Current concepts in calf and heifer feeding and the NASEM requirements

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Feeding and management of beef-on-dairy calves for optimal performance

- What do we know and what can we apply from our knowledge of heifer nutrition and growth?
  - Review the NASEM 2021 calf chapter
- Will NASEM equations accurately predict growth of cross-bred calves?

Management vs. genetics

- How much of difference in cross-bred beef on dairy is genetics and how much is management differences?

Comparison of male dairy calf vs beef calf rearing

Dairy bull calf

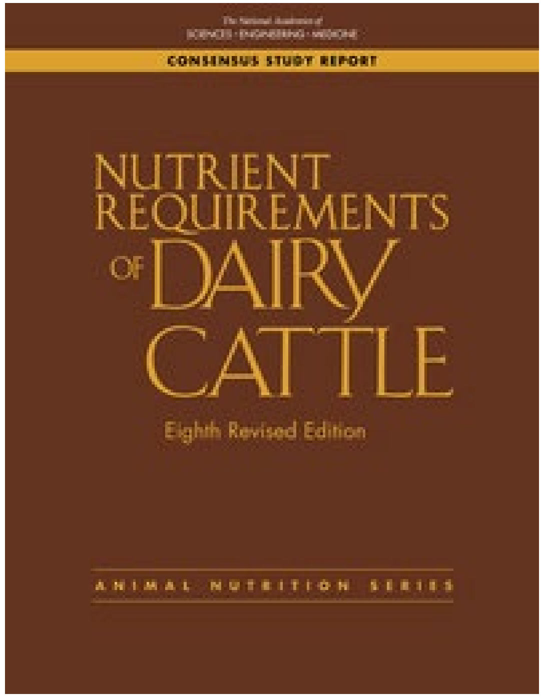
- Often colostrum deprived
- Transported within first few days
- Fed limited amount of milk or milk replacer
- Fed milk only 4-8 wk
- Forced on to high energy feed at early age

Beef bull calf

- Colostrum adequate
- Stays with mama
- Fed milk to appetite
- Fed milk at least 80 days
- Gradual increase of solid feed, often grass during early life

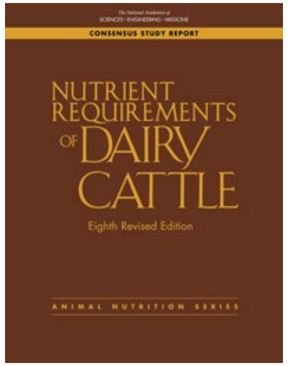
Do these differences affect early programming of growth and susceptibility of calves to liver abscesses?

NASEM Chapter 10
Nutrient Requirements of the Young Calf



An extensive revision

- Empty BW used for all calculations
- Starter intake estimation equations
- Energy requirements updated using composition of EBW gain
- Calculation of feed energy values revised
- New metabolizable protein (MP) system adopted
- Mineral requirement system was changed
- Some vitamins updated
- Extensive revisions of text sections on nutritional management



Calf or heifer?

- Calves: less than 18% of mature BW
  - <125 kg for Holstein with mature BW of 700 kg
- Heifers: greater than 18% of mature BW

Body weight conversions

- All calculations are made using an empty body weight (EBW) basis
- Milk only: EBW = 0.94 live BW
- Milk plus starter: EBW = 0.93 live BW
- Weaned calf: EBW = 0.85 live BW

Dry matter intake

- Calves < 65 kg (Holstein) consume ~2.25% of BW as milk solids if fed ad libitum
- Calves > 65 kg consume ~2.5% of BW as milk solids
- Calves < 8 wk fed limited amounts of milk and ad libitum starter consumed 1.93 ± 0.33% of BW as total DM (219 treatment means from 64 studies)
- Weaned calves > 8 wk consumed 3.06 ± 0.31% of BW (79 treatment means from 27 studies)

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).

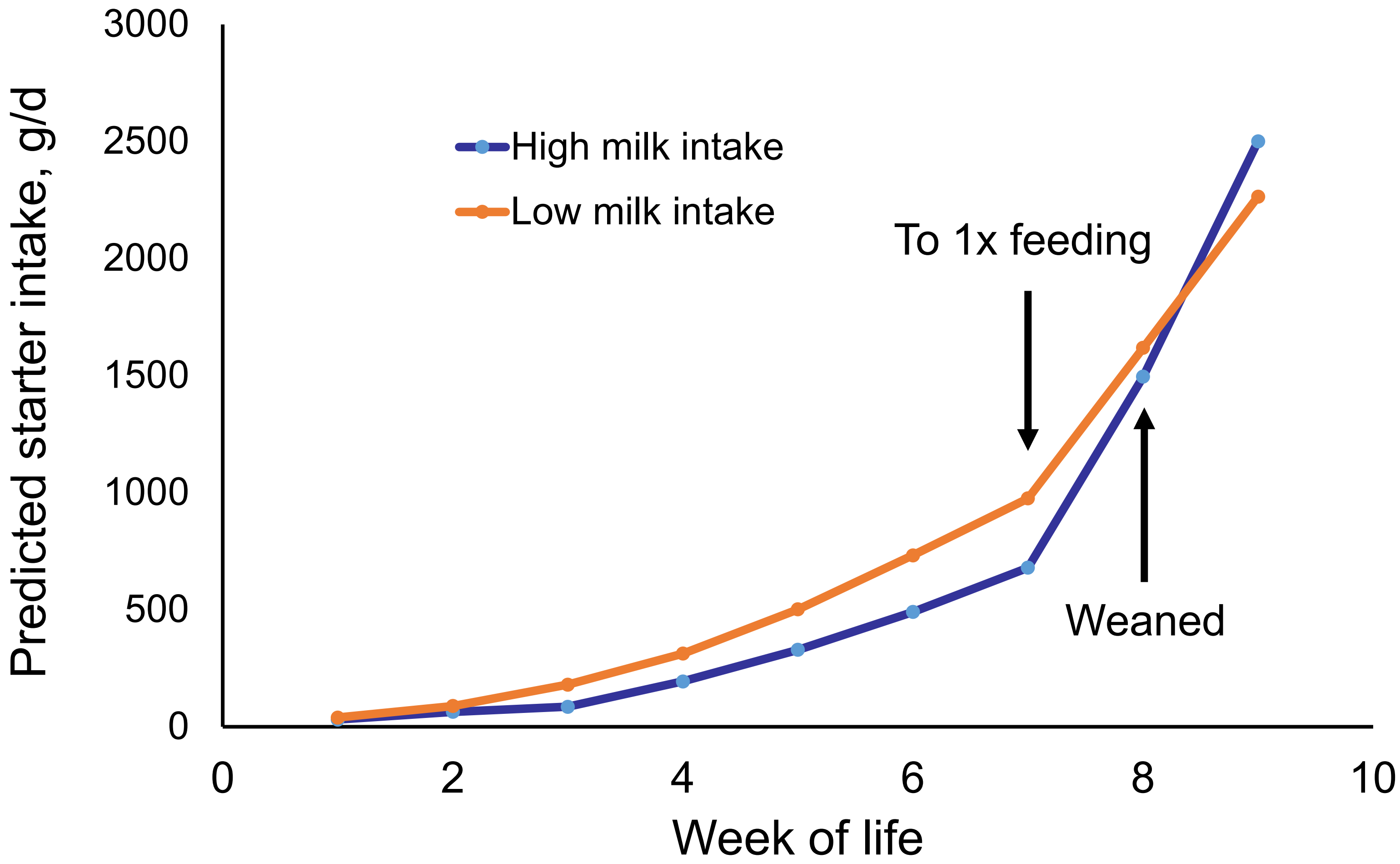
Prediction equations for starter intake (cont'd)

- 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

Predicted starter intake at two milk feeding levels



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.

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 where possible (new)
- *Prediction of retained energy (**RE**, i.e., net energy) is central to model performance.*

To determine RE we must know composition of BW gain

Comparative slaughter studies:

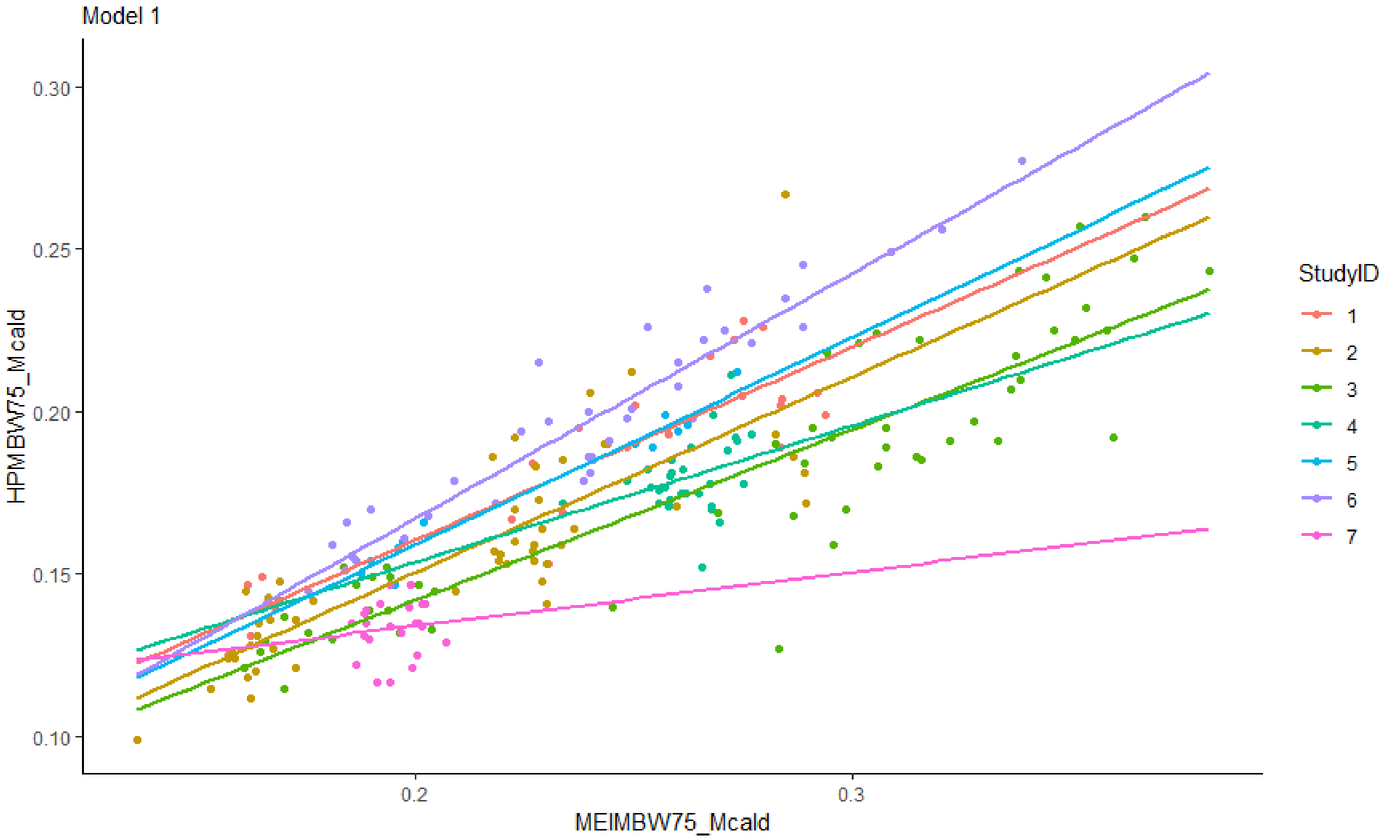
Measured RE = ME intake – Heat production

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

Heat production (HP), Mcal/d = MEI Mcal/d – RE, Mcal/d

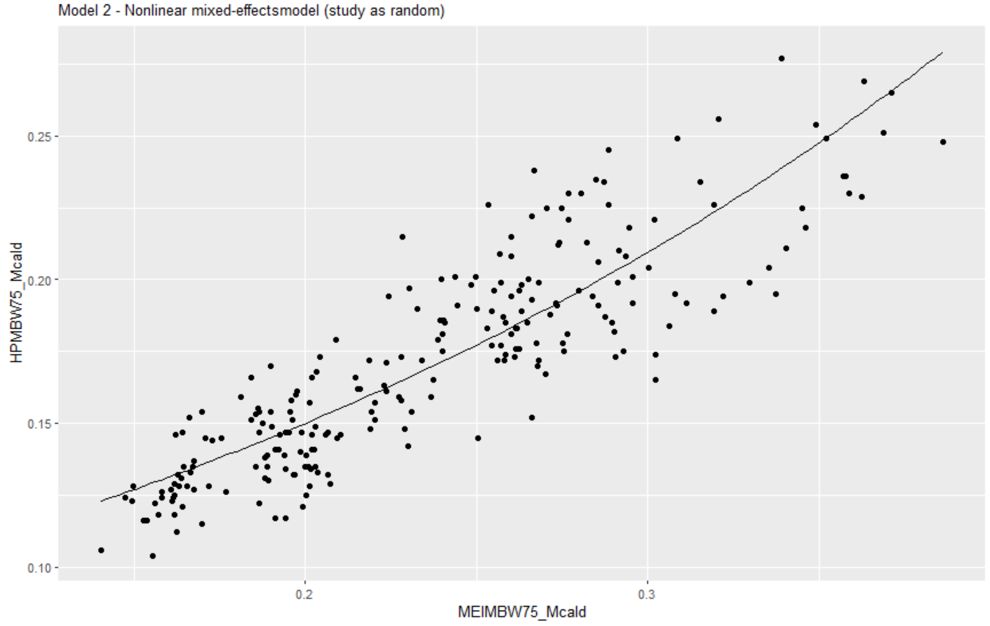
Pred HP_MBW75, Mcal/d

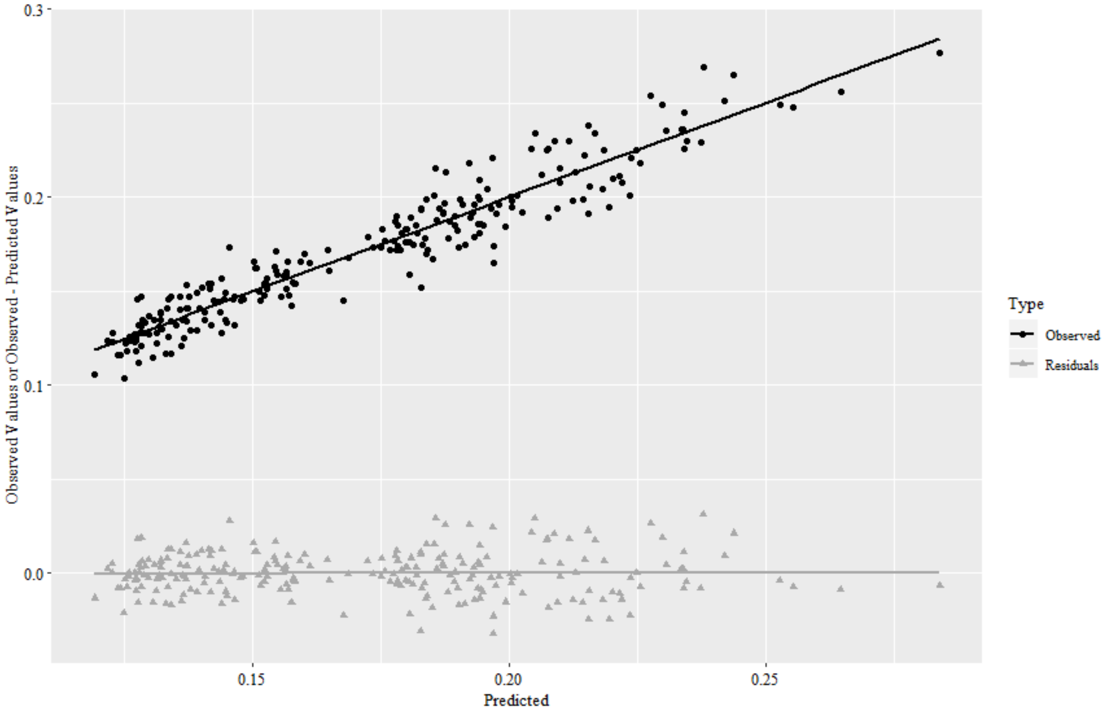


MEI_MBW75, Mcal/d

$$HP = \beta_0 \times e^{\beta_1 \times MEI}$$ (Ferrell and Jenkins, 1998)

HP, Mcal/kg EBW^0.75 = 0.077 × *e*^(3.3426 × MEI, Mcal/kg EBW^0.75)





NEm, Mcal/kg EBW^0.75 = 0.077

MEm, Mcal/kg EBW^0.75 = 0.107

Determination of maintenance requirement

- NEm = 0.077 Mcal/kg $EBW^{0.75}$
  - Considerably lower than value from NRC, 2001 (0.086 Mcal/kg $BW^{0.75}$) but consistent with other systems and data from Silva et al. (2017)
- Maintenance ME = 0.107 Mcal/kg $EBW^{0.75}$ or 0.101 Mcal/kg $BW^{0.75}$
  - Similar to NRC (2001)

Maintenance energy in weaned calves

- NEm = 0.097 Mcal/kg $EBW^{0.75}$
- Maintenance ME = 0.138 Mcal/kg $EBW^{0.75}$ or 0.117 Mcal/kg $BW^{0.75}$
  - Greater than NRC (2001) but lower than in other systems and in Beef NASEM (2016)

Effect of environmental temperatures on maintenance requirement

- +2.01 kcal/kg$^{0.75}$ per day for each degree of environmental temperature (°C) below the lower critical temperature (15°C for calf < 3 wk or 5°C for calf > 3 wk) or above the upper critical temperature (25°C)

Effects of environmental temperature on maintenance energy requirement

	Increase in maintenance energy, kcal of NEm/d		Increase in maintenance energy, %	
Temperature, °C (°F)	< 3 wk old	> 3 wk old	< 3 wk old	> 3 wk old
40 (104)	524	524	28	30
35 (95)	349	349	19	20
0 (32)	698	349	38	18
-10 (14)	1048	698	56	35

- 110-lb calf gaining 1.4 lb/d under thermoneutral conditions would gain only 1.1 lb/d at 104°F

Are maintenance energy values different for small-breed calves (e.g., Jersey)?

- Some data indicate maintenance energy may be up to 20% greater for small-breed calves, even when expressed on metabolic BW basis

- May be related to surface area to mass effects
  - $SA = 0.14 \times BW^{0.57}$ (Brody, 1945)
- So, smaller calf has greater surface to mass ratio, loses more heat, must have higher metabolic rate
- In absence of data committee did not make separate requirement for small calves

Derived an equation linking retained energy (NEg) to body weight gain

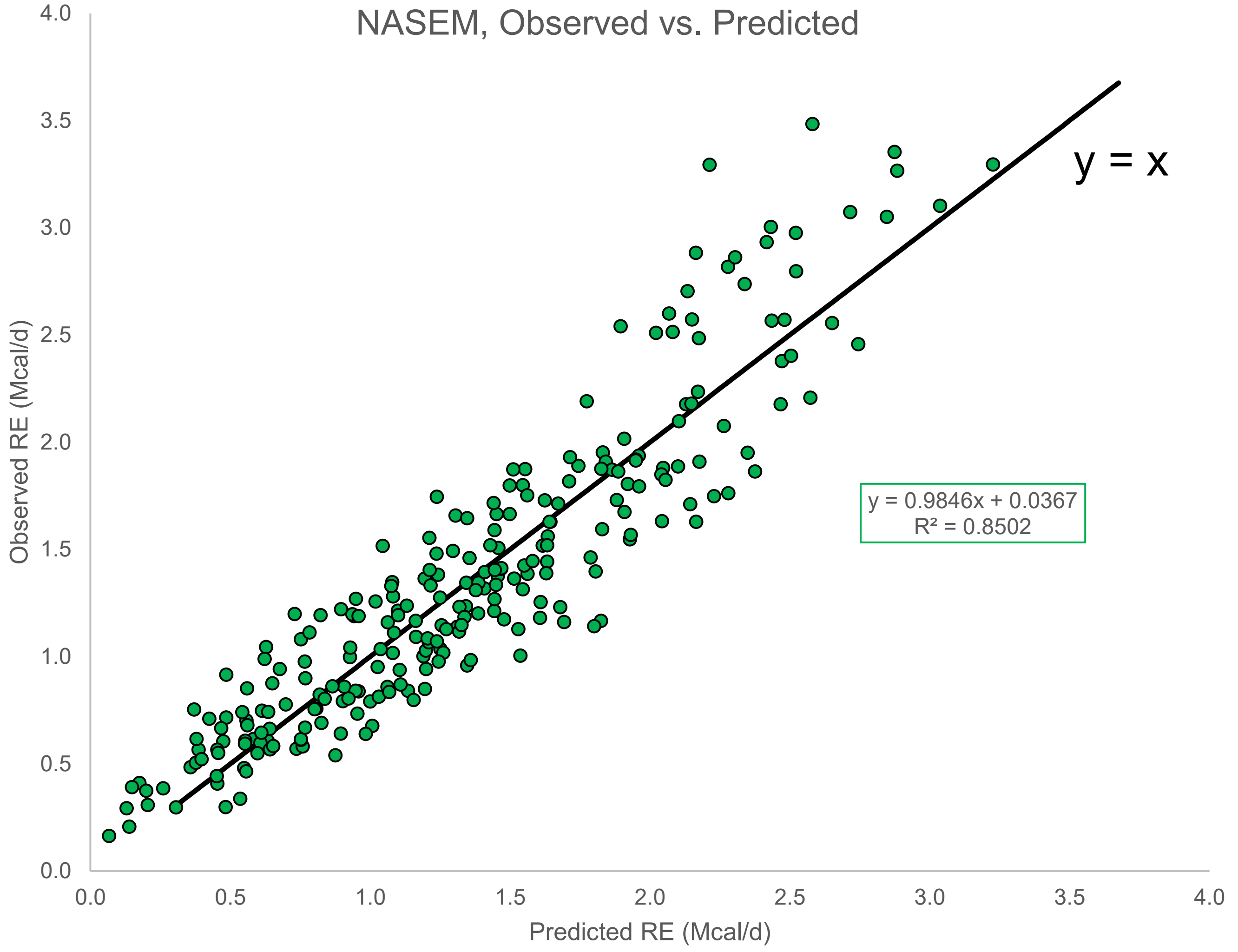
- Ultimately allows linking dietary energy (ME) supply to predicted BW gain
- Equation selected was:

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

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

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

Derived new equation



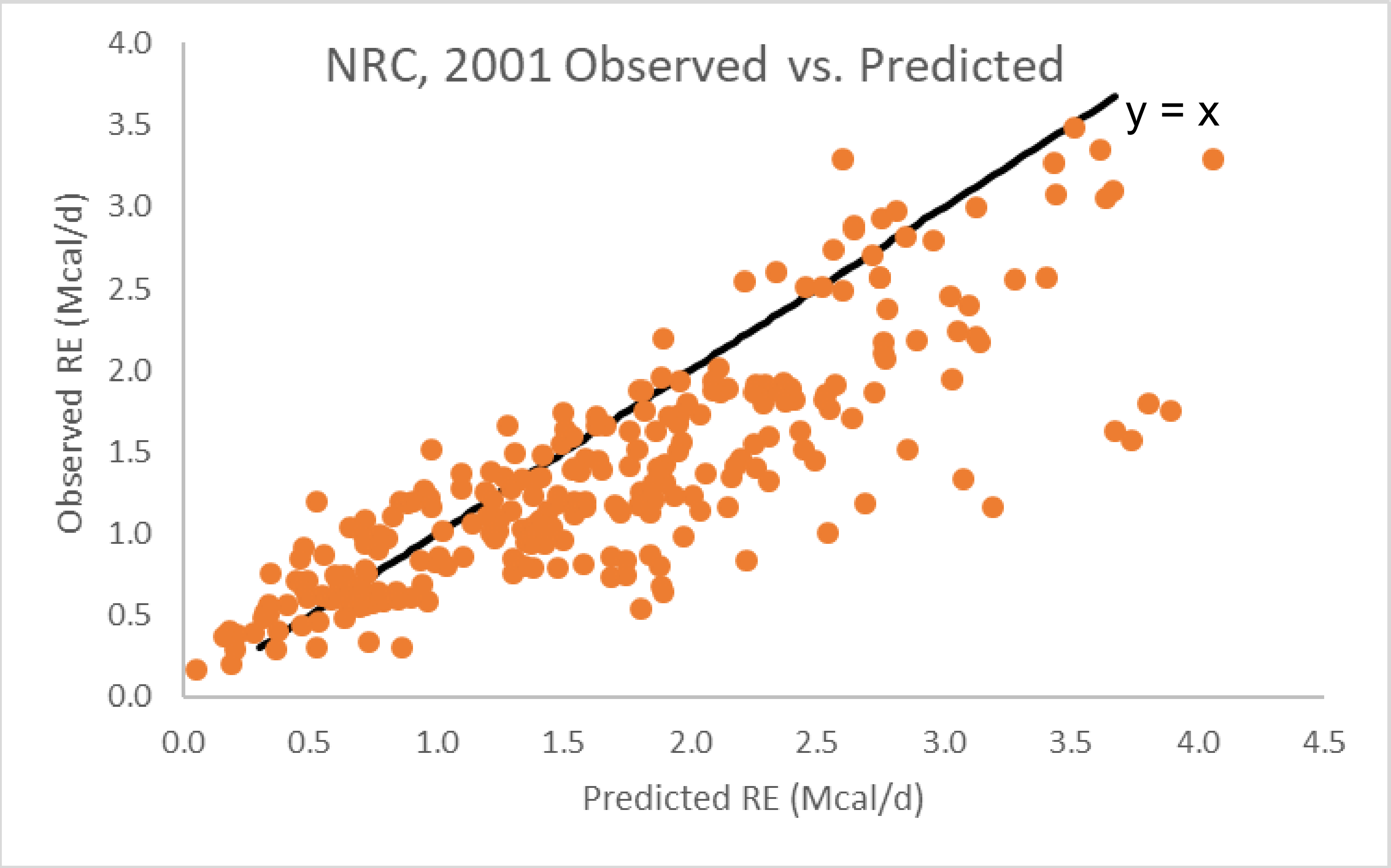
RE = (EBWG^1.1)*(EBW^0.205)

Best equation
(fit, least bias, lowest RMSE)

Random effect of study

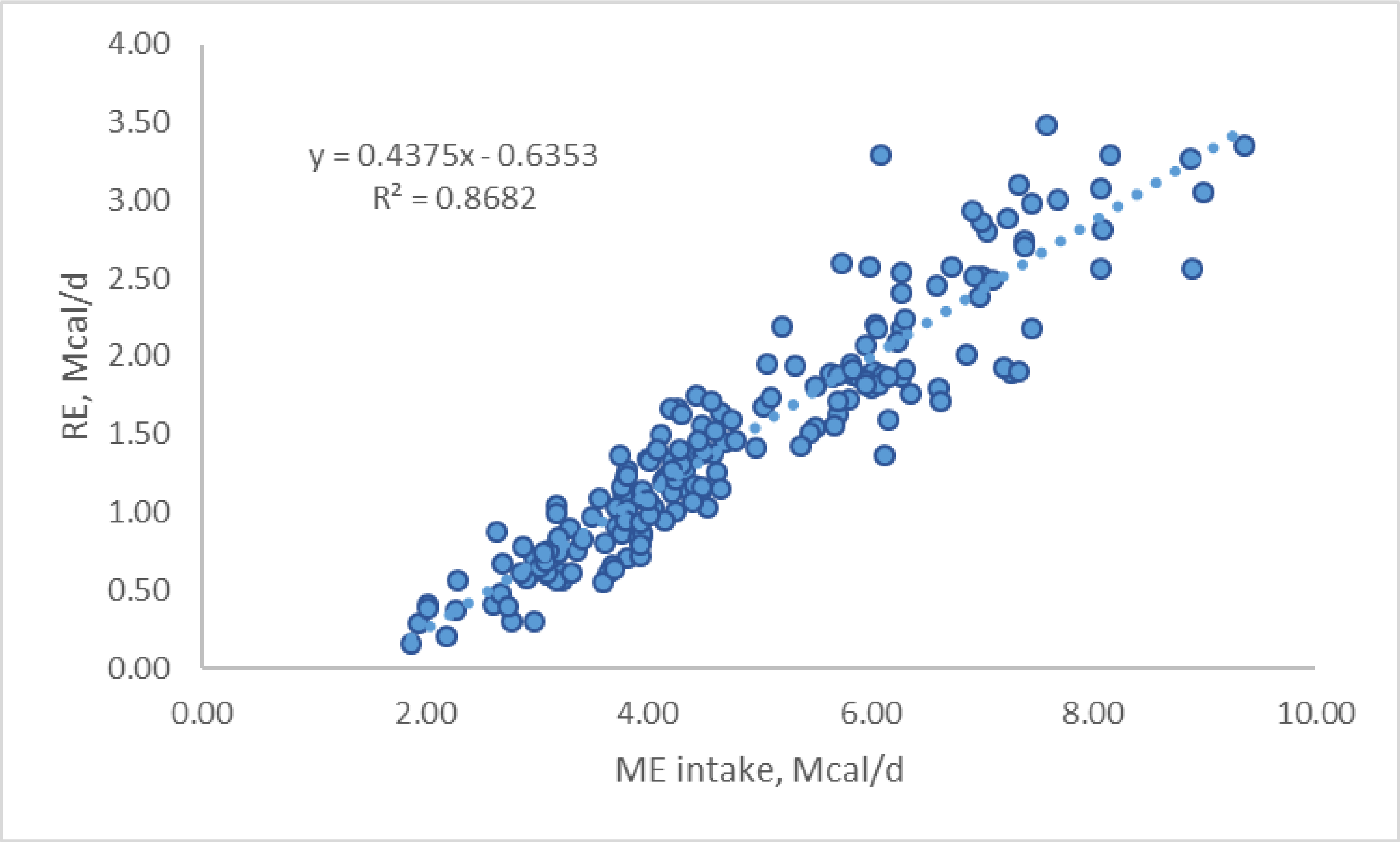
Drackley et al. unpublished

Comparison with NRC 2001



Drackley et al. unpublished

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

Efficiency of ME use = NEg / ME

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

Calculating proportions of fat and protein in gain

- Fat in EBG = 0.0786 + 0.0370 × RE, Mcal/d
- Protein in EBG = 0.1910 - 0.0071 × RE, Mcal/d
- At the mean RE for the data set (1.456 Mcal/d), predicted proportions of fat and protein in EBG are 0.132 and 0.181.

Protein for young calves

- Adopted use of metabolizable protein (MP) instead of apparently digestible CP (ADP) as used in NRC, 2001
- Equals true protein digested and absorbed in GI tract

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) for scurf and metabolic fecal protein (MFP)
- Equations:
  - Scurf CP, g/d = $0.22 \times BW^{0.60}$
  - EUCP, g/d = $2.75 \times BW^{0.50}$
  - MFP, g/d = $(11.9 \times \text{LFDMI, kg/d}) + (20.6 \times \text{SFDMI, kg/d})$

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:

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

Values are generally similar to those in NRC, 2001

Efficiency of use of absorbed amino acids for BW gain

Efficiency of MP use for NPgain decreases with age:

Efficiency of MP for gain = 0.70 - 0.532 × proportion of mature BW

Compared with 0.80 in NRC, 2001

Metabolizable protein

- Conversion of CP to MP:
  - 0.95 for milk CP
  - 0.75 for starter protein digested postruminally
  - 0.70 for dry feed digested with a functioning rumen (weaned calves)
- For calves fed milk and starter, conversion is the weighted average of the values for milk and starter

Vegetable proteins in milk replacer

- Increase endogenous losses of protein in feces
- Necessitates re-calculation of metabolic fecal CP to 34.4 g/kg DM from 11.9 g/kg DM from milk replacer
- Switch in model allows automatic calculation when chosen by user

Requirement tables

- Separate tables of calves of different BW and growth rates for:
  - Calves fed milk or milk replacer only
  - Calves fed both milk and starter
  - Weaned calves
  - Veal calves

Energy and protein for 110-lb Holstein calf (thermoneutral conditions) fed milk replacer, based on the NASEM equations:

ADG (lb/d)	DMI (lb/d)	ME (Mcal/d)	CP (g/d)	CP (% of DM)
0.44	1.23	2.56	102	18.2
0.88	1.58	3.29	156	21.6
1.32	1.96	4.05	209	23.7
1.76	2.33	4.85	262	24.7
2.20	2.73	5.66	315	25.5

Fed milk replacer containing 2.08 Mcal ME/lb DM

How much milk should be fed?

- The committee recommends that a minimum of 1.5% of birth BW as milk solids be fed (1.35 lb for 90-lb calf)
- Based on welfare research data showing hunger and stress in calves fed less

- NAHMS 2014 data shows US average amount fed is 5.7 L/d, which would be ~740 g/d (1.6 lb/d) of milk solids (Urie et al., 2018)

Calculation of feed ME contents: milk replacer

- GE, Mcal/kg DM = ((FA × 9.3) + (Protein × 5.7) + (100-Protein - FA - Ash × 4)) / 100
  - FA determined by multiplying fat content by 0.945
- Other organic components (hydrolyzed starch, dextrins, glucose, glycerol) assumed GE value of ~4 Mcal/kg
- Ash content should be analyzed
- Fat and CP contents listed on tag as “as fed basis” – milk replacers usually 95-97% DM
  - Model assumes 100% DM basis!

Calculation of feed ME contents: milk

- ME of milk replacer is found by multiplying GE by 0.91 (digestible energy = 0.95 GE, metabolizable energy = 0.96 DE)
- Whole milk ME = 0.93 GE (higher digestible energy for milk, 0.97 GE)

Calculation of feed energy values: solid feeds

- DE is calculated similarly to other classes of cattle, except that fat digestibility is assumed to be 0.81 rather than 0.74
- DE is calculated without discounts for intake or starch concentration
- ME is calculated as DE × 0.93
- Starter should be analyzed as described in chapter 3, including digestible NDF (NDFD48)

Summary of studies in which fat digestibility was measured in weaned calves (7 studies, 37 treatment means)

	Mean	Range	SD
BW, kg	98.7	63 – 135	24.6
Age, days	76	51 – 112	24.8
DM intake, kg/d	2.5	1.3 - 4.3	0.76
Dietary fat, % of DM	4.0	2.2 - 5.1	0.69
Fat digestibility	0.81	0.70 - 0.91	0.05

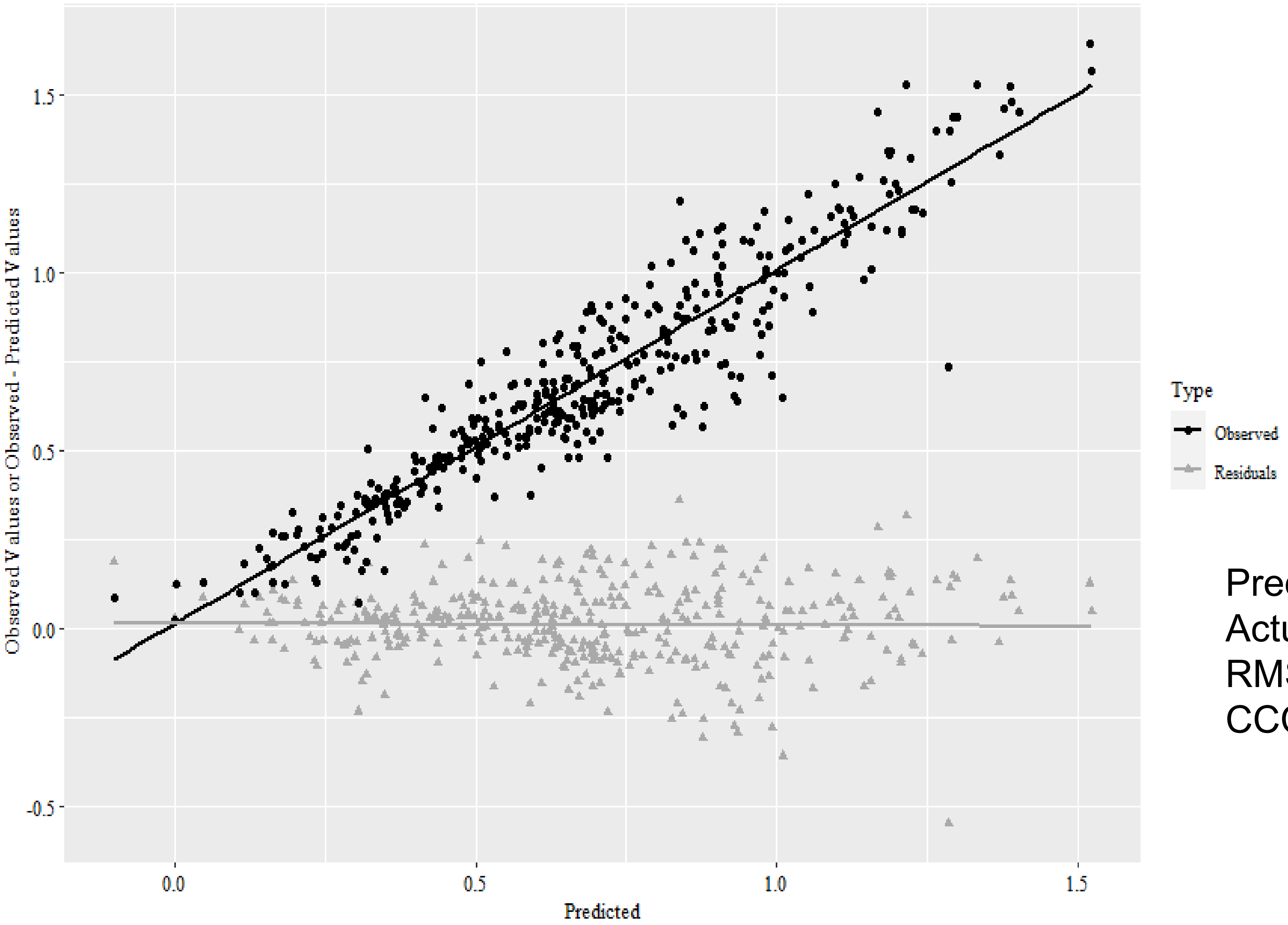
ME obtained from solid feed is lower when rumen is under-developed

- Actual ME obtained from digestion may be lower than calculated value if rumen is not fully developed (Quigley et al., 2018, 2019)
- Common in calves fed large amounts of milk
- Users have option to use discounted (10%) ME value for calves consuming large amounts of milk (>1.5% of BW as solids)

Validation of model with experimental data

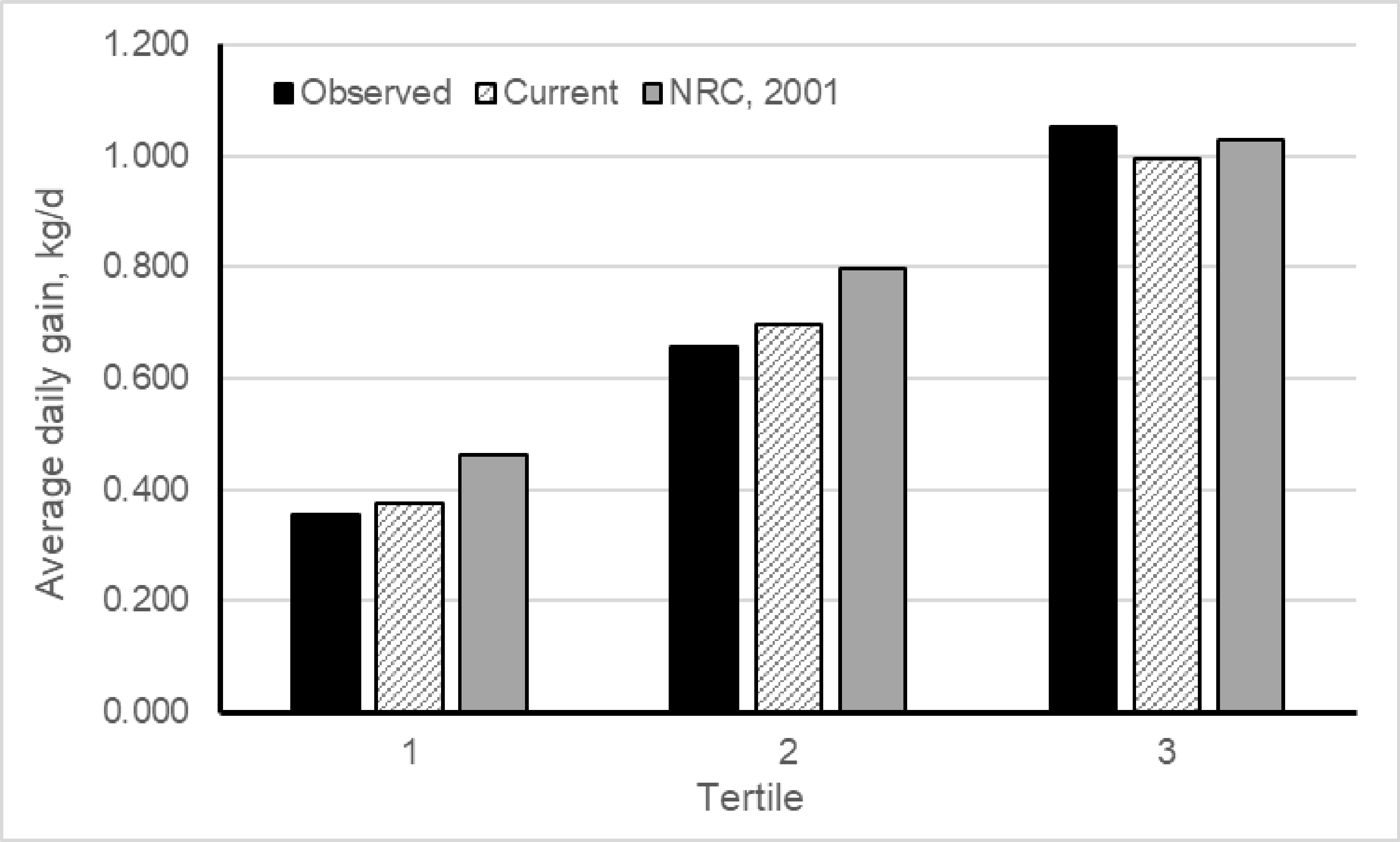
- 397 treatment means from 94 published studies that provided enough data to estimate ME intake, BW, and BW gains
- Included studies before and after NRC, 2001
- Represent a range of milk or milk replacer intakes, starter intakes, forage or not, and ADG

Observed minus predicted values for ADG (kg/d) from 397 literature treatment means, with residuals plotted

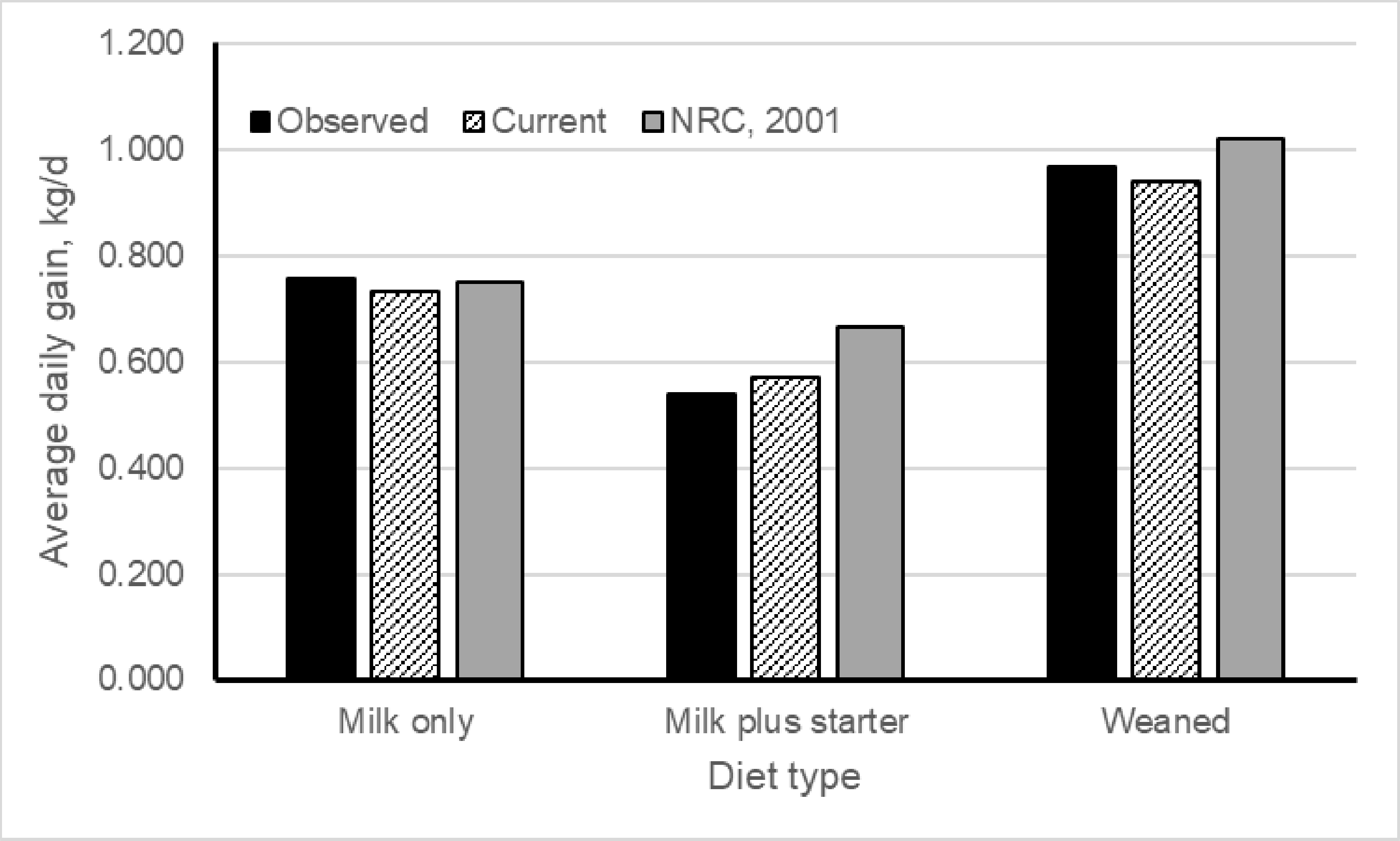


Predicted mean = 0.679 kg/d
Actual mean = 0.689 kg/d
RMSE = 0.110 kg/d (15.9% of mean)
CCC = 0.95

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 110-lb calf fed 1.2 lb of milk replacer (20/20) and consuming 1.25 lb of starter daily
- Predicted growth:
  - NASEM, 2021 = 1.28 lb/d
  - NRC, 2001 = 1.47 kg/d

Comparison of new system with NRC, 2001

- For a 110-lb calf fed 2.2 lb of milk replacer (28/20) and consuming 0.4 lb of starter daily
- Predicted growth:
  - New system = 1.9 lb/d
  - NRC, 2001 = 2.1 lb/d

Mineral requirement for calves

- Clear differences in absorption between calves and adults for many minerals
- More quantitative approach than previous edition
- Should be considered Adequate Intakes (AI) rather than requirements
- Detailed information is given in the text on how AI were calculated for each mineral

Recommended dietary concentrations

- To determine recommended dietary concentrations in milk replacer, AI were calculated for 20 different BW and ADG combinations and averaged
- Results were very similar to concentrations in whole milk (table provided)
- For starter, requirements calculated for weaned calves weighing 110 kg and 60 kg and gaining 0.5 to 1.2 kg/d
- For grower, same procedure except used calves weighing 80 kg and 125 kg

Recommended concentrations of macro minerals

	Milk replacer		Starter		Grower	
Mineral	NRC	NASEM	NRC	NASEM	NRC	NASEM
Ca, %	1.00	0.80	0.70	0.75	0.60	0.65
P, %	0.70	0.60	0.45	0.37	0.40	0.33
Mg, %	0.07	0.15	0.10	0.15	0.10	0.16
K, %	0.65	1.10	0.65	0.60	0.65	0.60
Na, %	0.40	0.40	0.15	0.22	0.14	0.20
Cl, %	0.25	0.32	0.20	0.17	0.20	0.15

Recommended concentrations of trace minerals

	Milk replacer		Starter		Grower	
Mineral	NRC	NASEM	NRC	NASEM	NRC	NASEM
Co, ppm	0.11	NA	0.10	0.20	0.10	0.20
Cu, ppm	10	5	10	12	10	12
I, ppm	0.5	0.8	0.25	0.8	0.25	0.5
Fe, ppm	100	85	50	60	50	55
Mn, ppm	40	60	40	40	40	60
Se, ppm	0.3	0.3	0.3	0.3	0.3	0.3
Zn, ppm	40	65	40	55	40	50

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)
  - AI = 110 IU/kg BW
- Vitamin D3: 3,500 IU/kg milk replacer solids
  - AI = 32 IU/kg BW
- Vitamin E: 200 IU/kg milk replacer solids (125 IU/d)
  - AI = 2.0 IU/kg BW
- No changes in B vitamins or choline (milk replacer)

Implications

- Using data published since NRC 2001, NASEM more accurately predicts RE, and therefore also more accurately predicts ADG.
- These recent advances allow improved predictions of calf requirements and predicted performance.
- Modified equations result in more accurate prediction of growth, both with and without starter.
- How well NASEM predicts beef-on-dairy calves remains to be determined as more data are accumulated.