction effect indicated an influence of other factors in the variation of pre-wean growth. Thus, a management protocol that shall provide better nutrition

and welfare is required to sustain the physiological requirements for ensuring better and uniform pre-wean growth in Marinduke pig.

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