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MORPHOMETRIC CHARACTERISTICS OF THE REPRODUCTIVE SYSTEM IN POLISH LARGE WHITE AND POLISH LANDRACE GILTS AT 100 KG BODY WEIGHT*

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Abstract

The study involved an analysis of the developmental stage of reproductive organs collected at slaughter from 160 gilts (Polish Large White (PLW), n = 80; Polish Landrace (PL), n = 80) at 100 kg body weight. Due to a large variation in slaughter age (140–190 days), three groups of animals were set up: A (less than 160 days), B (160 to 180 days) and C (more than 180 days). PL gilts reached their slaughter weight earlier than PLW gilts (P≤0.05). Uterine weight increased with the age of animals but due to high variability and large deviations from the mean value, statistically significant differences were demonstrated only between gilt groups A and B for both breeds together (120.57 g vs. 148.83 g; P≤0.05). Larger differences related to the age of the gilts were found for cervical length between the groups compared (P≤0.01). The total length of the right and left uterine horns showed a significant increase with age in PLW gilts (P≤0.05). The ratio between uterine weight without ligament and the length of uterine horns (g/cm) was significantly higher in group B than in group A in gilts of both breeds together (P≤0.05), which might indicate thickening of the uterine walls. Uterine capacity was significantly higher in older animals yet due to a large variability of this trait, no significant differences between the groups were shown. The length and diameter of oviducts, the weight of each ovary, their sum and dimensions did not reveal any consistent changes associated with the age or breed of pigs. However, the size of the ovaries determined volumetrically and reported as the volume of ovaries in gilts of both breeds was significantly larger in group B compared with C (P≤0.01). No significant differences related to the studied traits were stated between PLW and PL prepubertal gilts. However, the effect of age on morphometric development of the reproductive system was more pronounced in PLW than in PL gilts.

Key words: pig, gilts, age, reproductive tract, morphometric measures

The attainment of sexual maturity in gilts is preceded by a complete anatomical and physiological development of their reproductive system. The development of the reproductive system in gilts begins as early as foetal life, continues in the postnatal

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period and is connected with morphogenesis and cell differentiation (Bartol et al., 1993; 1999). Progressive growth of the reproductive system is possibly allometric and is not directly proportional to the increase in body weight (Ji et al., 2005; Szostak, 2010; Wu and Dziuk, 1995). Determining the actual stage of development of the reproductive system and the relationship between individual elements of its anatomy at a fixed body weight of 100 kg will allow for deeper and better understanding of the mechanisms regulating litter size in pigs. The main determinants of litter size include ovulation rate, embryo survivability, uterine capacity and losses before weaning. Uterine capacity is commonly defined as the ability of the uterus to deliver the nutrients necessary to maintain the foetuses and provide them with ample space (Bazer et al., 1969; Foxcroft et al., 2009; Vallet, 2000; Vallet and Freking, 2005). The possibility of collection and morphometric evaluation of reproductive organs concurrently with a slaughter assessment of gilts conducted at testing stations is highly conducive to obtaining valuable information about the stage of development and formation of the organs.

The purpose of this study was to assess the relationship between morphometric characteristics of the reproductive system in Polish Large White and Polish Landrace gilts before the onset of sexual maturity in order to predict their potential fertility.

Material and methods

The study was conducted at the Slaughter Pig Testing Station (SKURTCh) in Mełno in the years 2009–2010. It covered 160 gilts, of which 80 were Polish Large White (PLW) and 80 Polish Landrace (PL) animals. The selection of experimental gilts and the feeding and management conditions were consistent with the methodology developed for the Slaughter Pig Testing Station (Różycki and Tyra, 2010).

Complete reproductive systems of gilts collected directly after slaughter served as material for morphometric evaluation. After the dissection the vaginal length was measured and the uterus was separated, including the cervix, oviducts and ovaries. The weight of the uterus with the broad ligament was then determined and after its separation the uterine weight was measured without the ligament. Measurements of the cervical length, the length of the uterine horns (right and left), the length of the oviducts (left and right) and the diameter of the oviducts were taken. Length measurements were performed using a measure with an accuracy of up to 0.5 cm, whereas the diameter was determined with an electronic caliper with an accuracy of up to 0.01 mm.

In order to obtain a more comprehensive description of the uterus in the analysed gilts, the uterine weight to length ratio (g/cm) was calculated.

The analysis of uterine capacity was based on the method applied to determine the capacity of cavernous organs developed by Kwaśnicki (1951) and modified by Brudnicki et al. (2001). This method was revised once more for the purpose of uterine capacity measurement at the Department of Pig Breeding of the University of Technology and Life Sciences in Bydgoszcz. The uterus was completely immersed

in a clear vessel with physiological solution and then weighed. The immersed uterus was filled with solution through a funnel placed in the cervical canal previously cleared with a trocar designed for small ruminants. Filling up was continued until an internal pressure of a 10 cm water column inside the organ was reached, i.e. until the liquid appeared in the cervix stabilized 10 cm above the level of solution in the vessel. Then the whole vessel was weighed again on laboratory balance with an accuracy of up to 1 g. The uterine capacity was calculated from the difference between the weight of the container filled with physiological solution and the weight of the uterus before and after filling up, and then provided in cm^3 (weight g/1.042 g/cm^3). Composition of the physiological solution was 0.9% NaCl and its density 1.042 g/cm^3. The uterus was immersed and filled with physiological solution on account of further histological examinations of the organ.

The ovaries obtained were subjected to detailed analysis involving determination of their weight and the length, height and width measurements, taken using electronic calliper with an accuracy of up to 0.01 cm. Ovarian volume (cm^3) was determined by immersing the ovaries in a calibrated measuring cylinder containing a predetermined volume of physiological solution.

Age at slaughter was the criterion for allocating the gilts of both breeds to three groups: A (less than 160 days), B (160 to 180 days) and C (more than 180 days).

The results were analysed statistically. Both the arithmetic mean (x) and standard deviation (s) were calculated. A two-way analysis of variance (ANOVA/MANOVA) was performed allowing for the breed and age of the gilts at slaughter. The significance of differences between the analysed groups was estimated using the Duncan test. For calculations the STATISTICA 8 PL (2008) computer software was used.

Results

The study focused on the assessment of a number of properties of the reproductive system in PLW and PL gilts after reaching a fixed body weight of 100 kg. Slaughter performed at a steady body weight resulted in significant differences in the age of the animals, ranging from 140 to 190 days. In order to estimate the age-related differences the gilts were divided into three groups: A – less than 160 days, B – 160 to 180 days, and C – more than 180 days of age. Group B was the largest group of PLW animals, while the youngest group A was also the largest group of PL gilts, which indicates a faster growth of this breed.

Table 1 contains data on the age of the gilts and the characteristics of the uterus. Upon achieving 100 kg body weight, PL gilts were slightly younger than PLW animals ($P \leq 0.05$). The weight of the uterus with the ligament was generally similar for all gilts of both breeds and showed a large deviation from the mean. However, the weight of the uterus measured without the ligament was significantly greater in older gilts of both breeds ($P \leq 0.05$). Similarly, the length of the cervix in gilts of both breeds combined was significantly greater in older than in younger animals (PLW gilts $P \leq 0.01$, PL gilts $P \leq 0.05$).

Table 1. The age of gilts at slaughter and the weight and size of the uterus

Characteristic	Breed	Age at slaughter (days)			Average
		A ≤160	B 160–180	C >180	
Size (n)	PLW	22	39	19	80
	PL	38	28	14	80
Total		60	67	33	160
Age at slaughter (days)	PLW	147.8 A±9.42	169.23 B± 5.48	193.63 C±13.06	169.10 x ±18.69
	PL	148.71 A±10.35	168.78 B± 7.24	189.50 C±4.55	162.87 y±17.49
Av.		148.33 A±9.95	169.04 B± 6.23	191.88 C ±10.42	165.99 ±18.31
Uterine weight incl. ligament (g)	PLW	132.09±44.29	160.59±80.51	160.50±77.46	152.73 ±71.90
	PL	142.11±56.85	175.25± 89.65	164.21±54.67	157.57 ±70.62
Av.		138.43±52.43	166.72± 84.10	162.07±67.77	155.15 ±71.08
Uterine weight excl. ligament (g)	PLW	112.61±49.39	142.72±76.74	138.44±65.77	133.42 ±68.09
	PL	125.17±52.51	157.36± 84.66	145.00±50.34	139.91 ±66.14
Av.		120.57 a±51.33	148.83 b±79.85	141.22±58.93	136.66 ±66.99
Cervical length (cm)	PLW	10.91 A±1.69	12.36 B± 2.17	13.05 B±1.31	12.12±2.01
	PL	11.58 a±1.82	11.83± 2.41	13.07 b±2.46	11.93±2.20
Av.		11.33 Aa±1.79	12.14 b± 2.27	13.06 Ba±1.85	12.03±2.10
Length of the right horn (cm)	PLW	44.04±13.30	47.04± 7.87	49.28±12.99	46.75±10.91
	PL	45.79±9.07	47.03± 7.78	48.31±10.06	46.67±8.76
Av.		45.15±10.74	47.04± 7.77	48.87±11.67	46.71±9.86
Length of the left horn (cm)	PLW	45.11±13.08	49.87± 8.20	52.94±14.02	49.29±11.44
	PL	48.84±9.03	49.20± 7.54	51.42±9.70	49.42±8.60
Av.		47.47 a±10.74	49.59±7.88	52.30 b±12.22	49.35±10.09
Length of horns (R + L) (cm)	PLW	89.16 a±24.39	96.91±15.62	102.22 b ±26.39	96.04±21.37
	PL	94.63±17.51	96.23±14.55	99.73±19.24	96.08±16.74
Av.		92.62 a±20.28	96.63±15.07	101.16 b ±23.31	96.06±19.14
Weight/length (g/cm)	PLW	1.27±0.46	1.45±0.62	1.33±0.40	1.38±0.53
	PL	1.30±0.41	1.60±0.67	1.44±0.39	1.43±0.52
Av.		1.29 a±0.43	1.51 b±0.64	1.38±0.39	1.40±0.53
Uterine capacity (cm^3)	PLW	117.35±58.00	145.10±60.64	149.37±88.63	138.48 ±68.02
	PL	141.50±54.00	158.89±77.64	171.29±73.37	152.80 ±66.68
Av.		132.64±56.25	150.87±68.04	158.67±82.02	145.64 ±67.53

in rows A, B, C – P≤0.01; a, b – P≤0.05.
in columns x, y – P≤0.05.

Table 2. Characteristics of the oviducts and the ovaries

Characteristic	Breed	Age at slaughter, days			Average
		A ≤160	B 160–180	C >180	
Length of the right oviduct (cm)	PLW	17.07 X,A± 5.55	19.33 B± 2.86	18.72 C±2.93	18.56 X±3.88
	PL	19.84 Y±3.27	20.40±4.58	20.00±2.54	20.06 Y±3.65
Av.		18.82±4.42	19.78±3.69	19.26±2.81	19.31±3.83
Length of the left oviduct (cm)	PLW	18.23 x,a ±5.49	20.70 b±2.74	20.28±2.90	19.92±3.83
	PL	20.31 y±2.84	20.78±3.76	19.23±2.39	20.29±3.14
Av.		19.55±4.10	20.74±3.18	19.84±2.71	20.11±3.49
Length of oviducts, (R + L) (cm)	PLW	35.29±5.52	40.04±5.38	39.00±5.14	38.49±7.44
	PL	40.16±5.83	41.18±8.15	39.23±4.37	40.35±6.50
Av.		38.37±8.29	40.52±6.64	39.10±4.75	39.42±7.02
Average oviduct diameter (mm)	PLW	2.51±0.82	2.32±0.62	2.61±0.87	2.44±0.74
	PL	2.55±0.75	2.38±0.71	2.54±0.25	2.49±0.67
Av.		2.53±0.77	2.35±0.65	2.58±0.67	2.47±0.71
Weight of the right ovary (g)	PLW	3.50±1.16	3.35±1.19	3.21±0.77	3.36±1.09
	PL	3.54±0.98	3.27±0.90	3.10±1.01	3.37±0.96
Av.		3.53±1.04	3.32±1.07	3.16±0.86	3.36±1.02
Weight of the left ovary (g)	PLW	3.66±1.27	3.90±1.42	3.76±0.87	3.80±1.26
	PL	3.96±1.25	3.50±0.91	3.56±0.84	3.73±1.09
Av.		3.85±1.26	3.73±1.24	3.67±0.85	3.77±1.17
Weight of ovaries (R + L) (g)	PLW	7.17±2.37	7.25 ±2.52	6.97±1.56	7.16±2.26
	PL	7.50±2.11	6.77±1,56	6.66±1.69	7.10±1.88
Av.		7.38±2.20	7.05±2.17	6.84±1.60	7.13±2.08
Average ovarian height (R + L) (mm)	PLW	12.22±3.22	12.29±2.88	12.82±1.86	12.40±2.76
	PL	12.34±2.00	11.36±1.57	11.93±1.64	11.92±1.83
Av.		12.29±2.49	11.91±2.45	12.44±1.80	12.16±2.35
Average ovarian length (R + L) (mm)	PLW	24.22±5.72	24.37±5.11	25.33±2.59	24.56±4.79
	PL	25.65±2.47	24.94±2.53	24.97±2.49	25.28±2.49
Av.		25.13±3.99	24.60±4.21	25.18±2.51	24.92±3.82
Average ovarian width (R + L) (mm)	PLW	17.70±4.90	18.21±3,91	19.01±2.44	18.26±3.91
	PL	18.55±2.66	17.94±1.98	17.64±1.39	18.18±2.26
Av.		18.24±3.63	18.10±3.23	18.43±2.15	18.22±3.19
Volume of the right ovary (cm^3)	PLW	2.20±0.95	2.82 A±1.31	1.92 B±0.73	2.44±1.16
	PL	2.62±1.07	2.78±1.07	2.31±1.17	2.62±1.08
Av.		2.47±1.04	2.80 A±1.21	2.08 B±0.94	2.53±1.12
Volume of the left ovary (cm^3)	PLW	2.52±1.07	3.09 a±1.52	2.19 b±0.91	2.72±1.32
	PL	2.96±1.29	2.88±1.25	2.61±0.90	2.87±1.21
Av.		2.80±1.22	3.00 A±1.40	2.37 B±0.92	2.80±1.26
Total ovarian volume (P + L) (cm^3)	PLW	4.73±1.95	5.91 a±2.72	4.11 b±1.59	5.16±2.39
	PL	5.58±2.26	5.66±2.24	4.92±1.89	5.49±2.18
Av.		5.27±2.17	5.80 A±2.51	4.45 B±1.74	5,32±2.29

in rows A, B, C – P≤0.01, a, b – P≤0.05.
in columns X, Y – P≤0.01, x, y – P≤0.05.

For further uterine characterization of the analysed gilts the ratio between the weight of the uterus without the ligament and the length of its horns (weight/length) was calculated. This trait was differentiated by the age of the animals. The increase in the proportion of uterine weight to the length of its horns may indicate thickening of the uterine walls occurring in gilts aged 160–180 days compared with younger animals ($P \leq 0.05$). The size of the uterus filled up with physiological solution was also evaluated. Thus measured capacity was clearly larger in older gilts, which was particularly noticeable in the PL animals. These differences, however, were not statistically confirmed.

The characteristics of the oviducts and ovaries are presented in Table 2. The length of the oviducts considered separately for the right and the left ovary showed significant differences only between the youngest gilts of both breeds (group A). The length of the right oviduct in PLW gilts was significantly lower than in PL gilts ($P \leq 0.01$) and this was also the case for the length of the left oviducts ($P \leq 0.01$). These relationships did not recur in the assessment of the total length of both oviducts.

The weight of the ovary, its dimensions (height, length and width) and volume were also determined in the course of our study. The weight values for the right and left ovary, as well as their dimensions, were similar in all gilts, regardless of the breed or age. Such data as the height of the ovaries, their length and width were not significantly different in terms of breed or age of the gilts. Volume, on the other hand, showed significant age-related changes. Particularly marked changes in the ovarian size were demonstrated by PLW gilts. The largest ovarian volume (right, left and total) was noted in group B gilts aged 160–180 days compared with gilts older than 180 days ($P \leq 0.01$).

Discussion

Much of the literature data indicates the critical importance of the size of the uterus and in particular the length of its horns for the potential formation of a large litter. Uterine development begins prenatally and continues after birth. According to Bartol et al. (1993), the transformation of the uterine wall in terms of construction and histological structure occurs between birth and the 120th day of age. Further developmental changes are associated with the proliferation of uterine glands, formation of endometrial folds and myometrial growth, while appropriate development of these properties ensures higher survivability of embryos and foetuses during pregnancy (Bartol et al., 1993). Determining the weight and size of the uterus may serve as a reliable indicator of the degree of uterine development in gilts.

The degree of development of the uterus evaluated by its weight (without the ligament) was significantly diversified in this study by the age of the animals. Animals of both breeds together, less than 160 days old, had significantly lower weight of this organ compared to older animals in group B ($P \leq 0.05$).

The length of the uterine horns may exhibit large variability between individual animals (Chen and Dziuk, 1993). There is also no rule affecting the total length

of the right or left horn of the uterus. Larger total length may be characteristic of a potential ability of the uterus to provide nutrients for a higher number of foetuses (Chen and Dziuk, 1993; Vallet, 2000; Wu and Dziuk, 1989; Wu et al., 1987). There is little research evidence that would clearly demonstrate the correlation between the length of the uterus before and after the attainment of sexual maturity and during pregnancy (Christenson et al., 1987; Wu and Dziuk, 1988). Subsequent studies, however, consider the length of uterus determined in sexually immature gilts to be a good predictor of its further development and potential size of the litter (Vallet, 2000; Wu and Dziuk, 1995).

As this study demonstrated, the length of both uterine horns increased significantly with age in PLW gilts ($P \leq 0.05$). Our calculation of the ratio of uterine weight to the length of its horns in gilts of both breeds together showed that it was the highest at the age of approximately 170 days. This might indicate uterine wall thickening occurring in that period. This result is consistent with the opinion expressed by Bartol et al. (1993) that the purpose of the changes in development of the uterus after the 120th day of age is to ensure favourable conditions for embryo implantation.

Uterine capacity seems to characterize the possibility of accommodating foetuses during pregnancy and ensuring higher prenatal foetal survivability. The mortality of embryos and foetuses during early pregnancy is relatively high and ranges from 17% to 34% compared with the number of corpora lutea (Wu and Dziuk, 1989; Wu et al., 1987). Increased density of embryos in the uterus is conducive to higher mortality rate (Vallet, 2000; Wu and Dziuk, 1995). The uterine capacity determined in the course of our study in sexually immature gilts was slightly higher in older animals, primarily in PL gilts.

There is no evidence in the literature to suggest a significant role of the length of the oviducts in the evaluation of potential fertility of gilts. A considerably greater average length of the oviducts than that reported in this paper was demonstrated by Klocek (1997) in sows at 30 days of pregnancy. The average diameter of both oviducts was very similar in all gilts, regardless of their age or breed.

The role of the ovaries in the production of efficient to fertile ova cells is very important and is characterized by the ovulation rate determining to a large extent the reproductive potential of sows. Ovarian development is initiated in the prenatal period and undergoes various stages of ovarian follicle formation during the growth of animals (Bolamba et al., 1994; Dufour et al., 1985; Klocek, 1997; Klocek et al., 2006; Pejsak, 1984). The follicular growth increases with age and upcoming sexual maturity, as demonstrated in morphological (Dyck and Swierstra, 1983) and hormonal (Lutz et al., 1984) studies. Detailed microscopic examination of ovaries in growing Yorkshire and Hampshire gilts at the age of 105, 140 and 170 days demonstrated large variations in the diameter and size of ovarian follicles (Dufour et al., 1985).

The results of studies carried out by the authors cited above showed dynamic changes in ovarian morphology between 160 and 180 days of age before the attainment of sexual maturity by the gilts. It can be therefore assumed that the highest ovarian volumes demonstrated during the course of our study in gilts of both breeds at that particular age may reflect the intensification of hormonal changes at that time of a pulse and fluctuating nature, regulating the functions of ovarian follicles.

In conclusion it should be pointed out that no significant differences associated with the breed of gilts were observed in the reproductive system morphology. Nonetheless, the age of animals had some effect on certain characteristics. The youngest gilts of both breeds demonstrated a significantly lower weight of the uterus, uterine horn length and cervical length compared to the older gilts of the same body weight. A clear tendency towards higher capacity of the uterus, particularly in the PL breed, was observed in older gilts. Changes in the size of the ovaries did not show a linear relationship with the age of the animals. Significantly greater capacity of the ovaries was demonstrated by gilts of both breeds aged 160-180 days. No significant differences related to the studied traits were stated between PLW and PL prepubertal gilts.

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Charakterystyka morfometryczna układu rozrodczego loszek wielkiej białej polskiej i polskiej białej zwisłouchej przy masie ciała 100 kg

STRESZCZENIE

W niniejszej pracy oceniano u 160 loszek (wbp n = 80; pbz n = 80) stan rozwoju narządów rodnych pobranych przy uboju przy masie ciała 100 kg. Ze względu na duże zróżnicowanie wieku przy uboju (140–190 dni) utworzono trzy grupy zwierząt: A (poniżej 160 dni), B (od 160 do 180 dni) i C (powyżej 180 dni). Nieco wcześniej osiągały masę ubojową loszki rasy pbz niż rasy wbp ($P \leq 0.05$). Masa macicy zwiększała się wraz z wiekiem zwierząt, jednak ze względu na dużą zmienność i dużą wartość odchylenia od średniej, statystycznie istotne różnice wykazano tylko między grupą loszek A i B obu ras łącznie (120.57g wobec 148.83 g; $P \leq 0.05$). Większe różnice związane z wiekiem loszek wykazano dla długości szyjki macicy między porównywanymi grupami ($P \leq 0.01$). Długość prawego i lewego rogu macicy podana łącznie wykazała istotny wzrost wraz z wiekiem zwierząt u loszek rasy wbp ($P \leq 0.05$). Proporcja masy macicy bez więzadła do długości rogów (g/cm) była istotnie większa w grupie B, niż w grupie A u loszek obu ras łącznie ($P \leq 0.05$), co może wskazywać na pogrubienie ścian macicy. Pojemność macicy była wyraźnie większa u zwierząt starszych, lecz ze względu na dużą zmienność tej cechy nie wykazano istotności różnic między grupami.

Długość i średnica jajowodów, masa poszczególnych jajników, ich suma i wymiary nie wykazały systematycznych zmian związanych z wiekiem i rasą świń. Jednak wielkość jajników określona metodą wolumetryczną i podana jako objętość jajników u loszek obu ras była istotnie większa w grupie B w porównaniu z C ($P \leq 0.01$).

Nie wykazano istotnych różnic związanych z rasą w morfometrycznej budowie układu rozrodczego niedojrzałych płciowo loszek wbp i pbz. Jednak wpływ wieku na badane cechy był bardziej wyraźny u loszek rasy wbp niż pbz.