Rapid methods of Feed Analysis

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Need to increase animal production

**Monogastrics:** poultry, eggs and pigs

- High efficiency of feed utilization

- Food competition:
  - Humans
  - Bio-fuel
Efficiency of dietary N utilization

100 g N

25% Soils: eutrophication (Nitrate)

50% Underwater pollution (Nitrites)

25% "GOOD FARMING PRACTICE"

Methane emissions

Urine 25%

REduction Nitrogen EXcretion

50% "GOOD FARMING PRACTICE"

Soil eutrophisation (Nitrate)

Underwater pollution (Nitrites)

Greenhouse gas ($N_2O$, $NH_3$, $CH_4$)
Ruminants

- **Use fiber and non-protein N**
- Pastures no suitable for crops
- **Crop residues**
- **Industrial by-products**
Optimize the ruminant nutrition

Animal requirements
- In:
  - Energy
  - Protein
- Depend on:
  - Physiological stage
  - Animal performance
  - Others (BW, °C, activity)
- Estimation
  - "Trial and error" (production)
  - Tables (INRA, AFRC, NRC)

Feed nutritional value
Static approach for feed evaluation: Chemical analysis
Feeding systems

<table>
<thead>
<tr>
<th>System</th>
<th>Countries using the system (in brackets partly used)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PDI system</td>
<td>F, B, CZ, IRL, PL, P, SK, E, (I)</td>
</tr>
<tr>
<td>ARC system, FiM</td>
<td>GB, (IRL), (P)</td>
</tr>
<tr>
<td>AAT/PBV system</td>
<td>DK, S, FIN, N, IS, EST</td>
</tr>
<tr>
<td>NorFor</td>
<td>DK, S, N, IS (newly introduced)</td>
</tr>
<tr>
<td>DVE/OEB system</td>
<td>NL, B, (D)</td>
</tr>
<tr>
<td>nXP system</td>
<td>D, (PL)</td>
</tr>
<tr>
<td>NRC/CNCPS</td>
<td>USA, E, (I), (PL), (P)</td>
</tr>
<tr>
<td>CSIRO</td>
<td>AUS</td>
</tr>
</tbody>
</table>

Diagram: Flowchart of nutrient assimilation in ruminants, showing diet as the source of protein and energy, with degradation and microbial processes in the rumen and small intestine, leading to metabolisable protein/AA.
Dynamic approach for feed evaluation: In vivo measurements

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Abbreviation</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water soluble CP</td>
<td>CP&lt;sub&gt;WS&lt;/sub&gt;</td>
<td>Water</td>
</tr>
<tr>
<td>Total tract CP digestibility</td>
<td>CP&lt;sub&gt;TTD&lt;/sub&gt;</td>
<td>Mobile bag (Duodenum-faeces)</td>
</tr>
<tr>
<td>Rumen degradation pattern DM, CP and NDF</td>
<td>a, b, c and ED</td>
<td>In situ or in sacco method</td>
</tr>
</tbody>
</table>

**Effective Degradability**
(Ørskov and McDonald 1979)

$$ED = a + b \left[ \frac{c}{c + k} \right]$$

- k = rumen outflow rate DM, CP = 5%/h (2%/h for NDF)
- RRT of DM, CP = 20h (50h for NDF)
Dynamic approach for feed evaluation: 
*In vivo* measurements

**Alternatives**
- Rapid method for feed analysis
- Accurate prediction
- Simple and cost-effective

Martín-Orúe et al., 2000 An. Feed Sci. Tech
Infrared Spectroscopy
Infrared Spectroscopy

NIR vs. FTIR

Absorbance vs. Wavenumber, cm⁻¹

- NIR Range
- Combination
- 1-st Overtone
- 2-nd Overtone
- 3-rd Overtone

Fundamental bands (Mid IR)

Finger print

N-H Attached to heteroatoms
C-H
C≡C
C≡N
C=O
C=N
C=C

4000 3200 2800 2300 2100 1800 1500 1460, 1380 nujol 1000 cm⁻¹
IR spectroscopy does not analyze the sample, simply predicts the composition according to an initially proposed equation.
**RULES TO GET A GOOD CALIBRATION**

- **Laboratory determinations**: As more accurate as better calibration

- **Range of measurement**: Calibration samples must cover the range expected in the unknown samples

- **Number of samples & distribution**: High number and homogeneously distributed

- **Sampling**: Representative

- **Milling**: Adapted to the type of feed

- **IR analysis**: Avoid cross contamination

- **Data interpretation**:  
  - Typing errors
  - Model over fitting
Previous findings

Green-crops

Meadow grasses


Raju et al., 2011 (An. Feed. Sci. Tech.)
**Objective:** Evaluation the potential of IR spectrometry to predict the feed nutritional of ALL feeds used in ruminant nutrition

*Dataset = 786 samples (80 different feeds)*

<table>
<thead>
<tr>
<th>38 Barley-wheat forage</th>
<th>111 Grass-clover forage</th>
<th>39 Legume forage</th>
<th>200 Oil by products</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 Barley whole crop</td>
<td>36 Grass-clover forage</td>
<td>12 Lupinus whole crop</td>
<td>112 Rapeseed</td>
</tr>
<tr>
<td>10 Winter wheat whole crop</td>
<td>26 Grass silage</td>
<td>7 Lucerne forage</td>
<td>42 Soybean</td>
</tr>
<tr>
<td>8 Winter wheat silage</td>
<td>16 Grass-clover silage</td>
<td>5 Peas whole crop forage</td>
<td>25 Sunflower</td>
</tr>
<tr>
<td>4 Barley whole crop silage</td>
<td>14 Grass forage</td>
<td>4 Peas whole crop silage</td>
<td>12 Cotton seed</td>
</tr>
<tr>
<td>4 Green barley forage</td>
<td>7 Artificial-dry grass</td>
<td>4 Galega forage</td>
<td>2 Soypass</td>
</tr>
<tr>
<td>2 Barley straw</td>
<td>8 Clover forage</td>
<td>4 Field beans whole crop</td>
<td>2 Treated soybean meal</td>
</tr>
<tr>
<td></td>
<td>2 Grass straw</td>
<td>2 Artificial dry lucerne</td>
<td>4 Others</td>
</tr>
<tr>
<td></td>
<td>2 Festulolium forage</td>
<td>1 Peas straw</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>18 Mill by products</th>
<th>63 Cereal grains</th>
<th>18 Legume seeds</th>
<th>17 Protein products</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 Maize gluten feed</td>
<td>30 Barley</td>
<td>7 Peas</td>
<td>7 Guar meal</td>
</tr>
<tr>
<td>4 Maize feed meal</td>
<td>12 Wheat</td>
<td>3 Soybean</td>
<td>5 Malt sprouts</td>
</tr>
<tr>
<td>3 Wheat gluten feed</td>
<td>7 Rye</td>
<td>3 Toasted soybean</td>
<td>3 Brewers grains</td>
</tr>
<tr>
<td>2 Wheat bran</td>
<td>5 Triticale</td>
<td>2 Rapeseed</td>
<td>2 Potato protein</td>
</tr>
<tr>
<td>2 Amyfeed</td>
<td>4 Oat</td>
<td>2 Lupinus</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 Maize</td>
<td>1 Field beans</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 Grain mix</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>22 Maize silage</th>
<th>32 Maize forage</th>
<th>22 Beets</th>
<th>35 Distillers</th>
</tr>
</thead>
<tbody>
<tr>
<td>22 Maize silage</td>
<td>14 Dry sugar beet pulp</td>
<td>14 Dry sugar beet pulp</td>
<td>28 Corn distillers</td>
</tr>
<tr>
<td>2 Maize silage with pulp</td>
<td>6 Fodder beets</td>
<td>6 Fodder beets</td>
<td>5 Wheat distillers</td>
</tr>
<tr>
<td></td>
<td>2 Beet pulp</td>
<td>2 Beet pulp</td>
<td>2 Barley distillers</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>16 Soybean hulls</th>
<th>127 Concentrate mix</th>
<th>19 Total mixed ration</th>
<th>9 Tropical feeds</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>
FTIR analysis

- **Sample preparation:**
  - Dry at 60ºC and milled at 1.5 mm diameter

- **FTIR analysis:**
  - Equinox 55 FTIR spectrometer fitted with a Golden Gate ATR accessory
  - Wavelength: 500 to 4000 cm\(^{-1}\) (resolution 2 cm\(^{-1}\))
  - 64 scans per sample in duplicate

Raw spectra

1\(^{st}\) derivative & vector normalization
Modelling

• **Metadata (n=663)**
  - Mean centre scaled

• **Spectral data**
  - Calibration dataset (85% samples)
  - Validation dataset (15% samples)

• **Prediction models**
  - Partial Least Squares (PLS-Matlab)
  - Data transformation (de-trend, SNV, MSC)
    - 1st or 2nd derivative
    - Vector normalized (mean=0, variance=1SD)
    - Mean centre scale
  - Outliers (high hotelling, Q residuals, >3SD)
  - Cross validation (“Venetian Blinds”)
  - Number of LV chosen to minimize RMSECV
  - Model accuracy ($R^2$ & RPD=SD/SEP)
    - Very satisfactory $R^2 > 0.90$ & $RPD > 3.0$
    - Satisfactory: $R^2 > 0.80$ & $RPD > 2.5$
    - For screening: $R^2 > 0.70$ & $RPD > 2.0$
    - Inaccurate: $R^2 < 0.70$ & $RPD < 2.0$
Universal model
\% CP
\(n = 655\)

\(R^2 = 0.93\)
\(R_{PD} = 4.00\)

Very satisfactory
Universal models ($n=655$)

\[ R^2 = 0.82 \]
\[ RPD = 2.26 \]

Screening

\[ R^2 = 0.65 \]
\[ RPD = 1.99 \]

Inaccurate

Universal models

\[ R^2 = 0.6818 \]
\[ 8 \text{ Latent Variables} \]
\[ RMSEC = 6.8143 \]
\[ RMSECV = 6.4862 \]
\[ RMSEP = 7.3694 \]
\[ Calibration \ Bias = -3.1397e-014 \]
\[ CV \ Bias = -0.13359 \]
\[ Prediction \ Bias = -0.39596 \]
$CP_a$ $R^2 = 0.76$  
$RPD = 1.75$  
Inaccurate

$CP_b$ $R^2 = 0.74$  
$RPD = 1.65$  
Inaccurate

$CP_c$ $R^2 = 0.38$  
$RPD = 1.43$  
Inaccurate

$CP_{ED}$ $R^2 = 0.69$  
$RPD = 1.56$  
Inaccurate
Prediction DM degradability
Universal equation (n=663)

<table>
<thead>
<tr>
<th></th>
<th>Calibration</th>
<th>Cross validation</th>
<th>Prediction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SG</td>
<td>LV</td>
<td>$R^2_c$</td>
</tr>
<tr>
<td>DM$_{ED}$</td>
<td>2</td>
<td>7</td>
<td>0.69</td>
</tr>
<tr>
<td>a</td>
<td>1</td>
<td>6</td>
<td>0.77</td>
</tr>
<tr>
<td>b</td>
<td>1</td>
<td>7</td>
<td>0.73</td>
</tr>
<tr>
<td>c, %/h</td>
<td>1</td>
<td>6</td>
<td>0.50</td>
</tr>
</tbody>
</table>
 Canonical analysis of variance (10 PCs = 90% var)

- **CVA axis 1 (79% variance)**
- **CVA axis 2 (21% variance)**

**MANOVA, P<0.001**

- **Forage**
- **Concentrate**

- Starch
- Protein

- Barley/Wheat forage
- Maize silage
- Cereal grains
- Mill by products
- Tropical feeds
- Concentrate mix
- Distillers
- Forage products
- Protein products

**Starch**

**Protein**
Feeds classification

FORAGES
- Barley-wheat forage
- Grass-clover forage
- Maize forage
- Legume forage
- Total mixed ration
- Soybean hulls
- Beets

ENERGY-RICH concentrates
- Cereal grains
- Mill by products
- Tropical feeds
- Concentrate mix

PROTEIN-RICH concentrates
- Legume seeds
- Protein products (>30%CP)
- Oil by products
- Dried distiller grains (DGGS)
Crude protein

FORAGES (n=183)

ENERGY-RICH concentrates (n=215)

PROTEIN-RICH concentrates (n=266)
**CP<sub>WS</sub>**  
Water soluble CP

**FORAGES**  
(n=183)  
\[ R^2 = 0.91 \]  
\[ RPD = 2.68 \]  
Satisfactory

**ENERGY-RICH concentrates**  
(n=215)  
\[ R^2 = 0.74 \]  
\[ RPD = 1.42 \]  
Inaccurate

**PROTEIN-RICH concentrates**  
(n=266)  
\[ R^2 = 0.76 \]  
\[ RPD = 2.40 \]  
Screening
\[ R^2 = 0.79 \]
\[ RPD = 2.32 \]
**Screening**

\[ R^2 = 0.60 \]
\[ RPD = 2.32 \]
**Inaccurate**

\[ R^2 = 0.73 \]
\[ RPD = 2.85 \]
**Screening**

**FORAGES**
\( (n=183) \)

**ENERGY-RICH concentrates**
\( (n=215) \)

**PROTEIN-RICH concentrates**
\( (n=266) \)
**Fraction a**
Immediately degradable CP

**FORAGES**
\( n = 183 \)
\[ R^2 = 0.93 \]
\[ RPD = 2.89 \]
Satisfactory

**ENERGY-RICH concentrates**
\( n = 215 \)
\[ R^2 = 0.68 \]
\[ RPD = 1.85 \]
Inaccurate

**PROTEIN-RICH concentrates**
\( n = 266 \)
\[ R^2 = 0.83 \]
\[ RPD = 2.22 \]
Screening
Fraction $b$

Degradable but not soluble CP

FORAGES

$(n=183)$

$R^2=0.91$

$RPD=2.80$

Satisfactory

ENERGY-RICH concentrates

$(n=215)$

$R^2=0.68$

$RPD=1.91$

Inaccurate

PROTEIN-RICH concentrates

$(n=266)$

$R^2=0.82$

$RPD=2.08$

Screening
Value $c$

CP degradation rate of $b$

FORAGES

$R^2 = 0.64$

$RPD = 2.49$

Screening

$R^2 = 0.54$

$RPD = 1.82$

Inaccurate

ENERGY-RICH concentrates

$R^2 = 0.54$

$RPD = 1.82$

Inaccurate

PROTEIN-RICH concentrates

$R^2 = 0.71$

$RPD = 1.95$

Inaccurate
Effective digestible CP

FORAGES \((n=183)\)

**ENERGY-RICH** concentrates \((n=215)\)

**PROTEIN-RICH** concentrates \((n=266)\)
## Prediction DM digradability

<table>
<thead>
<tr>
<th>SG</th>
<th>LV</th>
<th>Calibration</th>
<th>Cross validation</th>
<th>Prediction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$R^2_c$</td>
<td>RMSEC</td>
<td>$R^2_{CV}$</td>
</tr>
<tr>
<td>----</td>
<td>----</td>
<td>-------------</td>
<td>-----------------</td>
<td>------------</td>
</tr>
<tr>
<td>FOR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$DM_{ED}$</td>
<td>2</td>
<td>8</td>
<td>0.87</td>
<td>3.92</td>
</tr>
<tr>
<td>$a$</td>
<td>1</td>
<td>8</td>
<td>0.94</td>
<td>3.61</td>
</tr>
<tr>
<td>$b$</td>
<td>2</td>
<td>8</td>
<td>0.94</td>
<td>4.45</td>
</tr>
<tr>
<td>$c, %/h$</td>
<td>1</td>
<td>5</td>
<td>0.75</td>
<td>1.24</td>
</tr>
<tr>
<td>ERC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$DM_{ED}$</td>
<td>2</td>
<td>8</td>
<td>0.84</td>
<td>3.23</td>
</tr>
<tr>
<td>$a$</td>
<td>1</td>
<td>7</td>
<td>0.59</td>
<td>6.59</td>
</tr>
<tr>
<td>$b$</td>
<td>1</td>
<td>7</td>
<td>0.63</td>
<td>6.48</td>
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<tr>
<td>$c, %/h$</td>
<td>1</td>
<td>7</td>
<td>0.69</td>
<td>3.72</td>
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<tr>
<td>PRC</td>
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</tr>
<tr>
<td>$DM_{ED}$</td>
<td>2</td>
<td>8</td>
<td>0.75</td>
<td>3.73</td>
</tr>
<tr>
<td>$a$</td>
<td>1</td>
<td>6</td>
<td>0.70</td>
<td>4.31</td>
</tr>
<tr>
<td>$b$</td>
<td>1</td>
<td>7</td>
<td>0.78</td>
<td>4.51</td>
</tr>
<tr>
<td>$c, %/h$</td>
<td>1</td>
<td>8</td>
<td>0.70</td>
<td>1.20</td>
</tr>
</tbody>
</table>
Prediction NDF parameters

- **NDF**
  - $R^2 = 0.90$
  - $\text{RPD} = 2.84$
  - Satisfactory

- **NDF$_{ED}$**
  - $R^2 = 0.95$
  - $\text{RPD} = 2.35$
  - Screening

- **Fraction b**
  - $R^2 = 0.85$
  - $\text{RPD} = 1.23$
  - Inaccurate

- **Fraction c**
  - $R^2 = 0.94$
  - $\text{RPD} = 2.25$
  - Screening

- **c-undegraded**
  - $R^2 = 0.87$
  - $\text{RPD} = 2.01$
  - Screening

- **iNDF**
  - $R^2 = 0.79$
  - $\text{RPD} = 2.17$
  - Screening
FTIR conclusions

- FTIR allows to classify feeds according to the nutritional value
- And determine:

<table>
<thead>
<tr>
<th></th>
<th>Universal</th>
<th>Forage</th>
<th>Protein rich concentrates</th>
<th>Energy rich concentrates</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP</td>
<td>Quantification</td>
<td>Quantification</td>
<td>Quantification</td>
<td></td>
</tr>
<tr>
<td>CP&lt;sub&gt;WS&lt;/sub&gt;</td>
<td>Screening</td>
<td>Quantification</td>
<td>Screening</td>
<td></td>
</tr>
<tr>
<td>CP&lt;sub&gt;TTD&lt;/sub&gt;</td>
<td>Screening</td>
<td>Quantification</td>
<td>Screening</td>
<td></td>
</tr>
<tr>
<td>CP&lt;sub&gt;ED&lt;/sub&gt;</td>
<td>Screening</td>
<td>Quantification</td>
<td>Screening</td>
<td></td>
</tr>
<tr>
<td>CP&lt;sub&gt;A&lt;/sub&gt;</td>
<td>Quantification</td>
<td>Screening</td>
<td>Screening</td>
<td></td>
</tr>
<tr>
<td>CP&lt;sub&gt;B&lt;/sub&gt;</td>
<td>Screening</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>CP&lt;sub&gt;C&lt;/sub&gt;</td>
<td>Screening</td>
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<tr>
<td>DM&lt;sub&gt;ED&lt;/sub&gt;</td>
<td>Screening</td>
<td>Quantification</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DM&lt;sub&gt;A&lt;/sub&gt;</td>
<td>Screening</td>
<td>Quantification</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DM&lt;sub&gt;B&lt;/sub&gt;</td>
<td>Screening</td>
<td>Quantification</td>
<td></td>
<td>Screening</td>
</tr>
<tr>
<td>DM&lt;sub&gt;C&lt;/sub&gt;</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NDF</td>
<td>Quantification</td>
<td>Quantification</td>
<td>Quantification</td>
<td></td>
</tr>
<tr>
<td>NDF&lt;sub&gt;ED&lt;/sub&gt;</td>
<td>Quantification</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>NDF&lt;sub&gt;B&lt;/sub&gt;</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>NDF&lt;sub&gt;C&lt;/sub&gt;</td>
<td></td>
<td>Screening</td>
<td></td>
<td></td>
</tr>
<tr>
<td>iNDF</td>
<td>Screening</td>
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</tr>
</tbody>
</table>
Near Infrared Spectroscopy (NIRS)

- Laser
- Wavelength selection
- Sample
- Detectors
NIR spectra

1st Derivative

2nd Derivative
## NIRS Materials & Methods

- **Group separation of feedstuffs**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Sugar-beet pulp</td>
<td>14</td>
</tr>
<tr>
<td>B</td>
<td>Oils byproduct</td>
<td>200</td>
</tr>
<tr>
<td>C</td>
<td>Byproduct</td>
<td>98</td>
</tr>
<tr>
<td>D</td>
<td>Concentrate</td>
<td>152</td>
</tr>
<tr>
<td>E</td>
<td>Grains &amp; seed</td>
<td>90</td>
</tr>
<tr>
<td>F</td>
<td>Forage (whole crop, straw, hay)</td>
<td>195</td>
</tr>
<tr>
<td>T</td>
<td>Tropical</td>
<td>9</td>
</tr>
<tr>
<td>G</td>
<td>Silage</td>
<td>52</td>
</tr>
<tr>
<td></td>
<td><strong>TOTAL</strong></td>
<td>809</td>
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</table>

**Grouping:**
- **Byproducts**
- **Concentrates**

**Validation & Calibration:**
- **Non-forages** (80%)
- **Forages** (20%)
NIRS Materials & Methods

- Mathematical treatment were performed using WinISI III (v. 1.6)
- Scatter correction transformations
  - Standard normal variate (SNV),
  - Detrend (D)
  - Standard normal variate -detrend (SNV-D)
  - Multiplicative scatter correction (MSC)
- Calibrations were developed by the modified partial least squares (MPLS) regression technique.
NIRS Results & Discussion

• Chemical composition (ALL)

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Derivate treatment</th>
<th>Scatter correction</th>
<th>$R^2$</th>
<th>SEC</th>
<th>$r^2$</th>
<th>SEP</th>
<th>RPD</th>
<th>RER</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP</td>
<td>2,4,4,1</td>
<td>MSC</td>
<td>0.99</td>
<td>0.96</td>
<td>0.99</td>
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<td>NDF</td>
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<td>0.92</td>
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<td>0.90</td>
<td>4.48</td>
<td>2.33</td>
<td>13.2</td>
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</table>
## CP degradability by NIRS

<table>
<thead>
<tr>
<th>Nutrient (%)</th>
<th>Group</th>
<th>Scatter correction</th>
<th>Derivate treatment</th>
<th>R²</th>
<th>SEC</th>
<th>r²</th>
<th>SEP</th>
<th>RPD</th>
<th>RER</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CP&lt;sub&gt;Ed&lt;/sub&gt;</strong></td>
<td>ALL</td>
<td>MSC</td>
<td>3.4.4.1</td>
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<td>0.80</td>
<td>0.906</td>
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<td>12.78</td>
</tr>
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<td></td>
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<td>SNV-D</td>
<td>3.4.4.1</td>
<td>0.89</td>
<td>0.027</td>
<td>0.86</td>
<td>1.012</td>
<td>2.63</td>
<td>9.76</td>
</tr>
<tr>
<td></td>
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<td>3.4.4.1</td>
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</tr>
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<td>MSC</td>
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## DM degradability by NIRS

<table>
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<tr>
<th>Nutrient (%)</th>
<th>Group</th>
<th>Scatter correction</th>
<th>Derivate treatment</th>
<th>R²</th>
<th>SEC</th>
<th>r²</th>
<th>SEP</th>
<th>RPD</th>
<th>RER</th>
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<tbody>
<tr>
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<td>ALL</td>
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<td>D</td>
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<td>0.026</td>
<td>0.80</td>
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<td>8.89</td>
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<td>SNV-D</td>
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<td>0.83</td>
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<tr>
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<td>MSC</td>
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<td>0.021</td>
<td>0.90</td>
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</tr>
<tr>
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<tr>
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<td>0.76</td>
<td>0.066</td>
<td>2.84</td>
<td>13.40</td>
</tr>
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<td>12.56</td>
</tr>
<tr>
<td>DM C</td>
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<td>MSC</td>
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<td>0.015</td>
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</table>
### NDF degradability by NIRS

<table>
<thead>
<tr>
<th>Nutrient (%)</th>
<th>Group</th>
<th>Scatter correction</th>
<th>Derivate treatment</th>
<th>R²</th>
<th>SEC</th>
<th>r²</th>
<th>SEP</th>
<th>RPD</th>
<th>RER</th>
</tr>
</thead>
<tbody>
<tr>
<td>NDF&lt;sub&gt;ED&lt;/sub&gt;</td>
<td>ALL</td>
<td>MSC</td>
<td>3.10.10.1</td>
<td>0.84</td>
<td>0.054</td>
<td>0.76</td>
<td>0.072</td>
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<td>7.48</td>
</tr>
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<td>SNV-D</td>
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<td>0.058</td>
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<td>8.66</td>
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<tr>
<td>NDF&lt;sub&gt;B&lt;/sub&gt;</td>
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<td>D</td>
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<td>0.095</td>
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<tr>
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<td>0.014</td>
<td>1.57</td>
<td>6.28</td>
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</tbody>
</table>
GENERAL CONCLUSIONS

• Universal equations can be used to predict chemical structure

• However, group separation of samples improved predictions of degradability data (except C)

• IR spectroscopy can be incorporated as a field tool to determine dynamic parameters of feed evaluation models (FORAGES)

• Current feeding evaluation systems must combine the traditional equations with IR data in order to improve the prediction of:
  – Feed nutritional value
  – Animal performance
## CONCLUSIONS TO KEEP IN MIND

<table>
<thead>
<tr>
<th>ADVANTAGES</th>
<th>DISADVANTAGES</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Quick analysis</td>
<td>- Indirect method (calibration)</td>
</tr>
<tr>
<td>- No destructive technique</td>
<td>- Technical support</td>
</tr>
<tr>
<td>- Low cost per sample</td>
<td>- Calibration updating</td>
</tr>
<tr>
<td>- Minimum sample preparation</td>
<td>- Dependence on the ref. method</td>
</tr>
<tr>
<td>- Easy to use</td>
<td></td>
</tr>
<tr>
<td>- Environmentally friendly (no waste)</td>
<td>- Analysis can be affected by:</td>
</tr>
<tr>
<td>- Multianalysis (several parameters)</td>
<td>- Particle size</td>
</tr>
<tr>
<td>- Simultaneous prediction of static and dynamic</td>
<td>- Temperature</td>
</tr>
<tr>
<td>parameters</td>
<td>- Humidity</td>
</tr>
<tr>
<td></td>
<td>- High investment in equipment</td>
</tr>
<tr>
<td></td>
<td>- Difficulty to compare between different</td>
</tr>
<tr>
<td></td>
<td>equipment</td>
</tr>
</tbody>
</table>
This study has been carried out with the financial support from:
The Commission of the European Communities (FP7, KBB-2007-1)
The Welsh Government

Thank you for your attention!!

Innovative and practical management approaches to reduce nitrogen excretion by ruminants