Evaluation of fill unit systems used for dairy cattle

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Why Prediction of Feed Intake?

- **Feed budgeting & diet formulation**
  - Identify feed surplus/shortage
  - Allocation of available feeds to groups of cows
  - Balancing diets

- **Explore different feeding strategies**
  - Alternative forage & concentrate options
  - Evaluate economical and environmental impact
    - Feed 50-70% of operational costs
    - N, P and GHG emissions
Regulation of Feed Intake

- Complex multi-pathway feedback mechanisms
  - Feedback mechanisms Central Nervous System
    - GIT: chemo- and mechanoreceptors (fill, pH, osmolality)
    - Metabolism: oxi-, gluco- and lipostatic regulation
    - Body composition (fatness)
    - Environment (housing, climate, photoperiodicity)
    - Feed: taste, smell, preference
    - Feeding method, feed availability, diet composition

- In short: Animal × Feed interactions
Feed intake models

- **Flexibility**
  - Suitable for various feeds
  - Easy measurable inputs

- **Should include**
  - Feed factors
  - Animal factors
  - External factors

- **Accurate and robust**
Modelling Feed Intake

- Mechanistic models
- Multiple regression models
  - Concentrate input, cell wall fractions (forage, concentrate)
  - Stage of lactation, lactation number, Milk yield
  - Temperature

- Fill Unit systems
  - Separation in Animal and Feed factors
  - Flexible, suitable in many different situations
“Fill” Unit systems

- The principle of fill-unit systems
  \[ \text{DMI (kg/d)} = \frac{\text{IC}}{\text{Fill}} \]
  \[ \text{IC} = \text{Intake Capacity in “Fill”-units/day} \]
  \[ \text{Fill} = \text{“Fill”-units per kg DM} \]

- Intake capacity
  - The animals ability to process the “Fill”

- “Fill”
  - Not only physical limitation of intake
  - Preference, digestibility, metabolic regulation
“Fill” Unit systems:

- France INRA (FR) (Jarrige et al. 1986, Faverdin et al. 2011)
- Netherlands (NL) (Zom et al. 2012)
- Nordic Countries NorFoR (NF) (Volden et al. 2011)
## Fill unit systems: animal factors

### Model inputs to predict Intake Capacity

<table>
<thead>
<tr>
<th>Factor</th>
<th>FR</th>
<th>NL</th>
<th>NF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage of lactation</td>
<td>×</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>Stage of gestation</td>
<td>×</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>Lactation number</td>
<td>×</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>Age</td>
<td>×</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Breed</td>
<td>(×)</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>BCS</td>
<td>×</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BW</td>
<td>×</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milk yield</td>
<td>×</td>
<td></td>
<td></td>
</tr>
<tr>
<td>maxPotMY kg/d</td>
<td></td>
<td></td>
<td>ECM kg/d</td>
</tr>
<tr>
<td>Max Pot.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Animal factors

- Animal factors represent the physiological and metabolic state of the cow
- Animal outputs (actual Milk Yield, BW, BCS) as input
  - Difficult to combine with predictive models of animal production
  - Require assumptions of a “potential” production
    - Potential production requires non limiting conditions
  - Iterative routines
Intake Capacity FR

Days in lactation

Intake Capacity

LN 1  LN 2  LN 3  LN 6
Intake Capacity NL

Intake Capacity NL

Days in lactation

Intake Capacity

LN 1  LN 2  LN 3  LN 6
Intake Capacity NF

![Graph showing intake capacity over days in lactation for different LN numbers.]
Intake Capacity

Intake Capacity FR

Intake Capacity NL

Intake Capacity NF
## Fill unit systems: feed factors

<table>
<thead>
<tr>
<th></th>
<th>&quot;Fill&quot; Value Forage</th>
<th>&quot;Fill&quot; Value Concentrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>FR</td>
<td>Table Values &amp; equations&lt;br&gt;Inputs: DM, Cfibre, CP</td>
<td>Variable Energy balance</td>
</tr>
<tr>
<td>NL</td>
<td>Feed specific equations&lt;br&gt;Inputs: DM, Cfibre, CP&lt;br&gt;Ash, %OMD</td>
<td>Variable equation</td>
</tr>
<tr>
<td>NF</td>
<td>Non specific equation&lt;br&gt;Inputs: NDF, %OMD fermentation products</td>
<td>Fixed</td>
</tr>
</tbody>
</table>
Fill unit systems: feed factors

- **Dry Matter**
  - Bulk volume, silage preservation, hydration, microbial colonisation ...

- **Crude Protein**
  - Nitrogen availability for rumen microbes ...

- **Crude Fibre / cell walls**
  - Particle size reduction, passage rate ...

- **Digestibility / OMD%**
  - Ruminal VFA production, ruminal disappearance ...
Approximate Fill value relative to grass silage

"Fill" relative to grass silage

- Maize Silage
- Fresh Grass
- Fresh Grass/clover
- Wheat Straw
- Maize Ears Silage
- Alfalfa silage

FR
Approximate Fill value relative to grass silage

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FR
NL
Approximate Fill value relative to grass silage

"Fill" relative to grass silage

Maize Silage  Fresh Grass  Fresh Grass/clover  Wheat Straw  Maize Ears Silage  Alfalfa silage

FR  NL  NF
Fill value of forage

- Within forage differences in relative “Fill”
- FR – NL – NR
  - Ranking of “Fill” of feeds similar
  - Fill Maize silage & Fresh grass < Grass silage
  - Fill Straw > Grass silage
Fill value of concentrate and substitution (I)

- Substitution of forage intake by concentrate intake
- “Concentrate” has no clear definition → arbitrary
- Systems are different
  - NL → simple
  - NR → linear with adjustment for sugar and starch content
  - FR → interaction with energy balance
Non-linear substitution rate (SR)

- Low substitution at low concentrate levels
  - Alleviate deficits (readily available CHO, N, etc.)
- High substitution at high concentrate levels
  - (Sub)-clinical rumen acidosis, reduced fibre digestion
Systems are different with regard to substitution of forage

- Non-linear
Fill value of concentrate and substitution (IV)

- Systems are different with regard to substitution of forage
- INRA system rather complex
  - Takes the energy balance into account
  - Reflects metabolic regulation
  - Needs an output (milk production) as an input
  - Feed intake model can only be used in conjunction with the UFL energy system
Fill value of concentrate and substitution (V)

- Systems are different with regard to substitution

- NL system:
  - Linear substitution → SR = Fill\textsubscript{Concentrate} / Fill\textsubscript{Forage}
  - Non-specific, substitution of any feed “x” by any feed “y”
  - Limitation: general “nutrition rules” have to taken into account
    - Minimum levels of physical structure (effective fibre)
    - Avoid deficits (N, minerals, physical structure), e.g. Rumen Degradable Protein balance >0
  - Suitable under practical conditions
Fill value of concentrate and substitution (VI)

- Linear substitution
  - Practical conditions

![Graph showing forage substitution in relation to concentrate level with sub-clinical rumen acidosis and alleviated deficits marked.]
Fill value of concentrate and substitution (VII)

- NR: Linear with adjustment for diet composition
  - NorFor system
    - Fixed Fill value for concentrate
    - Substitution rate is linear
    - Substitution is not a "concentrate" effect per se
    - Taking the whole diet into account
    - Adjustments for starch and sugars in the diet
Discussion (I)

- Fill Unit systems differ in:
  - Animal factors:
    - Actual and “potential” milk production
      - MY correlated with DMI → MY is pushed by (energy) intake
      - Intake lags behind milk yield
      - Potential milk production is not really known
      - Milk production may be associated with metabolic state (pull)
    - Genetic level or breed
      - Scaling factors
      - Genetic theoretic intake potential
Discussion (II)

Fill Unit systems differ in:

Feed factors:

- Limitations in available data, e.g.
  - Proportion of concentrates
  - Feed variables
  - Growing condition grass (N fertilization)
Discussion (III)

- National research efforts in feed evaluation
  - national systems create national “nutritional languages”
  - fragmentation of research efforts
  - individual EU countries: risk for reduced expertise, funding and involvement of young scientists
Discussion (IV)

- Harmonizing of feed evaluation systems in Europe
  - systematically compare feeding systems in use in EU
  - work towards a more unified system of farm animal nutrition in Europe
  - stimulate “European thinking” and shared language
  - collaborative capacity and network building
  - accelerate innovation
Discussion (V)

- Harmonizing Fill Unit systems in Europe:
  - Cross validation
    - Testing the models in different situations
    - Harmonizing datasets and feed variables
    - Parameterization to other datasets
  - Improve models
    - Harmonize models
    - Collaboration in future innovations
Future developments in fill unit systems

- Fill systems integrated with grazing systems
- Modelling differences in genetic potential
  - ...
  - ...
  - ...

Discussion (VI)
Thanks for your attention!

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