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Genetic Analysis of Male and Female Fertility After Artificial Insemination in Sheep: Comparison of Single-Trait and Joint Models

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ABSTRACT

The outcome of an insemination depends on male and female fertility. Nevertheless, few studies have incorporated genetic evaluation of these 2 traits jointly. The aim of this work was to compare genetic parameter estimates of male and female fertility defined as success or failure to artificial insemination (AI), using 8 different models. The first 2 models were simple repeatability models studying fertility of one sex and ignoring any information of the other. Models 3 and 4 took into account the information of the other sex by the inclusion of its random permanent environmental effect, whereas models 5 and 6 included fixed effects of the other sex. Models 7 and 8 were joint genetic evaluation models of male and female fertility ignoring or considering genetic correlation. Data were composed of 147,018 AI of the Manech Tête Rousse breed recorded from 2000 to 2004 corresponding to 79,352 ewes and 963 rams. The pedigree file included 120,989 individuals. Variance component estimates from the different models were quite similar; heritabilities varied from 0.050 to 0.053 for female fertility and were near 0.003 for male fertility. Correlations among estimated breeding values in the same sex using different models were higher than 0.99. The genetic correlation between male and female fertility was not significantly different from 0. These results show that for French dairy sheep with extensive use of AI, estimation of breeding values for male and female fertility might be implemented with quite simple models.
Key words: fertility, joint modeling, sheep

INTRODUCTION

The success of ovine AI depends on many factors. The male must produce and ejaculate normal fertile spermatozoa. The female must produce, store, and ovulate normal oocytes and provide a reproductive tract compatible with sperm transport, capacitation, and fertilization of the oocytes. The female must ensure embryo and fetal development and birth of progeny. Finally, the corresponding fetus must be viable. Because insemination is artificial, natural sexual behavior is absent and the male and female reproductive events have to be carefully synchronized to minimize the gamete waiting time before fertilization occurs. That also supposes that the sperm is correctly processed and transported and that insemination practices are sound.

Under the simplest biological considerations, AI success may be viewed as a combination of 2 main traits: one relative to the female (i.e., female fertility), the second relative to the male (i.e., male fertility). The same observation (AI success or failure) can be analyzed with respect to female fertility, male fertility or both. However, most genetic fertility studies generally consider only one of these 2 traits and model the AI response by fitting its specific genetic effect and the related environmental factors. Studies related to livestock male or female fertility have been conducted in many species and in many environmental conditions (Nadarajah et al., 1988; Boichard and Manfredi, 1994; Matos et al., 1997b; Ranberg et al., 2003; Gonzalez-Recio and Alenda, 2005). They consider several types of fertility variables, ranging from binary (e.g., nonreturn rate after 60 or 90 d or confirmed pregnancy) to continuous (e.g., calving interval or number of AI services per conception response). The results generally agree and indicate that, whatever the trait, heritabilities are very low (<0.10). Moreover, variance components associated with male fertility are generally smaller than those for female fertility.

The purpose of this study was to evaluate the impact of including all information relative to the AI event on variance component and breeding value estimations in sheep. This approach is possible because, in the French sheep industry, each on-farm recorded insemination can be matched to the corresponding ejaculate produced at the AI center and to the corresponding outcome,

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Table 1. Distribution of the number of inseminations per animal

Female		Male	
Number of inseminations	Number of females (%)	Number of inseminations	Number of males (%)
1	37,997 (48)	<60	219 (23)
2	22,433 (28)	60–180	553 (58)
3	12,736 (16)	180–300	87 (9)
4	4,983 (6.5)	300–420	37 (3)
5	1,203 (1.5)	>420	67 (7)

which is a binary response of success (1) or failure (0) observed at lambing.

MATERIALS AND METHODS

Data

Records of inseminations from 2000 to 2004 were provided by the Association Nationale des centres d'Insémination Ovine (ANIO). A small part (4%) of the initial data set containing missing records for the insemination result (ewes sold, dying before lambing, error in the data) were discarded. The final data file included 147,018 AI records of the Manech Tête Rousse breed located in southwestern France. Manech Tête Rousse ewes are managed in an annual lambing system. Each year depending on the breeding scheme, the breeders choose which ewes to inseminate. The ewes receive one single synchronization treatment (fluorogestone acetate vaginal sponge inserted for 14 d, pregnant mares' serum gonadotropin injection at withdrawal) and are inseminated without regard to estrus expression. Inseminated females are systematically exposed to rams for 6 d after insemination to ensure fecundation by natural mating. The other females are naturally mated without synchronization. Because there is no pregnancy test, the date of lambing is used to determine the fertile estrus (after insemination or natural mating). Ejaculates were collected from 963 rams using artificial vagina, and 79,352 different ewes were inseminated. After quality processing (volume, concentration, and motility); semen with a motility higher than 4 was diluted (dose concentration = 1.4 or 1.6×10^6 spermatozoa/mL) and stored at 4°C in a 0.25 mL straw until insemination a few hours later. The distributions of the number of inseminations for rams and ewes are in Table 1. The pedigree file (the first animal was born in 1958) included 120,989 individuals. For each insemination, a large list of information was recorded. The corresponding potential risk factors may be grouped into 3 categories. These were female (synchronization, reproductive, and productive career, etc.), male (sperm characteristics, collection, etc.), and nonsex-specific effects which were related to the insemination (operator, interval collection-AI, etc.) or common to all previous categories (year, season, herd).

Methods

Fertility was defined as the binary result of an insemination, considered a success (y = 1) when lambing occurred 144 to 158 d after insemination or a failure (y = 0). The percentage of successful inseminations was 57%. Eight linear animal models were used to study the insemination results. Fixed effects and all 2-way interactions with biological meaning were selected one at a time by comparing nested models with a likelihood ratio test. Models were fitted using the mixed procedure of SAS 8.1 (SAS, version 8, 1999) and the maximum likelihood estimation method. After model selection, female effects retained were age, synchronization on the previous year (0 = no, 1 = yes), total number of synchronizations during the female reproductive life, time interval between previous lambing and insemination, lactation status (0 = dry, 1 = lactating) at time of insemination, milk quantity produced during the previous year expressed as quartiles within each herd × year. Male effects retained were motility and dilution rate of the semen (ejaculate concentration/dose concentration). Nonsex specific effects were the inseminator, the interaction herd × year nested within inseminator considered as random effects, and the interaction of year and season considered as a fixed effect.

The first 2 and simplest models focused on the estimation of the fertility trait of only one sex (the male in model 1, the female in model 2) without introducing any terms related to the contributions from the other sex. The models included the fixed and random effects that are not sex specific as well as the fixed effects, the random permanent environmental and the genetic effects associated with the sex being considered by the respective model.

$$\text{Model 1: } \boldsymbol{y} = \boldsymbol{X_c}\beta_c + \boldsymbol{Kc} + \boldsymbol{Lh} + \boldsymbol{X_m}\beta_m + \boldsymbol{Z_m u_m} + \boldsymbol{W_m p_m} + \varepsilon$$

and

$$\text{model 2: } \boldsymbol{y} = \boldsymbol{X_c}\beta_c + \boldsymbol{Kc} + \boldsymbol{Lh} + \boldsymbol{X_f}\beta_f + \boldsymbol{Z_f u_f} + \boldsymbol{W_f p_f} + \varepsilon,$$

where $\boldsymbol{y}$ is the vector of the binary result of insemination, β_f β_m, and β_c are vectors of fixed effects related to the female, the male, or common to both sexes, respectively; $\boldsymbol{u_f}$ and $\boldsymbol{u_m}$ are vectors of female and male random genetic effects, respectively; $\boldsymbol{p_f}$ and $\boldsymbol{p_m}$ are vectors of