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INFLUENCE OF LITTER SIZE INTO WHICH GILTS ARE BORN ON THE DEVELOPMENT OF THEIR REPRODUCTIVE SYSTEMS

H. Jankowiak*, W. Kapelański and M. Bocian

Department of Animal Breeding, Faculty of Animal Breeding and Biology, UTP University of Science and Technology in Bydgoszcz, Poland.

*Corresponding author: jankowiak@utp.edu.pl

ABSTRACT

The aim of the study was to determine the relation between the morphometric characteristic of reproductive system of gilts and the litter size into which they are born. The research was conducted on 100 Polish Large White (PLW) gilts and 100 Polish Landrace (PL) gilts. The reproductive system was tested in respect to: uterine weight, cervical length, uterine horns length, intrauterine capacity, length of oviducts, ovarian weight and volume. The gilts were divided into 3 groups depending on the number of their siblings: below 11 piglets (group I), from 12 to 13 (group II), and more than 13 piglets (group III). The ratio between the weight of the uterus excluding the ligament and the length of its horns was significantly higher in gilts from the smallest litters. The uterine capacity was higher in PLW gilts than in PL gilts ($P \leq 0.05$). Both oviducts were longer in gilts of both breeds born in group I in comparison to group II. At the same time, PLW gilts from the largest litters also displayed significantly longer oviducts in the medium-sized litters group. In conclusion, these studies showed no negative effect of the litter size from which a gilt comes on her reproductive abilities.

Key words: gilts, fertility, pig production, reproduction.

INTRODUCTION

The insufficient capacity of the uterus limits the effectiveness of reproduction and increases the disproportion between the rate of ovulation and the number of piglets born per litter. According to Foxcroft *et al.* (2006), the prenatal losses of embryos (up to the 30^{th} day of gestation) and fetuses (after the 30^{th} day of gestation) may amount to 40–60 % of the fertilized eggs. These losses are caused by the inability of the uterus to provide adequate nutrition and free space for the embryos. For the fetus to develop fully, an appropriate uterus size is required (Chen and Dziuk, 1993; Wu and Dziuk, 1995; Fischer *et al.*, 2009). The genetic relationships between pig breeds and litter sizes are also important. A comparison of high fertility Meishan pigs as compared to less-prolific European pigs enhance the specific role of uterine space, uterine capacity, surface and number of villuses and weight of placenta in determining the fetal growth and litter size (Wähner and Fischer, 2005; Fischer *et al.*, 2005). Also the condition of umbilical cord providing on optimal blood supply to fetuses is substantial criterion for birth weight and vitality of piglets (Fischer *et al.*, 2005).

The selection for enlarge the capacity of the uterus and increase the number of piglets born (Johnson *et al.*, 1999) not always is profitable. Many piglets in a litter may be unevenly developed due to intrauterine crowding, which can lead to underweight or cachectic piglets (Foxcroft *et al.*, 2006; Wu *et al.*, 2014). The effects of intrauterine environmental conditions affect further stages of postnatal life and ultimately determine the functional value of pigs and their reproductive performance. There is also no clear opinion concerning whether gilts are best selected for breeding from the largest or smallest litters (Holl and Robison, 2003; Rekiel *et al.*, 2013).

It seems that determining the morphometrical development of the reproductive system of gilts just before reaching the state of sexual maturity and linking these data to the size of litters from which gilts come could shed light on the relationship between the size of the litter and the potential reproductive ability of gilts. The assessment of these relations is the aim of this work.

MATERIALS AND METHODS

Animals: The research was conducted at a Pig Testing Station (Polish abbreviation, "SKURTCh") on 100 Polish Large White (PLW) gilts and 100 Polish Landrace (PL) gilts. The choice of gilts for the research and the housing and feeding conditions were consistent with the methodology in force at the SKURTCh (Różycki and Tyra, 2010). The tested gilts from each breed were the offspring of 50 sows and 25 boars.

When the gilts had attained a body weight of approx. 100 kg ± 0.6 kg, they were slaughtered and their complete reproductive systems were collected for testing. 24 hours after slaughter, measurements of fatness and musculature were conducted on the cold carcasses. The experimental procedures were approved by the Local Ethics Committee (No 21/2008).

The removed reproductive systems of the tested gilts were evaluated with respect to uterus weight with and without broad ligament, length of uterine cervix and horns (left and right), length of oviducts, and weight and volume of ovaries. The capacity of the uterus was also determined volumetrically according to the methodology described by Kapelański *et al*. (2013). The proportion between the weight of the uterus without the broad ligament and the length of both horns of the uterine were calculated (g/cm).

The fattening characteristics of the assessed gilts were also evaluated: the slaughter age, daily gain, feed conversion, slaughter characteristics, 5 measurements of average backfat thickness, and the percentage of meat on the carcass.

The reproductive performance of mothers was evaluated in terms of the number of their offspring on the 1st and 21st day of life, the number of young boars and gilts on the 21st day of life, and their mortality during rearing.

The obtained results were compiled and analyzed in three groups: Group I contained gilts from litters with fewer than 11 piglets (24 mothers and 48 daughters). Group II was gilts from litters of 12 to 13 piglets (43 mothers and 86 of their daughters). Group III contained gilts from litters of 14 and more piglets (33 mothers and 66 daughters). The tested gilts were from first litters (32 %) and successive litters (68 %). Only 16 PLW gilts and 14 PL gilts in group I came from first litters, the other 18 gilts from this group were born in successive litters.

Statistical analysis: The obtained research results were statistically described. The arithmetic mean and the standard deviation were calculated. In order to compare the characteristics of the reproductive performance of mothers with the assessment of morphometric characteristics of the reproductive system of daughters (gilts), a two-way analysis of variance was conducted according to the following formula:

$$Y_{ijk} = \mu + m_i + w_j + e_{ijk}$$

where:

Y_{ijk} – value of characteristic ijk- of its specimen (sow);

μ – overall mean;

m_i – constant effect i – of its number of gilt litter number (i = I, II, III),

where: I - ≤ 11 piglets, II - 12-13 piglets, III - ≥ 14 piglets per litter;

w_j – constant effect j- of sows' breed (j = 1, 2), where: 1 – PLW, 2 – PL;

e_{ijk} – random error.

For the developed groups from the division of research material, the least squares method of the GLM procedure in the Statistica 8.0 PL (2008) package was used.

RESULTS

The presented data relate to a detailed analysis of two randomly selected gilts from each litter. Table 1 shows the characteristics of the 50 PLW litters and the 50 PL litters from which the tested gilts came. The smallest litters (group I) with fewer than 11 piglets contained 11 PLW and 13 PL. Average litters (group II) from 12 to 14 piglets contained 24 PLW and 19 PL. The biggest litters (group III) with over 14 piglets contained 15 PLW and 18 PL. There were significantly fewer PL piglets in the first and 21st day of life in group I than PLW ($P≤0.01$ and $P≤0.05$). In PLW and PL litters, definitely more gilts than boars reached the 21st day of life, regardless of the number of piglets per litter. The percentage of gilts in litters on average ranged from 53.14 % to 58.44 %. The mortality from birth to the 21st day of life was significantly related to the size of the litter: from 3.02 % in small litters up to 11 % in the largest ones.

The fattening and slaughter values of the tested gilts in relation to litter size are shown in Table 2. The age of obtaining 100 kg of body weight was very similar in all gilts and was not related to litter size. PLW gilts from the largest litters reached slaughtering age about 10 days later than the PL gilts ($P≤0.01$). Similarly, daily weight gains during the fattening period were lower in these gilts ($P≤0.05$). The conversion of feed, assessed as the amount of consumed feed per kg of gain, was most profitable in gilts of both breeds from medium-sized litters ($P≤0.05$). The slaughter value assessed by the average backfat thickness and by the percentage of meat on the carcass was very similar within the compared groups. A significantly thicker fat cover was found only in PLW gilts born in the smallest litters ($P≤0.05$). The meat content on a carcass did not significantly differ according to the size of the litter and in all groups ranged from 59 to 61 %.

The size of the uterus in gilts of both breeds (Table 3), determined by its weight with and without the broad ligament, did not show significant differences related to litter size. The same was true of the length of the cervix and the total length of both uterine horns. The ratio between the weight of the uterus without the ligament and the length of its horns, determined by approximately the thickness of the wall of the uterus, was significantly higher in gilts from the smallest litters ($P≤0.05$). Similarly, the capacity of the uterus in terms of the inner space of the organ in PL gilts vs. PLW gilts was highest in those born in the smallest litters ($P≤0.05$).

Table 4 shows the development state of oviducts and the ovaries of the examined gilts. Both oviducts were slightly longer in gilts of both breeds born in the smallest litters in comparison to medium-sized litters ($P≤0.05$). At the same time, PLW gilts from the largest litters also demonstrated significantly longer oviducts than those from the medium-sized litters group ($P≤0.05$). The observed differences do not indicate a systematic relationship between the size of the oviducts and litter size. They also did not show significant differences concerning the weight and volume of the ovaries in the compared groups of gilts.

Table 1. The characteristics of litters from derived the tested gilts.

Trait	Breed	Number of piglets in litter (n)		
		I ≤ 11	II 12-13	III ≥ 14
Number of sows (n)	PLW	11	24	15
	PL	13	19	18
Total		24	43	33
Av. number of alive piglets born (n)	PLW	$10.91^{AX} \pm 0.29$	$12.42^{B} \pm 0.50$	$14.73^{C} \pm 0.87$
	PL	$10.38^{AY} \pm 0.64$	$12.42^{B} \pm 0.50$	$14.72^{C} \pm 1.75$
Average		$10.62^{A} \pm 0.57$	$12.42^{B} \pm 0.50$	$14.73^{C} \pm 1.41$
Av. number of piglets reared until 21st day (n)	PLW	$10.54^{Ax} \pm 0.67$	$11.62^{B} \pm 0.87$	$13.13^{C} \pm 0.73$
	PL	$10.08^{Ay} \pm 0.84$	$11.79^{B} \pm 0.70$	$13.00^{C} \pm 0.96$
Average		$10.29^{A} \pm 0.80$	$11.70^{B} \pm 0.80$	$13.06^{C} \pm 0.86$
Number of boars at 21st day (%)	PLW	45.73	41.57	48.74
	PL	41.97	41.56	45.31
Average		43.73	41.56	46.86
Number of gilts at 21st day (%)	PLW	54.36	58.43	51.26
	PL	58.03	58.44	54.69
Average		56.27	58.44	53.14
Mortality piglets of from 1st to 21st day (%)	PLW	3.30	6.38	10.65
	PL	3.02	5.03	11.20
Average		3.15	5.78	10.95

PLW- Polish Large White, PL- Polish Landrace
$^{A, B, C}$ - values in rows with different letters differ significantly ($P \leq 0.01$)
$^{X, Y}$ and $^{x, y}$ - values in columns with different letters differ significantly ($P \leq 0.01$) and ($P \leq 0.05$)

Table 2. The characteristics of the fattening and slaughter value of gilts.

Trait	Breed	Number of piglets in litter (n)		
		I ≤ 11	II 12-13	III ≥ 14
Number (n)	PLW	22	48	30
	PL	26	38	36
Total		48	86	66
Age at slaughter (days)	PLW	167.77 ± 22.21	169.06 ± 15.37	$177.50^{X} \pm 17.79$
	PL	169.00 ± 21.45	165.87 ± 18.21	$164.17^{Y} \pm 15.38$
Average		168.44 ± 21.58	167.65 ± 16.66	170.23 ± 17.70
Daily gains (g/day)	PLW	$948^{a} \pm 105$	$940^{a} \pm 117$	$878^{bx} \pm 105$
	PL	929 ± 127	948 ± 131	$953^{y} \pm 148$
Average		938 ± 117	944 ± 123	919 ± 134
Feed efficiency (kg/kg)	PLW	2.68 ± 0.48	$2.59^{x} \pm 0.36$	2.65 ± 0.36
	PL	$2.64^{a} \pm 0.41$	$2.44b^{y} \pm 0.29$	2.55 ± 0.39
Average		$2.66^{a} \pm 0.44$	$2.52^{b} \pm 0.34$	2.60 ± 0.38
Av. back fat thickness measured at five points (mm)	PLW	$15.66^{ax} \pm 0.53$	$13.77^{b} \pm 0.26$	$13.61^{b} \pm 0.25$
	PL	$13.62^{y} \pm 0.25$	13.39 ± 0.27	13.94 ± 0.32
Average		14.56 ± 0.41	13.60 ± 0.26	13.79 ± 0.29
Meat in carcass (%)	PLW	58.73 ± 4.04	60.11 ± 3.32	60.02 ± 2.43
	PL	60.92 ± 2.34	60.43 ± 2.91	59.69 ± 3.23
Average		59.92 ± 3.38	60.25 ± 3.13	59.84 ± 2.88

PLW- Polish Large White, PL- Polish Landrace
$^{a, b}$ - values in rows with different letters differ significantly ($P \leq 0.05$)
$^{X, Y}$ and $^{x, y}$ - values in columns with different letters differ significantly ($P \leq 0.01$) and ($P \leq 0.05$)

Table 3. The assessment of the uterus weight and size of tested gilts.

Trait	Breed	Number of piglets in litter (n)		
		I ≤ 11	II 12-13	III ≥ 14
Uterine weight with ligament	PLW	152.89 ± 64.79	137.81 ± 45.89	158.93 ± 68.81
(g)	PL	180.31 ± 82.39	157.85 ± 70.15	161.62 ± 61.18
Average		167.74 ± 75.35	146.67 ± 58.37	160.40 ± 64.26
Uterine weight without ligament	PLW	136.76 ± 59.38	120.78 ± 43.45	137.10 ± 60,58
(g)	PL	158.69 ± 77.48	140.76 ± 65.44	144.77 ± 58.40
Average		148.64 ± 69.93	129.61 ± 54.84	141.29 ± 59.06
Cervical length (cm)	PLW	12.90 ± 2.00	12.39 ± 2.34	12.70 ± 2.23
	PL	12.28 ± 2.08	12.10 ± 2.24	12.67 ± 2.65
Average		12.57 ± 2.04	12.27 ± 2.30	12.68 ± 2.45
Length of uterine horns	PLW	96.37 ± 14.15	96.14 ± 14.31	101.26 ± 22.89
(R + L) (cm)	PL	102.38 ± 22.81	97.68 ± 17.87	99.02 ± 17.77
Average		99.62 ± 19.37	96.82 ± 15.86	100.04 ± 20.13
Weight/length of horns (g/cm)	PLW	1.49 ± 0.78	1.25 ± 0.34	1.33 ± 0.44
	PL	1.62 ± 0.80	1.41 ± 0.47	1.43 ± 0.41
Average		1.56[a] ± 0.79	1.32[b] ± 0.41	1.38 ± 0.42
Uterine capacity (cm^3)	PLW	120.80[x] ± 43.88	126.95 ± 53.17	150.13 ± 86.26
	PL	165.88[y] ± 71.87	153.16 ± 76.45	151.85 ± 53.27
Average		145.22 ± 64.21	138.53 ± 65.41	151.07 ± 69.63

PLW- Polish Large White, PL- Polish Landrace
[a, b] - values in rows with different letters differ significantly ($P \leq 0.05$)
[x, y] - values in columns with different letters differ significantly ($P \leq 0.05$)

Table 4. The characteristics of oviducts and ovaries.

Trait	Breed	Number of piglets in litter (n)		
		I ≤ 11	II 12-13	III ≥ 14
Length of oviducts, (R + L)	PLW	39.07 ± 5.33	37.97[a] ± 5.96	41.08[b] ± 4.96
(cm)	PL	43.68 ± 10.18	40.03 ± 6.65	40.22 ± 6.00
Average		41.55[a] ± 8.55	38.88[b] ± 6.32	40.61 ± 5.52
Weight of ovaries	PLW	7.67 ± 2.33	7.17 ± 1.90	7.02 ± 1.51
(R + L) (g)	PL	7.55 ± 2.33	6.99 ± 1.77	7.02 ± 1.94
Average		7.60 ± 2.30	7.09 ± 1.84	7.02 ± 1.75
Ovarian volume (R + L) (cm^3)	PLW	5.45 ± 2.24	5.48 ± 2.09	4.77 ± 2.05
	PL	5.63 ± 2.23	5.14 ± 2.07	5.07 ± 2.10
Average		5.55 ± 2.21	5.33 ± 2.08	4.93 ± 2.07

PLW- Polish Large White, PL- Polish Landrace
[a, b] - values in rows with different letters differ significantly ($P \leq 0.05$)

DISCUSSION

Progress in the field of reproductive performance of sows in Poland is marked but not very substantial. This prompts us to seek new ways to assess the value of reproductive performance and develop a deeper understanding of the factors that affect the relationship between the morphometric structure of the reproductive system and litter size. In the opinion of Jarczyk (1991) and Holl and Robison (2003), increasing litter size by direct selection leads to disclosure of the negative maternal impact between the size of the litter from which the gilt comes and the size of the litters to which she gives birth. The maternal effect reduced piglet birth weight and increased risk of mortality (Quinion *et al.*, 2002; Rosendo *et al.*, 2007). According to Holl and Robison (2003), rearing gilts intended for breeding in litters of not more than 10 piglets provides more ways to improve breeding efficiency.

The selection conducted in Denmark since 1992 used a multi-feature animal model with the selection of the type of MAS (Marker Assisted Selection), which resulted in an increased litter size up to 15 ± 3.5 (SD) piglets (Bjerre *et al.*, 2010).

The reasons of uneven fetal growth during embryonic period are complex and have respect to numerous aspects of postnatal pig growth. Insufficient transplacental nutrient supply for the growth of large litters may partially inhibit myogenesis and in consequence may lead to lower daily gain of reared and fattened animals and carcass meat content (Gondret *et al*., 2005; Rehfeldt and Kuhn, 2006). The above relations in the range of daily gains were observed within gilts of PLW breed.

The results obtained in this study did not confirm significant correlations between litter size and the morphometric characteristics of the reproductive system in two randomly selected gilts from each litter. The significantly greater uterus capacity of PL gilts from the smallest litters ($P \leq 0.05$) could be due to the fact that PL gilts attain sexual maturity earlier than PLW gilts. The same group of PLW gilts had thicker uterus walls (higher ratio of uterine weight to the length of horns) which were more wrinkled and had better mucosal blood flow, thus making them more suitable for the implantation and development of embryos (Kapelański *et al*., 2012). Changes in the uterus tissues and the rate at which gilts attain sexual maturity are related to the embryotrophic potential of the uterus (Bartol *et al*., 1993, 1999). The age at which gilts achieve sexual maturity is associated with rapid hormonal changes of the ovaries and is independent of growth intensity (Beltranena *et al*., 1993).

The capacity of the uterus may be determined as the ability to provide nutrients to the fetus (Vallet and Freking, 2006). Competition between embryos and fetuses for space in the uterus is reflected by the sex ratio of piglets per litter. During embryonic and fetal development, males require more intrauterine space than females and a higher concentration of embryos or fetuses increases male mortality (Vallet, 2000; Foxcroft *et al*., 2009; Rekiel *et al*., 2012, 2013). As a rule, the sex balance of litters is moving towards a greater proportion of gilts than young boars (Chen and Dziuk, 1993; Górecki, 2003; Bocian *et al*., 2016). In this study, the differences in the sex proportions of piglets per litter, expressed as a percentage, were large and sometimes exceeded 10 %. The fewest young boars in a litter was found in the smallest litters of PL sows. This result does not indicate the restriction of prenatal development of young boars due to the quantity of fetuses in the uterus. However, it should be noted that in this study the assessment of sex ratio in litters was routinely determined on the 21^{st} day of rearing, not at birth, and is not corrected by the sex of dead piglets over 21 days old. The mortality of piglets up to the 21^{st} day was proportional to the size of the litter and did not differ from the reports of other authors (Rekiel *et al*., 2013; Bocian *et al*., 2016).

In conclusion, these studies showed no negative effect of the litter size from which a gilt comes on her reproductive abilities.

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