Getting More from Forages

Targeted feeding strategies:

Accounting for variability

Modeling the rumen and beyond: A new approach

Jim Russell
Michael Murphy

The problem of biology is not to stand aghast at the complexity but to conquer it .

– Sydney Brenner

Nobel Prize in Physiology or Medicine 2002 (mRNA, triplet code, etc.)

Estimation of theoretical calorific relationships as a teaching technique. A review

Baldwin, R. L.

1968. J. Dairy Sci. 51:104-111.

- **A series of theoretical estimates of efficiencies of metabolic and physiological processes which could be related to nutritional energetic measurements was presented.**
- **The examples and format were developed for, and proved useful as, teaching aids in undergraduate and graduate courses in bioenergetics and were presented in the hope that others might find them useful.**

Although a variety of models have since been developed to simulate ruminal fermentation, their links to animal productivity (especially milk production) have been less sophisticated, including NRC (2001) – which represents perhaps the most mechanistic and accurate depiction of dairy cow metabolism to date.

Assessment of nutrient availability and milk production as a teaching technique. A Review

James B. Russell,
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STELLA has several features that facilitate the use of models in teaching:

1) an intuitive icon-based graphical interface,
2) stock and flow diagrams that provide insight into how the system works, and
3) causal loop diagrams that present relationships in a mechanistic fashion.

Using STELLA as a platform, we embarked on an effort to link a submodel of rumen function to another model that partitioned cow metabolism into physiological functions (e.g. maintenance, tissue turnover, growth and pregnancy).

By assessing these other functions, the ultimate goal was to eventually predict milk production and composition.

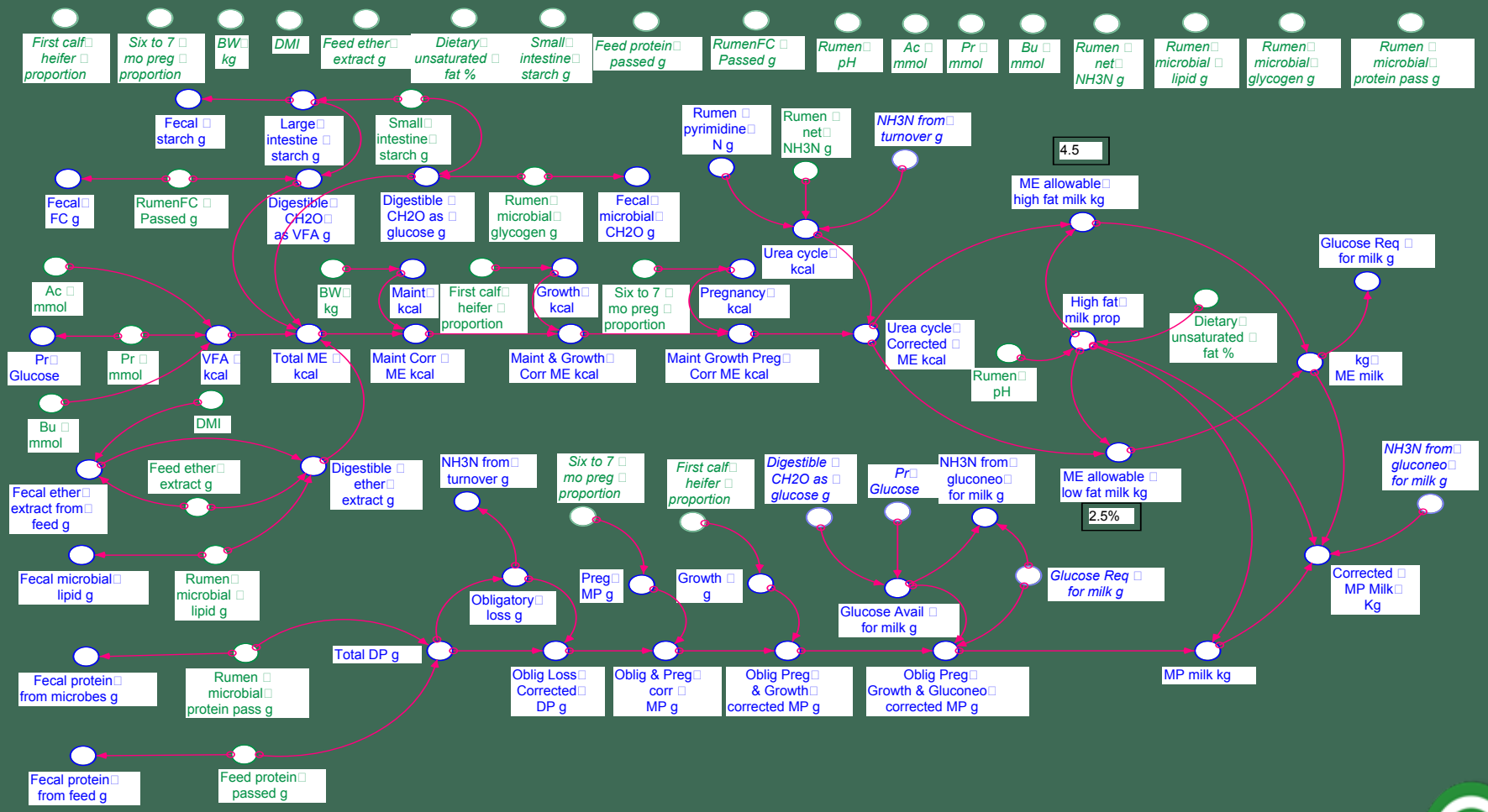
The animal submodel is the focus of this presentation; however, its inputs are determined by rumen function.

Among updates to the rumen section are:

- **Recognition of obligate amino acid fermenting (hyper-ammonia producing) bacteria**
- **A more mechanistic prediction of pH**
- **Stoichiometric relationships allowing the prediction of VFA ratios and methane**
- **Protozoa as a separate microbial pool**

- Only key aspects of animal metabolism are included in the animal model and it is not dynamic but based on a daily time step.
- Outputs of ruminal fermentation and nutrients passing to the lower gut are used as static inputs but can be easily varied.
- The model is transparent and readily modified; therefore, alternative representations and their impacts can be evaluated.

The STELLA model of animal metabolism



Inputs

Arrangement as “ghosts” simplifies the model by allowing organized access to each when needed while minimizing the number of arrows crossing each other.

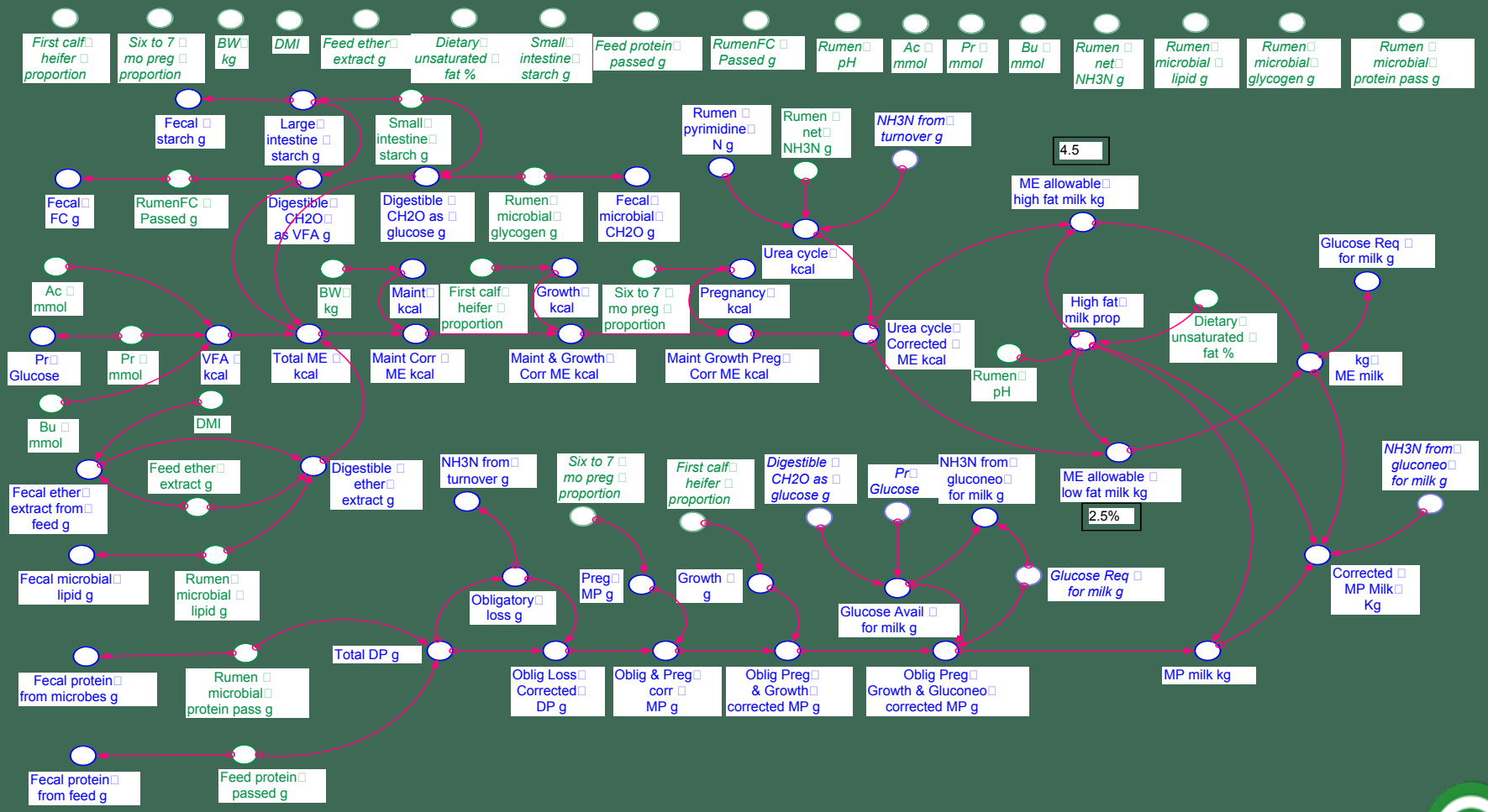
Inputs are spread across the top of the schematic.

The model itself is divided into two main (left to right) chains:

- energy transformations and expenditures, and
- protein utilization

As with the CNCPS model, predicted milk production is the minimum of that supported by energy or protein availability.

The STELLA model of animal metabolism



Input example

First-calf heifer proportion

- **Based on the concept that energy is required for both growth and milk production in the first lactation.**

Energy utilization

Metabolizable energy (ME) is estimated as the sum of absorbed carbohydrates, fat, and VFA.

The ME available for milk production is that remaining after energy needed to support maintenance, potential growth, potential pregnancy, and urea production are accounted for.

Energy utilization example

The ME needed to support growth is estimated as:

First_calf_heifer__proportion*(0.63*1000*431/365/0.55),

which is based on NRC (2001) pages 236-240 (growth requirements), and 327-328 (efficiency of ME use for gain).

Protein utilization

- Protein available for milk production is that from microbial and dietary sources remaining after losses associated with its other metabolic uses are accounted for.
- In addition to those listed for energy metabolism, certain obligatory losses associated with amino acid metabolism and gluconeogenesis are also included.

Protein utilization example

Pregnancy requirement for protein was calculated as:

Six_to_7__mo_preg__proportion*229

This is based on NRC (2001) pages 68 and 321

MPPreg (MP required for pregnancy)=

((0.69*DaysPreg - 69.2) x (CBW/45)) / EffMPPreg

EffMPPreg = 0.33, valid for 190 - 279 days of gestation, and assumed CBW = 45

average for days 180-240 (months 6 and 7) was 229

Milk production

Once the amounts of available energy and protein have been computed to support milk production, *"ME Milk kg" and 'MP milk kg"* were calculated.

Milk energy was based on Baldwin's (1984) observation that the efficiency of ME to NE of lactation is 70 to 80 % (75% *was used).* Differences related to variance in milk composition are minor (<1%).

Estimation of milk protein was again based on relationships described in NRC (2001); however, calculations were complicated by effects of milk composition and potential diversion of amino acids for gluconeogenesis depending on the relative supplies of propionate and starch absorbed from the small intestine.

The model attempted to predict the type of milk that is produced, high or low fat, based on the amount of unsaturated fat in the diet and ruminal pH.

Both of these factors have been correlated with milk fat depression, but it is conceivable that other aspects of ruminal and animal metabolism are also involved.

Output

STELLA provides output in both tabular and graphical formats.

Sensitivity (What if?) scenarios can also be easily constructed based on specified parameter values or various statistical distributions for them.

Conclusion

We think that this model can serve as a teaching aid in undergraduate and graduate courses.

STELLA is marketed by isee systems (www.iseesystems.com). Version 9.1 of isee Player allows free viewing and sharing of iThink and STELLA models for 30 days.

We hope that others might find it useful for this and other purposes.