Milking Efficiency – A Milkability Trait for Automatically Milked Cows

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ABSTRACT: Data from an experimental herd with automatic milkings from 486 first lactation cows were used to study alternative measures of milkability. One trait was milking efficiency, (kg milk per minute used in robot) the other "residual milking box time" using a linear regression to adjust daily time for daily fat and protein corrected yield. Both traits were moderate to highly heritable and closely correlated (r_a = 0.85). The two traits differed by milking efficiency being correlated to yield (r_a = 0.48). Residual box time was closely correlated to milking time (r_a = 0.93) compared to milking efficiency which showed only intermediate correlation. Both traits had weak correlations to somatic cell counts. It is concluded that either trait will be effective in selecting for cows giving more milk per minute occupying the milking robot, without increasing risk of mastitis.
Keywords: dairy cattle; milkability; AMS; efficiency

Introduction

Automatic milking is increasingly contributing to milk production, and therefore also to genetic evaluation programs. For many years milkability was considered an important functional trait, mainly recorded by interviewing staff milking the cows. The trait is heritable and in some countries included in the breeding goal and in total merit index. Milkability is subjective and somewhat vaguely defined as it includes both milking time and the cows' easiness-to-handle in the milking parlor.

Technological developments in milk recording devices have in recent years provided equipment that can automatically measure total amounts of milk, milking time, flow rates and flow rate profiles. Milk flow rates are suggested as alternatives or supplements to milkability scores (e.g. Gray et al. (2011)). It is, however, known that flow rate is unfavorably correlated to mastitis risk, so that selection for high flow rates may put cow health into jeopardy. For automatic milking systems (AMS) milked cows the milking process includes time to enter and leave the milking box. The total time a cow occupies the milking box may be seen as an expense and a limit to the availability of the milking system. Taking this view, the "AMS milking efficient cow" is the cow that gives most milk per minute it occupies the milking box. Milking efficiency may also be expressed in other ways, e.g. "residual milking time" where milking time is adjusted for yield as applied for parlor data (Berry et al. (2013)); and for AMS data (Carlström et al. (2013)).

Clearly, milking efficiency is a composite trait, in the same way as milkability. The main components of milking efficiency are milk flow and cow behavior. In the AMS, the cow's behavior during milking can be objectively defined because it is reflected in the total occupancy time and the frequency of incomplete milkings (Løvendahl and Chagunda (2011)).

The present study aimed at investigating genetic variation in milking efficiency and its co-variation with other milking traits as well as production and heath traits. In turn, residual milking time was studied in parallel and compared with milking efficiency.

Materials and Methods

Design and Animals. Data used were from a cohort study with animals kept in the experimental herd at the Danish Cattle Research Centre (Foulum, DK), with Holstein, Jersey and Red Dairy Cattle. Pedigrees were traced in the national cattle database. Cows were kept in 3 separate groups, each group freely accessing one AMS (VMS, DeLaval, Sweden). Cows were fed total mixed rations *ad lib* and supplemented with small amounts of concentrates during milking (approx. 3 kg/d). Although data were available for parities 1-3, only data from first parity cows (n = 486) were used in the present study.

Milking data. From each milking the total time spent in the milking box was recorded. Milk yield, and average flow rate were recorded at quarter level and summed per cow. Milking time was calculated from flow rate and total yield. The remaining time was defined as "handling time". Composition of milk was assayed for a subset of milkings, with fat, protein, lactose and somatic cell counts. A completion code was issued after each milking by the management software and incomplete milking were characterized by having less milk than expected on one or more quarters. Incomplete milkings were, often as a result of kicked off teat-cups. Milkings that were themselves deemed incomplete, and milkings following an incomplete milking were filtered away before statistical analysis, as previously described (Løvendahl and Chagunda (2011)).

Data. *Yield* was measured *per milking*, and extrapolated to *daily yield*. Energy corrected milk yield (ECM) was calculated for milkings where composition data was available. *Average flow* rate and variables *box_time, handling_time* and *milking_time* were used together to calculate *milking efficiency*, (in kg ECM per minute box_time). The "residual Box Time" was calculated as the residuals from a linear regression of daily BoxTime on daily ECM, as suggested by Berry et al. (2013).

Statistical analyses. Milking traits and their variance and co-variances are known to be influenced by stage of lactation. Therefore, the lactation was split into segments of 30 day duration, and hence a simpler model was applied. Each segment contained about data from about 12000 milkings. Diurnal effects were modeled using a waveform or Fourier approach (Løvendahl and Chagunda,

(2011)). For estimation of genetic parameters the DMU software package (Madsen and Jensen (2010)) was used to fit single and two-trait linear (animal) models.

Results and Discussion

Comparison of traits. Milking efficiency is a ratio trait that combines total time spent per day and yield corrected for milk composition into a single meaningful variable. The variable has approximately normal distribution and evolves slowly during lactation (Figure 1) with, reasonably stable variance (not shown), along with its component traits (Figure 1). Residual milking box time has by definition mean zero and normal distribution.
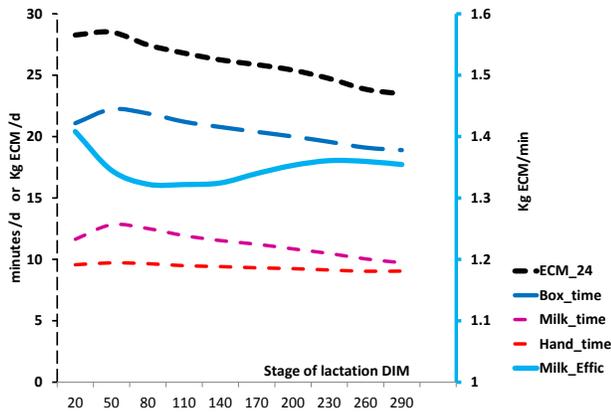
Figure 1. Milk yield (ECM_24) and time spent in the milking box (Box_time) for handling (Hand_time) and milking (Milk_time), and the resulting milking efficiency (Milk_Effic), over 10 stages (segments) of lactation (DIM).

The genetic analysis revealed that milking efficiency had higher heritability than residual milking box time (Figure 2), with both traits having intermediate heritability. The analysis also revealed that the two traits were highly correlated to each other as r_a was generally higher than 0.80 throughout lactation. The correlation was always negative, as expected because desirable values of residual milking box time are negative (cows using less time), and vice versa for milking efficiency where good cows are producing more milk per minute spent in the robot.
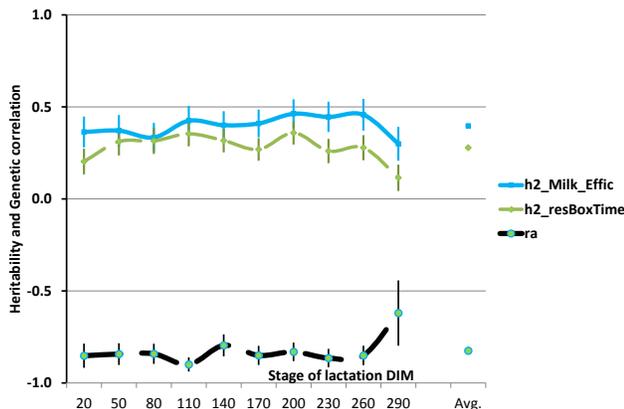
Figure 2. Heritability and genetic correlations between milking efficiency (Milk_effic) and residual milking box time (resBoxTime) during 10 stages of lactation.

Correlations to other traits. The genetic correlations of milking efficiency to ECM were on average 0.5 while those for residual box time to ECM were close to zero (Figure 3). This result was as expected. This is, because milking efficiency include yield in contrast to the residual trait which is adjusted for yield differences. In this case the adjustments were at the phenotypic level, but alternatively adjustments at the genetic level using breeding values for yield may presumably force all genetic correlations to zero as suggested by Berry et al. (2013). Both traits were correlated to their components, handling and milking time (Figure 4), and especially residual box time was strongly correlated to milking time. Both traits were also vaguely correlated to milk flow rates with correlations going in opposite directions at various stages of lactation (Figure 5), and on average the correlations were close to zero. The correlations to somatic cell count were on average close to zero for both traits (Figure 6). Adjustments to residual milking box time for somatic cell count (Carlström et al. (2013)), showed little extra effect. This is in agreement with the weak correlations shown in the present results.
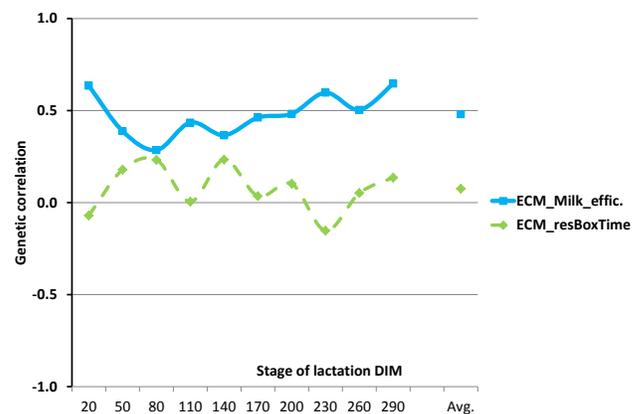
Figure 3. Genetic correlations between milk yield (ECM_) and milking efficiency (Milk_effic) or residual milking box time (resBoxTime), over 10 stages of lactation (DIM).

Consequences of selection. The present study focused on total time spent for the whole milking process for cows milked in AMS, mainly because the occupation of the AMS is a key management parameter in optimizing dairy herd performance with numbers of cows accessing each AMS unit (André et al. (2010)). The time used in the milking box can be broken down into a handling and a milking part. The milking part itself is related to the flow rate whereas the handling part is related to "milking temperament" but also closely related to morphological properties of the cow (Byskov et al. (2012)). Obviously, the time used for attachment of teat-cups becomes much longer if the udder shape makes it difficult to detect the correct positions. Also, cows that kick off the teat-cups will require extra time for re-attachments. These issues must be

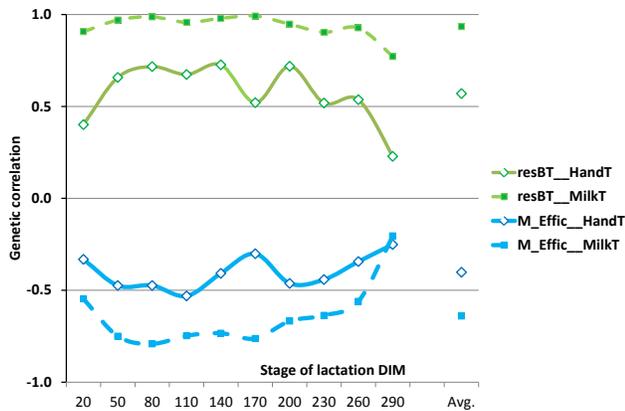investigated in further detail also by using available coordinate data from AMS (Byskov et al. (2012)).

Figure 4. Genetic correlations of handling (HandT) and milking time (MilkT) with milking efficiency (Milk_effic_) or residual milking box time (resBoxTime_), over 10 stages of lactation (DIM).
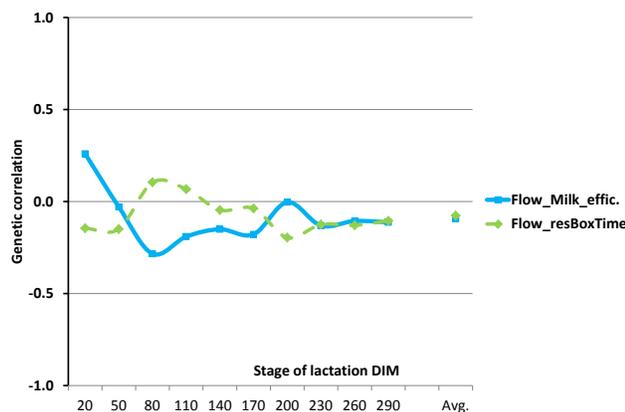

Figure 5. Genetic correlations between milk flow rate (Flow_) and milking efficiency (Milk_effic) or residual milking box time (resBoxTime), over 10 stages of lactation (DIM).

The present study showed weak correlations to somatic cell count for both traits. Since cell counts are an indicator of mastitis risk this implies that selection for milking efficiency or similarly for residual box time would not impact unfavorably on mastitis risk. This is in contrast to selection on flow rates which are commonly known to be unfavorably correlated to mastitis risk. Flow rates are obtainable from electronic milk meters and have been suggested as replacements for milkability scored by inspectors or users. However, flow rates are ignoring the time used for handling the cows, and as that takes up more than a third of the total time used for the milking process this important aspect is not included in the breeding program.

The main difference between the two suggested ways of expressing milking efficiency is in the way yield is included and adjusted for. The primary consequence may be that milking efficiency has a somewhat higher heritability driven by milk yield itself having a high heritability in the present study. Beyond that, milking

efficiency may be a more logically appealing trait to use for management purposes. However, for selection purposes the residual milking box time is more appealing as it is uncorrelated to the production traits going into the selection indexes on their own.
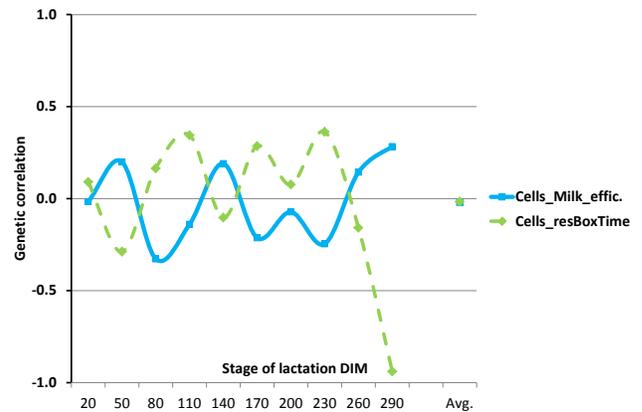

Figure 6. Genetic correlations between somatic cell count (Cells_) and milking efficiency (Milk_effic) or residual milking box time (resBoxTime), over 10 stages of lactation (DIM).

Conclusion

Milking efficiency and residual milking box time are both traits which are moderately heritable and highly correlated to other production traits. Using these traits in a selection program would provide future generations of cows that would give a lot of milk per minute spent in the AMS without significantly increasing their mastitis risk.

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