Genetic Parameters and Accuracy of recording Dry Matter Intake in first parity Holstein-Friesian cows

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ABSTRACT: A total of 30,483 records for dry matter intake (DMI) recorded between 1990 and 2011 were available from 1,273 Dutch Holstein-Friesian first-parity cows. Genetic parameters were estimated for the first 324 days in milk (DIM) using random regression models. Estimated heritabilities for DMI ranged from 0.21 to 0.40 across lactation, being highest between 80 and 205 DIM. Entire lactation heritability was 0.46. Genetic correlations between DMI in early lactation and during the rest of the lactation were negative (-0.5), and were most positive between DMI in mid lactation and during the rest of the lactation (0.80). Dry matter intake was genetically different across lactation, especially in early and mid lactation. Accuracies of selection for the entire lactation for DMI were 0.58, 0.47 and 0.33, when it was measured for 15, 10 or 5 weeks, respectively and best recording periods were during mid and late lactation.
Keywords: Dairy cattle; Feed-intake; Heritability; Genetic-correlation

Introduction

There is no doubt that breeding goals should be expanded to include feed intake or feed efficiency (de Haas et al. (2012); Veerkamp et al. (2012); Berry and Crowley (2013); Tetens et al. (2014)). However, which trait specifically should be included is still under discussion. Some authors have proposed residual feed intake, feed conversion ratio or even residual intake and gain. All these traits need information on DMI. Including dry matter intake directly in the breeding goal may be an easier concept to understand (Berry and Crowley (2013)) and to include in a national selection index. However, lactation stage-specific selection might optimize the trajectory of DMI across DIM but that would require information within lactation stages (Tetens et al. (2014)). Therefore, an important question is whether DMI is the same trait across lactation and what the optimal recording period is. Hence, the first objective of this paper was to determine if DMI can be regarded as the same trait across lactation based on the estimation of the genetic parameters. The second objective was to determine the best period of time to measure DMI, and the best frequency of measuring.

Materials and Methods

Data. Initially, a total of 163,126 daily feed intake records from 2,977 Holstein-Friesian cows that calved between 1990 and 2011 were available. These cows participated in nutritional experiments conducted on several farms in Netherlands. Description of the methodology of most of the experiments is summarized in previous studies (Veerkamp et al. (2000); Beerda et al. (2007); Zom et al. (2012)). All records from animals without information on pedigree, parity number, calving date or date of measurement were removed, and only DMI measured in the first 324 DIM (46 weeks) were retained. Daily DMI records were converted to the average weekly DMI in order to homogenize the data. Only first parity records and cows with at least 75% of Holstein Friesian genes were kept. This resulted in a final dataset of 30,483 weekly records from 1,273 animals.

Model. A random regression test-day model was performed to estimate the variance and covariance components for each day of lactation using ASReml (Gilmour et al. (2009)). The model included random effects for experiment, year-month of measurement, and the additive genetic, permanent environmental, and residual term. The fixed effects in the model were year by season of calving (four classes: Jan-Mar, Apr-Jun, Jul-Sep, Oct-Dec), age of cow at calving and days in milk (DIM), modeled with a third and fourth order Legendre orthogonal polynomial, respectively. Additive genetic and permanent environmental covariance functions were modeled using Legendre orthogonal polynomials of third order. Residual errors were assumed to have heterogeneous variances and were divided into 4 classes according to DIM (1= 1 to 48 d, 2= 49 to 97 d, 3= 98 to 160 d and 4= 161 to 324 DIM). Estimates of the (co)variance components of the random regression were used, together with the Legendre polynomials coefficients to calculate heritabilities, genetic and permanent environmental covariances, and genetic correlations for each DIM using the methodology proposed by Fischer et al. (2004). Additionally, heritabilities, genetic variances and genetic correlations for the entire lactation were calculated by summing the Legendre polynomials coefficients through 324 days, and multiplying this with estimates of the (co)variance components of the random regression (Liu et al., 2000). Selection index theory was used to calculate accuracy of predicting breeding values for the entire lactation, using different recording schemes.

Results and Discussion

The average DMI was 19.2 kg with a phenotypic standard deviation of 3.3 kg. The estimated heritability for entire lactation DMI was 0.46, which was higher than daily heritability estimates (0.21 to 0.40). Estimated daily heritabilities were highest between 80 and 205 DIM (Figure 1), and lowest in early lactation (~40 DIM). The results estimated in this study were within the range (0.12 to 0.54) published in previous studies (Veerkamp and Brotherstone (1997); Koenen and Veerkamp (1998); Veerkamp and Thompson (1999); Karacaoren et al. (2006); Berry et al. (2007); Vallimont et al. (2010); Spurlock et al. (2012); Tetens et al. (2014)). Although the estimated heritabilities were within the range of previous studies, the trajectory of the heritability during lactation in our study was different compared to several other studies (Karacaoren et al., (2006; Berry et al., (2007; Spurlock et al., (2012; Tetens et al.)). However, all studies agree that the heritability of DMI varies across lactation. In the current study, the main differences in heritability estimates for DMI were between 50 and 150 DIM, showing that the genetic contribution to differences in DMI is different during early and mid lactation. The genetic standard deviation was between 1.18 and 1.92 kg per day during early and mid lactation until 250 DIM, and it increased after that unit.
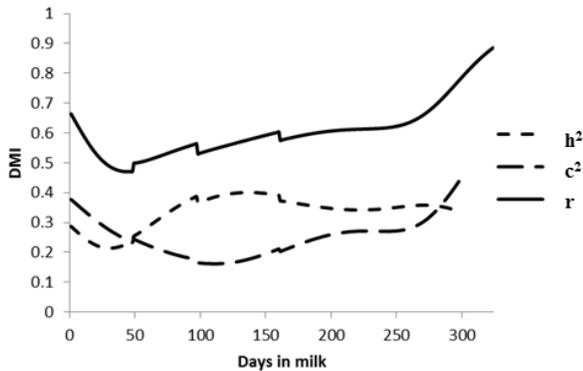
Figure 1. Estimated heritability (h^2), permanent environmental ratio (c^2) and repeatability (r) for dry matter intake (DMI), from 1 to 324 days in milk.
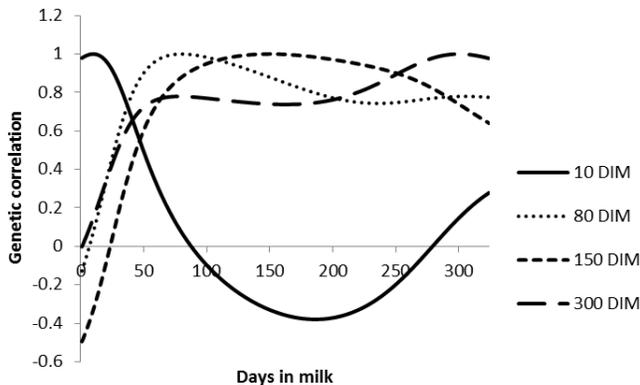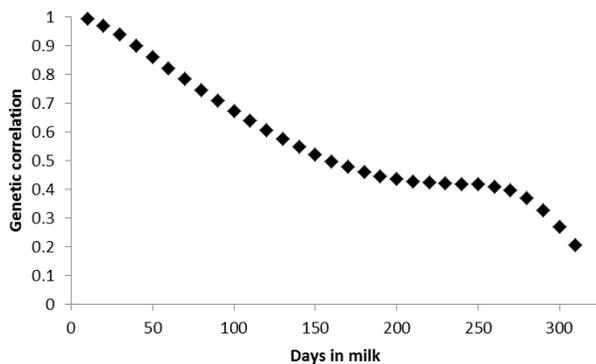

Figure 2. Genetic correlation between DMI recorded on a certain day (10, 80, 150 and 300 DIM) with DMI recorded on all other days in milk.

Genetic correlations between a certain day (10, 80, 150 and 300 DIM) with all other DIM are presented in Figure 2. The genetic correlations of DMI at all DIM with DMI recorded on 10 DIM declined rapidly from 0.97 at day 1 to -0.38 at day 190, followed by an increase at the end of the lactation finally reaching 0.28. The shape is a concave curve. The genetic correlations of DMI at all DIM with DMI recorded at 80 DIM increased from -0.13 at day 1 to 1 at day 80, and decreased after that until 0.74 at day 230. It is important to mention that the highest consumption of feed during lactation was at 83 DIM. The genetic correlations of DMI at all DIM with DMI recorded on 150 DIM had a convex shape being higher than 0.80 between day 67 and day 285. The genetic correlations of DMI with DMI recorded on day 300 were above 0.70 after day 47. Thereafter, we conclude that DMI differs in early and mid lactation. Similar results were reported by Koenen and Veerkamp, (1998) who estimated a negative genetic correlation (-0.14) between DMI recorded in week 3 (20 DIM) and in week 25 (175 DIM), and a high positive genetic correlation (0.98) between DMI recorded in week 15 (100 DIM) and in week 20 (135 DIM). Likewise, Buttchereit et al. (2011) presented a negative correlation (-0.55) between 15 and 180 DIM, and positive genetic correlations for DMI between shorter intervals; 0.54 between 15 and 60 DIM, and 0.83 between 120 and 180 DIM. Both studies, however, analyzed data up to 180 DIM, whereas in the current study the genetic parameters were estimated until 324 DIM. The results in this study were different from those reported by Karacaoren et al. (2006) with a slightly negative genetic correlation for DMI of -0.07 for adjacent days after 120 DIM until end of lactation (305 DIM). Finally, Huttmann et al. (2009) reported the lowest genetic correlation of 0.29 between DMI in early and mid lactation (11-30 DIM with 121-150 DIM) and highest genetic correlation of 0.97 between DMI in mid lactation periods (91-120 DIM with 121-150 DIM).
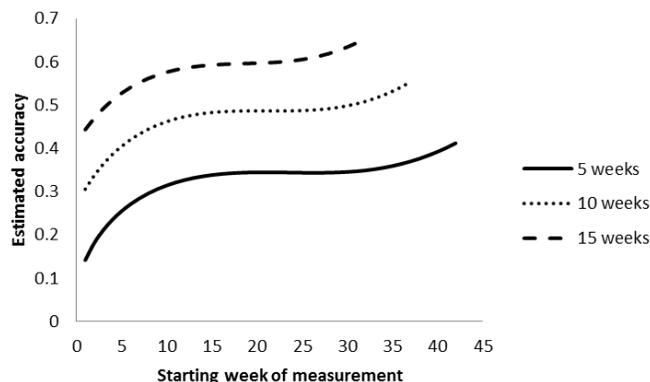
Estimated heritabilities, genetic variances and genetic correlations of DMI suggest that genetics of DMI is different across lactation, mainly during early and late lactation compared with mid lactation, and this information will be useful when measuring during DMI in a breeding program.

Genetic correlations within lactation were, as expected, highest between days close to each other, and decreased as time between measurements increased. Figure 3 shows the average of number of genetic correlations within DMI when the difference between two DMI-recordings is 10, 20, ..., 300, 310 DIM. The genetic correlations decreased gradually from 0.99 at 10 DIM of difference to 0.5 at 150 DIM of difference, and further down to 0.20 at 310 DIM of difference.

Figure 3. Average of genetic correlations within dry matter intake (DMI) when the difference between two DMI-recordings is 10, 20, ..., 310 DIM.

Accuracies were calculated for a breeding goal that consisted of DMI in the entire lactation, and a selection index that included DMI recorded for 5, 10 or 15 weeks. Figure 4 shows these accuracies when the recording period started in different weeks. It is obvious that the accuracy is highest when the length of the recording period is largest. Recording DMI for 15 weeks gave accuracy of 0.58, which was on average 0.25 more accurate than recording DMI for 5 weeks, and 0.11 more accurate than recording DMI for 10 weeks. Furthermore, starting to record DMI in mid or late lactation gave more accurate estimates than starting recording in early lactation. When the period of DMI recording (10 weeks) is split into two periods of 5 weeks (each one measured in a different stage of lactation: early, mid, and late) the accuracy varied between 0.43 and 0.50. However, when the period of DMI recording of 15 weeks was split in two periods of 7 and 8 weeks, the accuracy varied between 0.53 and 0.62 on average.

Figure 4. Calculated accuracies for DMI in the entire lactation when DMI is recorded for 5, 10 or 15 weeks starting at different weeks in lactation.

Conclusions

Estimated heritabilities, genetic variances and genetic correlations for DMI across DIM have demonstrated that DMI is genetically different across lactation, with the main differences being between early and late lactation. If recording of DMI is reduced from 15 to 10 and 5 weeks, the accuracy of selection for DMI in the entire lactation is reduced from 0.58 to 0.47 and 0.33, respectively. Therefore, the best recording scheme was with continuous recording for 15 weeks during mid and late lactation. However, when the 15 week recording period was split in two periods (7 and 8 weeks; during mid and late lactation, respectively), an average accuracy of 0.62 was observed.

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