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The effect of backfat thickness determined *in vivo* in breeding gilts on their reproductive performance and longevity

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The aim of this study was to determine the effects of backfat thickness (mean standardised measurement from *in vivo* assessment) of Polish Large White (PLW) gilts on their reproductive performance and productive lifespan. The study included 5,122 PLW gilts from 160 breeding herds in Poland, which reproductive performance was analysed on the basis of the rearing results of 20,662 litters. The gilts were divided into two groups differing in mean standardised backfat thickness (P2+P4/2) on the performance test day: I≤10 mm, II>10 mm. Sows in group I vs II had a three month shorter herd life (P≤0.001), gave birth to fewer litters and piglets (P≤0.001), but the average number of piglets born alive and reared to 21 days of age/litter was higher in them (P≤0.001). The number of live-born piglets per 100 days of reproductive life in group I was greater than in group II (P≤0.001). When culling sows in cycles 1–8 and later, there was more intensive culling in group I vs II from cycle 1 to 6 and a lower percentage of sows remaining in the herd. In group I vs II, the proportion of sows with a lifetime productivity of fewer than 30 piglets was 5.5 percentage points higher and that with a production of more than 100 piglets was 1.9 percentage points lower. Our results indicate that the level of fat reserves determined in vivo in breeding gilts can be a preliminary information about the reproductive potential of sows and their predisposition to longevity.

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The results of research initiated in the 1970s by Young *et al*. [1976] indicate that there are negative genetic correlations between reproductive traits and fattening and slaughter traits. Holm *et al.* [2004] showed genetic correlations close to zero between backfat thickness and reproductive traits. In a study by Imboont *et al.* [2007], the genetic and phenotypic correlations for backfat thickness and number of live-born piglets in Landrace sows over parity 2 and later parities were negative, suggesting that selection for reduced backfat thickness results in a decrease in the number of live-born piglets. A study by Szulc *et al*. [2013] shows that traits characterising fattening and slaughter value of sows are not antagonistic to their reproductive value. Analysing the effect of slaughter traits (backfat thickness, loin eye height, meatiness) determined in vivo and daily gains on the reproductive performance of primiparous and multiparous sows (parity 2) of the Polish Large White breed, the authors found that improvements in slaughter and fattening traits did not negatively affect reproductive traits of sows in the first and second reproductive cycle. Sows with the highest meatiness, i.e. above 60%, and a loin eye height above 60 mm produced the largest number of live piglets per litter. However, it should be noted that sows with the thickest backfat (>15 mm) produced the smallest litters.

Mijatovič *et al*. [2009] emphasised that the reproductive traits of Swedish Landrace primiparous sows, such as the age at first mating and the number of live piglets born per litter and the total number of piglets born, are dependent on the average lifetime daily gain, but not on backfat thickness and lean meat content assessed in vivo. According to the cited researchers, there is no clear evidence of a reduction in reproductive traits with intense selection pressure on backfat thickness or lean meat content. However, in the opinion of Bečková *et al*. [2005] backfat thickness and meatiness on the day of first mating are important and should be assessed when introducing young gilts into reproduction. Serenius *et al.* [2006] found that backfat thickness in gilts is a key determinant of success with the first litter born and to some extent determines the length of the female's productive life. According to the authors, the factors that have a decisive influence on the reproductive longevity of sows are the feed intake of the sow and the loss of fat reserves during lactation. Many more factors affecting reproductive longevity and reproductive performance of sows were mentioned by Koketsu *et al.* [2017] and Patterson and Foxcroft [2019]. Among these there are both sow-level and herd-level factors.

Selection for reduced pig fatness resulted in an increase in meat yield from 56.9 to 59.4% in PLW gilts between 2000 and 2019 [Blicharski *et al*. 2008, PZHiPTCh, 2020]. According to Roongsitthichai *et al.* [2011], better piglet rearing performance can be expected in gilts with thicker backfat and lower meatiness at the start of reproduction, but this does not mean that fat reserves should be very high. According to Kummer [2008] and Flisar *et al*. [2012], the proper body condition of sows at first mating manifested in adequate backfat thickness and body weight prevents problems in reproduction.

The results of a number of studies clearly show the validity of reproductive use of gilts with optimal fat reserves (backfat thickness). Overfatness – excessive fat reserves expressed in terms of backfat thickness, reduces the appetite of lactating sows. This results in reduced feed intake and greater loss of lipid reserves from the body during lactation, a longer period from weaning to the onset of oestrus after weaning of piglets, a decrease in the conception rate, an increase in the stillbirth rate at the next farrowing, a decrease in the number of piglets born alive and piglets reared, increased susceptibility to stress and a deterioration in female health [de Rensis *et al.* 2005, Lewis and Bunter 2011], which leads to their premature culling from the herd [Roongsitthichai *et al*. 2013, Wientjes *et al.* 2013, Rekiel and Więcek 2018]. Nguyen *et al*. [2004] demonstrated the negative effect of selection for improved growth rate and meatiness [reduced fatness] on body constitution traits, especially limb weakness, and reduced appetite. Culling due to weak limbs is more costly than due to other causes, because it occurs earliest. Gill [2007] reported that premature culling of sows, mainly due to reproductive problems and lameness, remains a major obstacle in determining the potential lifetime productivity of gilts. According to Sobczyńska and Blicharski [2015], a majority of sows in Polish commercial herds are generally culled after the birth of the third or fourth litter. Most culls are unplanned and the main cause is reproductive disorders or locomotive problems.

Hewitt and van Barneveld [2008] estimated that the lifetime reproductive potential of a sow is 80-90 piglets, while Sobczyńska *et al*. [2013] reported that the number of piglets reared from a Polish sow of a maternal breed is only 30-40. According to Gill [2007], a sow lifetime productivity of 30 to 40 piglets is the norm and few females give birth to and rear 60 piglets or more. Probably the reason for such low utilisation of the reproductive potential of sows is, among other things, low actual fertility and/or a short reproductive lifespan [Gill, 2007, Sobczyńska *et al*. 2013]. For production to reach the break-even point a sow should give birth to and rear three to four litters in her lifetime [Stalder 2020].

Reproductive longevity of sows and reproductive performance from individual litters are very complex traits that depend on many factors [Koketsu *et al*. 2017, Koketsu and Iida 2020]. Because the results of studies on the effect of gilt fatness on the length of their reproductive life and the reproductive performance obtained in individual litters are inconclusive, it was decided to analyse the above-mentioned relationships on extensive research material. Not all farms in Poland monitor the body fat reserves of females, but all breeding gilts in the country are performance tested at the age of about 180 days, i.e. approximately 2 months before the first mating. If the above-mentioned correlations occurred, the information on backfat thickness obtained during the performance testing could be preliminary information on the reproductive potential of the sow and her predisposition to longevity, which could be used by breeders in the management of the reproductive sector.

The aim of this study was to determine the effects of backfat thickness (mean standardised measurement from in vivo assessment) of Polish Large White gilts on their reproductive performance and productive lifespan.

Material and methods

Data on 5,122 Polish Large White (PLW) sows from 160 breeding herds [ranging from 8 to 120 head] in Poland were studied. Lifetime reproductive performance of the sows mated by purebred PLW boars was analysed from the date of first farrowing (2007-2009) to the date of removal from the herd. A total of 20,662 purebred litters were analysed (parities 1-15), the last farrowing was in 2017. Data were provided by the Polish Pig Breeders and Producers Association POLSUS. The animals were subjected to in vivo assessment at the age of 150-210 days according to the methodology approved in Poland, using a PIGLOG 105 ultrasound apparatus on the right side of the animal [Eckert and Żak 2011]. The following fattening and slaughter traits were determined: body weight of animals on the day of assessment (kg), backfat thickness at points P2 and P4 [mm], and loin eye height (mm). Backfat thickness at points P2 and P4 is standardised for 110 kg of body weight according to the formula:

$$P_2st = 15.15084\ P_2/(0.112345Z + 2.79289)$$

$$P_4st = 14.32432\ P_4/(0.100311Z + 3.29011)$$

where:

P_2st – backfat thickness measured in point P_2 standardised for 110 kg of body weight (mm);

P_4st – backfat thickness measured in point P_4 standardised for 110 kg of body weight (mm);

P_2 – backfat thickness measured 3 cm away from the mid-line behind the last rib (mm);

P_4 – backfat thickness measured 8 cm away from the mid-line behind the last rib (mm);

Z – body weight of the animal on the day of measurement (kg).

The animals with extreme values for the age at first farrowing (≥550 days) or with missing parity were excluded. In terms of breeding performance of sows the following were taken into account: age at first farrowing, age at culling, longevity [according to Engblom et al. 2008, from the birth of the first litter to culling from the herd], number of litters and piglets born alive to a sow during reproductive life, mean number of piglets born alive per litter, and breeding herd efficiency, which shows the number of piglets born alive to the sow over 100 days of productive life. Depending on the average standardised backfat thickness from two measurements (at points P2 and P4), data were divided into two groups: I≤10 and II>10 mm. The reproductive performance was analysed using a mixed linear model:

$$y_{ijkl} = \mu + a_i + b_j + c_k + e_{ijkl}$$

where:

µ – the overall mean;

a_i – the fixed effect of *i*-th group (i= 1, 2);

b_j – the fixed effect of *j*-th herd (j= 1, 2…160);

c_k – the fixed effect of k-th year of birth of the first litter (*k*= 2007, 2008, 2009);

e_{ijkl} – the random error.

The difference between the groups was considered statistically significant when P<0.05. These computations were performed using the IBM SPSS 2020 Statistics 27 software package.

Results and discussion

Females differing in their fat reserves (group I vs II) farrowed for the first time at similar ages (Tab. 1), but sows in group II vs I were used 94 days longer (P≤0.001). Sows with a thinner backfat layer (group I) and a shorter reproductive lifespan gave birth to 0.4 fewer litters than sows in group II (P≤0.001), while the number of piglets born alive and reared to day 21 over their productive life was 2.8 and 2.8 fewer, respectively (P≤0.001). The primiparous sows of group I compared to the first farrowing females of group II gave birth to and reared to day 21 more piglets per litter, by 0.4 and 0.5 piglets, respectively (P≤0.001). The mean number (from all litters in a female's lifetime) of piglets born alive and reared to 21 days of age in a litter of sows

Table 1. Reproductive performance

Parameter	Groups		SE	P-value
	I	II		
	≤10	>10		
Sow (n)	2425	2697		
Age at first farrowing (days)	351	351	0.43	0.994
Age at culling (days)	979	1073	6.38	0.001
Length of productive life (days)	628	722	6.37	0.001
Productive life – litters	3.9	4.3	0.04	0.001
Productive life – piglets born alive (head)	45.9	48.7	0.45	0.001
Productive life – piglets reared to day 21st of life (head)	42.7	45.5	0.42	0.001
Pigs per litter				
liveborn at first litter (head)	11.2	10.8	0.02	0.001
reared to day 21st of life at first litter (head)	10.6	10.1	0.02	0.001
liveborn mean for all litters (head)	11.6	11.3	0.02	0.001
reared to day 21st of life mean for all litters (head)	10.9	10.5	0.02	0.001
breeding herd efficiency*	7.3	6.7	0.02	0.001

*Liveborn pigs per 100 days in production.

with thinner backfat, compared to females with thicker backfat, was greater by 0.3 and 0.4 piglets, respectively ($P \leq 0.001$). The breeding herd efficiency in group I vs II was higher by 0.6 ($P \leq 0.001$).

In groups I and II, as a result of sow culling, the percentage of females remaining in the herd was lower from cycle to cycle (Tab. 2), but culling was greater in group I vs II starting from cycle one up to and including cycle five. After the end of the first cycle, the number of sows decreased in group I by 21.7% and in group II by 19.3%. Significantly more sows made it to cycle 6 in group II than in group I.

The percentage of sows with a lifetime performance of fewer than 30 piglets was higher in group I vs II by 5.5 percentage points, while the percentage of sows with a productivity of more than 60 piglets was lower by 3.6 percentage points. The percentage of sows with lifetime productivity exceeding 100 piglets was small (about 10%) in both study groups, but at the same time smaller in group I vs II by 1.9 percentage points (Tab. 3).

Table 2. Percentage of sows in each group, which have given birth to further parity

Litter	Groups	
	I (n=2425)	II (n=2697)
	standardised backfat thickness at point $(P_2 + P_4)/2$	
	≤10	>10
1	100	100
2	78.3	80.7
3	62.6	65.6
4	48.4	53.2
5	35.6	41.7
6	24.1	31.2
7	16.0	22.0
8 and more	10.0	14.7

Table 3. Percentage of sows that produced a certain number of piglets during their productive lifetime

No. of piglets	Groups	
	I (n=2425)	II (n=2697)
	standardised backfat thickness at point $(P_2 + P_4)/2$	
	≤10	>10
<30	51.3	45.8
>60	39.7	43.3
Including >100	9.0	10.9

The results of our own study confirm the findings of Čechová and Tvrdoň [2006], who showed that sows with a lower percentage of body fat were used in the herd for a shorter period than females with greater lipid reserves. According to Hoge and Bates [2011], long lifetime production and low culling rates in pig herds have significant economic benefits, as the cost of replacing sows in the herd is reduced and, at the same time, there are more mature sows in the herd that have reached maximum productivity. Sows increase their reproductive capacity with age, so it is not economical and reasonable to remove them from the herd too early [Sobczyńska 2014].

However, according to Čechová and Tvrdoň [2006] fatter sows are not always characterised by higher fertility. Our own research showed a correlation between backfat thickness in gilts and the average number of piglets born alive and reared in a litter by primiparas and primiparas and multiparas jointly over the entire productive period; the results were significantly better in leaner females with lower lipid reserves. In a study by Rekiel and Więcek [2002], backfat thickness measured at point P2 at the first mating, irrespective of the productive lifespan of the sows, i.e. one, two or three cycles, had no significant effect either on the studied reproductive indices of the sows – number of piglets and number of days open, or on the production results of the litters – body weight and number of piglets at 21 days of age. The results reported by Tummaruk *et al*. [2009], Amaral Filha *et al*. [2010] and Radović *et al.* [2019] on the basis of their studies, which included sows of different genotypes, are similar – the total number of piglets obtained from sows with different fat reserves was similar.

The results of our own study correspond with the results of the analysis presented by Ptak [2013] for sows of the maternal Polish Landrace (PL) breed. In the latter study sows of the PL breed from herds, where the average backfat thickness of the assessed gilts was less than 10.4 mm, gave birth to and reared more piglets in four consecutive litters, while sows from herds with the average value of this trait exceeding 11.58 mm gave smaller litters ($P \leq 0.01$). In the opinion of Ptak, it is difficult to estimate separately the effect of genotype and environment on sow reproductive performance on the basis of the results obtained. However, that author concluded that reproductive performance of sows increases with better environmental conditions in the herd, especially nutrition, and is the result of having and using genetically valuable material.

Lavery *et al.* [2019] emphasised the need in modern herds to monitor the body weight of sows and their backfat thickness in successive production cycles as potential indicators of productivity; such an action should be considered fully justified. According to Hu *et al*. [2016], body weight, age at first mating and backfat thickness influence the longevity of sows, therefore those authors recommended mating young gilts with backfat thickness of about 18 mm for Yorkshire pigs and 10.6-13 mm for Landrace pigs.

Čechova and Tvrdoň [2006] showed that gilts with the thickest backfat at 90 kg gave birth to the largest litters. Grzyb *et al.* [2007] when analysing reproductive performance of sows depending on backfat thickness assessed in vivo at P2 also noted the highest number of piglets born and reared to 21 days in the first litter for sows with the thickest backfat. The smallest number of piglets were born by sows in the group with the medium backfat thickness and reared by sows in the group with the thinnest backfat. However, considering all litters born by the sow in the analysis, the cited authors found that the best results in terms of the number of piglets born and reared in a litter were obtained by sows with the thinnest backfat, which corresponds to the results of our research. On the other hand, when analysing lifetime productivity in our own study, a higher number of piglets born alive and piglets reared to 21 days was noted in sows from group II vs I, with a simultaneous better performance efficiency index in group I vs II, i.e. in the group of females with lower body fat reserves.

Stalder *et al*. [2005] found that sows that had a backfat thickness >25 mm on the day of first parturition gave birth to smallest litters, but stayed in the herd the longest. According to Roongsitthichai and Tummaruk [2014], in order to achieve good reproductive performance in older sows, replacement gilts should have a backfat thickness of 18-23 mm at first insemination, while fat reserves should be monitored during productive life to prevent excessive fat loss. Fernández de Sevilla *et al*. [2008] reported a backfat thickness range at the end of the growth period of Duroc gilts at 16 to 19 mm as the optimum range. Sows with a backfat thickness of more than 19 mm showed a higher risk of culling due to poor reproductive performance. These studies show that in order to optimise sow longevity, backfat thickness must be monitored at the end of the growth period, avoiding values not only below 16 mm, but also greater than 19 mm. According to Serenius *et al.* [2006], an important element in ensuring a long productive life for sows is monitor parameters that positively influence their appetite and feed intake, because feed intake and fat tissue loss during lactation are the main factors associated with sow longevity. The differences between pig lines in the study by Serenius *et al.* [2006] also indicate the possibility of selecting sows for longevity, but according to the cited researchers more experiments are needed to determine optimal methods to improve this trait. The work of Stalder [2020] shows that the heritability of sow longevity, as estimated by different research teams, ranges from 0.05 to 0.35. On this basis, it can therefore be assumed that selection for functional longevity would be effective. However, Engblom *et al.* [2008] emphasised that intensive selection for productive and reproductive traits without consideration for functional traits may lead to reduced longevity in sows. Gill [2007] proposed that the focus should be shifted from fatness to the concept of fitness, which includes feeding and managing gilts and young sows for condition and healthy legs. According to many authors, the risk of early culling from the herd, resulting in reduced longevity of sows, is higher with poor leg condition [Poczta *et al*. 2009, Nikkila *et al*. 2013, Supakorn *et al*. 2018].

In our study, females from group I gave birth to and reared larger litters than sows from group II, but their lifetime productivity was lower, which is consistent with the results of a study by Sobczyńska [2014], who concluded that by selecting gilts with a very high performance test index (i.e. fast growth, high meatiness, thin backfat) as future mothers, we can expect very good reproductive performance in individual litters, but a short reproductive lifespan of the sows. This is uneconomical, because according to a study by Stalder *et al*. [2003] the costs of raising and keeping a gilt are paid back after she has given birth to 3-4 litters. Increased body weight of young females at reproductive maturity is associated with their greater housing requirements [McGlone *et al*. 2004], while reduced backfat thickness results in lower tolerance to nutritional deficiencies, environmental and housing changes. As a result of higher meatiness and lower fat reserves, sows' body condition deteriorates [Young and Aherne 2005, Rekiel and Więcek 2018]. Females used intensively for reproduction have greater nutritional requirements, their body is more stressed during lactation, whereas floor housing promotes injury to large sows that are leaner. The culling rate of these sows is higher, as observed in our study. This is due to a mismatch between the genetic potential of sows with smaller fat reserves – thinner backfat – and the environmental conditions compared to smaller, more fattened sows, thus more tolerant to such deficiencies. Our own results regarding the percentage of sows rearing fewer than 30 and more than 60 piglets support the selection of gilts with greater fat reserves for reproduction when assessed in vivo at around 180 days of age. The importance of early prediction of the reproductive potential of sows, based on the results obtained from the breeding work carried out, is important in terms of deciding whether to include young females in reproduction [Matoušek *et al*. 2011]. Objective measurement of the fat reserve in females should be considered fully justified [Běcková *et al*. 2005, Matoušek *et al.* 2011]. It should be carried out and used not only to determine the productive traits of gilts reared in the breeding herd as part of the performance test, but also to continue measuring and assessing the fat reserve of females at first mating, during gestation and at weaning of piglets. This will allow feeding to be programmed in order to maintain acceptable body condition scores in different physiological periods. It is necessary to constantly monitor and optimise the condition of the sows during their productive life through nutrition, as this is a fundamental factor in guaranteeing good reproductive performance of the sows and their reproductive longevity. It should also be remembered that the length of a sow's productive life is not only an economic issue, but is closely linked to her welfare [Hoge and Bates 2011]. The production persistency of sows and their fertility in successive litters should be analysed jointly, because the key to improve overall herd efficiency is to simultaneously increase the productive life of the sows in the herd and the number of piglets reared from each litter [Stalder *et al.* 2004].

Conclusion

On the basis of the conducted research, it may be concluded that information on the level of fat reserves determined in the performance test of young breeding gilts can provide preliminary information on the reproductive potential of sows and their predisposition to longevity. This knowledge should be used in the selection of replacement gilts in order to optimally match the gilt potential to the environmental conditions of the farm.

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