COMPARISON OF ENVIRONMENTAL VARIATIONS IN BOAR SEMEN CHARACTERISTICS OF SIX BREEDS AND THEIR CROSSBREDS OVER AN EIGHT-YEAR PERIOD

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Abstract

The aim of this study was to analyze environmental variations of the AI boar sperm output adjusted for other effects (breed-station, age of boar, interval between two collections and individuality of boar). A total of 303,748 records of semen collections were utilised to estimate statistics of semen traits of 3,392 boars belonging to the following groups of breeds: dam breeds Czech Large White (LW_{CZ}), Landrace (L), sire breeds Czech Meat Pig (CM), Duroc (D), Large White (LW), Pietrain (P) and crossbreds (D×H; D×LW; D×P; CM×P; H×P and LW×P). The evaluation was based on semen volume, percentage of abnormal spermatozoa, total number of spermatozoa and index of sperm efficiency. The linear model used for statistical analysis. In the monitored period the increasing trend of quantity of spermatozoa and in contrast decreasing trend of quality of spermatozoa were displayed in boars of dam breeds. The positive trends of quantity and quality of spermatozoa were recorded in boars of sire breeds. In contrast the decreasing trend of quantity and quality of spermatozoa was recorded in crossbreds. The seasonal variation displayed lower values of the semen volume and the number of spermatozoa in summer and higher values in autumn and winter.

Key Words: Boar; semen characteristics; environmental variations

The first practical experiments with an artificial insemination (AI) in the pig were conducted in the 1930s and from the mid-1960s AI expanded to other European countries including the Czech Republic. Monitoring the quality and quantity of boar semen has great economic importance for pig breeders. Furthermore, the economic return of an AI centre primarily depends on the boar's ability to produce spermatozoa during the period. Regardless of a boar's genetic potential to produce desirable offspring, he is worthless to an AI unit if he cannot produce semen (Robinson and Buhr, 2005). The boar's ability to produce semen is too important for maximum genetic progress in economically important traits because the boar's impact on the pig herd is high (Gadea, 2005) and in addition the quality and quantity of spermatozoa has a direct influence on the transfer speed of the genetic information from generation to generation (Tardif,1999). Therefore, research institutes in collaboration with large commercial swine units using AI design studies analyzing the wealth of data available in large boar studs for a male genetic influence on pregnancy rate. The present study describes and discusses environmental trends and seasonal variability of the sperm output of boars kept on insemination stations in the Czech Republic.

Material and Methods

Animals and traits

Data from insemination stations for boars were analyzed. The data set was made available by the Association of Pig Breeders in the Czech Republic.

The data set consisted of 303,748 records of semen collections from 3,392 boars obtained during the period from 2000 to 2007. The boars belonged to the following breed groups: (i) Dam breeds: Czech Large White (LW_{CZ}; 517 of boars; n=34,450 of collections) and Landrace (L; 620 ♂; n=49,421), (ii) Sire breeds: Czech Meat Pig (CM; 96 ♂; n=6,530), Duroc (D; 143 ♂; n=10,738), Large White (LW; 514 ♂; n=52,270) and Pietrain (P; 164 ♂; n=14,495) and (iii) Crossbreds: D×H (92 ♂; n= 8,880), D×LW (171 ♂; n=17,728), D×P (298 ♂; n= 29,965), CM×P (17 ♂; n=1,404), H×P (352 ♂; n= 33,820) and LW×P (426 ♂; n= 44,047). The number of boars, number of ejaculates, and average number of ejaculates per boar for each group are summarized in Table 1.

The collection and processing of semen was standardized using the methods described in the respective standard (ČSN, 1996) in all 19 selected stations. From basic measured semen traits: (i) semen volume in mL (i.e. volume of the sperm rich fraction measured in a calibrated container with accuracy ± 10 mL), (ii) concentration of spermatozoa (number of cells per mm^3; measured by photocolorimetry), (iii) progressive motion of spermatozoa (proportion of cells actively moving straightforward; evaluated microscopically) and (iv) proportion of abnormal spermatozoa (cells deformed or otherwise changed; also evaluated microscopically) the total number of spermatozoa (NO_T, in billions) and the index of sperm efficiency (I_{SE}, in percent) were calculated as follows:

$$NO_T = \frac{VO \times CO}{1000}$$

$$I_{SE} = \frac{MO}{100} \times \left(1 - \frac{AB}{100}\right)$$

where VO is the semen volume (ml), CO is the concentration of spermatozoa (in 1,000 cells per mm^3), MO is the progressive motion of spermatozoa (%) and AB is the proportion of abnormal spermatozoa (%).

Statistical analyses

The procedure GLM of SAS® was used (SAS Institute Inc., Cary, NC, USA, 1989) and the data were analyzed using the following linear model:

$$ST_{ijklmno} = \mu + B\_S_i + Y_j + M_k + YM_{(j*k)} + A_l + I_m + Bo_{(i)n} + \varepsilon_{ijklmno}$$

where $ST_{ijklmno}$ is the value of the given semen trait for the o^{th} collection in the n^{th} boar, m^{th} interval of collections, l^{th} age of boar, k^{th} month, j^{th} year and i^{th} breed-station; μ is the overall mean; B_S_i is the effect of the i^{th} breed-station; Y_j is the effect of the j^{th} year; M_k is the effect of the k^{th} month; $YM_{(j*k)}$ is effect of the interaction of collection year and month; A_l is the effect of the l^{th} age of boar in month; I_m is the effect of the m^{th} interval of collections; $Bo_{(i)n}$ is the effect of the n^{th} boar within the i^{th} breed-station and $\varepsilon_{ijklmno}$ is the residual effect.

To form age classes, each boar's age in months at each collection was calculated. Ejaculates from boars less than 8 mo of age were excluded from the data set. Age classes with monthly intervals were used up to an age of 36 mo. For animals aged between 37 to 48 mo, three-month intervals were formed. For animals over 48 mo of age, the following 2 classes were formed: 49 to 60 mo and over 60 mo.

For intervals between two semen collections less than 12 d, classes were formed with an interval of 1 d. For intervals of 13 d and more, the following 3 classes were formed: 13 to 15 d, 16 to 21 d, and 22 to 30 d. The first semen collection of each boar and semen collections with an interval of 1 d or more than 21 d also were not included in the analyses.

Results

All effects included in the linear models (breed-station, year, month, interaction of year and month, age of boar, interval collection and boar) were statistically significant for all the traits ($P<0.001$). The average values of traits are summarized in Table 1. Least square means in sperm traits by years of collection as shown in Table 2.

Table 1. *Basic statistics of dataset for boar ejaculates collected over an 8 yr-period in the Czech Republic which represented two dam breeds (Czech Large White and Landrace), four sire breeds (Czech Meat, Duroc, Large White and Pietrain) and their crossbreds.*

Variable	Dam breeds	Sire breeds	Crossbreds
Numbers			
No. of boars	1,137	917	1,338
No. of ejaculates	83,871	84,033	135,844
Average number of ejaculates per boar	74	92	102
Means			
Semen volume (mL) – VO	281	270	278
Percentage of abnormal spermatozoa (%) – AB	12	11	11
Total number of spermatozoa (billion) – NO_T	115	112	110
Index of sperm efficiency (%) – I_{SE}	67	68	67
Interval between two collections (day)	7	7	7
Age of boar (month)	22	27	29

Table 2. *Least square means (LSM) and standard error (S.E.) in semen traits by years of collection for boar ejaculates collected over an 8 yr-period in the Czech Republic which represented two dam breeds (Czech Large White and Landrace), four sire breeds (Czech Meat, Duroc, Large White and Pietrain) and their crossbreds*

Trait[1]	Year	Dam breeds			Sire breeds			Crossbreds		
		N[2]	LSM	S.E.	N	LSM	S.E.	N	LSM	S.E.
VO	2000	8,921	278	18.2	8,735	237	8.3	10,787	279	4.9
	2001	10,33	265	13.8	11,707	233	5.8	13,566	270	3.7
	2002	12,488	278	9.4	13,251	245	3.4	18,343	280	2.5
	2003	11,625	279	5.0	12,354	238	1.3	19,015	275	1.4
	2004	10,966	278	1.2	11,742	244	2.0	17,778	275	0.8
	2005	10,992	277	4.2	9,964	252	4.4	18,746	276	1.4
	2006	11,192	275	8.5	9,328	265	6.8	22,429	276	2.5
	2007	7,357	272	13.0	6,952	268	9.3	15,18	271	3.7
AB	2000	8,921	7	1.2	8,735	12	0.6	10,787	7	0.3
	2001	10,33	6	0.9	11,707	11	0.4	13,566	7	0.2
	2002	12,488	8	0.6	13,251	11	0.3	18,343	9	0.2
	2003	11,625	10	0.3	12,354	11	0.1	19,015	10	0.1
	2004	10,966	12	0.1	11,742	11	0.2	17,778	11	0.1
	2005	10,992	14	0.3	9,964	12	0.3	18,746	12	0.1
	2006	11,192	15	0.6	9,328	10	0.5	22,429	12	0.2
	2007	7,357	16	0.9	6,952	8	0.7	15,18	13	0.2
NO_T	2000	8,921	110	8.5	8,735	78	4.2	10,787	132	2.4
	2001	10,33	106	6.4	11,707	84	2.9	13,566	122	1.8
	2002	12,488	111	4.4	13,251	95	1.7	18,343	118	1.3
	2003	11,625	117	2.3	12,354	113	0.6	19,015	121	0.7
	2004	10,966	119	0.6	11,742	118	1.0	17,778	117	0.4
	2005	10,992	122	1.9	9,964	127	2.2	18,746	111	0.7
	2006	11,192	119	4.0	9,328	136	3.4	22,429	105	1.3
	2007	7,357	121	6.0	6,952	144	4.7	15,18	103	1.8
I_{SE}	2000	8,921	75	1.6	8,735	69	0.8	10,787	74	0.4
	2001	10,33	75	1.2	11,707	69	0.5	13,566	74	0.3
	2002	12,488	73	0.8	13,251	69	0.3	18,343	71	0.2
	2003	11,625	70	0.4	12,354	68	0.1	19,015	69	0.1
	2004	10,966	68	0.1	11,742	68	0.2	17,778	68	0.1
	2005	10,992	66	0.4	9,964	67	0.4	18,746	67	0.1
	2006	11,192	63	0.7	9,328	67	0.6	22,429	65	0.2
	2007	7,357	62	1.1	6,952	68	0.9	15,18	64	0.3

[1]For abbreviations of traits see Table 1.
[2]N – Number of collections

There was no clear decreasing or increasing trend in the semen volume during monitored period (2000-2007) in dam breeds and crossbreds (Figure 1). In contrast, the clear growth of the semen volume was recorded in sire breeds. The clear manifestation of seasonal cycles in the semen volume was observed in the all groups of boars. The higher values were observed in autumn and early in winter, the lower values in summer.

During the monitored period the proportion of abnormal spermatozoa in dam breeds roughly increased from 6 % at the start of the period to 17 % at the end of the period (Figure 2). There was an increase from 6 % to 13 % in the crossbreds. In contrast a moderate decline of the proportion of abnormal spermatozoa was recorded in sire breeds (from initial 12 % to 10 % at the end). Seasonal changes of this trait were not clear.

The trend line on Figure 3 shows that the average total number of spermatozoa increased in dam breeds from 110 to 125 of billions (from beginning of the year 2000 to the end of the year 2007). The vehement increase from 75 to 150 of billions was recorded also in sire breeds. However, the decreasing trend of the average total number of spermatozoa from collection was recorded in the crossbreds (from 130 to 100 of billions. Seasonal cycles were evident and changes moved congenerously as in the semen volume, i.e. the highest values occurred in autumn and winter and the lowest in summer.

The index of the sperm efficiency (I_{SE}) means biological value of spermatozoa it is the proportion of qualitative viable spermatozoa. I_{SE} had the decreasing trend in of all three groups of boars (Figure 4), from 77 to 61% in dam breeds, from 69 to 67% in sire breeds and from 75 to 63% in crossbreds. The seasonal fluctuation was not perceptible.

Figure 1. Comparison of trends and seasonal variations among semen volume measurements for boar ejaculates collected over an 8 yr-period in the Czech Republic (n = 303,748 records of semen collections) which represented two dam breeds: Czech Large White and Landrace (wheel symbol), four sire breeds: Czech Meat Pig, Duroc, Large White and Pietrain (square symbol) and crossbreds (triangle symbol).

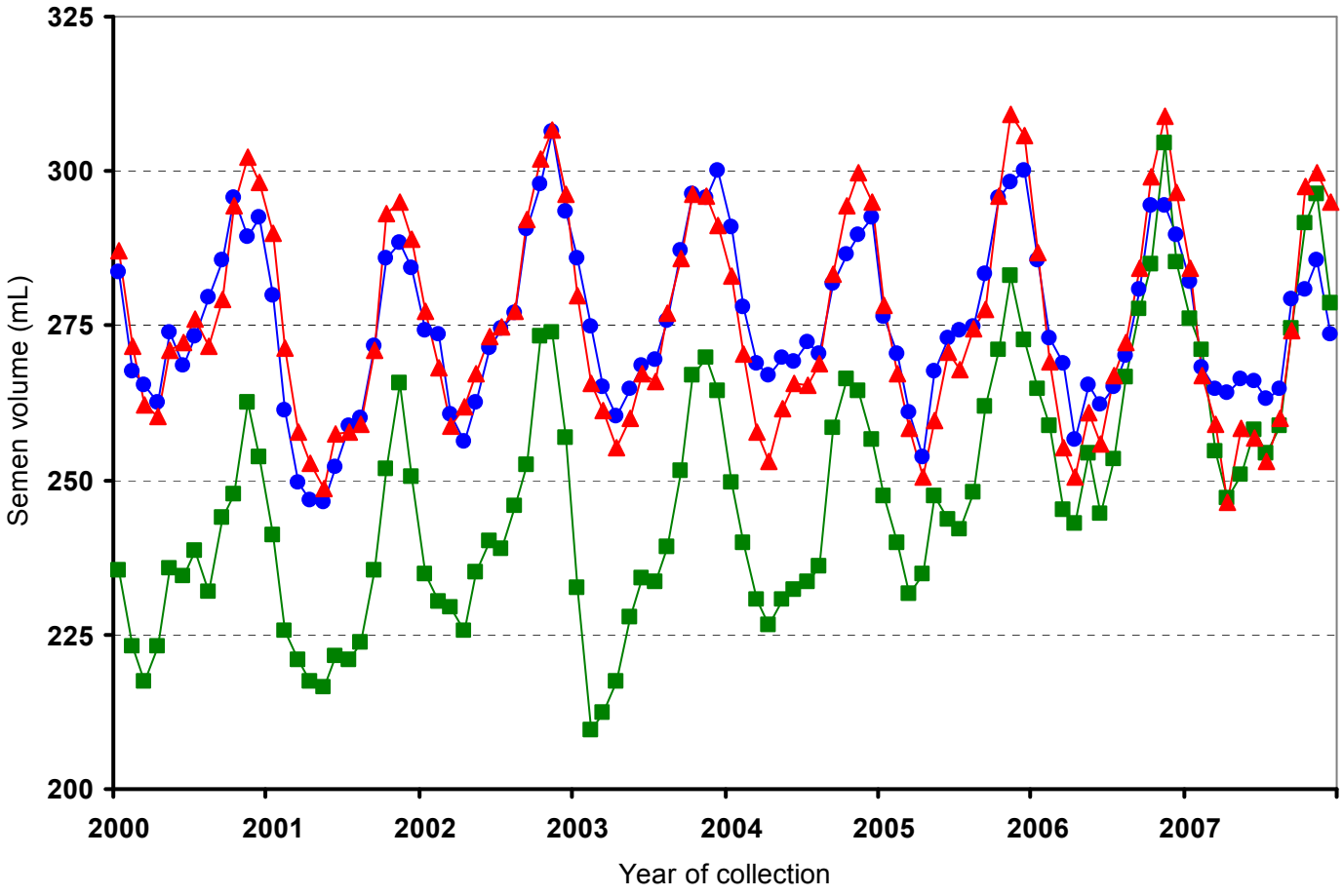


Figure 2 . Comparison of trends and seasonal variations among proportion of abnormal spermatozoa measurements for boar ejaculates collected over an 8 yr-period in the Czech Republic (n = 303,748 records of semen collections) which represented two dam breeds: Czech Large White and Landrace (wheel symbol), four sire breeds: Czech Meat Pig, Duroc, Large White and Pietrain (square symbol) and crossbreds (triangle symbol).

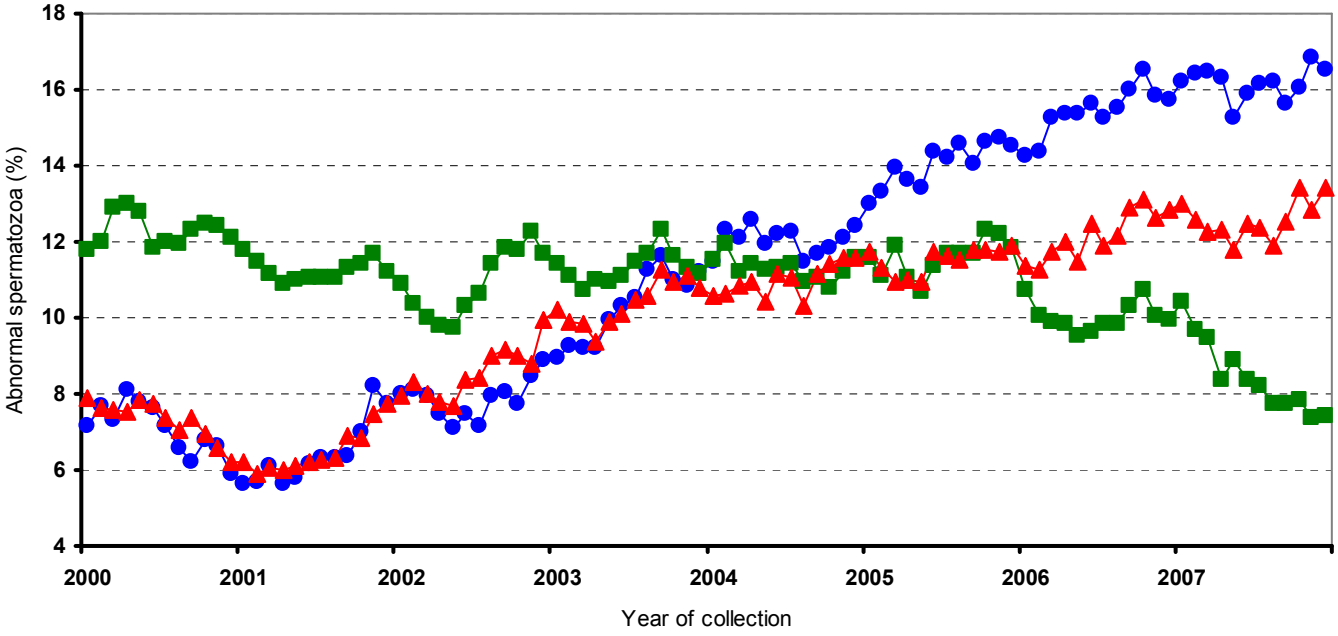


Figure 3. Comparison of trends and seasonal variations among ejaculates in the total number of spermatozoa for boar ejaculates collected over an 8 yr-period in the Czech Republic (n = 303,748 records of semen collections) which represented two dam breeds: Czech Large White and Landrace (wheel symbol), four sire breeds: Czech Meat Pig, Duroc, Large White and Pietrain (square symbol) and crossbreds (triangle

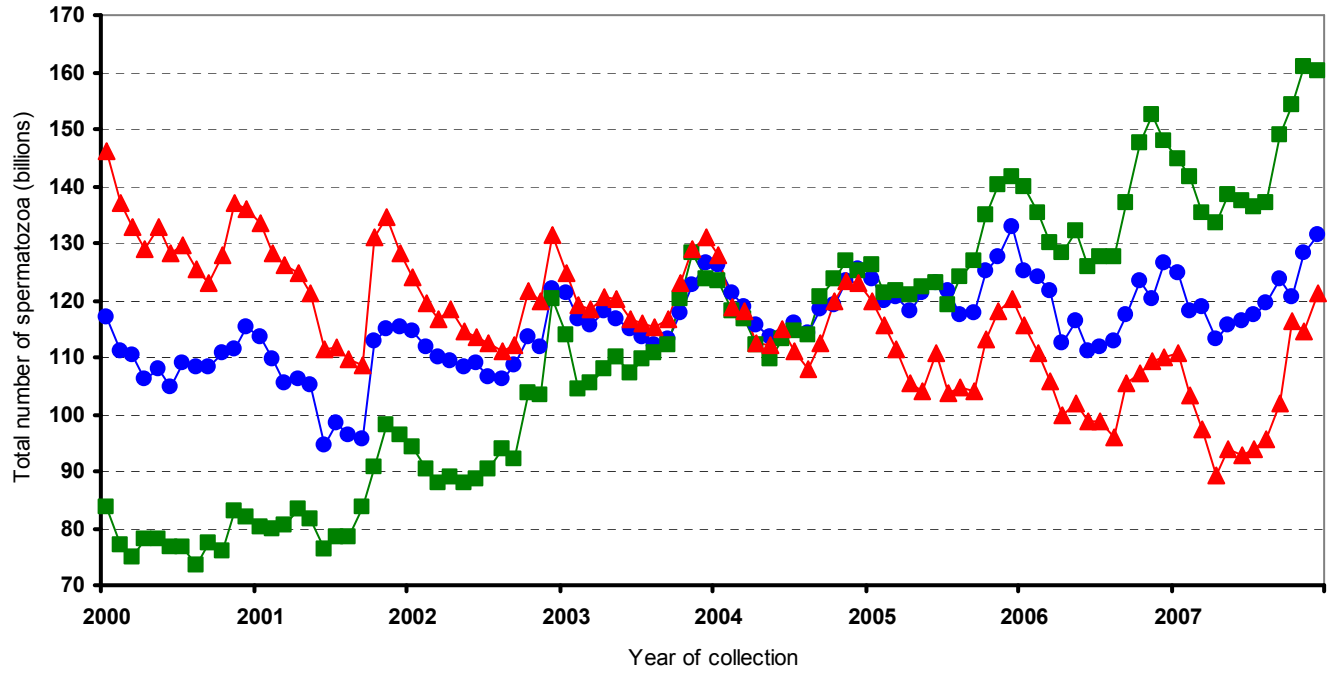
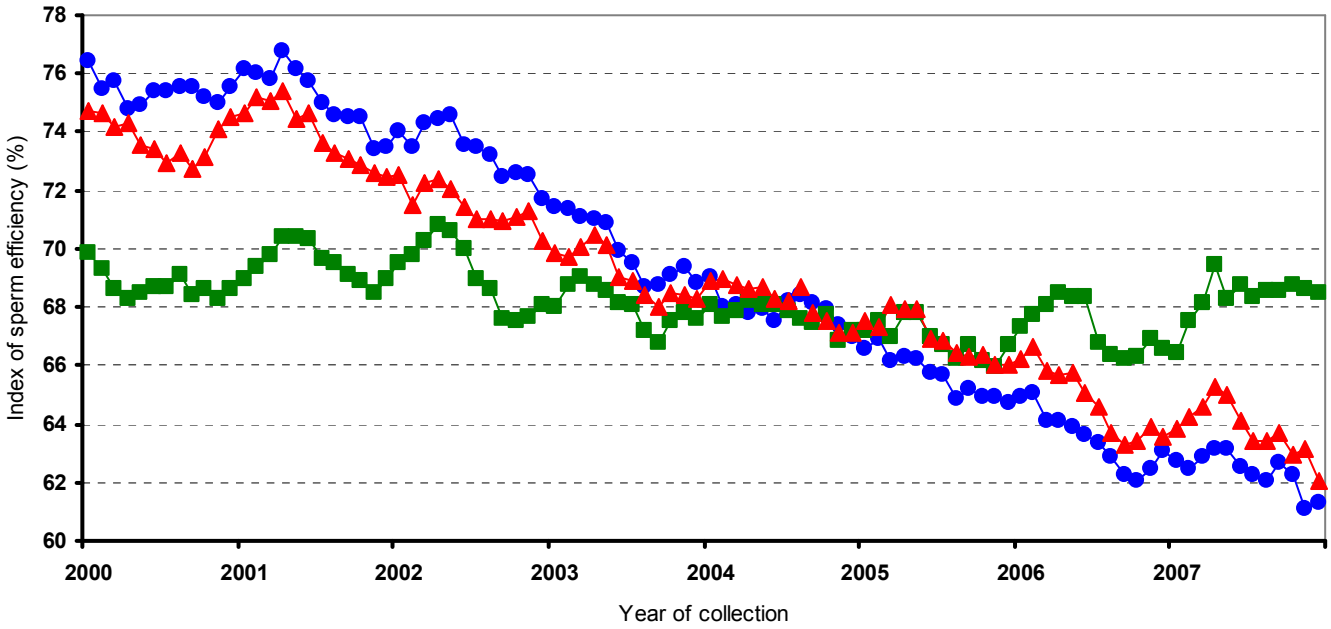


Figure 4. Comparison of trends and seasonal variations among ejaculates in the index of sperm efficiency for boar ejaculates collected over an 8 yr-period in the Czech Republic (n = 303,748 records of semen collections) which represented two dam breeds: Czech Large White and Landrace (wheel symbol), four sire breeds: Czech Meat Pig, Duroc, Large White and Pietrain (square symbol) and crossbreds (triangle symbol).



Discussion

As the effect of interaction of year and month was statistically significant (P<0,001) for all traits, the least square mean values demonstrate the trends in the observed semen characteristics in the given period. The other effects included in the model, i.e. breed-station, year, month, age of boar, interval collection and boar were also highly significant therefore they were incorporated in the equation of the linear model mentioned above.

The effect of breed on semen characteristics has been described by most authors (Kuciel et al., 1980; Kennedy and Wilkins, 1984; Rothschild, 1996; Jankeviciute and Zilinskas, 2002; Oh et al., 2003). Most authors agree that no breed excels in all semen characteristics. Differences between breeds are often manifested by extremely low volume of ejaculate in Duroc boars (Smital, 2009).

The effect of boar's age on sperm output was observed in a many studies (Colenbrander and Kemp, 1990; Jankeviciute and Zilinskas, 2002; Marchev et al., 2003). Semen output increases rapidly with the boar's age during the first two years, which is connected with increasing live weight and testicular weight of boars. It culminates at the age of 3.5 years together with the termination of growth of boar and declines later on (Falkenberger et al., 1992; Smital, 2009).Many researchers have demonstrated that changes in semen characteristics are related to the sexual intensity of the boars. Most authors agree that with increasing frequency of collections semen volume and sperm concentration and thereby total sperm output decrease (Čeřovský J., 1976; Falkenberger et al., 1992; Frangež et al., 2005; Pruneda et al., 2005).

Season appears to be another comparatively important factor affecting fertility of boars. A number of authors have come to the conclusion, that in our latitude, decreasing daylight in autumn generally causes physiological changes stimulating reproduction functions in boars and increasing the sperm output (Claus and Weiler, 1985; Trudeau and Sanford, 1990; Mudra et al., 1990; Ciereszko et al., 2000; Sancho et al., 2004; Chemineau et al., 2007).

Conclusion

In the monitored period 2000 to 2007 the increasing trend of number of spermatozoa per ejaculate from one collection and, in contrast, decreasing trend of quality of spermatozoa (i.e. the growth of the proportion of abnormal spermatozoa per ejaculate) displayed in boars of dam breeds. The positive trends of changes in watched semen characteristics were recorded in boars of sire breeds. In the group the growing trend of the number of spermatozoa and slightly improving or consistent quality of spermatozoa were observed. It could be due to the massive import of boars of breeds Large White from abroad. In contrast, the decreasing trend of number of spermatozoa and the ingravescent tendency of semen quality was recorded in crossbreds. It could be caused

among other things by using of unsuitable combinations in the crossing process. The seasonal variations i.e. lower values of the semen volume and the number of spermatozoa in summer and higher values in autumn and winter were evident in all groups.

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This study was supported by the project of National Agency for Agricultural Research (NAZV QH71284) of the Czech Republic.
The author thanks to the Pig Breeders Association of the Czech Republic for making the data available and Bc. Pavlína Chadrabová for excellent technical assistance.