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A CANONICAL CORRELATION ANALYSIS OF RELATIONSHIPS BETWEEN GROWTH, COMPOSITIONAL TRAITS AND LONGEVITY, LIFETIME PRODUCTIVITY AND EFFICIENCY IN POLISH LANDRACE SOWS*

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Abstract

Relationships between performance test traits (growth rate, backfat thickness, loin depth, lean meat percentage, exterior, phenotypic selection index) and longevity traits (length of productive life, number of litters, total number of weaned pigs, number of weaned piglets per year, number of litters per year) in Landrace sows were evaluated using canonical correlation analysis. The data set consisted of 23,012 purebred sows that farrowed from 1994 to 2011 in 161 herds. The first three canonical correlations (0.37, 0.25, 0.07) were highly significant (P<0.0001). Correlations of the first canonical variate with the original measured variables indicated that sows with high values for this variate had lower growth rate (r=–0.31) and loin depth (r=–0.43), greater backfat thickness (r=0.23), as well as being older at birth of their last litter (r=0.98). These sows also had a greater number of litters (r=0.94) and better lifetime efficiency (r=0.61 and r=0.70 for number of weaned piglets per year and number of litters per year, respectively). Canonical loadings for the second canonical function indicate that sows with high values for the second set of variates had high growth rate (r=0.79) and phenotypic selection index (r=0.83), excellent conformation (r=0.62), as well as better efficiency in pig production (r=0.67). The squared multiple correlations show that the first canonical variate of the performance traits is a poor predictor of longevity (0.13) and nearly useless for predicting efficiency traits (0.07). Performance test traits explain 11% of the variance in the variables of longevity and lifetime productivity, whereas dependent variables explain only 3% of the variance in performance test traits. The relationships between performance test data and subsequent lifetime productivity or longevity were significant and unfavourable but low for Polish Landrace population.

Key words: canonical correlation analysis, compositional traits, longevity, sow

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Regardless of economic conditions, sows that remain in the breeding herd longer have an increased opportunity to recuperate their initial cost and could result in producing larger and heavier litters, improve acquired immunity to diseases, and have lower replacement costs (Lucia et al., 2000; Stalder et al., 2004). Sow longevity can be defined in several ways and each definition has somewhat different interpretation. Some definitions are based more on production efficiency (lifetime piglets born alive per parity, annualized lifetime pigs weaned), while others are more time dependent (parity at removal, length of productive life).

Throughout the years the Polish Landrace has become a fast-growing and lean pig. The relationship between longevity and production traits should be known to predict and avoid undesirable side effects in the future pig populations. Different results can be found in the scientific literature regarding the association between longevity and production. Some research (Tholen et al., 1996; López-Serrano et al., 2000; Serenius and Stalder, 2004; Knauer et al., 2010; Hoge and Bates, 2011) indicates that relationships between longevity and production traits are generally slightly unfavourable. Other work has identified lack of antagonistic relationship between production traits and longevity (Rozeboom et al., 1996; Yazdi et al., 2000; Serenius et al., 2006). No research was reported on the relationship between lifetime efficiency and production traits.

The production traits comprise different traits related to growth and carcass composition. Similarly, most longevity research investigates variables that possibly have multiple causes and multiple effects and thus create problems when the variables are examined separately. Therefore, the objective of the study was to investigate the phenotypic association of longevity, productivity and lifetime efficiency with growth and different traits related to body composition in Polish Landrace sows by the method of canonical correlation analysis.

Material and methods

Data

The data included farrowing and growth records of 23,012 Polish Landrace sows. The data were collected from purebred herds over the period from August 1994 until May 2011. These commercial piglet-producing herds (161) were drawn from among the largest herds of the breed. The average number of sows recorded per herd was 86 (range: 50–383). The animal environment conditions such as housing, feeding or production management varied among the farms. Sows were usually mated naturally and at farrowing they were kept in individual crates. In general, the piglets were weaned at about 4 weeks of age. The litter records contained the identification number of the sow, date of birth and dates of the successive farrowings, date of culling, parity of the sow and number of piglets born alive and weaned in consecutive farrowings. Different longevity, lifetime productivity or lifetime efficiency traits were defined. The length of productive life (LPL, longevity trait) was defined as the number of days between birth and last farrowing. The number of litters (NL, longevity trait) was the number of litters over a sow's lifetime. The lifetime pig production (LTP, lifetime productivity trait) was defined as the weaned piglets produced summed over all the parities that sow remained in the breeding herd. The lifetime pig efficiency (LTP365, lifetime efficiency trait) was calculated as the LTP divided by the LPL in years. The lifetime litter efficiency (NL365, lifetime efficiency trait) was calculated as the NL divided by LPL in years. The growth records included the traits measured at the on-farm performance test: average daily gain, backfat thickness, longissimus muscle depth and conformation score. Gilts were tested at a mean age of 171 days (range: 141–237, SD=15.1) and at an average body weight of 102 kg (range: 70–160, SD=12). The growth rate (ADG) was defined as the average weight gain per day from birth until the test day. Average daily gain was adjusted to 180 days of age. The ultrasonic measurements of the backfat thickness (BF) were taken at two points: 3 and 8 cm away from the back midline behind the last rib. Backfat thickness was defined as the average value of two points. Longissimus muscle depth (LMdepth) was measured behind the last rib approximately 8 cm off the midline. Backfat thickness and LMdepth were measured by the same ultrasound equipment and they were adjusted to a constant weight of 110 kg. The lean meat percentage (LMP) was predicted using the BF and LMdepth and was adjusted to 180 days of age. The conformation index (exterior) was determined by scoring forequarters (20 points), length (20 points), back (20 points), ham (20 points), type, leg and teat conformation, appearance of external reproduction organs (20 points). Exterior traits were scored using a scale from 0 (worst) to 100 (best). Phenotypic selection index (PSI) was calculated on the basis of adjusted LMP and ADG after performance test. Only sows with at least one reproductive record in the data were analysed. The animals with extreme values for the age at first farrowing (≤250 days and ≥550 days), still alive and with missing parity were excluded. Any records with missing information in the traits measured at the performance test were also removed. The sows were selected based on BLUP-AM breeding values with combined index for reproduction traits and growth, placing more emphasis (60%) on reproduction. Descriptive statistics for both production and longevity traits including arithmetic means, standard deviations and ranges of the data are presented in Table 1.

Table 1. Descriptive statistics of gilt production and sow longevity traits

Traits[1]	Mean	Standard deviation	Range
ADG	619.3	73.3	401–958
BF	10.9	2.1	1.8–25
LMdepth	50.2	5.7	34–81
LMP	57.4	2.3	44.2–67.6
Exterior	82.4	7.5	60–100
PSI	122.5	15.9	55–195
LPL	828.3	431.7	259–3066
NL	3.8	2.5	1–15
LTP	41.5	27.8	1–162
LTP365	16.8	4.2	1.1–31.8
NL365	1.5	0.3	0.5–2.3

[1]ADG – adjusted daily gain, BF – adjusted backfat thickness, LMdepth – adjusted longissimus muscle depth, LMP – adjusted lean meat percentage, exterior – scored exterior of sow, PSI – phenotypic selection index, LPL – days between birth and last farrowing, NL – number of litters, LTP – total number of weaned piglets, LTP365 – total number of weaned piglets per year, NL365 – number of litters per year.

The average LPL was 828 days which corresponds to an age of 2 years and 3 months at culling. On average, females in this study had a herd life of 3.8 parities with 41.5 pigs produced during their productive life. In general, the gilts were fast growing (average ADG=619) and lean (average BF=10.9) animals, but variability in the growth rates and leanness was high.

Statistical analysis

A canonical correlation analysis was conducted using the six performance test traits as predictors of the five longevity, lifetime productivity and efficiency variables to evaluate the multivariate shared relationship between the two variable sets. Performance test traits: ADG, BF, LMdepth, LMP, PSI and exterior were designated as the set of independent variables (performance test data). The set of dependent variables (longevity data) were defined as LPL, LTP, NL, LTP365 and NL365. The canonical correlation analysis was restricted to deriving five canonical functions because the maximum number of canonical functions that can be extracted from the sets of variables equals the number of variables in the smallest data set. The choice of number of canonical functions was guided by three criteria: level of statistical significance of the function, magnitude of the canonical correlation, and redundancy measure for the percentage of variance accounted for from the two data sets. Canonical correlation analysis was performed to compute canonical coefficients for variables (canonical weights), overall relationships between the canonical variates (canonical correlations), linear correlation between the dependent and independent variables with their respective canonical variates (canonical loadings), linear correlation of each observed independent or dependent variable with the opposite canonical variate (canonical cross-loadings). Squared multiple correlations between dependent variables and canonical variates of the performance test traits were estimated. Canonical coefficients were normalized to give canonical variables with unit variance. Canonical redundancy analysis was conducted to determine standardized variance of the dependent and independent variables explained by their own or the opposite canonical variate. The first statistical significance test was for the canonical correlations of each of the five canonical functions. In addition to tests of each canonical function separately, multivariate tests of all functions were performed simultaneously. The test statistics included Wilks' lambda, Pillai's trace, Hotelling-Lawley trace, and Roy's greatest root. Statistical analysis was performed with SAS/STAT using Cancorr procedure (SAS 9.3, 2011).

Results

Correlations among the original variables

The correlations among the original variables are given in Table 2.

The correlations between different longevity, productivity and efficiency traits were all high and positive, ranging from 0.65 to 0.99. They were larger within longevity/productivity traits (correlations of 0.96–0.99) than between longevity and efficiency traits (0.65–0.81). The lowest correlation was found between LPL and

LTP365 (0.65) and NL365 (0.72). This is not surprising since the sows with a comparable number of piglets weaned per parity and comparable LPL may have different values of LTP365 trait due to different length of subsequent farrowing intervals, which allows lifetime piglets weaned to be different, too. The same is true for NL and NL365. Phenotypic selection index was moderately correlated with ADG (0.64) and LMP (0.56). Phenotypic association between BF and ADG was close to zero. There was no correlation between exterior and traits measured ultrasonically; however, there was a weak positive correlation with growth rate (0.24), suggesting that faster growing pigs obtain higher exterior scores. The highest correlation was found between BF and LMP (–0.75). The correlations between longevity and lifetime productivity traits with performance test traits are small, the largest being 0.21 between PSI and LTP365. Although the correlations of growth and compositional traits with longevity traits were very low, most of the relationships were unfavourable.

Table 2. Correlations among the original variables

Correlations among performance test traits[1]					
	BF	LMdepth	LMP	exterior	PSI
ADG	0.01	0.34	0.06	0.24	0.64
BF		0.01	–0.75	–0.08	–0.31
LMdepth			0.50	0.05	0.29
LMP				0.06	0.56
exterior					0.16
Correlations among longevity, productivity and efficiency traits[1]					
	LTP	NL	LTP365	NL365	
LPL	0.96	0.98	0.65	0.72	
LTP		0.99	0.79	0.81	
NL			0.74	0.81	
LTP365				0.91	
Correlations between performance test traits and longevity, productivity or efficiency traits[1]					
	LPL	LTP	NL	LTP365	NL365
ADG	–0.10	–0.06	–0.08	0.08	0.01
BF	0.08	0.07	0.08	0.03	0.06
LMdepth	–0.16	–0.13	–0.14	–0.05	–0.08
LMP	–0.04	–0.03	–0.04	0.02	–0.01
exterior	–0.04	–0.02	–0.04	0.06	–0.00
PSI	0.11	0.14	0.12	0.21	0.15

[1]see Table 1 for trait names.

Canonical correlations

Five canonical correlations were obtained in the analysis of the performance test and longevity data (Table 3).

The maximum correlation between linear functions of dependent and independent variables (the first canonical correlation) was 0.37, which corresponds to a canonical root 0.14. The first canonical correlation appears to be substantially larger than any of the between-set correlations. The first three canonical correlations (0.37, 0.25, 0.07) were highly significant (P<0.0001) whereas the remaining canonical correlations are not worthy of consideration, as can be seen from the probability levels. It should be noted that large samples will have a tendency to indicate statistical significance in all instances, even where practical significance is not indicated. Multivariate test of significance (Wilks' lambda, Pillai's trace, Hotelling-Lawley trace, and Roy's greatest root, data not shown) indicate that the canonical functions, taken collectively, are statistically significant at the 0.0001 level.

Table 3. Canonical correlations and overall model fit

Canonical function	Canonical correlation	Squared canonical correlation	F statistic	Probability
1	0.37	0.14	169.28	< 0.0001
2	0.25	0.06	79.96	< 0.0001
3	0.07	0.01	10.00	< 0.0001
4	0.02	0.00	1.57	0.1516
5	0.01	0.00	0.29	0.7461

Given the squared canonical correlation effects for each function, only the first two functions were considered noteworthy from the traits examined (14% and 6% of shared variance, respectively). The last three functions explained only 0.5% of the remaining variance in the variable sets after the extraction of the prior functions. Therefore, although the third canonical function was statistically significant, the relationship between the two sets of variables may be reduced to a two-dimensional space with the first dimension accounting for the majority of the observed variation.

Table 4. Standardized canonical weights, loadings and cross-loadings for the first two canonical functions

Variables[1]	Canonical weights		Canonical loadings		Canonical cross-loadings	
	1	2	1	2	1	2
Independent						
ADG	–1.07	0.30	–0.31	0.79	–0.11	0.17
BF	0.45	–0.14	0.23	–0.23	0.08	–0.06
LMdepth	–0.32	0.02	–0.43	0.24	–0.16	0.06
LMP	–0.31	–0.17	–0.11	0.33	–0.04	0.08
exterior	0.01	0.45	–0.12	0.62	–0.04	0.15
PSI	1.38	0.61	0.28	0.83	0.10	0.20
Dependent						
LPL	2.24	0.67	0.98	0.03	0.36	0.01
LTP	1.31	1.25	0.92	0.20	0.34	0.05
NL	–2.79	–2.58	0.94	0.08	0.35	0.02
LTP365	–0.56	1.73	0.61	0.67	0.22	0.17
NL365	0.80	–0.64	0.70	0.34	0.26	0.08

[1]see Table 1 for trait names.

Canonical weights, loadings and cross-loadings

Table 4 contains the standardized canonical weights, loadings and cross-loadings for the two canonical functions. The coefficients in the canonical variates reflect differences in contributions of the variables to canonical correlation. The first canonical variate for the performance test variables is a weighted difference of PSI (1.38) and ADG (–1.07), with more emphasis on PSI. The standardized canonical coefficients for BF and LMP have similar magnitude but are opposite in sign (0.45 and –0.31, respectively). The coefficient for exterior was near 0. Variables with the highest canonical weights on the second independent variate are PSI (0.61) and exterior (0.45). The first canonical variate for the dependent variables also shows a mixture of signs, subtracting NL (–2.79) and LTP365 (–0.56) from LPL (2.24), LTP (1.31) and NL365 (0.8), with the most weight on NL. All the correlations between dependent variables and the first canonical variate (loadings) were positive, indicating that NL is a suppressor variable. All correlations between longevity traits show moderate and high values (Table 2). Thus the interpretation based on canonical weights is probably biased.

The canonical loading reflects the variance that the observed variable shares with the canonical variate and can be interpreted like a factor loading in assessing the relative contribution of each variable to each canonical function (Rencher, 2002). Longissimus muscle depth was moderately associated with their first canonical variate with a correlation of –0.43. Less influential were the independent variables ADG and PSI, which have correlations with the first canonical variate of –0.31 and 0.28, respectively. The loadings for the longevity traits show that their first canonical variate seems to represent all five dependent variables, with degree of LPL, NL and LTP being the most influential (average 0.95). Canonical loadings indicate that sows with high values for the first canonical variate had lower ADG and LM depth, greater BF, as well as being older at culling. These sows also had a greater NL and better lifetime efficiency. The second canonical function represents a second independent relationship between the performance test and longevity variables. The second set of canonical variates is characterized on the variate of independent variables by a high canonical loading on PSI (0.83), ADG (0.79) and exterior (0.62), whereas the variate of dependent variables is characterized by a high canonical loading on LTP365 (0.67) and moderate canonical loading on NL365 (0.34). Canonical loadings for the second canonical function indicate that sows with high values for the second set of variates had high ADG and PSI, excellent conformation, as well as better efficiency in pig production.

Table 4 also includes cross-loadings. Considering the first canonical function, all dependent variables exhibit small to moderate correlations with the independent canonical variate (0.22–0.36). This reflects that an average of 12% of the variance in longevity and productivity traits (LPL, LTP, NL) and an average of 6% in efficiency traits (NL365, LTP365) is explained by the first function (Table 5).

Therefore, the first canonical variate of the performance test traits has some predictive power for longevity but is a poor predictor of efficiency traits. Squared multiple correlations between longevity traits and the second canonical variate for performance test traits were slightly higher for efficiency production traits (8%).

Looking at the independent traits' cross loadings, the highest correlation with the first dependent canonical variate have LMdepth (–0.16) and ADG (–0.11). The highest cross-loadings of the independent variate correspond to the variables with the highest loadings as well. Correlations between performance test traits and the second dependent variate were also small being higher for PSI (0.20) and ADG (0.17). Examining the signs of the cross-loadings it can be established that all independent variables except PSI had unfavourable relationship with the dependent canonical variate.

Table 5. Squared multiple correlations between longevity traits and the first two canonical variates of performance test traits

Longevity traits[1]	Canonical variate	
	1	2
LPL	0.13	0.13
LTP	0.12	0.12
NL	0.12	0.12
LTP365	0.05	0.08
NL365	0.07	0.07

[1]see Table 1 for trait names.

Redundancy analysis

The amount of shared variance for the first and the second canonical variates of independent variables was 0.07 and 0.32, respectively (Table 6). Likewise, the amount of shared variance for the first and the second canonical variates of dependent variables was 0.71 and 0.12, respectively.

Although the dependent canonical variate predicts 71% of the variance in the individual original dependent variables, the redundancy index shows that the first canonical variate of the performance test traits explains only 10% of the variance in longevity and lifetime productivity traits. The first variate for dependent variables explains 1% of the independent variable. The low redundancy index calculated for independent variables was due to very low degree of shared variance explained by the independent variate (0.07). For the second canonical function, the opposite canonical variate explained 2 and 1% of the standardized variance of the performance test traits and longevity traits, respectively. The explained variance for two functions can be added, because two functions are independent. This means that performance test traits explain 11% of the variance in the variables of longevity and lifetime productivity, whereas dependent variables explain only 3% of the variance in performance test traits.

Table 6. Canonical redundancy analysis of independent[1] and dependent[2] variables for two canonical functions

	Standardized variance of the independent variables explained by				
	their own canonical variate (shared variance)		the opposite canonical variate (redundancy)		
Canonical function	proportion	cumulative proportion	canonical R^2	proportion	cumulative proportion
1	0.07	0.07	0.14	0.01	0.01
2	0.32	0.39	0.06	0.02	0.03
	Standardized variance of the dependent variables explained by				
	their own canonical variate (shared variance)		the opposite canonical variate (redundancy)		
Canonical function	proportion	cumulative proportion	canonical R^2	proportion	cumulative proportion
1	0.71	0.71	0.14	0.10	0.10
2	0.12	0.83	0.06	0.01	0.11

[1] ADG, BF, LMdepth, LMP, PSI, exterior.
[2] LPL, LTP, NL, LTP365, NL365.
See Table 1 for trait names.

Discussion

Investigations concerning the relationships between longevity, lifetime productivity and production traits are based mainly on survival analysis (Yazdi et al., 2000; Serenius et al., 2006; Tarrés et al., 2006 a, b; Serenius and Stalder, 2007; Fernàndez de Sevilla et al., 2008; Hoge and Bates, 2011), some use linear models (López-Serrano et al., 2000; Serenius and Stalder, 2004; Stalder et al., 2005) and only one literature report deals with canonical analysis (Johnson and Nugent, 2008). The canonical correlation analysis carried out by Johnson and Nugent (2008) showed that the relationships between performance test data and subsequent lifetime productivity traits were low or not significant for Landrace, Yorkshire and Duroc sows, although a significant relationship was found for Hampshire sows, that are selected only for growth rate, leanness and feed efficiency. Hampshire sows with high values for the first canonical variate had lower weights at 100 and 177 days of age, larger loin area and greater backfat thickness as well as being younger at culling. Fatter and slower growing Yorkshire sows for which more emphasis was given to maternal index had greater number of litters, total number born alive and length of productive life. This can indicate that the association between longevity and production traits is likely breed dependent and may also vary with combinations of maternal and performance indexes for sows that were selected. The redundancy index found by Johnson and Nugent (2008) in Landrace, Yorkshire and Hampshire sows was lower than that obtained in this study: approximately 1.5% of the variance in lifetime productivity traits (number of litters, total number born alive, total weight of litters weaned and age of sow at birth of last litter) was explained by the independent variate (representing weights of sows at 100 and 177 days of age, body length, loin eye area and backfat thickness).

Different results found in the literature indicate that associations between carcass traits and longevity seem to depend on the population being studied. However, most studies suggest the existence of antagonistic relationships. The results in the present study are in agreement with those concluding that slower growing gilts with more backfat had longer productive life and were more productive. López-Serrano et al. (2000) found unfavourable genetic correlations between stayability to second and third parity and backfat thickness (from 0.11 to 0.27) and daily gain (from –0.06 to –0.32) in Landrace and Large White sows. This relationship became more unfavourable with increasing age in Large White sows. Serenius and Stalder (2004) found substantial genetic correlation (0.22) between longevity (and lifetime prolificacy) and backfat thickness in the Large White population. Serenius and Stalder (2007) found that the greater backfat thickness and the greater age at 100 kg live weight were associated with lower sow culling risk in Finnish crossbred population at any time point, but this effect was very small. Correlations of the second variate with original observed variables obtained in this study indicate that sows with high values for this variate had high ADG (r=0.79) as well as better lifetime efficiency (r=0.67). Probably, the fast growing gilts reach the puberty earlier and can be mated at a younger age than the slow growing ones. Therefore, lifetime pig efficiency of these sows may be better even though there is no difference in NL between fast and slow growing gilts (loading for NL is near 0). Moreover, gilts with a higher growth rate may have a larger litter size. Tummaruk et al. (2001) showed that gilts with a high growth rate had a subsequent larger litter size, shorter wean-to-first-service interval and higher farrowing rate. On the other hand, Stalder et al. (2005) showed that sows from slowest growing group (>210 days to 113.4 kg) had greater lifetime number of piglets weaned when compared to faster growing groups. However, the trends (not significantly different) from that study suggested that the slower growing sows had the poorest lifetime number of piglets born alive. Sows that were heavier before selection and fatter before mating had better longevity to the second parity phenotypically (Lewis and Bunter, 2011). The trend from the study of Stalder et al. (2005) indicated that gilts from the groups with greater amounts of BF had more lifetime number of piglets born alive and greater number of parities during their lifetime as a sow. Associations observed between longevity and other economically important performance traits were probably affected by selection and by sow culling due to poor reproduction or health problems. When no culling due to poor production was allowed until a sow had reached the fourth parity, the relationship observed between longevity and compositional traits (BF and ADG) was different in six maternal genetic lines; however, significant associations were unfavourable for BF trait (Serenius et al., 2006). The results obtained by Hoge and Bates (2011) indicate that regardless of definition, developmental performance does provide insight into sow longevity: Yorkshire gilts that grew slower and had more BF had a decreased risk of being culled. The influence of backfat thickness on longevity could be explained through leg weakness syndrome as a consequence of lower backfat thickness or difficulties in sows becoming pregnant due to negative energy balance, since reproduction problems are an important reason for culling (López-Serrano et al., 2000). In a study of Serenius et al. (2006) when gilts that never farrowed were included in the analysis, backfat thickness was significantly associated with sow longevity, but when they were removed this association weakened, suggesting that backfat thickness viewed as a source of energy for the sow may play a role in conception rates and maintaining pregnancy. Indeed, Tummaruk et al. (2001) and Holm et al. (2004) reported unfavourable correlations between backfat thickness and wean to first service interval. It is possible that fat content measured at gilt stage is not a critical measure of the animal energy supply later in their reproductive life. Gill (2007) suggested that fatness is less critical than achieving a targeted body weight for fertility, so body condition and fitness is more important than backfat thickness at gilt stage.

Not all studies are in agreement with the current findings. Growth rate and side-fat thickness at performance test had no significant influence on longevity of Swedish Landrace sows, though a negative relation between weight at performance and longevity was found (Yazdi et al., 2000). In a study of Tarrés et al. (2006 a) average daily gain during the growth test had a limited effect on the risk of culling of Duroc sows, because only after 850 days of productive life the group of sows with ADG higher than 585 g/day slightly tended to have more risk of being culled. Results obtained by Rozeboom et al. (1996) showed no large effects of gilt body composition at first breeding on sow longevity and productivity over three parities. Similarly, Serenius and Stalder (2004) found no phenotypic or genetic association of longevity and lifetime productivity with production traits in Finnish Landrace. The growth rate of Landrace sows was not associated with lifetime measured as age at last farrowing or maximum number of parities in the study of Stalder et al. (2005). Difference of growth rate and backfat depth did not result in differences in sow efficiency defined as ratio between lifetime production days and total of liveborn piglets (Flisar et al., 2012).

Different results were obtained by Fernàndez de Sevilla et al. (2008) when three breeds were compared: survivability decreased for fatter sows at 6 months of age in Duroc breed and tended to be less for leaner Landrace sows, but the effect of BF was not significant for survivability in Large White sows. Association between growth rate and lifetime productivity and longevity was significant but the effect was negligible in a study of Flisar et al. (2012): although higher daily gain resulted in better reproductive performance in the first three parities, lifetime productivity was lower for –1.98 live born piglets per increase of 100 g/day and total number of litters was smaller due to culling at an earlier age. Knauer et al. (2010) reported an unfavourable relationship between ADG and gilt BF with the ability of the sow to stay in the herd to the fourth parity (stayability) in some genetic lines while not in others. Genetic correlations between fatness at selection or mating and survival from the first to second farrowing obtained by Lewis and Bunter (2011) were positive and moderate in magnitude (average 0.3) but not significantly different from zero. In a study of Tarrés et al. (2006 a) backfat thickness at the end of the growth test had different effects throughout Duroc sows' productive life, since only after 300 days sows with reduced backfat thickness (less than 16 mm) had an increased risk of culling. Flisar et al. (2012) found that backfat thickness did not influence lifetime productivity, although sows with 10 mm thicker backfat farrowed more litters in lifetime and were culled 50 days later. The genetic correlations between litters per sow per year and the post-weaning traits: backfat thickness, days to 100 kg and lean percentage obtained by Abell et al. (2012) had large standard errors resulting in the direction of the correlation being unclear.

An unfavourable relationship between longevity traits and loin depth disagrees with the results reported by most authors. Stalder et al. (2005) found that gilts with larger LM area had better longevity and more lifetime litters than gilts that have less than 36 cm^2 of LM area. Although not always significant, the lifetime number of piglets born alive increased with each successive loin muscle area group from lightest to heaviest muscled. Loin depth did not affect stayability in a study of Knauer et al. (2010). Lewis and Bunter (2011) found unfavourable but not significant genetic correlation (–0.24) between survival from the first to second farrowing and loin muscle depth in two maternal lines of Large White and Landrace origin; however, phenotypic correlation between these traits was positive (0.05) and differing significantly from 0. Loin depth at first farrowing in a study of Tarrés et al. (2006 a) had a different effect on the risk of culling at different intervals of productive life: before 300 days of age loin depths less than 40 mm were associated with higher risk of culling, but after 300 days of productive life, sows with loin depth over 50 mm presented a higher risk of being culled.

The relationship between exterior and longevity seems to be evident, because sows with the best conformation scores should have a lower risk of culling. An important component of conformation index is the leg score trait since leg weakness has a great impact on fitness and longevity of animals. Correlations of the second variate with original measured variables obtained in this study indicate that sows with the high value for this variate had a better conformation index (r=0.62) and better lifetime pig efficiency (r=0.67) but they were not different in longevity (r=0.03 and 0.08 for LPL and NL, respectively). If gilts with poor exterior scores are not selected and do not stay in a herd it may introduce a downward bias in the correlation. López-Serrano et al. (2000) found favourable genetic correlations between stayability to second and third litter and leg score in Landrace breed (from 0.19 to 0.36), while in Large White sows these correlations were around zero. In the same study the genetic correlations with other exterior traits (length of sow, muscle, height and type) were unimportant and inconsistent in two breeds. Tarrés et al. (2006 b) reported that Swiss LW sows with the best phenotypic index for feet and leg scores had a lower risk of culling and their productive life expectation was reduced from 1.8 years for the optimal index value to less than 1 year for the worst value. Similarly, Fernàndez de Sevilla et al. (2008) found that leg conformation had a substantial effect on longevity in Duroc, Landrace and Large White sows whereas the conformation of teats did not affect sow longevity for any of the breeds.

In conclusion, the relationships between performance test data and subsequent lifetime productivity or longevity were significant and unfavourable but low for Polish Landrace population. Performance test traits explain only 11% of the variance in the variables of longevity, which explain only 3% of the variance in performance test traits. The results obtained in this study can be useful for breeders of the Polish Landrace pig population to more accurately define the breeding programme; however, the genetic correlation between the performance test traits and lifetime productivity traits should be estimated.

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