Updating nutrient requirements and supply: NRC (2001) vs. (NASEM 2021)

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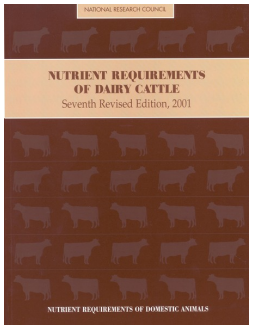
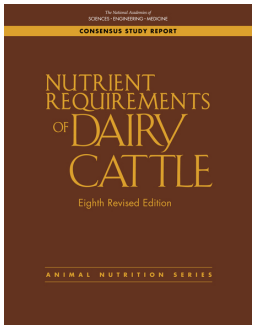




Overview

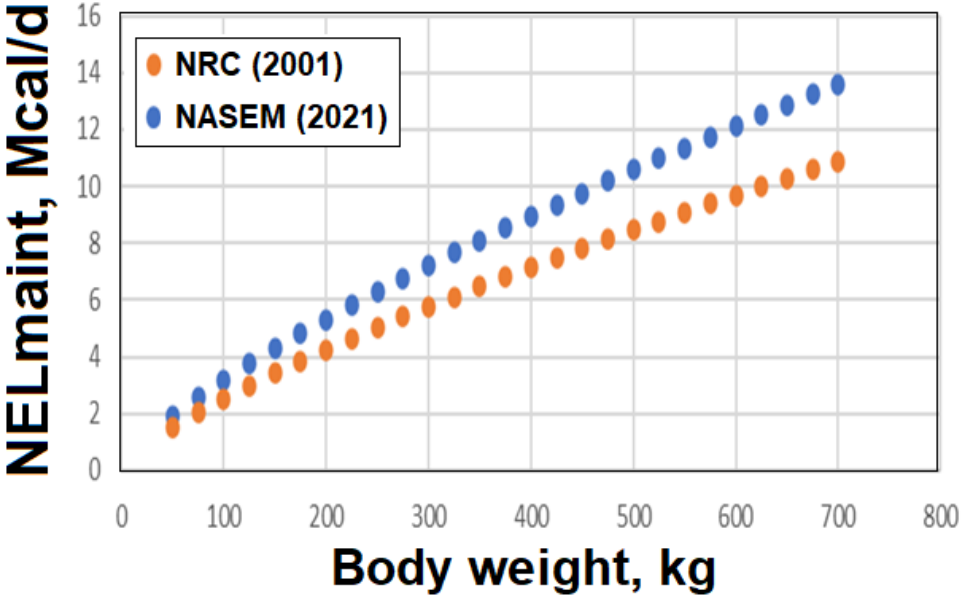
- ✓ Nutritional recommendations for feeding dairy cattle in the USA have been updated. **NRC (2001) vs NASEM (2021).**
- ✓ **RuFaS** model still formulates rations based on **NRC (2001) system.**
- ✓ A simulation for predicting both nutrient requirements and nutrients supply is presented – **dairy cow example**.
- ✓ **On-going and future work.**

Nutritional requirements for feeding dairy cattle have been updated

Energy requirements

- ✓ Studies after the **NRC (2001)** was released indicated that system **underestimated the maintenance requirement of modern dairy cattle.**
- ✓ **Lactation** energy requirements changed slightly because the **efficiency coefficient (0.66) has changed from 0.64.**
- ✓ Better predictions of true BW gains (frame) in NASEM (2021) as **beef cattle data is not longer considered.**

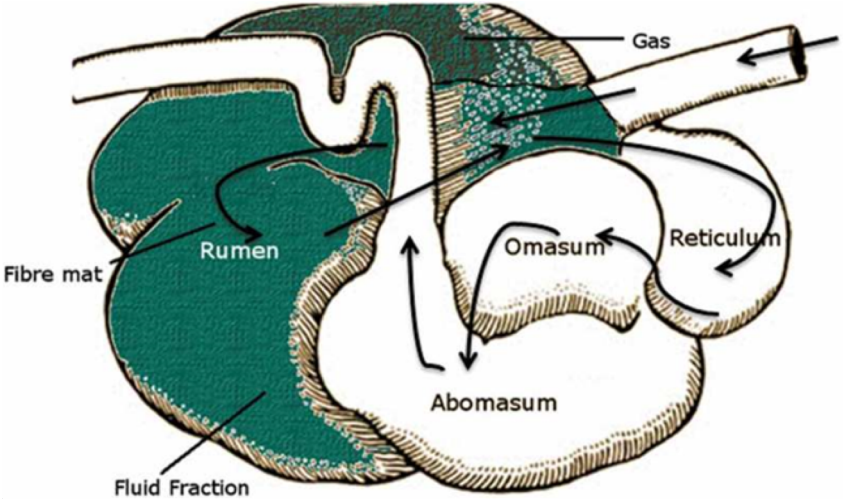
$$NElmaint = 0.8\ vs\ 0.10 \times BW^{0.75}$$



Protein requirements

- ✓ **In addition to metabolizable protein (MP), requirements of individual AA's have been considered in NASEM (2021).** However, there is no "first limiting" amino acid concept as such.

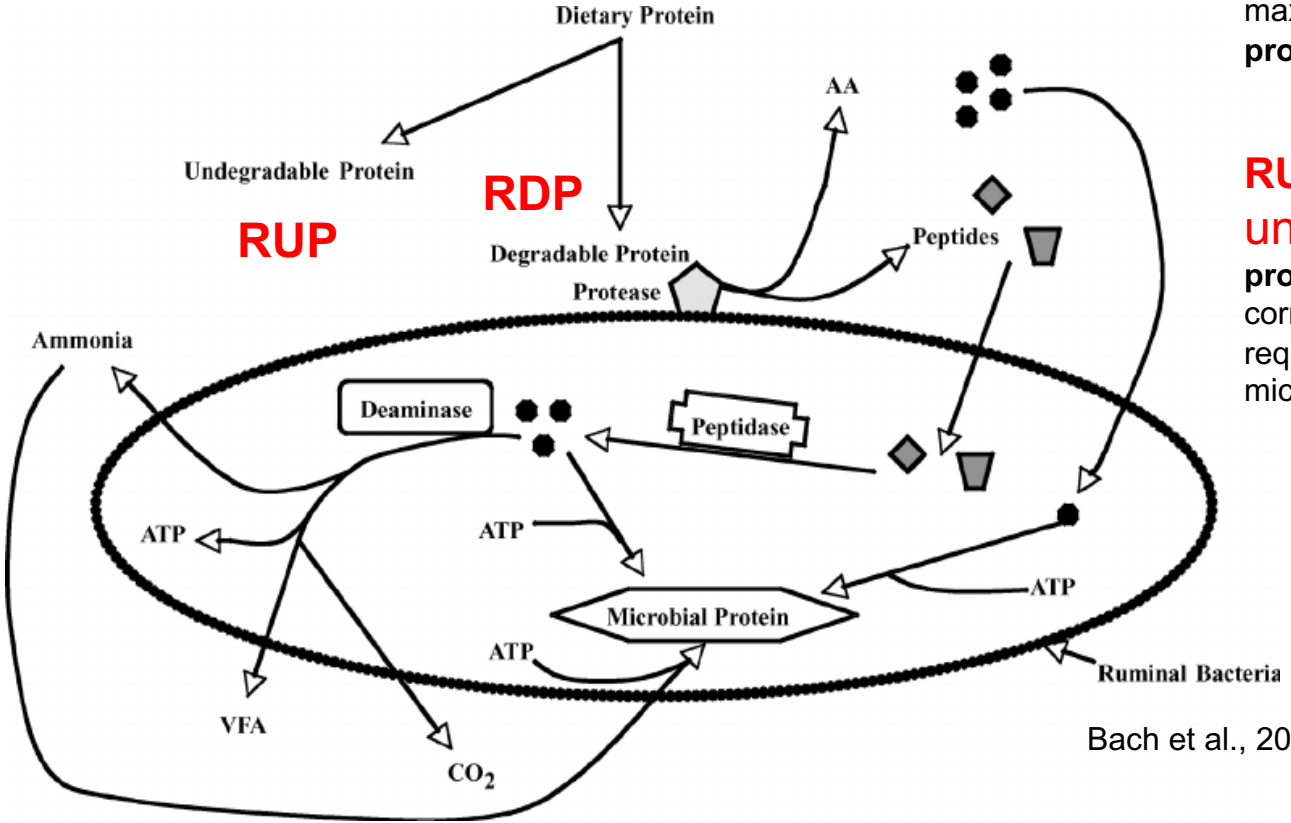
- ✓ The protein and amino acids model has been adjusted focusing on milk protein yield.



Matthews et al. 2019. Gut Microbes 10(2):115-132.

- ✓ In both systems, total MP requirements includes = met. fecal + end. urinary + scurf + growth + lactation., **But NASEM (2021) uses a combined efficiency of use of both MP and AA's.**

Protein degradation and fate of end products in the rumen



RDP = Rumen degradable protein. To meet ammonia and amino acids (**AA**) requirements to maximize synthesis of **microbial protein (MicP).**

+

RUP = Rumen undegradable protein. **To provide the additional AA**, in the correct balance, that the animal requires that are not provided by microbial protein.

=

MP = Metabolizable protein.

The MP supply depends on RUP and microbial protein synthesis.

Bach et al., 2005. JDS 88:(E. Suppl.):E9–E21

Energy and MP requirements - gestation

Day of gestation	Gestation NEL, Mcal/d		Gestation MP, g/d	
	NRC (2001)	NASEM (2021)	NRC (2001)	NASEM (2021)
10	0	0.01	0	0
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

For pregnancy weight gains…

NRC (2001). Linear from 190 days of gestation.

NASEM (2021). Considers an exponential function and that yields increased requirements prior calving!

Minerals

Calcium

NRC (2001) Absorbed grams

- Maint = 0.0154 (nonlact) or 0.031 (lact) g/kg BW
- Milk = 1.22 (H) or 1.45 (J) g/kg milk

NASEM (2021) Absorbed grams

- Maint = 0.9 x DMI (kg)
- Milk = 1.03 (H) to 1.13 g/kg milk (function of milk protein)

Phosphorus requirements change very little!

Some considerations on nutrients supply

Dry matter intake equations for lactating cows

NRC (2001)

$$\mathrm{DMI} = (0.372 \times \mathrm{FCM} + 0.0968 \times \mathrm{BW}^{0.75}) \times \left(1 - \exp^{(-0.192 \times (\mathrm{WOL} + 3.67))}\right)$$

NASEM (2021)

$$\mathrm{DMI} = [(3.7 + \mathrm{Parity} \times 5.7 + 0.305 \times \mathrm{MilkE} + 0.022 \times \mathrm{BW}) + (-0.689 - 1.87 \times \mathrm{Parity}) \times \mathrm{BCS}] \times \left[1 - (0.212 + \mathrm{Parity} \times 0.136) \times \exp^{(-0.053 \times \mathrm{DIM})}\right]$$

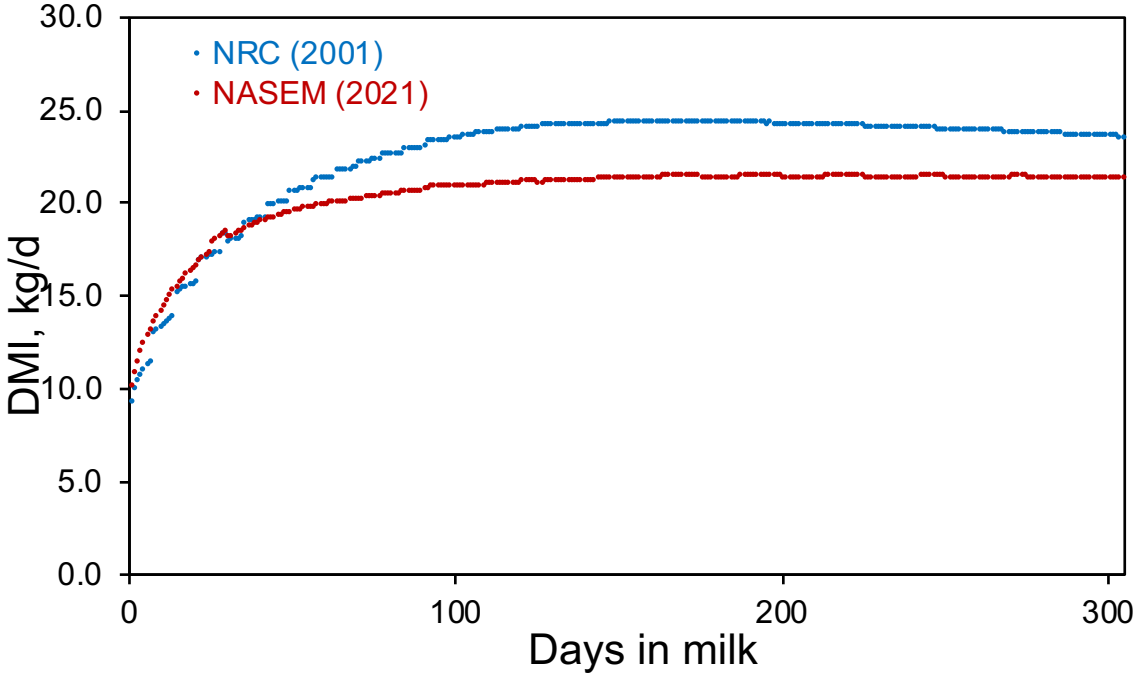
Similarities

- ✓ Milk composition
- ✓ Body weight
- ✓ Lactation time

NASEM updates

- ✓ Effect of parity
- ✓ Body condition score

DMI predictions for lactating cows



NASEM (2021) also includes an additional equation accounting for **ration effects (fNDF, ADF/NDF).**

Growing heifers

In addition to mature BW and actual BW, there is also available a second exponential equation which includes **diet concentration of NDF as predictor variable.**

Energy supply

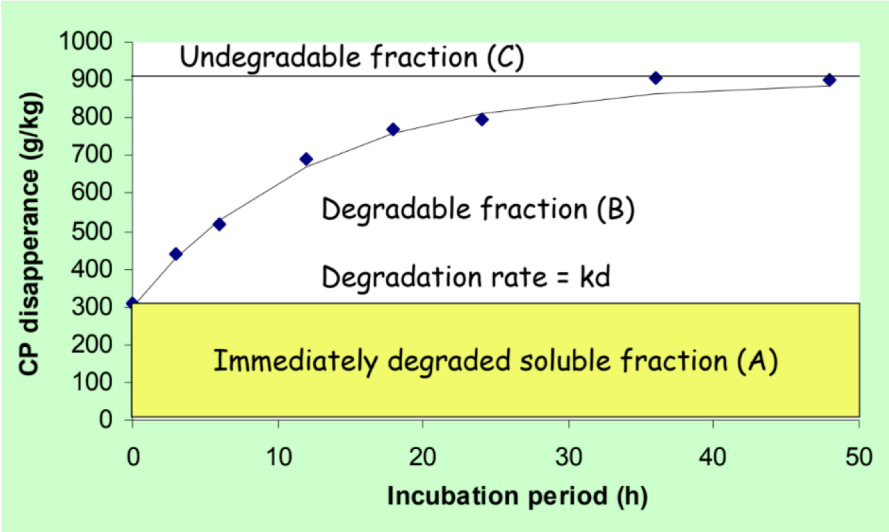
- ✓ Digestibility discount as intake increases was too large in NRC (2001).
- ✓ Discount energy based on % of BW instead of multiples of maintenance.
- ✓ Total digestible nutrients (TDN) vs starch contents of feeds. **TDN is not longer used in NASEM (2021).**
- ✓ The non-fiber carbohydrate fraction (NFC) fraction was replaced with starch and residual organic matter (ROM).
- ✓ Energy supply improves based on discount values, CH_4, production and N discounts.

Protein supply

- ✓ In NASEM (2021), microbial protein is estimated based on estimated rumen digested starch and fiber (according to diet composition, not digestion rates).

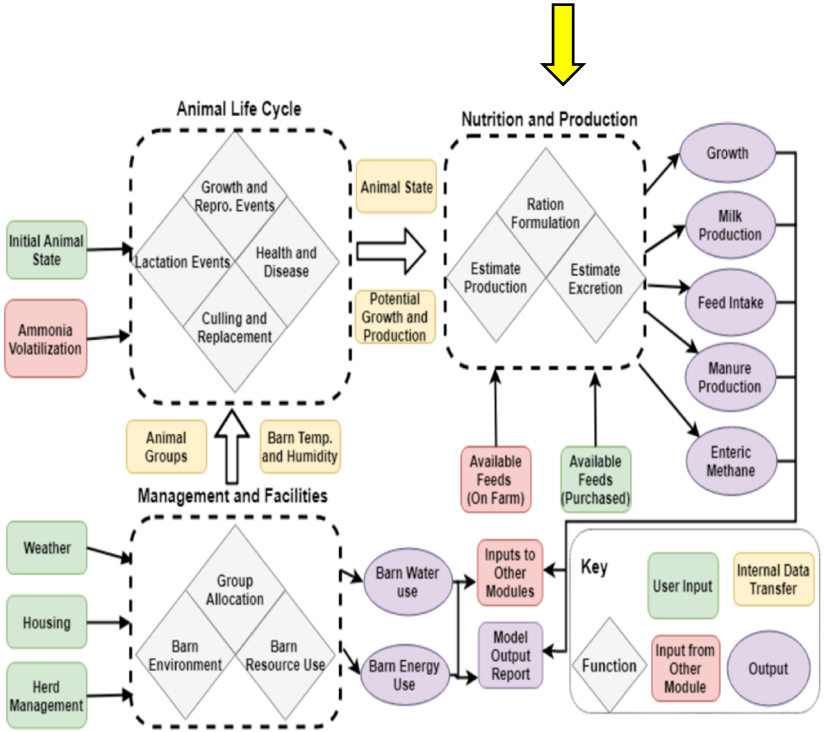
- ✓ **Constant rates of passage are used for both forages and concentrates (NASEM, 2021).** Instead of estimation of passage rate based on intake (NRC, 2001).

- ✓ **Endogenous protein is NOT included in the MP supply in the updated system (NASEM, 2021).**



Rumen undegradable protein is still based on the A, B, C fraction scheme described in NRC (2001)

Current version of RuFaS model formulates rations based on NRC (2001)



Animal Module overview

- ✓ **Least-cost diets** formulated for five animal categories including: calves, heifers, and cows (lactating and dry) on a daily basis: **herd dynamics**.
- ✓ **Nonlinear programming-based** deterministic global optimization (MINLP_DGO) according to herd dynamics and available feedstuffs.
- ✓ **Diets are formulated** to fulfill energy, protein and minerals, along with other limitations on intake, FDN, and fat are considered as contrasts (**NRC, 2001**).

An example of ration report for a pen (csv files)

main.py | pen_report.json

```
{
    "pens_report": {
        "produce_csv": true,
        "produce_graphics": true,
        "report_name": "pen_report",
        "ration_report": {
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            "produce_graphics": true,
            "report_name": "ration_report",
            "ration_interval": 7
        },
```

Herd dynamics (day-to-day)

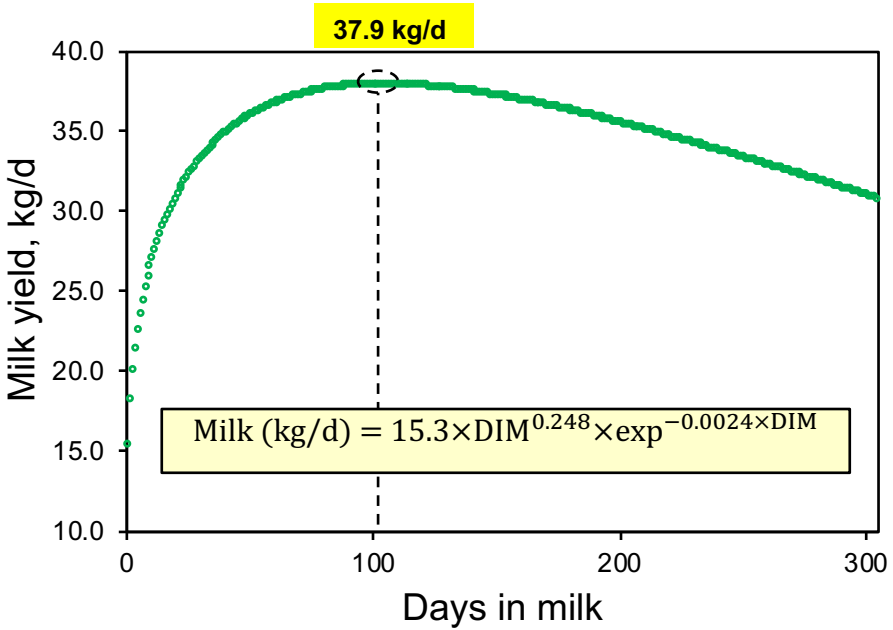
Feed library - **NRC (2001)**
Daily amounts to be offered to the animals

year	j_day	num_animals	86 (LEGUMES, FORAGE)	26 (CORN, YELLOW)	118 (SOYBEAN)	103 (OATS)	136 (Dicalcium Phosphate, dibasic)	139 (Limestone, ground)
			kg	kg	kg	kg	kg	kg
2009	244	851	11270	9512	0	0	95.2	0
▪	▪	▪	▪	▪	▪	▪	▪	▪
▪	▪	▪	▪	▪	▪	▪	▪	▪

Updating nutritional recommendations NRC (2001) vs NASEM (2021)

Animal model

- ✓ Breed: Holstein (481 kg at 1 DIM).
- ✓ **Parity: 1**. Pregnant at 90 DIM.
- ✓ BW data retrieved from a random cow within RuFaS simulation.
- ✓ Wood's lactation curve (Li et al. 2022).
- ✓ Milk composition. Diet = 50 For. : 50 Conc. (Cabezas-Garcia et al. 2021).
- ✓ BCS according to Truman et al. 2022.



- ✓ Milk yield at 305 DIM = **10575 kg**
- ✓ Average production = **34.7 kg/d**

Diet offered – ingredient composition

Ingredient	% DM basis
Corn silage	32.7
Alfalfa	17.8
Shelled corn	24.5
Fuzzy cottonseed	9.3
Soybean meal	5.2
Soybean meal heated	5.2
Distillers grain	5.2

Forage-to-concentrate ratio **50:50**

By-product

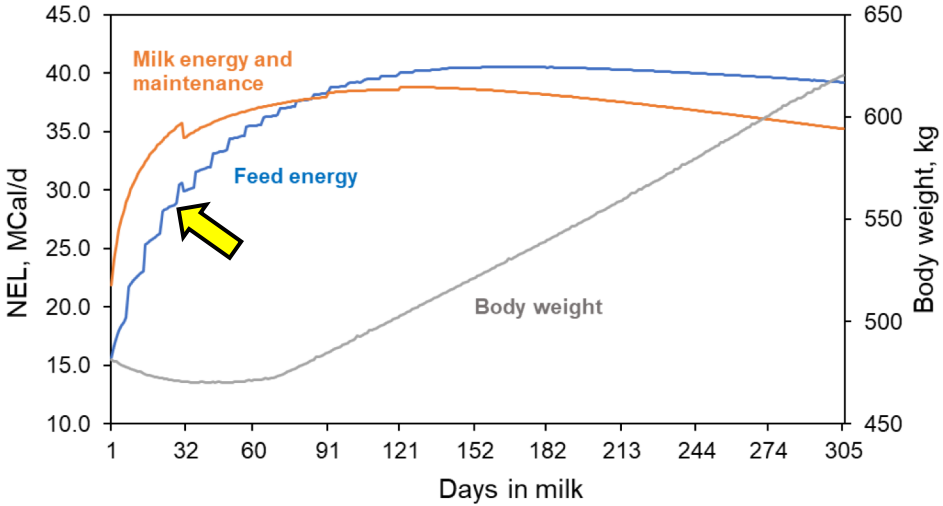
Diet offered – nutrients supply

Nutrient	NRC (2001)	NASEM (2021)
NEL, Mcal/kg	1.66	1.81
Crude protein, %	16.2	17.2
NDF, %	29.7	30.2
Calcium, %	0.64	0.60
Phosporus, %	0.39	0.38

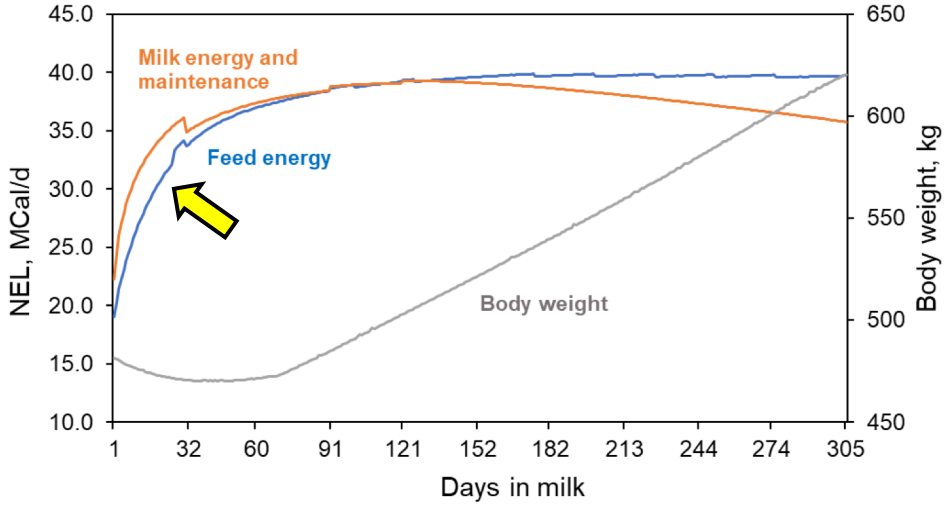
In addition to differences in prediction equations, **this may suggest considerable differences in feedstuffs composition – libraries.**

Comparison of feeding systems – NEL requirements

NRC (2001)



NASEM (2021)



The NRC (2001) predicted an increased energy deficiency (NEL, Mcal/d) during the first of lactation for the offered diet.

Comparison – MP requirements at the peak of lactation

Item	NRC (2001)	NASEM (2021)
Animal factors		
Milk yield, kg/d	37.9	
Time to peak, DIM	105	
DMI, kg/d	23.7	21.0
Met. Protein, g/d		
Supply	2289	2100
Requirement	2492	2395
Balance	-203	-295

Final remarks

On-going and pending work

- ✓ **To implement revised Pseudo-code** with updated NASEM (2021) equations within RuFaS.
- ✓ **To evaluate user-input diets** for comparison purposes with optimized diets.
- ✓ I'm happy to discuss ideas towards improvements in feed formulation submodule. **Feedback is always appreciated!**

$$P_{main} = 1.0 * DMI + 0.0006 * BW, for\ lactating\ cows; \quad [A.Cow.C.7]$$

P_{main} = Phosphorus maintenance requirement, g/day

$$P_{growth} = (1.2 + 4.635 * MW^{0.22} * BW^{-0.22}) * ADG \quad [A.Cow.C.8]$$

P_{growth} = Phosphorus growth requirement, g

$$Ppreg = 0.02743 * exp\left((0.05527 - 0.00007) * DGest\right) - 0.02743 * exp\left((0.05527 - 0.000075 * (DGest - 1)\right) * (BW/715) * (DGest - 1)), if\ DGest > 190; \quad 0, otherwise \quad [A.Cow.C.8]$$

P_{preg} = Phosphorus pregnancy requirement, g

$$P_{lact} = MYield * (0.49 + 0.13 * TPMilk);\ Myield * 0.90 \quad [A.Cow.C.9]$$

Otherwise when milk protein is unknown

eCornell

python™

panke_buisse_feed.json | pen_report.json

```
"feed_database": "input/databases/feeds.sqlite",
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"nutrient_table": "nutrients",

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                          "118": 0.39, "136": 0.1, "139": 0.05, "155" : 0.82, "157": 0.44},
"farm_grown_feeds": [],
```


Thank you!