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

Ingredient	% of DM
Corn silage	32.1
Wheat straw	36.3
Corn gluten feed	8.2
Soy hulls	6.6
Wheat midds	6.2
Soybean meal	5.8
Bypass protein	2.6
Minerals and vitamins	2.2

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):**

  $= 1.47 – [(0.365 – 0.0028 \times \text{NDF})\ \text{week}] – 0.035 \times \text{week}^2$

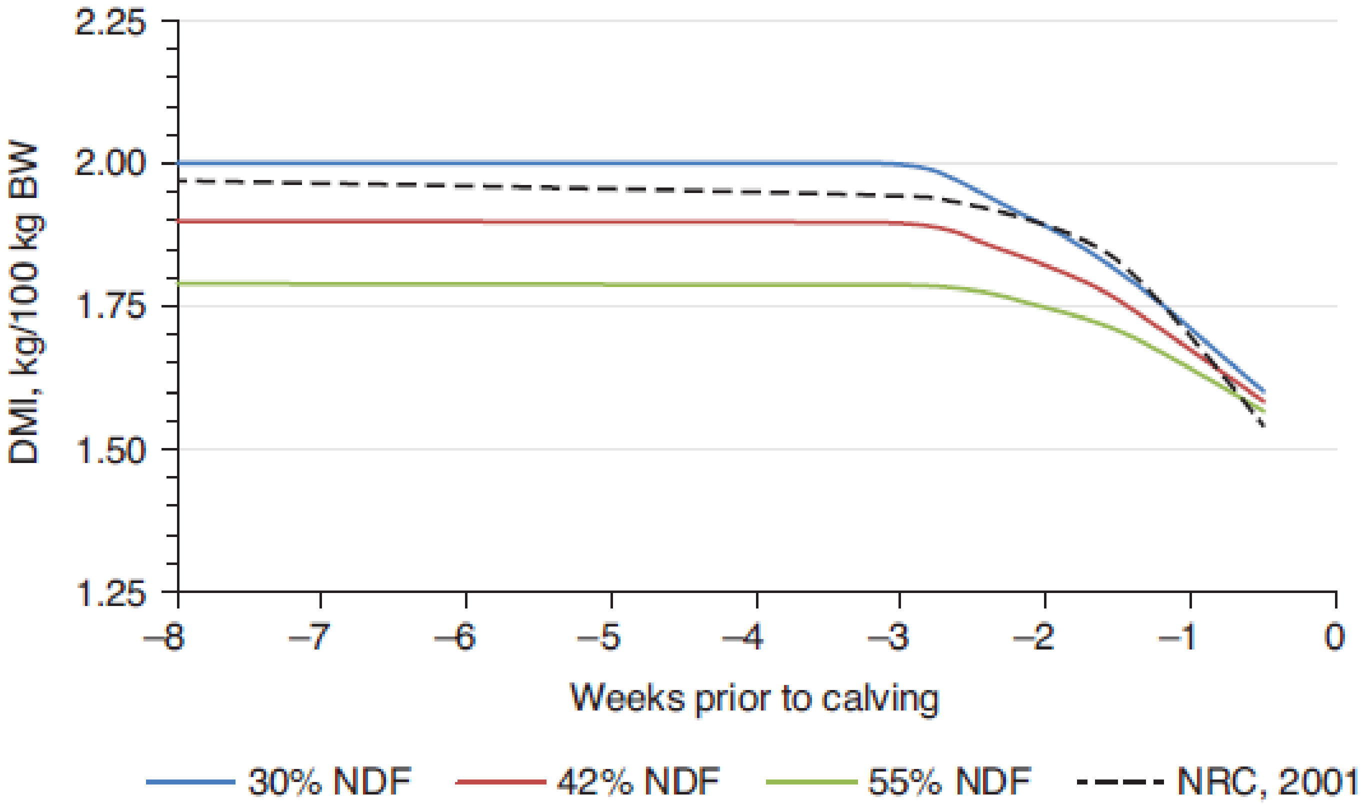
  where week = week from calving (i.e., it is negative)

  If cow > 3 wk from parturition, week = -3

- **Heifers:** Cow equation × 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)

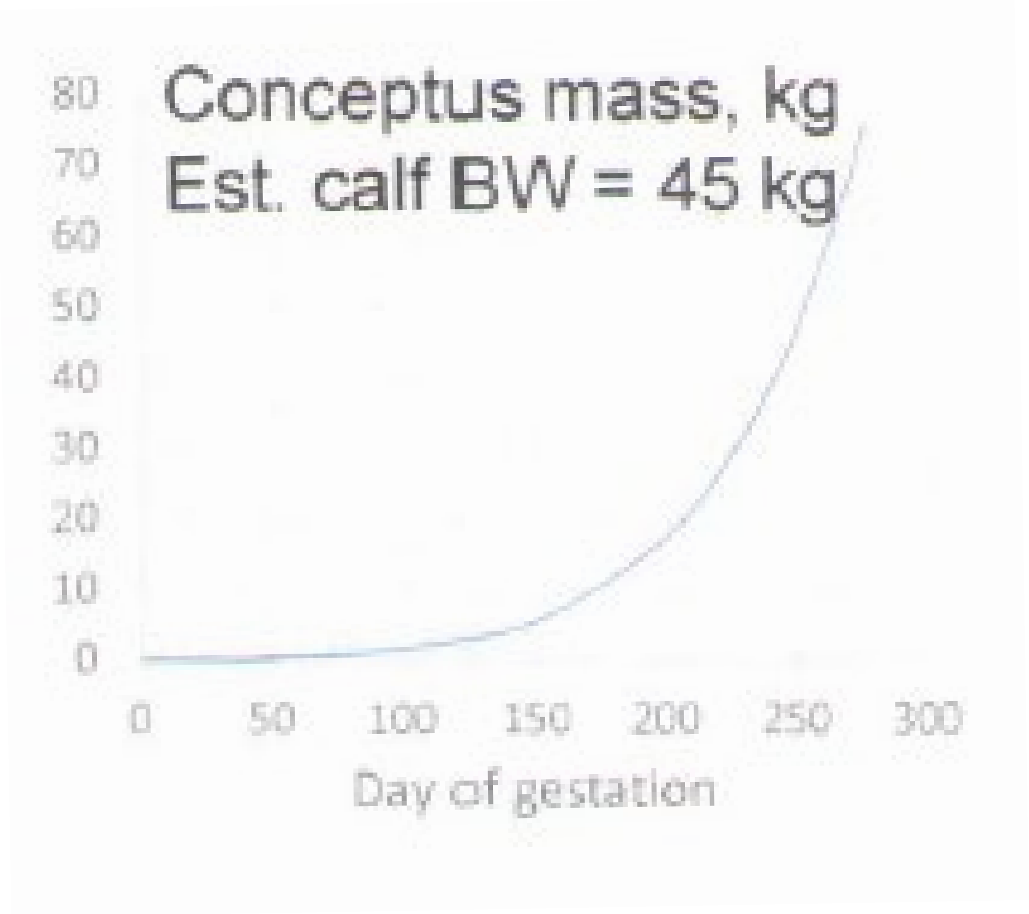
- DMI will be between 1.8 and 2% of BW
- Negatively correlated with dietary NDF

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

	Gestation NEL, Mcal/d		Gestation MP, g/d	
Day of gestation	NRC 2001	NASEM 2021	NRC 2001	NASEM 2021
50	0	0.04	0	3
100	0	0.1	0	13
150	0	0.5	0	43
200	2.7	1.4	199	125
220	3.0	2.0	245	185
250	3.4	3.5	306	320
275	3.8	5.4	357	489

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

- ~11% CP (6.5% MP) will ~meet requirement
- 12% CP (7.2% MP) recommended because of limited data and potentially inadequate RDP

Close-up cow and heifer

- ~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

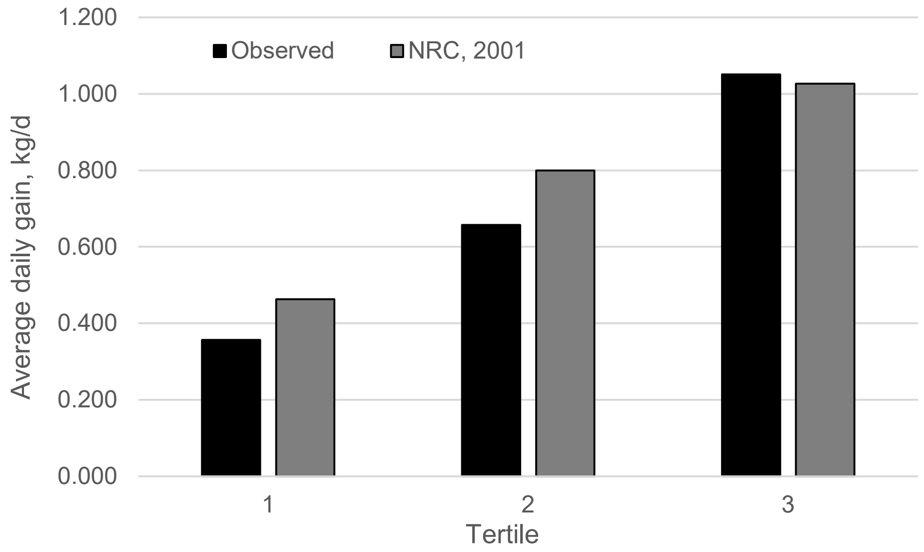
- Negative DCAD, Ca, P, Mg for hypocalcemia
- Higher vitamin E based on mastitis, RP, and metritis
- No other specific requirements

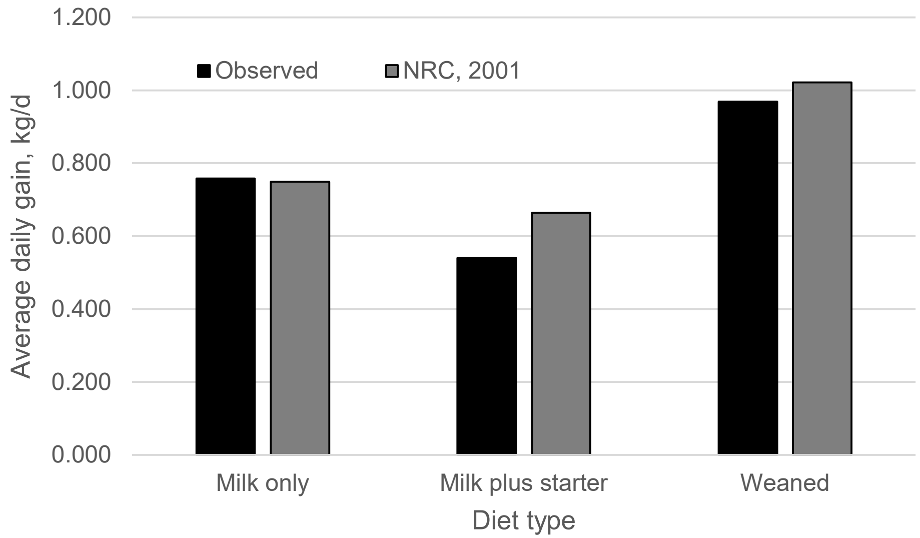
Calves

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

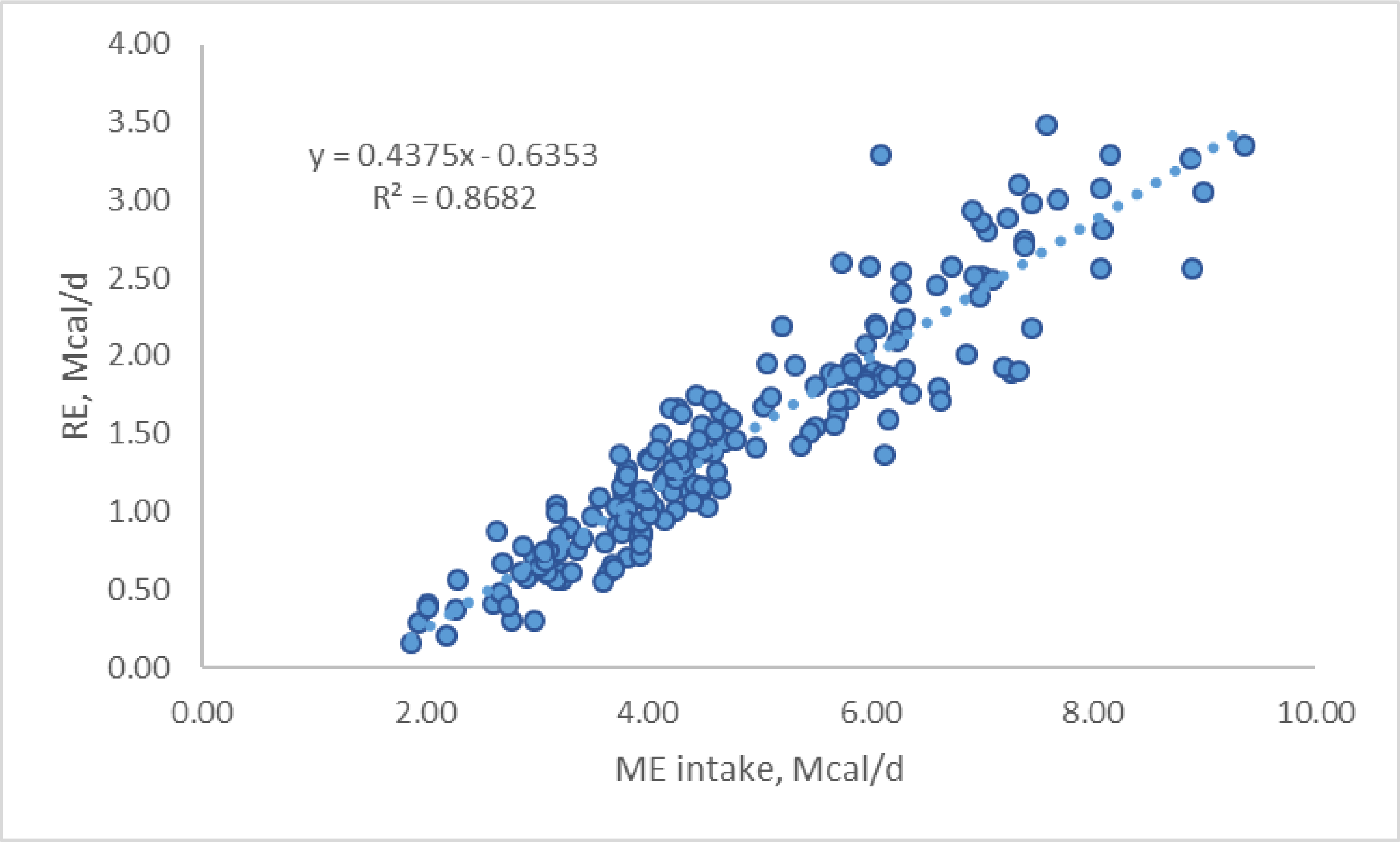
- Ultimately allows linking dietary energy (ME) supply to predicted BW gain
- Equation selected was:

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

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

$$\text{EBW gain (kg/d)} = \text{RE, Mcal/d} / (\text{EBW}^{0.205}\text{, kg})^{1/1.1}$$

Efficiency of ME use for gain, milk only from model development dataset



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

$$NEg,\ Mcal/kg\ DM = (1.1376 \times ME) - (0.1198 \times ME^2) + (0.0076 \times ME^3) - 1.2979$$

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:

$$NPg = (166.2 \times \text{EBW gain, kg/d}) + (6.1276 \times (\text{RE, Mcal/d} / \text{EBW gain, kg/d}))$$

Efficiency of use of absorbed amino acids

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

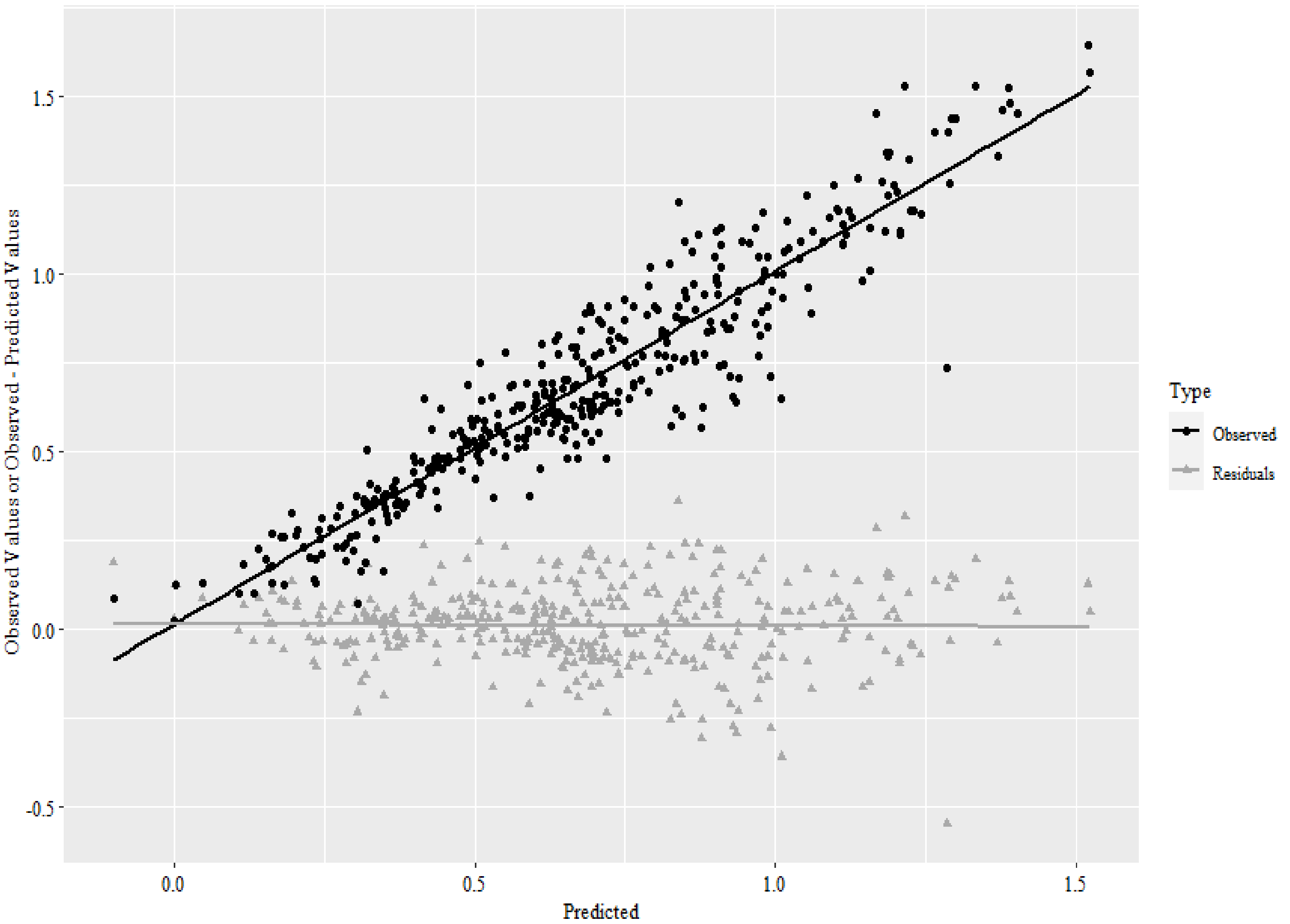
Compared with 0.80 in NRC, 2001

Energy and protein for 50-kg Holstein calf (thermoneutral conditions), based on the NASEM equations:

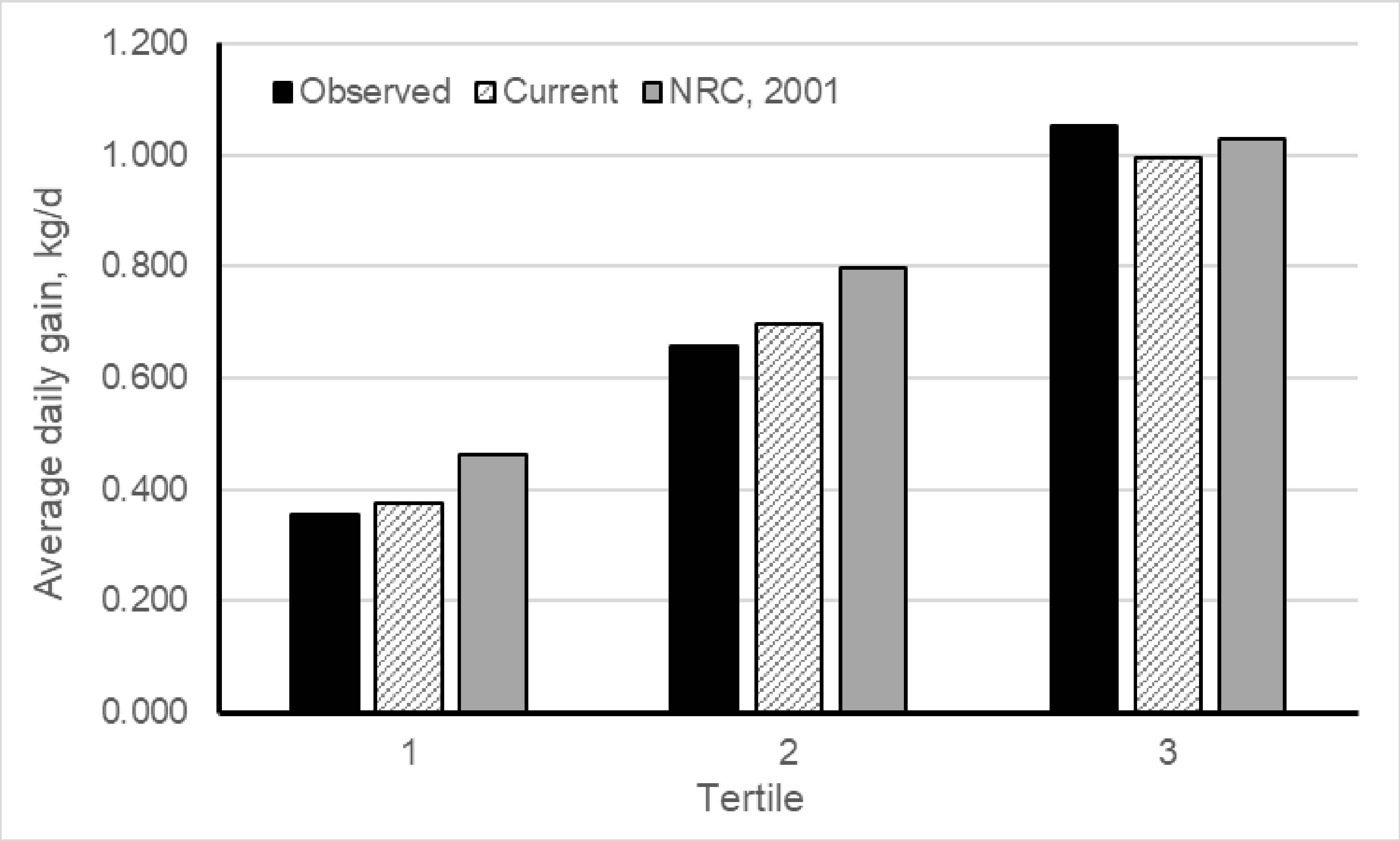
ADG (kg/d)	DMI (kg/d)	ME (Mcal/d)	CP (g/d)	CP (% of DM)
0.2	0.56	2.56	102	18.3
0.4	0.71	3.29	155	21.8
0.6	0.88	4.05	209	23.7
0.8	1.05	4.85	262	24.9
1.0	1.23	5.66	315	25.6

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



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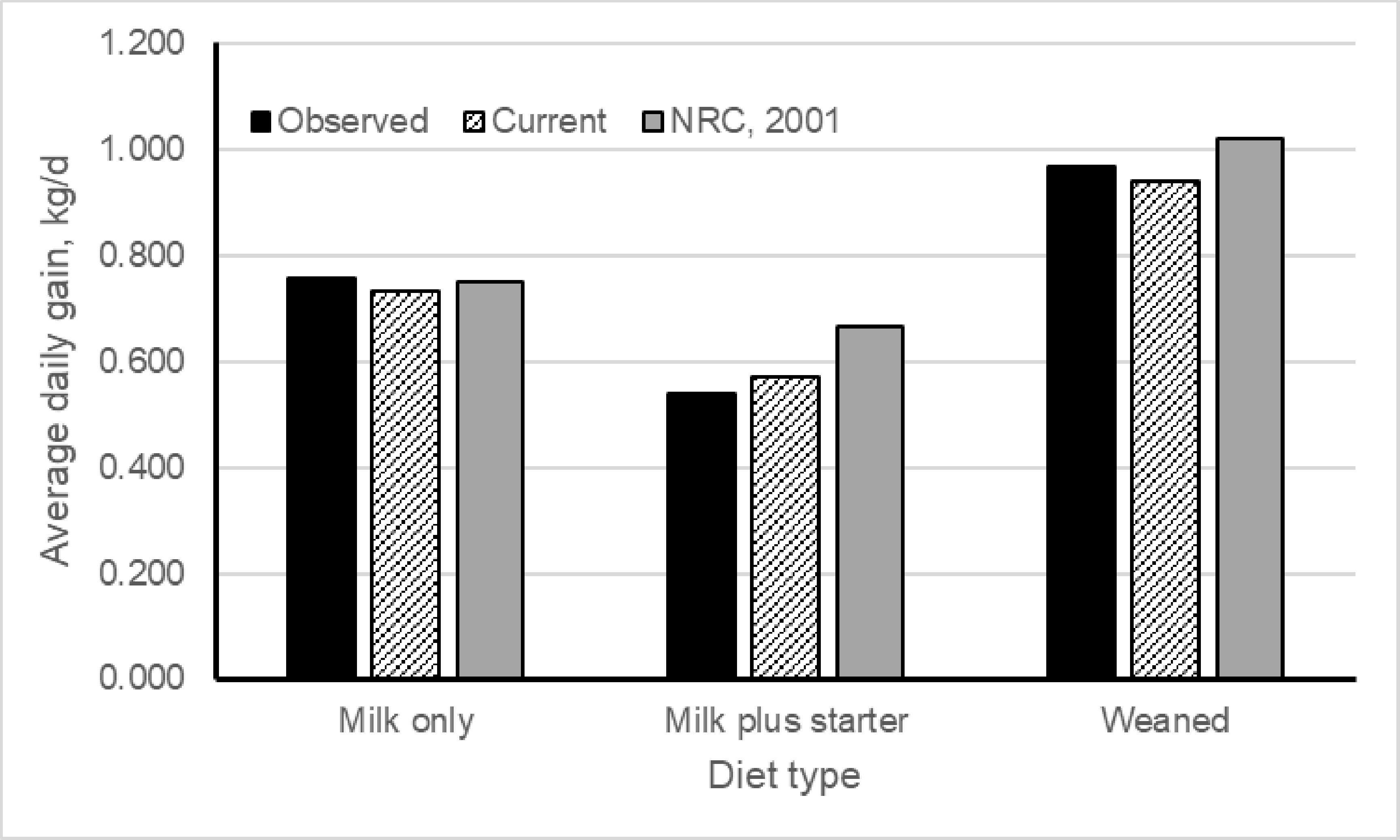


Comparison of new system with NRC, 2001

- 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?

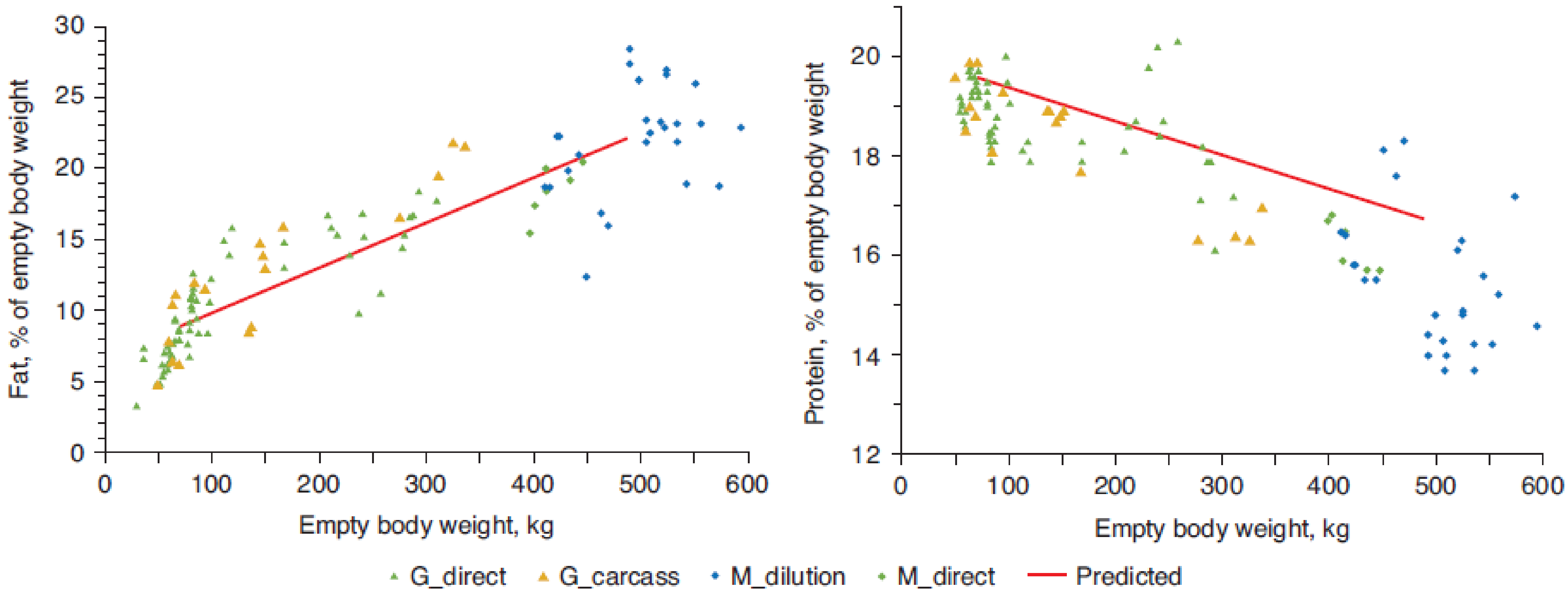
- The committee recommends that a minimum of 1.5% of BW as milk solids be fed (675 g/d for 45-kg calf)
- Based on welfare research data showing hunger and stress in calves fed less

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

- Overall RE equation:

  RE (Mcal/kg) = $0.85 \times [1.74 + 308 \times (\text{BW/Mature BW})]$

Requirements for energy and protein in Holstein heifers

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

Predicting ADG from ME intake

- New equations (assuming dietary protein meets requirements)

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

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

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