Feeding the metabolic race car: *a discussion on the use of starch and fat as fuels to support milk production*

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August 3, 2021
10:00 AM EST
Real Science Lecture Series

balchem
Solve Today. Shape Tomorrow.

Live is a Chemical Process

Lavoisier and Laplace, 1783; proved animals “combust” feed

- Observed that the amount of heat produced by a guinea pig is equal to the amount of. which has been ice melted.
- Also determined that an animal and a fire produced the same amount of heat per unit of carbon dioxide produced.
- Others showed that the amount of heat produced when an animal *__metabolized a substance__* was the same as the amount of heat when the substance was *__combusted__*.

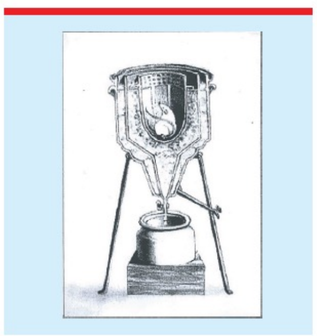
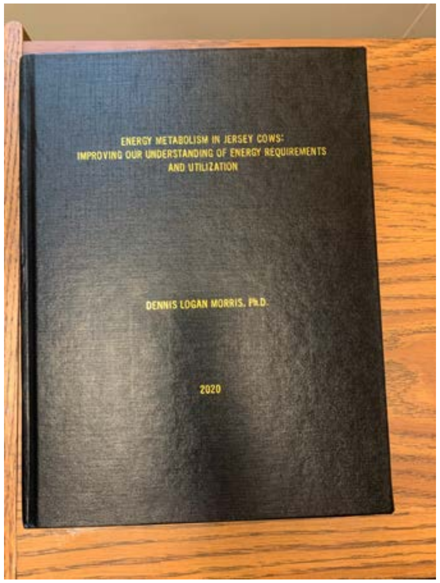


Figure 2. The ice calorimeter of Lavoisier.

Todays workshop:

Energy metabolism in Jersey Cows: *Improving our Understanding of Energy Requirements and Utilization*

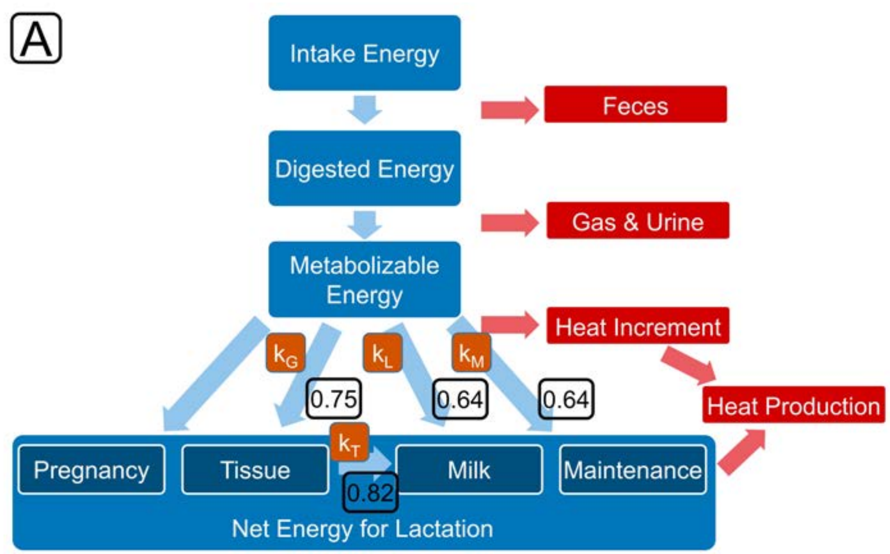
- D. L. Morris (2020)



Laws of thermodynamics

Application to animal nutrition (Weiss, 2007)

1st Law: Energy cannot be created or destroyed; all energy consumed must be accounted for.

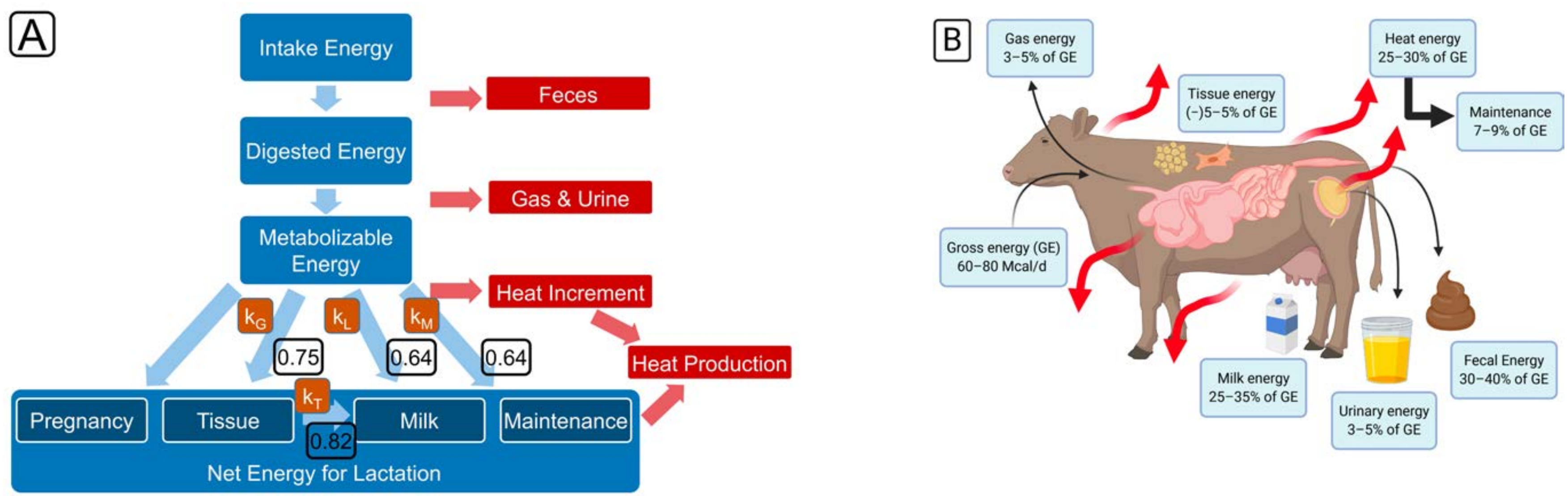


Laws of thermodynamics

Application to animal nutrition (Weiss, 2007)

1st Law: Energy cannot be created or destroyed; all energy consumed must be accounted for.

2nd Law: Entropy of the universe always increases; no transformation of energy is 100% efficient and inefficiencies are lost as heat.

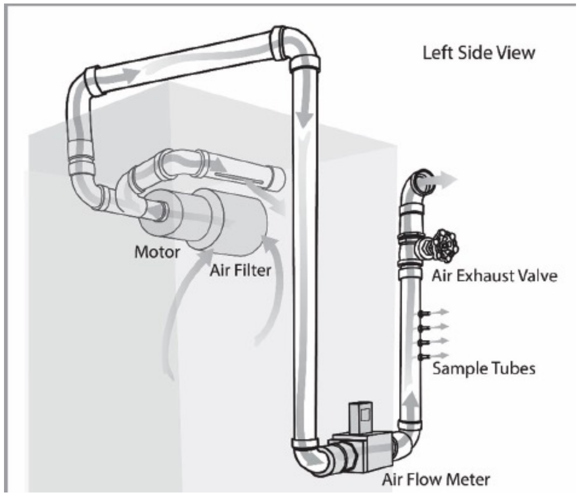


Indirect calorimeter

The study of energetics, measuring heat production

- Respiration Chamber used to estimate heat production from gaseous exchange.
- Measures O2 consumption and CO2 and CH4.
- Assumes all oxygen is used to degrade "fuel."
- Can calculate heat produced by body using an equation which is based on the combustion of starch, protein, and fat resulting CO2, CH4 and urea as end products (Brouwer, 1965).

$$\text{Heat (kcal/d)} = 3.866 * O_2 + 1.200 \times CO_2 – 0.518 * CH_4 – 1.431 * N$$



Morris, D. L. 2020. PhD Dissertation; Energy Metabolism in Jersey Cows: Improving our Understanding of Energy Requirements and Utilization.

Indirectly measuring heat loss during lactation in Jersey and Holstein Cows

Item	**Amount, (per unit of $BW^{0.75}$)**
Oxygen consumption, L/d	5, 917[1] (51)
Carbon dioxide production, L/d	6, 380 (55)
Methane production, L/d	504 (4.35)
Urinary nitrogen excreted, g/d	200 (1.73)
Heat Produced, Mcal/d	29.5 (0.25)

[1] Jersey ~ 5, 000 L and Holstein ~ 6, 800 L

[2] As calculated by the Brower equation, $HP = 3.866 \times O_2 + 1.200 \times CO_2 - 0.518 \times CH_4 - 1.431 \times N$

Data on file, University of Nebraska-Lincoln

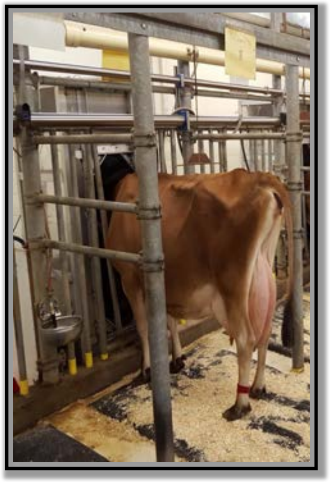
Indirectly measuring heat loss during lactation

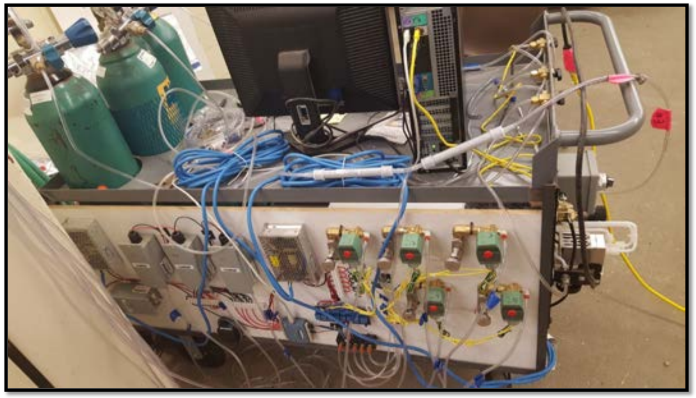
Item	Volume	per unit of $BW^{0.75}$
Oxygen consumption, L/d	5, 917	51
Carbon dioxide production, L/d	6, 380	55
Methane production, L/d	504	4.35
Urinary nitrogen excreted, g/d	200	1.72
Heat Produced, Mcal/d	29.5	0.25

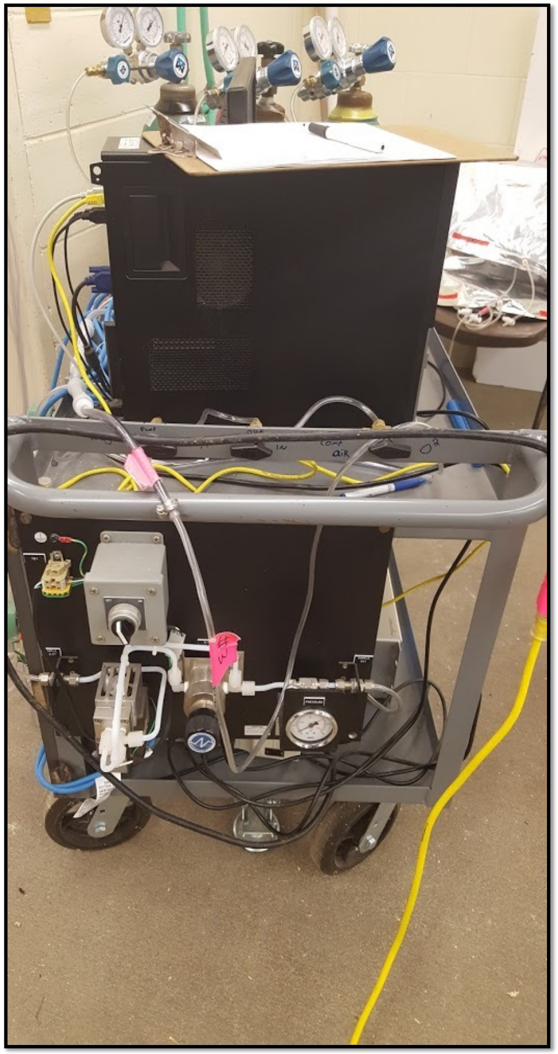
[1] As calculated by the Brower equation, HP = 3.866 X O2 + 1.200 X CO2 – 0.518 X CH4 – 1.431 X N

Activity	Oxygen Consumption, L/min (L/d)	Daily, per unit of $BW^{0.75}$
Adult male, at rest	0.25/(360)	13
Athletically trained male exercising	4.00/(5, 760)	213
Male marathon runner	5.10/(7, 344)	272

UNL Energy Research







What is energy?

- Ability of a feed to support work done or products formed
- Amount of heat released when something is completely burned

1 lbs (2.01 Mcal/lb) 1 lbs (4.3 Mcal/lb)

=

- Will they support to the same amount production?

Not all energy is created equally

Starch

- ➢Supports microbial protein
- ➢Propionate production
- ➢Glucose supply

Fat

- ➢"Rumen-inert"
- ➢Energy dense
- ➢Support milk fat

How does manipulating energy source affect metabolism?

Experimental diets

- **STA** = High starch; **HFA** = High fat

Items, % of DM	STA	HFA
Corn silage	38.1	38.1
Alfalfa hay	21.0	21.0
Ground corn	22.5	2.5
Soyhulls	4.1	6.5
Soybean meal	11.5	10.9
Bypass Soy[1]	—	0.6
Cottonseed hulls	—	12.5
DDGS	—	2.5
Fat[1]	—	2.6
Other[2]	2.8	2.8

[1]Soypass; Energy Booster 100
[2]Rumen-protect Lys and Met; vitamins and minerals

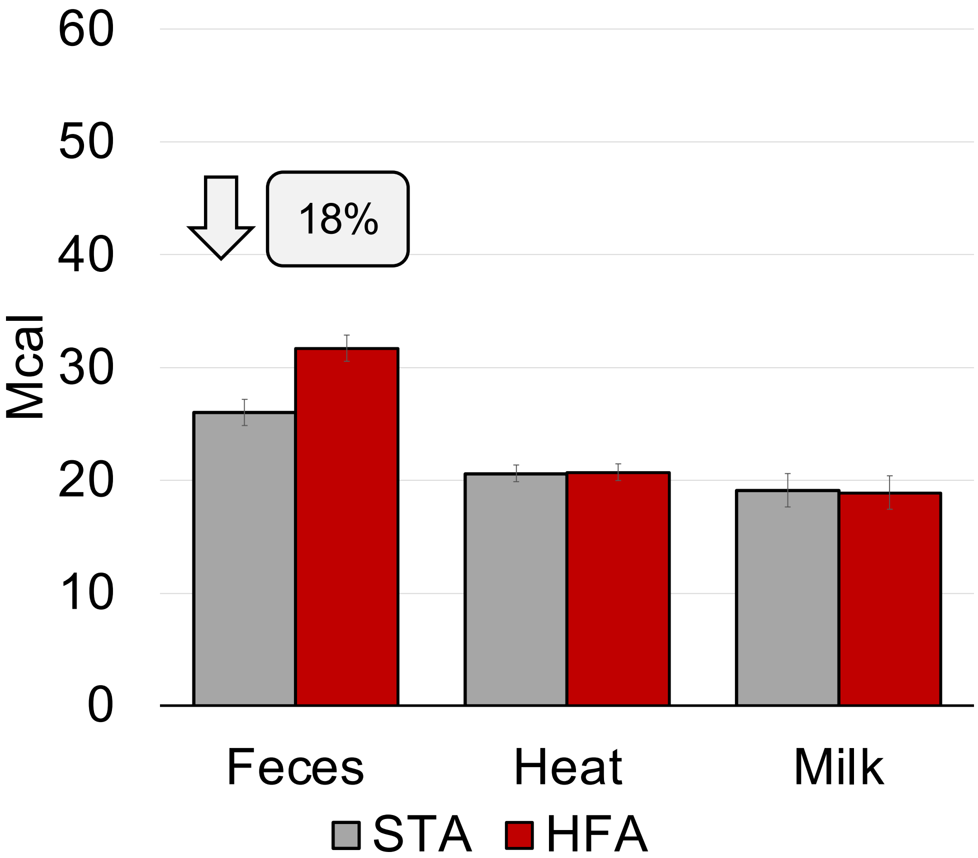
Items, % of DM	STA	HFA
CP	15.5 (0.52)	16.0 (0.35)
NDF	31.8 (3.19)	41.7 (1.90)
Starch	30.8 (0.42)	16.8 (0.85)
Fatty acids	1.88 (0.02)	4.06 (0.14)
NEL, Mcal/kg	1.55	1.56

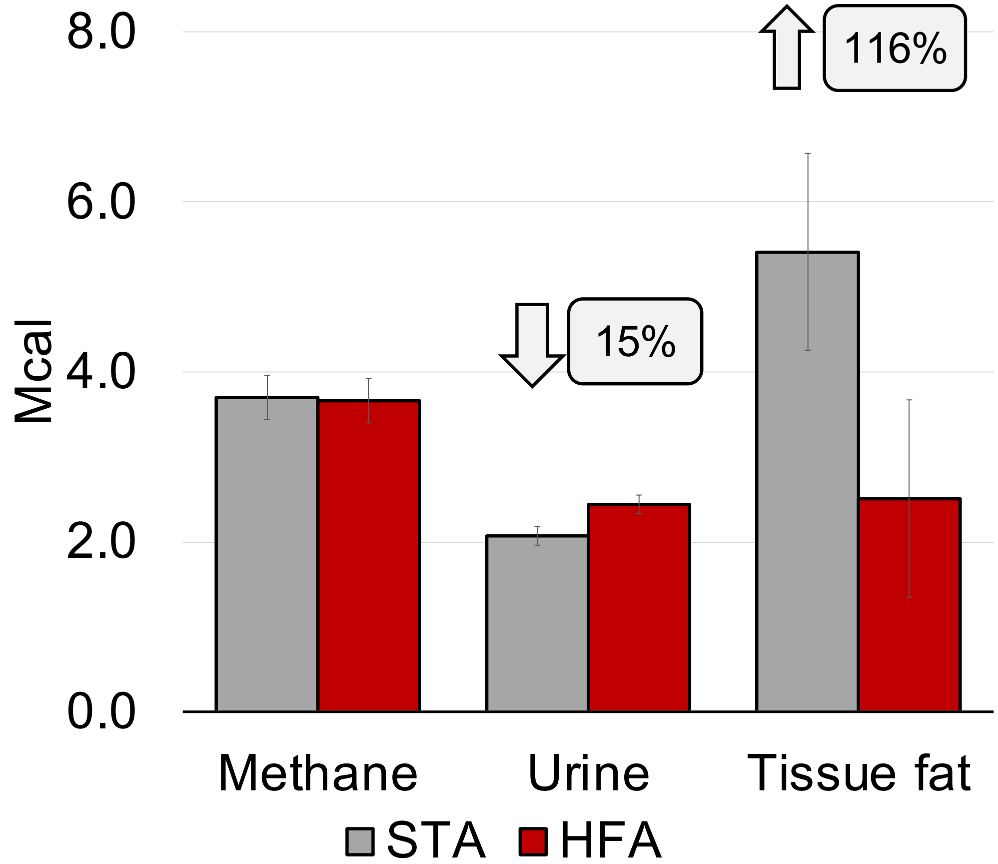
[1]NRC, 2001 using mean production and measured composition

Animals used

- Lactating Jersey cows, 192 DIM and 1037 lbs

Energy utilization

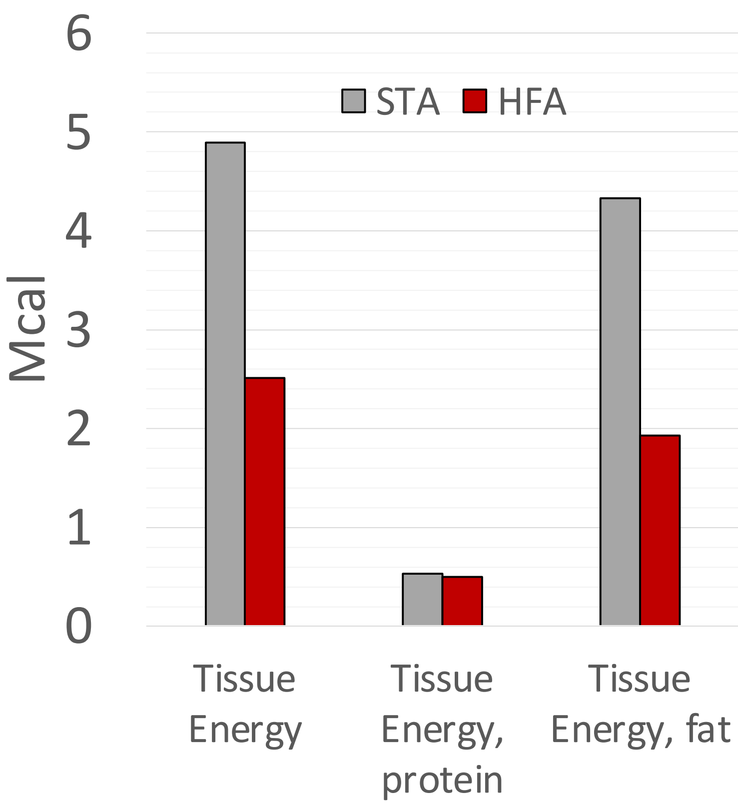




Morris et al., 2020 JDS:4378

Energy utilization

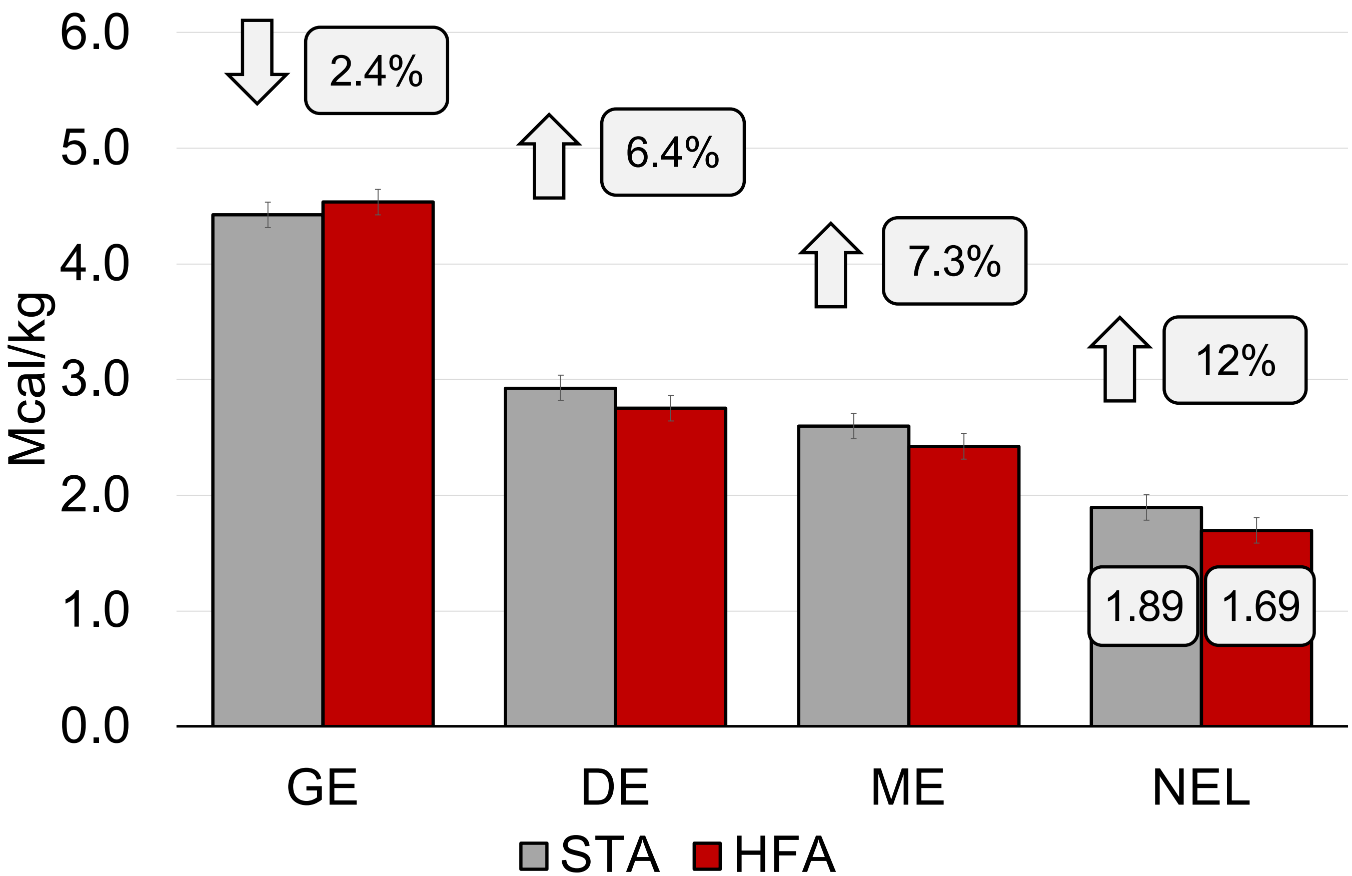
Feeding more starch resulted in more tissue energy as fat



Respiratory quotient, (CO_2 production/02 consumption, L/L)

- oxidation of lipids, protein, and carbohydrates yield an RQ of 0.71, 0.81, 1.00.
- An RQ > 1.0 indicates lipid synthesis.
  - STA = 1.09
  - HFA = 1.05
- Indication of increase insulin from increasing the supply of glucogenic precursors.

Dietary energy content

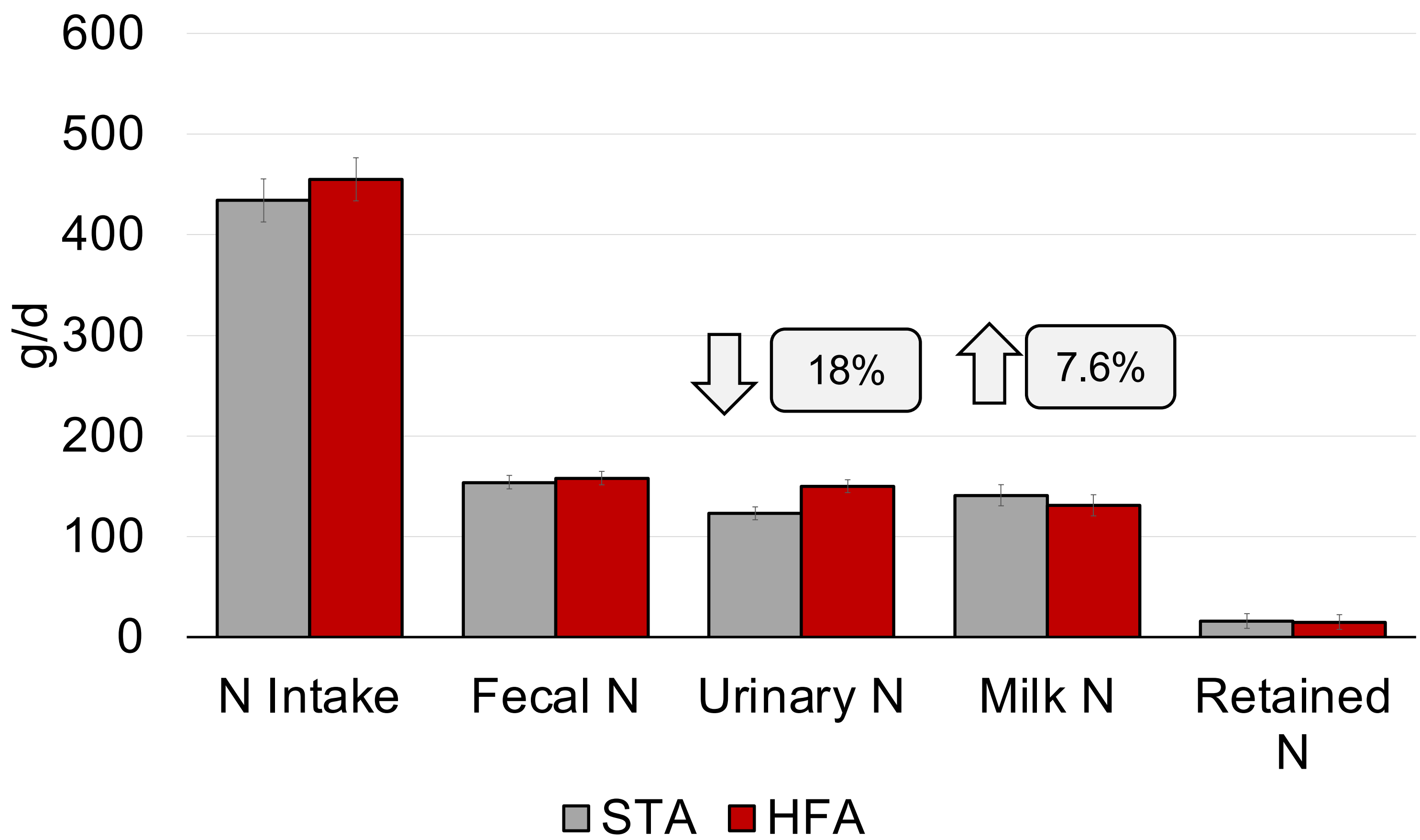


Morris et al., 2020 JDS:4378

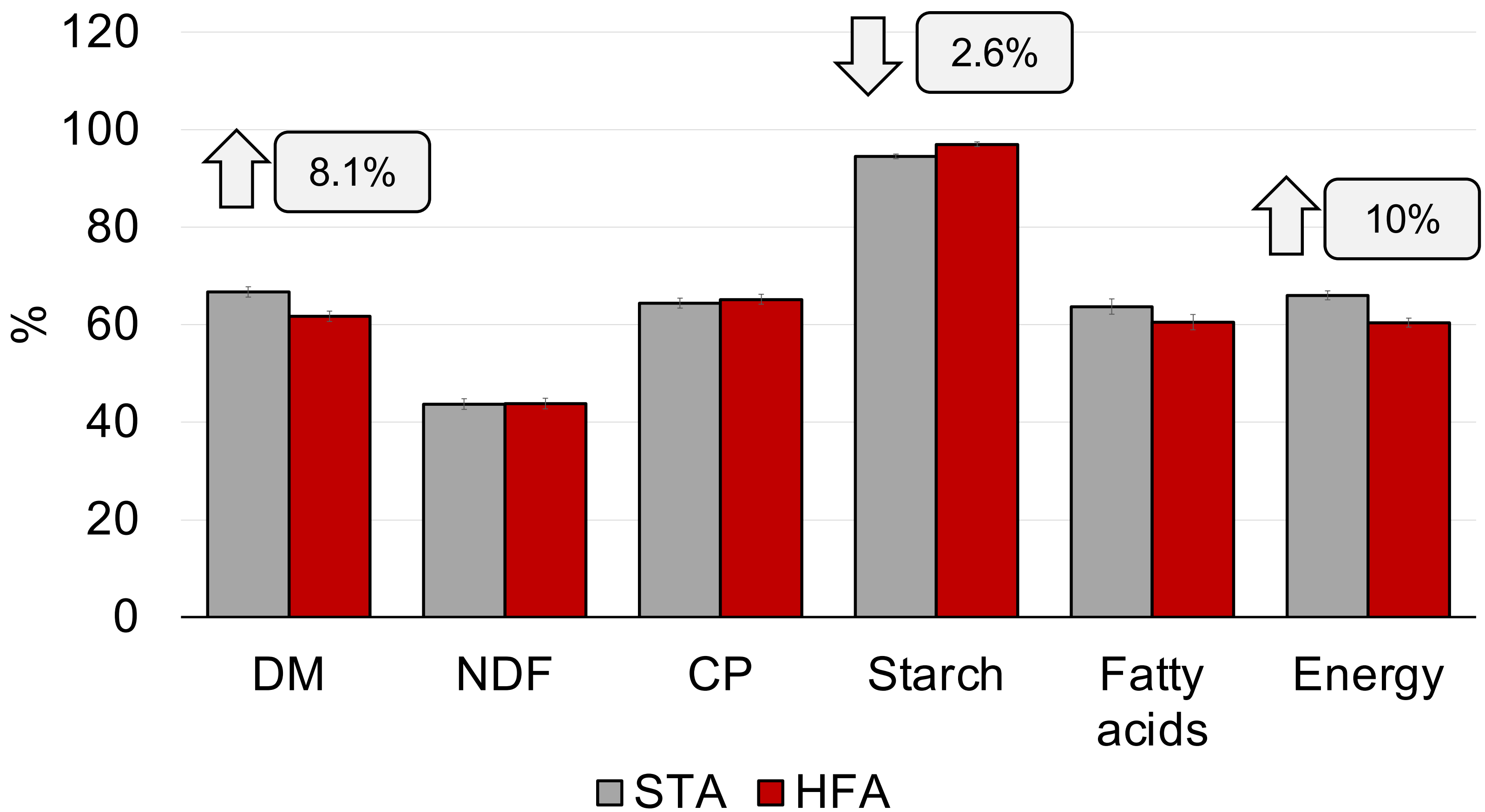
NRC, 2001 NEL

- STA = 1.56
- HFA = 1.55

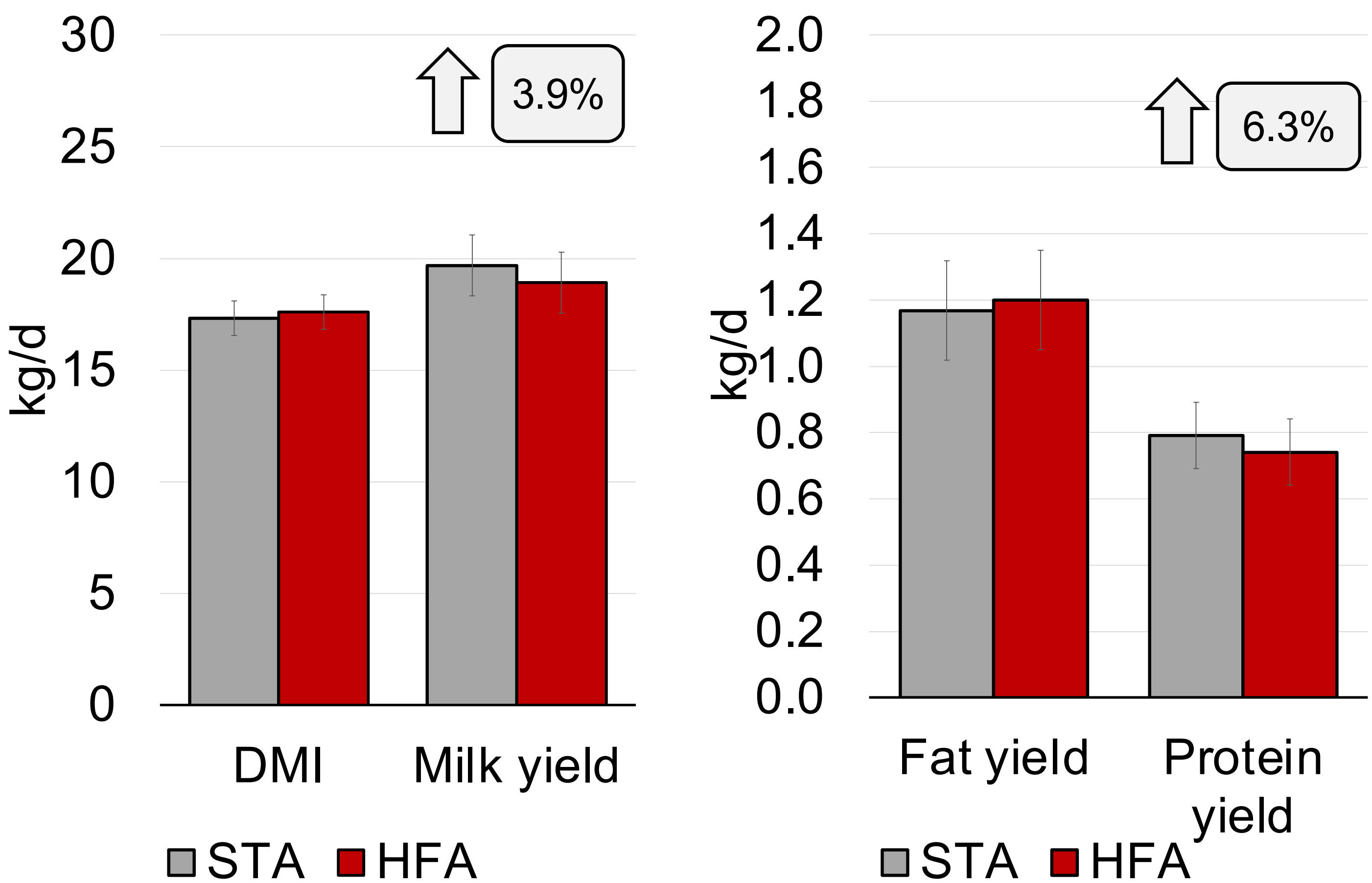
Nitrogen Utilization



Nutrient Digestibility



DMI, milk production and composition



Morris et al., 2020 JDS:4378

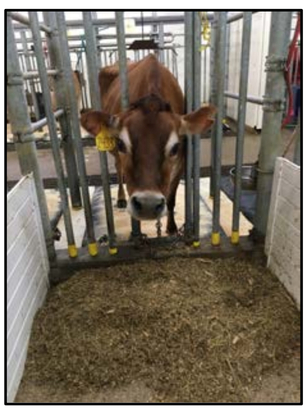
Practical implication of feeding starch vs. fat

- Corn is $240 to 300 per ton
- Fat is $1500 to 2000 per ton
- Milk protein is ~$2.0/lbs
- Milk fat is $1.90/lbs

- ↑ dietary starch to ↓ cost and ↑ milk protein
  - Too much starch = milk fat depression
  - Can lead to increased body weight gain
- Bring in fat to meet energy requirements

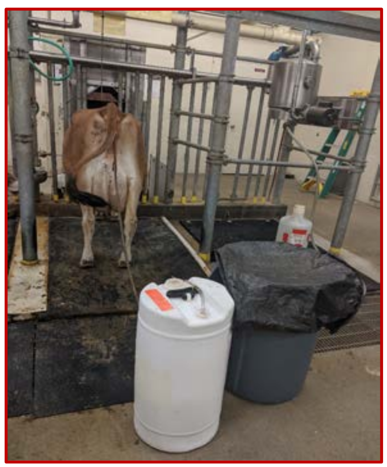
How does energy interact with amino acids metabolism?

- FA supplies 4-10 % of DE
  - saturated fat used postabsorptive and may be directly transferred to milk fat.
- Starch supplies 25 – 40 % of DE
  - supplies ruminal and post-ruminal energy.
  - tends to support milk protein and reduce milk fat.
- Lys is thought to be limiting in corn-based diets.



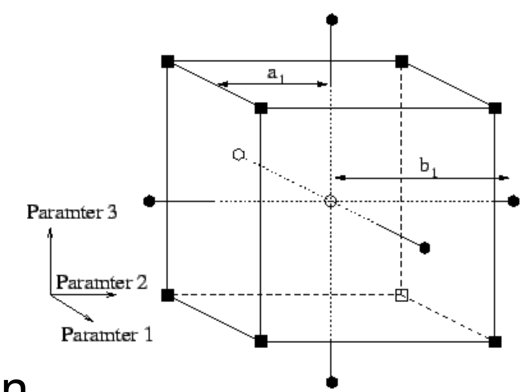
Hypothesis

- Milk protein synthesis as well as energy and N utilization with increased Lys supply will depend upon dietary energy source.



Treatments and stats

- Response surface experiment conducted to test the interaction between 3 factors:
  - Dietary fatty acids (**FA**; 3.0 to 6.2%)
    - 0 to 4% supplemental fat (EB Merge) (57g/100 FA; C16:0, 21% C18:0, 11% C18:1)
    - Replaced soyhulls
  - Dietary starch (20.2 to 31.3%)
    - Replaced soyhulls with corn grain
  - Supplemental digestible Lys (**dLys**; 0 to 15.8 g/d)



- 5 levels of each factor arranged in a central composite design
  - 15 treatments
- Regressions with linear and quadratic effects and all two-way interactions

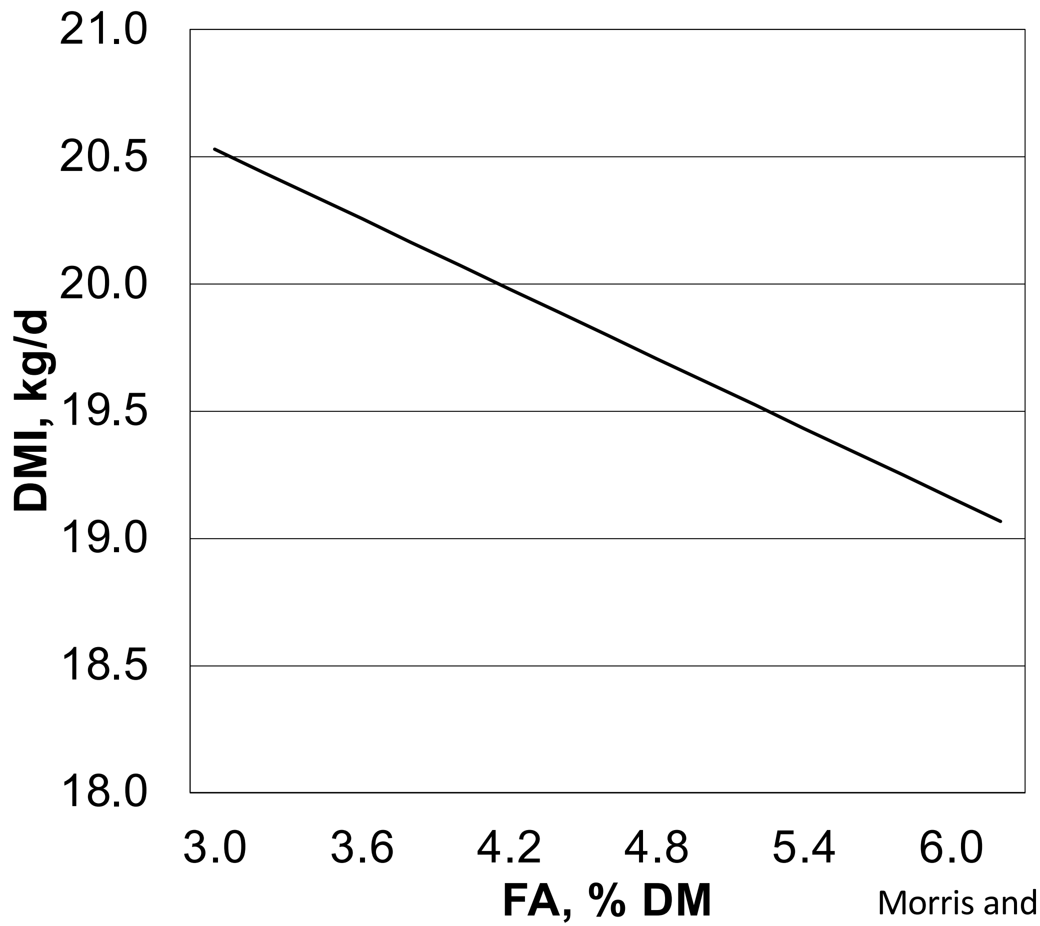
Morris and Kononoff, In Press

Descriptive statistics

Item	Mean	SD	Min	Max
N (cows)	25			
BW, kg	424	38	365	498
DMI, kg/d	19.7	2.1	14.9	24.7
ECM, kg/d	35.1	4.0	27.7	48.3
Fat, g/d	1415	186	1078	2167
Protein, g/d	981	126	758	1324

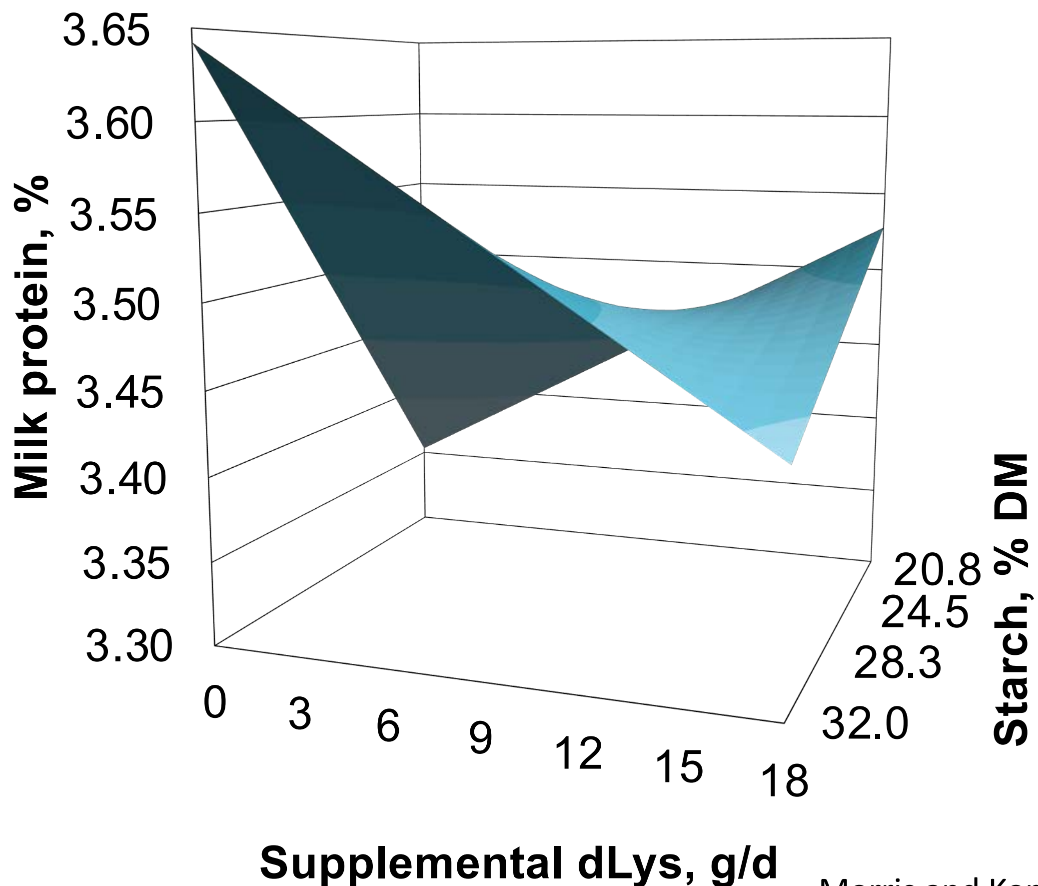
Morris and Kononoff, In Press

Dry matter intake



Morris and Kononoff, In Press

Milk protein, %



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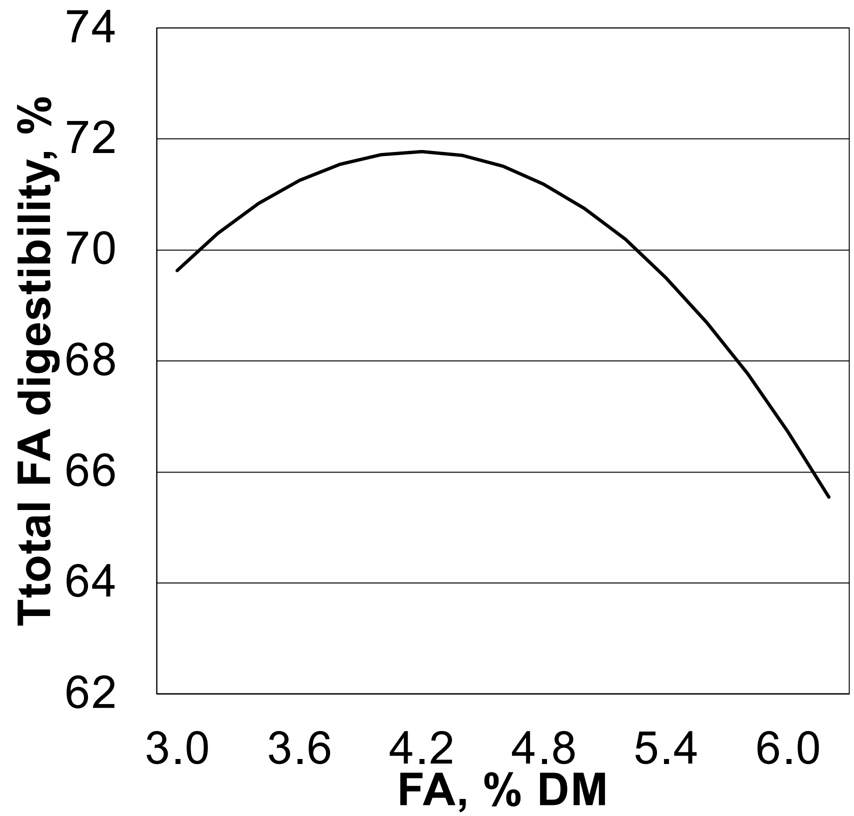
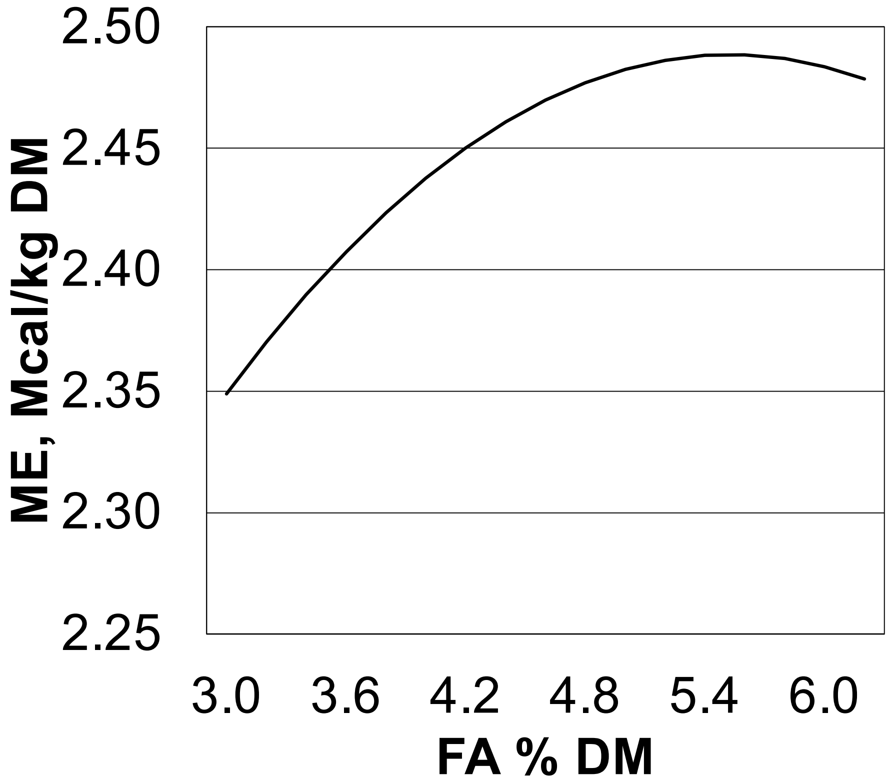
Digestibility



- 4.2% FA = ~ 0.65 lbs of supplemental fat

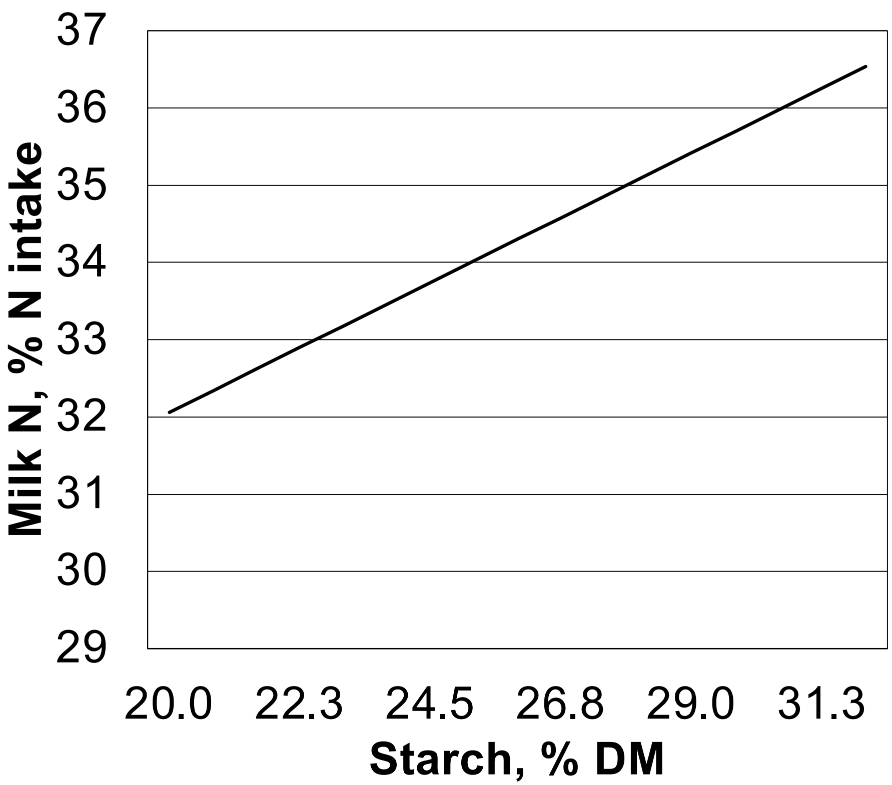
Morris and Kononoff, In Press

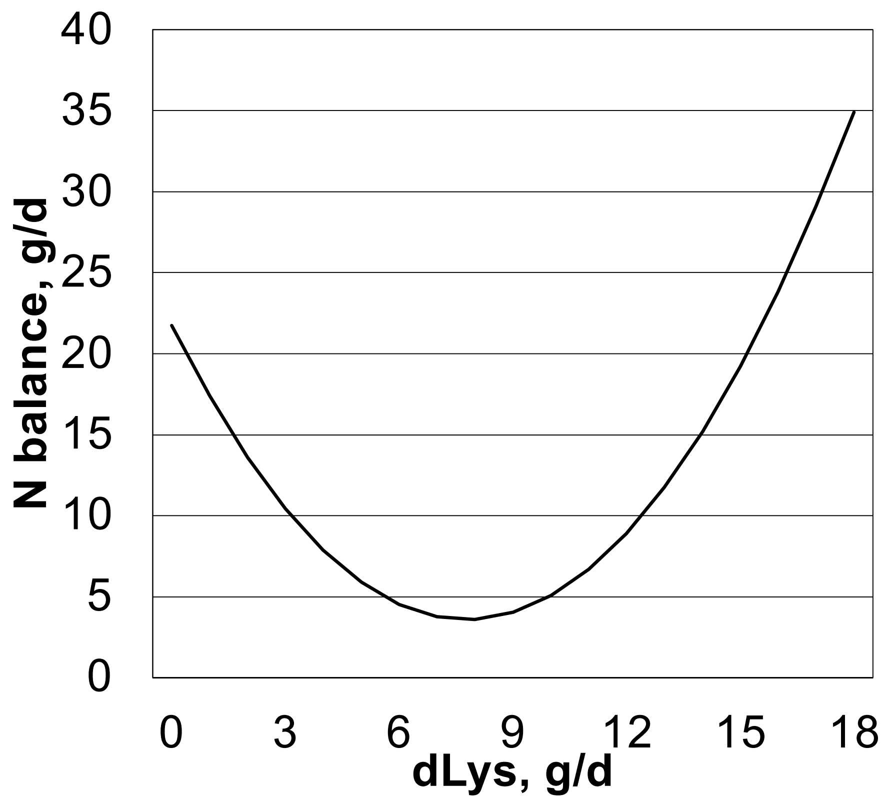
Energy



- 4.2% FA = ~ 0.65 lbs of supplemental fat

N utilization





Morris and Kononoff, In Press

Conclusions

- Increasing dietary starch "*generally*" increases milk protein yield and body fat gain.
- Increasing dietary FA and starch increase conversion of DE into ME (less urine and methane energy loss)
- Increasing Lys increase milk protein % in low but not high starch diets.
- Lys may be preferentially used by muscle tissue when starch is high.

Some general thoughts

- Most nutrition models assume a constant efficiency of converting ME into NEL and DE into ME.
  - improved by estimating partial efficiencies for fat, protein, and lactose?
- Milk protein synthesis is an energy and AA dependent process.
  - Starch: rumen or post-absorptive metabolism?
  - Other AA Arg, Ile, Leu, and Thru?
- Energy from starch may enable a greater response from supplemental Lys

Questions?