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Exploring the genetic basis of milking ability in the Italian Mediterranean buffalo

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Introduction

The Italian Mediterranean Buffalo (IMB) represents a livestock resource of major economic importance, particularly for milk production destined for the manufacture of Mozzarella di Bufala Campana PDO (Protected Designation of Origin). In recent years, research in the field of genetic improvement has progressively broadened its focus, shifting from exclusively productive traits to functional traits aimed at enhancing management efficiency and the sustainability of farming systems. Among these, milking ability plays a strategic role, as it directly affects labor time, management costs, the efficiency of milking equipment use, and animal welfare, while also having important implications for udder health and productive longevity tast.

Milkability is a functional trait closely related to the efficiency of the milking process and represents a significant component of herd profitability. Improvement of this trait is of particular interest to farmers, as it is associated with reduced labor costs and a lower risk of involuntary culling. Shorter milking times allow for more rational labor management, reduced wear of milking equipment, and better organization of farm operations (Boettcher *et al*., 1998). Conversely, poor milkability may indicate functional udder problems, with potential negative consequences for animal health and herd longevity (Vicario *et al*., 2006).

Recent studies have further highlighted how milk ejection physiology, milk flow parameters, and the technical configuration of milking systems significantly influence milking efficiency and animal welfare in buffalo species, emphasizing the importance of an integrated management of physiological and technological aspects (Matera *et al*., 2023, Pierro *et al*., 2025).

Despite its practical and economic relevance, milkability has so far received limited attention in genetic selection programs for buffalo. A deeper understanding of its genetic basis is therefore essential to assess its potential inclusion in breeding schemes. In this context, the present study aims to investigate the genetic variability of milking ability in the Italian Mediterranean Buffalo population, providing useful information for the development of more efficient and sustainability-oriented selection strategies.

Materials & Methods

Data and trait definition

Milking ability was defined as the ratio between milk yield and milking time, expressed as kilograms of milk per minute (kg/min). A total of 27,145 test-day records from 2,068 Italian Mediterranean Buffalo cows were included in the analysis. Records were edited for consistency and completeness prior to statistical analyses.

Model

Genetic parameters for milking ability were estimated using a single-trait animal model including fixed and random effects. The model accounted for the fixed effects of contemporary group (herd, year, season), year–month of test day, age at calving, milking session (morning or evening), and days in milk class defined in 30-day intervals (DIM30). The additive genetic effect of the animal and the residual error were included as random effects. The animal model was defined as:

$$\mathbf{y} = \mu + \mathbf{Z}_1\mathbf{h} + \mathbf{Z}_2\mathbf{a} + \mathbf{e} \quad (1)$$

where **y** is the vector of observations for milking ability, μ is the overall mean, **h** is the vector of fixed effects, **a** is the vector of random additive genetic effects of the animals, $\mathbf{Z}_1$ and $\mathbf{Z}_2$ are the corresponding incidence matrices, and **e** is the vector of residual effects. Variance components were estimated using a pedigree including 4,495 animals.

Software

Data preparation, editing procedures, and all statistical analyses were performed using the R programming environment (R Core Team, 2019). Variance components estimation for milking ability was carried out using the GIBBSF90+ software (Misztal *et al.*, 2002).

Results

Descriptive statistics revealed high phenotypic variability for milking ability in the analyzed population. The average milking ability was 0.32 kg/min, with values ranging from extremely low (0.00044 kg/min) to very high (11.65 kg/min). The coefficient of variation reached 72%, indicating substantial heterogeneity among animals (Table 1).

Table 1. Descriptive statistics for milking ability (kg/min) in Italian Mediterranean buffalo

Trait	Mean	SD[1]	Min[1]	Max[1]	CV[1]
Milking ability	0.32	0.23	0.044E-03	11.65	0.72

[1] SD, Standard deviation; Min, Minimum; Max, Maximum, CV, coefficient of variation.

Regarding the genetic component, milking ability showed a moderate heritability estimate ($h^2 \approx 0.20$), suggesting that a meaningful proportion of the observed phenotypic variance is attributable to additive genetic effects (Table 2). This result indicates that milking ability has the potential to respond effectively to genetic selection.

Table 2. Descriptive statistics for milking ability (kg/min) in Italian Mediterranean buffalo

Trait	σ^2a[1]	σ^2pe[1]	σ^2r[1]	h^2
Milking ability	9994.6	904.13	38709	0.20

[1] σ^2a, additive genetic variance; σ^2pe, permanent environmental variance; σ^2r, residual variance; h^2, heritability.

Discussion

The results of the present study highlight a marked phenotypic variability for milking ability in the Italian Mediterranean Buffalo population, as indicated by the wide range of observed values and the high coefficient of variation. This variability suggests substantial differences among animals in their efficiency during the milking process, likely reflecting both individual physiological characteristics and management-related factors. Similar levels of heterogeneity in milking-related traits have been reported in dairy cattle and buffalo, emphasizing the complexity of this trait (Boettcher *et al*., 1998, Matera *et al*., 2023).

The estimated heritability for milking ability ($h^2 \approx 0.20$) indicates a moderate genetic control, comparable to values reported for milking speed and milk flow traits in dairy cattle populations

(Rensing and Ruten, 2005, Strapák *et al*., 2011). This finding suggests that a relevant proportion of the phenotypic variance is attributable to additive genetic effects, supporting the feasibility of genetic improvement through selection. In buffalo, recent studies have underlined the importance of milk ejection dynamics and milk flow parameters as determinants of milking efficiency and animal welfare (Pierro *et al*., 2025), reinforcing the biological plausibility of a genetic basis for this trait.

From a practical perspective, improving milking ability could contribute to reducing labor time, optimizing the use of milking equipment, and potentially improving udder health and productive longevity. As previously reported, inefficient milking performance may be associated with an increased risk of udder-related problems and involuntary culling (Vicario *et al*., 2006). Despite these advantages, milking ability has so far received limited attention in buffalo breeding programs. The moderate heritability estimated in this study suggests that incorporating this trait into genetic evaluation schemes could enhance overall farm efficiency and sustainability, especially when combined with appropriate management and technological optimization of milking systems (Matera *et al*., 2023).

Conclusions

The results of this study demonstrate that milking ability in the Italian Mediterranean Buffalo is characterized by substantial phenotypic variability and a moderate level of heritability, indicating a meaningful genetic basis. These findings support the feasibility of improving this trait through genetic selection. The inclusion of milking ability in genetic evaluation programs could contribute to enhanced farm productivity by improving milking efficiency and reducing labor and management costs. Furthermore, considering its association with animal welfare, udder health, and work efficiency, selection for improved milking ability may represent a valuable strategy for promoting more sustainable and economically viable buffalo production systems.

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