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Effect of photoperiod on sexual activity of boar

Radomir Savić[1], Milica Petrović[1]

[1] University of Belgrade, Faculty of Agriculture, Belgrade-Zemun, Republic of Serbia.

ABSTRACT - The main objective of this study was to assess the effect of photoperiod on sexual activity of three breeds of boars: Swedish Landrace (n=34), Large White (n=38), and Duroc (n=32). Boar sexual activity was analysed based on the libido index and intensity of ejaculation. The libido index was calculated as the ratio between the duration of ejaculation and time of preparation until ejaculation. The intensity of ejaculation was the volume of ejaculate (mL) secreted in the unit of time (min). The effect of photoperiod was analysed as the effect of duration of daylight (<12 h and >12 h) within photoperiod intervals (increasing and decreasing). Impact assessment was carried out by applying the General Linear Model procedure. Libido and intensity of ejaculation varied under the impact of photoperiod and the breed of boars. With the increase in age, the boar libido weakened, while the volume of ejaculate and intensity of ejaculation increased. Boars manifested better libido when the daylight lasted longer than 12 h in both photoperiod intervals. Different from libido, the volume of ejaculate and intensity of ejaculation were highest when the daylight was shorter than 12 h, but only in the decreasing photoperiod interval. Swedish Landrace boars manifested best libido, while in the production of sperm the Duroc boars were inferior compared with Swedish Landrace and Large White. The phenotypic relationship among libido, ejaculate volume, and ejaculation intensity ranges from very low to high; however, the coefficients were positive, which indicates the possibility of simultaneous improvement of these traits.

Key Words: breed, intensity of ejaculation, libido

Introduction

Noble swine breeds require modern housing facilities in which microclimate parameters can be maintained within optimal limits throughout the entire year. Nevertheless, in certain periods of the year, in modern breeds, maximum phenotype values or trait manifestations that are characteristic only of that certain period have been observed. The pig domestication process has not completely eliminated the behaviour characteristic of their ancestors (Knecht et al., 2013).

Boar reproductive performance variables (quality of ejaculates, fertility, and sexual behaviour) show distinct seasonal changes (Pinart and Puigmulé, 2013). The boar sexual activity can be influenced by a number of genetic and paragenetic factors, and, according to the report of Hemsworth and Tilbrook (2007), the understanding of the regulation of boar sexual behaviour is important for the optimization of its reproductive performance. The sexual behaviour of males depends on the interaction between the body and the environment (Wysokińska and Kondracki, 2014). While some authors think that the autumn photoperiod, with decrease in daylight, has a stimulatory effect on the boar reproductive ability in comparison with the photoperiod when the daylight increases, other studies indicate significant differences between the breeds and their reaction to the light regime (Pinart and Puigmulé, 2013). Photoperiod is a well-known modulator of sperm production in mammals as an effect of the melatonin regulation mechanism (Knecht et al., 2013).

According to the report of Levis and Reicks (2005), there is no standardised procedure for the assessment of sexual behaviour of boars used in artificial insemination, and the understanding of the effect of sexual behaviour on boar fertility is significantly more limited than the understanding of the physiological mechanism of sperm production. The assessment of sexual libido can be carried out based on the time needed for the mount, duration of erection, period from the moment when the boar enters the room with phantom up to ejaculation, duration of ejaculation, duration of copulation, number of mounts, etc. (Okere et al., 2005; Szostak and Sarzyńska, 2011; Oberlender et al., 2012; Kondracki et al., 2013; Savić et al., 2014; Wysokińska and Kondracki, 2014). During reproductive exploitation, the manifestation of the boar sexual activity is a complex process that demands more objective defining of libido and

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Corresponding author: savic@agrif.bg.ac.rs
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the analysis of supplementary traits. It is desirable that the boar secrete the largest volume of ejaculate in the shortest time period, reducing the time spent handling the boar as well as possible harmful effects of the ambient temperature on the ejaculate and bacterial or mechanical contamination of the ejaculate.

The dominant genotypes in pig populations in Serbia are Swedish Landrace and Large White as fertile breeds and Duroc as a pronounced meat breed. For that reason, the objective of this study was to evaluate the effect of photoperiod on sexual activity of these three breeds of boars analysed on the basis of libido and intensity of ejaculation.

Material and Methods

This research work was conducted in accordance with high animal welfare ethical standards and approved by a relevant ethical committee of the institution. The trial included 7156 mounts of 104 boars of three breeds (Table 1), raised in production conditions in the period from 2004 to 2012. The farm has its own reproductive and production breeding stock, and is located at 44°54'51"N 20°24'14"E geographical coordinates.

Boars were kept in reproduction facilities together with a groups of sows (from weaning to mating) and individually kept sows (during the period of pregnancy), but in individual pens of 5 m² (2.30 × 2.20 m). The fence of the pen was made of metal bars, which enabled visual contact between the animals. The floor was made of concrete (1/2 concrete and 2/2 grid). The nutrition of animals was rationed (in the morning and in the afternoon), according to nutritional requirements, in a total daily amount of 2.7 to 3.2 kg dry mixture. During the entire trial period, the composition of fodder mixture was standardized to 13.00 MJ kg^{-1} of metabolizable energy; 165 g kg^{-1} of crude protein; maximum 60 g kg^{-1} of crude cellulose; 8-10 g kg^{-1} of Ca, and 6 g kg^{-1} of P. Water was available *ad libitum*, in automatic drinking troughs.

The boar mounts were analysed during the two photoperiod intervals (PH): increasing (from early winter to late spring) and decreasing (from early summer to late autumn). The PH included two classes of light duration (LD): <12 h (winter and autumn period) and >12 h (spring and summer period). The boars mounting in both LD classes within both PH were included in the trial. The interval between two successful mounts was 1 to 21 days. The preparation time up to ejaculation (PT) and the duration of ejaculation (DE) were measured using a digital watch and expressed in minutes (min). The ejaculate volume (VOL) was measured using a graduated cylinder, with ±10 mL precision. The ejaculates were collected by the standard manual method, in a separate section of the object in which the phantom was situated. The object was not air-conditioned (no heating or cooling), so the microclimate parameters depended primarily on a roof and canal-ventilation system which functioned on the under-pressure principle. The boar ejaculate was collected in the period from 7.00 h to 13.00 h. The air temperature (ºC) in the object (inside temperature) and the outside temperature were measured at the collection of the ejaculate using analogous thermometers (Table 2).

Boar sexual activity was analysed on the basis of libido index (LI) and intensity (rate) of ejaculation (IE).

The non-productive period is the time of preparation until ejaculation, from bringing the boar into the section of the object with phantom up to the start of ejaculation. The productive period is the duration of the boar ejaculation. It is assumed that longer duration of ejaculation and shorter preparation period are the parameters of good libido. The libido index (LI) was calculated the ratio between the duration of ejaculation (DE) and the time of preparation up to the moment of ejaculation (PT), i.e., as a relationship of the productive and non-productive periods, as shown by the following formula:

$$LI = DE/PT.$$

Table 1 - Structure of the dataset per breed

Breed	N	Number of jumps	Average
Swedish Landrace	34	2323	68.32
Large White	38	2508	66.00
Duroc	32	2325	72.66
Total	104	7156	68.81

N - number of boars.

Table 2 - Inside and outside temperature within analysed photoperiod

Photoperiod interval (duration of daylight)		N	Inside temperature (ºC)		Outside temperature (ºC)	
			$\bar{X}$±SD	Interval	$\bar{X}$±SD	Interval
Increasing	<12h, winter	1670	12.51±2.66	1.00-23.00	6.29±5.52	–12.00-22.00
	>12h, spring	1682	20.10±4.51	6.00-33.00	21.09±6.43	2.00-35.00
Decreasing	<12h, autumn	1974	15.34±3.73	4.00-31.00	12.47±6.45	–12.00-30.00
	>12h, summer	1830	24.80±3.92	10.00-35.00	27.02±5.07	11.00-40.00

N - number of jumps; SD - standard deviation.

The intensity of ejaculation represents the volume of ejaculate (mL) that is being secreted in the time unit (min), calculated as ratio between volume of ejaculate (VOL) and the duration of ejaculation (DE), according to the following formula:

$$IE = VOL/DE.$$

Impact assessment was carried out by applying the General Linear Model procedure of the statistical package SAS (Statistical Analysis System, version 9.1.3), using the following model:

$$y_{ijkl} = \mu + \varphi(\lambda)_{ij} + \beta_k + \beta_1(x_{ijkl} - \bar{x}) + \beta_2(x_{ijkl} - \bar{x}) + e_{ijkl},$$

in which y_{ijkl} = the analysed trait; $\varphi(\lambda)_{ij}$ = the effect of light duration within photoperiod interval; β_k = effect of breed; $\beta_1(x_{ijkl} - \bar{x})$ = linear regression effect of the age of boar; $\beta_2(x_{ijkl} - \bar{x})$ = linear regression effect of temperature inside the object; and e_{ijkl} = random error.

Least Square Means (LSM) values were compared using the t- test with three levels of significance ($P<0.05$, $P<0.01$, and $P<0.001$). Mean LSM values of LI are calculated in three decimals to better understand the differences, while the other traits are calculated in two decimals. The relationship among the studied traits was determined by Pearson's correlation coefficient, and explained on the basis of rough approximation of the height of correlation according to Petz (2004).

Results

The coefficients of variation for libido index and intensity of ejaculation (Table 3) showed a homogenous arrangement of variants.

The sexual activity traits of boars varied under the impact of photoperiod and breed (Table 4). With the increase in the boar age in the jump by one day, at constant temperature inside the object, libido can weaken by –0.0080 index points, and volume and intensity of ejaculation can increase (for 0.0880 mL and 0.0100 mL min^{-1}). The linear regression coefficient of the effect of temperature in the object shows that with its increase at constant age, the boar libido increases as well. This increase in libido, which has a small practical significance particularly because of a low regression coefficient (0.0002), can be limiting, since the rise in ambient temperature above the biological optimum has a negative effect on the body physiological status and sperm production.

The mean LSM values of the studied traits show the differences existing between the duration of daylight within the photoperiod interval (Table 5). The boars manifested better libido when the daylight lasted longer than 12 h in both photoperiod intervals. The largest difference was perceived between the winter and summer periods (0.069 index points; $P<0.01$). Different from libido, when the daylight lasted less than 12 h, although only in the decreasing photoperiod interval, the volume of ejaculate and ejaculation intensity were higher. It is clear that shortening the LD has a stimulatory effect on neurohumoral mechanisms of sperm production. During the winter period, when LD was shorter than 12 h, the phenotypic values of VOL and IE were below the average, so shortening LD in this period had no stimulatory effect.

Boars of fertile breeds (Swedish Landrace and Large White) displayed superiority compared with the

Table 3 - Basic statistical parameters

Trait	$\bar{X}$±SD	Interval	CV (%)
Age of boar (day)	551.44±232.82	161.00-1080.00	42.22
Preparation time until ejaculation (min)	3.56±0.63	2.00-7.00	17.70
Duration of ejaculation (min)	6.06±0.69	3.00-8.00	11.39
Libido index	1.76±0.41	0.67-4.00	23.30
Volume of ejaculate (mL)	231.80±73.90	50.00-810.00	31.88
Intensity of ejaculation (mL min^{-1})	37.65±8.80	8.33-101.25	23.37

SD - standard deviation; CV - coefficient of variation.

Table 4 - Significance (P) of effects on variability of analysed traits

Trait	PH(LD)	B	Linear regression impact			
	P		b_1	P	b_2	P
Libido index	0.0001	<0.0001	–0.0080	<0.0001	0.0002	<0.0001
Volume of ejaculate (mL)	0.0193	<0.0001	0.0880	<0.0001	0.1283	0.5741
Intensity of ejaculation (mL min^{-1})	0.0079	<0.0001	0.0100	<0.0001	0.0305	0.2650

PH(LD) - duration of daylight within photoperiod interval; B - breed, b_1 - coefficient of linear regression effect of age of boar; b_2 - coefficient of linear regression effect of inside temperature.

pronounced meat breed Duroc (Table 6). Swedish Landrace boars displayed better libido (higher by 0.077 and 0.099 index points in relation to Large White and Duroc). As for the production of sperm, Duroc boars were inferior compared with Swedish Landrace and Large White boars, since their ejaculate volume was lower (P<0.001) by 18.24 and 21.36 mL, and so was the intensity of ejaculation, by 2.08 and 2.46 mL min^{-1}.

The phenotypic relationship among the sexual activity traits indicates the possibility of simultaneous improvement of these traits (Table 7). A high relationship (r>0.9000) exists between volume of ejaculate and intensity of ejaculation, which implies that as volume of ejaculate is increased, the volume of ejaculate secreted in the unit of time simultaneously increases as well. Indeed, the increase in the ejaculate volume means better sperm secretion efficiency, because no linear increase occurs in the duration of ejaculation. A weak relationship (r<0.2000) occurred between libido and intensity of ejaculation, but coefficients were positive, which enables simultaneous improvement of both traits. By comparing the relationship of libido with VOL and IE among the breeds, we can see that the correlation coefficients are the lowest in the Large White breed. This weak or poor relationship in the Large White breed is most probably a consequence of weaker criteria or non-continual selection work on the Large White breed.

Table 5 - Comparison of LSM values between photoperiod within analysed traits

Photoperiod interval (duration of daylight)		Libido index	Volume of ejaculate (mL)	Intensity of ejaculation (mL min^{-1})
Increasing	<12h, winter	1.730±0.012A,Aa	230.06±2.19a	37.42±0.26Aa
	>12h, spring	1.795±0.010B,D	229.26±1.81Aa	37.38±0.22Aa
Decreasing	<12h, autumn	1.734±0.010C	236.19±1.77b,Bb	38.25±0.21Bb,a
	>12h, summer	1.799±0.013Bb,D	231.05±2.30	37.47±0.28b
μ		1.764	231.64	37.63

LSM - least square means; μ - general population average.
Differences between values within analysed traits are statistically significant: a,b - P<0.05; Aa,Bb - P<0.01; A,B and C,D - P<0.001.

Table 6 - Comparison of LSM values between breeds within analysed traits

Breed	Libido index	Volume of ejaculate (mL)	Intensity of ejaculation (mL min^{-1})
Swedish Landrace	1.823±0.009A	236.68±1.53A	38.20±0.18A
Large White	1.746±0.008B	239.80±1.46A	38.58±0.18A
Duroc	1.724±0.009B	218.44±1.50B	36.12±0.18B
μ	1.764	231.64	37.63

LSM - least square means; μ - general population average.
Differences between breeds within analysed traits are statistically significant: A,B - P<0.001.

Table 7 - Phenotypic correlation coefficient (r) between analysed traits

Breed	Photoperiod interval (duration of daylight)		LI-VOL	LI-IE	VOL-IE
Swedish Landrace	Increasing	<12h, winter	0.2405***	0.1463**	0.9338***
		>12h, spring	0.1907***	0.1189**	0.9578***
	Decreasing	<12h, autumn	0.2256***	0.1653***	0.9642***
		>12h, summer	0.2516***	0.1728***	0.9566***
Large White	Increasing	<12h, winter	0.2013***	0.1581***	0.9684***
		>12h, spring	0.1090**	0.0423ns	0.9565***
	Decreasing	<12h, autumn	0.1681***	0.0860*	0.9585***
		>12h, summer	0.1649***	0.0837*	0.9621***
Duroc	Increasing	<12h, winter	0.1372**	0.0701ns	0.9487***
		>12h, spring	0.2040***	0.1420**	0.9450***
	Decreasing	<12h, autumn	0.2016***	0.1372***	0.9571***
		>12h, summer	0.2332***	0.1306**	0.9513***
Total	Increasing	<12h, winter	0.2059***	0.1360***	0.9506***
		>12h, spring	0.1694***	0.1030***	0.9546***
	Decreasing	<12h, autumn	0.2121***	0.1449***	0.9605***
		>12h, summer	0.2187***	0.1329***	0.9578***

LI - libido index; VOL - volume of ejaculate; IE - intensity of ejaculation.
Statistical significance: ns - not significant; * P<0.05; **P<0.01; ***P<0.001.

Within fertile breeds (Swedish Landrace and Large White), during the spring, the weakest relationship of libido and the VOL and IE traits is perceived, which is most probably the consequence of above-average libido, lower volume of ejaculate, and lower intensity of ejaculation during this period.

Discussion

In research conducted by Szostak and Sarzyńska (2011), the preparation time until ejaculation varied from 1.99 to 14.65 min depending on the boar genotype. The preparation time until ejaculation and duration of ejaculation were shorter compared with the study of Kondracki et al. (2013), in which, depending on the length of duration of boar reproductive exploitation, the following intervals of variation were determined: 264.18-378.96 s (4.40-6.32 min) and 402.20-568.84 s (6.70-9.48 min). A possible reason for the shorter duration of non-productive period in our trial could be a better motivation of boar and secretion of pheromone, since the boars were housed in the same facility with breeding sows, which enabled visual, audible, and olfactory contact among animals. This can be supported by the report of Hemsworth and Tilbrook (2007), who pointed to a depressive influence that isolation from sows can have on boar manifestation of sexual activity during exploitation. Comparing libido in the studies of other authors is difficult, because of differences in methodologies of assessment. Subjective assessment of libido depends on the assessor himself so that as many objective methods as possible can be defined to prevent biased assessments. The libido assessment solely based on duration of ejaculation is not the most suitable method, and it would be necessary to take into account the period before the start of ejaculation as well. When libido is evaluated based on the total time necessary for taking ejaculate, the period before the start of ejaculation is not differentiated from the time needed for sperm collection. Because of the differences in the way libido is assessed, the results of this study differ from the results found by Okere et al. (2005), in which the assessment of libido in Yorkshire boars during different seasons ranged from 3.44 to 3.56, and in Landrace boars, from 3.09 to 3.38. The average intensity of ejaculation in this study is lower in relation to the intensity determined in the study of Oberlender et al. (2012), which was 39.89 mL min^{-1}, as the average duration of ejaculation was 378.15 s (6.30 min), while the average ejaculate volume 251.29 mL.

Partial similarity with the results of this study can be found in the research of Okere et al. (2005), in which the ejaculate volume varied under the influence of season and breed; however, this was not observed for boar libido. Similar results can also be found in the research of Szostak and Sarzyńska (2011) and Wysokińska and Kondracki (2014) when considering the effect of breed on libido variability. In the study of Szostak and Sarzyńska (2011), better libido was determined in young boars as compared with older boars, which agrees with the results of our research. Kondracki et al. (2013) concluded that the boar sexual experience did not favor the intensity of manifestation of sexual behaviour, which is also a general conclusion of this study in relation to libido manifestation. For this reason, Estienne (2014) points out that prostaglandin administered by injection can enhance libido in older boars that show weaker sexual drive. The effect of daylight within photoperiod interval is in agreement with the research of Knecht et al. (2013), in which a significant effect of photoperiod was determined on the variability of ejaculate volume. There is a trend of increase in the volume of ejaculate with the increase in boar age, which is consistent with the investigations of Wolf and Smital (2009), Banaszewska and Kondracki (2012), and Savić et al. (2013). The increase in ejaculate volume with aging also agrees with the results of Kondracki et al. (2013), who showed that in boar, the volume increased at the beginning of utilisation, after three months and after six months of exploitation (221.72, 251.14, and 269.20 mL). Taking also into consideration the duration of ejaculation (expressed in min; 6.70, 7.55, and 9.48 min) in these time terms, in the study of these authors, no distinct increase was determined in ejaculation intensity (33.09, 33.26, and 28.40 mL min^{-1}). The increase in the ejaculate volume with aging is a consequence of the increase in the mass of testes. According to the report of Ford et al. (2006), a primary factor for daily production of sperm is the number of Sertoli cells, which is linked to the mass of the testes. Considering a multiphase of the ejaculation, the increase in volume at older ages can be a consequence of higher activity of accessory sexual glands; in the first place. prostate, whose secretion highly contributes to increasing the ejaculate volume. Contrary to our research, Tomiyama et al. (2008) did not establish any kind of dependency of ejaculate volume on boar age.

The results of this experiment agree with the results of the study of Knecht et al. (2013), who, in July-December (decreasing interval), determined the ejaculate volume of 261.16 mL and which was 17 mL higher in comparison with the period of January-June (increasing interval). Similarity can also be found with the study of Pokrywka et al. (2014), who determined higher ejaculate volume of 280.61 mL in boars born in summer and used during autumn. Pinart and Puigmulé (2013) point out the stimulatory effect of day

shortage during autumn on boar reproductive capability (increase in the ejaculate volume). The study of Andersson (2000) shows the stimulatory effect of a short day on puberty maturing of spermatogenesis. The duration of daylight affects the boar reproductive capacity by regulating the secretion of melatonin, via the retina-pineal gland-hypothalamus mechanism. The results of the investigation of Andersson (2000) show that pigs display a typical circadian rhythm of secretion of melatonin with clearly increased secretion during the night and a low level during the day. Some authors point to the link in blood testosterone concentration with sexual activity and sperm production. Hemsworth and Tilbrook (2007) report that the problems in manifestation of sexual behaviour can be linked to a low concentration of blood testosterone. In the research of Borg et al. (1993), the testosterone concentration fluctuated under the effect of season; therefore, the serum testosterone was highest during the autumn in all examined breeds, which could indicate a stimulatory effect of testosterone on the sperm production mechanism. If we take into account that the autumn is the period when wild founders of domestic pigs are mating and the values of the traits of ejaculate are highest, it can be concluded that some trends, regardless of the process of domestication and selection, were also retained in modern noble breeds. This conclusion is confirmed by the study of Andersson (2000), in which distinct differences in secretion of melatonin between wild founders and domestic breeds were not observed.

The Swedish Landrace population was the most abundant one, which allowed stricter criteria to be conducted during selection and which probably influenced the better sexual activity of the boars of this breed on the account of best libido and over-average volume of ejaculate and intensity of ejaculation. The established superiority of Swedish Landrace boars compared with Large White boars is in contradiction with the study of Okere et al. (2005), who determined weaker libido in Landrace boars compared with Yorkshire boars during various seasons, although these differences were not significant. Opposite results can also be found in the research of Szostak and Sarzyńska (2011), in which the best libido was determined in hybrid boars and Duroc. This disagreement is a consequence of differences in genetic structure of the examined population and the method of defining and assessing the boar libido. The lower ejaculate volume of Duroc boar agrees with the results of Banaszewska and Kondracki (2012), in which the volume of 162.75 mL was determined, while the Polish Large White and Polish Landrace boars had an ejaculate volume of 247.03 and 257.03 mL. The confirmed inferiority of the Duroc breed in sexual activity compared with fertile breeds might be a consequence of selection directed towards high meat production or of smaller population abundance, which imposed lower intensity of selection.

Lower negative correlation coefficients (from –0.183 to –0.171) between libido parameters and ejaculate volume were determined in the study of Szostak and Sarzyńska (2011). Very weak or slight relationship between libido and ejaculate volume agrees with the results found by Kondracki et al. (2013) and Wysokińska and Kondracki (2014), who, between the parameters of boar sexual activity and the ejaculate volume, determined phenotype correlation values of –0.06 to 0.28 and from –0.277 to 0.324. This research differs in the direction of correlation, since in the study of the abovementioned authors a negative correlation was found between ejaculate volume and some boar sexual activity parameters.

Conclusions

The boar sexual activity can be analysed based on libido and ejaculation intensity. The boar libido and ejaculation intensity can vary with photoperiod and breed. The libido of boars weakens with time, while the ejaculate volume and ejaculation intensity increase. Boars manifest better libido when the daylight lasts longer than 12 h in both photoperiod intervals. Different from libido, the ejaculate volume and ejaculation intensity are highest when the daylight lasts less than 12 h; however only in the decreasing photoperiod interval. Swedish Landrace boars best manifest libido, while in sperm production the Duroc boars are inferior compared with the Swedish Landrace and Large White boars. The phenotypic relationship between libido, ejaculate volume, and ejaculation intensity can be very weak to high, with positive coefficients, indicating the possibility of simultaneously improving these traits.

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