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Evaluation and prediction of semen parameters of breeding boars and their use in stock management

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ABSTRACT

Artificial insemination constitutes the main method of pig breeding in Europe. According to literature, statistical models which allow prediction of productive capacity can be used as additional tools which may be helpful in making selection decisions concerning breeding boars. The aim of the research was to evaluate the influence of boar's age, standardized daily growth rate, standardized meat content in the carcass, the number of nipples, the age when the boar starts to be used for breeding, the number of semen collections per month, and the interval between semen collections on selected qualitative and quantitative parameters of the semen and to calculate multiple regression equations, which would allow prediction of productive capacity of AI landrace boars. The material for the analysis comprised 47596 ejaculates obtained over the period 1995-2014 from 306 Polish Landrace boars. The obtained results show that semen parameters of the examined boars depend on physiological and organizational factors included in the analysis. It was observed that the following factors, measured with the number of produced semen doses, were of particular significance for the efficiency of use of the boars: boar's age, the daily growth rate, meat content in the carcass, as well as the number of collections and the interval between collections. The conducted statistical analysis points to the possibility of predicting semen parameters accurately using regression analysis. The models are characterized by very high accuracy, which points to their potential for application. The calculated determination coefficients for the multiple regression equations assumed the R^2 value of above 0.92. The highest value of the determination coefficient (R^2 –0.99) was obtained for the percentage of sperm cells showing progressive motility. The calculated regression equations may be used in the management of the stock of breeding boars and when making selection decisions.

1. Introduction

The results of breeding use of insemination boars depend on numerous genetic, environmental and organizational factors (Knecht et al., 2017a; Petrocelli et al., 2015; Pokrywka et al., 2014; Smital, 2009) and are directly associated with quantitative and qualitative parameters of the produced semen. Therefore, boars used in insemination stations should produce ejaculates of high volume and sperm concentration (Gadea et al., 2004; Smital, 2009). Ejaculates with these characteristics allow for the production of a large number of semen doses, which is a measure of the economic efficiency of AI boars' use (Banaszewska and Kondracki, 2012; Knecht et al., 2017b). In order to achieve high production effects, the most valuable animals should be selected for use in AI stations, with the selection of the boars conducted on the basis of all available sources of information. Inter-relations between the parameters of in-vivo evaluation of the boars and the properties of their semen may be used to predict the parameters of boars' reproductive performance. According to literature on the subject, genetic and phenotype correlation coefficients play a particularly significant role in this respect. Previous research showed important correlations between semen quality and the daily growth rate (Knecht et al.,

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2017c), meat content of boars and the indicator of in-vivo evaluation (Szostak et al., 2015). According to the most recent research results (Knecht et al., 2017b), models of multiple regression, used in many other areas of animal breeding and use, should be recommended for an accurate evaluation of insemination boars (Schaeffer, 2004).

So far, regression analysis has been used in the evaluation of boars' reproductive capacity to a very limited extent. Infrequent studies point to a possibility of predicting productivity based on boar's age, season and frequency of semen collections (Knecht et al., 2017b). Boars' productive capacity was also predicted on the basis of data concerning the reproduction of sows, comprising the indicators of insemination efficiency, fertility, and litter size (Gadea et al., 2004). Research also involved the possibility of applying the parameters of the semen used for insemination to predict the indicators of sows' fertility (Daigneault et al., 2015).

The aim of the study was to evaluate the influence and use of selected factors to predict semen parameters of Polish Landrace boars in insemination stations on the basis of multiple regression analysis.

2. Material and methods

The material for the analysis comprised 47596 ejaculates obtained over the period 1995-2014 from 306 Polish Landrace boars used in Boars Exploitation Station in Czermin, belonging to Małopolskie Center of Biotechnology. The animals were kept in accordance with applicable welfare standards included in (WE) EUR-Lex (2004). The boars were kept in closed rooms in separate coops of 6m2 size, inlaid with sawdust. The temperature in the room was maintained between 12 °C and 20 °C, with relative humidity of 70- 75%. The boars were fed individually using a delivery system with complete feed granular mixture for breeding boars, containing on average 12.5 (JM) of metabolic energy and 16.5g general protein. The animals had constant access to water.

Before semen collection, boars were stimulated by a short physical activity involving a walk from the coop to the sampling point. Ejaculates were collected by the manual method described by King and Macpherson (1973).

The collected ejaculates underwent laboratory tests: the volume of the semen (ml) was measured directly after the collection by means of a scaled cylinder with the accuracy up to 10ml; sperm concentration ($x10^6$ ml^{-1}) in an ejaculate was measured by means of the coli metric spectrophotometric method involving a measurement of the intensity of light passing through a suspension of sperm cells in an isotonic solution of sodium chloride or sodium citrate. On the basis of semen volume and sperm cell concentration, the total number of sperm cells per ejaculate was calculated and expressed as 10^9 sperm cells per ejaculate. The percentage of sperm cells demonstrating progressive motility (%) was estimated using a microscope in 200-times magnification (Nikon Eclipse E100, Nikon Instruments, Japan). The total number of sperm cells demonstrating progressive motility (10^9) was calculated as the product of the total number of sperm cells per ejaculate and the percentage of sperm cells demonstrating progressive motility. The number of insemination doses (n) was calculated after dividing diluted semen (MERCK III dilutant) into insemination doses of 100m volume containing $3,0 \times 10^9$ sperm cells.

3. Statistical analysis

The collected numerical material was statistically analyzed by means of Statistica 12.0 software. The hypotheses concerning the diversification of subsequent parameters of the quality of the semen depending on the selected factors (boar's age, the daily growth rate, standardized meat content in the carcass, the number of nipples, the age when the boar starts to be used for breeding, the number of collections per month, the interval between semen collections) were verified by means of single-factor variance analysis (ANOVA). Post-hoc analysis was conducted by means of the least significant difference (LSD) test. Conclusions were drawn at the significance level of $p \leq 0.05$. Results were presented by means of arithmetic averages and standard deviations.

Multiple regression analysis was used to predict semen parameters of breeding boars, with the following explanation variables included: x1 – boar's age, x2– the age when the boar starts to be used for breeding, x3– the number of collections per month, x4 – intervals between semen collections, x5– standardized meat content in the carcass, x6– standardized daily growth rate, x7– the number of nipples.

The following semen parameters were included as dependent properties: The volume of sperm cell fraction, the percentage of sperm cells demonstrating progressive motility, sperm cell concentration, the total number of sperm cells in an ejaculate, the number of insemination doses. The procedure of stepwise progressive regression was used in the calculations, adding to the list of explanatory variables those variables which had the greatest influence on the dependent variable until the best model was obtained. Calculations were done for the model without an intercept.

The analysis also included the calculation of the multidimensional coefficient of determination – R^2, informing about the proportion of the factors included in the model in the variation; the calculation of "b" standardized partial regression coefficients, which constitute a measure of the relative significance of the respective explanatory variables in the model; the estimation of the statistical significance of "b" regression coefficients performed by means of t-Student test; verification of H0: b= 0 zero hypothesis was performed at the significance level of $p \leq 0.05$.

4. Results

The study examined a significant number of 47596 ejaculates obtained from 306 Polish Landrace boars. The obtained results show that the level of qualitative and quantitative parameters of the semen of the examined boars depended both on physiological and organizational factors. A compilation of the obtained statistically significant differences concerning the examined parameters of the semen depending on selected factors is presented in Table 1. It was observed that the youngest boars at the age below one year produced semen of significantly lower qualitative and quantitative parameters compared with older boars.

Table 1: Influence of the examined factors on boars' semen parameters

Factor	Ejaculate volume (ml)	Percentage of sperm cells demonstrating progressive motility (%)	Sperm cell concentration (x106 ml-1)	Total number of sperm cells per ejaculate (x109)	Number of insemination doses (n)
Boars' age (days)	*	*	ns	*	*
Number of nipples	*	ns	*	ns	ns
Daily growth rate (g)	*	*	ns	*	*
Meat content (%)	ns	*	*	*	*
Age when the boar starts to be used for breeding (days)	ns	ns	ns	ns	ns
Number of collections per month	*	*	*	*	*
Interval between collections (days)	*	*	*	*	*

*: Statistically significant effect at – p≤0.05; ns: not significant

As a result, the lowest number of insemination doses, that is 20.86 portions on average, was produced from a single ejaculate obtained from those boars. Boars at the age above one year were characterized by a similar level of reproductive properties, while the semen with the highest sperm cell concentration, the highest total number of sperm cells in an ejaculate and proportion of sperms cells demonstrating progressive motility was obtained from the oldest, four-year-old boars (Table 2). The study showed that boar's age did not have an influence only on the index of sperm cell concentration. It was shown that boars with the highest daily growth rate produced semen of greater volume and total number of sperm cells in an ejaculate. At the same time, the semen of these males was characterized by a higher percentage of sperm cells demonstrating progressive motility. From the ejaculates of boars with the daily growth rate above 800g, 2.36 more portions on average were obtained (Table 2).

Analyzing the influence of meat content of the examined males on the properties of the ejaculates, it was observed that boars with better muscle content were characterized by better breeding results. From the semen of boars with meat content above 60%, on average 25.82 portions of semen were produced, while from the ejaculates of boars with meat content of 58-59,9%, only 22.71 insemination doses were obtained. The reproductive capacity of the examined boars as to the volume of the ejaculates and sperm cell concentration depended on the number of nipples. Boars with more than 14 nipples produced ejaculates of greater volume and lower sperm cell concentration that was shown in Table 2. As a result of this correlation, a nearly identical number of semen insemination doses was obtained from both compared groups. The study showed that breeding properties of the examined boars did not depend on the age when the boar starts to be used for breeding (Table 2).

The number of semen collections per month represented one of the factors which significantly shape the properties of the semen of the examined boars. It was observed that with an increase in the intensity of breeding use, the volume of ejaculates produced by the boars increased as well. The volume of ejaculates of the boars from which semen was collected 1-3 times per month amounted to 190.5 (ml) on average, whereas boars used more than 8 times per month produced ejaculates with the volume larger than 100ml. An increase in the frequency of semen collections positively influenced the total number of sperm cells and the proportion of sperm cells demonstrating progressive motility, and had a negative influence on the index of sperm cell concentration in an ejaculate (Table 2). The examined boars were intensively used for breeding, as the number of the ejaculates collected with the frequency of up to 5 days was the greatest. At the same time, these ejaculates had the largest volume amounting to 284.1 ml on average, with the total number of sperm cells per ejaculate amounting on average to 76.05x109. A shorter interval between collections had a positive influence on the index of sperm cells demonstrating progressive motility. It was observed that the interval between collections amounting to more than 7 days has a definite negative influence on the properties of the semen which determine the number of produced doses (significant p≤0,05) (Table 2). In line with the aim of the undertaken study, the obtained results of the evaluation of breeding use were used to develop equations of multiple regression making it possible to predict the properties of selected parameters of boars' semen (Table 3). It was shown that the independent variables included in the developed models shape the general variance of the respective dependent variables to a large extent. The conducted

calculations showed that using multiple regression analysis, in which in-vivo coefficients were used as explanatory variables, makes it possible to estimate the properties of the semen with a high degree of precision. The calculated determination coefficients for all the semen parameters included in the study assumed the R^2 value of above 0.92.

Table 2: Influence of the examined factors on boars' semen parameters (means±Sd)

Properties	N	Examined properties				
		Ejaculate volume (ml)	Sperm cells demonstrating progressive motility (%)	Sperm cell concentration (x10^6 ml^{-1})	Total number of sperm cells per ejaculate (x10^9)	Number of insemination doses (n)
Boar's age (days)						
up to 365	6048	211.50±82.90a	64.54±12.50a	437.20±112.30	62.35±15.69a	20.86±5.32a
366-730	18907	255.50±65.20b	67.19±3.69b	436.80±92.70	72.61±11.99b	23.96±3.99b
731-1095	13733	269.20±66.90b	68.23±2.52b	442.00±83.40	77.80±11.30b	25.73±3.66b
1096-1460	6570	258.00±41.80b	68.23±2.64b	439.50±67.20	75.71±8.77b	25.19±2.79b
above 1460	2338	259.60±46.20b	68.34±2.23b	452.80±72.70	78.97±12.00b	26.15±3.88b
Growth rate (g)						
up to 800	24526	250.90±70.81a	66.20±4.41a	434.30±99.00	71.06±13.52a	23.50±4.51a
above 800	23070	266.10±57.22b	68.91±4.25b	444.80±74.31	78.17±9.80b	25.86±3.14b
Meat content in the carcass (%)						
up to 58,00	11305	267.50±63.51	64.49±3.23a	412.40±80.91a	68.18±7.92a	22.52±2.57a
58,10-59,90	8274	234.10±74.80	66.13±3.09b	454.60±72.22b	69.16±16.75a	22.90±5.37a
60,00-61,90	19462	247.80±54.83	67.03±4.70b	472.50±82.46c	77.36±11.59b	25.61±3.72b
above 61,90	8555	255.00±62.85	68.93±4.97b	445.50±74.35b	77.79±10.39b	25.82±3.49b
Number of nipples						
up to14	22036	248.60±63.01a	67.21±5.09	454.50±89.29b	74.25±12.86	24.56±4.23
above 14	25560	266.00±68.19b	67.73±4.08	425.40±85.21a	74.29±12.22	24.57±4.02
Age when the boar starts to be used for breeding (days)						
up to 240	15522	257.50±63.80	66.95±5.59	437.80±90.60	72.33±13.57	23.93±4.44
241-270	19089	260.10±69.20	67.80±4.32	434.30±88.50	75.70±12.56	25.06±4.19
271-300	8796	242.00±61.70	67.41±3.66	465.10±81.70	73.52±11.22	24.30±3.60
above 300	4189	269.10±66.50	67.97±2.29	431.10±86.80	75.42±10.03	24.89±3.24
Number of collections per month						
1-3	1987	190.50±58.40a	63.28±10.85a	464.50±98.00b	62.88±13.91a	21.03±4.85a
4-6	30679	254.00±56.60b	67.64±3.10b	451.60±80.10b	75.80±11.71b	25.07±3.83b
7-8	12691	277.20±64.40c	68.20±2.29b	412.20±92.20a	73.16±11.20b	24.14±3.72b
9 and more	2239	298.30±78.10d	68.92±1.77b	426.50±92.20a	80.01±11.37c	26.44±3.62b
Interval between collections (days)						
up to 5	24702	284.10±61.00c	68.34±2.23b	412.90±85.20a	76.05±11.98b	25.15±3.94b
6-7	18660	247.70±57.90b	67.41±3.33b	452.70±79.50b	74.48±11.52b	24.65±3.79b
8 and more	4234	180.20±51.30a	63.79±11.24a	507.80±96.90c	65.57±14.02a	21.77±4.76a

a, b, and c – identical letter symbols indicate a lack of a statistically significant difference between the values of the average in the LSD test ($p \leq 0.05$)

Explanatory variables of the greatest significance for the calculation of multiple regression equations comprised the daily growth rate, meat content and the number of nipples. It was observed that the highest value of the determination coefficient was obtained for the percentage of sperm cells demonstrating progressive motility that was shown in Table 3. Independent variables included in the developed model shaped the general variance of this dependent variable to a high degree, amounting to as much as 99.4%. Explanatory variables of the highest significance in this model comprised the meat content of the boars and the number of nipples. The value of "b" coefficient in this equation shows that with an increase of meat content in the carcass by 1%, the percentage of sperm cells demonstrating progressive motility increases by 0.677%, and an increase in the number of nipples by 1 leads to a positive variation of this property by 0.692%. Regression equations to predict the remaining semen parameters including precise values of standardized partial regression coefficients are presented in Table 3. The calculated R^2 coefficients for the remaining dependent variables were similar and ranged between 0.921 (the total number of sperm cells per ejaculate) and 0.928 (the number of doses).

5. Discussion

The analysis of the parameters of reproductive capacity of insemination boars has already been the subject of extensive research. Interest in this problem results from a wish to improve the effectiveness of use of insemination boars and their significance in the breeding process.

The factors included in the present study proved significant in shaping the properties of the semen, which was confirmed in the diversified number of produced semen doses. In the group of analyzed physiological factors, it was observed that semen parameters depend on boar's age. As indicated in the previous research (Banaszewska and Kondracki 2012; Knecht et al, 2017b; Smital, 2009), younger boars, especially those of the age below one year, produced less semen. This relation is undoubtedly connected with the development of the male reproductive system. In ejaculates produced by young boars, especially in the early months of use,

the highest number of sperm cells with morphological changes can be found.

Table 3: Multiple regression equations for the prediction of boars' semen parameters

Examined properties	N	Regression equations	R^2
Ejaculate volume	39889	$Y = 0.152x_6 + 0.043x_1 + 6.164x_3 + 6.699x_7 - 0.396x_5 + 0.437x_4 - 0.027x_2$	0.942
Percentage of sperm cells demonstrating progressive motility	39889	$Y = 0.677x_5 + 0.013x_6 + 0.540x_3 + 0.692x_7 + 0.013x_2 + 0.001x_1 - 0.045x_4$	0.994
Sperm cell concentration	39889	$Y = 10.239x_5 - 0.201x_6 + 3{,}881x_4 - 0.029x_1 - 4.648x_3 + 0.158x_2 - 1.376x_7$	0.922
Total number of sperm cells per ejaculate	38444	$Y = 1.001x_5 + 0.006x_1 + 0.534x_4 - 0.013x_6 + 0.357x_3 + 0.012x_2 - 0.369x_7$	0.921
Number of insemination doses	38444	$Y = 0.334x_5 + 0.002x_1 + 0.158x_4 + 0.004x_6 + 0.151x_3 - 0.120x_7 + 0.003x_2$	0.928

x_1 – boar's age, x_2 – the age when the boar starts to be used for breeding, x_3 – the number of collections per month, x_4 – intervals between semen collections, x_5 – standardized meat content in the carcass, x_6 – standardized daily growth rate, x_7 – the number of nipples

The properties of boars' semen improve with age (Smital, 2009), which was also confirmed in the present study. According to authors (Kennedy and Wilkins, 1984; Banaszewska and Kondracki, 2012), an optimum age of breeding use is 2-3 years. Additionally, own research has shown that high parameters of breeding use were observed in older boars, at the age of more than four years, which indicates that, with no other contraindications, males of this age can be successfully used in insemination stations. Long-term use of boars in insemination stations, however, requires close monitoring of semen distribution, which allows for the elimination of inbreeding and its potential unfavourable consequences (Banaszewska and Kondracki, 2012). It is worth noting the relations obtained in the study between the daily growth rate, meat content of the boars and the properties of ejaculates. Szostak et al. (2015) showed a negative influence of these properties on the results of reproductive performance. Such relations have not been confirmed in the present research. On the contrary, boars which grew faster (above 800g) and with greater muscle content (above 60%) produced ejaculates from which around two doses of semen more could be obtained (Table 2). Similar results were reached by Knecht et al. (2017c), who observed that the best ejaculates were produced by boars with the daily growth rate of 800-850g and meat content of 62.5% to 65%. The intensiveness of boars' reproductive performance, measured with intervals between semen collections is one of the most important organizational factors strictly connected with economic results of insemination stations. According to Frangež et al. (2005) and Knecht et al. (2017a), semen may be obtained from boars 1-2 times per week. In the present study, most of the boars were used with such intensiveness. Other authors (Bajena et al., 2016) point to individual predispositions of selected boars to very intensive reproductive performance. Semen from such boars may be obtained even every 2 or 3 days, without worsening its parameters. This observation was confirmed in the present study, which showed that the most intensively used boars (Table 2) produced ejaculates of the greatest volume and the total number of sperm cells, including those demonstrating progressive motility. The obtained results are confirmed by the indicator of intervals between collections (Table 2). Searching for tools and information supporting the decision making process concerning the selection of boars for a station encompasses the possibility of using regression analysis (Daigneault et al., 2015; Knecht et al., 2017b; Quintero-Moreno et al., 2004). In the present study, the possibility of obtaining additional data based on multiple regression analysis was proposed. The developed equations make it possible to predict semen properties based on selected physiological and organizational factors. Our solution forms part of the discussion undertaken by Knecht et al. (2017b), who showed that regression equations, in which boar's age, the interval between semen collections, and the time of semen collection were included as independent variables, allow the assessment of semen parameters with a high degree of precision. In other studies, (Daigneault et al., 2015), it was stated that regression equations in which quality parameters of the semen were used as independent variables, allow the prediction of insemination efficiency (r^2 =0.87), litter size (r^2 =0.57), and allow an improvement of insemination efficiency performed by means of frozen semen. We believe it contributes to rare literature data concerning the possibility of using regression in planning insemination boars. It should also be underlined that the developed models are characterized by high precision. The calculated determination coefficients for the multiple regression equations assumed the R^2 value of above 0.92. The highest value of the determination coefficient (R^2–0.99) was obtained for the percentage of sperm cells showing progressive motility. This points to their potential for application in the decision-making process concerning the selection of Polish Landrace boars for use in insemination stations. The obtained high precision of the method is associated with a large amount of input data considered in the calculations.

6. Conclusion

The obtained results show that semen parameters of the examined boars depend on

physiological and organizational factors considered in the study. It was observed that boar's age, the daily growth rate, meat content in the carcass, as well as the number of semen collections and the interval between collections were particularly significant for the efficiency of boars' use. The conducted statistical analysis points to the possibility of predicting the parameters of boars' breeding use accurately by means of multiple regression analysis. The developed models are characterized by high precision, which points to their potential for application.

Compliance with ethical standards

Conflict of interest

The authors declare that they have no conflict of interest.

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