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Genetic and phenotypic relationships of live body measurement traits and carcass traits in crossbred pigs of Korea

Chang-hee Do[1]*, Chan-hyuk Park[1], Nidarshani Wasana[1], Jae-gwan Choi[2], Su-Bong Park[2], Si-dong Kim[2], Gyu-ho Cho[2], Dong-hee Lee[3]

[1]*Chungnam National University, Daejeon 305-764, Republic of Korea*
[2]*National Institute of Animal Science, R.D.A., Chungnam, 331-801, Republic of Korea*
[3]*University of Seoul, Seoul, 151-742, Republic of Korea*

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Abstract : This study presents the estimates of heritabilities of body measurement traits and carcass traits, and genetic and phenotypic correlations of those traits for crossbred pigs in Korea. Body and ultrasound (A mode: Piglog 105) measurements in 221 pigs including body weight, length, height and width, three back fat thickness at the points of 4th, 14th rib and chine bone, eye muscle area and lean meat percent were collected at the ages of 70, 145 and 180 days and then slaughtered to measure carcass weight, back fat, belly, collar butt, spare rib, picnic shoulder, hind leg, loin, tenderloin, lean meat yield and intramuscular rough fat content in loin. Genetic analysis was done using a multi-trait animal model. Heritabilties of the body measurements were ranged from 0.331 to 0.559 and three measurements of back fat thickness were also high as range varying from 0.402 to 0.475 for the ages of 145 and 180 days. However, eye muscle area was moderate (0.296) at the age of 180 days. Heritabilities of retail cut yields were also high as ranged from 0.387 to 0.474 and of IMF content in loin was 0.499. Heritabilities of the cut percent traits were ranged from 0.249 to 0.488. Important positive genetic and phenotypic correlations were noted for all carcass yield traits (0.298 to 0.875 and 0.432 to 0.922, respectively). IMF showed low negative genetic correlations with carcass yield traits, such as carcass weight, picnic shoulder, hind leg, loin, tenderloin and lean meat yield whereas low positive genetic correlations with back fat, belly, collar butt and spare rib. Loin, tenderloin and lean meat percent showed negative genetic correlations with carcass weight, back fat thickness, collar butt, spare rib and picnic shoulder percent. The four body measurements at the ages of 70, 145 and 180 days had positive genetic correlations with belly, shoulder butt, spare rib, picnic shoulder and hind leg percent, but negative genetic correlations were shown with loin and tenderloin percent except body measurements at 70 days. The results suggest that carcass yield are negatively correlated with intramuscular fat content, which is a major factor deciding pork quality and the yield of loin and tenderloin are not increased as much as increase in body size. However, the proportions of belly and collar butt are increased with the body size. In conclusion, selection strategy should be designed according to the preference on composition of carcass in each country.

Key words **:** Pork retail cuts, Body measurement, Genetic correlation, Heritability, Selection, Ultrasound A mode

I. Introduction

Preference on a cut among retail pork cuts is different in each country. Although loin is considered as the most popular pork cut in many countries (Fortomaris et al., 2006) pork belly is still the popular portion in domestic pork market (Cho et al., 2007) and its value is high as twice of loin in Korea. It is hardly achieved the balance of consumption and production in retail cuts of pig in any country. Since growing lean to fat ratio of pig carcasses has been one of main objectives in breeding programs for many years, substantial increase in the body composition of pigs have been gained through genetic selection (Latorre et al., 2008).

Even though interests in improving preference composition of carcass and better meat quality traits have been increased due to the demand of consumers and industry,(Dransfield et al., 2005; Ngapo et al.,

***Corresponding author:** Tel: +82-42-821-5784
E-mail address: ivando@cnu.ac.kr

2007a,b; Vidal et al., 2005), the selection is being practiced mainly based on the growth traits in republic of Korea.

Therefore, an optimum selection strategy should aim at increasing the rate of growth and improving carcass composition and pork quality simultaneously. Therefore, animal breeders are interested in the relationship among those traits. Thus the objective of this study was to estimate the heritabilities, genetic and phenotypic correlations of body measurements traits and carcass traits to understand the relationship of those traits of crossbred pigs (YLD, YLB and DB) in Korea.

II. Materials and Method

1. Data

The data was collected from commercial experimental farms for assessing crossbred YLD (Yorkshire, Landrace and Duroc), YLB (Birkshire) and DB in 2007 in South Korea, and data of 221 pigs with pedigree information were used after preliminary selection and restrictions. The Body measurements including body weight, body length, body height, body width, ultrasound (A mode: Piglog 105) measurements of three back fat thicknesses at the points of 4th rib (BF1), 14th rib (BF2) and chine bone (BF3), eye muscle area (EMA) and lean meat percent (Lean %) were collected according to the ages of 70, 145 and 180 days as shown in Table 1. Then, slaughtered after last body measurements. The carcass was split down the midline and the head was removed. Carcasses were placed in a chiller (4°C) approximately 1h postmortem where they were held overnight. At 24-h postmortem, cold carcass weight was recorded, and carcass measurements were obtained from the left side of each carcass such as back fat, belly, collar butt, spare rib, picnic shoulder, hind leg, loin, tenderloin and lean meat yield. Moreover, intramuscular rough fat (IMF) content in loin was measured as follows.

Adhering adipose and connective tissue was removed from the longissimus muscle which was then ground and analyzed for moisture and fat (Association of Official Analytical Chemists, 1997). Moisture was determined gravimetrically by drying at 102 C for 24 h. Petroleum ether fat extractions were conducted for 10 min on the resultant dried product using a Tecator Soxtec Extraction System (Tecator AB, Hoganas, Sweden).

2. Statistical analysis

Genetic parameters were estimated using the multi-traits restricted maximum likelihood (MTREML) procedure based on an animal model, using the Wombat program (Meyer, 2010). The statistical model for the traits was as follows.

$$y_i = Xb_i + Za_i + e_i$$

where y_i is the vector of observations for the ith trait, and b_i is the vector of fixed effects, including the breed, herd, sex, and a covariate of age days at measurement, which adjust the effects of age on the measurements. Sex includes gilts, and castrated. For random effects, a_i is the vector of random animal effects for the ith trait, and e_i is the vector of random residual effects. X and Z are incidence matrices relating records of a trait to fixed effects and random effects. If a_i represents the vector of animal genetic effects for the traits, and represents the vector of residual effects, then the random effects can be assumed to follow a normal distribution with zero mean and the following distribution parameters,

$$var\begin{bmatrix} a \\ e \end{bmatrix} = \begin{bmatrix} A \otimes G & 0 \\ 0 & I \otimes R \end{bmatrix}$$

where A is the numerator relationship matrix; G is a matrix accounting variance and covariance of the genetic effect between traits and matrix I is the

Table 1. Genetic (upper diagonal) and phenotypic (lower diagonal) correlations and heritabilities of body and ultrasound measurements at the ages of 70, 145 and 180 days.

		Body weight	Body length	Body height	Body width	BF1	BF2	BF3	EMA	Lean %
	Body weight	**0.559**	0.803	0.720	0.779					
70 days	Body length	0.768	**0.396**	0.600	0.630					
	Body height	0.679	0.565	**0.517**	0.584					
	Body width	0.768	0.632	0.548	**0.581**					
	Body weight	**0.347**	0.781	0.682	0.724	0.514	0.511	0.554		-0.511
145 days	Body length	0.708	**0.331**	0.586	0.455	0.356	0.406	0.480		-0.387
	Body height	0.518	0.420	**0.442**	0.407	0.274	0.275	0.246		-0.271
	Body width	0.627	0.329	0.226	**0.529**	0.422	0.535	0.431		-0.481
	BF1	0.539	0.361	0.166	0.375	**0.428**	0.616	0.647		-0.634
	BF2	0.453	0.366	0.154	0.460	0.547	**0.431**	0.624		-0.702
	BF3	0.571	0.489	0.124	0.369	0.616	0.532	**0.475**		-0.693
	Lean %	-0.476	-0.360	-0.131	-0.408	-0.521	-0.563	-0.584		**0.411**
	Body weight	**0.544**	0.537	0.540	0.606	0.370	0.359	0.293	0.039	-0.407
180 days	Body length	0.564	**0.546**	0.363	0.156	0.202	0.188	0.143	-0.011	-0.245
	Body height	0.615	0.387	**0.655**	0.252	0.145	0.155	0.127	-0.040	-0.166
	Body width	0.570	0.185	0.276	**0.531**	0.429	0.421	0.328	0.099	-0.435
	BF1	0.405	0.326	0.197	0.415	**0.406**	0.731	0.568	-0.206	-0.693
	BF2	0.390	0.376	0.244	0.373	0.665	**0.402**	0.611	-0.173	-0.747
	BF3	0.272	0.225	0.138	0.301	0.516	0.582	**0.413**	-0.119	-0.603
	EMA	-0.039	-0.052	-0.060	0.132	-0.100	-0.120	-0.146	**0.296**	0.342
	Lean %	-0.400	-0.380	-0.227	-0.389	-0.601	-0.678	-0.556	0.239	**0.399**

identity matrix of appropriate dimension in each case, and R is the covariance matrix of residual effects.

III. Results and Discussion

Generally, the heritability estimates of both body and ultrasound measurements (Table 1) were moderate to high ranging from 0.31 to 0.655 except for eye muscle area where heritability was 0.296 which is in the range of estimates done by Salces et al., (2006). The heritability of body weight, length, height and width at age of 70 days through 180 days were increased with age. Three ultrasound measurements of back fat thickness at the age of 145days are 0.428, 0.431, and 0.475 and minor deviations observed at the age at 180days. Lean percent has heritabilities of 0.411 and 0.399 at the age of 145days and 180 days respectively. Marja et al., (2008) have estimated much similar heritabilities for body weight traits. However, estimates of Marja et al., (2008), Johnson and Nugent (2003) and Tomiyama et al., (2009) for body length, body height and body width are considerably low values than estimates of the present study. For the heritability of back fat thickness, Marja et al., (2008) and Suzuki et al., (2005) have found higher values between 0.72 and 0.65 whereas S nchez et al., (2013) has low estimation (0.23 to 0.29) than the present study. Moreover, our estimates are according to the Ciobanu et al., (2011). Medium heritability of Eye muscle area and Lean meat percentage are in the range of previous estimations of

Table 2. Genetic (upper diagonal) and phenotypic (lower diagonal) correlations and heritabilities of retail cut yields and intramuscular rough fat content in loin.

	Carcass weight	Back fat	Belly	Collar butt	Spare rib	Picnic shoulder	Hind leg	Loin	Tenderloin	Lean meat	IMF
Carcass weight	**0.450**	0.488	0.878	0.776	0.658	0.815	0.749	0.706	0.568	0.902	0.083
Back fat	0.417	**0.474**	0.457	0.251	0.274	0.174	0.160	0.209	0.072	0.289	0.197
Belly	0.832	0.365	**0.444**	0.648	0.559	0.713	0.579	0.571	0.432	0.804	0.237
Collar butt	0.727	0.207	0.553	**0.448**	0.606	0.839	0.748	0.729	0.544	0.873	-0.017
Spare rib	0.565	0.151	0.485	0.507	**0.455**	0.572	0.543	0.440	0.432	0.675	0.128
Picnic shoulder	0.770	0.087	0.633	0.741	0.506	**0.408**	0.809	0.741	0.620	0.922	-0.063
Hind leg	0.691	0.144	0.433	0.629	0.437	0.696	**0.436**	0.763	0.703	0.914	-0.140
Loin	0.629	0.149	0.431	0.637	0.298	0.596	0.700	**0.418**	0.615	0.847	-0.191
Tenderloin	0.527	0.095	0.377	0.420	0.360	0.498	0.638	0.485	**0.407**	0.690	-0.193
Lean meat	0.890	0.235	0.744	0.814	0.612	0.871	0.875	0.785	0.627	**0.387**	-0.030
IMF	-0.007	0.059	0.205	0.035	0.182	-0.052	-0.134	-0.216	-0.110	-0.025	**0.499**

Salces et al., (2006) and Suzuki et al., (2005) and much higher heritability was estimated by Escriche et al., (2011) and Marja et al., (2008). All the traits are positively correlated with each trait and lean percentage negatively correlated with all the other traits. Additionally, loin eye area showed a slight negative genetic correlation with traits other than lean meat percentage proving that Loin eye is associated with the lean growth of the pigs. Moreover, all the correlations at the age of 180days become comparatively low than early ages of pigs.

Moderate Heritability values were obtained for all the retail cut yields, IMF range varying from 0.48 (Picnic shoulder) to 0.474 (back fat) (Table 2) and reasonable results were reported by Newcom et al., (2002), S nchez et al., (2013). As explained by Sellier, (1998) IMF found a moderate to high heritability (0.499) in the present study. Sánchez et al., (2013) and Suzuki et al., (2005) found heritabilities for IMF as 0.54, 0.48 and 0.46 respectively. Lean meat yield had a heritability of 0.387 which is fairly low than the results of Escriche et al., (2011). All retail cut traits are genetically and phenotypically correlated positively. However, important low genetic correlations were observed in Back fat with all retail cut traits indicating that increase in Back fat thickness causes reduction in meat yield. In contrast, the Belly which is theoretically relative to the amount of back fat, showed a positive correlation with Back fat. Present study obtained a low genetic and phenotypic correlation between IMF and other retail cut traits. Our estimates of genetic and phenotypic correlation between IMF and lean meat percentage were −0.03 and −0.25 respectively. Hovenier et al., (1992) reported −0.44 and −0.31 for Duroc and Dutch Large White pigs and Sonesson et al., (1998) examined 0.02 and −0.05 for Large White pigs. Therefore, we assume that lean meat percentage correlates negatively with IMF.

Heritabilities of percent retail cuts (Table 3) which were obtained by taking it as a percentage of carcass weight ranged from 0.249 (Tenderloin) to 0.500 (Belly) and no considerable difference with the data in table 2 except percent Tenderloin. When considering the genetic correlation between percent traits and carcass weight, it showed large positive genetic correlation with percentage Belly followed by Collar butt, Sparerib, Picnic shoulder and Hind leg. That moderate with percent Back fat thickness which needs to manage in order to increase leanness and improve carcass con-formation (Sanchez et al., 2013). As previously mentioned, belly is the most expensive and demanding portion of pork meat in Korea and people don't concern much about loin compared to US and Europe. Therefore,

Table 3. Genetic (upper diagonal) and phenotypic (lower diagonal) correlations and heritabilities of percentages of retail cuts from carcass weight and intramuscular rough fat content in loin.

	Carcass weight	Back fat	Belly	Collar butt	Spare rib	Picnic shoulder	Hind leg	Loin	Tenderloin	Lean meat	IMF
Carcass weight	**0.523**	0.484	0.882	0.791	0.680	0.824	0.740	-0.022	-0.270	-0.139	0.010
Back fat	0.569	**0.488**	0.458	0.257	0.270	0.161	0.152	-0.234	-0.378	-0.441	0.177
Belly	0.926	0.541	**0.500**	0.653	0.593	0.709	0.541	-0.129	-0.330	-0.149	0.196
Collar butt	0.866	0.452	0.739	**0.411**	0.620	0.826	0.741	0.241	-0.106	0.257	-0.046
Spare rib	0.843	0.325	0.874	0.728	**0.320**	0.607	0.554	-0.043	-0.114	0.095	0.115
Picnic shoulder	0.877	0.261	0.792	0.731	0.892	**0.384**	0.807	0.207	-0.044	0.296	-0.126
Hind leg	0.704	0.224	0.464	0.696	0.621	0.759	**0.479**	0.364	0.151	0.457	-0.221
Loin	-0.312	-0.461	-0.523	-0.074	-0.390	-0.212	0.286	**0.479**	0.403	0.724	-0.396
Tenderloin	-0.529	-0.494	-0.644	-0.448	-0.392	-0.319	0.127	0.554	**0.249**	0.552	-0.295
Lean meat	-0.495	-0.665	-0.603	-0.277	-0.239	-0.179	0.201	0.766	0.772	**0.467**	-0.256
IMF	-0.066	0.115	0.154	0.059	0.262	-0.135	-0.338	-0.570	-0.257	-0.184	**0.582**

swine breeders aim is to maximize belly portion in a carcass compare with other cuts. However, in the present study, lean meat percentage showed moderate to high positive genetic correlation varying from 0.257(Collar butt) to 0.724(Loin) yet negative with Back fat, Intramuscular fat and also Belly. Therefore, further studies are needed on those relationships. However, high positive correlations were observed for IMF with all yield traits (Table3). As far as the pork quality is concerned IMF is an important trait that is related to the taste and intra-oral smoothness of meat (Suzuki et al., 2005).

Table 4 and 5 presents the genetic correlation of Body and Ultrasound measurements and Carcass yield traits and percentage traits respectively. As shown in tables, all body measurement traits such as Body weight, length, height and width are positively highly correlated with carcass weight and it increases with the age in both yield and percentage traits. There were relatively low genetic correlations ranged from 0.096 to 0.457 between body size traits and back fat yield while low to slightly high genetic correlations (0.143 to 0.669) between body size and Back fat percentage trait. Moderate to high genetic correlation (0.256 to 0.817) observed in Belly yield and body size traits and the correlation was similar to that of belly percentage and body size traits (0.291 to 0.888). Both yield and percentage traits of Shoulder butt, Spare rib, Picnic shoulder and Hind leg showed moderate to high correlation with Body size traits and correlations are larger in percentage traits than yield traits while increasing them all with the increase of age.

However, Loin, Tenderloin and Lean meat percentage traits are negatively correlated with body measurements traits and negative relationships become weak with the growth of animals. In contrast, yield Loin, Tender loin and Lean meat are positively correlated with high to moderate values and positive relationships turn into strong with the growth of animals. Both yield and percentage IMF traits are low and negatively correlated with body measurements. Overall a significant decrease in that correlation could be observed when age increases.

In general, the thickness of the pork belly is related to the back fat content in a carcass. Similarly Belly is highly correlated with Ultrasound back fat thickness above all other carcass yield and percentage traits. Moreover, when animals are grown correlations of back fat thickness with both yield and percent traits become weak. However, correlations of yield Loin and Tenderloin with ultrasound Back fat are fluctuating around zero whereas its percentage traits show high negative correlation and decreases with age. Low, positive

Table 4. Genetic correlations of body measurements traits and yield traits in carcass.

		Carcass weight	Back fat	Belly	Shoulder butt	Spare rib	Picnic shoulder	Hind leg	Loin	Tenderloin	Lean meat yield	IMF
70 days	Body weight	0.470	0.230	0.287	0.379	0.221	0.314	0.327	0.359	0.226	0.383	-0.337
	Body length	0.455	0.161	0.298	0.380	0.184	0.317	0.309	0.385	0.192	0.381	-0.312
	Body height	0.596	0.148	0.415	0.469	0.371	0.511	0.464	0.485	0.403	0.552	-0.349
	Body width	0.380	0.278	0.256	0.269	0.153	0.221	0.232	0.290	0.110	0.289	-0.294
145 days	Body weight	0.842	0.366	0.728	0.613	0.531	0.617	0.456	0.478	0.437	0.703	-0.032
	Body length	0.619	0.241	0.585	0.427	0.333	0.411	0.253	0.371	0.313	0.487	0.002
	Body height	0.409	0.096	0.331	0.263	0.362	0.384	0.198	0.163	0.249	0.337	-0.003
	Body width	0.593	0.373	0.521	0.418	0.392	0.448	0.311	0.270	0.185	0.481	0.067
	BF1	0.457	0.438	0.406	0.267	0.196	0.147	0.040	0.077	0.147	0.218	0.076
	BF2	0.401	0.413	0.392	0.176	0.144	0.133	0.008	-0.019	0.133	0.166	0.110
	BF3	0.508	0.414	0.514	0.366	0.208	0.195	0.050	0.172	0.106	0.289	0.086
	Lean %	-0.430	-0.413	-0.358	-0.245	-0.168	-0.105	-0.055	-0.054	-0.060	-0.191	-0.183
180 days	Body weight	0.956	0.326	0.817	0.748	0.600	0.795	0.715	0.657	0.602	0.864	-0.172
	Body length	0.607	0.097	0.586	0.488	0.338	0.484	0.368	0.418	0.409	0.527	-0.096
	Body height	0.584	0.161	0.472	0.374	0.336	0.460	0.453	0.423	0.492	0.518	-0.260
	Body width	0.548	0.457	0.535	0.365	0.253	0.411	0.338	0.357	0.257	0.455	-0.090
	BF1	0.437	0.473	0.396	0.269	0.191	0.199	0.139	0.144	0.182	0.254	-0.023
	BF2	0.438	0.494	0.413	0.238	0.116	0.181	0.123	0.135	0.161	0.237	0.020
	BF3	0.261	0.371	0.304	0.113	0.069	0.036	-0.039	0.003	-0.005	0.079	0.126
	EMA	-0.017	0.115	-0.028	0.053	-0.029	0.034	0.084	0.120	0.108	0.059	-0.099
	Lean %	-0.426	-0.452	-0.410	-0.172	-0.143	-0.174	-0.066	-0.078	-0.106	-0.196	0.056

Table 5. Genetic correlations body measurements and percentage traits in carcass.

		Carcass weight	Back fat	Belly	Shoulder butt	Spare rib	Picnic shoulder	Hind leg	Loin	Tenderloin	Lean meat yield	IMF
70 days	Body weight	0.562	0.266	0.318	0.522	0.294	0.446	0.371	0.087	-0.487	-0.305	-0.481
	Body length	0.642	0.278	0.395	0.636	0.315	0.504	0.454	0.156	-0.482	-0.277	-0.534
	Body height	0.890	0.228	0.711	0.799	0.664	0.802	0.674	0.120	-0.464	-0.198	-0.523
	Body width	0.441	0.472	0.291	0.363	0.160	0.233	0.232	0.092	-0.503	-0.354	-0.425
145 days	Body weight	0.944	0.557	0.887	0.821	0.766	0.797	0.527	-0.384	-0.648	-0.616	-0.020
	Body length	0.834	0.551	0.860	0.701	0.619	0.566	0.356	-0.407	-0.691	-0.691	0.073
	Body height	0.629	0.312	0.642	0.427	0.638	0.613	0.343	-0.444	-0.249	-0.412	0.087
	Body width	0.795	0.664	0.723	0.636	0.657	0.654	0.459	-0.406	-0.631	-0.566	0.059
	BF1	0.759	0.651	0.719	0.654	0.431	0.482	0.204	-0.465	-0.753	-0.841	-0.051
	BF2	0.678	0.702	0.674	0.545	0.399	0.357	0.130	-0.624	-0.739	-0.883	0.182
	BF3	0.716	0.586	0.741	0.679	0.420	0.402	0.122	-0.409	-0.840	-0.804	0.045
	Lean %	-0.723	-0.735	-0.704	-0.723	-0.488	-0.384	-0.236	0.553	0.685	0.779	-0.318
180 days	Body weight	0.974	0.328	0.888	0.821	0.816	0.872	0.764	-0.047	-0.319	-0.102	-0.122
	Body length	0.727	0.143	0.814	0.644	0.561	0.642	0.444	-0.085	-0.318	-0.142	-0.033
	Body height	0.711	0.236	0.735	0.401	0.539	0.572	0.527	-0.077	0.027	-0.182	-0.283
	Body width	0.708	0.669	0.628	0.514	0.447	0.509	0.490	-0.217	-0.288	-0.338	-0.145
	BF1	0.556	0.665	0.562	0.394	0.258	0.281	0.152	-0.434	-0.425	-0.643	-0.066
	BF2	0.551	0.582	0.632	0.396	0.223	0.241	0.105	-0.434	-0.418	-0.668	0.023
	BF3	0.253	0.493	0.385	0.126	0.004	-0.111	-0.178	-0.472	-0.401	-0.733	0.222
	EMA	-0.112	0.311	-0.207	-0.037	-0.215	-0.062	0.161	0.216	0.486	0.280	-0.219
	Lean %	-0.508	-0.665	-0.559	-0.288	-0.188	-0.201	-0.086	0.433	0.429	0.692	0.067

correlations of both yield and percentage IMF with ultrasound Back fat could be observed. For high quality meat, high IMF and low Back fat should be achieved. However Sanchez et al., (2013) mentioned that simultaneous genetic improvement of both IMF and Back fat is difficult because of their positive genetic correlation.

Eye muscle area shows low correlation with all yield traits range varying from −0.099 (IMF) to 0.12 (Loin) and moderate to low correlations with percent traits from −0.215 (Spare rib) to 0.486 (Tenderloin). Lean meat percentage is negatively correlated with all yield and percentage traits except IMF, percent Loin, Tenderloin. Negative correlations are significant with back fat and belly traits which are comprise with large fat amount. Finally, while predicted lean meat percentage in live pigs is weakly negatively correlated with lean meat yield, it showed strong positive correlation with percent lean meat in carcass. In conclusion, The results of this study suggest that carcass yield are negatively correlated with intramuscular fat content, which is a major factor deciding pork quality and the yields of loin and tenderloin are not increased as much as increase in body size. However, the proportions of belly and collar butt are increased with the body size. In conclusion, selection strategy should be designed according to the preference on composition of carcass in each country.

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