Models originally compiled to predict nutrient absorption from the digestive tract and metabolized in various tissues could be adapted for CH₄ predictions. Numerous empirical equations and mechanistic models to predict CH₄ emission are available. The Molly cow model is a mechanistic, dynamic model describing digestion and metabolism of dairy cattle with the ability to predict the animal-related factors that affect the environment, including CH₄ emission (Hanigan et al., 2013). The Nordic cow model Karoline is a dynamic, mechanistic model describing digestion and metabolism in dairy cows (Danfær et al., 2006), and it was confirmed by Ramin and Huhtanen (2015) to be a useful tool in predicting CH₄ emissions in cattle. The aim was to evaluate these models for predicting CH₄ emissions in cattle using a data set consisting of 267 treatment means from 55 respiration chambers studies. The data set contained DMI (14.2 ± 5.82 kg/d); ingredient proportions; dietary contents of CP (156 ± 30.8 g/kg) and NDF (356 ± 105.9 g/kg); BW (531 ± 131.1 kg); and CH₄ (303 ± 118.7 g/d) which covers the range of typical cattle diets. The simulations were conducted using observed DMI, BW and dietary nutrient concentrations and digestion rates. Each treatment mean was simulated and predictions of nutrient digestibility and CH₄ output were collected in a database. The relationships between observed and predicted CH₂(pCH₂) were assessed by regression analysis. Root mean square error (RMSEpE) was calculated as: RMSEpE = \sqrt{\sum (Obs - Pred)^2/n}]. Molly predictions were: CH₂ (g/d) = 0.81 ± 0.018 x pCH₂ (g/d) + 38 ± 6.4 (RMSpE = 54.9 (18.1% of observed mean) CCC = 0.910). The corresponding equation for Karoline was: CH₂ (g/d) = 1.00 ± 0.019 x pCH₂ (g/d) + 5 ± 6.0 (RMSpE = 34.6 (11.4%) CCC = 0.955). Both mean (−27 g/d) and linear bias (−0.19) were significant (P < 0.001) with Molly, but only mean bias (4 g/d) was significant (P = 0.04) with Karoline. Proportions of MSE attributable to mean and linear bias and random error were 23, 24 and 53% for Molly, and 2, 0 and 98% for Karoline, respectively. Based on predictions it can be concluded that both models predicted CH₂ emissions reasonably well in terms of high CCC, but Karoline was more accurate based on smaller RMSE, mean and slope bias.

Key Words: dynamic model, methane emission, prediction equation


Our objective was to predict dry matter intake (DMI) by lactating cows using factors related to the filling effect of rations. A database of 156 treatment means from 44 experiments reported in the literature was developed. The database included data for cows ranging from 60 to 309 d postpartum and included diet forage NDF (FNDF) content (23.6 ± 5.8, mean ± SD), diet ADF/NDF (0.61 ± 0.08, mean ± SD), and a laboratory measure (in vitro or in situ) of NDF digestibility (LNDFD) of the sole forage or major forage (51.2 ± 12.1, mean ± SD). Models included the random effect of study as well as its interaction with LNDFD to account for differences in methods used to determine LNDFD. The full model also included linear and quadratic effects of FNDF, ADF/NDF, and LNDFD, as well as their linear and quadratic interactions, mean milk yield (MY) for each study and its interaction with the diet factors. Equations were developed with stepwise regression with backward elimination and treatment means were weighted by the inverse of their variance. The prediction equation for DMI (r² = 0.80, RMSE = 2.76 kg/d) is: DMI (kg/d) = 13.4 - 0.078 x FNDF + 8.264 x ADF/NDF + 0.0126 x LNDFD + 8.453 x (ADF/NDF-0.602)² + 0.178 x MY – 0.172 x (ADF/NDF-0.602) x (MY-33.1) + 0.0060 x (LNDFD-48.2) x (MY-33.1) + 8.183 x (ADF/NDF-0.602)² x (MY-33.1). DMI was positively related to MY and ADF/NDF and negatively related to FNDF, while LNDFD was negatively related to DMI for cows with low MY but positively for cows with high MY. Response to higher ADF/NDF was greater as MY increased. ADF/NDF was included to represent differences in forage fragility between grasses and legumes but it is also affected by the fraction of cereal grain in the diet. The following equation was developed for when LNDFD data is not available (r² = 0.77, RMSE = 3.01 kg/d) using the same database: DMI = 11.6 – 0.097 x FNDF + 8.31 x ADF/NDF + 0.268 x MY. DMI was related positively to MY and ADF/NDF and negatively to FNDF with no interactions detected with MY. These
equations might be useful to evaluate DMI response to factors related to the filling effects of rations.

**Key Words:** rumen fill, diet formulation, forage


There are limited published studies evaluating the concentration of starch in a dry starter diet on growth and digestibility in Holstein dairy calves through 16 wk of age. Our objectives were to improve this understanding using a database developed from published studies in our lab that included 4 trials from 0 to 8 wk of age (10–43% starch), 8 trials from 8 to 16 wk of age (19–50% starch), and 3 digestibility trials from 6 to 16 wk of age (13–50% starch). A meta-analysis was conducted to examine potential relationships between starch concentration in the starter (% dry matter, DM; STA) and ADG (kg/d), hip width change (cm/d; HWC), or DM digestibility (%; DMD). Factors such as ME intake (Mcal/d), CP intake (g/d), DM intake (% of body weight), and ambient temperature, which might have influences on the responses to STA, were also evaluated using mixed-effects models. Milk replacers (4.7–4.8 Mcal ME/kg) were fed at an equal rate among starter treatments within a trial. Chopped grass hay (5%) was blended with the starter from 8 to 16 wk. Starters were 18–20% CP and 2.8–3.0 Mcal ME/kg. Within a trial, starters were equal in CP with a high starch (>38%) control. Depending upon the trial, one or more low starch ingredients (cottonseed hulls, soybean hulls, wheat middlings, distillers dried grains with solubles) replaced corn to reduce the starch and ME concentrations of the feed. Linear relationships were: 0–8 wk HWC = 0.000262 × STA + 0.0562 (P = 0.01; R² = 0.75); 0–8 wk ADG = 0.001345 × STA + 0.4817 (P = 0.13; R² = 0.42); 8–16 wk HWC = 0.000724 × STA + 0.7432 (P < 0.0001; R² = 0.76); 8–16 wk ADG = 0.00575 × STA + 0.8608 (P = 0.003; R² = 0.61); 6–16 wk DMD = 0.2777 × STA + 69.988 (P = 0.02; R² = 0.89). Increasing intake of ME (P < 0.001) improved ADG from 8 to 16 wk along with STA. Intake of CP and DM and ambient temperature did not impact growth or digestibility. From this, changing a feed from 20 to 38% starch (within a typical range in the US industry) was predicted to increase DMD from 6 to 16 wk by 6%, HWC from 0 to 8 wk of age by 7%, and HWC from 8 to 16 wk of age by 14%. Increasing starch concentration of feeds increased digestibility and calf growth through 16 wk of age.

**Key Words:** calf, formulation, starch

### 332  Repeatability of residual feed intake across diets with two levels of dietary protein content. E. Liu* and M. J. VandeHaar, Michigan State University, East Lansing, MI.

Our objective was to examine the repeatability of residual feed intake (RFI) across diets with different levels of dietary protein. Mid lactation Holstein cows with initial MY 42 ± 10 kg/d (n = 88, in 3 blocks) were fed either a high protein diet (18% CP; 18P) or a low protein diet (14% CP; 14P) in a crossover design with 2 28-d treatment periods. Diets were similar and both contained at least 10% RDP (DM basis). The 18P diet contained expeller soybean meal, which was replaced by soybean hulls and ground corn in the 14P diet; 18P diet provided 4 percentage units more CP, 2 units less starch and 2 units less NDF than 14P. Cows were milked 2×/d; DMI and MY were recorded daily. Milk composition was measured during 4 consecutive milkings each week and BW was measured 3× weekly. Fixed effects of experiment, parity, diet and period nested within experiment and random effect of cow were included in the model to compare intake and production performance of treatments. RFI value was calculated for each cow on each treatment based on her actual intake, milk energy output, metabolic BW, and body energy change. Cows were ranked as high (>0.5 SD), medium (±0.5 SD) or low (<-0.5 SD) RFI. Compared with the 14P diet, the 18P diet increased DMI by 1.3 kg/d (27.1 vs. 25.8 kg/d; P < 0.01), milk yield by 5.1 kg/d (43.8 vs. 38.7 kg/d; P < 0.01), and BW gain by 0.22 kg/d (0.49 vs. 0.27 kg/d; P < 0.01). Ranking of cows for RFI was relatively repeatable (r = 0.64; P < 0.01). Of all cows, 64% maintained their group ranking across treatments whereas 33% changed ranking by 1 group. Only 2% moved in the ranking from the high to the low RFI group or vice versa. Compared with the previous studies where RFI repeatability was 0.73 across starch levels and 0.44 across forage levels, we presume that nutrient digestibility and protein efficiency are the 2 main sources for RFI variation. In conclusion, RFI was relatively repeatable across 2 diets varying in protein content enough to cause marked changes in production. We suggest this supports the use of RFI as part of a genomic breeding index to enhance feed efficiency.

**Key Words:** deficient dietary protein, residual feed intake, breeding index
333 Early lactation meal size, but not meal frequency, is positively associated with whole-lactation milk production and retention in the dairy herd. A. J. Carpenter, M. Wood, and B. J. Bradford*, Kansas State University, Manhattan, KS.

The importance of feed intake for a successful transition to lactation in dairy cattle is frequently cited, but little is known about whether feeding patterns predict key lactation outcomes. To explore this, data from 185 cows in 4 transition studies (10 treatments) were collated for meta-analysis. Cows were housed in tie stalls for > 20 d postpartum, with continuous monitoring of feed bunk weight to determine size and duration of each meal. Unique meals were ≥ 0.2 kg DM and were separated by ≥ 12 min. Additional data included treatment, parity, month of calving, year of calving, time to removal from herd (only if before subsequent calving), and 305-d mature equivalent milk yield (305MEM, kg). Associations with 305MEM were assessed in mixed models with predictors tested as linear and quadratic effects, and with treatment(study) as a random effect; model selection was by minimum Bayesian Information Criterion. A similar approach was used to model risk of removal from the herd in a proportional hazards model. DMI through 20 d in milk was positively associated with 305MEM (P < 0.001), but only accounted for 10% of variation, and DMI through 20 DIM was not associated with the risk of removal from the herd. Postpartum meal length (ML) and size (MS) explained 20% and 18% of the variation in 305MEM, respectively (both P < 0.001). Backward stepwise regression generated the following model (all factors P < 0.05, model r² = 0.53): 305MEM = 12508 + 1.71 × MilkPTA + 229 × MS – 43.5 × (MS – 5.46)², where MS is expressed in kg DM. In contrast to these findings, meal frequency was negatively associated with 305MEM (P = 0.02, r² = 0.03). Survival analysis revealed significant associations with 305MEM, year, parity, and ML; a 1-min increase in mean ML was associated with an 11% decrease in risk of removal from the herd (risk ratio 95% CI: 0.82–0.97; P < 0.01). Meal frequency and MS were not associated with altered risk of removal. Increased 305MEM and longer retention in the herd were associated with longer, but not more frequent, meals in the first 20 d of lactation.

Key Words: transition cow, feeding behavior, appetite


The objectives of this study were to evaluate the effects of particle size and source of undigested neutral detergent fiber (uNDF) on dry matter intake (DMI), milk production and composition, and chewing behaviors. Fifty-six Holstein cows averaging 102 (SD = 28) DIM were fed one of 3 brown midrib (BMR) corn silage based diets balanced for equal uNDF240 intake (2.32 kg/d) and varying straw length (0.82 vs 0.66 physical effectiveness factor, pef) in a completely randomized block design with a 2-wk covariate period and 4-wk treatment period. Treatments were 1) 42% BMR corn silage (1.01 kg/d of uNDF240) and 7% long straw (0.74 kg/d of uNDF240; LS), 2) 42% BMR corn silage (1 kg/d of uNDF240) and 7% short straw (0.73 kg/d of uNDF240; SS), and 3) 60% BMR corn silage (1.54 kg/d of uNDF240) and 2% long straw (0.23 kg/d of uNDF240; BMR). Cows were housed in freestall pen, fed TMR daily with Calan bins, and milked 3x/d. Feed intake and milk yield were collected daily. Milk composition and body weight were collected weekly. Chewing behavior was collected for 72 h the last week of both periods. Data were summarized by week and analyzed using MIXED procedure in SAS with cow as experimental unit. The uNDF240 intake for the LS, SS, and BMR diets were 2.32, 2.28, and 2.36 kg/d. Results reveal that particle size and source of uNDF will affect milk fatty acid profile and chewing behaviors.

Table 1 (abstract 334).

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<th>Item</th>
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<th>BMR</th>
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<td>De novo</td>
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<td>25.6</td>
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<td>43.6</td>
<td>0.2</td>
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<td>Rumination, min/d</td>
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<td>495</td>
<td>516</td>
<td>7</td>
<td>0.12</td>
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</table>

335 Impact of ration nutrient density on the energy balance and inflammatory response of dairy cows during and after dry-off. K. M. Dancy*, E. S. Ribeiro, and T. J. DeVries, Department of Animal Biosciences, University of Guelph, Guelph, ON, Canada.

The objective of this study was to assess the effects of ration nutrient density on the energy balance and inflammatory response of dairy cows during and following dry-off. Forty-eight Holstein dairy cows (1.7 ± 0.9 lactations) were dried-off over a 5-d period, approximately 60 d before their expected calving dates. At the start of dry-off (d 1), cows were randomly assigned to either 1 of 2 TMR: control diet (1.48 Mcal/kg, 13.3% CP and 32.0% NFC) and treatment diet (1.44 Mcal/kg, 12.6% CP and 29.7% NFC), which was diluted with extra straw. During dry-off, cows were milked 1x/d on d 1, 2, 3 and a final time on d 5. Before the start of dry-off, cows were producing 26 ± 5.5 kg/d, milking 2x/d, and consuming a TMR (1.65 Mcal/kg, 16.1% CP and 41.7% NFC). Blood samples were collected from the coccygeal vein on d 1, 5, 7, 13, 19 and 25, and analyzed to determine serum concentrations of NEFA, glucose, and haptoglobin. Data were summarized by cow and day and analyzed in a repeated measures linear mixed-effect regression model. From d 5 to 25, NEFA concentrations were lower (P < 0.009) than at d 1 for both treatments. Cows fed the diluted ration tended to have lower NEFA on d 5 (0.08 vs 0.10 mmol/L; P = 0.09) and d 7 (0.07 vs 0.09 mmol/L; P = 0.06) than cows fed the control ration. Higher BW at dry-off was associated (P = 0.09) with greater haptoglobin during and after dry-off. These results suggest energy balance and inflammatory response of dairy cows during and after dry-off may be altered by controlling cow body weight, milk yield, and the magnitude change, from lactation to the dry period, in nutrient density of the ration consumed.

Key Words: dry-off, energy balance, inflammation
The objective of this study was to determine if behavior, reticulorumen health, and production in early lactation dairy cows varies with TMR straw particle size. For 28 d after calving, 40 multiparous Holstein cows, housed in free-stalls, were individually fed (24 h/d feed access) either 1 of 2 TMR with 8.8% wheat straw (DM basis) chopped to: 1) 2.54 cm (Short; n = 20) or 2) 5.08 cm (Long; n = 20). Enrollment in the trial was on a rolling basis; cows were evenly distributed between treatments by parity and previous 305-d milk yield. Wireless telemetry boluses were used to measure reticulorumen pH. Automated systems recorded TMR DMI, milk yield, and rumination activity. TMR and orts samples were collected every 3 d to determine feed sorting. A particle separator was used to separate feed samples into 4 fractions: long (>19mm), medium (<19mm, >8mm), short (<8mm, >4mm), and fine (<4mm) particles. Feed sorting was calculated as: actual intake of each particle fraction expressed as a % of its predicted intake. Data were analyzed in mixed-effect linear regression models and were modeled with polynomial functions over the 28 d of observations. The fitted data indicated treatment differences in linear slopes (P < 0.01), quadratic coefficients (P < 0.01), and cubic coefficients (P < 0.01) for DMI (Long: kg/d = 2.9d – 0.2d^2 + 0.003d^3 + 22.3), and rumination time (Long: min/d = 52.9d – 3.5d^2 + 0.07d^3 + 265.7; Short: min/d = 38.5d – 1.9d^2 + 0.03d^3 + 251.14). Mean reticulorumen pH decreased at a greater rate from calving to 10 DIM for cows on the Long treatment (pH = -0.079d + 0.005d^2 – 0.0001d^3 + 6.53) than for cows on the Short (pH = -0.076d + 0.005d^2 – 0.0001d^3 + 6.44), as indicated by differences in linear slopes (P < 0.01). Cows tended to sort the longest TMR particles differently by treatment (P = 0.06); on the Long treatment cows sorted against long particles (94.1 ± 1.7%; P < 0.01), while on the Short treatment cows did not sort for or against these particles (98.8 ± 1.7%; P = 0.5). These results suggest that cows fed a diet with longer straw particles selected against physically-effective fiber, which may have contributed to greater fluctuations in rumination time, reticulorumen pH, DMI, and milk production in early lactation.

**Key Words:** sorting, rumination, straw


Activated immune cells avidly utilize glucose and are insulin sensitive. Chromium (Cr) increases insulin sensitivity and thereby may affect immune function. Objectives were to evaluate supplemental Cr (KemTRACE Chromium 0.04%, Kemin Industries Inc., Des Moines, IA) effects on circulating metabolites and leukocytes following an i.v. lipopolysaccharide (LPS) challenge in lactating cows. Cows were enrolled in a 2x2 factorial design and assigned to 1 of 4 treatments: 1) pair-fed (PF) and control (PF-CON; 5 mL saline; n = 5), 2) PF and Cr (PF-Cr; 5 mL saline; n = 5), 3) LPS-euglycemic clamp and control (LPS-CON; 0.375 μg/kg BW LPS; n = 5), and 4) LPS-euglycemic clamp and Cr (LPS-Cr; 0.375 μg/kg BW LPS; n = 5). Cows received experimental diets throughout the trial. After acclimation (3 d) baseline values were obtained during period 1 (3 d). At the initiation of period 2 (2 d), a 12 h LPS-euglycemic clamp was conducted or cows were PF to their respective dietary counterparts. Circulating NEFA in PF cows increased (95%) from 6 to 18 h post-bolus while LPS cows increased from 12 to 18 h (63%); thereafter, NEFA decreased in all treatments (P < 0.01). Circulating BUN was increased in LPS vs. PF cows throughout P2 (31%; P = 0.02). Circulating β-hydroxybutyrate tended to decrease in LPS vs. PF cows (16%; P = 0.07) and increased in all cows throughout the 2 d (P < 0.01). Relative to PF cows, circulating LPS-biding protein and serum amyloid A in LPS cows increased 2 and 5-fold, respectively (P < 0.01). Overall, Cr-supplemented cows had increased (22%; P = 0.03) monocytes. Relative to PF cows, WBC and neutrophil counts in LPS cows initially decreased, then progressively increased 58 and 163%, respectively (P < 0.01). Between 12 and 48 h post-bolus, neutrophils increased (12%; P = 0.04) in LPS-Cr vs. LPS-CON cows. In summary, Cr increased the neutrophil response following an LPS challenge, but had minimal effects on circulating energetic metabolites.

**Key Words:** LPS, chromium, neutrophil