Short communication: Feed utilization and its associations with fertility and productive life in 11 commercial Pennsylvania tie-stall herds

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ABSTRACT

The objectives of this study were to quantify the relationships of various definitions of feed utilization with both fertility and productive life. Intake and body measurement data were collected monthly on 970 cows in 11 tie-stall herds for 6 consecutive months. Measures of feed utilization for this study were dry matter intake (DMI), dry matter intake efficiency (DME, defined as 305-d fat-corrected milk/305-d DMI), DME with intake adjusted for maintenance requirements (DMEM), crude protein efficiency (defined as 305-d protein yield/305-d crude protein intake), and 2 definitions of residual feed intake (RFI). The first, RFI_{reg} , was calculated by regressing daily DMI on daily milk, fat, and protein yields, body weight (BW), daily body condition score (BCS) gain or loss, the interaction between BW and BCS gain or loss, and days in milk. The second, RFI_{NRC} , was estimated by subtracting 305-d DMI predicted according to their fat-corrected milk and BW from actual 305-d DMI. Data were analyzed with 8-trait animal models and included one measure of feed utilization and milk, fat, and protein yields, BW, BCS, days open (DO), and productive life (PL). The genetic correlation between DME and DO was 0.53 (± 0.19) and that between DME and PL was 0.66 (± 0.10). These results show that cows who had higher feed efficiency had greater DO (undesirable) and greater PL (desirable). Results were similar for the genetic correlation between DO and crude protein efficiency (0.42). Productive life had genetic correlations of -0.22 with BW and -0.48 with BCS, suggesting that larger, fatter cows in this study had shorter PL. Correlations between estimated breeding values for feed utilization and official sire genetic evaluations for fertility were in agreement with the results from the multiple-trait models. Selection programs intended to enhance feed efficiency should

factor relationships with functional traits to avoid unfavorable effects on cow fertility.

Key words: feed efficiency, productive life, fertility

Short Communication

The impact of nutrition on fertility has been established and it is known that poor nutrition during the dry period and early lactation will affect fertility (Roche, 2006). Data also support the unfavorable relationship between negative energy balance and fertility (Walsh et al., 2011); however, data describing the relationship between feed efficiency and fertility are limited. Energy efficiency at wk 15 of lactation was not a significant predictor of pregnancy status at d 150 in a study of first-lactation animals by Olson et al. (2011). Coleman et al. (2010) found no association between residual feed intake and fertility, regardless of whether residual feed intake was considered in early lactation or over the entire lactation. The objectives of this research were to quantify the relationships of various definitions for feed utilization with fertility and productive life (PL).

Intake and body measurement data were collected monthly on 970 Holstein cows in 11 tie-stall herds in Pennsylvania for 6 consecutive months. Details of the data collection can be found in Vallimont et al. (2010). Final data for this study included updated test-day records through August 2011 for those cows in the herd during the time of on-farm data collection. In total, 47,223 test-day records from 1,777 cows through their seventh lactation and through 500 DIM were included. Test-day records were analyzed and used to generate 305-d records as in Vallimont et al. (2010). These 305-d averages were used for the genetic analyses.

Six measures of feed utilization were studied: DMI, DMI efficiency (DME), DME adjusted for maintenance needs (DMEM), CP efficiency (CPE), and 2 estimates of residual feed intake. Dry matter intake efficiency was defined as 305-d FCM/305-d DMI. Dry matter intake was adjusted for maintenance needs using the BW function of the DMI equation from NRC (2001) and the final equation was: 305-d FCM/[305-d

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DMI $-(BW^{0.75} \times 0.0968)$. Crude protein efficiency was defined as 305-d protein yield/305-d CP intake. The first measure of residual feed intake, $\mathbf{RFI}_{\text{reg}}$, was calculated in a fashion identical to that in Vallimont et al. (2011). Briefly, $\mathbf{RFI}_{\text{reg}}$ was estimated by regressing daily DMI on daily milk, fat, and protein yields, BW, daily BCS gain or loss, interaction between BW and BCS gain or loss, and DIM. The second measure of residual feed intake, $\mathbf{RFI}_{\text{NRC}}$, was estimated by subtracting 305-d DMI that was predicted from daily FCM and BW records according to NRC equations (NRC, 2001) from actual 305-d DMI.

Productive life was the sum of the total DIM from each lactation of a cow's productive career. Days in milk was capped at 365 d per lactation for the PL calculation. In total, 227 cows were alive at the last test-day included in this study. Average PL was 25.6 mo (range 0.2 to 80.2 mo, SD = 14.5 mo) for the 1,755 cows included in the PL analysis, and average days open (DO) was 158.6 d (range 26 to 726 d, SD = 94.2 d) for the 3,159 cow-lactation records with DO.

Data were analyzed with 8-trait animal models in ASReml (Gilmour et al., 2006). Traits in the model included milk, fat, and protein yields, BW, BCS, DO, PL, and each of the feed utilization traits separately. Traits were analyzed with the following model:

$$y_{ijkl} = L_{ij} + HCC_{ik} + A_{il} + P_{il} + \varepsilon_{ijkl},$$

where y is the lactation record for trait i ; L is the fixed effect of lactation j for trait i ; HCC is the random effect of herd-calving-cluster k (Vallimont et al., 2010) for

trait i ; A is the random additive genetic effect of animal l for trait i ; P is the random permanent environmental effect of cow l for trait i (not included for PL); and ε is random error.

Output from ASReml provided EBV and reliabilities for all traits. Correlations between sire EBV for feed utilization, production, DO, and PL with PTA for daughter pregnancy rate (DPR), cow conception rate (CCR), heifer conception rate (HCR), and productive life (PTA_{PL}) were estimated for 301 sires that had daughters with DMI and an official sire evaluation. The average number of daughters per sire ranged from 1 to 22. These correlations were adjusted by dividing the product-moment correlation for the 2 traits by the square root of the product of the 2 reliabilities for the 2 traits, as in Rogers et al. (1999).

Results from the 8-trait animal models are presented in Table 1. The genetic correlation between DME and DO was 0.53, which was stronger than that between DO and the production traits (range: 0.32 to 0.42). The phenotypic correlation for DME and DO was 0.13. The top quartile of cows for DME EBV had an average DO of 212.3 d versus 145.5 d for the bottom quartile of DME EBV. Crude protein efficiency had a genetic correlation of 0.42 and a phenotypic correlation of 0.09 with DO. These results show that the more efficient cows, those with higher DME or CPE, also have higher DO or reduced fertility.

The genetic correlations of DMEM with BW (0.09 $\pm$ 0.14) and BCS (−0.08 $\pm$ 0.21) were essentially neutral, which is in contrast to the unfavorable genetic correlations of DME with BW (−0.37 $\pm$ 0.11) and BCS

Table 1. Genetic (r_g) and phenotypic (r_p) correlations for days open (DO) and productive life (PL) with feed utilization and production traits, BW, and BCS¹

Trait ²	r_g		r_p	
	DO	PL	DO	PL
DMI	−0.14 $\pm$ 0.29	0.49 $\pm$ 0.18*	0.09 $\pm$ 0.03*	0.03 $\pm$ 0.06
DME	0.53 $\pm$ 0.19*	0.66 $\pm$ 0.10*	0.13 $\pm$ 0.03*	0.19 $\pm$ 0.04*
DMEM	0.39 $\pm$ 0.25	0.62 $\pm$ 0.13*	0.07 $\pm$ 0.03*	0.17 $\pm$ 0.06*
CPE	0.42 $\pm$ 0.18*	0.63 $\pm$ 0.09*	0.09 $\pm$ 0.03*	0.17 $\pm$ 0.04*
$\mathbf{RFI}_{\text{reg}}$	−0.50 $\pm$ 0.40	−0.23 $\pm$ 0.29	0.01 $\pm$ 0.03	−0.01 $\pm$ 0.04
$\mathbf{RFI}_{\text{NRC}}$	−0.51 $\pm$ 0.76	0.22 $\pm$ 0.45	−0.02 $\pm$ 0.04	−0.06 $\pm$ 0.06
Milk	0.42 $\pm$ 0.15*	0.64 $\pm$ 0.08*	0.17 $\pm$ 0.02*	0.15 $\pm$ 0.03*
Fat	0.32 $\pm$ 0.16	0.54 $\pm$ 0.08*	0.14 $\pm$ 0.02*	0.11 $\pm$ 0.03*
Protein	0.35 $\pm$ 0.15*	0.63 $\pm$ 0.08*	0.13 $\pm$ 0.02*	0.15 $\pm$ 0.03*
BW	−0.23 $\pm$ 0.18	−0.22 $\pm$ 0.10*	−0.07 $\pm$ 0.03*	−0.02 $\pm$ 0.05*
BCS	−0.23 $\pm$ 0.24	−0.48 $\pm$ 0.15*	−0.17 $\pm$ 0.03*	0.00 $\pm$ 0.05
Days open		−0.04 $\pm$ 0.19		−0.10 $\pm$ 0.03*

¹Correlations for yield, BW, and BCS are averages of results from each individual 8-trait analysis.

²DME = dry matter efficiency; DMEM = DME adjusted for maintenance needs; CPE = CP efficiency; $\mathbf{RFI}_{\text{reg}}$ = residual feed intake estimated by regressing daily DMI on daily milk, fat, and protein yields, BW, daily BCS gain or loss, interaction between BW and BCS gain or loss, and DIM; $\mathbf{RFI}_{\text{NRC}}$ = residual feed intake estimated by subtracting 305-d DMI that was predicted from daily FCM and BW records according to NRC (2001) equations.

* $P < 0.05$.

(-0.39 ± 0.15). This suggests potential for measures of efficiency that are adjusted for body maintenance such as DMEM. The genetic correlation between DMEM and DO was $0.39 (\pm 0.25)$, which was not as strong as that between DME and DO (0.53 ± 0.19). Standard errors were moderately high for these correlations, so caution must be taken when comparing correlations of DO with DME or DMEM.

It was previously reported that higher gross efficiency was associated with lower BCS in these herds (Vallimont et al., 2011), and lower BCS is associated with poorer reproductive performance (Dechow et al., 2004) and a longer interval to commencement of luteal activity (Royal et al., 2002). The genetic correlations between DO and both BW and BCS were negative but not significant. Coleman et al. (2010) found no relationship between fertility and feed conversion efficiency or residual feed intake in a grazing study. Olson et al. (2011) found no relationship between pregnancy status and feed efficiency at wk 15 of lactation; however, cow numbers were low in that study.

The relatively neutral relationship between DMI and DO (-0.14 ± 0.29) may reflect the multifaceted relationships among DMI, yield, and DO. Higher yield was associated with higher DMI in these herds (genetic correlation between DMI and FCM yield of 0.55; Vallimont et al., 2010) and unfavorably associated with reproductive performance.

Dry matter intake efficiency and DMEM had high positive genetic correlations with PL, 0.66 and 0.62, respectively. Phenotypic correlations were 0.19 and 0.17 for DME and DMEM, respectively. The genetic correlation between DMI and PL was high, 0.49, and

the phenotypic correlation for those traits was 0.03. In these herds, higher DMI was associated with a longer PL. These herds appear to have a strong emphasis on production with regard to culling decisions, and the cows that ate the most and were more efficient were likely to be those in a higher production group. In addition, BCS and PL had a high, negative genetic correlation of -0.48 , and the yield traits had high positive genetic correlations with PL (range from 0.54 to 0.64), supporting the observation that these herds culled fatter cows with lower milk yield. A genetic correlation of zero between DO and PL was found in the herds of this study, suggesting that fertility may be less of a focus in their culling decisions compared with most commercial US herds. This value has been reported to be -0.59 in national data (VanRaden et al., 2004). Dechow et al. (2011) reported lower mortality rates and lower early lactation culling rates due to poor cow health for tie-stall facilities compared with freestall housing facilities. This would allow for more voluntary or low production culling for the herds in this study because all were tie-stall herds.

Results for analyses of residual feed intake were similar to those for gross feed efficiency, but were associated with very large standard errors due to the low heritability of residual feed intake. The genetic correlations between DO and RFI_{NRC} and between DO and RFI_{reg} were not significant (-0.50 ± 0.40 and -0.51 ± 0.76 , respectively). These results may indicate that cows whose nutrient intake exceeds what is needed for maintenance and production have improved fertility; however, additional research is needed with larger data sets to refine the genetic correlation estimates.

Table 2. Reliability-adjusted correlations of EBV from 8-trait animal models with official genetic evaluations for daughter pregnancy rate (DPR), cow conception rate (CCR), heifer conception rate (HCR), and productive life

Trait ¹	DPR	CCR	HCR	Productive life
DMI	-0.05	-0.03	0.23*	-0.12
DME	-0.22*	-0.12	-0.09	0.02
DMEM	-0.20*	-0.15	-0.09	-0.08
CPE	-0.21	-0.11	-0.08	0.02
RFI_{reg}	0.22*	0.11	0.14	-0.10
RFI_{NRC}	0.24*	0.22*	0.44*	0.00
Days open	-0.73*	-0.63*	-0.55*	-0.34*
Productive life	0.10	0.13	0.12	0.15
Milk	-0.27*	-0.24*	-0.13	-0.17
Fat	-0.14	-0.01	0.08	0.08
Protein	-0.16	-0.15	-0.10	-0.08
BW	0.03	-0.06	0.08	-0.21*
BCS	0.25*	0.19	0.19	0.06

¹DME = dry matter efficiency; DMEM = DME adjusted for maintenance needs; CPE = CP efficiency; RFI_{reg} = residual feed intake estimated by regressing daily DMI on daily milk, fat, and protein yields, BW, daily BCS gain or loss, interaction between BW and BCS gain or loss, and DIM; RFI_{NRC} = residual feed intake estimated by subtracting 305-d DMI that was predicted from daily FCM and BW records according to NRC (2001) equations.

* $P < 0.05$.

Table 3. Standard deviation of transmitting abilities (SD_{TA}) and minimum and maximum sire PTA for feed utilization, fertility, and productive life traits

Trait ¹	SD_{TA}	PTA_{min}	PTA_{max}
DMI (kg)	92.597	-177.359	170.213
DME	0.063	-0.090	0.111
CPE	0.015	-0.029	0.031
RFI_{reg} (kg)	46.878	-63.339	45.417
RFI_{NRC} (kg)	44.916	-59.846	84.505
Days open	11.395	-17.055	16.830
Productive life	3.022	-4.035	4.751

¹DME = dry matter efficiency; CPE = CP efficiency; RFI_{reg} = residual feed intake estimated by regressing daily DMI on daily milk, fat, and protein yields, BW, daily BCS gain or loss, interaction between BW and BCS gain or loss, and DIM; RFI_{NRC} = residual feed intake estimated by subtracting 305-d DMI that was predicted from daily FCM and BW records according to NRC (2001) equations.

Reliability-adjusted correlations with official PTA for DPR, CCR, HCR, and PTA_{PL} are presented in Table 2. The adjusted correlation between DO and DPR was -0.73. This supports the accuracy of the data in the current study because DPR is derived from DO. Genetic correlations between CCR and HCR were also high, -0.63 and -0.55, respectively. The adjusted correlation between PL in these herds and PTA_{PL} was not different from zero, which supports the previous observation that culling occurs for different reasons in tiestall herds than in herds using other housing systems.

Greater feed efficiency was also correlated unfavorably with fertility and health trait PTA from national genetic evaluations. Higher DME, DMEM, RFI_{reg} , and RFI_{NRC} were significantly, and unfavorably, associated with PTA DPR, and RFI_{NRC} was unfavorably correlated with PTA CCR and HCR. The inclusion of BCS when generating RFI_{reg} but not RFI_{NRC} may partly explain the more unfavorable associations for RFI_{NRC} and highlights the need to include BCS when estimating residual feed measures. All 6 measures of feed utilization had adjusted correlations with PTA_{PL} that were not different from zero.

Table 3 shows results for PTA and standard deviation of the transmitting abilities (SD_{TA}) for feed utilization traits, DO, and PL. The range for DME among sires (PTA_{min} to PTA_{max} : -0.090 to 0.111) suggests that substantial change in DME is possible, but could be biased upward because milk yield observations are likely more accurate than feed intake observations (Vallimont et al., 2010). The PTA range and SD_{TA} for the 2 measures of residual feed intake was approximately half of that observed for DMI.

Although genetic variation exists in feed utilization, the genetic correlations presented here suggest that selection programs intending to enhance feed efficiency

should factor associations with functional traits to avoid unfavorable correlated responses.

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