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In vivo evaluation of the fat content and muscularity of gilts with different genotypes using an Aloka SSD-500 ultrasound scanner in relation to selected reproductive performance indicators

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The aim of the study was to determine the fat and meat content in gilts with different genotypes on the basis of in vivo ultrasound measurements made with an Aloka SSD-500 scanner and to define the relationships between them, as well as to determine their effect on the number of piglets born alive and weaned. The study was performed on 240 gilts raised in identical production conditions. The gilts were divided into 3 groups depending on their genotype: group 1 – 80 gilts of the Polish Landrace breed (PL), group 2 – 80 gilts of the Polish Large White breed (PLW) and group 3 – 80 crossbred gilts PL×PLW. In vivo assessment of gilts and the of fat and muscle content during the first mating was carried out using an Aloka SSD-500 scanner equipped with a 17 cm UST-5044 linear transducer with an operating frequency of 3.5 MHz. The relationships between the parameters were verified by calculating Pearson correlation coefficients (r). The greatest fatback thickness at point P2 was recorded in the crossbred PL×PLW gilts (P≤0.01). A similar relationship was observed for fatback thickness at point P4. The greatest length of the longissimus dorsi (LD) muscle was observed in the PL×PLW gilts (P≤0.01). The lowest values for the LD muscle length were recorded for the PL gilts (P≤0.01). The largest cross-sectional area of the longissimus dorsi muscle and fat area over this muscle were noted for the PL×PLW gilts. Analysis of the correlations shows that the pure-bred PL gilts achieved a similar result to the crossbred PL×PLW gilts in the case of the relationship between the width of the LD muscle and the fat area over this muscle. The research showed that the number of piglets born alive and weaned increased with the fat content and muscularity of the gilts.

KEY WORDS: fat content / muscularity / gilts / Aloka SSD-500

Since the early 1990s, consumers have been more interested in purchasing pork with a high content of meat and low content of fat [5]. This has forced a lasting change in breeding work in Poland, focusing mainly on the use of pigs for meat. The use of intensive selection of pigs to improve meat content has increased this parameter not only in boars, but also in the gilts of all breeds raised in the country [1, 14]. Analysis of the changes in carcass characteristics of gilts of maternal breeds reveals significant improvement in the value of these traits. The average meat content of pigs in the country has already risen to 57% [25].

Many authors have demonstrated a direct relationship between carcass traits and reproductive traits [3, 6, 24]. Unfortunately, as a result of selection for meatiness, the level of fat in gilts at first mating has been significantly reduced. This is due to the negative correlation between meatiness and fat cover, which means that as meat content increases, the fat content of the gilt decreases. Increased levels of fat at the time of first mating may improve reproductive indices [2, 9]. One way to increase fat in gilts may be to delay first mating to a later age. For the producer, the most important reproductive indicators are the number of live-born piglets and the number of weaned piglets. It should be emphasized that these performance parameters in gilts are influenced by many factors, including the quality of boar semen [7, 8].

The aim of the study was to determine the fat content and muscularity of gilts of different genotypes based on ultrasound measurements of living animals using an Aloka SSD-500 ultrasound console and to define the correlations between them, as well as to determine their effect on the number of live-born and weaned piglets.

Material and methods

The experiment was conducted on an industrial pig fattening farm in the Opole Voivodeship in 2013. The research was carried out on 240 gilts kept under identical production conditions. The gilts were divided into three groups depending on their genotype: group 1 – 80 gilts of the Polish Landrace breed (PL), group 2 – 80 gilts of the Polish Large White breed (PLW), and group 3 – 80 crossbred gilts (PL x PLW).

The average body weight of the gilts was 127.06 ± 9.34 kg. The gilts were housed on a partially slatted floor, in accordance with regulations (the area per gilt was 1.64 m^2, of which 0.95 m^2 was solid floor), and fed in accordance with Pig Feeding Standards [13], with constant access to water.

An Aloka SSD-500 ultrasound console, equipped with a 17 cm UST-5044 transducer with a frequency of 3.5 MHz, was used to assess the live gilts and determine their fat content and muscularity at the time of their first mating. The use of a camera in combination with dedicated computer software enabled the linear and surface area measurements described in Table 1. The probe was placed perpendicular to the axis of the body. When the optimum outline of the longissimus dorsi muscle and the fat layer over that muscle appeared on the ultrasound monitor, the image was frozen. Then, after the best quality ultrasound image was obtained, simultaneous linear and surface area measurements were taken. It should be noted that the width of the *longissimus dorsi* (LD) muscle was measured at its widest point. The average values of the linear and surface measurements, following manual determination by the individual performing the test, were calculated automatically by Designer Gene's Image Analysis software.

In order to check the reproducibility of the results, each ultrasound measurement was performed three times. The collected data were checked for normality of distribution by the Kolmogorov-Smirnov (K-S) test with Lilliefors's correction. In addition, the Brown-Forsythe (B-F) test was used to determine whether the distribution of variables had equal variance. Statistical analysis of the numerical data was performed using Statistica 2013 software, by one-way analysis of variance (ANOVA). Significance of differences was confirmed by the Tukey (HSD) test. The significance levels were $0.01<P\leq0.05$ (significant) and $P\leq0.01$ (highly significant). The following linear model was used:

$$x_{ij} = \mu + \alpha_i + \varepsilon_{ij}$$

where:

x_{ij} – value of dependent variable

μ – grand mean

α_i – main effect of genotype: i = 1 – PL, 2 – PLW, 3 – (PL x PLW)

ε_{ij} – sampling error with normal distribution, with mean equal to zero and variance σ^2

Table 1

Linear and surface measurements made with an Aloka SSD-500 ultrasound scanner

Measurement	Description of the measuring point
UP2	Fatback thickness at point P2 (cm): fatback thickness at the last rib, at the junction of the thoracic and lumbar vertebrae – 3 cm from the midline of the spine
UP4	Fatback thickness at point P4 (cm): fatback thickness at the last rib, at the junction of the thoracic and lumbar vertebrae – 8 cm from the midline of the spine
UWLD	Length of the *longissimus dorsi* muscle at point P4 (cm): length of the eye of the loin, at the junction of the thoracic and lumbar vertebrae – 8 cm from the midline of the spine
USLD	Width of the *longissimus dorsi* muscle (mm)
UPLD	Cross-sectional area of the *longissimus dorsi* muscle (cm^2)
UPT	Cross-sectional area of fat on the surface of the *longissimus dorsi* muscle (cm^2)

To test the relationships between characteristics, Pearson's linear correlation coefficients (r) were calculated as well. Two levels of significance were established for the coefficients: significant $0.01<P\leq0.05$ and highly significant $P\leq0.01$. Then, to verify the occurrence of the genotype effect, a test of differences for correlation coefficients was performed according to the procedure given by Stanisz [16]. Statistical differences between Pearson's linear correlation coefficients were calculated only for coefficients that were statistically significant at $P\leq0.05$.

Results and discussion

The results for fat content and muscularity of gilts of different genotypes, based on assessment of live gilts with an Aloka SSD-500 ultrasound console, are presented in Table 2. The greatest backfat thickness at point P2 was recorded in the crossbred PL x PLW gilts ($P\leq0.01$). The thinnest fat at this point was shown in the LPW gilts. A similar relationship was observed in the case of backfat thickness at point P4. Similar findings for backfat thickness using ultrasound measurement techniques have been reported by Cisneros et al [4]. It should be noted, however, that the authors cited measured the thickness of the fat behind the last rib at a distance of 6.5 cm from the midline of the back in the Duroc breed using the Aloka 210 DX. The mean thickness of the backfat measured at this point was about 1.87 cm, which was comparable to the backfat thickness at P4 obtained for the crossbred PL x PLW gilts. Newcom et al. [12] obtained much higher values for ultrasound measurements of backfat thickness behind the last rib. Tyra and Żak [19] obtained different results for fat content in gilts. In their study, conducted on purebred gilts, gilts of the PLW breed had slightly higher fat content than PL gilts. A later study by Tyra et al. [20], performed using the Aloka SSD-500 ultrasound console, confirmed a greater backfat thickness at points P2 and P4 in PL gilts than in PLW gilts, which is consistent with our results.

The greatest length of the longissimus dorsi muscle was observed in the PL x PLW gilts ($P\leq0.01$). Lower results for this trait were obtained in interbreed crosses by Vilchez and Chavez [21]. The lowest values for LD muscle length were noted in the purebred PL gilts ($P\leq0.01$). The study showed a similar LD muscle width in the PL and PLW breeds and a significantly higher value for this feature in the PL x PLW crossbred gilts ($P\leq0.01$). Among purebred gilts, as in the study by Tyra et al. [20], PLW gilts had greater LD width. The largest cross-sectional area of the longissimus dorsi muscle was recorded in the PL x PLW gilts. The surface area of the LD muscle in these gilts was greater than in both the PL ($P\leq0.01$) and PLW ($P\leq0.05$) gilts. Moeller and Christian [11] reported lower results of ultrasound measurement of area of the LD muscle. The cross-sectional area of fat on the surface of the longissimus dorsi muscle was greatest in the PL x PLW crossbreds ($P\leq0.01$) and the PL gilts ($P\leq0.05$). A smaller area of fat on the LD muscle of the PLW breed was reported by Tyra et al. [20].

Table 2
Fat content and muscularity of gilts of different genotypes

Measurement	Genotype	$\bar{x}$	*s*	min	max
UP2 (mm)	pbz[1]	22.40[a]	4.14	13.20	31.87
	wbp[2]	21.27[Bb]	3.74	13.86	30.21
	pbz x wbp[3]	23.08[A]	4.76	16.56	36.16
UP4 (mm)	pbz	17.72[a]	3.78	11.83	26.98
	wbp	16.42[Bb]	3.67	10.25	25.70
	pbz x wbp	18.56[A]	4.71	12.35	31.43
UWLD (mm)	pbz	57.87[B]	6.11	39.52	72.37
	wbp	59.49	6.10	36.90	72.76
	pbz x wbp	61.47[A]	6.75	36.73	72.32
USLD (mm)	pbz	131.70[B]	8.18	116.30	150.21
	wbp	131.96[B]	7.21	115.43	149.50
	pbz x wbp	135.10[A]	8.97	115.22	155.24
UPLD (cm^2)	pbz	59.43[B]	9.12	35.24	81.04
	wbp	61.71[b]	6.94	35.27	79.87
	pbz x wbp	65.16[Aa]	7.82	46.33	85.32
UPT (cm^2)	pbz	25.38[a]	5.74	14.78	40.25
	wbp	23.46[Bb]	4.99	12.34	35.65
	pbz x wbp	26.13[A]	7.43	17.10	49.84

[1]pbz – PL (Polish Landrace)
[2]wbp – PLW (Polish Large White)
[3]pbz x wbp – PL x PLW (PL x PLW crossbreed)
a, b – in the same column for the same feature indicate statistically significant differences at $P \le 0.05$
A, B – in the same column for the same feature indicate statistically highly significant differences at $P \le 0.01$

Results showing correlations between the characteristics studied, taking into account the genotype of the gilts, are presented in Table 3. A very high correlation was found between backfat thickness at points P2 and P4 in the PL and PLW breeds ($P \le 0.01$). The strongest correlation between these features was observed in the PL x PLW gilts, in which the correlation was nearly complete ($P \le 0.01$). Michalska et al. [10] reported a weaker relationship between backfat thickness at points P2 and P4; the correlation coefficient was 0.55 in the PLW breed. Statistically significant differences between correlation coefficients were observed between backfat thickness at point P2 and LD width in the PLW breed and the PL x PLW crossbred gilts ($P \le 0.05$). Similar relationships were observed between backfat thickness at P2 and the cross-sectional area of the LD muscle and of the fat on the surface of this muscle. The strongest correlation for these characteristics was observed in the crossbred gilts ($P \le 0.01$, $P \le 0.05$). Large differences between breeds in the strength of correlations between characteristics were observed for the correlation of backfat thickness at P4 and the cross-sectional area of the longissimus dorsi muscle in PL and in the PL x PLW crossbreds (P≤0.05). Lower correlation coefficients between the LD muscle area and backfat thickness – only 0.26 (backfat thickness measured on the back) and 0.20 (measured above the shoulder) – were reported by Skałecki [15].

A marked weakening of the association between the height of the LD muscle and the area of the fat over this muscle was observed in the PLW gilts (P≤0.01). The weakest correlation between the width of this muscle and its area was noted in the PL gilts (P≤0.05). It should be emphasized that these characteristics are strongly correlated with the content of meat in the carcass; Tereszkiewicz and Molenda reported correlations of 0.50 and 0.72 [18]. Considerable differences were observed in the strength of the relationship between the width of the LD muscle and the area of the fat on the cross section of the muscle. A very high correlation between features was noted in the PL x PLW crossbreds (P≤0.01). A high correlation was observed in the PL breed (P≤0.05), but an average correlation in the PLW breed; the strength of the relationship between these characteristics as compared to the other gilts was the lowest (P≤0.01, P≤0.05). Analysis of the strength of the relationship between the area of the longissimus dorsi muscle and the area of fat above this muscle reveals a very strong relationship between these traits in PL x PLW gilts, in which the

Table 3

Correlations between parameters with respect to the genotype of the gilts

Measurement	Genotype	UP2	UP4	UWLD	USLD	UPLD
UP4	pbz[1]	0.80**B				
	wbp[2]	0.83**B				
	pbz x wbp[3]	0.94**A				
UWLD	pbz	0.48**	0.30**			
	wbp	0.37**	0.15			
	pbz x wbp	0.53**	0.46*			
USLD	pbz	0.58**	0.42**	0.69**		
	wbp	0.38**b	0.16	0.77**		
	pbz x wbp	0.64**a	0.58**	0.75**		
UPLD	pbz	0.51**b	0.31**b	0.89**	0.78**b	
	wbp	0.39**B	0.13	0.88**	0.84**	
	pbz x wbp	0.70**Aa	0.62**a	0.88**	0.89**a	
UPT	pbz	0.84**b	0.90**	0.43**	0.58**a	0.47**B
	wbp	0.78**B	0.88**	0.23*B	0.33**Bb	0.26*B
	pbz x wbp	0.92**Aa	0.92**	0.59**A	0.76**A	0.77**A

[1]pbz – PL (Polish Landrace)
[2]wbp – PLW (Polish Large White)
[3]pbz x wbp – PL x PLW (PL x PLW crossbreed)
* Statistically significant correlation at P≤0.05
**Statistically highly significant correlation at P≤0.01
a, b – in the same column for the same feature indicate statistically significant differences at P≤0.05
A, B – in the same column for the same feature indicate statistically highly significant differences at P≤0.01

correlation was very high (P≤0.01). The correlation between these traits was average in the PL breed and weak in the PLW breed. Completely different results concerning the relationships between LD muscle area and fat area were obtained by Suzuki et al. [17]. In these authors' research the correlation was –0.41.

The correlations between the features tested and the number of live-born and weaned piglets are presented in Table 4. It should be noted that the highest correlation coefficients between UP2, UP4 and UPT and the number of live-born and weaned piglets were observed for the crossbred PL x PLW gilts (P≤0.01). The same was true for the UWLD, USLD, and UPLD measurements, except that the effect of these features on the number of live-born piglets was significantly smaller (P≤0.05). Matysiak et al. [9], in their study on crossbred gilts, obtained lower correlation coefficients for backfat thickness at points P2 and P4 and the height of the LD muscle with the number of live pigs and weaned pi-

Table 4

Correlations between the measured parameters and the number of piglets born alive and weaned

Measurement	Genotype	Number of piglets born alive	Number of piglets weaned at 28 days
UP2	pbz[1]	0.35*^{b}	0.45**^{b}
	wbp[2]	0.28	0.31*^{B}
	pbz x wbp[3]	0.56**^{a}	0.67**^{A,a}
UP4	pbz	0.30*	0.40**
	wbp	0.19	0.11
	pbz x wbp	0.42**	0.55**
UWLD	pbz	0.22	0.42**
	wbp	0.13	0.27
	pbz x wbp	0.33*	0.61**
USLD	pbz	0.29	0.46**^{b}
	wbp	0.16	0.33*^{B}
	pbz x wbp	0.37*	0.69**^{A,a}
UPLD	pbz	0.26	0.42**^{b}
	wbp	0.14	0.29
	pbz x wbp	0.35*	0.64**^{a}
UPT	pbz	0.32*	0.43**
	wbp	0.25	0.23
	pbz x wbp	0.47**	0.59**

[1]pbz – PL (Polish Landrace)
[2]wbp – PLW (Polish Large White)
[3]pbz x wbp – PL x PLW (PL x PLW crossbreed)
* Statistically significant correlation at P≤0.05
** Statistically highly significant correlation at P≤0.01
a, b – in the same column for the same feature indicate statistically significant differences at P≤0.05
A, B – in the same column for the same feature indicate statistically highly significant differences at P≤0.01

glets. These authors also found strong relationships between slaughter characteristics and indicators of reproductive performance.

The results observed may be linked to the phenomenon of heterosis, or 'hybrid vigour'. PL x PLW gilts had the highest fat and muscle content, which according to Nowachowicz et al. [14] can be explained by the superiority of first-generation crossbreds over the phenotypic value of their parents. In livestock, the advantage of first-generation crossbreds over the average phenotypic value of parental traits varies from 1% to even 15%. Zhang et al. [23], however, emphasize that in the second generation obtained from mating first-generation individuals, the effect of heterosis decreases due to the loss of the beneficial interaction between allelic and non-allelic genes.

The correlation coefficients clearly show that an increase in the fat cover and muscularity of gilts at first mating determines an increase in the number of live-born piglets and the number of piglets weaned at 28 days, as confirmed by Matysiak et al. [9]. These correlations may be explained by two processes associated with the sow's metabolism – anabolism and catabolism. Anabolism is the process of accumulating energy reserves, including fat tissue. Holm et al. [6] point out that when energy reserves are insufficient (less fat at first mating), the development of the embryo and its implantation in the uterus may be impaired, leading to an increased number of embryos resorbed in the uterus and fewer live-born piglets. The piglet rearing period is associated with enormous physiological effort for the body of the sow. A mechanism called catabolism is activated, during which energy stored in adipose tissue, and subsequently in the muscles, is released. Zak et al. [22] stress that the metabolism of gilts, focused on energy storage during the long gestation period, has difficulty quickly switching over to utilization of feed to produce milk. As a result, while the gilts consume feed, they continue to use it to accumulate reserves, which are a source of nutrients necessary for milk production. Weaker anabolism during gestation is likely to reduce lactation in gilts, which may result in fewer weaned piglets, due in part to insufficient milk production.

In conclusion, the ultrasound measurement technique (USG) is very useful in assessing the degree of fat cover and musculature of gilts. Assessment of live gilts using the Aloka SSD-500 provided important information on the fat content and muscularity of the gilts of the three tested genotypes. The PL x PLW crossbred gilts had the highest indices for all tested features. Furthermore, stronger relationships between features were observed in these gilts. Statistically significant differences were found between the values of the traits in the PL x PLW gilts and the purebred PL and PLW gilts. It should be noted, however, that in the case of backfat thickness at points P2 and P4 and the cross-sectional area of the fat on the surface of the longissimus dorsi muscle, the PL gilts had slightly lower values than the PL x PLW crossbreds. Analysis of the correlations also reveals that the purebred PL gilts achieved a similar result to the PL x PLW crossbreds in the case of the correlation between the width of the LD muscle and the area of the fat above this muscle. The study showed that as the fat content and muscularity of the gilts increased, the number of live-born and weaned piglets increased as well, with the strongest correlations noted in the PL x PLW gilts.

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