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VARIANCE COMPONENT ESTIMATES OF SOME BOAR SEMEN CHARACTERISTICS AND THEIR USE IN DESIGNING EXPERIMENTS*

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Summary. Semen records of ten ejaculates from each of ten Yorkshire boars were used to estimate the boar and ejaculate variance components for eleven semen characteristics. These data were used to estimate the power of the test. In ten of eleven characteristics, a minimum of five boars and five ejaculates per boar provided at least a 90% chance of detecting a difference of 50% of the mean. For these same ten characteristics, a minimum of fourteen boars and forty-three ejaculates per boar provided at least a 90% chance of detecting a difference of 25% of the mean.

INTRODUCTION

Estimates of the magnitude of the variation resulting from the measurement of boar semen characteristics have not been found in the literature by the authors. In cases where this variation arises from more than one source, it is important to determine what portion of the total variation is contributed by each source. Estimates of the variance components for these sources may then be used to estimate the magnitude of error variance. The error variance estimate can be used to determine the size of an experiment (animals and number of observations per animal) required to detect a specified treatment difference at a specified level of significance (P_I), and with a specified probability ($1-P_{II}$ = the power of the test), of detecting the difference.

The purpose of this study was to obtain estimates of the variance components contributing to total variance of some boar semen characteristics, and to use these estimates to determine the size of future boar semen studies.

MATERIALS AND METHODS

Estimates of the variance components of seminal characteristics of ten ejaculates from each of ten Yorkshire boars were used in this study. The animals were 14 to 15 months of age and the collection interval was 6 days.

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The two sources of variation considered in the variance component analysis and their expected mean squares are, boars = $\sigma_E^2+k\sigma_B^2$ and ejaculates within boars = σ_E^2. Analytical error (samples within ejaculates) was not estimated in this study. The boar source was considered to be random and the ejaculate source to be random and nested within boar. The following linear model was considered to be appropriate for these data:

$$X_{ij} = \mu+\beta_i+e_{ij}$$

where X_{ij} is the value of the jth ejaculate from the ith animal. In this model, μ is the population mean, β_i and e_{ij} components are assumed to be random variables normally and independently distributed with means zero and variances of σ_B^2 and σ_E^2, respectively.

The composition of the expected mean squares and the coefficient of the component σ_B^2 were determined by the method of Henderson (1953, 1960).

In an experiment where treatments are applied to the boars, the mean square for boars ($\sigma_E^2+k\sigma_B^2$) becomes the error term for testing treatment differences. The standard deviation of a treatment mean can then be estimated by:

$$s_{\bar{x}} = \sqrt{\left(\frac{s_E^2}{eb}+\frac{s_B^2}{b}\right)}$$

where s_E^2 is the ejaculate variance, s_B^2 is the boar variance, e is the number of ejaculates per boar and b is the number of boars. For a two-treatment experiment, P_{II} was calculated by computing Tang's ϕ for these data. A modification of the expression shown by Kempthorne (1952) was used and is given by:

$$\phi = \sqrt{\left(\frac{\Delta^2}{4\sigma^2}\right)}$$

where Δ is the treatment difference to be detected and σ is the standard deviation of a treatment mean. This is equivalent to the formula for calculating ϕ used by Hafs, Bratton, Henderson & Foote (1958) and shown by Henderson (1960). After computing ϕ, P_{II} was determined from Tang's tables of ϕ (Tang, 1938; Kempthorne, 1952).

The power of the analysis of variance F test ($1-P_{II}$) was estimated for some possible two-treatment experiments with varying numbers of boars and ejaculates per boar.

All computations were performed by an IBM 7040 computer at the University of Connecticut Computer Center. The techniques for determining these semen characteristics are described by Pickett, Komarek, Gebauer, Benson & Gibson (1967).

RESULTS AND DISCUSSION

The ejaculate means, standard deviations and coefficients of variation for the eleven semen characteristics are shown in Table 1. The initial motilities of the ejaculates from one boar were all estimated at or near zero. The data from this boar for the other ten semen characteristics appeared normal and were in the same range as the values for the other nine boars. Therefore, estimates for initial motility were computed deleting this one boar.

TABLE 1

EJACULATE MEANS, STANDARD DEVIATIONS, COEFFICIENTS OF VARIATION AND VARIANCE COMPONENT ESTIMATES FOR BOAR SEMEN CHARACTERISTICS

Characteristic	*Mean*	*Standard deviation*	*Coefficient of variation*	*Variance components*	
				Boars	*Ejaculates*
Gel (g/ejac)	52·44	26·93	51	474·60	293·91
Gel-free semen (ml/ejac)	323·17	77·47	24	2038·63	4148·26
Sperm concentration (10^6/ml)	315·47	81·08	26	3433·90	3447·03
Initial motility (%)*	87·11	12·78	15	41·22	126·42
Dry weight					
Whole semen (%)	4·63	1·04	22	0·57	0·57
Gel (mg/g)	116·94	12·42	11	72·38	88·36
Seminal plasma (mg/ml)	40·77	10·26	25	55·53	54·73
Spermatozoa (μg/10^6)	22·42	3·04	14	3·89	5·74
Lipid					
Gel (μg/g)	329·27	91·85	28	2080·48	6612·15
Seminal plasma (μg/ml)	136·03	33·93	25	221·44	950·01
Spermatozoa (μg/10^6)	2·25	0·1749	8	0·0032	0·0276

* Based on nine boars with ten ejaculates per boar.

Table 1 shows the values of the variance component estimates for these data. The minimum numbers of boars and ejaculates per boar required to detect a treatment difference of 25% and 50% of the mean at the 5% level of significance with at least a 90%, 95% or 99% chance (power of the test= $1-P_{II}$) are shown in Table 2.

TABLE 2

MINIMUM NUMBER OF BOARS PER TREATMENT AND EJACULATES PER BOAR REQUIRED TO DETECT A TREATMENT DIFFERENCE OF 50% OR 25% OF THE MEAN WITH AT LEAST A 90%, 95% OR 99% CHANCE AT THE 5% LEVEL OF SIGNIFICANCE

Characteristic	*Treatment difference*											
	50% *of mean*						25% *of mean*					
	90%*		95%		99%		90%		95%		99%	
	B/T†	*E/B*‡	*B/T*	*E/B*	*B/T*	*E/B*	*B/T*	*E/B*	*B/T*	*E/B*	*B/T*	*E/B*
Gel volume (g/ejac)	16	36	20	17	26	16	>30	>50	>30	>50	>30	>50
Gel-free semen (ml/ejac)	4	4	4	7	5	12	8	36	10	28	14	17
Sperm concentration (10^6/ml)	5	4	5	17	7	22	14	10	16	37	22	14
Initial motility (%)	3	2	3	2	3	3	4	7	4	17	5	49
Dry weight												
Whole semen (%)	4	5	5	3	6	10	11	10	13	17	17	22
Gel (mg/g)	3	1	3	1	3	2	4	3	4	6	5	14
Seminal plasma (mg/ml)	5	3	5	11	7	13	13	19	16	17	21	19
Spermatozoa (μg/10^6)	3	2	3	2	3	4	4	37	5	9	7	9
Lipid												
Gel (μg/g)	4	5	4	10	5	16	8	43	10	35	14	22
Seminal plasma (μg/ml)	3	8	3	23	4	10	6	20	7	28	10	21
Spermatozoa (μg/10^6)	2	2	2	2	2	3	2	8	2	14	3	3

* Chance of detection.
† Boars per treatment.
‡ Ejaculates per boar.

The low number of boars and ejaculates per boar required for initial motility, gel and spermatozoa dry weight, and lipid content of spermatozoa reflect the low coefficients of variation for these characteristics (Table 1). In all characteristics, except gel volume, a minimum of five boars and five ejaculates per boar provides at least a 90% chance of detecting a treatment difference of 50% of the mean. The high coefficient of variation for gel volume is reflected in the relatively high minimum number of boars (sixteen) and ejaculates per boar (thirty-six) required to provide at least a 90% chance of detecting a difference of 50% of the mean. To detect a difference of 25% of the mean, a minimum of fourteen boars and forty-three ejaculates per boar provides at least a 90% chance in all characteristics except gel volume. Even with thirty boars and fifty ejaculates per boar, gel volume does not provide a 90% chance of detecting a difference of 25% of the mean.

The alternatives available to the investigator for increasing the power $(1-P_{II})$ of the test include increasing the level of significance (using a P_I of 10% rather than 5%), attempting to detect a larger difference, using more boars or ejaculates per treatment and/or reducing the mean square for error. The final choice of these alternatives is determined by the importance of the detectable difference and the resources the investigator has available.

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