NASEM Nutrient Requirements of Dairy Cattle: Dry Cows, Calves, and Heifers

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Dry and Transition Cows
Changes from NRC 2001

• Up-to-date lit review on:
  ▪ Metabolic disorders
  ▪ Ruminal changes during transition
  ▪ Colostrum composition

• DMI equations

• Gestation requirement model structure

• Effects of dry cow nutrition on milk production

• Specific requirements of close-up (pre-fresh) where justified
NEL concentration of diets

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>% of DM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn silage</td>
<td>32.1</td>
</tr>
<tr>
<td>Wheat straw</td>
<td>36.3</td>
</tr>
<tr>
<td>Corn gluten feed</td>
<td>8.2</td>
</tr>
<tr>
<td>Soy hulls</td>
<td>6.6</td>
</tr>
<tr>
<td>Wheat midds</td>
<td>6.2</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>5.8</td>
</tr>
<tr>
<td>Bypass protein</td>
<td>2.6</td>
</tr>
<tr>
<td>Minerals and vitamins</td>
<td>2.2</td>
</tr>
</tbody>
</table>

814 kg, 270 DCC, 12.0 kg/d DMI

- NEL NRC 2001:
  1.44 Mcal/kg
  (0.65 Mcal/lb)
- NEL NASEM 2021:
  1.60 Mcal/kg
  (0.73 Mcal/lb)

Requirements also increase so net change in energy balance is minimal
Estimated DMI by NASEM 2021

- Equations include parity, diet NDF, and week prepartum
  - Week used because of uncertainty of calving date
- Insufficient data for true meta-analysis
- Insufficient data to evaluate interactions among parity, diet, and time prepartum
- Data from 2001 and all newer data available were used
- Almost all experiments used high forage diets; diets with byproduct NDF sources not represented
Estimating DMI using NASEM 2021

- **Cows (% of BW):**
  \[
  = 1.47 - [(0.365 - 0.0028 \times NDF) \times \text{week}] - 0.035 \times \text{week}^2
  \]
  where week = week from calving (i.e., it is negative)
  If cow > 3 wk from parturition, week = -3

- **Heifers:** Cow equation \times 0.88
  Insufficient new data, therefore average parity effect from 2001 was retained
Estimated DMI by cows using NASEM 2021
New DMI equations

For far-off dry cows (>3 wk prepartum)
• DMI will be between 1.8 and 2% of BW
• Negatively correlated with dietary NDF

For close-up dry cows (<3 wk prepartum)
• DMI starts decreasing ~2.5 wk prepartum
• Rate of decline negatively correlated with dietary NDF
• At about wk 1 prepartum DMI about the same for all NDF (1.65% of BW)
Calculation of gestation requirements

- Mass model for conceptus starts at d 10 of gestation (compared with d 190 in NRC 2001)
- Function of maternal BW (heifer has smaller calf)
- Energy = 0.88 Mcal/kg
- CP = 125 g/kg
# Gestation energy and protein requirements

<table>
<thead>
<tr>
<th>Day of gestation</th>
<th>Gestation NEL, Mcal/d</th>
<th></th>
<th>Gestation MP, g/d</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NRC 2001</td>
<td>NASEM 2021</td>
<td>NRC 2001</td>
<td>NASEM 2021</td>
</tr>
<tr>
<td>50</td>
<td>0</td>
<td>0.04</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>100</td>
<td>0</td>
<td>0.1</td>
<td>0</td>
<td>13</td>
</tr>
<tr>
<td>150</td>
<td>0</td>
<td>0.5</td>
<td>0</td>
<td>43</td>
</tr>
<tr>
<td>200</td>
<td>2.7</td>
<td>1.4</td>
<td>199</td>
<td>125</td>
</tr>
<tr>
<td>220</td>
<td>3.0</td>
<td>2.0</td>
<td>245</td>
<td>185</td>
</tr>
<tr>
<td>250</td>
<td>3.4</td>
<td>3.5</td>
<td>306</td>
<td>320</td>
</tr>
<tr>
<td>275</td>
<td>3.8</td>
<td>5.4</td>
<td>357</td>
<td>489</td>
</tr>
</tbody>
</table>
Close-up starch, fiber, and energy

• Almost impossible to separate these effects (e.g., as NDF goes up starch and NEL usually go down)

• Increasing prefresh energy (more starch, less NDF):
  - Increases prepartum DMI
  - Generally little effect on postpartum DMI
  - Most studies show no effect on milk yield
Use of pre-fresh diet to adapt rumen

• To “help rumen deal with higher starch postpartum diet”

“Based on available data, benefits of feeding a diet of moderate starch and fiber to transition ruminal cells and rumen tissue morphology from a high-forage diet to a higher-starch lactation diet are not evident.”
Dry cow dietary protein and milk production

- Most studies fed treatments during entire dry period, not just pre-fresh
- Milk and milk composition during first 3 wk to 17 wk were the primary outcome variables

- In few studies, diets were as low as 10% CP without effect on milk production (cows)
- Diet with 10% CP prepartum remained in protein balance at d -10 (Putnam and Varga, 1998)
Dry cow dietary CP and milk production

Meta-analysis (Lean et al., 2013)
12 studies, 26 treatment comparisons
Control diets: 9.7 to 14.1% CP (avg. = 12.3)
Treatment diets: 11.7 to 23.4% CP (avg. = 15.9%)
Milk yield first 28 d to 120 d (avg = 65 DIM)

Average increase in milk = 0.1 kg/d (-0.6 to +1.2 kg/d)
Dry cow dietary MP and milk production

Meta-analysis (Husnain and Santos, 2019)

- 27 comparisons for heifers
- 97 comparisons for cows
  - Mostly prefresh treatment comparisons

Diets: 9 to 21% CP (avg. = 14.0%)

- 6 to 10% MP (avg. 13% for cows; 8.3 to 9.3%)

MP calculated according to NRC 2001
Dry cow dietary CP and milk production

• No difference in milk yield for cows
  ➢ Milk protein increased 60 g/1000 g MP intake in cows producing >36 kg/d milk

• Increased milk and milk protein in first lactation cows

(Husnain and Santos, 2019)
NASEM 2001 model

Far-off dry cow and heifer
- \( \sim 11\% \) CP (6.5\% MP) will \( \sim \)meet requirement
- 12\% CP (7.2\% MP) recommended because of limited data and potentially inadequate RDP

Close-up cow and heifer
- \( \sim 13\% \) CP (7.8\% MP) will meet requirement
- Might not be optimum for heifers
- Model ignores MP for colostrum and immune function
Specific minerals/vitamins for transition cows

- Negative DCAD, Ca, P, Mg for hypocalcemia
- Higher vitamin E based on mastitis, RP, and metritis
- No other specific requirements
Calves
General features of calf model

- Based on energy-Allowable growth.
- Protein requirements calculated as maintenance plus body N deposition at energy-Allowable growth rate.
- Minerals and vitamins calculated based on factorial requirements (new)
- Prediction of retained energy (RE, i.e., net energy) is central to model performance.
Comparison of Observed and Predicted ADG for Calves

111 treatment means from the literature

Drackley, unpublished 2021
Problems with NRC 2001 energy equations

- Data from which Toullec ME equation was derived came from studies with heavier veal calves fed milk only.

- Efficiency of converting ME to RE is too high for lighter weight growing calves depositing primarily protein.
To determine RE we must know composition of BW gain

Comparative slaughter studies:
Measured RE = ME intake – Heat production
Since publication of NRC 2001, several body composition studies have been reported

- Database of 255 calves (7 studies: Cornell, Illinois, Virginia Tech) with full body composition and changes from baseline (RE)
  - 6 published, 1 Ph.D. thesis
  - 6 Holstein, 1 Jersey
  - 2 with starter, 5 without

- Used to derive:
  - maintenance energy
  - relationships between retained energy and empty body weight gain and metabolic body size
  - efficiencies of ME use
  - nitrogen deposition
Effects of cold and heat stress on maintenance

• Maintenance ME = 0.107 Mcal/kg BW^{0.75}

• +2.01 kcal/kg^{0.75} per day for each degree decrease in environmental temperature (°C) below the lower critical temperature or above the upper critical temperature
Next need to derive an equation linking retained energy (NEg) to body weight gain

• Ultimately allows linking dietary energy (ME) supply to predicted BW gain
• Equation selected was:

$$RE, \text{ Mcal/d} = (EBG^{1.100}, \text{ kg/d}) \times (EBW, \text{ kg}^{0.205})$$

• Can rearrange to calculate EBG (and then ADG):

$$EBW \text{ gain (kg/d)} = RE, \text{ Mcal/d} / (EBW^{0.205}, \text{ kg})^{1/1.1}$$
Efficiency of ME use for gain, milk only from model development dataset

\[ y = 0.4375x - 0.6353 \]
\[ R^2 = 0.8682 \]
Efficiency of ME use for gain, milk only

- On a metabolic body weight basis = 46%
- Summary of older studies, basis of NRC 2001 = 69%
- INRA, 2019 = 55%
- Use 55% as compromise to represent all calves
- Efficiency for calves fed milk plus starter is lower
Efficiency of ME use from starter

NEg, Mcal/kg DM = (1.1376 × ME) - (0.1198 × ME²) + (0.0076 × ME³) - 1.2979

Galyean et al. (2016)

Over typical starter ME range (i.e., 2.5 to 3.5 Mcal/kg), RE:ME varies from 0.38 to 0.44

Efficiency of mixed diet (milk plus starter) is additive
Metabolizable protein for maintenance

- Relatively small
- Calculated similarly to NRC, 2001 except with addition of scurf protein and reduced efficiency of use (0.68 vs 0.80)
Nitrogen Composition of the Gain

NRC 2001 used a mean value of 30 g N/kg liveweight gain (Blaxter and Wood, 1951; Roy, 1970; Donnelly and Hutton, 1976)

- Equivalent to 188 g CP/kg LWG

Re-evaluated from the new model development database using the Beef NRC equation format:

\[ NPg = (166.2 \times EBW \text{ gain, kg/d}) + (6.1276 \times \frac{RE, \text{ Mcal/d}}{EBW \text{ gain, kg/d}}) \]
Efficiency of use of absorbed amino acids

Used combined efficiency of maintenance and growth of 0.68 (Lapierre et al)

Compared with 0.80 in NRC, 2001
Energy and protein for 50-kg Holstein calf (thermoneutral conditions), based on the NASEM equations:

<table>
<thead>
<tr>
<th>ADG (kg/d)</th>
<th>DMI (kg/d)</th>
<th>ME (Mcal/d)</th>
<th>CP (g/d)</th>
<th>CP (% of DM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
<td>0.56</td>
<td>2.56</td>
<td>102</td>
<td>18.3</td>
</tr>
<tr>
<td>0.4</td>
<td>0.71</td>
<td>3.29</td>
<td>155</td>
<td>21.8</td>
</tr>
<tr>
<td>0.6</td>
<td>0.88</td>
<td>4.05</td>
<td>209</td>
<td>23.7</td>
</tr>
<tr>
<td>0.8</td>
<td>1.05</td>
<td>4.85</td>
<td>262</td>
<td>24.9</td>
</tr>
<tr>
<td>1.0</td>
<td>1.23</td>
<td>5.66</td>
<td>315</td>
<td>25.6</td>
</tr>
</tbody>
</table>

Drackley, 2021 unpublished
Observed minus predicted values for ADG (kg/d) from 401 literature treatment means, with residuals plotted.
Comparison of actual mean ADG from 111 treatment means from the literature with values predicted by the current model or the previous (NRC, 2001) model.
Comparison of actual mean ADG from 111 treatment means from the literature with values predicted by the current model or the previous (NRC, 2001) model.
Comparison of new system with NRC, 2001

• For a 50-kg calf fed 0.55 kg of milk replacer (20/20) and consuming 0.56 kg of starter daily

• Predicted growth:
  – New system = 0.58 kg/d
  – NRC, 2001 = 0.67 kg/d
Comparison of new system with NRC, 2001

• For a 50-kg calf fed 1.0 kg of milk replacer (28/20) and consuming 0.2 kg of starter daily
• Predicted growth:
  – New system = 0.88 kg/d
  – NRC, 2001 = 0.96 kg/d
Comparison of new system with NRC, 2001

- For a 50-kg calf fed 0.68 kg of milk replacer (26/17) and consuming 0.4 kg of starter daily
- Predicted growth:
  - New system = 0.63 kg/d
  - NRC, 2001 = 0.72 kg/d
Prediction equations for starter intake

- Compiled database of 26,952 observations from 1,356 calves from 28 studies carried out in 4 U.S. states and the Netherlands (Georgia, n = 168; Illinois, n = 1,925; Minnesota, n = 6,052; Ohio, n = 16,457; and the Netherlands, n = 2,350).

- An external data set (n = 8,891 individual observations, 9 studies) was developed to evaluate the models using data from four U.S. states (Iowa, n = 6,332; New Hampshire, n = 1,519; New York, n = 892; Virginia, n = 148).
Prediction equations for starter intake (cont’d)

• Equation selected for calves in temperate conditions:

\[
\text{Starter DMI (g/d)} = -652.525 + (\text{BW} \times 14.734) + (\text{MeiLD} \times 18.896) + (\text{Fpstarter} \times 73.303) + (\text{FPstarter}^2 \times 13.496) - (29.614 \times \text{Fpstarter} \times \text{MEiLD})
\]

• RMSE of 262 g/d, CCC of 0.71
Prediction equations for starter intake (cont’d)

• For calves in subtropical environments, equations to predict starter intake were developed using individual animal data ($n = 3,491$ observations from 853 calves) from 15 studies carried out in the United States and Brazil (Florida, $n = 1,127$; Georgia, $n = 179$; Brazil, $n = 2,185$).

• An independent data set ($n = 479$ individual observations, five studies) was used to evaluate the models using data from the United States and Brazil (Georgia, $n = 96$; Brazil, $n = 383$).
Prediction equations for starter intake

• For calves in subtropical environments, equation selected:

\[
\text{Starter DMI (g/d)} = 600.053 \times (1 + 14863.651 \times (\exp(-1.553 \times \text{FPstarter})))^{-1} + (9.951 \times \text{BW}) - (130.434 \times \text{MEiLD})
\]

• RMSE of 222 g/d, CCC of 0.78.

• When users enter environmental temperature > 35°C, this equation is used.
Changes in recommended mineral concentrations

Compared to NRC, 2001:

• Ca lower for MR but similar for starter and grower.
• P about 15 percent lower for MR, starter and grower.
• K concentration in MR is about 70 percent higher but similar for starter and grower.
• Cu about half the previous value.
• Fe is about 15 percent lower for MR but similar for starter and grower.
• Mn is higher for MR but similar for starter and grower.
• Zn about 40 percent greater.
Changes in recommended vitamin allowances

• Vitamin A: 11,000 IU/kg milk replacer solids (9,900 IU/kg for calves consuming > 1 kg MR/d)
• Vitamin D3: 3,500 IU/kg milk replacer solids
• Vitamin E: 125 IU/d
How much milk should be fed?

• The committee recommends that a minimum of 1.5% of BW as milk solids be fed (675 g/d for 45-kg calf)

• Based on welfare research data showing hunger and stress in calves fed less
Growing heifers
Changes from NRC 2001

• Developed new ME system based on data from Holsteins (NRC 2001 from beef cattle)
• Set reference animal as Holstein
• Does not include environmental effects
• Added discussion on effects of diet on milk production potential and on responses to dietary protein
• Included prediction of gain based on ME intake
Fat and protein content of EBW in Holsteins
Growth equations

- Maintenance ME = $0.16 \times BW \ kg^{0.75}$
- Fat in ADG = $0.85 \times [0.067 + 0.375 \times (BW/\text{Mat BW})]$
- Protein in ADG = $0.85 \times [0.201 - 0.081 \times (BW/\text{Mat BW})]$
- RE in ADG = $9.4 \times \text{fat gain} + 5.55 \times \text{protein gain}$

Overall RE equation:

$$RE \ (\text{Mcal/kg}) = 0.85 \times [1.74 + 308 \times (BW/\text{Mature BW})]$$
## Requirements for energy and protein in Holstein heifers

<table>
<thead>
<tr>
<th>Live BW, kg</th>
<th>224</th>
<th>336</th>
<th>420</th>
<th>560</th>
</tr>
</thead>
<tbody>
<tr>
<td>BW as % of mature BW</td>
<td>32</td>
<td>48</td>
<td>60</td>
<td>80</td>
</tr>
<tr>
<td>Estimated DMI, kg/d</td>
<td>6.0</td>
<td>8.0</td>
<td>9.3</td>
<td>10.9</td>
</tr>
<tr>
<td>For ADG of 700 – 980 g/d:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ME required, Mcal/d</td>
<td>13.3 – 14.9</td>
<td>17.3 – 19.3</td>
<td>20.2 – 22.3</td>
<td>28.8 – 31.3</td>
</tr>
<tr>
<td>MP required, g/d</td>
<td>599 – 672</td>
<td>711 – 790</td>
<td>767 – 846</td>
<td>952 – 1034</td>
</tr>
<tr>
<td>ME/kg diet</td>
<td>2.2 – 2.5</td>
<td>2.2 – 2.4</td>
<td>2.2 – 2.4</td>
<td>2.6 – 2.9</td>
</tr>
<tr>
<td>CP, % of diet</td>
<td>14.3 – 16.0</td>
<td>12.6 – 14.0</td>
<td>11.8 – 13.0</td>
<td>12.5 – 13.5</td>
</tr>
</tbody>
</table>
Predicting ADG from ME intake

• New equations (assuming dietary protein meets requirements)

  \[
  \text{RE (Mcal/d)} = (\text{ME intake} - \text{ME for maintenance}) \times 0.40
  \]

  \[
  \text{ADG (kg/d)} = \frac{\text{RE}}{0.85 \times (1.74 + 3.08 \times (\text{BW/Mat BW})) \times (0.0012 \times \text{Mature BW}^{0.1})^{1/1.1}}
  \]