System and biological effects on quantitative milking speed phenotypes from inline milk meters

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Abstract

Milking speed (MS) is actively used by herds with both conventional and automatic milking systems (AMS) in the USA. A genetic evaluation for MS could be of significant economic value, and dairy producers surveyed express enthusiasm for the development of this new trait. The classification system successfully implemented in other countries that evaluate MS is unlikely to be practical in the USA due to larger average herd sizes, and so the use of quantitative measurements of milking speed is being explored. Many farms now have in-line milk meters that can supply the information required to calculate MS, but there is not a strong consensus on the milking system effects and other biological influences on quantitative milking speed phenotypes. A large dataset was assembled comprising ~300 U.S. herds, >230,000 cows, >300,000 lactations, and >40 million observations of individual milkings from January 2022 to February 2023, and representing 6 dairy breeds, 11 different meter manufacturers, and 2X, 3X, and AMS herds. Milking speed was defined as lbs per minute and calculated for every milking in a day for each individual cow. Data quality control involved only using records with durations between 1 and 15 minutes, weights between 1 and 60 lbs, speeds between 1 and 15 lbs per minute, and cows with at least 10 observations. Milking speed varied by breed, lactation number, and milking frequency. Among 2X and 3X herds, MS mirrored the milking curve over the course of a lactation for Holstein and Jersey, which was to be expected given the favorable correlations between MS and milk yield observed in the literature and this dataset (R2 = 0.4-0.6). Trends were less clear for Ayrshire, Brown Swiss, Guernsey, and Milking Shorthorn due to the sparsity of data available for those breeds. The highest variation in MS was observed during early and late lactation, suggesting MS for genetic selection should be measured during a certain window of DIM only. Among Holstein, the speed of those milked by AMS also mirrored the milk production curve, but with substantial differences observed between meter manufacturers. This is likely an artifact of how the data is collected by each manufacturer, such as differing definitions of when milk flow begins, and the total duration of a milking (box time, or amount of time the milking unit is attached), suggesting that meter manufacturer is a major effect that will need to be accounted for in the harmonization of data collected from different systems. The work to characterize other system and biological effects like udder health parameters and milking interval is

ongoing, and will be integral to our efforts to standardize quantitative MS phenotypes and determine their suitability for selection.

Keywords: milking speed, system effects, biological effects, dairy cow, quantitative phenotype.

Introduction

Dairy producers actively use milking speed (**MS**) metrics to guide their management and make economic decisions. While the USA does not yet have evaluations for MS, at least 18 other countries regularly supply this information to their producers. The Milking Speed Evaluations Task Force was appointed in October 2021 by the Council on Dairy Cattle Breeding (**CDCB**) to review the possibility of implementing genetic evaluations for MS in all dairy breeds and to make recommendations to the CDCB Board of Directors on the necessary steps to make this happen. Interbull-participating countries with evaluations for milking speed collect nearly all phenotypes during the first lactation and sometimes from a single classification. In the rare instance that quantitative milk flow rates are available the classifications are discarded, but the availability of these data varies by country and breed. A classification system is unlikely to be practical in the USA with larger average herd sizes and the task force agrees that eliminating the human factor is ideal for both reducing labor costs and the potential biases introduced with subjective scoring. Genetic correlations for MS across participating countries are calculated routinely as part of the Multiple Across Country Evaluation (**MACE**) report for "Workability" traits, and they are quite high for all breeds. This is encouraging because if this much uniformity can be achieved using subjective scores, attempts to integrate and use quantitative data are likely to be successful.

The long-term goal of this work is to provide accurate, low-cost genomic evaluations for MS that can be predicted at birth. Following analysis of preliminary data, the task force concludes that considerable research is required to develop a clear phenotype definition and identify the relevant data types and quality control/assurance measures required to standardize and integrate these data into the existing national evaluation system. Many OEM meters now provide the type of data needed to calculate milking speed but even these quantitative measurements are subject to confounding bias. In addition to the genetic analysis of MS, phenotypic studies are required to characterize any system effects (automatic take-off, variable pulsation ratios, time in parlor, incomplete udder evacuations, automatic animal ID detection and validation) and biological effects (stage in lactation, breed, parity, herd effects, cow effects like yields and SCS, etc.). No dataset like this exists, and there is a critical need to describe the trait and any environmental and biological effects that should be included in evaluation models before a detailed recommendation can be made and we can proceed with implementation. These concerns will be addressed by the following specific objectives:

- **Objective 1:** Assemble a high-resolution dataset pertinent to MS representing different dairy breeds, equipment manufacturers, parlor types, and milking management strategies
- **Objective. 2:** Characterize MS for herds grouped by equipment manufacturer and parlor type and assess the impact of additional system effects on the phenotype
- **Objective. 3:** Characterize any biological effects that impact MS, especially concerning udder health
- **Objective. 4:** Standardize MS trait definition and estimate heritability to determine its suitability for selection

Materials and methods

Dairy Records Management Systems (DRMS) is a dairy records provider in the USA that supplies herd management software and other services to producers. Every 30 days, DRMS extracts raw milking parlor data from 304 herds. These data comprise milk weights, milking times, breed, parity, meter manufacturer (OEM). This dataset dates to January 2022 and is constantly growing with the addition of new data. As of February 2023, it contained > 40 million observations of individual milkings, representing > 300,000 lactations and > 230,000 cows from 31 different states, 6+ breeds, and 11 OEMs. Data cleaning measures included removing duplicates, restricting raw records to dates from 1 January 2022 to 1 January 2023, requiring a milking duration of greater than zero or less than 15 minutes, a milk weight of greater than 0 and less than 60 lbs, a milking speed of greater than 1 and less than 15 lbs/min, d in milk (DIM) greater than zero, and only including cows with at least 10 observations in each lactation. After data cleaning, the dataset comprised > 22 million records and > 165,000 cows.

Results

Data were stratified by breed, milking frequency, and lactation number, and milking speed (lbs/min) calculated for each stratum (shown for conventional non-robot herds in Figure 1). Each data point represents the mean milking speed for that breed-lactation number. Holstein and Jersey milking speed trend similarly, with older animals tending to milk a little slower (it also should be noted that significantly fewer animals are represented in higher lactation numbers). Jerseys milked 3X per day milk significantly faster than 2X. The trends are less clear for the other breeds, but there is far less data available for them (AY = 165 cows, BS = 749, GU = 82, HO = 138,373, JE = 3,873, MS = 51). Primiparous cows do seem to milk slower than 2nd and 3rd parity cows; this could reflect selection bias with hard milkers being removed from the herd or biological phenomena like the teat sphincter relaxing with age.

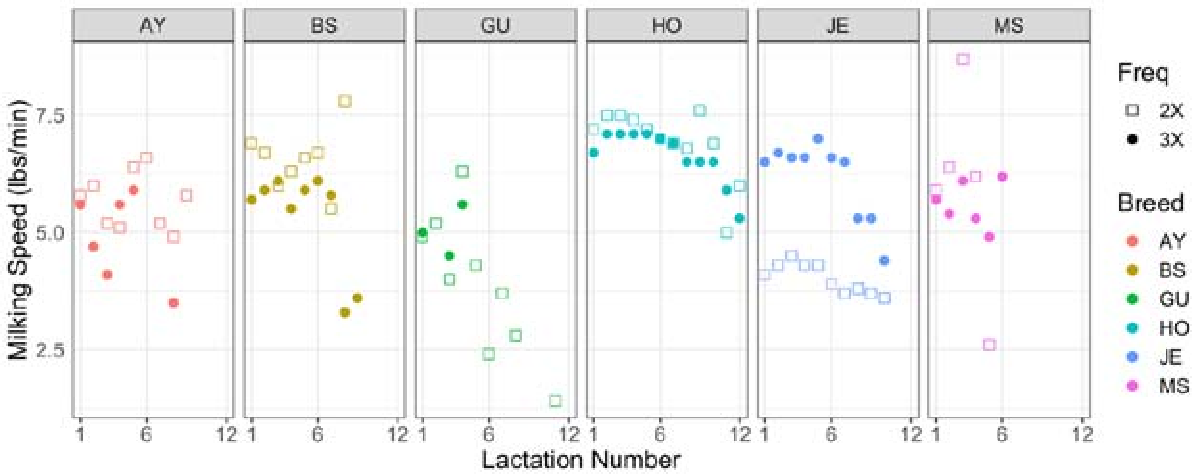

Figure 1. Milking speed by breed, lactation number, and milking frequency.

Milking speed trends were also examined by plotting across days in milk (DIM) to explore any effects of lactation stage (Figure 2). Both Holstein and Jersey milking speed mirror the milk production curve, which is to be expected given the moderately high correlations between MS and milk yield observed both in the literature and in this dataset (R^2 = 0.55-0.7). Trends are less clear for other breeds due to data availability.

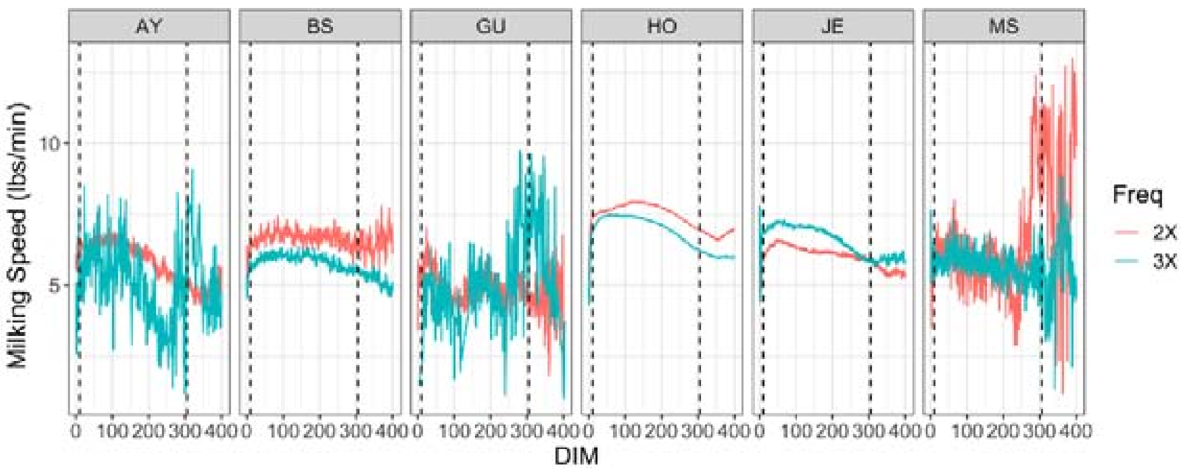

Figure 2. Milking speed by breed, DIM, and milking frequency.

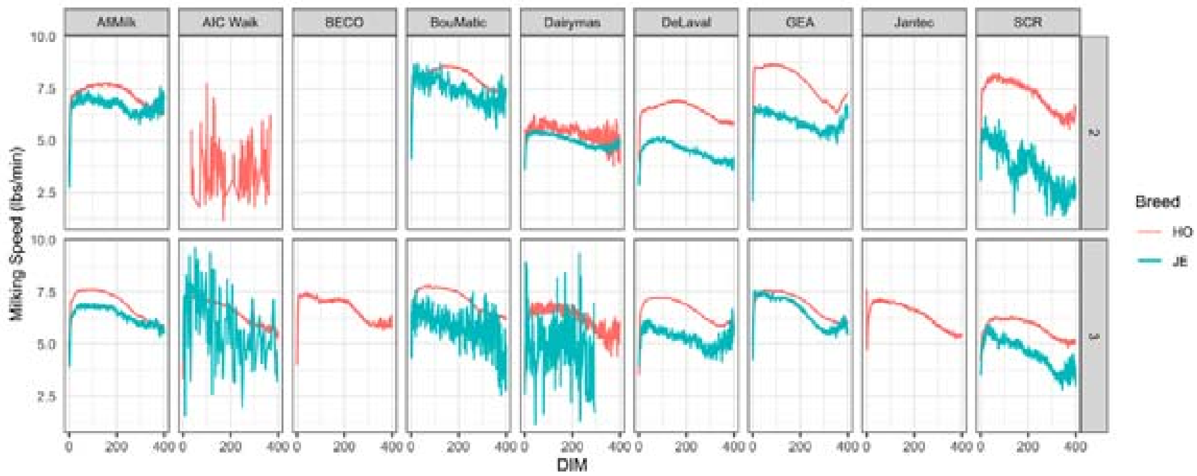

Figure 3. Milking speed, DIM, OEM, and milking frequency (2X, 3X) for Holstein and Jersey. Blank grids indicate that no data was available (e.g., no 2X herds in this dataset used a BECO system).

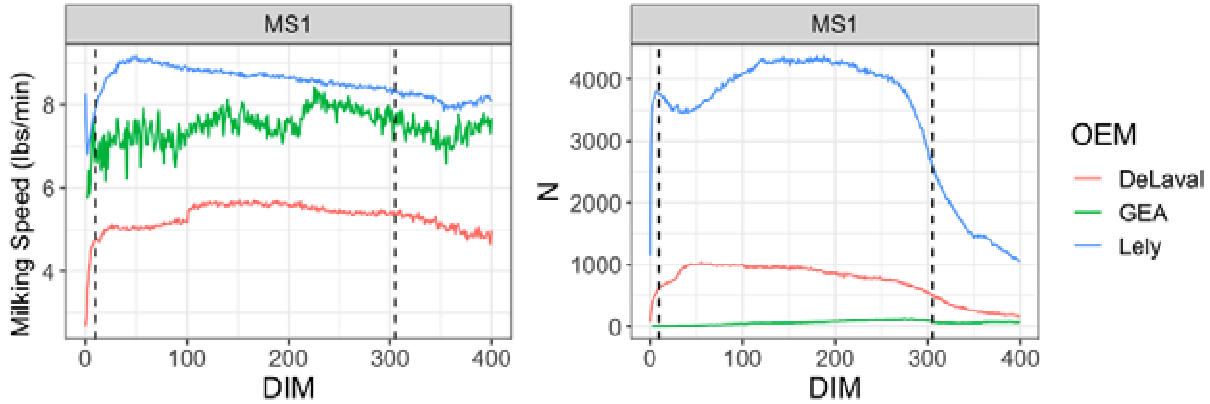

Figure 4. Milking speed, DIM, OEM (left); Number of observations, DIM, OEM (right) for Holstein only in AMS herds.

Trends in milking speed were also examined by OEM for Holstein and Jersey (Figure 3). A clear OEM effect is observed in that speeds vary by meter manufacturer. Smoothness of the curves reflect the amount of data available for each stratum. This pattern can also be observed very clearly by examining the differences in AMS herds (Figure 4). For example, DeLaval and Lely have parallel trends in milking speed, mirroring the milk production curve, but very different speeds overall. This does NOT suggest that cows will milk slower on a DeLaval system! It is an artifact of how the data is collected by each OEM. Every OEM will have their own criteria for when milk flow actually begins and how milking duration is measured (e.g., box time versus milking time). This simply demonstrates that there is a clear OEM effect that will need to be considered in the harmonizing of data collected from different systems.

Milking speed appears to be higher for the first milking of the day across breeds and milking frequencies, as shown in Table 1.

Table 1. Milking speed by milking number, milking frequency, and breed. Milking 1 = first of a 24 hr period, 2 = 2nd of a 24 hr period, 3 = 3rd of a 24 hr period.

	AY		BS		GU		HO		JE		MS	
Milking	2X	3X	2X	3X	2X	3X	2X	3X	2X	3X	2X	3X
1	5.9	5.2	6.7	5.8	4.9	5.1	7.5	7.0	6.1	6.7	6.2	5.7
2	5.6	5.2	6.4	5.8	4.6	5.1	7.3	7.0	5.9	6.6	6.1	5.6
3	--	5.0	--	5.7	--	4.6	--	6.9	--	6.5	--	5.4

An analysis of milking interval suggests that it has overall little effect on milking speed (Table 2). Milking speed was correlated with the interval prior to that milking event. Because cows in AMS herds have free choice of the robot, they may be milked up to 6X per day. To account for the multiple possible combinations of milking interval, intervals were calculated between the 2nd, 3rd, 4th, 5th, and 6th milkings of the prior day and the 1st milking of the subsequent dayy.

Table 2. Milking interval and milking speed correlations. MI = Milking Interval, MS = Milking speed.

	HO			JE		
	2X	3X	AMS	2X	3X	AMS
MI21:MS1[a]	0.01	--	--	0.07	--	--
MI31:MS1	--	-0.03	0.08	--	0.01	0.05
MI41:MS1	--	--	0.06	--	--	0.03
MI51:MS1	--	--	0.05	--	--	0.02
MI61:MS1	--	--	0.01	--	--	0.07
MI12:MS2	0.05	0.04	0.12	0.07	0.17	0.18
MI23:MS3	--	0.04	0.09	--	-0.05	0.10
MI34:MS4	--	--	0.05	--	--	0.05
MI45:MS5	--	--	0.03	--	--	0.00
MI56:MS6	--	--	0.01	--	--	0.03

[a]Notation indicates interval between prior milking and the milking corresponding to MS

Conclusions

Next steps include higher level modelling to better account for the effects of multiple variables, investigation of the highly variable milking intervals and frequencies for AMS herds, and relationship to udder health parameters. These data will also be used to calculate PTAs for various milking speed phenotypes, including the fixed effects identified as important in this paper.