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SHORT COMMUNICATION

Factors affecting daughters distribution among progeny testing Holstein bulls

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Abstract

The aim of this study was to investigate factors influencing the number of daughters of Holstein bulls during the progeny testing using data provided by the Italian Holstein Friesian Cattle Breeders Association. The hypothesis is that there are no differences among artificial insemination studs (AIS) on the daughters distribution among progeny testing bulls. For each bull and beginning from 21 months of age, the distribution of daughters over the progeny testing period was calculated. Data were available on 1973 bulls born between 1986 and 2004, progeny tested in Italy and with at least 4 paternal half-sibs. On average, bulls exited the genetic centre at 11.3±1.1 months and reached their first official genetic proof at 58.0±3.1 months of age. An analysis of variance was performed on the cumulative frequency of daughters at 24, 36, 48, and 60 months. The generalized linear model included the fixed effects of year of birth of the bull (18 levels), artificial insemination stud (4 levels) and sire of bull (137 levels). All effects significantly affected the variability of studied traits. Artificial insemination stud was the most important source of variation, followed by year of birth and sire of bull. Significant differences among AI studs exist, probably reflecting different strategies adopted during progeny testing.

Introduction

Historically, the method of genetic evaluation used by artificial insemination studs (AIS) to allowing for prediction of breeding values of bulls has been the progeny testing (PT). As reported by the Italian Holstein Friesian Cattle Breeders Association (ANAFI, 2009), the first step of PT in Italy is the selection of elite dams to produce about 500 young bulls calves which are purchased by and moved to the AIS. At one year of age, young bulls are test mated to the population: about 1300 doses of semen are distributed, after 500 inseminations AI bulls become waiting bulls, and when 20 daughters from 20 different herds complete the first lactation, approximately at 62.5 months of age of the bull, they have first official proof. Only 5% of PT bulls are authorized for AI as proven. Bulls for PT are chosen based on their pedigree index and a large number of animals in the PT increase the probability to find the best bulls (Funk, 2006). In Italy the number of bulls authorized for PT by ANAFI increased from 201 in 1987 to 376 in 2009 (Cassandro *et al.*, 2002; ANAFI, 2009).

The duration of PT depends on different factors such as the time between the distribution of the semen and their utilization, the age of daughters at calving, and the time to collect and analyze data. The disadvantages of PT are the long generation interval and consequently high cost to maintain the bull for a long unproductive period. As reported by Norman *et al.* (2003) and König *et al.* (2009), several strategies such as multiple ovulation and embryo transfer or marker-assisted selection have been carried out to anticipate the first publication of bulls. In the next future, the genomic selection, a new technology that is revolutionizing animal breeding (Meuwissen *et al.*, 2001), will enhance traditional estimated breeding value (EBV) with genomic information (DGV) to obtain higher accuracy of genomic estimated breeding values (GEBV) as compared to the accuracy of an EBV after PT (Schaeffer, 2006; Hayes *et al.*, 2009; Maltecca *et al.*, 2010). Therefore, there are two strategies to increase the accuracy of GEBV: first, to increase the accuracy of DGV, which can be achieved through the increase in markers number, improvement in statistical methodology and, most important, in the reference population size; second, to maximize the number of daughters per bull during PT.

Hence, the aim of this study was to investigate factors affecting the number of daughters of Holstein bulls during the PT period assuming, as hypothesis zero, that there were no differences among AIS involved in the national PT scheme.

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Materials and methods

Data and computations

Data were provided by ANAFI and consisted of two datasets, updated to November 2009. The first included information on AI bulls proven in Italy, namely identity codes of the individuals and their parents, AIS of origin, and date of birth, and on important steps of their career, namely the exit from the genetic centre, the authorization to PT, the first, 300th and 500th AI, and the first official proof. The second dataset included information on identity codes and date of birth of Holstein cows officially enrolled in the national herd book.

Data on bulls born between 1986 and 2004 were extracted; animals were required to have exited the genetic centre at minimum age of 9 months, had the first AI at minimum age of 9 months and the first official proof within 70 months of age. Only bulls from Italian AIS and with at least 4 paternal half-sibs were considered. For each bull, beginning from 21 months of age, the distribution of daughters during PT was monitored. The cumulative frequencies at 24, 36, 48, and 60 months of age were calculated and only bulls with daughters in each class were retained. After editing, 1973 bulls offspring of 137 sires and progeny tested by four AIS were available for subsequent investigation.

Statistical analysis

Statistical analysis was performed using the GLM procedure of SAS (SAS, 2008) according to the following linear model:

$$y_{ijkl} = \mu + A_i + C_j + S_k + (A \times C)_{ij} + e_{ijkl}$$

where
y_{ijkl} is the cumulative frequency of daughters at 24, 36, 48, or 60 months of age of the bull;
μ is the overall intercept of the model;
A_i is the fixed effect of the ith year of birth of the bull (i=1986 to 2004);
C_j is the fixed effect of the jth AIS (j=1 to 4);
S_k is the fixed effect of the kth sire of bull (k=1 to 137);
$(A\times C)_{ij}$ is the fixed interaction effect between year of birth of the bull and AIS;
e_{ijkl} is the random residual ~ N (0, σ^2_e).

The different factors were progressively added to the model. A multiple comparison of means was performed for the effect of AI stud, using Bonferroni's correction (P<0.01).

Results and discussion

Descriptive statistics and distributions

On average, bulls exited the genetic centre at 11.3 months of age, had the first AI at 13.1 months, and achieved the 300th and 500th AI at 16.3 and 18.0 months, respectively. Moreover, they had the first official proof at 58.0 months (Table 1), in accordance with statistics reported by Powell *et al.* (2003); these authors showed that Italian bulls reached their first official proof later than bulls from other countries. Reasons for this delay have to be attributed to the different criteria of evaluation adopted by countries (e.g., minimum threshold of reliability for publication), breeding programs (e.g., seasonal pattern of New Zealand), and PT strategies (e.g., early distribution of young bull semen in The Netherlands; Powell *et al.*, 2003).

The number of bulls per AIS over the whole period (1986 to 2004) ranged from 378 to 631 (*data not shown*), suggesting that studs contributed differently to the PT scheme of the Holstein breed. Bulls were offspring of 137 sires, so that on average 14 sons per bull were available; the majority of sires (61) had between 5 and 10 sons, whereas 20 had more than 25 sons.

The distribution of daughters during the PT of bulls depicts a typical pattern (Figure 1). At about one year of age semen of young bulls is distributed in the population according to the PT scheme adopted by ANAFI and at approximately 21 months the first progeny appears. The number of daughters reaches 137 at 36 months of age of the bull and remains almost constant thereafter. The plateau between 36 and 60 months (the end of PT) is due to the waiting

Table 1. Descriptive statistics of age of progeny tested bulls at different times of their career.

	N	Mean	SD	Minimum	Maximum
Months of age at					
Exit from the genetic centre	1973	11.3	1.1	9	16
First AI	1973	13.1	1.5	9	20
Authorization to progeny test	1973	13.3	1.2	10	21
300th AI	1972	16.3	2.4	12	36
500th AI	1954	18.0	6.1	12	122
First official genetic proof	1973	58.0	3.1	51	70

AI, artificial insemination.

Table 2. Results from ANOVA (*F* values) for cumulative daughters at 24, 36, 48, and 60 months of age of bulls.

Model	Source of variation°				R^2	ΔR^2	RMSE
	AIS, df=3	Year of birth, df=17	Sire of bull, df=136	Year of birth* AIS, df=51			
Age 24 months							
Model 1	32.02				0.047	-	29.15
Model 2	27.13	22.66			0.204	0.157	26.75
Model 3	28.53	3.23	1.53		0.286	0.082	26.27
Model 4	16.76	3.35	1.56	3.77	0.356	0.070	25.31
Age 36 months							
Model 1	19.57				0.029	-	51.13
Model 2	22.43	8.57			0.096	0.067	49.53
Model 3	19.34	4.99	2.20		0.224	0.128	47.59
Model 4	17.24	4.13	2.28	6.56	0.348	0.124	44.26
Age 48 months							
Model 1	29.04				0.042	-	53.85
Model 2	29.29	9.31			0.114	0.072	52.02
Model 3	26.23	4.93	2.23		0.241	0.127	49.92
Model 4	23.26	4.13	2.31	6.42	0.360	0.119	46.50
Age 60 months							
Model 1	29.10				0.042	-	54.92
Model 2	29.16	9.46			0.115	0.073	53.02
Model 3	26.07	5.00	2.25		0.243	0.128	50.85
Model 4	23.10	4.19	2.31	6.42	0.361	0.118	47.34

°All effects are highly significant (P<0.001); AIS, artificial insemination stud; RMSE, root mean square error.

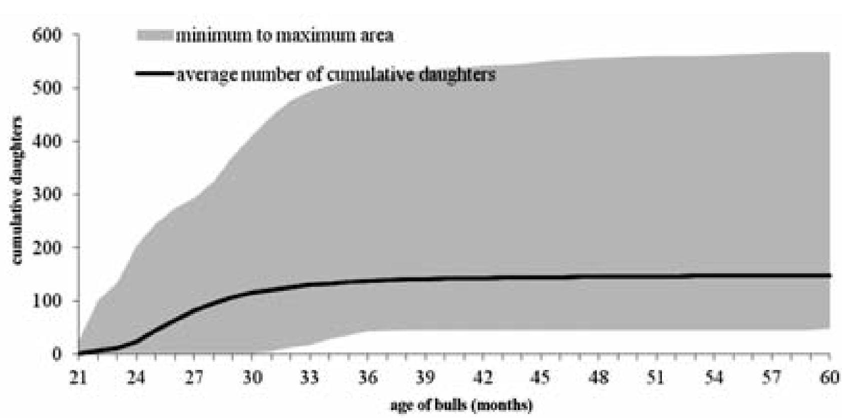

Figure 1. Average cumulative number of daughters and range between minimum to maximum over progeny testing of bulls.

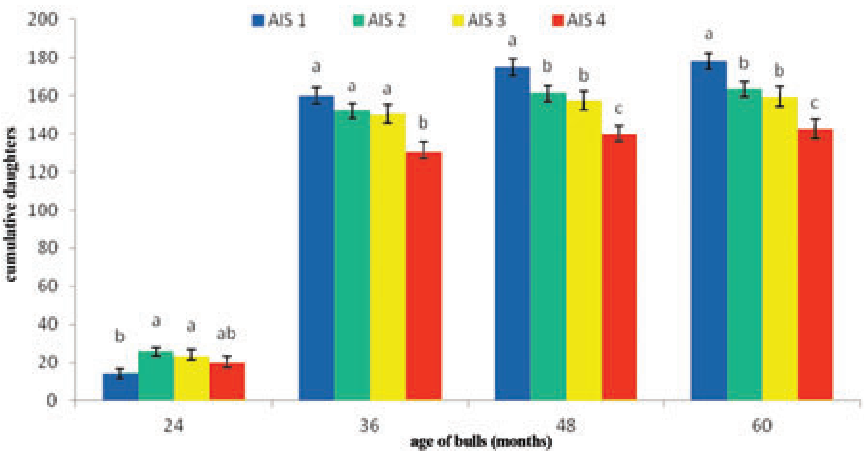

Figure 2. Least squares means and standard errors of average cumulative number of daughters of bulls across age of bull and AI studs. Least squares means with different letters within age of bull differ (P<0.01).

period before the first official evaluation of the bull. There is high variation in the number of daughters per bull and some bulls had more than 300 daughters at 36 months of age (Figure 1).

Analysis of variance and artificial insemination stud effect

Results from the ANOVA are summarized in Table 2. The coefficients of determination (R^2) were 0.35 for cumulative daughters at 36 months of age of bulls and 0.36 for cumulative daughters at 24, 48, and 60 months of age, respectively, and root mean square error (RMSE) ranged from 25 to 55, confirming that a consistent proportion of variability could not be accounted for by factors included in the model. All effects significantly ($P<0.001$) explained the variation of the 4 traits. In particular, AIS was the most important factor and is therefore discussed.

The average cumulative number of daughters at 24 months of age of bulls progeny tested by AIS1 was significantly ($P<0.01$) lower than that by AIS2 and AIS3 (Figure 2), suggesting that the beginning of PT for bulls from AIS1 is delayed compared to others studs. However, the situation is opposite thereafter and the average cumulative number of daughters at 48 and 60 months of age is significantly higher for bulls progeny tested by AIS1 than AIS2 and AIS3. The AIS4 did not differ significantly from other studs at 24 months of age of bulls, whereas significant differences were found in the following ages. Reasons for differences among AIS could be attributed to different marketing strategies (e.g., promotion of PT bulls) to reach early the required number of daughters to evaluate bulls. However, as reported by Norman *et al.* (2003), differences in the number of daughters are more evident comparing different breeds, due to time to distribute semen, the use of semen by breeders and fertility differences among breeds.

Conclusions

The cumulative number of daughters at different ages of PT bulls was influenced by year of birth, sire of bull and AIS effects with the largest differences among AIS, and thus the hypothesis zero was rejected and statistically significant differences among AIS exists in the national PT scheme. Possible explanations for the strong effect of AIS might be attributable to marketing strategies promoting the use of PT bulls to reduce the waiting period and anticipate the first official proof of animals.

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