The effect of season on semen parameters in cross-bred boars and phenotypic correlations between semen characteristics in different seasons

Wpływ sezonu na parametry nasienia knurów mieszańców oraz korelacje fenotypowe pomiędzy cechami nasienia w poszczególnych sezonach roku

Bogdan SZOSTAK[1]* and Łukasz PRZYKAZA[2]

[1] University of Life Science in Lublin, Faculty of Biology and Animal Breeding, Institute of Animal Nutrition and Bromatology, Poland; *correspondence: bogdan.szostak@up.lublin.pl

[2] Mossakowski Medical Research Centre, Polish Academy of Sciences, Departament of Neurosurgery, Warsaw, Poland

Abstract

The study evaluated ejaculates of cross-bred boars produced by reciprocal cross-breeding of the breeds Duroc and Pietrain, as well as the effect of the season of the year on qualitative and quantitative parameters of the semen of these boars. Phenotypic correlations between semen characteristics in particular seasons of the year were estimated as well. The analysis included a total of 1156 ejaculates from 2-year-old boars, collected manually at 3-4-day intervals. The following traits were evaluated: ejaculate volume (ml), sperm concentration ($x10^6$ x ml^{-1}), percentage of live sperm (showing progressive motion) (%), total number of live sperm in the ejaculate (in billions), number of sperm per insemination dose, and the number of insemination doses obtained from one ejaculate. No significant differences were noted in the semen characteristics of boars produced by reciprocal cross-breeding of the Duroc and Pietrain breeds. The season of the year significantly affected the characteristics of the ejaculates. Ejaculates collected in the spring had the greatest volume, while the highest sperm concentration and sperm count were noted in the ejaculates collected in the autumn and winter. The volume of the ejaculates decreased substantially in the summer, together with the sperm count, resulting in fewer insemination doses obtained per ejaculate. The value of the phenotypic correlations between semen characteristics was not significantly affected by the season of the year.

Keywords: boars, ejaculates, insemination, sperm

Abstrakt

W pracy dokonano oceny ejakulatów knurów mieszańców pochodzących z reciprokalnego krzyżowania ras Duroc i Pietrain oraz wpływu sezonu na parametry jakościowe i ilościowe nasienia tych knurów. Oszacowano również korelacje fenotypowe pomiędzy cechami nasienia w poszczególnych sezonach roku. Analizie poddano 1156 ejakulatów pobieranych od knurów w wieku 2 lat, metodą manualną, w odstępach 3-4 dniowych. Oceniano następujące cechy: objętość ejakulatu (ml), koncentrację plemników ($x10^6$ x ml^{-1}), odsetek plemników żywych (wykazujących ruch postępowy) (%), ogólną liczbę plemników żywych w ejakulacie (mld), liczbę plemników w dawce inseminacyjnej, i liczbę dawek inseminacyjnych uzyskiwanych z jednego ejakulatu (szt.). Nie stwierdzono istotnych różnic w cechach nasienia knurów pochodzących z reciprokalnego krzyżowania ras duroc i pietrain. Sezon roku wywierał istotny wpływ na cechy ejakulatów. Największą objętością charakteryzowały się ejakulaty pobierane w okresie wiosennym, natomiast najlepszą koncentracją i liczbą plemników ejakulaty pobierane jesienią i zimą. W okresie lata objętość ejakulatów znacząco malała, a wraz nią malała również liczba plemników, co niekorzystnie przełożyło się na liczbę dawek inseminacyjnych otrzymanych z jednego ejakulatu. Wartość korelacji fenotypowych pomiędzy cechami nasienia nie zmieniała się istotnie pod wpływem sezonu.

Słowa kluczowe: ejakulaty, inseminacja, knury, nasienie

Abstrakt rozszerzony

W niniejszym opracowaniu podjęto próbę oceny, wpływu sezonu na parametry nasienia knurów mieszańców (duroc x pietrain i pietrain x duroc) oraz ustalenia korelacji fenotypowych pomiędzy cechami nasienia w poszczególnych sezonach roku kalendarzowego. Materiał analityczny stanowiły dane dotyczące 816 ejakulatów pobranych od knurów mieszańców duroc x pietrain i 340 ejakulatów pobranych od knurów pietrain x duroc. Były to knury w wieku około 2 lat, żywione indywidualnie według norm. Ejakulaty pobierano metodą manualną w odstępach 3-4 dni. Badane ejakulaty pochodziły ze Stacji Unasieniania Loch w Białce k. Radzynia Podlaskiego. Każdy pobrany ejakulat poddano ocenie kontrolując następujące cechy fizyczne: objętość ejakulatu (ml), koncentrację plemników ($x10^6$ x ml^{-1}), odsetek plemników żywych (wykazujących ruch postępowy (%), ogólną liczbę plemników żywych w ejakulacie (mld), liczbę plemników w dawce inseminacyjnej, liczbę dawek inseminacyjnych uzyskiwanych z jednego ejakulatu (szt.). Analizę wpływu wariantu krzyżowania knura i sezonu na cechy nasienia wykonano za pomocą dwuczynnikowej ANOVA i testu post hoc Tukeya. Korelacje między cechami nasienia określono współczynnikiem korelacji Pearsona. Z analizy danych wynika, że w zakresie podstawowych cech ejakulatów knurów duroc x pietrain wystąpiły istotne różnice pomiędzy ejakulatami pobieranymi w różnych porach roku. Pobierane wiosną charakteryzowały się największą średnią objętością – 309,5 ml i miały o 70 ml większą objętość niż ejakulaty pobierane latem.

Z przedstawionych danych wynika, że sezon w którym pobierano ejakulaty nie wpływał istotnie na koncentrację plemników, natomiast miał wysoko istotny wpływ na odsetek plemników o ruchu postępowym. Liczba plemników w dawkach inseminacyjnych sporządzanych w Stancji Unasieniania, z której pochodzą analizowane dane była różnicowana sezonem eksploatacyjnym knurów. Dawki inseminacyjne sporządzane w okresie wiosennym zawierały istotnie większą liczbę plemników żywych (2,6 mld) w porównaniu z dawkami inseminacyjnymi w pozostałych sezonach roku (2,5 mld). Porównując cechy ilościowe i jakościowe nasienia knurów duroc x pietrain z nasieniem knurów pietrain x duroc można zauważyć, że wartości cech są bardzo zbliżone. Nie stwierdzono istotnych różnic w wartościach cech charakteryzujących nasienie knurów z analizowanych grup. Stwierdzono natomiast istotne różnice w cechach nasienia pobieranego w różnych sezonach roku. W tabelach 3a, 3b i 4a, 4b zestawiono wartości korelacji fenotypowych pomiędzy cechami ejakulatów knurów duroc x pietrain w poszczególnych sezonach roku. Można zauważyć, że wysokość niektórych korelacji fenotypowych zmieniała się w zależności od pory roku. W niniejszych badaniach stwierdzono wysoką korelację fenotypową pomiędzy objętością ejakulatu i liczbą plemników w ejakulacie. Wiosną wynosiła ona 0,86 ($P < 0,01$), latem – 0,89 ($P < 0,01$), jesienią – 0,88 ($P < 0,01$), a zimą – 0,91 ($P < 0,01$). Tabele 5a, 5b i 6a, 6b zawierają wartości korelacji fenotypowych pomiędzy cechami ejakulatów knurów pietrain x duroc w obrębie poszczególnych sezonów. Wartości korelacji fenotypowych pomiędzy cechami ejakulatów knurów pietrain x duroc kształtowały się na zbliżonym poziomie do korelacji cech nasienia knurów duroc x pietrain. Nie stwierdzonych znaczących różnic w poszczególnych sezonach roku.

W podsumowaniu należy podkreślić, że nie stwierdzono istotnych różnic w cechach nasienia knurów pochodzących z reciprokalnego krzyżowania ras duroc i pietrain. Sezon roku wywiera istotny wpływ na cechy ejakulatów. Największą objętością charakteryzowały się ejakulaty pobierane w okresie wiosennym, natomiast najlepszą koncentracją i liczbą plemników ejakulaty pobierane jesienią i zimą. W okresie lata objętość ejakulatów znacząco maleje a wraz z nią również maleje liczba plemników, co przekłada się niekorzystnie na liczbę dawek inseminacyjnych otrzymanych z jednego ejakulatu. Wartość korelacji fenotypowych pomiędzy cechami nasienia nie zmieniała się istotnie pod wpływem sezonu.

Introduction

Cross-bred boars are often used for reproduction because they have high libido (Ciereszko et al., 2000; Nelly and Robison, 2010) and ejaculate easily, which is particularly important in boars used for insemination (Wysokińska et al., 2008). Many authors have found that ejaculates obtained from cross-bred boars have better quantitative and qualitative characteristics than ejaculates from pure-bred boars (Kondracki et al., 2003; Wysokińska and Kondracki, 2004). There have also been studies in which heterosis was not found to have a positive effect on the characteristics of cross-bred boar ejaculates (Smital, 2009).

The results of many studies indicate seasonal changes in quantitative and qualitative indicators of boar semen (Ciereszko et al., 2000; Marchev and Szostak, 2013; Pietruszka et al., 2006; Pokrywka and Ruda, 2001; Savić et al., 2013; Sławeta and

Morstin, 1982; Szostak et al., 2015). The impact of the season on these parameters varies depending on the breed of the boars and the conditions in which they are raised (Okere et al., 2005). For this reason further research and observations should be conducted on the reaction of breeders of different genotypes in different seasons.

In the present study an attempt was made to evaluate the effect of the season of the year on semen parameters in cross-bred boars (Duroc x Pietrain and Pietrain x Duroc) and to determine phenotypic correlations between semen characteristics in different seasons of the year.

Materials and methods

The material for the analysis consisted of data concerning 1156 ejaculates collected from Duroc x Pietrain and Pietrain x Duroc boars. The boars were about 2 years old and were fed individually according to norms. They were kept in closed housing that met the requirements for animal well-being. The ejaculates were collected by the manual method at 3-4-day intervals. The ejaculates were supplied by the Sow Insemination Station in Białka.

The following physical characteristics were evaluated in each ejaculate:

– volume of the ejaculate (ml)

– sperm concentration ($x10^6$ x ml^{-1})

– percentage of live sperm (exhibiting progressive motion) (%)

– total live sperm count in the ejaculate (billions)

– number of sperm per insemination dose

– number of insemination doses obtained from one ejaculate

The volume of the ejaculate was determined after filtering out the gel fraction. Sperm concentration in the ejaculate was determined by the colorimetric method. The percentage of sperm cells exhibiting progressive motion was determined by microscopic examination. The total number of sperm in the ejaculate exhibiting progressive motion and the number of insemination doses that could be obtained from one ejaculate were calculated using SYSTEM SUL computer software.

The data collected were arranged according to the season when the semen was collected: spring (354 ejaculates), summer (305 ejaculates), autumn (151 ejaculates) or winter (346 ejaculates).

The effect of the cross-breeding variant and the season on the semen characteristics was analysed using two-way ANOVA and Tukey's post hoc test, except for the trait 'percentage of live cells', for which non-parametric tests were used. Correlations between semen characteristics were determined by Pearson's correlation coefficient.

Results

Table 1 presents the values for the physical characteristics of the ejaculates from the Duroc x Pietrain boars in each season of the year. Analysis of the data shows pronounced and substantial differences in the main characteristics of the ejaculates between ejaculates collected during different seasons of the year.

Ejaculates collected in the spring had the greatest mean volume – 309.5 ml, which was 70 ml more than the ejaculates collected in the summer. The differences in volume between ejaculates collected in the spring and summer were highly significant ($P < 0.001$). Highly significant differences in ejaculate volume were also noted between spring and winter, autumn and summer, and winter and summer ($P < 0.001$). The difference in ejaculate volume between spring and autumn was significant at $P < 0.05$.

The data presented in the table 1 show that the season in which the ejaculates were collected did not significantly affect sperm concentration, but had a highly significant effect on the percentage of sperm with progressive motion. The lowest percentage of sperm with progressive motion was noted in the ejaculates collected in the spring (73.4%), and the highest was noted for the winter ejaculates (83.4%). The differences in the percentage of sperm with progressive motion in the ejaculates collected in the spring and in other seasons were highly significant ($P < 0.001$).

The total sperm count in the ejaculate is of fundamental importance in insemination practice because it determines the number of semen portions that can be prepared from the ejaculate. The table 1 shows that the number of sperm showing progressive motion in the Duroc x Pietrain ejaculates ranged from 48.9 to 61.9 billion and depended on the season when the ejaculates were collected. The lowest number of sperm was noted in the ejaculates collected in the summer (48.9 billion), which was highly significantly less than in the ejaculates collected in other seasons, when the sperm count was at equal levels, ranging from 60.9 to 61.9 billion.

The number of sperm in the insemination doses prepared at the Insemination Station from which the data were obtained varied according to the season when the ejaculates were collected. The insemination doses prepared in the spring contained significantly more live sperm (2.6 billion) than the insemination doses from other seasons (2.5 billion).

From 19.3 to 24.6 insemination doses were prepared from the ejaculates collected from the Duroc x Pietrain boars. The fewest insemination doses were prepared from the ejaculates collected in the summer (19.3). The mean number of insemination doses prepared from the ejaculates collected in the summer was significantly less ($P < 0.001$) than the mean number of doses prepared in the other seasons. This difference exceeded 4 doses.

Table 2 illustrates the effect of the season on the ejaculate characteristics of the Pietrain x Duroc boars. Comparison of the quantitative and qualitative characteristics of the semen of the Duroc x Pietrain boars (Table 1) with the semen of the Pietrain x Duroc boars (Table 2) shows that the values are very similar. No significant differences were noted in the values for the traits characterizing the semen of the boars from these groups. Significant differences were noted in the characteristics of the semen collected in different seasons. The effect of the season on particular

semen characteristics of the Pietrain x Duroc boars was similar to the effect observed in the case of the Duroc x Pietrain cross-breeds. The greatest differences were noted for the volume of the ejaculates collected in the summer and in the other seasons ($P < 0.001$). The ejaculates collected from the Pietrain x Duroc boars in the summer had significantly lower sperm concentrations than those collected in the autumn and winter ($P < 0.5$).

Table 1. The effect of season on semen parameters in cross-bred boars Duroc x Pietrain

Tabela 1. Wpływ sezonu na parametry nasienia knurów mieszańców Duroc x Pietrain

Traits of semen	Spring (1) n = 239		Summer (2) n = 214		Autumn (3) n = 102		Winter (4) n = 261		Significance of differences
	X	SE	X	SE	X	SE	X	SE	
Ejaculate volume [ml]	309.54	4.743	238.64	3.964	286.17	6.377	283.02	3.796	1-2***, 3*, 4***; 2-3***, 4***
Concentration of spermatozoa [$x10^6 \times ml^{-1}$]	266.96	2.841	254.78	2.827	263.60	5.328	264.58	3.787	n.s.
Percent of live spermatozoa [%]	73.43	0.319	79.34	0.169	80.00	0.000	83.41	3.448	1-2***, 3***, 4***
Number of live spermatozoa [bln]	60.90	1.203	48.88	1.126	61.70	2.182	61.95	1.503	1-2***; 2-3***, 4***
Number of spermatozoa per insemination dose [bln]	2.58	0.007	2.54	0.009	2.54	0.006	2.54	0.006	1-2**, 4***
Number of insemination doses	23.80	0.481	19.33	0.462	24.30	0.873	24.57	0.600	1-2***; 2-3***, 4***

X – mean, n – number of ejaculates, SE – standard error; * – $P < 0.05$; ** – $P < 0.01$; *** – $P < 0.001$; n.s. – no significances

X – średnia, n – liczba ejakulatów, SE – błąd standardowy; * – $P < 0.05$; ** – $P < 0.01$; *** – $P < 0.001$; n.s. – brak istotności

Table 2. The effect of season on semen parameters in cross-bred boars Pietrain x Duroc

Tabela 2. Wpływ sezonu na parametry nasienia knurów mieszańców Pietrain x Duroc

Traits of semen	Spring (1) n = 115		Summer (2) n = 91		Autumn (3) n = 49		Winter (4) n = 85		Significance of differences
	X	SE	X	SE	X	SE	X	SE	
Ejaculate volume [ml]	310.70	6.256	235.94	5.909	289.79	9.437	283.52	6.545	1-2***, 4*; 2-3***, 4***
Concentration of spermatozoa [x10^6 x ml^{-1}]	264.06	3.240	248.65	4.594	269.51	8.219	269.98	7.067	2-4*
Percent of live spermatozoa [%]	73.04	0.448	79.12	0.298	80.00	0.000	80.11	0.117	1-2***, 3***, 4***
Number of live spermatozoa [bln]	60.03	1.518	47.01	1.732	64.70	3.638	63.38	2.559	1-2***; 2-3***, 4***
Number of spermatozoa per insemination dose [bln]	2.58	0.012	2.54	0.012	2.54	0.007	2.55	0.011	1-2*
Number of insemination doses	23.54	0.658	18.63	0.726	25.51	1.463	24.77	1.024	1-2***; 2-3***, 4***

X – mean, n – number of ejaculates, SE – standard error; * – P < 0.05; ** – P < 0.01; *** – P < 0.001

X – średnia, n – liczba ejakulatów, SE – błąd standardowy; * – P < 0.05; ** – P < 0.01; *** – P < 0.001

The effect of season on the percentage of sperm with progressive motion and on the total sperm count was similar in the ejaculates of the Duroc x Pietrain and the Pietrain x Duroc boars. Ejaculates collected in the spring had the lowest percentage of live sperm, while the lowest total number of live sperm was noted in the ejaculates collected in the summer. The number of insemination doses per ejaculate in the Pietrain x Duroc boars was lowest in the summer (18.6), and the differences with respect to the other seasons were highly significant (P < 0.001).

Tables 3a, 3b and 4a, 4b present the phenotypic correlations between the ejaculate characteristics of Duroc x Pietrain boars in each season. Analysis of the results shows that the size of some of the phenotypic correlations varied depending on the season. The present study found a high phenotypic correlation between ejaculate volume and the number of sperm in the ejaculate: 0.86 in the spring (P < 0.01), 0.89 (P < 0.01) in the summer, 0.88 (P < 0.01) in the autumn and 0.91 (P < 0.01) in the

winter. High, significant phenotypic correlations were found between the volume of the ejaculate and the number of insemination doses (r from 0.85 to 0.91).

Table 3a. The phenotypic correlations between semen characteristics in boars Duroc x Pietrain in spring

Tabela 3a. Korelacje fenotypowe pomiędzy cechami nasienia knurów Duroc x Pietrain wiosną

	Ejaculate volume [ml]	Concentration of spermatozoa [$x10^6$ x ml^{-1}]	Percent of live spermatozoa [%]	Number of live spermatozoa [bln]	Number of spermatozoa per insemination dose [bln]	Number of insemination doses
Ejaculate volume [ml]		0.38 ***	-0.45 ***	0.86 **	-0.09	0.85 **
Concentration of spermatozoa [$x10^6$ x ml^{-1}]	0.38 ***		-0.18 **	0.75 **	-0.12	0.74 **
Percent of live spermatozoa [%]	-0.45 ***	-0.18 **		-0.23 ***	-0.11	-0.21 **
Number of live spermatozoa [bln]	0.86 **	0.75 **	-0.23 ***		-0.13 *	0.98 **
Number of spermatozoa per insemination dose [bln]	-0.09	-0.12	-0.11	-0.13 *		-0.26 ***
Number of insemination doses	0.85 **	0.74 **	-0.21 **	0.98 **	-0.26 ***	

* – P < 0.05; ** – P < 0.01; *** – P < 0.001

Table 3b. The phenotypic correlations between semen characteristics in boars Duroc x Pietrain in summer

Tabela 3b. Korelacje fenotypowe pomiędzy cechami nasienia knurów Duroc x Pietrain latem

	Ejaculate volume [ml]	Concentration of spermatozoa [$x10^6$ x ml^{-1}]	Percent of live spermatozoa [%]	Number of live spermatozoa [bln]	Number of spermatozoa per insemination dose [bln]	Number of insemination doses
Ejaculate volume [ml]		0.39 ***	-0.02	0.89 **	-0.31 ***	0.89 **
Concentration of spermatozoa [$x10^6$ x ml^{-1}]]	0.39 ***		-0.02	0.74 **	-0.02	0.70 **
Percent of live spermatozoa [%]	-0.02	-0.02		0.09	0.05	0.03
Number of live spermatozoa [bln]	0.89 **	0.74 **	0.09		-0.22 **	0.97 **
Number of spermatozoa per insemination dose [bln]	-0.31 ***	-0.02	0.05	-0.22 **		-0.35 ***
Number of insemination doses	0.89 **	0.70 **	0.03	0.97 **	-0.35 ***	

** – P < 0.01; *** – P < 0.001

The differences in the size of these correlations in different seasons were slight. High phenotypic correlations were also noted between the total sperm count and sperm concentration: 0.74 – 0.75 in the spring and summer, and 0.84 and 0.91, respectively, in the autumn and winter, at P < 0.01. Significant, high correlations were noted between the number of live sperm per ejaculate and the number of insemination doses obtained from the ejaculates. The season in which the semen was collected did not substantially affect the size of the correlations.

Tables 5a, 5b and 6a, 6b present the values for the phenotypic correlations between characteristics of ejaculates from Pietrain x Duroc boars within each season. Analysis of the data reveals that the values for these correlations were similar to the corresponding correlations in the Duroc x Pietrain boars. No substantial differences were noted in different seasons of the year.

Table 4a. The phenotypic correlations between semen characteristics in boars Duroc x Pietrain in autumn

Tabela 4a. Korelacje fenotypowe pomiędzy cechami nasienia knurów Duroc x Pietrain jesienią

	Ejaculate volume [ml]	Concentration of spermatozoa [$x10^6$ x ml^{-1}]	Percent of live spermatozoa [%]	Number of live spermatozoa [bln]	Number of spermatozoa per insemination dose [bln]	Number of insemination doses
Ejaculate volume [ml]		0.50 ***	-	0.88 **	-0.10	0.88 **
Concentration of spermatozoa [$x10^6$ x ml^{-1}]	0.50 ***		-	0.84 **	-0.02	0.83 **
Percent of live spermatozoa [%]	-	-	-	-	-	-
Number of live spermatozoa [bln]	0.88 **	0.84 **	-		-0.10	0.99 **
Number of spermatozoa per insemination dose [bln]	-0.10	-0.02	-	-0.10		-0.16
Number of insemination doses	0.88 **	0.83 **	-	0.99 **	-0.16	

** – P < 0.01; *** – P < 0.001

Table 4b. The phenotypic correlations between semen characteristics in boars Duroc x Pietrain in winter

Tabela 4b. Korelacje fenotypowe pomiędzy cechami nasienia knurów Duroc x Pietrain zimą

	Ejaculate volume [ml]	Concentration of spermatozoa [$x10^6$ x ml^{-1}]	Percent of live spermatozoa [%]	Number of live spermatozoa [bln]	Number of spermatozoa per insemination dose [bln]	Number of insemination doses
Ejaculate volume [ml]		0.68 **	-0.02	0.91 **	-0.15	0.91 **
Concentration of spermatozoa [$x10^6$ x ml^{-1}]	0.68 **		0.00	0.91 **	-0.05	0.90 **
Percent of live spermatozoa [%]	-0.02	0.00		-0.02	0.03	0.01
Number of live spermatozoa [bln]	0.91 **	0.91 **	-0.02		-0.10	0.99 **
Number of spermatozoa per insemination dose [bln]	-0.15 *	-0.05	0.03	-0.10		-0.17 **
Number of insemination doses	0.91 **	0.90 **	0.01	0.99 **	-0.17 **	

* – P < 0.05; ** – P < 0.01

Table 5a. The phenotypic correlations between semen characteristics in boars Pietrain x Duroc in spring

Tabela 5a. Korelacje fenotypowe pomiędzy cechami nasienia knurów Pietrain x Duroc wiosną

	Ejaculate volume [ml]	Concentration of spermatozoa [x10^6 x ml^{-1}]	Percent of live spermatozoa [%]	Number of live spermatozoa [bln]	Number of spermatozoa per insemination dose [bln]	Number of insemination doses
Ejaculate volume [ml]		0.47 ***	-0.40 ***	0.92 **	-0.30 **	0.87 **
Concentration of spermatozoa [x10^6 x ml^{-1}]	0.47 ***		-0.38 ***	0.74 **	-0.25 **	0.70 ***
Percent of live spermatozoa [%]	-0.40 ***	-0.38 ***		-0.30 **	0.22 *	-0.22 *
Number of live spermatozoa [bln]	0.92 **	0.74 **	-0.30 **		-0.31 **	0.95 **
Number of spermatozoa per insemination dose [bln]	-0.30 **	-0.25 **	0.22 *	-0.31 **		-0.39 ***
Number of insemination doses	0.87 **	0.70 ***	-0.22 *	0.95 **	-0.39 ***	

* – P < 0.05; ** – P < 0.01; *** – P < 0.001

Table 5b. The phenotypic correlations between semen characteristics in boars Pietrain x Duroc in summer

Tabela 5b. Korelacje fenotypowe pomiędzy cechami nasienia knurów Pietrain x Duroc latem

	Ejaculate volume [ml]	Concentration of spermatozoa [$x10^6$ x ml^{-1}]	Percent of live spermatozoa [%]	Number of live spermatozoa [bln]	Number of spermatozoa per insemination dose [bln]	Number of insemination doses
Ejaculate volume [ml]		0.37 ***	-0.05	0.86 **	-0.30 **	0.86 **
Concentration of spermatozoa [$x10^6$ x ml^{-1}]	0.37 ***		0.19	0.75 ***	-0.10	0.73 ***
Percent of live spermatozoa [%]	-0.05	0.19		0.17	0.21 *	0.14
Number of live spermatozoa [bln]	0.86 **	0.75 ***	0.17		-0.21	0.97 **
Number of spermatozoa per insemination dose [bln]	-0.30 **	-0.10	0.21 *	-0.21		-0.30 **
Number of insemination doses	0.86 **	0.73 ***	0.14	0.97 **	-0.30 **	

* – P < 0.05; ** – P < 0.01; *** – P < 0.001

Table 6a. The phenotypic correlations between semen characteristics in boars Pietrain x Duroc in autumn

Table 6a. Korelacje fenotypowe pomiędzy cechami nasienia knurów Pietrain x Duroc jesienią

	Ejaculate volume [ml]	Concentration of spermatozoa [x10^6 x ml^{-1}]	Percent of live spermatozoa [%]	Number of live spermatozoa [bln]	Number of spermatozoa per insemination dose [bln]	Number of insemination doses
Ejaculate volume [ml]		0.75 ***	-	0.94 **	-0.41 **	0.94 **
Concentration of spermatozoa [x10^6 x ml^{-1}]	0.75 ***		-	0.92 **	-0.36 *	0.92 **
Percent of live spermatozoa [%]	-	-	-	-	-	-
Number of live spermatozoa [bln]	0.94 **	0.92 **	-		-0.41 **	0.99 **
Number of spermatozoa per insemination dose [bln]	-0.41 **	-0.36 *	-	-0.41 **		-0.45 **
Number of insemination doses	0.94 **	0.92 **	-	0.99 **	-0.45 **	

* – P < 0.05; ** – P < 0.01; *** – P < 0.001

Table 6b. The phenotypic correlations between semen characteristics in boars Pietrain x Duroc in winter

Table 6b. Korelacje fenotypowe pomiędzy cechami nasienia knurów Pietrain x Duroc zimą

	Ejaculate volume [ml]	Concentration of spermatozoa [x10^6 x ml^{-1}]	Percent of live spermatozoa [%]	Number of live spermatozoa [bln]	Number of spermatozoa per insemination dose [bln]	Number of insemination doses
Ejaculate volume [ml]		0.56 ***	-0.13	0.86 **	-0.15	0.86 **
Concentration of spermatozoa [x10^6 x ml^{-1}]	0.56 ***		0.35 **	0.88 **	-0.01	0.86 **
Percent of live spermatozoa [%]	-0.13	0.35 **		0.12	-0.06	0.13
Number of live spermatozoa [bln]	0.86 **	0.88 **	0.12		-0.08	0.99 **
Number of spermatozoa per insemination dose [bln]	-0.15	-0.01	-0.06	-0.08		-0.16
Number of insemination doses	0.86 **	0.86 **	0.13	0.99 **	-0.16	

** – P < 0.01; *** – P < 0.001

Discussion

Many studies have shown that the origin of boars (breed or cross-breeding variant) plays a significant role in shaping the quantitative and qualitative characteristics of their ejaculates (Foote, 2003; Gączarzewicz et al., 2000; Kondracki et al., 2003; Knecht et al., 2004; Savić et al., 2013). In recent years cross-bred boars have enjoyed considerable popularity. According to many authors these boars produce quantitatively and qualitatively better ejaculates than pure-bred boars (Kondracki et al., 2003; Neely and Robison, 1983; Wysokińska and Kondracki, 2004). This should not, however, be accepted as a rule, as the effects of cross-breeding depend to a considerable degree on the selection of breeds and on the cross-breeding programme. The results of the present study showed that the cross-breeding variant (Duroc x Pietrain and Pietrain x Duroc) did not affect either the quantitative or the qualitative characteristics of the semen. A significant factor affecting these characteristics was the season in which the ejaculates were collected. The effect of the season on semen characteristics should mainly be considered in terms of the

effect of day length and ambient temperature (Claus et al., 1985; Sancho et al., 2004; Trudeau and Sanford, 1990). Kozdrowski and Dubiel (2004) based on a study of the effect of the season on semen characteristics in wild boar, conclude that the function of the reproductive organs of the wild boar is seasonal, and the direction of the seasonal changes in the volume and qualitative traits of ejaculates is similar to that observed in ejaculates produced by boars of modern breeds. The authors observed an increase in the volume of the ejaculates and the number of sperm per ejaculate during the period when the days were shorter (November, December). These observations confirm that the activity of the reproductive organs in the wild boar is highest in the autumn, as Mauget and Boissin (1987) and Weiler et al. (1996) had previously reported, explaining that this was due to the higher level of testosterone in the blood serum during this period. Observations of sexual behaviour and the effect of the season on semen quality in boars of the primitive East Balkan breed, which is phenotypically similar to the wild boar, have also confirmed that the quality of ejaculates is highest in the autumn (Marchev and Szostak, 2013).

The results of the present study show that boars produced by cross-breeding of modern breeds have retained the tendency towards better semen quality (sperm concentration, percentage of sperm with progressive motion, sperm count) during periods when the day is shorter and the temperatures are lower. In the summer, when temperatures are high, boars have lower libido (Szostak and Przykaza, 2011) and lower semen production. The data from the present study show that in the summer the ejaculates had the lowest volume, sperm concentration, and total number of sperm with progressive motion. A similar effect of seasonal factors on the characteristics of ejaculates in boars of modern breeds has been observed in the climate conditions of Bulgaria (Marchev et al., 2003).

Conclusions

To sum up, it should be emphasized that no significant differences were observed in the characteristics of semen from boars produced by reciprocal cross-breeding of the breeds Duroc and Pietrain. The season of the year had a significant effect on the characteristics of the ejaculates. The greatest volume was noted in the ejaculates collected in the spring, while the highest concentration and sperm count were observed in the ejaculates collected in the autumn and winter. In the summer the volume of the ejaculates and the sperm count substantially decrease, which adversely affects the number of insemination doses obtained per ejaculate. The value for the phenotypic correlations between the semen characteristics was not significantly affected by the season.

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