



Appropriate level of gilt fatness and muscularity during insemination can improve the efficiency of piglet production

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Abstract

The aim of this study was to determine the degree of fatness and muscularity of gilts with different genotypes on the basis of intravital measurements using an Aloka SSD-500 ultrasound scanner and defining the influence of these parameters on selected indicators of reproductive performance. Research was performed on 462 gilts maintained under the same production conditions. Gilts were divided into 3 groups according to genotype: 154 Landrace gilts (L), 154 Large White (LW), 154 Landrace × Large White – [L × LW]. Four selected reproductive indicators were analyzed: the number of piglets born alive (n), average piglet birth weight (kg), number of piglets weaned at 28 days (n) and the average weaned piglet weight (kg). Our results clearly show that an appropriate level of gilt fatness during insemination can contribute to significant improvements in the efficiency of piglet production. In order to increase the number of piglets born alive, the number of piglets at weaning and the masses in these periods, it is recommended insemination of L, LW and [L × LW] gilts when their backfat thickness behind the last rib 3 cm from the midline of the spine exceeds 25 mm. In the case of backfat thickness measured 8 cm from the midline of the spine, to improve the production efficiency of these gilts it is recommended to proceed to insemination, when the value of this trait exceeds 20 mm. In addition, insemination of gilts with the genotype [L × LW] should occur when the amount of LD muscle exceeds 60 mm, the width of the muscle is greater than 135 mm, and its surface is greater than 70 cm².

Keywords: Aloka SSD-500, birth, body composition, female pigs, reproductive performance, weaning.

Introduction

The reorientation of pork consumer preferences caused by the global trend for a healthy lifestyle directly changed the characteristics of pig meat. Pork has to be characterised by a high content of lean meat with a low proportion of fat (Resurreccion, 2004). Such situation forced a permanent change in the national breeding programs. It began to focus primarily on increasing pigs content of lean muscle. During an analysis of changes in the slaughter traits of gilts, there is a significant improvement in the value of these traits, particularly in terms of meat content in the carcass, which in Landrace and Large White gilts has already increased to around 59% (Szulc *et al.*, 2013; Blicharski *et al.*, 2014).

Numerous studies (Zhang *et al.*, 2000; Holm *et*

al., 2004; Imboonta *et al.*, 2007; Patterson *et al.*, 2010; Kim *et al.*, 2013; Szulc *et al.*, 2013) reported that important relationships exist between body composition and reproduction. This was also confirmed in the research of Tummaruk *et al.* (2001), Čechova and Tvrdoň (2006), and Mijatović *et al.* (2009). Gilts reach puberty with different body composition, however puberty is initiated by metabolic signals, among which special significance for growth and differentiation of cells plays leptin and insulin-like growth factor-I (IGF-I; Bidanel *et al.*, 1996; Barb *et al.*, 1997; Roongsitthichai and Tummaruk, 2014). Some authors have emphasized that the traits associated with reproduction should be taken into account in the development of breeding strategies aimed at improving the fattening and slaughter traits (Kuehn *et al.*, 2009; McPherson *et al.*, 2014). Many authors have confirmed the occurrence of the negative impact of selection focused only on improving the fattening and slaughter traits, which exacerbate some reproductive parameters, and evidently this process can be seen precisely in the example of gilts (Tummaruk *et al.*, 2001; Holm *et al.*, 2004; Imboonta *et al.*, 2007).

It should be noted that long-term and the unilateral selection for higher lean meat content has considerably decreased the level of gilt fatness at first mating. This is mainly related to the occurrence of a negative meatiness-fatness correlation, which means that with increasing meat content, the level of fatness in gilts decreases. Tummaruk *et al.* (2001) clearly concluded that an increase in the muscularity and a reduction in the level of fat has an adverse effect on the reproductive performance of pigs. The research of Matysiak *et al.* (2010) confirmed that a higher level of fatness at the moment of the first mating/insemination can improve reproductive indicators of gilts. One way to increase the level of gilt fatness may be mating/insemination for the first time at an older age (Chen *et al.*, 2003).

According to Quinton *et al.* (2006), the most important from economic point of view reproductive indicators are the number of piglets born alive, the number of piglets at weaning and the weight of piglets in the same periods. It is worth noting that these parameters of gilts reproductive performance are affected by many additional factors, of which one of the most important is the quality of boar semen (Knecht *et al.*, 2014a, b).

Taking into account the above problems, the aim of this study was to determine the degree of fatness and muscularity of gilts with different genotypes on the basis of intravital measurements using an Aloka SSD-500 ultrasound scanner. Subsequently the influence of

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these parameters on selected indicators of reproductive performance was defined.

Materials and Methods

Experimental location and design

The experiment was carried out in 2014 at an industrial pig fattening farm located in Poland, in the province of Opole (51.0431°N, 17.8583°E). The research population consisted of gilts during first insemination with different genotypes, which the degree of fatness and muscularity was determined by ultrasound, and then investigated whether these parameters can affect the selected indicators of reproductive performance.

Experimental animals, environmental conditions and feeding

Research was performed on 462 gilts maintained under the same production conditions. Gilts were divided into 3 groups according to genotype: 154 Landrace gilts (L), 154 Large White (LW), 154 Landrace × Large White - [L × LW]. At the time of the insemination the average weight of gilts were 127.42 ± 7.45 kg for L, 129.32 ± 9.59 kg for LW, 128.73 ± 8.42 kg for [L × LW], the average age were 237.18 ± 12.14 days for L, 238.58 ± 16.56 days for LW, 250.44 ± 14.08 days for [L × LW], and the average daily gains were 577.33 ± 15.55 g for L, 582.04 ± 19.86 g for LW, 580.18 ± 21.38 g for [L × LW] ($P > 0.05$).

Selection of gilts was carried out around the age of two months, on the basis of gilts appearance: long body, healthy leg and at least 12 active nipples. Sows, mothers of gilts were in average 2.68 ± 0.59 parity. Since the selection, gilts were specially fed by the appropriate composition of vitamins, micro- and macronutrients in the feed, which enable correct, comprehensive development and their subsequent use in reproduction. The average daily gain during this period was maintained below 600 g.

The maintenance conditions of gilts were consistent with the provisions of cross compliance concerning animal welfare. Gilts after insemination were housed for 4 weeks in individual pens with an area of 1.20 m² equipped with a slatted floor. Gilts in the period between 4 weeks after insemination to 1 week prior to farrowing were maintained in groups (22 gilts/pen), on the floor was a partially slatted grate. Pen area per gilt was 1.64 m², with 0.95 m² the complete floor. A week before parturition gilts were moved to partially slatted farrowing pens with a total area of 3.5 m². The temperature in pens for gilts in early pregnancy was 14.82°C ± 0.93, in the case of lactating gilts and gilts in high pregnancy it was 20.05°C ± 1.02. Relative humidity in the premises for gilts was 70.44% ± 5.11. The movement of air inside buildings was 0.30 m/s for the gilts in early and late pregnancy and 0.20 m/s for lactating sows.

Gilts were fed according to Grela and Skomial (2014), with *ad libitum* access to water. Dietary doses for gilts after insemination to 90 days of pregnancy

contained 11.8 MJ metabolisable energy, 143.6 g of digestible protein, 6.4 g lysine, 5.3 g of methionine and cystine, 8.2 g calcium, 6.3 g phosphorus and 2.7 g of sodium. Rations for gilts over 90 days of pregnancy and lactating gilts contained 12.5 MJ metabolisable energy, 170.2 g of digestible protein, 10.1 g lysine, 6.5 g of methionine and cystine, 9.9 g calcium, 7.2 g phosphorus and 3.6 g of sodium. After insemination until 90 days of pregnancy, each gilt received about 2.80 kg of feed per day, and after this period, the amount of feed was increased to 3.30 kg. None additional feed management after insemination was used.

Insemination

Estrus was checked twice a day with the presence of mature teaser boar. Animals were located in individual pens. Estrus was diagnosed by detecting the standing reflex using the back pressure test. The detection of estrus was started from 170 day of life gilts. Gilts were inseminated in their third heat two-times: the first time after 12 h of the onset of estrus and the second time after 12 to 18 h of the first insemination.

L, LW and [L × LW] gilts were inseminated by semen of five Duroc × Pietrain boars - [D × P], with a proportionate contribution to eliminating the single boar effect. The semen was collected by the manual method (King and Macpherson, 1973), using a container with a filter and only the sperm-rich fraction was used. Ejaculates were diluted, when meet the following requirements: color from gray to milky white, flavor specific (sensoric subjective evaluation), lack of foreign admixtures, more than 70% of progressive motile sperm cells (microscopic evaluation), pH 7.0-7.9, maximum changes to 15% (5% primary, 10% secondary). Insemination doses (irrespective of boar genotype) were similar with the concentration of sperm cells - 3.5×10^9 per 100 ml. Semen was diluted using a short-term BTS boar semen extender, Version 13525/0100 Antibiotic Free, Minitube International, Verona, WI, USA. Gilts were inseminated with cooled semen stored at 15°C for not longer than 48 h. Safe Blue Clear Glide™ (Minitube) catheters were used for the standard (cervix) insemination. Before insemination, seminal doses were heated to a temperature of 30°C. A pregnancy test was performed twice in 29 and 35 day after insemination using ultrasound - USG DRAMINSKI® SonoFarm profi.

Ultrasound measurements

Using an Aloka SSD-500 ultrasonograph equipped with a 17 cm UST-5044 transducer at an operation frequency of 3.5 MHz in vivo assessment of gilts was performed at the level of their fatness and muscularity during the first insemination. The use of the device in conjunction with dedicated computer software - Designer Gene's Image Analysis, enabled the performance of linear and surface measurements as: BF₁ - backfat thickness measured at the last rib, on the border of thoracic and lumbar vertebrae - 3 cm from the midline of the spine (mm); BF₂ - backfat thickness measured at the last rib, on the border of thoracic and



lumbar vertebrae - 8 cm from the midline of the spine (mm); BFA - cross-sectional area of fat on the surface of the LD muscle (cm²); HLD - height of the LD muscle measured on the border of thoracic and lumbar vertebrae - 8 cm from the midline of the spine (mm); WLD - width of the LD muscle (mm); LDA - cross-sectional area of the LD muscle (cm²).

The transducer was applied perpendicular to the axis of the gilt's body. At the time of the appearance on the ultrasonograph monitor of the optimal outline of *Longissimus dorsi* (LD) muscle and a layer of fat over the muscle the image was immediately frozen. Then, after obtaining the best quality ultrasound image the analysis proceeded to the simultaneous performance of linear and surface measurements. It should be noted that the measurement of the width of the *Longissimus dorsi* muscle was performed at its widest point, which has direct relevance in the performance of measurements of the area of fat over the muscle. Average values of linear and surface measurements after the initial manual determination by the person conducting the study were calculated automatically by the Designer Gene's Image Analysis software.

After completing all measurements, gilts were divided in terms of their degree of fatness and muscularity. For each measurement, taking into account the distribution of the variables in the population, mean and standard deviation, three levels of each factor were set out in such a way that in the subgroup of research within each breed there were ultimately no less than 30 and no more than 40 gilts.

Reproductive performance analysis

The next stage of the research was to assess the reproductive performance of gilts taking part in the experiment. Farrowing rates were 92.96% for L, 92.04% for LW, 92.06% for [L × LW] and differences between groups were not proven statistically significant (χ^2 test, $P > 0.05$). Four selected reproductive indicators were analyzed: the number of piglets born alive (n), average piglet birth weight (kg), number of piglets weaned at 28 days (n) and the average weaned piglet weight (n). Differences between gilt genotypes in relation to different degrees of fatness and muscularity were examined statistically.

The statistical analysis

In order to check the reproducibility of the results, each ultrasound measurement was performed three times. The collected data were checked for the normality of the Kolmogorov-Smirnov (KS) test with Lilliefors correction. Further, the Brown-Forsythe (BF) test was employed to determine whether the distributions of the variables had the same variance. Numerical material was statistically analyzed with STATISTICA (2014), using analysis of variance (ANOVA). The significance of differences was confirmed by Tukey's test. Levels of the significance of differences were given conventionally: significant $0.01 < P \leq 0.05$ and highly significant $P \leq 0.01$. The model

used was as follows:

$x_{ijk} = \mu + \alpha_i + \beta_j + \varepsilon_{ijkl}$, where,

x_{ijk} - value of the dependent variable,

μ - general average,

α_i - main effect of the i -th genotype of gilts,

β_j - main effect of the j -th level of fatness or level of muscularity of gilts,

ε_{ijkl} - random experimental error normally distributed with zero mean and variance σ^2 .

Results

Figure 1 shows the degree of fatness and muscularity of gilts taking part in the experiment. The highest backfat thickness at both points was noted for hybrid gilts [L × LW] ($P \leq 0.01$). A relatively high value for this parameter was also quoted for L gilts ($P \leq 0.05$). The smallest area of fat over the LD muscle, compared to [L × LW] and L gilts was seen in LW gilts ($P \leq 0.05$; $P \leq 0.01$). There was a very clear difference between the amount of *Longissimus dorsi* muscle in [L × LW] gilts, and LW gilts ($P \leq 0.01$). Hybrid gilts, in comparison with purebred gilts, were characterised by a much greater width of the LD muscle ($P \leq 0.01$). The smallest area of the LD muscle was recorded for L gilts ($P \leq 0.01$), while the highest values of this parameter, in conjunction with L and LW gilts, were observed for hybrid gilts [L × LW] ($P \leq 0.05$; $P \leq 0.01$).

The effect of the fatness and muscularity of gilts on the number of piglets born alive is presented in Table 1. Definitely more statistically validated differences in the number of piglets born alive were observed in the case of the parameters defining fatness, namely BF₁, BF₂, and BFA. Gilts with the thickest of dorsal backfat (BF₁ > 25 mm; BF₂ > 20 mm), regardless of genotype achieved the highest number of alive piglets (all differences statistically proven on the level $P \leq 0.05$ or $P \leq 0.01$). Purebred gilts and hybrid gilts with the genotype [L × LW], which had the lowest surface of the fat over the LD muscle (<20 cm²), bore the least alive piglets ($P \leq 0.05$; $P \leq 0.01$). Parameters defining the musculature of gilts, i.e. HLD, WLD and LDA, to a lesser degree determined the number of live-born piglets. It has been shown that the hybrid gilts [L × LW], characterised by highest (>60 mm) and widest (>135 mm) size of *Logissimus dorsi* muscle, with an area greater than 70 cm², bore more alive piglets ($P \leq 0.05$; $P \leq 0.01$). It is worth noting that for the L and LW gilts it was not statistically confirmed that a change in the degree of muscularity may determine the number of live-born piglets ($P > 0.05$).

Table 2 shows the influence of the degree of fatness and muscularity of gilts on the average weight of piglets at birth. The lowest weight at birth was noted in piglets born by LW gilts, which at the time of insemination had the thinnest backfat (BF₁ <20 mm; BF₂ <15 mm) ($P \leq 0.05$; $P \leq 0.01$). The heaviest piglets were born by [L × LW] gilts, characterised by the highest surface of fat over the *Longissimus dorsi* muscle (>30 cm²) ($P \leq 0.05$; $P \leq 0.01$). In the case of hybrid gilts, it was observed that higher LD muscle parameters, namely the height, width and surface area,

increase the birth-weight of the piglets. Piglets born from [L × LW] gilts characterised by the surface of the LD muscle in excess of 70 cm² ($P \leq 0.05$; $P \leq 0.01$) were the heaviest of all. It should be noted that in LW gilts the height, width, and surface of *Longissimus dorsi* muscle did not affect the average weight of the piglets at birth ($P > 0.05$).

The effect of the fatness and muscularity of gilts on the number of piglets at weaning is presented in Table 3. The smallest number of piglets at weaning was recorded in L and LW gilts, characterised by the thinnest backfat thickness ($BF_1 < 20$ mm; $BF_2 < 15$ mm) ($P \leq 0.05$). A similar observation was noted for the surface of the fat over the LD muscle. The least piglets were weaned from pure breed gilts with BFA less than 20 cm² ($P \leq 0.05$; $P \leq 0.01$). The largest number of piglets at weaning, taking into account the genotype, were observed in hybrid gilts [L × LW] characterised by the highest degree of muscularity (HLD > 60 mm; WLD > 135 mm; LDA > 70 cm²) ($P \leq 0.05$; $P \leq 0.01$). It should be noted that the analysis of data concerning the number of piglets at weaning showed no statistically validated difference for the parameters of HLD, WLD and LDA, defining the musculature of L and LW gilts during the first insemination ($P > 0.05$).

Table 4 demonstrates the effect of the degree of fatness and muscularity of gilts on the average weight of piglets at weaning. LW according to BF_1 gilts bore the lightest piglets ($P \leq 0.01$). The lowest weight of piglets at weaning was listed in L gilts for BF_2 parameter ($P \leq 0.05$). Hybrid gilts [L × LW] weaned the heaviest piglets regardless of the area of fat over the *Longissimus dorsi* muscle ($P \leq 0.05$; $P \leq 0.01$). Statistical analysis confirmed that the increase in the area of fat over the LD muscle had a significant effect on increasing the weight of the piglets at weaning, both for gilts L and LW purebred, as well as [L × LW] hybrid gilts ($P \leq 0.05$; $P \leq 0.01$). The lightest piglets were weaned by L gilts which a *Longissimus dorsi* muscle height of less than 55 mm ($P \leq 0.05$). The heaviest piglets were weaned by the [L × LW] gilts, with *Longissimus dorsi* muscle ranging from 55 to 60 mm ($P \leq 0.01$). Piglets born from pure breed gilts L and LW were much lighter in comparison with piglets born from hybrid gilts [L × LW], which confirms, among others, the analysis of the LD muscle area ($P \leq 0.01$). It is worth noting that in the case of L gilts the degree of muscularity had no effect on the average weight of piglets at weaning (HLD, $P > 0.05$; WLD, $P > 0.05$; LDA, $P > 0.05$).

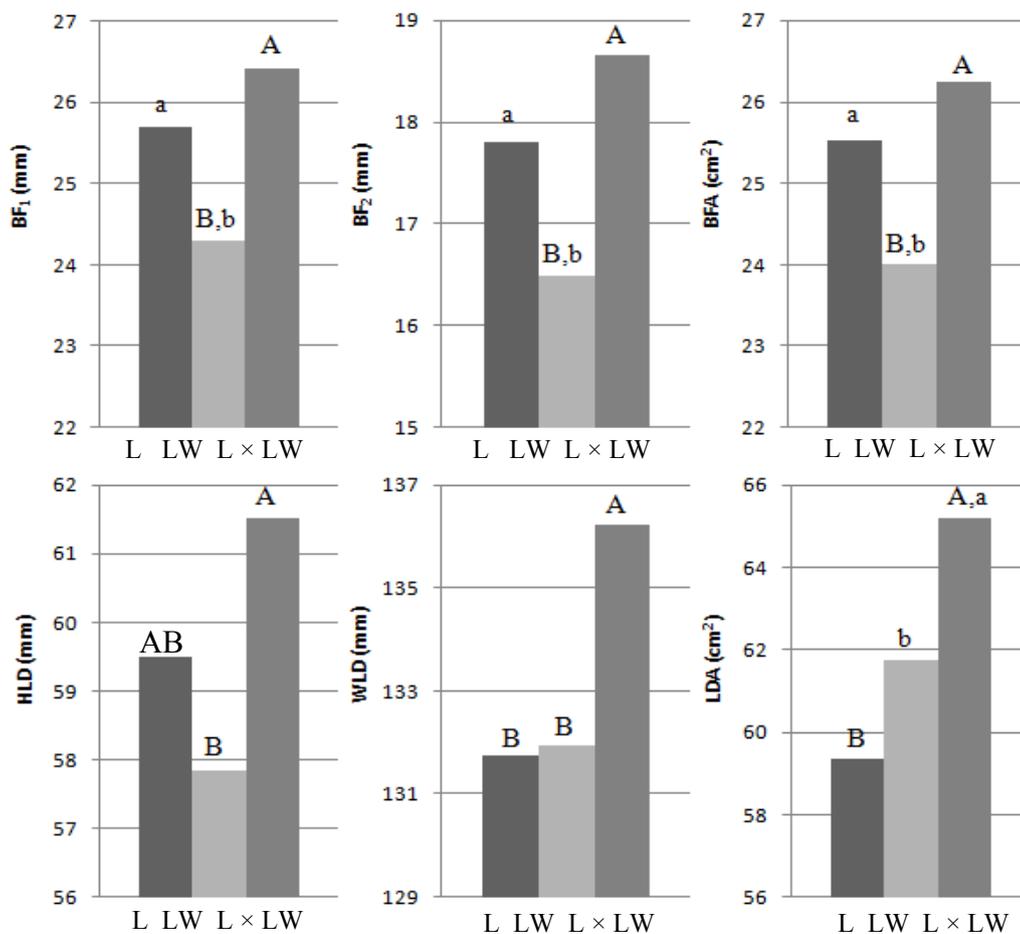


Figure 1. The degree of fatness and muscularity of gilts with different genotypes. L - Landrace, LW - Large White, L × LW - Landrace × Large White; BF_1 - backfat thickness measured at the last rib, 3 cm from the midline of the spine; BF_2 - backfat thickness measured at the last rib, 8 cm from the midline of the spine; BFA - cross-sectional area of fat on the surface of the LD muscle; HLD - height of the LD muscle; WLD - width of the LD muscle; LDA - cross-sectional area of the LD muscle. ^{a,b}indicate statistically significant differences between genotypes, at $P \leq 0.05$. ^{A,B}indicate statistically highly significant differences between genotypes, at $P \leq 0.01$.



Table 1. The influence of fatness and muscularity of gilts on the number of piglets born alive.

Measurement	Level	Number of piglets born alive (n)		
		L n = 154	LW n = 154	[L × LW] n = 154
BF ₁	<20 mm	9.02 ^b ± 0.57	9.00 ^b ± 0.58	9.51 ^B ± 0.45
	20-25 mm	9.50 ± 0.48	9.46 ± 0.50	9.84 ^b ± 0.40
	>25 mm	9.83 ^{a,y} ± 0.40	9.80 ^{a,y} ± 0.43	10.64 ^{A,a,x} ± 0.35
BF ₂	<15 mm	9.11 ^b ± 0.60	9.10 ^b ± 0.65	9.60 ^B ± 0.49
	15-20 mm	9.58 ± 0.53	9.60 ± 0.56	9.94 ^b ± 0.41
	>20 mm	9.91 ^{a,y} ± 0.42	9.93 ^{a,y} ± 0.50	10.75 ^{A,a,x} ± 0.33
BFA	<20 cm ²	9.15 ^{B,b} ± 0.59	9.19 ^b ± 0.61	9.77 ^B ± 0.52
	20-30 cm ²	9.95 ^a ± 0.50	10.00 ^a ± 0.53	10.08 ^b ± 0.47
	>30 cm ²	10.16 ^A ± 0.38	10.08 ^{a,y} ± 0.37	10.89 ^{A,a,x} ± 0.30
HLD	<55 mm	9.20 ± 0.54	9.15 ± 0.57	9.90 ^b ± 0.43
	55-60 mm	9.49 ± 0.50	9.40 ± 0.53	9.99 ± 0.39
	>60 mm	9.94 ± 0.43	9.89 ^y ± 0.43	10.70 ^{a,x} ± 0.34
WLD	<130 mm	9.13 ± 0.63	9.09 ± 0.66	9.83 ^b ± 0.45
	130-135 mm	9.40 ± 0.52	9.37 ± 0.57	9.90 ± 0.41
	>135 mm	9.89 ± 0.44	9.84 ^y ± 0.49	10.65 ^{a,x} ± 0.37
LDA	<60 cm ²	9.18 ± 0.56	9.14 ± 0.58	9.90 ^b ± 0.45
	60-70 cm ²	9.49 ± 0.49	9.41 ± 0.50	9.95 ± 0.42
	>70 cm ²	9.97 ± 0.40	9.70 ^y ± 0.48	10.72 ^{a,x} ± 0.35

^{a,b} indicate statistically significant differences between levels of measurement, at $P \leq 0.05$. ^{A,B} indicate statistically highly significant differences between levels of measurement, at $P \leq 0.01$. ^{x,y} indicate statistically significant differences between genotypes, at $P \leq 0.05$. ^{X,Y} indicate statistically highly significant differences between genotypes, at $P \leq 0.01$. L - Landrace, LW - Large White, L × LW - Landrace × Large White; BF₁ - backfat thickness measured at the last rib, 3 cm from the midline of the spine; BF₂ - backfat thickness measured at the last rib, 8 cm from the midline of the spine; BFA - cross-sectional area of fat on the surface of the LD muscle; HLD - height of the LD muscle; WLD - width of the LD muscle; LDA - cross-sectional area of the LD muscle.

Table 2. The influence of fatness and muscularity of gilts on the average piglet birth weight.

Measurement	Level	Average birth piglet weight (kg)		
		L n = 154	LW n = 154	[L × LW] n = 154
BF ₁	<20 mm	1.35 ^y ± 0.28	1.33 ^{b,Y} ± 0.30	1.45 ^{b,x,x} ± 0.27
	20-25 mm	1.40 ± 0.25	1.38 ^y ± 0.27	1.49 ^x ± 0.24
	>25 mm	1.44 ^y ± 0.21	1.43 ^{a,Y} ± 0.23	1.55 ^{a,x,x} ± 0.19
BF ₂	<15 mm	1.32 ^{B,y} ± 0.31	1.30 ^{B,Y} ± 0.35	1.42 ^{b,x,x} ± 0.28
	15-20 mm	1.36 ^y ± 0.29	1.35 ^Y ± 0.30	1.47 ^{x,x} ± 0.26
	>20 mm	1.44 ^A ± 0.23	1.42 ^{A,y} ± 0.20	1.52 ^{a,x} ± 0.20
BFA	<20 cm ²	1.30 ^{B,b,y} ± 0.32	1.31 ^B ± 0.30	1.40 ^{B,x} ± 0.26
	20-30 cm ²	1.40 ^a ± 0.27	1.39 ± 0.27	1.48 ± 0.21
	>30 cm ²	1.45 ^{A,y} ± 0.25	1.43 ^{A,Y} ± 0.23	1.56 ^{A,x,x} ± 0.18
HLD	<55 mm	1.36 ± 0.29	1.34 ± 0.28	1.41 ^B ± 0.24
	55-60 mm	1.42 ± 0.26	1.40 ± 0.24	1.46 ^B ± 0.22
	>60 mm	1.45 ^Y ± 0.25	1.43 ^Y ± 0.23	1.58 ^{A,x} ± 0.17
WLD	<130 mm	1.39 ^y ± 0.28	1.40 ± 0.26	1.49 ^{b,x} ± 0.20
	130-135 mm	1.45 ^y ± 0.22	1.46 ± 0.23	1.55 ^x ± 0.17
	>135 mm	1.48 ^y ± 0.20	1.49 ^y ± 0.20	1.59 ^{a,x} ± 0.15
LDA	<60 cm ²	1.38 ^b ± 0.28	1.41 ± 0.26	1.47 ^B ± 0.24
	60-70 cm ²	1.44 ± 0.24	1.45 ± 0.23	1.53 ± 0.16
	>70 cm ²	1.49 ^{a,y} ± 0.19	1.50 ^y ± 0.19	1.60 ^{A,x} ± 0.13

^{a,b} indicate statistically significant differences between levels of measurement, at $P \leq 0.05$. ^{A,B} indicate statistically highly significant differences between levels of measurement, at $P \leq 0.01$. ^{x,y} indicate statistically significant differences between genotypes, at $P \leq 0.05$. ^{X,Y} indicate statistically highly significant differences between genotypes, at $P \leq 0.01$. L - Landrace, LW - Large White, L × LW - Landrace × Large White; BF₁ - backfat thickness measured at the last rib, 3 cm from the midline of the spine; BF₂ - backfat thickness measured at the last rib, 8 cm from the midline of the spine; BFA - cross-sectional area of fat on the surface of the LD muscle; HLD - height of the LD muscle; WLD - width of the LD muscle; LDA - cross-sectional area of the LD muscle.



Table 3. The influence of fatness and muscularity of gilts on the number of weaned piglets.

Measurement	Level	Number of piglets weaned at 28 days (n)		
		L n = 154	LW n = 154	[L × LW] n = 154
BF ₁	<20 mm	8.84 ^b ± 0.37	8.85 ^b ± 0.40	9.33 ^B ± 0.39
	20-25 mm	9.23 ± 0.28	9.30 ± 0.34	9.65 ^b ± 0.35
	>25 mm	9.65 ^{a,y} ± 0.24	9.66 ^{a,y} ± 0.30	10.48 ^{A,a,x} ± 0.25
BF ₂	<15 mm	8.90 ^b ± 0.40	8.94 ^b ± 0.42	9.45 ^B ± 0.40
	15-20 mm	9.40 ± 0.35	9.43 ± 0.36	9.79 ^b ± 0.34
	>20 mm	9.70 ^{a,y} ± 0.31	9.75 ^{a,y} ± 0.32	10.61 ^{A,a,x} ± 0.23
BFA	<20 cm ²	8.96 ^{B,b} ± 0.38	9.03 ^b ± 0.44	9.60 ^B ± 0.32
	20-30 cm ²	9.77 ^a ± 0.34	9.85 ^a ± 0.27	9.88 ^b ± 0.29
	>30 cm ²	9.99 ^A ± 0.28	9.89 ^{a,y} ± 0.25	10.70 ^{A,a,x} ± 0.20
HLD	<55 mm	9.01 ± 0.43	9.01 ± 0.43	9.71 ^b ± 0.36
	55-60 mm	9.27 ± 0.37	9.24 ± 0.38	9.80 ± 0.34
	>60 mm	9.78 ± 0.33	9.73 ^y ± 0.31	10.53 ^{a,x} ± 0.25
WLD	<130 mm	8.95 ± 0.44	8.90 ± 0.46	9.65 ^b ± 0.39
	130-135 mm	9.19 ± 0.38	9.15 ± 0.40	9.74 ± 0.36
	>135 mm	9.66 ^y ± 0.32	9.61 ^y ± 0.35	10.48 ^{a,x} ± 0.30
LDA	<60 cm ²	9.03 ± 0.43	9.00 ± 0.41	9.71 ^b ± 0.38
	60-70 cm ²	9.32 ± 0.36	9.28 ± 0.36	9.79 ± 0.35
	>70 cm ²	9.80 ± 0.29	9.54 ^Y ± 0.30	10.55 ^{a,X} ± 0.24

^{a,b} indicate statistically significant differences between levels of measurement, at $P \leq 0.05$. ^{A,B} indicate statistically highly significant differences between levels of measurement, at $P \leq 0.01$. ^{x,y} indicate statistically significant differences between genotypes, at $P \leq 0.05$. ^{X,Y} indicate statistically highly significant differences between genotypes, at $P \leq 0.01$. L - Landrace, LW - Large White, L × LW - Landrace × Large White; BF₁ - backfat thickness measured at the last rib, 3 cm from the midline of the spine; BF₂ - backfat thickness measured at the last rib, 8 cm from the midline of the spine; BFA - cross-sectional area of fat on the surface of the LD muscle; HLD - height of the LD muscle; WLD - width of the LD muscle; LDA - cross-sectional area of the LD muscle.

Table 4. The influence of fatness and muscularity of gilts on the weaned piglet weight.

Measurement	Level	Average weaned piglet weight (kg)		
		L n = 154	LW n = 154	[L × LW] n = 154
BF ₁	<20 mm	8.33 ^{b,y} ± 0.45	8.30 ^Y ± 0.47	8.44 ^{b,x,x} ± 0.35
	20-25 mm	8.39 ± 0.38	8.34 ^Y ± 0.44	8.48 ^X ± 0.31
	>25 mm	8.43 ^{a,y} ± 0.31	8.39 ^Y ± 0.39	8.55 ^{a,x} ± 0.20
BF ₂	<15 mm	8.36 ^{b,y} ± 0.43	8.39 ± 0.38	8.46 ^{B,x} ± 0.33
	15-20 mm	8.40 ± 0.35	8.43 ± 0.33	8.49 ± 0.30
	>20 mm	8.47 ^{a,y} ± 0.30	8.48 ^y ± 0.29	8.58 ^{A,x} ± 0.18
BFA	<20 cm ²	8.39 ^{b,y} ± 0.40	8.41 ^b ± 0.38	8.50 ^{B,x} ± 0.25
	20-30 cm ²	8.44 ^Y ± 0.35	8.47 ± 0.31	8.56 ^X ± 0.21
	>30 cm ²	8.49 ^{a,y} ± 0.28	8.51 ^{a,y} ± 0.23	8.63 ^{A,x} ± 0.15
HLD	<55 mm	8.38 ^y ± 0.38	8.41 ± 0.32	8.48 ^{B,x} ± 0.28
	55-60 mm	8.41 ^Y ± 0.28	8.45 ^Y ± 0.25	8.60 ^{A,x} ± 0.16
	>60 mm	8.47 ± 0.25	8.50 ± 0.21	8.55 ± 0.18
WLD	<130 mm	8.40 ± 0.37	8.43 ^b ± 0.34	8.49 ± 0.23
	130-135 mm	8.45 ± 0.34	8.48 ± 0.30	8.53 ± 0.18
	>135 mm	8.49 ± 0.25	8.53 ^a ± 0.21	8.50 ± 0.20
LDA	<60 cm ²	8.36 ± 0.40	8.38 ± 0.35	8.45 ^b ± 0.32
	60-70 cm ²	8.40 ^Y ± 0.35	8.42 ^Y ± 0.31	8.56 ^{a,x} ± 0.20
	>70 cm ²	8.44 ± 0.28	8.46 ± 0.23	8.49 ± 0.23

^{a,b} indicate statistically significant differences between levels of measurement, at $P \leq 0.05$. ^{A,B} indicate statistically highly significant differences between levels of measurement, at $P \leq 0.01$. ^{x,y} indicate statistically significant differences between genotypes, at $P \leq 0.05$. ^{X,Y} indicate statistically highly significant differences between genotypes, at $P \leq 0.01$. L - Landrace, LW - Large White, L × LW - Landrace × Large White; BF₁ - backfat thickness measured at the last rib, 3 cm from the midline of the spine; BF₂ - backfat thickness measured at the last rib, 8 cm from the midline of the spine; BFA - cross-sectional area of fat on the surface of the LD muscle; HLD - height of the LD muscle; WLD - width of the LD muscle; LDA - cross-sectional area of the LD muscle.

Discussion

The effect of fatness and muscularity on the reproductive performance parameters of sows is often indicated in the literature (Zhang *et al.*, 2000; Holm *et al.*, 2004; Čechova and Tvrdoň, 2006; Mijatović *et al.*, 2009; Szulc *et al.*, 2013), but there is not enough data, which discusses whether and how these parameters measured during the first insemination affect the reproductive indicators of gilts.

Body weight of gilts were not analysed because according to the studies relating to the dissection of pig carcasses, more reliable indicator is the analysis of individual parameters of muscle and fat. Due to differences in anatomical structure, carcasses with the same weight may differ in dimensions of fat and muscle or tissues composition (Marcoux *et al.*, 2007; Duziński *et al.*, 2015; Knecht and Duziński, 2016). Additionally, average body weight among genotypes was similar, with no statistically proven differences ($P > 0.05$).

In our study, we have shown both that the reproductive performance of gilts is significantly affected by the fatness degree during insemination, and that the level of muscularity has no such great significance (except for the hybrid gilts). The increase in the degree of fatness and additionally in the case of gilts [L × LW] the level of muscularity during the first insemination may determine the improvement of reproductive indicators. The highest number of piglets born alive and weaned has been reported in gilts with the thickest backfat ($BF_1 > 25$ mm, $BF_2 > 20$ mm). It is partially connected with control of proper ovulation (Gonçalves *et al.*, 2012). However, Matysiak *et al.* (2010) found that the number of piglets born alive and weaning are positively correlated with the thickness of backfat respectively $r = 0.31$ and $r = 0.24$, which means that gilts with thicker backfat bore more piglets and weaned a higher number of piglets; and this was also observed in our study. These results may explain the two processes related to the metabolism of gilts, namely anabolism and catabolism. Holm *et al.* (2004) note that when energy stores are too low (gilts characterised by a lower degree of fatness during the first insemination), the development and implantation of the embryos in the uterus may not function properly, resulting in an increase in the number of embryos that experience resorption in the uterus, and as a result this contributes to a reduced number of piglets born alive. Vanroose *et al.* (2000) presented other factors that influence the resorption of embryos, such as viral infections, stress, poor nutrition or reproductive seasonality.

The lowest piglets birth weights were listed in gilts which were characterised by the lowest backfat thickness during insemination ($BF_1 < 20$ mm, $BF_2 < 15$ mm). It should be noted that a lower degree of gilt fatness during insemination may impair the development of the fetus and exert a deleterious influence on their growth. It may also affect the lower weight of the piglets at birth, which probably contributed to the worse performance of our reproductive values in this regard. Roehe (1999), Milligan *et al.* (2002), Wolf *et al.* (2008) stress that low

body weight at birth is accompanied by a rise in the number of piglets born dead and an increased number of falls during rearing, which is associated with the great physiological effort demanded of gilt organism. During this period the process called catabolism is in effect, during which the stocks of energy previously stored in the form of body fat are released. Zak *et al.* (1998) emphasized that the metabolism of gilts, set for a long period of gestation for the deposition of energy reserves, encounters problems associated with switching in a very short period of time to use all the ingredients of feed for milk production. As a result, gilts retrieving the feed continue to use the feed for stock collection and use fat reserves as a source of components necessary for the production of milk. Rozeboom *et al.* (1996) suggested that the weaker pregnancy anabolism probably slows lactation in sows, which may result in the reduction of the number of piglets weaned, as a result of the insufficient production of milk. Holm *et al.* (2004) found that the backfat thickness, which is considered a source of energy for sows, may also have an important role in the subsequent reproductive cycles.

Szulc *et al.* (2013) reported that very high levels of gilt fatness during mating/insemination can lead to hormonal disorders in young females. In the case of that study, the authors noted that the gilts with the thickest dorsal backfat (>15 mm) bore the least alive piglets. The authors explained their results via the characteristic transformation of estradiol to estriol, a weaker estrogen that occurs in more obese females. In our study we observed the opposite effect. Gilts that had the highest backfat thickness at both points bore and weaned more piglets with very high weight at birth and weaning. Similar results were obtained in the study of Tummaruk *et al.* (2001).

Many authors have confirmed a very strong positive correlation between the backfat thickness, and litter size (Čechova and Buchta, 1995; Karsten *et al.*, 2000; Chen *et al.*, 2003). Our studies confirm that gilts with a higher backfat thickness at the time of insemination may bore more piglets, characterised by a higher weight at birth. A similar trend is also observed for the analysis of fat on the surface of the LD muscle, except that in the case of L and LW purebred gilts in order to obtain satisfactory reproductive results the insemination treatment can be carried out at BFA greater than 20 cm². Kawecka *et al.* (2009) found a significant inverse relationship between the meatiness of gilts and their subsequent reproductive performance during the next three parities, which means that too large a degree of muscularity aggravates the reproduction indicators. In the case of our study an increase in the degree of muscularity as regards parameters HLD, WLD and LDA resulted in improved reproductive performance indicators, but only for hybrid gilts [L × LW].

The observed results may be related to the occurrence of heterosis. Hybrid gilts [L × LW] are characterised by the greatest degree of fatness and muscularity and achieve better results in a range of reproductive parameters, which according to Nowachowicz *et al.* (2009) can be explained by the



predominance of the hybrids of the first generation over the phenotypic values of their parents. In livestock, the advantage of first generation hybrid mean values for phenotypic characteristics over those of the parents is important and this difference can be as high as 15%. Zhang *et al.* (2000) noted that in the second generation obtained from mating animals of the first generation the heterosis effect is significantly reduced as a result of a definitely weaker interaction of genes. Slightly worse performance in hybrid gilts was demonstrated in the research published by Matysiak *et al.* (2010).

Our results clearly show that an appropriate level of gilt fatness during insemination can contribute to significant improvements in the efficiency of piglet production. In order to increase the number of piglets born alive, the number of piglets at weaning and the weights in these periods, it is recommended that insemination of L, LW and [L × LW] gilts should occur, when: backfat thickness measured behind the last rib 3 cm from the midline of the spine exceeds 25 mm; backfat thickness measured 8 cm from the midline of the spine exceeds 20 mm. Additionally, insemination of gilts with the genotype [L × LW] should occur when the amount of LD muscle exceeds 60 mm, the width of the muscle is greater than 135 mm, and its surface is greater than 70 cm².

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