User approach of expanded MAGENTC for animals; parsimonious modelling trials

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Committed dose depends on time integrated intake and not on details about dynamics → Time integrated concentration in animal products

Animals of interest - cow (meat and milk), sheep (meat and milk), beef, goat (meat and milk), pig, chicken

<table>
<thead>
<tr>
<th>Animal Product</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>cow milk after HTO intake</td>
<td>good</td>
</tr>
<tr>
<td>cow milk after OBT intake</td>
<td>1 exp</td>
</tr>
<tr>
<td>goat milk after OBT intake</td>
<td>moderate</td>
</tr>
<tr>
<td>goat milk after HTO intake</td>
<td>no exp</td>
</tr>
<tr>
<td>sheep milk after HTO intake</td>
<td>no exp</td>
</tr>
<tr>
<td>sheep milk after OBT intake</td>
<td>no exp</td>
</tr>
<tr>
<td>broiler meat after HTO intake</td>
<td>no exp</td>
</tr>
<tr>
<td>broiler meat after OBT intake</td>
<td>no exp</td>
</tr>
<tr>
<td>egg after HTO intake</td>
<td>Russian data</td>
</tr>
<tr>
<td>egg after OBT intake</td>
<td>no exp</td>
</tr>
<tr>
<td>beef meat after HTO intake</td>
<td>2 exp( ?)</td>
</tr>
<tr>
<td>beef meat after OBT intake</td>
<td>no exp</td>
</tr>
<tr>
<td>veal after OBT intake</td>
<td>Poor</td>
</tr>
<tr>
<td>pig after OBT intake</td>
<td>Poor</td>
</tr>
<tr>
<td>piglets after OBT or HTO intakes</td>
<td>Medium</td>
</tr>
<tr>
<td>sheep after OBT intake</td>
<td>Partial</td>
</tr>
</tbody>
</table>

Experimental data base very sparse → generic model → Common process for all farm animals and particularization
• Complex dynamic model for H-3 and C-14 transfer in mammals
• full description given in:


- 6 organic compartments;
- distinguishes between organs with high transfer and metabolic rate (viscera), storage and very low metabolic rate (adipose tissue), and ‘muscle’ with intermediate metabolic and transfer rates;
- Liver, kidney, heart, GIT, stomach content, small intestine – high metabolic rates → “viscera” compartment
- Blood - separated into RBC and plasma (plasma is the vector of metabolites in the body and also as a convenient bioassay media);
- The remaining tissues - bulked into “remainder”;
- All model compartments have a single component (no fast-slow distinction)
Steps for MAGENTC

• Step 1: Collect relevant experimental data;
• Step 2: Basic understanding of metabolism and nutrition; Reviews of the past experience (STAR, TRIF, OURSON, UFOTRI, PSA etc);
• Step 3: Formulate basic working hypothesis;
• Step 4: Using the rat (very good experimental data base thanks to H. Takeda, NIRS Japan) for exercise;
• Step 5: Understanding the animal nutrition from literature and make a standardization;
• Step 6: Developing the conceptual and mathematical model;
• Step 7: Test the model with experimental data;
• Step 8: Make prediction for the cases without experimental data;
• Step 9: Trials for simplify without losing the predictive power.
Working material (IFIN-HH, Romania)

1. Experimental data (Revision prepared by A. Melintescu, 2000)

- Cows and mini goats
- Pig and piglets
- HTO and OBT intake
- Old data, experimental conditions poorly reported.
- Available in English as an internal document and can be incorporated as an annex in WG7 (maybe as a Tecdoc!?)
2. **Feed intake of farm animals, a briefing for environmental transfer models**

Efficiency of energy transfer (k) = the ratio between net energy utilized and metabolisable energy consumed

<table>
<thead>
<tr>
<th>k factor</th>
<th>Efficiency of utilization</th>
</tr>
</thead>
<tbody>
<tr>
<td>$k_m$</td>
<td>maintenance</td>
</tr>
<tr>
<td>$k_p$</td>
<td>protein deposition</td>
</tr>
<tr>
<td>$k_f$</td>
<td>fat deposition</td>
</tr>
<tr>
<td>$k_g$ (or $k_{pt}$)</td>
<td>growth in general</td>
</tr>
<tr>
<td>$k_i$</td>
<td>milk production (lactation)</td>
</tr>
<tr>
<td>$k_c$</td>
<td>fetal growth (the conceptus)</td>
</tr>
<tr>
<td>$k_w$</td>
<td>work (e.g. in draught animals)</td>
</tr>
<tr>
<td>$k_{wool}$</td>
<td>wool growth</td>
</tr>
</tbody>
</table>

**Energy flow**

- GE in food
- DE
- ME
- Basal Met.
- Heat of Dig.
- Cold Therm.
- Used for work, Growth, re-prod
- NE
Ruminants

Efficiencies $\rightarrow$ metabolizability, $q_m = \text{the ratio between ME and GE}$

We used the following relationships:

\[ k_m = 0.35q_m + 0.503 \]
\[ k_g = 0.78q_m + 0.006 \]
\[ k_l = 0.35q_m + 0.420 \]
# Ruminants’ standardized feed

<table>
<thead>
<tr>
<th>Feed</th>
<th>Dry mate r</th>
<th>Protein digestibility</th>
<th>Digestible protein (g/kg fw)</th>
<th>Digestible fat (g/kg fw)</th>
<th>Digestible cellulose (g/kg fw)</th>
<th>Digestible SEN (g/kg fw)</th>
<th>Organic matter digestibility</th>
<th>Metabolisable energy (kJ/kg fw)</th>
<th>q</th>
<th>K&lt;sub&gt;m&lt;/sub&gt;</th>
<th>K&lt;sub&gt;i&lt;/sub&gt;</th>
<th>K&lt;sub&gt;g&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>hay</td>
<td>0.86</td>
<td>0.61</td>
<td>70</td>
<td>12</td>
<td>141</td>
<td>247</td>
<td>0.592</td>
<td>7160</td>
<td>0.45</td>
<td>0.66</td>
<td>0.577</td>
<td>0.357</td>
</tr>
<tr>
<td>concentrate rates</td>
<td>0.88</td>
<td>0.79</td>
<td>110</td>
<td>27</td>
<td>17</td>
<td>518</td>
<td>0.815</td>
<td>10690</td>
<td>0.64</td>
<td>0.74</td>
<td>0.657</td>
<td>0.528</td>
</tr>
<tr>
<td>grain</td>
<td>0.88</td>
<td>0.77</td>
<td>83</td>
<td>15</td>
<td>14</td>
<td>626</td>
<td>0.87</td>
<td>11528</td>
<td>0.715</td>
<td>0.75</td>
<td>0.667</td>
<td>0.564</td>
</tr>
<tr>
<td>straw</td>
<td>0.88</td>
<td>0.07</td>
<td>14</td>
<td>3.6</td>
<td>3.8</td>
<td>122</td>
<td>0.84</td>
<td>1147</td>
<td>0.302</td>
<td>0.60</td>
<td>0.525</td>
<td>0.241</td>
</tr>
<tr>
<td>pasture</td>
<td>0.215</td>
<td>0.71</td>
<td>22.2</td>
<td>4.24</td>
<td>36</td>
<td>78</td>
<td>0.72</td>
<td>2181</td>
<td>0.56</td>
<td>0.7</td>
<td>0.617</td>
<td>0.443</td>
</tr>
<tr>
<td>upland pasture</td>
<td>0.376</td>
<td>0.6</td>
<td>20.3</td>
<td>9.4</td>
<td>90</td>
<td>190</td>
<td>0.51</td>
<td>2200</td>
<td>0.344</td>
<td>0.65</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Metabolisable energy intake = maintenance + production

\[ ME_{\text{intake}} = ME_m + ME_{pd} \]

\[ ME_m = M \times KK \times S \times \frac{0.26 \times LBW^{0.75} \times \max(0.84, \exp(-\frac{0.03 \times t}{365}))}{K_m} + 0.1 \times ME_{pd} \]

\[ M = \max(1, 1 + 0.26 \times \frac{t_{wstop} - t}{t_{wstop} - t_{wstart}}) \]

- Correction for suckling mammals

**KK - animal type**

**S – gender differentiation**

<table>
<thead>
<tr>
<th>S</th>
<th>Gender</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.15</td>
<td>male</td>
</tr>
<tr>
<td>1</td>
<td>female and castrate</td>
</tr>
</tbody>
</table>
ENERGY REQUIREMENT FOR ACTIVITY

- minimal activity for survival: standing, eating etc, and the estimates depend on animal weight

- We introduced this minimal activity in the maintenance needs and then we approximated the activity needs for grazing animals in various conditions (plain, hill, good or low quality pasture)

- We deduce the following equation for activity allowance:

\[ \text{ME}_{\text{activity}} = (F_p \cdot F_q) \cdot a_2 \cdot \text{ME}\text{stable} \]

\( W \) – animal weight (kg);
\( a_2 \) – fraction of maintenance;
\( F_p \) – time fraction on the pasture;
\( F_q \) – index of pasture quality

<table>
<thead>
<tr>
<th>Animal type</th>
<th>( a_2 )</th>
<th>( F_q )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheep</td>
<td>0.12</td>
<td>1 – good pasture</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.5 – average pasture</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.5 – uplands</td>
</tr>
<tr>
<td>Goat</td>
<td>0.15</td>
<td>1 – good pasture</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.5 – average pasture</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.5 – uplands</td>
</tr>
<tr>
<td>Cow</td>
<td>0.1</td>
<td>1 – good pasture</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 – scarce pasture</td>
</tr>
</tbody>
</table>

- For pig and hen - we did not split minimal activity from maintenance
- For wild animals - activity is 50-60 % from maintenance
ENERGY REQUIREMENT FOR WOOL PRODUCTION

-Wool production for sheep and goat - considered at a generic level of 4 kg/y with a need of ME 125 kJ/kg

ENERGY REQUIREMENT FOR LACTATION

-we considered the body mass constant
-the lactation energy need depends on animal type and fat content.
The metabolic energy need, per litter of milk:

\[
\text{ME (kJ/L)} = b + c \cdot \text{FP}
\]

FP - the fat percentage
b, c - constants

<table>
<thead>
<tr>
<th>specie</th>
<th>b</th>
<th>c</th>
</tr>
</thead>
<tbody>
<tr>
<td>cow</td>
<td>2470</td>
<td>672</td>
</tr>
<tr>
<td>sheep</td>
<td>3630</td>
<td>556</td>
</tr>
<tr>
<td>goat</td>
<td>3200</td>
<td>447</td>
</tr>
</tbody>
</table>

ENERGY REQUIREMENT FOR EGG PRODUCTION

-The metabolizable energy need for egg production is related with mass of egg production per day multiplied by metabolizable energy need per unit mass of egg.
-Average production of a laying hen - 250 eggs per year
-average mass of egg - 62 g
-For each g of egg are necessary 10.2 kJ and the composition of egg is few variable among breeds.
WATER INTAKE

- Sources of water:
  - drinking water;
  - water in food;
  - metabolic water;
  - respiration;
  - skin absorption.
- Water content of the body depends strongly on fat content → protein content is quite constant with age and breed.
- body composition
- water content are known
- If the water turn over half-times are experimentally known
- water balance - known we deduce the water intake

Water intake depends on animal type:
- body mass;
- dry matter intake;
- lactation stage (if it is necessary);
- ambient temperature;
- management practice.

There are various empirical formulas of assessing drinking water, but in practice, there is a quite large natural variability.
• Metabolic Water - MW can be easy assessed knowing the feed composition:
  - digestible proteins, DP;
  - digestible fats, DF;
  - digestible carbohydrates, DCH

  \[ MW = 0.42 \times DP + 1.07 \times DF + 0.6 \times DCH \]

• Respiration and skin absorption can be assessed by analogy with humans (Zach 1985) in absence of relevant data
• Respiration rate of standard man is multiplied by the ratio of metabolic energy used.
• For mammals using \( ME_m \) and \( ME_p \) and knowing \( k_p \), an approximation for inhalation rate is:

  \[ \text{Inhrate} = \frac{ME_m + (1 - k_p) \times ME_p}{13400 \times 23} \]

  with energy in kJ and inhalation rate in m\(^3\)/d

  little effect on overall uncertainty, because respiration and skin absorption have a low share in the water input

Drinking water + water from food → recommendation based on milk production (where is the case) and DMI
Water intake – increases with environmental temperature
Water intake – large variability, even for the same animal type

- cow  \[ WI = DM \times 2.15 + MP \times 0.73 + 13.5 \]  (Voors, 1989)

- cow  \[ WI = DM \times [3.3 + 0.082 \times (T_{env} - 4)] + 0.87 \times MP \]  (ARC 1980)

- sheep  \[ WI = 0.82 \times MP + DM \times [1.26 + 0.1 \times (T_{env} - 5)] \times 1.35 \]  (ARC 1980)

- sheep  \[ WI = DM \times (0.18 \times T_{env} + 1.25) \]  (NRC 1985)

- goat  \[ WI = 0.1456 \times BM^{0.75} + 0.143 \times MP \]  (NRC 1981)

- pig  \[ WI = DM \times 3.6 + 0.03 \]

- hen  \[ WI = \frac{BM}{8} \times (1 + 0.6 \times \frac{T_{env} - 20}{15}) + 0.68 \times \frac{EP}{1000} \]

WI – water intake;
DM – dry matter;
MP – milk production;
BM – body mass
T_{env} – environmental temperature;
EP – egg production per day
Body composition (protein, CH, fat) + 4 % ash → body water → body water mass (BWM)

Water turnover half-time:

\[ TW = 0.693 \times \frac{BMW}{WI} \]

Body water half-times for different mammals

<table>
<thead>
<tr>
<th>Mammal</th>
<th>TW (days)</th>
<th>Ranges (days)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Veal</td>
<td>3.4</td>
<td>2.8 - 3.6</td>
<td>Black</td>
</tr>
<tr>
<td>Beef</td>
<td>3.4</td>
<td>2.9 - 4.1</td>
<td>Black</td>
</tr>
<tr>
<td>Cow non-lactating</td>
<td>4</td>
<td>Single value</td>
<td>Thorn</td>
</tr>
<tr>
<td>Cow lactating</td>
<td>3.5</td>
<td>3 - 4.5</td>
<td>Kirchmann</td>
</tr>
<tr>
<td>Sheep</td>
<td>3.1</td>
<td>2.5 - 3.5</td>
<td>Crout</td>
</tr>
<tr>
<td>Goat lactating</td>
<td>4.1</td>
<td>2.9 - 5.3</td>
<td>Hoeck</td>
</tr>
<tr>
<td>Goat non-lactating</td>
<td>8.3</td>
<td>6.7 - 10.4</td>
<td>Hoeck</td>
</tr>
<tr>
<td>Pig</td>
<td>3.8</td>
<td>3.3 - 4.3</td>
<td>Kirchman</td>
</tr>
<tr>
<td>Saw after weaning</td>
<td>10</td>
<td>Single value</td>
<td>Van Hess, 2000</td>
</tr>
<tr>
<td>Broiler</td>
<td>4.9</td>
<td>Single value</td>
<td>Kirchmann</td>
</tr>
</tbody>
</table>
**Growth** - described in relative units;
- refers to Standard Reference Weight (when skeletal development is complete and fatness is in the middle)
- unified approach, except lean beef

<table>
<thead>
<tr>
<th>Sheep</th>
<th>Females</th>
<th>Castrates</th>
<th>Males</th>
</tr>
</thead>
<tbody>
<tr>
<td>Merino (small, e.g. Saxon), Southdown</td>
<td>40</td>
<td>48</td>
<td>56</td>
</tr>
<tr>
<td>Merino (medium), Hampshire, Polwarth, Dorset x Merino, Ryeland</td>
<td>50</td>
<td>60</td>
<td>70</td>
</tr>
<tr>
<td>Border Leicester x Merino, Cheviot, Corriedale, Dorset, Drysdale, Romney, Suffolk, Tukidale</td>
<td>55</td>
<td>66</td>
<td>77</td>
</tr>
<tr>
<td>Merino (large, e.g. South Australian), Border Leicester</td>
<td>60</td>
<td>72</td>
<td>84</td>
</tr>
<tr>
<td><strong>Cattle</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jersey</td>
<td>400</td>
<td>480</td>
<td>560</td>
</tr>
<tr>
<td>Ayrshire, Guernsey</td>
<td>450</td>
<td>540</td>
<td>630</td>
</tr>
<tr>
<td>Beef Shorthorn, Dairy Shorthorn, Devon (Red), Galloway, Red Poll Angus, Hereford</td>
<td>500</td>
<td>600</td>
<td>700</td>
</tr>
<tr>
<td>Blonde d’Aquitane, Brahman, Brahman x Hereford, Murray Grey, Limousin, Lincoln Red, Friesian, South Devon</td>
<td>550</td>
<td>660</td>
<td>770</td>
</tr>
<tr>
<td>Charolais, Maine Anjou, Simmental</td>
<td>650</td>
<td>780</td>
<td>910</td>
</tr>
<tr>
<td>Chianina</td>
<td>700</td>
<td>840</td>
<td>980</td>
</tr>
</tbody>
</table>
Mass dependence (relative units) for viscera mass fraction, specific metabolic rates – SMR ((MJ kg\(^{-1}\)day\(^{-1}\)) and partition fractions for maintenance metabolic energy

<table>
<thead>
<tr>
<th>Relative body weight (EBW/SRW)</th>
<th>Viscera mass fraction normalized to EBW</th>
<th>Specific metabolic rate (MJ kg(^{-1})day(^{-1}))</th>
<th>Partition fraction maintenance metabolism</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>liver</td>
<td>PDV</td>
</tr>
<tr>
<td>0.07</td>
<td>0.09</td>
<td>1.5</td>
<td>0.77</td>
</tr>
<tr>
<td>0.2</td>
<td>0.11</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>0.3</td>
<td>0.12</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>0.41</td>
<td>NA*</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>0.48</td>
<td>NA</td>
<td>2.9</td>
<td>0.47</td>
</tr>
<tr>
<td>0.64</td>
<td>NA</td>
<td>2.6</td>
<td>0.36</td>
</tr>
<tr>
<td>0.77</td>
<td>NA</td>
<td>2.4</td>
<td>0.3</td>
</tr>
<tr>
<td>1</td>
<td>0.08</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>
Animal Products in Human Diets

Meat, milk, eggs and fish supply:

- 16% of human food energy
- 36% of human food protein

Large variations among countries and regions.

Taken from James W. Oltjen
Dept. Animal Science University of California, Davis
Past and projected total consumption of various meats

Taken from James W. Oltjen
Dept. Animal Science University of California, Davis
PIGS

- Model developed for pig growth – adapted from INRA France (Noblet and Van Milgen);

- 3 contrasting genotypes analyzed:
  - Synthetic Line (SL) - ‘conventional’ genotype;
  - Pietrain (PP) - lean genotype with low visceral mass;
  - Meishan (MS) - fat genotype

Dynamics of pig body mass and MEI intake for different pig genotypes
Dynamics of adipose and viscera mass for different pig genotypes
Muscle mass as a function of body mass for different pig genotypes
Sensitivity of muscle concentration to SMR in remainder organs
Sensitivity of muscle concentration to SMR in viscera

![Graph showing sensitivity to SMR_visc](image)
• Constant OBT and HTO concentration in food (intensive farming);

• Tested with experimental data and inter-compared with other models (MCT – Japan, STAR, PRISM – UK, OURSON – France, ETMOD – Canada);

Predicted-to-observed ratios for HTO in organs (84 days after start of contamination)

<table>
<thead>
<tr>
<th>Organ</th>
<th>MCT</th>
<th>FSA</th>
<th>IFIN</th>
<th>PRISMDG</th>
<th>STAR-H3(DG)</th>
<th>EDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart</td>
<td>0.54</td>
<td>33.4</td>
<td>2.17</td>
<td>1.31</td>
<td>0.81</td>
<td>0.19</td>
</tr>
<tr>
<td>Lungs</td>
<td>0.56</td>
<td>11.7</td>
<td>2.25</td>
<td>1.36</td>
<td>0.84</td>
<td>0.20</td>
</tr>
<tr>
<td>Liver</td>
<td>0.51</td>
<td>5.39</td>
<td>2.07</td>
<td>1.25</td>
<td>0.77</td>
<td>0.18</td>
</tr>
<tr>
<td>Jejunum</td>
<td>0.54</td>
<td>11.2</td>
<td>2.17</td>
<td>1.31</td>
<td>0.81</td>
<td>0.19</td>
</tr>
<tr>
<td>Ileum</td>
<td>0.56</td>
<td>38.4</td>
<td>2.27</td>
<td>1.37</td>
<td>0.85</td>
<td>0.20</td>
</tr>
<tr>
<td>Colon</td>
<td>0.58</td>
<td>5.89</td>
<td>2.35</td>
<td>1.42</td>
<td>0.88</td>
<td>0.21</td>
</tr>
<tr>
<td>Kidney</td>
<td>0.52</td>
<td>29.2</td>
<td>2.09</td>
<td>1.26</td>
<td>0.78</td>
<td>0.18</td>
</tr>
<tr>
<td>Muscle</td>
<td>0.53</td>
<td>0.42</td>
<td>2.13</td>
<td>1.29</td>
<td>0.80</td>
<td>0.19</td>
</tr>
<tr>
<td>Brain</td>
<td>0.53</td>
<td>7.70</td>
<td>2.15</td>
<td>1.30</td>
<td>0.80</td>
<td>0.19</td>
</tr>
<tr>
<td>Blood</td>
<td>0.62</td>
<td>2456</td>
<td>2.51</td>
<td>1.52</td>
<td>0.94</td>
<td>0.22</td>
</tr>
</tbody>
</table>
## Predicted-to-observed ratios for OBT in organs (84 days after start of contamination)

<table>
<thead>
<tr>
<th>Organ</th>
<th>MCT</th>
<th>FSA</th>
<th>IFIN</th>
<th>PRISMDG</th>
<th>STAR-H3(DG)</th>
<th>EDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart</td>
<td>2.05</td>
<td>9.89</td>
<td>1.40</td>
<td>1.51</td>
<td>1.29</td>
<td>1.29</td>
</tr>
<tr>
<td>Lungs</td>
<td>2.79</td>
<td>4.11</td>
<td>1.90</td>
<td>2.06</td>
<td>0.13</td>
<td>1.30</td>
</tr>
<tr>
<td>Liver</td>
<td>1.92</td>
<td>1.04</td>
<td>1.11</td>
<td>1.20</td>
<td>0.08</td>
<td>0.84</td>
</tr>
<tr>
<td>Jejunum</td>
<td>3.00</td>
<td>3.23</td>
<td>1.73</td>
<td>1.88</td>
<td>0.12</td>
<td>1.09</td>
</tr>
<tr>
<td>Ileum</td>
<td>2.24</td>
<td>13.0</td>
<td>1.53</td>
<td>1.65</td>
<td>0.10</td>
<td>0.96</td>
</tr>
<tr>
<td>Colon</td>
<td>3.28</td>
<td>2.23</td>
<td>2.24</td>
<td>2.42</td>
<td>0.15</td>
<td>1.40</td>
</tr>
<tr>
<td>Kidney</td>
<td>2.17</td>
<td>8.46</td>
<td>1.48</td>
<td>1.60</td>
<td>0.10</td>
<td>1.17</td>
</tr>
<tr>
<td>Muscle</td>
<td>4.44</td>
<td>0.23</td>
<td>1.90</td>
<td>3.65</td>
<td>0.23</td>
<td>3.11</td>
</tr>
<tr>
<td>Brain</td>
<td>3.91</td>
<td>4.69</td>
<td>-</td>
<td>3.17</td>
<td>0.20</td>
<td>1.65</td>
</tr>
<tr>
<td>Blood</td>
<td>3.04</td>
<td>970</td>
<td>1.27</td>
<td>1.92</td>
<td>0.12</td>
<td>1.22</td>
</tr>
</tbody>
</table>
Tests with growing pigs and veal

Few experiments
1. Pigs of 8 weeks old fed for 28 days with HTO:
   Muscle P/O ~ 1
   Viscera P/O ~ 1

2. Pigs of 8 weeks old fed for 28 days with milk powder contaminated with OBT:
   Muscle P/O ~ 3
   Viscera P/O ~ 2

3. Pigs of 8 weeks old fed for 21 days with boiled potatoes contaminated with OBT:
   Muscle P/O ~ 0.2
   Viscera P/O ~ 0.3
   } Not quite sure about these values → Potential explanation: old and insufficiently reported experimental data

4. Two calves of 18 and 40 days old, respectively fed for 28 days with milk powder contaminated with OBT:
   Muscle P/O ~ 1
   Viscera P/O ~ 2.5
CONCLUSIONS

• The model is apparently research grade, but it is tested with experimental data without calibration;
• It is continuously improved in parallel with literature search on animal nutrition and metabolism;
• Input parameters need only a basic understanding of metabolism and nutrition and the recommended values can be provided;
• Results (not shown) give arguments for distinction between subsistence and intensive farming (observed also for Cs-137 post-Chernobyl);
• Model provides robust results for all intake scenarios of interest
**PARSIMONIOUS APPROACH**

*Parsimonious model* = a model with as few parameters as possible for a given quality of a model

- Models of complex environmental processes and systems - widely used as tools to assist the development of research, and to support decision making at a number of levels (e.g. international, national government, corporate);

- Many models become unwieldy, over-parameterised and difficult to test as they seek to capture the temporal and spatial dynamics of relevant processes. The performance of most models is usually assessed through some kind of 'test' against observed data → this testing is commonly a simple comparison between a given model and a given set of observed data.

- Invariably there are many plausible model representations of particular processes and the influence of these alternatives on model performance is rarely investigated.

  We believe that models should be parsimonious, i.e. as simple as possible, but no simpler.

Many thanks to Prof Neil Crout (Univ. of Nottingham, UK), because he taught me what “Parsimonious” is and made enjoyable this type of “games”.
Approach

- create families of related models which vary in their level of detail, structure and parameterisation;
- 'measure' model performance, in particular predictive capability;
- to compare this performance between members of the model families to either:
  (a) allow the selection of the 'best' model
  (b) facilitate the averaging of predictions by different models.
Model selection

• There are many statistical approaches to model selection. Broadly, these fall into two types:
  (i) those in which the "best" model is chosen according to some criterion;
  (ii) those in which some kind of averaging takes place over a possible class of models.
• Approaches of type (i) → frequentist
• Approaches of type (ii) → Bayesian

• A typical approach of type (i) can be described as follows:
  1. Explicitly identify the class of models to be considered, including if possible a "minimal" model and a "maximal" model.
     Potential problem: time consuming
  2. Use the data to select the "best" model, basing the selection on a suitable model choice criterion.
     Potential problem: too many candidate models which fit the data → unable to identify a single best model
  3. Proceed as if the selected model is correct.
     Potential problem: underestimation of the true uncertainty
Case Study Models

TRIF Model (NRPB, UK, 1996)
- simple, compartmental
- predicts H-3 transfer in cows (meet and milk) and sheep (meet and milk)
- comparisons with the experiments are not successful
UFOTRI (W. Raskob, FZK, Germany)

- simple, compartmental
- predicts H-3 transfer in cows (meet and milk)
- direct transfer from grass OBT to cow HTO, cow OBT, milk OBT
- comparisons with the experiments are good
- OBT partition intake is justified in MAGENTC
- this model can applied for other lactating animals

![Diagram showing the transfer of OBT in cows and milk](image)
MAGENTC (IFIN-HH, Romania)
- complex, dynamic
- predicts H-3 and C-14 transfer in various growing mammals, biota and birds
- comparisons with the experiments are good

Inter-comparison between TRIF, UFOTRI, MAGENTC for OBT in milk after an OBT intake
Using complex models to get to simple models for dairy farm animals

Compartments:

1. Animal (EBW) water: Free Hydrogen or HTO in body water
2. Animal OBH (OBT)
3. Milk water (Free Hydrogen or HTO)
4. Milk OBH (OBT)
5. Intake water (FH, HTO)
6. Intake OBH (OBT)
7. \( f_h \) Intake fraction of OBH going to body FH
8. \( f_o \) Intake fraction of OBH going to body OBH

Transfers:

- \( K_{11} \) water loss to environment
- \( K_{12} \) transfer body FH to body OBH
- \( K_{13} \) body FH to milk FH
- \( K_{14} \) body FH to milk OBH
- \( K_{21} \) body OBH to body FH
- \( K_{24} \) body OBH to milk OBH
**Model inputs:**

MP milk production  
Milk OBH content per liter Milk OH (Moh)  
Milk water (Mfh)  
Milk FH content per liter  
Animal composition, depends on body condition – taken as average  
Animal FH (Afh), Animal OH (Aoh), Milk FH (Mfh) and Milk OH (Moh) – known

**Select water halftime from existed Tables:**

\[(k_{11} + k_{12} + k_{13} + k_{14}) = 0.693 / T_w \]  \[1\]

**Excretion of FH and OH in milk:**

\[ MP * M_{obh} = k_{24} * A_{oh} + k_{14} * A_{fh} + I_{obh} * (1 - f_o - f_h) \]  \[2\]  
\[ MP * M_{fh} = k_{13} * A_{fh} \]

→  
\[ k_{13} \text{ (body FH to milk FH)} \]

**Equilibrium of Afh and Aoh →**

\[ Afh * 0.693 / T_w = I_{fh} + I_{oh} * f_h + k_{21} * A_{oh} \]  \[3\]  
\[ Aoh * (k_{21} + k_{24}) = I_{oh} * f_o + Afh * k_{12} \]  \[4\]

**Take K21 from MAGENTC** (body OBH to body FH)

Adjust MAGENTC to Tw and constant mass, metabolic needs  
Use MAGENTC Ioh as metabolisable oh intake and Ioh

**Impose that x ~0.3 from Aoh comes from metabolism of Afh**

\[ X * A_{oh} * (k_{21} + k_{24}) = Afh * k_{12} \]  \[5\]  
\[4\] + \[5\] → (1-x) Afh K12 = x * fh *loh
Comparison between UFOTRI and MAGENTC for OBT concentration in muscle

We must follow the previous steps and hope for the best!!!
Pig case (EMRAS Scenario)

Flowchart of the simple models STAR (on the left) and OURSON (on the right)

- STAR sends all organic intake to body water → it overpredicts total tritium concentrations in urine and underpredicts OBT concentrations in pig organs.
- OURSON sends all organic intake to the body OBT compartment → it underestimates total tritium concentrations in urine and HTO concentrations in meat, and overestimates OBT concentrations in organs.
MCT does not consider the fraction of input organic tritium that is directly absorbed in the body OBT → explains the under prediction in urine.

Both models have fast and slow OBT compartments but:

- MCT transfers catabolic OBT to body water, whereas
- PRISM transfers it out of the body, which is perhaps an oversimplification.
CONCLUSIONS

• A simple but robust model for dairy farm animals can be developed starting from UFOTRI, but using MAGENTC’s data base and results;

• A simple, but robust model for meet production can be developed, but this needs more work and collaboration;

• The experimental data base collected in IFIN is available, because models’ tests are mandatory for parsimonious approach.
Thank you!