HISTORY OF NUTRITION MODELS – THE EARLY YEARS

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The original modeling effort started in 1978. Dr. Danny Fox had just returned to Cornell in 1977 from Michigan State and Dr. Charles Sniffen had just joined the staff from the University of Maine. Dr. Fox already had a significant amount of experience, gained while he was at Michigan State, working with Dr. Roy Black. They had developed a beef nutrition management model. Dr. Sniffen had limited experience in the modeling area but was actively involved in modeling activities at Cornell and had begun the process of developing models at Maine.

Danny and Charlie discussed the development of nutrition models. Danny pointed out that the NRC models were too limited in the environmental and animal activity areas. He was familiar with the real world of the cow/calf and feed lot operations of the beef industry. The dairy industry suffered the same problem. It was pointed out that data existed that would allow the development of a sensitive environmental and activity sub models.

It was observed, from the experiences of testing feeds at the forage testing lab in Ithaca, that there is a large variance in the nutritional value of the forages and byproduct feeds being fed our livestock. Further, it was observed that the current equations being used to predict the energy value of forages were inadequate.

Danny and Charlie felt that it was important to our cattle industry to develop an integrative model that would better capture the dynamics of animal performance. During this period, there were several modeling activities going on. Dr. Mertens, then at the University of Georgia, came to Cornell to work specifically in the modeling area with Drs. Oltenacu and Sniffen. He had been very active in developing rumen models with Dr. Ely, also of Georgia. He was the stimulation needed to think about a mechanistic approach in the development of models. It was decided to start with the development of a mechanistic rumen sub-model. Dr. Mertens hired a technician, James O'Connor to help him in implementing the development of a mass action rumen sub model as well as to work with Dr. Oltenacu to develop nonlinear models in the prediction of lactation and whole herd production parameters. The rumen sub model effort went beyond Dr. Mertens time at Cornell. The model became so complex that we ended up using the Cornell Super Computer. One can term this as a learning process. We realized that there were areas that we had too little knowledge in for the model to be successful. It was after almost 3 years of effort on this that we decided that we needed to step back, aggregate the model and move forward with an empirical model with some dynamic components that was manageable. During this time, we looked closely at the efforts of Baldwin's modeling effort and that became the long term goal that we would finally get to that point.

During this period a programmer was hired to develop a applied nutrition model that would run on a Radio Shack Model I computer. Out of this activity came two models, one was a beginning ruminant model that Danny and Charlie were developing and the second was a field nutrition model that Larry Chase and Charlie developed, based on the latest NRC. The first CNCPS model was written in Radio Shack Basic. It just focused on the dairy cow and had rate of passage equations in it that even responded to cold conditions. The programmer left and Danny and Charlie did not have a shred of understanding of the code or Radio Shack Basic The field model that Larry and I developed and went on a Model I computer (Chase et al, 1980, Brown et al, 1981) was done with the help of a dairyman in the Hudson Valley, George Allen. We did not have the money to buy a computer. He bought it, we developed the program and we brought the computer to him! He said that he paid for the investment in one month. Drs. Chase and Sniffen, (Milligan et al, 1980, 1981) in cooperation with groups in the department of Agricultural Economics at Cornell, primarily Milligan and Knoblauch, and at Michigan State were active in developing a least cost program that was used by extension in Michigan and New York that was accessed on the University of Michigan's computer in Michigan from remote terminals. Further, Drs. Sniffen and Chalupa (NRC, 1985) were actively involved in the development of a new NRC protein sub-model. This activity involved also several of the staff as well as Dave Mertens, who was with us at the time this was going on and made significant input into the effort.

All of this activity, (Fox et al, 1979, 1980, 1982, Van Soest et al, 1982) along with the intense work, through state/federal (Hatch regional funds to support O'Connor) supported regional modeling efforts, of whole farm models that included weather, crop growth, machinery and nutrition models, formed the nucleus of the philosophy linking the biology with the application in the field,

Danny and Charlie decided that it was absolutely necessary to develop a model for the large ruminant that:

1. Could be easily modified by the scientists as the model evolved.
2. Be relevant and useable in the field.
3. The inputs into the model be measurable and obtainable
4. The model would be based on documented research
5. That the model would be shared with anyone interested

With these objectives in mind, it was decided to turn to the use of spreadsheet technology, which by this time was very useable on small computers and would be understood by many people. It was decided that we needed to develop a feed analytical system that could be accomplished in our laboratories. Dr. Van Soest provided the answer for this in combination with the work of graduate students in the department (Krishnamoorthy et al, 1983). Dr Van Soest using protease decay data, from many feedstuffs, observed that there were several protein fractions in many of the feedstuffs. He further developed rates for each of these pools. He suggested that the detergent system could be used as an initial means of estimating these pools. He reasoned that possibly the proteins insoluble in neutral detergent without the use of sodium sulfite might have a slow rate of degradation in the rumen and would be correlated with the slower pools that he observed from curve peeling. He further reasoned that the protein soluble in detergent would have a faster rate. This pool was further divided, using a one-hour extraction with borate phosphate buffer. The reasoning here was that protein soluble in buffer would be rapidly degraded in the rumen. This fraction was further divided into true protein, using a 10% TCA to precipitate the true proteins and large peptides, and the supernatant. The unavailable protein was assumed to be the protein insoluble in acid detergent. The subtraction of this fraction from the protein insoluble in neutral detergent would define the slow pool. Dr. Van Soest strongly suggested at the time that this system needed verification. This was then, the birth of the Net Protein system (Van Soest et al, 1982, Fox et al, 1982). This approach was appropriate from a commercial lab perspective. Crude protein, soluble protein and acid detergent insoluble protein assays were already being routinely run in many commercial forage laboratories. We just needed to get laboratories to analyze the N in the neutral detergent insoluble residue. This was accomplished.

It quickly became obvious that we needed to expand the concept. We had very limited data on passage kinetics and microbial yield. Dr Van Soest suggested that the equation: Digestion of a pool = Pool*(Kd/(Kd+Kp). Dr. Mertens and then graduate student Dr. Michael Allen discussed the application of applying lag and the importance of prediction of passage. Peter Robinson and Van Soest, using a Michaelis-Menton approach, described the microbial growth data in the literature. Dr. Russell expanded on this concept and developed a microbial sub model with two microbial pools, fiber and starch/sugar. This model was unique in the recognition that microbes have a maintenance requirement that can be influenced by their environment and they have a growth rate that is also unique to the microbial type and can be influenced by the environment. This sub model set the stage for evolving the microbial sub model into a more complex model that could generate fermentation acid and include more microbial niches. In that growth is a function of degraded CHO, it was necessary to expand the model to include a CHO sub model. It was at this point that the Net Protein System became the Net Carbohydrate/Protein System. This was done based on the detergent system because laboratories were routinely using the detergent system for fiber analysis and the measurement of the unavailable protein in forages (ADIP). The additional analysis required was lignin. The “sugar” and “starch” were expressed as a % of the NFC because there was at the time of development no methodology for these assays available in the commercial forage laboratories. In reality the sugar was the fermentation acids and the sugars. The starch was starch + soluble fiber + plant metabolic acids. It should be added that the laboratories quickly adapted sugar and starch assays (still with much controversy on the methods!) which they offered to nutritionists in the field. All of these ideas were integrated into the animal model developed by Danny coupled with the environmental sub model. At this point, there was also not a viable passage model.

Dr. Chalupa suggested that we could not continue to use the “look-up” tables developed by Sniffen. He recommended that we use the liquid passage equations developed by Essi Evans in Canada and the solids passage equations developed by Daniel Sauvant from INRA in France. The solids equations were modified to include the effective NDF concept of Mertens with the modification, using the concepts of Jim Welch, University of Vermont, on functional specific gravity and particle size.

It was decided that there was a need to expand the model to include amino acids. The original model was based on the model of Evans and Patterson. The original concept was expanded to include rumen degraded amino acids and rumen undegraded amino acids, using the amino acid profile of each of the protein pools, A, B1, B2, B3, and C. This approach, although laudable, was not possible at the time, due to the lack of data (the only paper on this was Muscato et al, 1993 on a very limited number of samples), the model size would exceed the spreadsheet capability and the cost of the analyses were prohibitive. This resulted in the use of the larger data set of the insoluble amino acid profile of feeds, knowing that some day there needed to be an improvement on this approach. The amino acid concept was expanded by Bill Chalupa to include the concept of Henri Rulquin, INRA and of Charles Schwab, U. of New Hampshire of expressing the requirement of Lysine and Methionine as a % of the metabolizable protein. This was a significant step forward. Schwab expanded these concepts in the 2001 release of NRC.

There was a need to publish the results of the work that had been done up to this point. The approach was to present many of these ideas at the Cornell Nutrition Conference (Sniffen et al, 1987, Fox et al, 1990a, b, Russell et al, 1990) and other meetings and put the information in Cornell Experiment publications. The first peer reviewed publications of the model (Fox et al, 1992, Sniffen et al, 1992, Russell et al, 1992 and O'Connor et al, 1993) were in the Journal of Animal Science. These papers set the base with many collateral papers that were referenced in these publications.

The model had now moved to the point where it could possibly be used in the field (1987) and it became obvious that a limitation of 11 feeds was not very viable. Dr. Bill Chalupa and the team at New Bolton Center of Animal Health and Productivity, University of Pennsylvania, had significant experience in the development of nutrition models for the field. They moved the spreadsheet into a Quattro Pro spreadsheet that allowed for many more feeds and also, through the use of excellent macros, allowed for much quicker formulation of rations.

This was the beginning of two approaches: the Cornell CNCPS spreadsheet and the Penn spreadsheet. Both Penn and Cornell recognized it was time to move beyond spreadsheets. The Penn approach evolved into what is called the Cornell – Penn – Miner platform – CPM for short. The most significant improvement in this model was the incorporation of the non-linear optimizer by Dr. Ray Boston that improved the robustness of the solution and dealt with the non-linear components of the model correctly. The Cornell model evolved into a dedicated model called the Cornell Net Carbohydrate Protein System, with many versions. This was changed into a much-needed whole farm model (concepts driven by the early regional across discipline modeling activities) and is much of the driving force in the equation improvements in both platforms. Two platforms in the field are confusing to the many people using the system and now there will be an effort to bring them back together. It is recognized that this is going to eventually happen, so in the meantime every effort is being made to make sure that the master feed dictionaries and the core biology and equations are the same in the two platforms. Not an easy task, to be sure.

What has happened in the research sector? Much of the research has been done at Cornell to improve the model each year. Penn did do a significant amount of research to develop the new lipid sub model that is being refined for CPM 3.0. The new CHO sub model that is in 3.0 is really a function of the library which is being developed and coordinated at The Miner Institute. As the new equations and ideas evolve, they are incorporated into both platforms. At this moment, there is CPM Dairy 3.0 which was released in August, 2006. CNCPS 5.0 (Fox et al, 2004) is the current release for the Cornell system. It is hoped that after the release of CPM 3.0 and CNCPS 6.0 (now in Beta form and should be released by the date of this conference) that the two models will actually be one with one number. That will probably be within the next three to four years. The model will continue to improve and respond to the users in the field. Cornell, Penn and Miner will continue to be the primary coordinators of the development. The first generation of this effort (Van Soest, Sniffen, Fox, and Chalupa – in the order of retiring) has retired now and are customers (maybe Peter isn't). It is hoped that the next generation will continue the effort and will have the vision to bring other scientists to the table to work with them.

One of the exciting aspects of this effort was the impact on the beef and dairy nutrition research effort at Cornell. The modeling effort helped identify many areas where there was a lack of knowledge. The research efforts, in many areas, became more directed and efficient. The effort has enhanced the undergraduate and graduate teaching effort and has enhanced the graduate student research effort as well.

The model approach has been exciting. The system is being used and tested extensively around the world. There is, of course, much discussion about the equations, the assay methodology, and the predictions. This, of course, is what was intended when the approach was started in 1978 – 79. We hope it will continue and in the continuation there will be more excellent research that will end up at the bottom line – the continued increase in efficiency of our ruminant industry. At some point, it is hoped that the model will become fully mechanistic – and with this goal achieved, to more nearly meet the objectives that Dr. Lee Baldwin, University of California, set out in the development of nutrition models for robustness and good biology.

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