SO MANY DECISIONS...

• Surrounded by decisions...
• What is the best decision?
  • Do I have a choice?
• Best based on what?
  • “Gut” feeling – “Rumen” feeling
  • Education / Background
  • External influence (boss, colleague, wife/husband/sons,...)
  • ...
  • ...
DSS: DECISION SUPPORT SYSTEM
SDT: SMART DECISION TOOL

- We all use a DSS or an SDT in our daily life
  - E.g. weather forecast
- Mainly driven by data and models
- In agriculture they have contributed to increased productivity and profitability since the 80’s
  - Increased microcomputers capability
  - Increased knowledge in science...(to be continued)
RUMINANT NUTRITION: WHAT TYPE OF DECISIONS?

- What to feed?
- How much to feed of each ingredient?
  - How to feed?
- What should I expect?
- ...

- Ultimately, we need to estimate animal requirements and nutrients derived from feeds
  - Diet >>><<<< Animal
RUMINANT FORMULATION

- (Mathematical) Technique for devising a mixture of food ingredients which, when eaten in the expected amounts, will provide the animal with specified amounts of nutrients
  - GOAL: feed for specific requirements
  - Techniques have been developed for commercial and educational/research purposes, using various forms of mathematical approaches for many decades
“TRADITIONAL” APPROACH

1. Tabled animal nutrients requirements
2. Choose nutrients/ingredients
   - Feed nutrients’ concentration
3. Set voluntary feed intake/consumption
4. Feeds costs
5. Constraints of nutrients and ingredients
6. Algorithm >>> Least cost ration
Many mathematical approaches used for more than 100 years
Pearson’s square?
Fixed formulas used until 50’s

\[
\begin{align*}
\text{Roughage} & \quad 60 & \quad 3 & = & \boxed{13.0} \% \text{ Diet DM} \\
\text{Concentrate} & \quad 83 & \quad 20 \div 23 & = & \boxed{87.0} \% \text{ Diet DM}
\end{align*}
\]
Linear programming used from this era (Dent and Casey, 1967):
• Mathematical routine to calculate the proportions of ingredients which meet specified nutrient requirements at the lowest cost

Hypothesis: the optimum nutrient level for rations is an economic as well as a biological question
• Ration specifications are also economic variables
• 1 hour needed to formulate a single diet!

- 1980’s LP used extensively
- Exploring other areas of formulation...
  - Negative effects and variability of different nutrient ingredients and their interactions
  - Sensitivity analysis for various nutrient ingredients also done in this period
- Nutrient variability in feeds managed by providing a margin of safety for the nutrients
  - ...
LIMITED APPROACH: LIFE IS NOT LINEAR!

- Recommendations mostly based on tabular values
- The algorithms, made up of linear, static nutrient relationships between milk production and nutrient inputs, were used to set nutrient requirements
- Does performance increase linearly?
  - E.g.: Gain in milk production per unit of feed consumed gets smaller and smaller!
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REALITY OR FICTION?

- What is missing?
- Type of car, car condition, accidents,…
- Road works, traffic, protests…
- Weather
- Fuel costs along the way
- Meals, (Lodging)
- Driver condition/health
- Passengers needs
- Value of time vs. Real cost
...BRIEF HISTORY: 1990 - PRESENT
REALIZED TRADITIONAL APPROACH LIMITATIONS

- Great computing improvement: great speed for LP but...
- In the meanwhile... huge scientific progress
- Diet characteristics can NOT correspond anymore to the weighted average of fixed nutritional parameters from all ingredients!
  - E.g. the contribution and consequences of feeding 5 kg of maize grain will change depending on many other factors!
...BRIEF HISTORY: 1990 - PRESENT

• Need of more “dynamic systems”
• Animal performance becomes a function of integrated effects of intake, rumen fermentation, intestinal digestion, absorption and metabolism
• Need for a more mechanistic approach
NUTRIENTS

Limited predictability of intake
Digestibility vs. intake level vs. efficiency
Nutrients interactions/synchronization
Variable maintenance requirements
Metabolizable protein
Rumen fill, health, pH
Physical characteristics of diet
Variable retention time/digestibility
Site of digestion
Body tissue reserves
Variable milk composition
Specific amino acids effects
Specific fatty acids effects
.....

RUMINANT

NUTRIENTS

FEEDS
Milk yield in relationship to dietary CP

Adapted from Ipharraguerre and Clark, 2005
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Would you bet on an Italy win against the Springboks?
Remember 19/11/2016??
WHAT IS A RUMINANT NUTRITION MODEL?

• A (ruminant) nutrition model is defined as an integrated set of equations and transfer coefficients that describe nutrient requirements and feed utilization by ruminants in each production scenario (Gill et al., 1989)

• It provides
  • an understanding of the system
  • predictions of its future behaviour
  • a guide to its optimal utilization
EXAMPLE OF A (SUB)MODEL

- Attempt to “model” dependency of intake on ambient temperature
- Options:
  - No dependency
  - Intake decreases with an increase in temperature
  - Compromise
Example: WAYS TO PREDICT TEMPERATURE EFFECT ON INTAKE

- **Empirical**: based only on field data
  - Fitting of equations to data
  - Often limited application (data range)

- **Mechanistic**: describes the behavior mathematically
  - In this case, it probably needs to include also heat increment due to eating and ability of heat loss of the animal
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Knowledge and understanding of the “system”
To describe its quantitative and qualitative behavior
Mostly mechanistic
What is unclear or missing?
Indicate future research directions
FIELD/MANAGEMENT MODELS

- The goal of understanding the system is secondary to that of using it effectively in the field.
- Must have a known, and useful, range of applicability.
- Most of the times a “research” model becoming usable for management.
  - Robust to misuse or misunderstanding.
- Temperature-Intake: what intake should I expect at 35 ºC?
- Often accompanied by some type of optimization.
OCCAM’S RAZOR PRINCIPLE

- Attempt to use the simplest model that adequately describes the data
- A simple model that describes a system adequately is a better predictor of future behaviour of a system than a more complex one
- NOT A DUPLICATION, rather A SIMPLIFICATION
- Distinguish between the essential and the superfluous
ANIMAL ORGANIZATIONAL HIERARCHY & DIRECTION

- Group of animals (herd, flock)
- Animal
- Organ
- Tissue
- Cell
- Organelle
- Macromolecule
NO DIRECTION OF HIERARCHY: SINGLE LEVEL

- **Empirical**: experimental data are used directly to quantify relationships and are based at a single level
- Sets out to describe
- Based on observations and experiments
- Not necessarily based on any preconceived biological theory
EMPIRICAL EXAMPLE: INTAKE IN NON-LACTATING RUMINANTS

- After observing some data...
- \( \text{Intake} = a_0 + a_1 BW + a_2 dBW/dt + a_3 D \)
- The equation does not say much about the mechanisms
- It can be very useful...
- Only limited to the data that fits!
DOWNWARD DIRECTION

- **Mechanistic**: based and seek to understand causation
- Divides the investigated system into key components
- Analyse the behaviour of the system in terms of its individual components and their interactions with one another
MECHANISTIC EXAMPLE: INTAKE IN NON-LACTATING RUMINANTS

- Physical factors: rumen receptors, particle size, comminution rate, ...
- Chemostatic factors: volatile fatty acids “strength”, leptin, glucose, NEFA, hypothalamus receptors, ...
- Interactions: protein and fat turnover, gluconeogenesis from various substrates, ...
MECHANISTIC VS. EMPIRICAL

- Completely mechanistic models do not exist...
- Most biological responses are integrated, non-linear and change over time (dynamic)
- Balance between empirical and mechanistic in most models
- Most have developed from simple systems and generalized feeding situations
- Simplification (possible) >>> Duplication (impossible)
Example: prediction of metabolism nutrients not as advanced as the prediction of ruminal fermentation

- Metabolic pathways are too complex
- Multiple nutrient interactions
- Metabolic regulations by hormones

Modern models deal then with aggregated response of whole compartments (sub-models)
LEVEL OF AGGREGATION...

• Finding the optimal level of aggregation for rationing models is often the main issue
• More complexity needs more detailed inputs
• More (and reliable) inputs will result in a more precise and accurate prediction
  • Both requirements and supply
• CNCPS is for example a mix of mechanistic and empirical representations of functions
  • Given the objectives of such model
  • Given the availability of data
  • Given the scientific progress
We now tend to model more complex systems, with mechanistic components, which aim to account for many variables, including animal, dietary, and environmental factors.

Because modern nutritional models are more comprehensive, they require more inputs than the traditional, simpler systems.

Subjected to continuous revisions and updates as new research becomes available.
ANOTHER METAPHOR...
WHICH TOOLS WOULD YOU USE?
WHAT ABOUT FEEDING RUMINANTS: WHICH TOOLS WOULD YOU USE?
THE GOAL IS TO REDUCE THE GAP BETWEEN THE GENOTYPE AND ITS EXPRESSION…

Many of these models allow flexibility of adjusting inputs according to what is available... until predicted and observed performance agree.
MODEL ADVANTAGES: REQUIREMENTS VS SUPPLY

- Predictions of specific functions’ requirements (maintenance, growth, pregnancy, lactation and tissue reserves) and how they vary
- Supply of nutrients
  - Dry matter intake, feed carbohydrate and protein fraction pool sizes and their characteristic digestion and passage rates, microbial growth, intestinal digestion and metabolism of absorbed nutrients
MODEL ADVANTAGES: SPECIFICITY VS. SENSITIVITY

- Solutions specific for the particular group of animals, their environment and the composition of the diet that is chosen to be used
- Can be used to investigate different nutritional scenarios
  - possible predictions in a continuous range of variables and conditions
  - possible to “relax” nutritional constraints (profit vs. animal welfare)
- Can be used to identify specific negative factors affecting performance
MODEL ADVANTAGES:
PRODUCTION VS. PRODUCTIVITY

- Nutritional models also allow estimation of environmental consequences of animal production
- Environmental indicators can be considered among the most useful proxies to target efficiency of production systems
- N excretion among the most useful indicator for productivity!
CONCLUSIONS AND IMPLICATIONS: REALITY OR FICTION?
SIMPLIFICATION!

- Challenge is to develop systems that are “aggregated” at a level reflecting our understanding of the underlying biology...
- ...yet, be usable on farm considering information available, ability to monitor and quantify key input variables and animal responses, and knowledge and time available of the consultant using the models

- Stay up to date! Farm profit must be the driver!
- New technologies will be of great help!