Considerations in using quantitative measurements of milking speed for genetic evaluations for all dairy breeds in the USA

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Abstract

Milking speed is a trait evaluated in several breeds internationally, and most phenotypes are assembled using a subjective scoring system where a trained classifier travels to the farm to individually appraise cows alongside the farmer. This is unlikely to be practical in the United States due to larger average herd sizes and so the use of quantitative data generated by milk meters is being explored. The US Council on Dairy Cattle Breeding has appointed a task force to investigate the feasibility of implementing routine genetic evaluations for milking speed in all dairy breeds. In this presentation, we evaluate the economic importance of milking speed evaluations for US dairy producers, review data types and quality standards, and discuss the system and biological effects that need to be accounted for in the accurate characterization of milking speed in the US dairy population.

Key words: milking speed, genetic evaluation, data standardization, quantitative traits, trait definition

Introduction

The Milking Speed (MS) Evaluations Task Force was appointed in October 2021 by the Council on Dairy Cattle Breeding (CDCB; Bowie, MD, USA) to review the possibility of implementing genetic evaluations for milking speed in all dairy breeds and to make recommendations to the CDCB Board of Directors on the necessary steps to make this happen. The scope of the task force includes evaluating the economic importance of providing milking speed evaluations, reviewing the existing data types and developing a clear definition of the trait to be adopted by CDCB and member sectors, and suggesting quality standards for milking speed data.

Milking speed is a trait evaluated in several breeds internationally, however, most current national evaluations continue to utilize subjective scoring (Interbull, Uppsala, Sweden). Interbull-participating countries with evaluations for milking speed include Australia, Canada, Denmark/Sweden/Finland, France, Germany/Austria/Luxembourg, Great Britain, Italy, Japan, Netherlands, New Zealand, Norway, Poland, Slovenia, and Switzerland. Nearly all of these phenotypes were collected during the first parity only and sometimes from a single classification. Norway indicated these measurements must occur between 20-300 DIM, and Denmark/Finland/Sweden suggest a range of 20-240 DIM. In the rare instance that milk flow rates were available, the classifications were discarded, but the availability of this data varied by country and breed. A classification system is unlikely to be practical in the USA with larger average herd sizes and the MS 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 milking speed across participating countries are calculated routinely as part of the MACE Workability report 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.

Despite limited implementation, there have been several studies that investigate the use of quantitative milking speed or milk flow measures such as milking duration, milking speed, ascending time, average milk flow, maximum milk flow, plateau time, and descending time. The lowest heritabilities are reported for ascending and descending time ranging from 0.02 (Gray et al., 2012) to 0.10 (Samoré et al., 2011). Other objective milk flow or speed traits have moderate heritabilities ranging from 0.11 for maximum milk flow (Gray et al., 2012) up to 0.42 for milking duration (Gray et al., 2012). Heritability of average milk flow or milking speed ranges from 0.18 (Fourdraine et al., 2018) to 0.27 (Gray et al., 2012). Additional studies investigated the use of residual traits such as residual milking duration, residual milk flow, and residual milking duration accounting for SCS (Berry et al., 2013; Edwards et al., 2014). These alternative traits utilize residuals from a regression model of milking duration on milk yield (or milk yield and SCS) as a strategy to increase milking speed without impacting milk yield (Berry et al., 2013).

Many of these studies also report repeatabilities, giving us an indication of how well a single measurement per cow will perform. Most research reports high repeatabilities suggesting that one record per cow may be sufficient. Repeatabilities for average milk flow or milking speed ranged from 0.40 (Fourdraine et al., 2018) to 0.54 (Gray et al., 2011). Among the literature, there was conflicting evidence regarding the differences between primiparous and multiparous animals. For example, Edwards et al. (2014) reported that primiparous cows had a different milk flow profile, having lower maximum flow, whereas Fourdraine et al. (2018) reported that variation across lactations was negligible.

Another important consideration is the correlation of milking speed with other traits of economic importance or with health and welfare concerns. Most research reports a favorable correlation between milk flow traits and milk yield (e.g., Gray et al., 2011; Samoré et al., 2011; Fourdraine et al., 2018). Results are not as clear when it comes to SCS and udder health. For example, Zwald et al. (2005) reported an unfavorable correlation of -0.15 between milking duration and SCS, while finding no significant correlation with clinical mastitis. Additional research has supported the negative genetic correlation between milking duration and SCS (e.g., Gray et al., 2011). While Samoré et al. (2011) did not find a significant correlation between total milking time and SCS, other research has indicated that selection for average milk flow may result in reduced udder health (Edwards et al., 2014). These conflicting results lead most authors to conclude that there is an intermediate optimum relationship between milk flow traits and SCS or mastitis resistance (Wiggans et al., 2007; Samoré et al., 2011; Fourdraine et al., 2018).

There are still many unanswered questions, like how milking speed may change by a cow's physiological state (e.g., pregnancy, lactation stage), and if these changes occur, how many times she must be sampled to accurately assess her milking speed. Other unknowns concern practical application, especially considering how this information would be most useful to producers. Conventional milking herds use MS to choose their milking groups and optimize parlor efficiency, but herds utilizing automatic milking systems (AMS) also use MS to make important economic decisions like how many robots to buy. This is the primary reason the task force believes "milking duration" may not be the best phenotype despite appearing to have the highest heritability. Milking duration does not account for the amount of milk produced and so is not a useful metric for AMS herds who want to maximize milk per robot, not necessarily cows per robot. This also prompts the questions of whether AMS and conventional herds should be evaluated together. Given these unknowns, the relatively small body of literature, and conflicting reports on MS, the task force recognized the need to describe the trait before a recommendation could be made.

Materials and Methods

A file Format 6 was developed by CDCB to facilitate health event reporting. It includes 4 management traits, including milking speed. There is no industry-standard scale, so subjective classifications must include both the range of the scale (e.g., up to 9 points) as well as the cow's ranking on that scale. Currently Format 6 also gives an option to report milking time (MM:SS) but it should be noted that this is not a measure of milking speed, just the duration of the milking. There have only been 21 reports of milking speed transmitted to CDCB since its addition to Format 6 in 2006.

The herd management software PCDART records and stores milking weights and duration for 100 days, and daily milk weights for an additional 300 days. With no data available through CDCB for milking speed, a preliminary analysis was conducted using archival PCDART data from 9 herds. Unfiltered and unedited archival data files were provided to CDCB by Dairy Records Management Systems (DRMS). Of these herds, 2 herds were AMS and 7 were using conventional milking parlors, and these two herd types were analyzed separately. The reported herd IDs were anonymously and arbitrarily assigned.

We proposed a simple definition for milking speed of lbs/min taken by dividing the milk yield of a particular milking by the duration. The data cleaning steps and reduction to the raw dataset are shown in Table 1. The goals of the data cleaning were to 1) address sparsity issues in these unprocessed archival records, 2) eliminate obvious recording errors (e.g., if a cow had a milking that lasted 1 hour but her milk yield was 0 lbs), and 3) control for biological phenomena that may impact milking speed temporarily (e.g., clearance of colostrum, inflammation post-parturition). An average of approximately 30% of conventional herd data was removed and 50% of AMS herd data was removed.

Trends in MS were evaluated by lactation number, and Pearson's correlations were calculated to describe the relationship of milking speed to milking interval, milk yield, and among milkings within a single day. Within-cow variability in MS was calculated by taking the variance in milking speed among all milkings in a particular day for an individual cow.

Table 1. Data quality standards and the number of records retained at each data cleaning step.

	AMS	Conventional
Starting # records	140,623	2,321,980
Data Sparsity		
Holstein only	132,069	2,158,623
Last 150d only	**116,065**	**1,826,761**
Recording Errors		
Milking Duration[1]	109,390	1,586,230
Milk Weights[2]	105,725	1,572,231
Milking Speed[3]	83,882	1,511,435
>10 records/cow[4]	57,826	1,266,156
Biological Phenomena		
DIM[5]	58,504	1,270,626
Final # records	**57,826**	**1,266,156**
% reduction[6]	**50.2%**	**30.7%**

[1]duration > 1 min and < 15 minutes
[2]milk weights >1 lb and < 60 lbs
[3]milking speed > 1 lb/min and < 15 lbs/min
[4] at least 10 observations per cow
[5]days in milk > 10 and < 305
[6]data lost per herd relative to bolded # of subset after controlling for data sparsity, not starting #

Results & Discussion

Milking speed did vary by DIM and appeared to mirror the lactation curve as shown in Figure 1. The trend is supported by the fairly high correlation between MS and milk yield observed in this dataset, ranging from 0.52-58. Prior to 10 DIM, MS appeared slower which makes sense as cows are clearing colostrum which would milk more slowly due to higher viscosity and the recovery from inflammation common post-parturition. In addition, average MS was fairly consistent until about 350 DIM, when in the cases of persistent lactations MS becomes more variable. This is most likely explained by changing management of those cows and small sample size (Figure 2). The number of available records drops steeply after the standard lactation length of 305 d.

An assessment of how a cow's MS may change within a single day and across time is shown in Figure 3. While MS does appear to vary, the amount of variance is again consistent within that 10-305 DIM window. The case for restricting usable MS records to certain DIM is supported by similar edits used by some Interbull-participating countries.

Thus far, MS measurements appear consistent for conventional herds. The 2 AMS herds were analyzed separately, and MS measurements were highly variable, as is shown in Figure 4. Both herds had up to 6 milkings a day per cow, but an individual cow may not have been milked the same number of times each day. One day she may milk 2 times, then 4, then 3, etc. The times of day she milked may also not be consistent. Sophisticated programming will be required to fully understand these patterns, but more data is needed before any conclusions about AMS herds can be drawn.

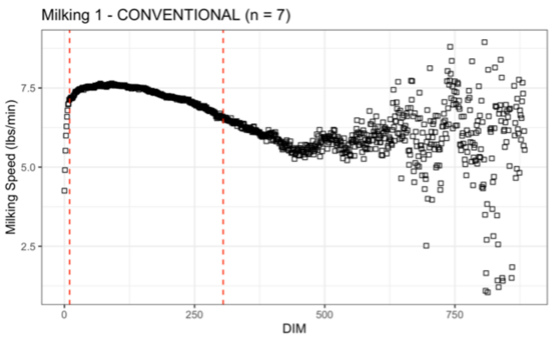

Figure 1. Average milking speed for the first milking of the day plotted over DIM for the 7 conventional herds. The red dashed lines represent 10 and 305 DIM, the chosen cutoffs for usable milking speed records.

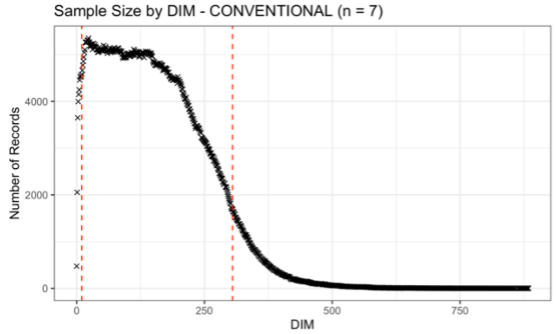

Figure 2. The number of available records by DIM. The red dashed lines represent 10 and 305 DIM, the chosen cutoffs for usable milking speed records.

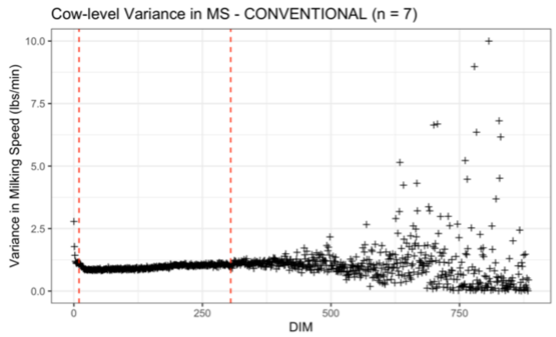

Figure 3. Within cow variability in milking speed by DIM. Variance in milking speed is an individual cow's variation in milking speed across all her milkings on a given DIM. The red dashed lines represent 10 and 305 DIM, the chosen cutoffs for usable milking speed records.

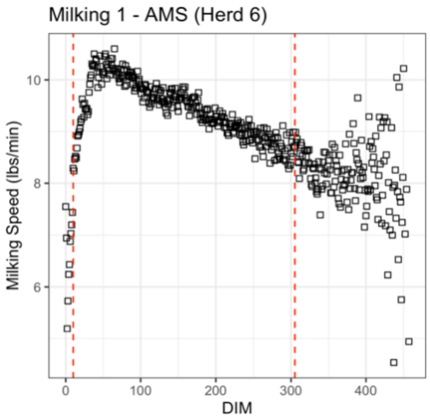

Figure 4. Average milking speed for the first milking of the day plotted over DIM. The red dashed lines represent 10 and 305 DIM, the chosen cutoffs for usable milking speed records.

Other observations from this preliminary analysis include the fact that AMS cows milked faster by 1-2 lbs/min on average than conventional cows. This may be because AMS herds have been selecting for MS on their own to maximize the return on investment in their robots. MS tended to be a little higher for the first milking of the day, though there did not appear to be any significant correlation between MS and milking interval for conventional herds. This will need to be further explored for AMS herds were milking interval may vary greatly by individual cow and by particular day. First lactation cows milked slower on average than multiparous cows. This is probably partially explained by culling bias with hard milkers being removed from the herd but could also be related to biological phenomena like the teat sphincter relaxing with increasing age.

Many questions cannot be fully answered with this preliminary analysis. A full investigation of the system biological effects on MS is needed and some key factors that may impact our understanding of MS are shown in Table 2. These include system effects, especially concerning meter manufacturer and milking management protocols. Some OEM meters provide fractional flow rates and information regarding milking performance (counts of cluster detachment/reattachment). These fractional flow rates are more relevant to management insights, indicating equipment and milker performance (udder preparation, initial letdown, etc.) and will vary greatly by cow, milking event, and milkers. Some data are available at this level of precision, but their exact relationship to overall milking speed and how useful they may be are unknown. Other meters may provide milking duration and milking weight, from which speed can be calculated. These weights and durations will not account for factors like incomplete udder evacuation or milking event interruptions and manual reattachment.

Table 2. Other factors whose impact on milking speed are unknown and need to be quantified.

System Effects	Meter manufacturer
	Automatic take-off
	Variable pulsation ratios
	Milking frequency
	Milker/milking management effect
	Individual meter effect
	Time in parlor
	Incomplete udder evacuation
	Automatic ID detection & validation
	Calibration & maintenance protocols
Biological Effects	Stage in lactation
	Breed
	Parity
	Season/region effects
	Cow effects
	Fat/protein content

The MS-TF agrees that eliminating the human factor is ideal for both keeping labor costs down and reducing the biases of subjective scoring. Even in using quantitative measurements from milking meters, we must account for 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.). Given the variable interfaces of OEM meters and herd management software, the different methods of calculating milking speed, and concerns over automatic animal ID detection, perhaps the easiest way to have standardized, high-quality milking speed records flow into the national cooperator database is by including this in regular DHI testing plans.

Conclusions

The US Council on Dairy Cattle Breeding has appointed a task force to investigate the feasibility of implementing routine genetic evaluations for milking speed in all dairy breeds. This preliminary analysis suggests that primiparous cows milk slower than multiparous cows, but this may be an artifact of selection bias in the population. Milking interval does not appear to have an impact on MS for conventional herds, but this may not hold for

AMS herds with less consistent milking schedules among and within cows. Consistent with edits used by some other countries, MS records should be restricted to certain DIM to avoid biases introduced by post-parturition inflammation and colostrum as well as changing management of cows with high lactation persistency. A full investigation of system and biological effects on MS, and the validation and interpretation of these observations, is required to ensure the delivery of accurate predictions that will be practical in different systems (e.g., conventional and AMS herds). Further exploration of the relationship between MS and SCS is required to determine whether we should be selecting linearly for MS or if it is more appropriately treated as a two-way trait with an optimum.

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