EFFECT OF DIFFERENT FACTORS ON WEANING-TO-FIRST-SERVICE INTERVAL IN LITHUANIAN PIG HERDS

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Summary. The aim of this study was to investigate and describe the factors influencing weaning-to-first-service interval **(**WSI) duration in Lithuanian pig herds and WSI effect on reproductive traits. The present study was based on data from 399 crossbred between native Lithuanian White and Danish Landrace (LWxDL) and 239 purebred Danish Landrace (DL) sows from different herds.

The 1st model factors influencing WSI interval were analysed. WSI was regarded as dependent variable. The factors first mating after weaning (FM), parity number (PN), weaning month (WM), influencing WSI were classified and included in the model as independent variable. The effect of WSI on litter size was analysed in the 2nd statistical model. Effect of herd and breed interaction on sow reproductive performance was analysed in the 3^{d} model.

Results in Lithuanian pig herds indicate that WSI was 9.34±1.12 days, and it was about 2 days longer compared with other countries commercial herds. Our analysis of WSI revealed that the FM, PN, WM, sow herd-breed all had significant influence ($0.05 \geq p \leq 0.001$). Total litter size decreased for about 0.71 piglet when WSI duration was longer than 4 days ($p<0.05$). There was a difference between purebred DL and crossbred LWxDL in respect of several reproductive traits, including WSI, age at first mating (AFM), gestation length (GL), lactation length (LL), sow's age at culling (SAC) and litter size ($p \leq 0.001$). In Lithuanian pig herds the average of AFM was 10 days shorter for LWxDL than for DL gilts ($p \leq 0.001$).

Key words: sow, weaning-to-first-service interval, reproductive performance.

SKIRTINGŲ VEIKSNIŲ ĮTAKA LAIKOTARPIO TRUKMEI NUO PARŠELIŲ ATJUNKYMO IKI RUJOS POŽYMIŲ PASIREIŠKIMO

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Santrauka. Mūsų tyrimo tikslas buvo ištirti ir aprašyti faktorių, darančių įtaką paršeliams nuo atjunkymo iki rujos požymių pasireiškimo (WSI) Lietuvos veislinių kiaulių ūkiuose ir WSI įtaką paršavedžių reprodukciniams rodikliams. Tyrimui panaudoti 399 Lietuvos baltųjų ir Danų landrasų mišrūnių kiaulių bei 239 grynaveislių Danų landrasų veislės kiaulių duomenys.

Lietuvos veisliniuose kiaulių ūkiuose atlikti tyrimai parodė, kad WSI buvo dviem dienomis ilgesnis už kitose šalyse gautus rezultatus. Nustatėme, kad pirmas sėklinimas, paršingumas, atjunkymo mėnuo, ūkis ir paršavedės veislė turėjo reikšmingą įtaką WSI trukmei ($0,05 \geq p \leq 0,001$). Paršelių skaičius lizde sumažėjo 0,47 peršelio, kai WSI tęsėsi ilgiau kaip 4 dienas ($p<0,05$). Nustatėme kai kurių reprodukcinių rodiklių (WSI, pirmo sėklinimo amžiaus, paršingumo trukmės, laktacijos trukmės, paršavedės išbrokavimo amžiaus ir paršelių lizdo dydžio) skirtumus tarp Lietuvos baltųjų ir Danų landrasų veislių kiaulių ($p \leq 0,001$). Lietuvos veisliniuose kiaulių ūkiuose mišrūnės kiaulės buvo sėklinamos 10 dienų jaunesnės negu grynaveislės Danų landrasų veislės kiaulės ($p \leq 0,001$).

Raktažodžiai: paršavedė, atjunkymo-rujos laikotarpis, reprodukciniai rodikliai.

Introduction. The majority of sows return to oestrus within two weeks after weaning. Swine herds attempt to optimize production by reducing the weaning to service interval (WSI). Some sows fail to resume *oestrus* cyclicity after weaning; however, the endocrinologic pathogenesis of these *anoestrus* sows is speculative. The capacity to return to *oestrus* following weaning, the onset of puberty and the ability to conceive and maintain pregnancy are affected by some factors: season, lactation length, daily feed intake, parity number (Kaplon et al., 1991).

The incidence of increased weaning to *oestrus* interval, post weaning *anoestrus*, decreased farrowing rate and decreased litter size become more frequent the earlier sows are weaned. These potential disadvantages need to be weighed against the potential increase in the number of litters/sow/year and improved health and growth rate of the pigs produced. In addition, WSI is an important reproductive trait that has normally been regarded as an outcome variable. The average WSI is influenced by numerous factors, including season, environmental temperature, photoperiod, nutrition, stress, facility design, lactation length, and management practices. The length of WSI influences subsequent reproductive performance and can be used to indicate the fertility in subsequent reproductive cycles (Holder et al., 1993; Tummaruk et al., 2000). Variation is quite great for sows of all parities, but is most obvious in sows after weaning their first litter. Primiparous sows usually have a longer WSI than multiparous sows (Benjaminsen et al., 1981; Einarsson et al., 1974; Tummaruk, 2001). Sows that take 7 to 10 days to return to *oestrus* after weaning often have decreased farrowing rates and litter sizes compare sows that return earlier. Numerous studies have found that an inadequate intake of energy or protein during lactation affects body fat and protein reserves and prolongs the WSI. Influence of photoperiod on weaning-to-oestrus interval also was found (Virolainen, 2005). Much of the variation is due to management and environmental effects; genetic variation also is important because the mean interval from weaning to first service differs among breeds and breed crosses (Adamec and Johnson, 1997; Kerzienė, Juozaitienė, 2002; Tantasuparuk et al., 2000; Ten Napel and Johnson; 1997). Studies showed that the length of WSI mostly was longer for purebred sow then crosses ones (Tantasuparuk et al., 2000; Tummaruk, 2001; Vesseur et al., 1994).

Fertility disturbances lead to culling of female pigs, which results in reduced production. Reproductive failure occurs on Lithuanian farms in many different forms, but the most common reason is failure to return to heat. The most common sow in Lithuanian commercial herds is a breed crosses between native Lithuanian White and Danish Landrace and purebred Danish Landrace (DL). To optimize productivity, knowledge on the reproductive performance of individual females and how various factors influence their productivity is important (Kerzienė, Juozaitienė, 2004; Klimas, Klimienė, 2000; Mason, 1996).

Reproduction performance and WSI depends on many outside and intrinsic factors. In that reason the aim of this study was to investigate and describe the factors influencing WSI duration in Lithuanian herds.

Materials and methods. This study was performed on commercial herds in Lithuania to test sow reproductive factors and investigate inter-relationships between factors influencing WSI duration. The present study was based on data from 399 crossbred sows (LWxDL) and 239 purebred sows (DLxDL), from different herds.

The primary data obtained from the database of the herds and the animal identities was birth date, parity, farrowing date, number of total piglets, number of piglets born alive, number of mummies, weaning time, mating date, mating type (artificial insemination), female breed, boar breed and the size of the litter in which the gilt was born (LSGWB). Variables like weaning to service interval (WSI), age at first mating (AFM), sow age at culling (SAC), gestation length (GL) and lactation length (LL) were calculated from the primary information.

In all herds dry sows were grouped in loose housing system and individual feeding according to a Lithuanian standard level (Jatkauskas ir kt., 2002), whereas lactating sows were kept separately in farrowing pens. The average established in all herd lactation length was 30 days. After weaning, the sows were immediately transferred to the mating/gestation units.

Statistical analyses were performed using the SPSS statistical package (SPSS Inc., Chicago, IL, USA, No. 15). The analysis of the variance used the General linear model (GLM) procedure. The factors and interactions included in the statistical model were tested for significance and omitted from the model in a stepwise fashion, leaving only factors and interactions, in most cases, with a significance level of $p<0.05$. The study was conducted from 2003 to 2007. The statistical models were used for analysing the data. The 1st model factors influencing weaning-to-first-service interval were analysed. WSI was regarded as dependent variable. The factors first mating (FM), parity number (PN), weaning month (WM) influencing WSI were classified and included in the model as independent variable. FM was classified into two groups (successful and not successful). Parity number was classified into five groups (primiparous, 2nd, 3-4th, 5-6th, 7th parity). The effect of WSI on litter size was analysed in the 2nd statistical model. WSI was classified into three groups (1-4, 5-10, 11≤ days). Effect of herd and breed interaction on sow reproductive performance was analysed in the 3d model. Variables describing the reproductive performance of sows: WSI, AFM, LL, GL, SAC were regarded as dependent variables. Differences between the groups and factors were analysed using the LSD method of multiple comparison. Differences were regarded to be statistically significant when $p\leq0.05$.

Results. 1 Model. Effect of first mating on WSI and SAC are presented in Table 1. As can be seen the first successful mating after weaning had a significant ($p\leq0.001$) influence on WSI and SAC. When the first mating was successful the WSI was 16.89 d shorter and sow was culled 141 d later than the first mating was unsuccessful.

Table 1. **Effect of first mating on WSI and SAC (multiple comparison)**

First mating	WSI (d)		SAC (d)	
	N	M±m	N	M±m
Successful	2453	7.16±12.19***	273	1061.30±300.15***
Not successful	410	24.05±23.24***	141	919.96±274.64***

* - p≤0.05; ** - p≤0.01; *** - p≤0.001

Table 2. **Effect of parity number on WSI**

Parity number	WSI (d)	
	N	M±m
Primiparous ^{a}	599	$11.34\pm16.68^{b, c, d}$
2nd^{b}	570	6.91 ± 12.04^{a}
3 and 4th^{c}	953	5.61 ± 8.37^{a}
5 and 6th^{d}	459	5.43 ± 7.89^{a}
7th^{e}	52	8.94 ± 27.35

Different lower case (a, b, c, d and e) within a column indicate significant difference (p<0.05)

Table 3. **Seasonal variations and month effect on WSI** (multiple comparison)

Weaning month	WSI (days)	
	N	M±m
January ^{a}	226	5.77 ± 7.25^{d}
February ^{b}	217	6.32 ± 6.72^{d}
March ^{c}	181	8.04 ± 11.10
April ^{d}	236	$8.97\pm13.87^{a, b, f, g, h, j, k, l}$
May ^{e}	214	7.15 ± 8.91
June ^{f}	227	6.65 ± 7.58^{d}
July ^{g}	220	6.67 ± 8.10^{d}
August ^{h}	231	5.99 ± 6.21^{d}
September ^{j}	253	6.83 ± 7.15^{d}
October ^{k}	226	6.25 ± 7.17^{d}
November ^{l}	219	6.18 ± 6.53^{d}
December ^{m}	174	4.01 ± 15.80
Total	2624	

Different lower case (a, b, c, d and e, f, g, h, j and k, l, m) within a column indicate significant difference (p<0.05)

The analysis revealed that primiparous sows in Lithuanian herds had longer WSI, (p<0.05) compare with multiparous sows (Table 2). The 2nd parity sows WSI was 4.43 d sows and the 3 and 4th parities sows WSI was 5.73 d shorter than primiparous sows (p<0.05). From 7th parity sows WSI started to be longer and WSI was 2.4 d shorter than primiparous but 3.33 d longer than the 3 and 4th parities sows (p<0.05).

Table 3 demonstrates seasonal variations and weaning month effect on WSI. Sows weaned in spring months had 8.06 days longer WSI than sows weaned in winter ones (p<0.05). Sows weaned from March until May had a significantly (p<0.05) longer WSI than sows weaned in summer and autumn months 4.85 and 4.90 days respectively (p<0.05). In the present study the sows weaned in April had a significantly longer WSI than sows weaned in the other months (p<0.05). The sows weaned in December had the shortest WSI (4.01±15.80 d), however the sows weaned in April had the longest WSI (8.97±13.87 d), (p<0.05).

2 Model. In our study the WSI had effect on litter size (Table 4). Litter size was significantly (p<0.05) lower as WSI was longer. This study showed that when WSI was 5-10 days, the total litter size was 0.33 piglet bigger than when WSI was 11 days and alive litter size was 0.62 piglet bigger respectively (p<0.05). In our study the difference in total litter size and live litter size between sows with 1-4 days WSI and those with 11≤ days WSI was 0.71 and 0.80 piglet respectively (p<0.05).

3 Model. The descriptive statistics of the parameters number of cases, arithmetic means, standard deviation and significance of herd and breed combination effect analysed are showed in Table 5. As can be seen, the mean of WSI was longer 15.6 % for LWxDL compared with purebred sows (p≤0.01). In the present study, the average of age at first mating was 10 days shorter for LWxDL than for DL gilts (p≤0.001).

The present study showed that, on average, purebred DL had 0.87 day lower GL and 0.43 day lower LL than crossbred LWxDL (p≤0.001). Sows age at culling was 58 days lower in purebred sows than in crossbred (p≤0.001).

Table 4. **Effect of WSI on litter size**

WSI	Litters size			
	Total born		Born alive	
	N	M±m	N	M±m
1-4 days^{a}	1687	$12.31\pm2.41^{b, c}$	1687	11.15 ± 2.12^{c}
5-10 days^{b}	667	11.93 ± 2.41^{a}	667	11.07 ± 2.17^{c}
11≤ days^{c}	265	11.60 ± 2.79^{a}	266	$10.35\pm2.75^{a, b}$

Different lower case (a, b and c) within a column indicate significant difference (p<0.05)

In present study the total litter size was 0.24 piglet bigger in purebred sows than in crossbred (p<0.05). However the alive litter size was 0.56 piglet bigger in crossbred (p≤0.001). The LWxDL had 50% mummies less than DLxDL (p≤0.001), (Table 5).

Discussion. WSI was the focus of the present study. In the first model analysis of WSI we revealed that many factors had significant influence (p<0.05).

1 Model. For the breeding herd, reproductive performance after weaning is limited by the expression of *oestrus* and the occurrence of ovulation. Identifying factors that influence the expression of *oestrus* may help to improve breeding management (Tummaruk et al., 2000). Therefore in the first part of the study we investigated some factors

effects on WSI duration of studied sows (n=638).

Limitations to reproduction in swine arise from a failure to accurately determine onset of *oestrus* for timing inseminations and a failure of sows to express *oestrus* shortly after weaning. Approximately 95 % of sows express *oestrus* between 3 and 8 days after weaning (Knox and Rodriguez, 2001). Results of our study in Lithuanian herds indicate that WSI was 9.34±1.12 days, and it was longer compared with other countries commercial herds (Knox and Rodriguez, 2001; Vesseur et al., 1994). Sows with longer WSI intervals ovulate earlier after onset of *oestrus* and should therefore be inseminated earlier after onset of *oestrus* than sows with shorter WSI and duration of *oestrus* decreases at longer WSI (Kemp and Soede, 1996).

Table 5. **Herd-breed effect on pig reproductive performance**

Factors	LWxDL		DLxDL	
	N	M±m	N	M±m
WSI (d)	1869	10.13±17.45**	994	8.55±10.76**
AFM (d)	400	259.40±20.67***	239	269.92±33.14***
GL (d)	2029	116.86±2.93***	1056	117.73±2.85***
LL (d)	1922	30.73±2.90***	997	30.30±2.53***
SAC (d)	281	1063.65±292.24***	135	905.55±283.69***
Mummies	1971	0.11±0.45***	1036	0.21±0.59***
Litter size total	2033	11.90±2.71*	1044	12.14±2.86*
Litter size alive	1986	10.94±2.56***	1062	10.38±3.03***

*- p≤0.05; ** - p≤0.01; *** - p≤0.001

From a management perspective, things such as semen quality, detection of *oestrus*, and the technical competence of breeding technicians all play important roles in the relative success or failure of fertilization (Koketsu et al., 1997). Problems with fertilization are almost exclusively external rather than internal. In other words, they typically aren't related to failure of some aspect of sow physiology, but rather the result of a management deficiency, such as poor detection of *oestrus*. Our study's data (Table 1) demonstrate a significant (p≤0.001) influence of the first successful mating after weaning on WSI and SAC. When the first mating was successful the WSI was 7.16±12.19 days and sow was culled at 1061.30±300.15 day. There were shorter and later than sows the first mating was unsuccessful. The present study showed that WSI duration depended on parity number, and WSI was longer in primiparous sows than in older sows (Table 2). Primiparous sows in Lithuanian herds had the longest WSI 11.34 days, (p<0.05) in accordance with earlier studies (Benjaminsen, Karlberg, 1981; Einarsson, Settergren, 1974; Tummaruk, 2001). The longer WSI in primiparous sows might be due to a combination of poorer nutrition and higher weight loss during lactation than in multiparous sows. Primiparous sows also have fewer body reserves to mobilize lactation than multiparous sows because they are still growing toward their mature size. This increased energy demand for body and lactation, combined with decreased feed intake in primiparous as compared to multiparous sows, may result negative energy balance. The resulting catabolic state inhibits the secretion of hormones that drive the growth of ovarian follicles and the post weaning return to *oestrus*. It is possible that physiological differences in the reproductive systems of gilts and primiparous sows could be responsible for the decreased reproductive performance compared to multiparous sows. Sterning et al. (1998) determinated that the gilts reached puberty late also have long WSI after weaning the first litter primiparous sows.

Our study revealed that seasonal variations and weaning month effected (p<0.05) on WSI (Table 3). Koketsu et al. (1997) observed that spring-farrowing sows have longer weaning-to-service intervals. The manifestation of seasonal infertility is mainly seen among restricted-feed sows with body weight loss in lactation (Xue et al., 1994). A long time is needed for a recovery from the negative energy status, which prolongs the weaning to service interval (Virolainen; 2005). In present study sows weaned in spring months had 8.06 days longer WSI than sows weaned in winter ones (p<0.05). Sows weaned from March until May had a significantly (p<0.05) longer WSI than sows weaned in summer and autumn months (p<0.05). Seasonal variation was found for different herds and breeds in many of the reproductive traits (Tummaruk, 2001; Willis et al., 2003). A recent study showed that the month of weaning also had a greater influence on return to *oestrus* after weaning in primiparous sows compared to multiparous sows (Merks and Molendijk; 1995; Xue et al., 1994). In the present study in April weaned sows WSI was about 9 days. WSI in April was longer than in other months (p<0.05). An increase in WSI was found in April in some other studies, too (Tantasuparuk et al., 2005; Vesseur et al., 1994; Xue et al., 1994). Part of the problem with the return to *oestrus* in sows that are weaned in spring may be related to reduce feed intake.

Results of the present study indicate that WSI is one of the main reproductive factors which duration depends on reproductive performance of pigs. Our analysis of WSI revealed that the first sow mating after weaning, sow parity number, weaning month, sow herd-breed all had significant influence (0.05≥p≤0.001).

2 Model. Effect analyses of WSI on litter size in our study are showed in Table 4. Litter size decreased as WSI increased ($p<0.05$). Negative correlation between weaning-to-service interval (WSI, varying from 4 to 9 d) and subsequent litter size and farrowing rate have been found in large data sets by Kemp and Soede (1996), too. In our study the difference in total litter size and live litter size between sows with 1-4 days WSI and those with 11 and more days WSI was significant ($p<0.05$). Sows with shorter WSI are those that show *oestrus* most quickly after weaning because they are in good nutritional and physiological state. Because of this good state, they have a larger litter size than sows conceiving later (Holm et al., 2005).

3 Model. Herds and breeds differences in reproductive performance have been reported from many countries with various breeds (Marois et al., 2000; Tummaruk, 2001). The herd effect represented various environmental factors such as housing system, management facility and stock-manship. Management practice as well as factors related to physiology of the sow like feed consumption, metabolic rate and weight loss during lactation may contribute to the breed difference. Tantasuparuk et al. (2000) showed breed differences between Swedish Landrace and Yorkshire. The most common sow in Lithuanian commercial herds is a breed crosses between native Lithuanian White and Danish Landrace and purebred Danish Landrace in that reason in our study we choose these two breeds.

Variation in the interval from WSI is determined by variation in the incidence of prolonged interval and duration of normal intervals (Ten Napel and Johnson, 1997; Ten Napel et al., 1998). Lithuanian White and Danish Landrace and purebred Danish Landrace had the different WSI duration. LWxDL crossbred sows had 1.58 day longer WSI than purebred DL ($p<0.01$). Tantasuparuk et al. (2000) found that Landrace gilts were significantly younger at first mating than Yorkshire gilts (244 versus 249 days, ($p<0.05$)). In the present study for LWxDL and DL gilts, the average age at first mating was 259 and 269 days respectively (Table 5). However in both breeds AFM was relatively high compared with Swedish commercial crossbred herds (Koketsu et al., 1999; Schukken et al., 1994, Tummaruk, 2000). Holder et al. (1993) and Merks et al. (1995) studies demonstrated selection for lower age at puberty in pigs has been showed to have a favourable effect on the interval from weaning to *oestrus* and to first mating. These studies indicate that a high age at puberty could be unfavourable for the reproductive ability of sows. It is quite possible that gilts age at puberty depends on social environment and climate factors. Schukken et al. (1994) showed that the age of gilts at conception influenced their longevity and culling reason. Sows age at culling was 58 days lower in purebred sows than in crossbred. Gilts conceiving at an older age had a shorter longevity than gilts conceiving at a younger age and culling due to infertility problems increased with increasing age at conception.

In present study the breed differences were also found in gestation and lactation length. Lactation length and management during lactation are important for reproductive performance of the sows in the subsequent reproductive cycle. Willis et al. (2003) showed that there was a marginal effect of duration of lactation on WSI and duration of *oestrus*. The present study showed that, on average, purebred DL had a lower GL and lower LL than crossbred LWxDL. LL influences the WSI and the subsequent litter size (Tummaruk et al., 2000). A longer lactation period led to a shorter WSI and a larger subsequent litter size (Tummaruk, 2001).

Koketsu et al. (1999) reported that, for lifetime production, increased age at conception was also associated with a lower number of pigs born alive. In our study the total litter size was significantly bigger in purebred sows than in crossbred. However the live litter size was bigger in crossbred sows. Wu et al. (1988) found that a longer uterus had greater space per foetus, a larger number of live foetuses and a lower incidence of mummies.

Local breeds can consume lower quality feed and require less intensity of time and care compared to exotic pigs or purebred pigs, and the input required for local breeds is lower, e.g. the price of buying animals, cheap feed resources, and a lower requirement of veterinary care and better adaptation to local environment. However, the productivity of local pigs is also high. Klimas, Klimienė (2000) detected that the litter size of purebred Lithuanian White was 8.74 to 11.30. It is used to advantage by commercial breeding companies, which market high-performance hybrids in the secure knowledge that they will not breed true and the characteristics of their progeny can not be predicted.

In present study the LWxDL had 50% mummies less than DLxDL (Table 5). Foetal death is highly dependent on stage of gestation. Finally, small litters with a high number of stillborns are caused by problems that occur during the last week of gestation or during farrowing itself (Holm et al., 2004; Kaplon et al., 1991). Environmental factors such as increased ambient temperature and seasonal infertility affect death rates, as do specific individual sow characteristics, nutritional factors, and toxicities (Zak et al., 1997). The causes of stillborns, mummies, abortions, and early embryonic death are often difficult to ascertain, but the potential rewards make investigation efforts worthwhile.

The present study showed that there was a difference between purebred DL and crossbred LWxDL in respect of several reproductive traits, including WSI, age at first mating, gestation length, lactation length, sow's age at culling and litter size ($p\leq0.001$).

References

1. Adamec T. A. and Johnson R. Genetic analysis of rebreeding intervals, litter traits, and production traits in sows of the National Czech nucleus. Livest. Prod. Sci., 1997. N. 48. P. 13.

2. Benjaminsen E., Karlberg K. Postweaning ooestrus and luteal function in primiparous and pluriparous sows. Res. Vet. Sci., 1981, N. 30. P. 318-322.

3. Einarsson S., Settergren I. Fertility and culling in some pig breeding herds in Sweden. Nord. Vet. Med., 1974. N. 15. P. 26-42.

4. Holder R. B., Bates R. O. and Lamberson W. R. Effect of decreased age at puberty on lifetime productivity of sows. In: Proceeding of the 4th International conference on Pig reproduction. May, Missouri-Columbia, USA, Paper 86, 1993. P. 23-26

5. Holm B., Bakken M., Klemetsdal G. and Vangen O. Genetic correlations between reproduction and production traits in swine. J. Anim. Sci., 2004. N. 82. P. 3458-3464.

6. Holm B., Bakken M., Vangen O. and Rekaya R. Genetic analysis of age at first service, return rate, litter size, and weaning-to-first service interval of gilts and sows. J. Anim. Sci., 2005. N. 83. P. 41-48.

7. Jatkauskas J., Vrotniakienė V., Kulpys K., Triukas K. Mitybos normos galvijams, kiaulėms ir paukščiams (parengtos pagal ES šalių reikalavimus). Kaunas. „Leidykla“, 2002. P. 29-35.

8. Kaplon M. J., Rothschild M. F., Berger J. P., and Healey M. Population parameter estimates for performance and reproductive traits in polish large white nucleus herds. J. Anim. Sci., 1991. N. 69. P. 91-98.

9. Kaplon M. J., Rothschild M. F., Berger J. P., and Healey M. Genetic and phenotypic trends in polish large white nucleus swine herds. J. Anim. Sci., 1991. N. 69. P. 551-558.

10. Kemp B. and Soede M. N. Relationship of Weaning-to-oestrus interval to timing of ovulation and fertilization in sows. J. Anim. Sci., 1996. N. 74. P. 944-949.

11. Kerzienė S., Juozaitienė V. Lietuvos Baltųjų veislės kiaulių reprodukcinių savybių selekciniai-genetiniai parametrai. Veterinarija ir Zootechnika, 2002. T. 17. Nr. 39. P. 78-82.

12. Kerzienė S., Juozaitienė V. Paveldimųjų kiaulių savybių priklausomybės nuo ūkinių sąlygų statistiniai tyrimai. Veterinarija ir Zootechnika, 2004. T. 28(50). P. 61-64.

13. Klimas R., Klimienė A. Phenotypic correlation of pig productivity traits. Biologija. Vilnius, 2000. N. 3. P. 46-48.

14. Knox V. R. and Rodriguez Zas S. L. Factors influencing oestrus and ovulation in weaned sows as determined by transrectal ultrasound. J. Anim. Sci., 2001. N. 79. P. 2957-2963.

15. Koketsu Y., Dial G. D. & King V. L. Influence of various factors on farrowing rate on farms using early weaning. J. Vet. Med. Sci., 1997. N. 75. P. 2580-2587.

16. Koketsu Y., Takahashi H., Akachi K. Longevity, lifetime pig production and productivity, and age at first conception in a cohort of gilts observed over six years on commercial farms. J. Vet. Med. Sci., 1999. N. 61. P. 1001-1005.

17. Marois D., Brisbane J. R., and Laforest J.–P. Accounting for lactation length and weaning-to-conception interval in genetic evaluations for litter size in swine. J. Anim. Sci., 2000. N. 78, P. 1796-1810.

18. Mason I. L. A World Dictionary of Livestock Breeds, Types and Varieties. Fourth Edition. C.A.B International, 1996.

19. Merks J. W. M. and Molendijk R. J. F. Genetic correlations between production traits and first parity traits. In: Proceeding of the 46th Annual Meeting of the European Association for Animal Production, Prague, Czech Republic, Abstract., 1995. P. 4-11.

20. Schukken Y. H., Buurman J., Huirne R. B. M., Willemse A. H., Vernooy J. C. M., van den Broek J., Verheijden J. H. M. Evaluation of optimal age at first conception in gilts from data collected in commercial swine herds. J. Anim. Sci., 1994. N. 72. P. 1387-1392.

21. Sterning, M., Rydhmer, L., Eliasson-Selling, L. Relationship between age at puberty and interval from weaning to oestrus and between oestrus signs at puberty and after the first weaning in pigs. J. Anim. Sci., 1998. N. 76. P. 353-359.

22. Tantasuparuk W., Lundeheim N., Dalin AM., Kunavongkrit A., Einarsson S. Reproductive performance of purebred landrace and Yorkshire sows in Thailand with special reference to seasonal influence and parity number. Theriogen., 2000. N. 54. T. 3. P. 481-496.

23. Tantasuparuk W., Techakumphu M., Dornin S., Relationships between ovulation rate and litter size in purebred Landrace and Yorkshire gilts. Theriogen., 2005. N. 63. T. 4. P. 1142-1148.

24. Ten Napel J. and Johnson R. Genetic relationships among production traits and rebreeding performance. J. Anim. Sci., 1997, N. 75. P. 51-54.

25. Ten Napel J., Meuwissen T. H., Johnson R. K., Brascamp E. W. Genetics of the interval from weaning to oestrus in first-litter sows: correlated responses. J Anim Sci., 1998. N. 76. T. 4. P. 937-947.

26. Tummaruk P. Reproductive performance of purebred Swedish Landrace and Swedish Yorkshire Gilts and sows / Thesis of Doctorate, Swedish University of Agricultural Science, Uppsala, 2001. P.11-40.

27. Tummaruk P., Lundeheim N. Einarsson S and Dalin A. M. Reproductive performance of purebred Swedish Landrace and Swedish Yorkshire sows: I. Seasonal variation and parity influence. Acta Agric. Scand., Sect. A, Animal Sci., 2000. N. 50. P. 205-216.

28. Vesseur P. C., Kemp B., den Hartog L. A. Factors affecting the weaning-to-oestrus interval in the sow. J. Anim. Physio. Anim. Nutr., 1994. N. 72. P. 225-233.

29. Virolainen J. Post-breeding effect of feeding on reproduction in gilts and sows. Thesis of Doctorate, Helsinki, 2005. P.5-46.

30. Willis J. H., Zak J. L. and Foxcroft G. R. Duration of lactation, endocrine and metabolic state, and fertility of primiparous sows. J. Anim. Sci., 2003. N. 81. P. 2088-2102.

31. Wu M. C., Hentzel M. D, Dziuk P. J. Effect of stage of gestation, litter size and uterine space on the incidence of mummified fetuses in pigs. J. Anim. Sci., 1988. N. 66. T.12. P. 3202-3207.

32. Zak L. J., Cosgrove J. R., Aherne F. X., Foxcroft R. G. Pattern of feed intake and associated metabolic and endocrine changes differentially affect postweaning fertility in primiparous lactating sows. J. Anim. Sci., 1997. N. 75. P. 208-216.

33. Xue J. L., Dial G. D., Marsh W. E. and Davies P. R. Multiple manifestation of season on reproductive performance of commercial swine. J. Am. Vet. Med. Assoc., 1994. N. 204. P. 1486-1489.