Genetics of twinning rate in Italian Holstein cattle

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Introduction

- In dairy cattle, twin birth affects calving ease, metabolic aspects, reproductive performance, fertility, and longevity of the dam, along with abortion rate and survival of calves, leading to non-negligible economic losses.
- Twinning rate is affected by both environmental and genetic factors.
- The current state of twinning rate, its variance components, and genetic determinism within the Italian Holstein cattle population remain undocumented.

Aims

- To estimate **genetic parameters of twinning rate** in the **Italian Holstein** population using both linear and threshold animal models.
- To explore if there is possibility to **manipulate** this trait through **genetic strategies**.

Materials and Methods

Data

- 1,630,363 calvings of 686,354 Italian Holstein cows with records including cow, herd, calving date, calving type (0 = singleton, 1 = twin or triplet), twin category (female-female, male-male, and male-female), parity, and sex of the calf.
- 2.1 million animals born between 1970 and 2023 in the pedigree file.

Data editing

- Calving records from cows of parity >10 were discarded from the dataset.
- After editing, 1,625,859 calvings of 685,666 cows from 1,830 herds were retained.

Binary logistic regression

- A binary mixed logistic regression model was used to estimate the log odds of twinning rate.
- Calving type was the dependent variable; parity (4 classes: first, second, third, and ≥fourth) and season (4 classes: winter, spring, summer, and autumn) were the fixed effects; and calving year and herd were the random effects.

Estimation of genetic parameters

- Linear and threshold single-trait animal models were used to analyze the twinning rate.
- The models included the fixed effect of parity, and the random effects of herd-year-season (*HYS*), permanent environment (*PE*), additive genetic animal (*AG*), and residual (*e*) as random effects.
- Heritability (h^2) and repeatability (t) were estimated as follows:

$$h^2 = \frac{\sigma^2 AG}{\sigma^2 AG + \sigma^2 PE + \sigma^2 HYS + \sigma^2 e}$$

$$t = \frac{\sigma^2 AG + \sigma^2 PE}{\sigma^2 AG + \sigma^2 PE + \sigma^2 HYS + \sigma^2 e}$$

- A multiple-trait approach with both linear and threshold animal models was used to estimate genetic correlations for twinning rate across parities.
- The models included season of calving as fixed effect, and herd-year (*HY*), *AG*, and *e* as random effects.
- Genetic correlations of twinning rate across parities were computed as: $rg = \frac{COV(AG1, AG2)}{\sqrt{(\sigma^2 AG1 \times \sigma^2 AG2)}}$
- Gibbs sampling until 150,000 rounds with GIBBSF90+ and post-Gibbs analysis with POSTGIBBSF90 (burn-in: 50,000 samples, thinning interval: 200 samples) were performed to obtain the marginal posterior distribution of estimates.

Heritability, repeatability, and genetic correlations of twinning rate

- Heritability from the linear and threshold model analyses was 0.017 and 0.063, respectively (Table 1), which agree with [3, 4].
- Repeatability from the linear and threshold model analyses was 0.019 and 0.068, respectively (Table 1).
- The Spearman correlation between linear and threshold evaluations was 0.93 (Figure 3).
- Genetic correlations ranged from 0.81 to 0.96 with the linear model and 0.73 to 0.93 with the threshold model (Table 2).
- The strongest genetic correlation from the linear model was estimated between parity 2 and ≥4 (0.96), and the strongest from the threshold model was estimated between parity 3 and ≥4 (0.93) (Table 2).

Table 1. Estimates of variance components, heritability (h^2) and repeatability (t) from linear and threshold animal models.

Item	Linear model	Threshold model
σ^2HYS	0.00025	0.06502
σ^2PE	0.00003	0.00572
σ^2AG	0.00046	0.07215
σ^2e	0.02557	1.0001
σ^2P	0.02631	1.14299
h^2	0.017 ± 0.001	0.063 ± 0.006
t	0.019 ± 0.001	0.068 ± 0.006

Table 2. Estimates of genetic correlations from linear animal and threshold animal models.

Parities	Linear model	Threshold model
1 and 2	0.81 ± 0.03	0.80 ± 0.02
1 and 3	0.82 ± 0.02	0.75 ± 0.03
1 and ≥4	0.85 ± 0.03	0.73 ± 0.03
2 and 3	0.94 ± 0.01	0.88 ± 0.01
2 and ≥4	0.96 ± 0.01	0.86 ± 0.01
3 and ≥4	0.95 ± 0.01	0.93 ± 0.01

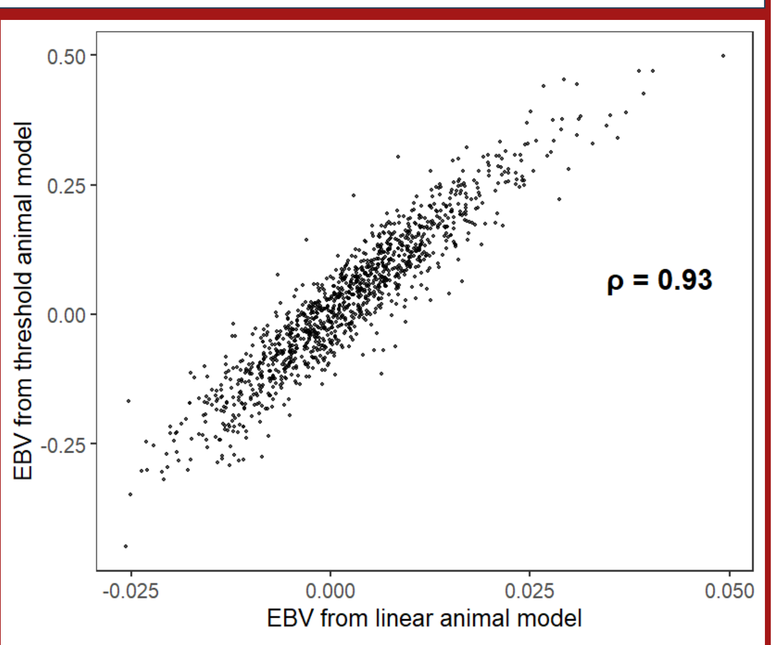

Figure 3. Relationship between the estimated breeding values (EBVs) of Italian Holstein sires for twinning rate from linear and threshold animal models. EBVs of sires born between 2005 and 2023 with reliability ≥0.6 and with at least 50 daughters were considered (n = 1,199).

Conclusions

- **Estimates of h^2 and repeatability were <10%.**
- **Genetic correlations of twinning rate across parities were less than unity.**
- **The non-zero h^2 suggests that genetic strategies can be adopted to stabilize multiple births in the population.**

Results and Discussion

Descriptive statistics

- The overall twinning rate was 2.71%.
- Twinning rate across herds ranged from 0.0 to 7.9%.
- The calf sex ratios were 48% males and 52% females amongst singleton calvings, and 33% female-female, 37% male-female, and 29% male-male for twins.

Parity

- The twinning rate increased with parity: 0.68%, 2.67%, 3.46%, and 3.44% in first, second, third, and ≥ fourth parities, respectively (Figure 1).
- The higher twinning rate in multiparous than primiparous cows is likely due to higher occurrence of double ovulation [1], and lower abortion rate [2].

Season of calving

- Summer had the highest twinning rate (2.56%) and winter the lowest (1.94%) (Figure 2).
- Heat stress-induced double ovulations, followed by favorable ambient temperatures, may potentially lead to a high conception rate of twins.

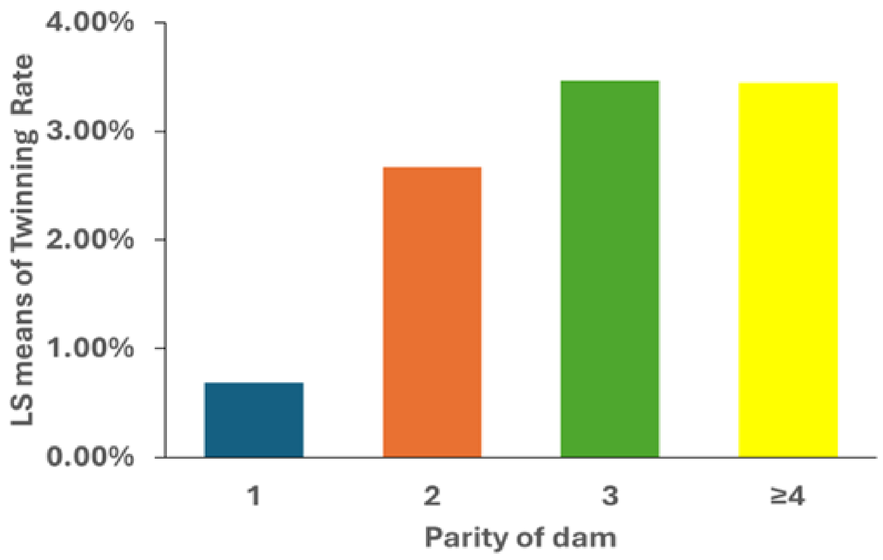

Figure 1. Least squares means of twinning rate in different parities.

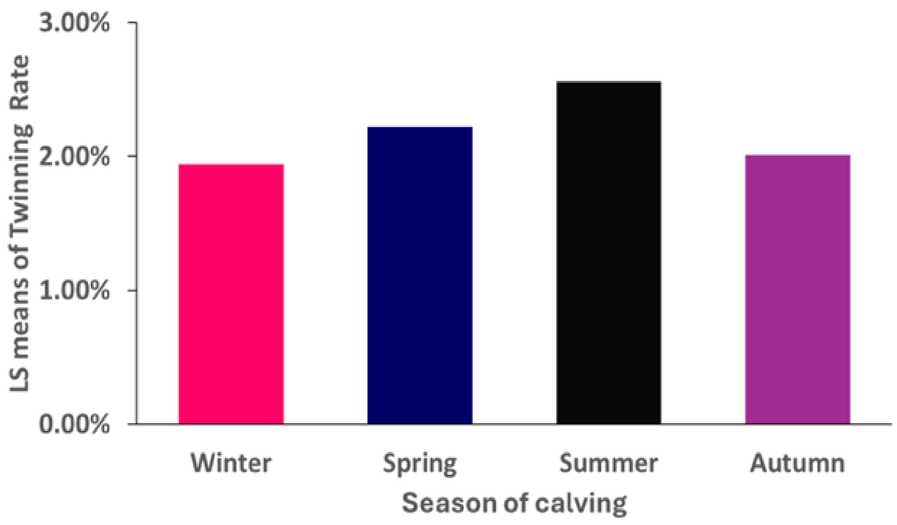

Figure 2. Least squares means of twinning rate in different calving seasons.

References

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Acknowledgements

This research was conducted within the project "Study of phenotypic and genetic aspects of traits of economic relevance in the Italian Holstein cattle breed", supported by ANAFIBJ (Cremona, Italy) in the framework of a wider project titled "Dairy cattle breeds for the definition of sustainable breeding approaches – LATTeco2", funded by the Ministry of agriculture, food sovereignty and forestry (MASAF, Rome, Italy), National Rural Development Programme 2014/2022 – Measure 10.2 – Conservation, use and sustainable development of genetic resources in agriculture.