AUTOMATIC MILKING SYSTEM, A SOURCE FOR NOVEL PHENOTYPES AS BASE FOR NEW GENETIC SELECTION TOOLS

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Summary

Automatic Milking Systems (AMS) provide data to derive phenotypes comparable with the current set of phenotypes used for breeding value estimation, but AMS are also a source for novel phenotypes as a base for new breeding values. In this general overview possible applications of data from AMS in breeding are discussed. Cartesian teat coordinates measured by AMS provide new opportunities to derive udder conformation traits and can be used as indicator trait for udder oedema. Regarding body weight, a regression model using the Wilmink function can be used to predict body weight during lactation. New phenotypes describing the milk flow, especially the start of the milk flow are possible by AMS techniques. For traits like AMS efficiency and milking speed current breeding values can be updated by new information. AMS data show great opportunities for developing breeding tools to breed a more efficient and healthy cows.

Keywords: automatic milking system, new traits, genetics

Introduction

Approximately a third of the dairy farms in the Netherlands is equipped with an automatic milking system (AMS). The AMS measures and records a lot of data, every time a cow visits the milking box. The data includes measurements comparable with current phenotypes measured in another way, for example milking speed (MS) and some of the udder conformation traits (Byskov *et al.*, 2012, Carlström *et al.*, 2013 and 2016). The data also provides information for novel phenotypes, especially phenotypes that are subject to change during lactations and during the lifetime of a cow. For research purposes, a data set based on 70 AMS herds was provided. This paper gives a general overview of research projects about phenotypes derived from AMS measurements and opportunities to develop breeding values used to select cows suitable for an AMS.

Material and methods

Trait definitions

Udder conformation traits

To be able to automatically attach teat cups to the teats, the AMS detect the three-dimensional location of the teat tips using laser techniques (De Koning, 2011). The locations of the teat tips are recorded as Cartesian coordinates (x, y, z). The z coordinate is a measure of the distance from the teat tip to the floor, the y coordinate is a measure of the position of the teat on the axis parallel to the long side of the robot, and the x coordinate is a measure of the position of the teat on the axis perpendicular to the long side of the robot. The Cartesian teat coordinates were used to derive traits that were informative about udder conformation. The udder conformation traits rear teat distance, front teat distance, udder depth, distance front-rear, udder balance, udder balance left-right (UBLR) and unevenness were derived. A specification of the udder conformation traits is given in Table 1, in the appendix. Besides the linear udder conformation traits the daily measurements provides perspectives for novel phenotypes like an indicator of udder oedema. Since udder oedema causes udders to swell, it was expected that teats are further apart and the udder is deeper. The indicator traits for udder oedema were given in Table 1.

Body weight curve

The farms included in this project have AMS with a weight measuring function. Every time a cow visits the its AMS body weight was measured in kilograms. Body weight trends of cows during lactation were constructed for the first three parity groups. A fixed linear regression model using the Wilmink function was fitted to the weight curve of the cows for each parity (Roche *et al.*, 2006). The Wilmink function was originally used to fit the lactation curve (Wilmink, 1987), which has an opposite trend as the body weight curve. Body weight of a cow at a particular time was fitted with the following function:

$$y_{ij} = a + bt + ce^{(-kt)} + e_{ij},$$

where a, b and c were parameters of the function. With a is the initial body right after calving, b is the body weight gain from nadir weight (lowest weight) and c is the body weight loss after peak weight. Novel traits describing body weight changes could be derived from the weight curves. A specification of four body weight change traits are given in Table 2 in the appendix.

Automatic milking system efficiency

AMS efficiency was defined as milk production in kg milk produced per total box time, expressed in kg milk per minute. Total box time is the time between the moment the cow enters the AMS till she leaves the AMS. Efficiency could be based on successful milkings only, but it is possible that a cow visits the milking system without a complete milking. Only occupying the AMS, while not producing milk would reduce AMS efficiency. Therefore, in this research two definitions for AMS efficiency were defined. The first definition was the milk production in kg milk produced divided by total box time, based on the current milking only (EFF1). The second definition takes previous incomplete milkings into account (EFF2). Efficiency was defined as the sum of the milk production of the current milking and previous incomplete milkings, devided by the sum of the box time of the current milking and previous incomplete milkings. The first definition is comparable with the definition used for breeding values estimation in the Netherlands since 2015 (Vosman *et al.*, 2014).

Automatic milking system start milk flow

Since the AMS registers exactly the time to each event during milking, it is possible to make a difference between animals started the milk flow immediately after attaching teat cups and animals where this process takes more time. Different definitions were defined to describe the trait. The first definition was the dead milk time (DMT) of first attached quarter, with dead milk time as the difference in attachment time (AT) and start of the milk flow. The second definition was the average DMT of the four quarters. The third derived definition was the sum of the DMT, the AT and the pretreatment time (sDAP). The last definition was chosen because the farmer can change the AMS settings to a longer (or shorter) pretreatment time.

Milking speed

MS was derived by dividing the total milk yield (in kg) by the milk time (in minutes). Milk time was defined as the time between attachment of the first teat cup and the detachment of the last teat cup, re-attachments included.

The dataset

The dataset consisted of continuous milking records from the AMS. Records were obtained from 70 commercial dairy farms in the Netherlands in the time period from 14-03-2006 to 18-08-2016. The data includes 85,023,135 AMS visits, with 39,668,935 AMS milking records on 20,017 cows. The different research topics had specific data edits. In general, only records from herd book registered animals with a known pedigree and at least 87.5% Holstein Friesian were used. A pedigree file was available for all animals in the study.

Statistical models

For each of the traits described a genetic analysis was performed, in which heritability and variance components were estimated, as well as genetic and phenotypic correlations. Analyses were performed with ASReml (Gilmour, 2015).

Results and Discussion

Udder conformation traits

The heritabilities of nearly all AMS udder conformation traits were in a range of 0.45 and 0.74. The only trait that showed a low heritability, was UBLR (0.03). Therefore UBLR is not considered as an useful trait. The heritabilities of the AMS udder conformation traits were higher than the heritabilities of the corresponding traits scored by classifiers. A reason for that could be that scoring of udder conformation by classifiers is subjective, while measuring teat coordinates by milking robots is objective. Furthermore, the AMS measured multiple times a day during the entire lactation, while classification scores are only scored once. The high genetic correlations between the AMS udder conformation traits and the corresponding classification traits (ranging from 0.91 to 0.97) indicate that the traits are genetically similar.

Indicators for udder oedema traits had heritabilities between 0.25 and 0.29, only change in distance front-rear had a lower heritability (0.07). Therefore, measurements of change in rear teat distance, change in front teat distance and change in udder depth in early lactation would be useful as indicator for udder oedema.

Body weight curve

High R^2 values indicates that the model used fits body weight measurements very well. First parity cows have a shorter period from calving to nadir weight, a smaller body weight loss and a faster past-nadir weight gain compared to older cows. That indicates smaller energy deficits in early lactation and growth towards mature weight for first parity cows. Weight curves for the first three parities were given in the appendix. In general, the heritabilities for the defined definitions were highest for first parity. Initial body weight had the highest heritability (0.48 first parity), followed by weight loss (0.23). Based on genetic correlations with fertility, udder health and ketosis, these traits offer possibilities for select more efficient and healthier cows. Calo correlations (Calo *et al.*, 1973) between body weight change traits and breeding values for health traits are given in Table 3 of the appendix.

Automatic milking system efficiency

The average EFF1 is 1.57 kg/min, and for EFF2 the average is 1.50 kg/min. In general visits with a higher milk yield were more efficient. EFF1 had an overall heritability of 0.33 and heritability for EFF2 was 0.29. The genetic correlation between EFF1 and EFF2 was 0.98, indicating there are small to no differences in ranking of the animals. It is therefore better to use the second definition to penalize failed milkings in breeding.

Automatic milking system start milk flow

The time between the attachment of the teat cups and the start of the milk flows differed per cow, but also during lactation. Immediately after calving the average DMT is shorter (14 sec.), compared to later on in lactation (19 sec.). But the average sDAP was larger in the first days after calving (109 sec.), and shortest in the second week after calving (101 sec.). The average DMT had a heritability of 0.26 in the first week after calving and increased to a heritability of 0.57 in week 6 after calving. Heritabilities for DMT based on the first attached teat were 20% lower. The sDAP had a heritability of 0.07 in the first week after calving, which increased to 0.16 in week 6 after calving. DMT had a high genetic correlation (0.93) with MS, while the genetic correlation between sDAP and MS was much lower (0.70). A lower correlation indicates that the trait based on the sDAP was more different from MS than DMT only. Therefore, the sDAP is a more favorable indicator describing start of milk flow.

Starting milk flow immediately after first contact with the teats is not desired. This kind of definitions also offers possibilities to develop a selection tool for leakage.

Milking speed

MS could be derived from milk time and milk yield immediately after calving. The average MS on udder level is 2.27 kg/minute, on teat level the average is 0.8 kg/minute. Data showed that a higher milk yield resulted in a higher MS. Milk speed across all parities had a heritability of 0.46, whereas 0.51 for parity 1. The heritability was much higher compared to the heritability based on a more subjective farmer score. Genetic correlations between parity 1 and parity 3 and higher were 0.94, correlations between all other parities were 0.98 or higher.

Genetic correlation between MS based on AMS measurements and farmers scores was 0.9. This correlation was based on breeding values of a small group of bulls. Results from this study indicate that milk time and milk yield recorded by AMS can be used to calculate MS and it is no longer necessary that farmers score the animals for MS if they were milked by AMS.

Conclusion

Data that are routinely collected by AMS during each milking visit of a cow can be used to measure existing phenotypes with higher accuracy or to define new phenotypes which are hard or impossible to measure without AMS.

This research implies that breeding value estimation for udder conformation traits scored by classifiers would be improved if information about teat coordinates would be added. Body weight curves could be described by a fixed regression model using the Wilmink function. New phenotypes can be derived from the body weight curves to select against a decrease in body weight at the beginning of the lactation, to select for more efficient and healthier cows. Calculating AMS efficiency is possible in two ways, based on the current milking only (current way of calculating efficiency) or by taking previous failed milkings into account. Genetic correlations between both definitions were high. By using AMS data MS could be derived from milk time and milk yield immediately after calving, providing a more objective way of scoring than a farmer score. The AMS data offers possibilities to study new phenotypes describing the milk flow, especially the start of the milk flow. AMS technique provide an objective way of recording current traits and newly defined phenotypes that can be used to develop new breeding values to select cows suitable for an AMS. AMS data show great opportunities for developing breeding tools to breed for more efficient and healthier cows.

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Attachment

Table 1. Description of the udder conformation traits derived from the Cartesian Automatic milking system teat coordinates.

Trait	Description
Udder depth	Average distance of teat ends to the floor in mm
Front teat distance	Distance between left and right front teat ends in mm
Rear teat distance	Distance between left and right rear teat ends in mm
Distance front-rear	Average distance between the front and rear teat ends in mm
Udder balance	Average difference in distance to the floor between the front and rear teats in mm
Udder balance left-right	Absolute mean difference in distance to the floor between left and right teats in mm
Unevenness	Number that reflects the difference in depth of the four teats: the higher the number, the less even the udder
Change front teat distance	Average front teat distance on day 2, 3, and 4 corrected for the average front teat distance of day 27, 28 and 29
Change rear teat distance	Average rear teat distance on day 2, 3, and 4 corrected for the average rear teat distance of day 25, 26 and 27
Change udder depth	Average udder depth of day 24, 25, and 26 minus the average udder depth of day 2, 3, and 4
Change distance front-rear	Average distance front – rear teats on day 2, 3, and 4 corrected for the distance front – rear teats of day 19, 20, and 21

Table 2. Description of the body weight change traits derived from the body weight curves.

Trait	Description
Initial body weight	Body weight at calving
Weight loss	Difference between calving weight and minimum weight during lactation (nadir weight)
Days to nadir	Number of days elapsed by a cow to reach the minimum body weight of lactation period (Hojman and Ephraim, 2007)
STDev(BW)	Standard deviation of body weight during lactation

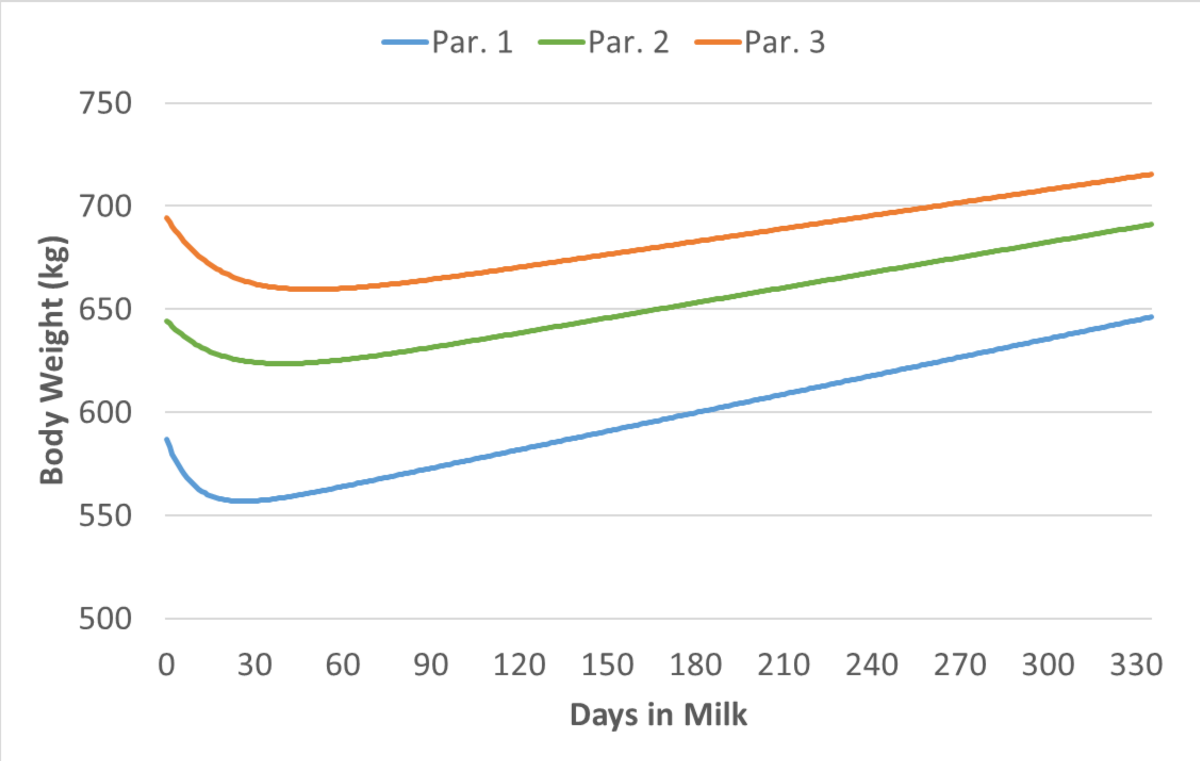

Figure 1. The body weight trend of dairy cows in their first three parities fitted with a Wilmink curve.

Table 3. Calo correlations between body weight change traits and breeding values for health traits.

Trait	Initial body weight	Weight loss	Days to nadir	STDev
		Parity 1		
Sub Clinical Mastitis	0.13	-0.45	-0.58	0.12
Clinical Mastitis	0.05	-0.50	-0.78	0.19
Longevity	-0.31	-0.20	-0.29	-0.49
Calving interval	-0.03	-0.14	-0.32	0.08
Interval First-Last insemination	-0.08	-0.02	-0.28	-0.04
Ketosis	0.16	-0.49	-0.55	0.08
		Parity 2		
Sub Clinical Mastitis	0.22	-0.33	NE	0.22
Clinical Mastitis	0.14	-0.33	NE	0.14
Longevity	-0.21	-0.28	NE	-0.21
Calving interval	0.05	-0.17	NE	-0.04
Interval First-Last insemination	-0.11	-0.06	NE	0.00
Ketosis	0.37	-0.60	NE	-0.31
		Parity 1		
Sub Clinical Mastitis	0.30	-0.47	NE	-0.14
Clinical Mastitis	0.25	-0.31	NE	0.08
Longevity	-0.02	-0.46	NE	-0.63
Calving interval	0.16	-0.30	NE	0.14
Interval First-Last insemination	-0.02	-0.12	NE	0.22
Ketosis	0.45	-0.36	NE	-0.10

NE = not estimated