Breeding of Cows Suitable for an Automatic Milking System

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Abstract

Genetic parameters were estimated for traits based on data from automatic milking systems (AMS). Traits are AMS efficiency (EF) which is the produced amount of milk in kg per total box time in minutes, milking interval (MI) which is the time between 2 consecutive successful milkings in minutes and habituation of heifers (HH), reflecting the time period a heifer needs to get familiar with the AMS. The heritabilities are 0.23 for EF, 0.08 for MI, and 0.07 for HH. Genetic correlations between same traits measured in heifers and multiparous cows are moderate to high. Genetic correlations between second calf cows and higher parities are strong, indicating that these traits can be considered the same trait.

Key words: automatic milking system, heritabilities, genetic correlations, efficiency, milking interval, habituation heifers, cows

Introduction

About half of the new milking systems placed in the Netherlands and Flanders are currently automatic milking systems. The AMS measures and records a lot of data about the milking.

For farmers with an AMS it is important to use the milking system as efficient as possible. To increase the efficiency of an AMS, it is important to breed cows that are suitable for this system. Suitable cows should be active and visit the AMS frequently. A visit should result in a milking. A higher milking speed leads to a reduction of the total milking time per cow, followed by an increase in AMS capacity, and an increase of the AMS efficiency. But a too high milking speed can lead to a decrease in udder health and increase in somatic cell count (Gäde *et al*., 2007). Therefore, an optimal milking speed is preferable and attention should be paid to udder health when selecting sires.

In case of heifers it is important that they get used to the milking system within a short time period after calving. Fetching cows to the AMS is labour intensive. Breeding cows that are suitable for AMS milking and habituate fast to the automatic system requires breeding values of bulls based on AMS data. Characteristics as AMS efficiency, visiting interval and milking interval could be useful. And in case of heifers a breeding value for habituation could be useful. These traits are important with respect to AMS capacity and efficiency.

This report describes the results of the genetic analysis of the traits AMS efficiency, milking interval and habituation of heifers to the AMS.

Materials and Methods

Materials

To estimate genetic parameters a data set with the following restrictions was created. Observations ranged from January 1998 till February 2013. Only animals that are at least 75% Holstein Friesian were included. Sire, herd, birthdate and calving date had to be known and the animal had to be herdbook registered. Only records of sires with at least 25 first lactation daughters were included, except for habituation of heifers, where the minimum number of daughters per sire is 10.

Only records from cows between parity 1 and 10 were used. Minimum age at first calving was 640 days. Stage of lactation should be between day 5 and day 350, for habituation of heifers also observations before day 5 were included. Specific for AMS efficiency the starting and end time of the box visit has to be

known. Records with a total box time of more than 20 minutes are excluded. Milk yield has to be known and between 1.6 kg and 40 kg milk per milking.

In table 1 number of observations, number of animals with observations, number of sires and number herds per trait is shown.

Table 1. Number of observations, number of animals, number of sires and number of herds for AMS efficiency (EF), milking interval (MI), and habituation of heifers (HH).

Trait	Observations	Animals	Sires	Herds
EF	2,349,411	37,289	2,225	488
MI	3,206,231	55,652	2,919	693
HH		78,510	1,001	2,776

Definition of the traits

AMS efficiency (**EF**) per milking was defined as milk production in kg milk produced per total box time, expressed in kg milk per minute. Box time is milk time plus treatment time where treatment time consist of attachment time and time for cleaning, spraying, etc. Milk time is the major factor in box time. This trait indicates the time the system is occupied to produce 1 kg of milk. AMS efficiency outside the range of 0.5 kg/min to 5.0 kg/min are excluded.

Milking interval (**MI**) describes the time between two consecutive successful milkings. A milking is successful if the milk yield is between 1.6 kg and 40.0 kg per milking, and the interval is between 240 minutes and 1200 minutes. Dividing 24 hours by the MI gives the number of AMS milkings per day. Observations of the first 30 days after a herd started to milk with a AMS are excluded, to exclude the habituation period.

The purpose of the trait habituation of heifers (**HH**) is to compare sires for the time a heifer needs to get familiar with the AMS. Habituation of heifers is analyzed by the following formula:

$$HH = Average\ MI_{week\ 1-3} - Average\ MI_{week\ 10-12}$$

HH compares the average milking interval in the first three weeks after calving with a period when the heifer is habituated, in this report represented by week 10, 11 and 12 after calving.

Parameter estimation of AMS traits

For AMS traits genetic parameters were estimated with univariate and bivariate linear sire models. ASREML (Gilmour *et al*., 2006) was used to estimate variance components. Parameters were estimated according to the following sire-models:

$$Y1_{ijklmno} = HYS_i + PDIM_j + AGE_k + MC_l + Sire_m + PE_n + e_{ijklmno}$$

$$Y2_{ijklmn} = HYS_i + AGE_j + MC_l + Yield_n + Sire_m + e_{ijklmn}$$

where,

$Y1_{ijklmno}$ = AMS efficiency or milking interval observation.
$Y2_{ijklmn}$ = Observation on habituation of heifers.
HYS_i = Herd by year-month of milkdate i.
$PDIM_j$ = Days in milk by parity j
AGE_k = Age class of calving j
MC_l = Month of calving l
$Yield_n$ = Difference in average milk yield n between the two periods in classes
$Sire_m$ = Sire of cow or additive genetic effect m
PE_n = Permanent Environmental effect of cow n
$E_{ijklmno}$ = Error term of $Y1_{ijklmno}$ describing the unexplained variation by the model.
E_{ijklmn} = Error term of $Y2_{ijklmn}$ describing the unexplained variation by the model.

Sire, permanent environment and error are random effects, other effects are fixed. For the sire effect pedigree data (with sire-mgs structure) was included.

Genetic variances were calculated as 4 times sire variance. Phenotypic variances were calculated as the sum of the genetic variance, permanent environmental variance and the error variance.

Heritabilities and genetic correlations were derived from variance components.

Repeatabilites were calculated with the following formula:

$$W = \frac{(\sigma_S^2 + \sigma_{PE}^2)}{(\sigma_S^2 + \sigma_{PE}^2 + \sigma_e^2)}$$

Overall traits for EF and MI were computed form lactation 1, 2 and 3 as the average over all the observations.

Results and Discussion

Trait description

In Table 2 number of observations, phenotypic means for milk yield per milking, and means for each trait with standard deviations are shown.

Table 2. Number of observations (N), milk yield per milking, phenotypic means with standard deviations of all traits per lactation given in subscript.

AMS efficiency				
Lac	N	Milk yield (kg)	Box time (min)	EF (kg /min)
1	725,823	9.3	6.8	$1.45_{0.46}$
2	653,016	10.6	6.8	$1.66_{0.51}$
3+	970,572	11.4	7.1	$1.70_{0.53}$
All	2,349,411	10.5	6.9	$1.61_{0.52}$
Milking interval				
Lac	N	Milk yield (kg)		MI (min)
1	979,425	9.4		521_{149}
2	897,182	10.7		497_{149}
3+	1,329,624	11.5		504_{158}
All	3,206,231	10.6		507_{153}
Habituation of heifers				
Period	N	Milk yield (kg)		MI (min)
Wk 1 – 3	71,955	9.1		578_{113}
Wk 10 – 12	64,974	9.9		492_{104}
HH	55,373	-0.8		81_{108}

The AMS efficiency found is in range with literature. Castro *et al.* (2012) found an average of 1.44 kg milk per minute milking time, and Heringstad *et al.* (2014) found an average of 1.5 kg milk per minute. Other studies showed a milk flow rate which includes only the pure milking time (Carlström *et al*., 2009; Hogeveen *et al*., 2001, Gäde *et al*., 2007), as a trait comparable with AMS efficiency. A comparable trend that heifers show a lower value compared to multiparous cows is observed.

A milking interval of 507 minutes is equal to (24 h x 60 min / 507 min) 2.84 milkings / day, which is comparable to literature. Other studies showed a range from 2.47 to 2.96 milkings /day (Gygax *et al*., 2007; Castro *et al*., 2012; Madsen *et al*, 2010). The number of milkings is among others dependent on the amount of milk produced, parity and herd factors, which differs per study.

Heritabilities

Overall heritability are 0.23 for EF, 0.08 for MI, and 0.07 for HH. The traits EF and MI show slightly higher heritabilities for lactation 1 compared to lactation 2 and higher. For HH the heritability for milking interval in de first three weeks after calving is 0.12, for week 10 – 12 this is 0.17. Genetic variance, phenotypic variance and heritabilities for all traits per lactation are given in table 3.

Table 3. Genetic variance (σ_A^2), phenotypic variance σ_{PA}^2, heritability (h^2) and standard error (SE) of h^2 of all traits per lactation. SEs of h^2 are in subscript.

AMS efficiency				
Lac	σ_A^2	σ_P^2	h^2	
1	0.039	0.175	0.23	$_{0.027}$
2	0.044	0.227	0.20	$_{0.027}$
3+	0.051	0.250	0.20	$_{0.024}$
All	0.051	0.220	0.23	$_{0.018}$
Milking interval				
Lac	σ_A^2	σ_P^2	h^2	
1	1635	18607	0.088	$_{0.012}$
2	1326	17544	0.076	$_{0.012}$
3+	1195	20137	0.059	$_{0.008}$
All	1492	19109	0.078	$_{0.007}$
Habituation of heifers				
Period	σ_A^2	σ_P^2	h^2	
Wk 1 – 3	841	7012	0.12	$_{0.02}$
Wk 10 – 12	971	5556	0.17	$_{0.02}$
HH	413	5675	0.07	$_{0.01}$

The heritability of EF is in line with heritabilities found in literature on comparable traits. Literature shows heritabilities for milk speed in a range of 0.19 to 0.32 (Carlström *et al*., 2009, Gäde *et al*., 2007). For milking interval estimated heritabilities are between 0.09 and 0.26 (Carlström *et al*., 2013). The heritability found in this study is slightly lower. No previous genetic analyses are done for the trait habituation of heifers. Comparisons with other studies based on AMS data is complicated. Most studies are based on research farms with more standardized environmental conditions or they are based on a small number of farms (N < 50).

Genetic correlations

In table 4 genetic correlations between lactations are presented for EF and MI. For HH, the genetic correlation between milking interval in week 1 – 3 and week 10 – 12 is presented. For AMS efficiency the correlation between second lactation cows and cows of third lactation and higher is 1.00, indicating that these parities are genetically identical. Correlations between other lactations are very strong for AMS efficiency.

For milking interval lactation 1 shows moderate correlations with other lactations, the correlation between lactation 2 and 3+ is strong (0.96).

For habituation of heifers there is a moderate genetic correlation (0.83) between milking interval in week 1 – 3 and milking interval in week 10 – 12.

Table 4. Genetic correlation between lactations for AMS efficiency and Milking interval, and between week 1 – 3 and week 10 – 12 for habituation of heifers. SEs are in subscript.

AMS efficiency		
Parity	2	3+
1	0.98 $_{0.02}$	0.94 $_{0.03}$
2		1.00 $_{0.01}$
Milking interval		
Parity	2	3+
1	0.85 $_{0.05}$	0.75 $_{0.08}$
2		0.96 $_{0.03}$
Habituation of heifers		
Week	10 – 12	
1 – 3	0.83 $_{0.04}$	

Conclusions

The number of cows milked by an automatic milking system is increasing. Average AMS efficiency defined as the milk yield per minute box time is 1.61 kg/min. The average milking interval is 507 minutes. Heritabilities are 0.23 for AMS efficiency and 0.08 for milking interval. Correlations between lactations are high, especially between lactation 2 and 3+. Traits on second and higher lactating cows can be considered the same trait.

The new trait ‘habituation of heifers’, reflects the time period a heifer needs to become familiar with the AMS. Heritability for this trait is 0.07. These results show that EF, MI and HH show enough genetic variation to be used as traits to make genetic improvement for AMS suitability.

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