The PDI system

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A brief history

1978: first version of the PDI system
80’s: utilisation increased (feed manufacturers, technicians, farmers)

1988: new version of the PDI system

1999: software to calculate feed value

2002: revised feed values
2007: revised forage values
revised FU system
Presentation of the system
Each feedstuff: 2 values: PDIN et PDIE
Actual value = the smallest
Potential value = the highest
Objective: diet PDIN = diet PDIE
Animal requirements

Maintenance: $3.25 \, \text{g PDI} / \, \text{kg LW}^{0.75}$

$\approx$ From 500 to 700 kg : $95 + 0.5 \, \text{LW}$
$\approx 395 \, \text{g PDI} / \, \text{day (600 kg)}$

Yield: **protein yield / 0.64**

$= 0.56 \times \text{MY} \times \text{protein content}$

$\approx 48 \, \text{g PDI} / \, \text{kg milk (31 g/kg protein)}$

Pregnancy: **0.07 x Birth LW x exp (0.111 x week pregnancy)**

from 75 g to 205 g PDI / day

Growth: 250 to 350 g PDI / kg LWG

**One dairy cow** (600 kg – 25 kg milk) $= 1600 \, \text{g PDI} / \, \text{day}$
How to formulate a diet for a dairy cow?

<table>
<thead>
<tr>
<th>Feed (g/kg DM)</th>
<th>Feed (g/kg DM)</th>
<th>Diet (g/d)</th>
<th>Diet (g/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PDIN</td>
<td>PDIE</td>
<td>PDIN</td>
</tr>
<tr>
<td>15 kg Maize Sil</td>
<td>51</td>
<td>71</td>
<td>765</td>
</tr>
<tr>
<td>2.5 kg Barley</td>
<td>79</td>
<td>101</td>
<td>198</td>
</tr>
<tr>
<td>3.0 kg SBM</td>
<td>377</td>
<td>261</td>
<td>1131</td>
</tr>
<tr>
<td></td>
<td>2094</td>
<td>2101</td>
<td></td>
</tr>
</tbody>
</table>

Net energy supply = 35 kg milk

Expected milk: \((2100 - 395) / 48 = 35.5\) kg

Expected N excretion: \(N_{\text{I}} - N_{\text{milk}} = 9.5\) g/kg milk
Origin of the coefficients and tables of feed values
Evaluation of the PDI value of feed

Feed

- Duodenal flow
- AA content
- AA true digestibility
- PDI value of feed

Protein

- Undegraded dietary protein
  - 1.11 (1 - DT6)
- Microbial protein
  - 0.9
- Endogenous protein
  - 145 FOM

Energy

- 33 NDOM

PDIA

- 1.0
- 0.55 to 0.95

PDIN

- 0.8

PDIMN

- 0.8

PDIME

- PDIE
Disappearance of N from Nylon bag method

The method was strictly and carefully standardized (4 labs)
- Conditions: animal, diets, bag procedures
- Calculations
  - Reduction of variability and bias between animals, labs,
  series of measurements: one reference sample

Particles outflow rate: 6%/h
- Do not affect the ranking of feed

DT6 is not an exact estimate of actual *in vivo* degradation
and need to be calibrated
By pass protein and efficiency of microbial synthesis

Duod Flow = Undegraded Prot + Microbial Prot + endogeneous Prot

\[
\begin{align*}
&\downarrow \quad \downarrow \quad \downarrow \\
& a \times \text{bag undeg CP} \\
& b \times \text{FOM} \\
& c \times \text{NDOM}
\end{align*}
\]

FOM : DOm – non deg protein – fermentation products - fat

Data basis
405 diets (20 teams, 142 sheep, 101 beef, 162 dairy cows)
Cover a large range of feeding situations

Duod flow = 1.11 \ bag undeg Prot + 145 \ FOM + 33 \ NDOM
Evaluation of Proteins requirements

Based on production trials with a large range of PDI supply
Calculated to be coherent with feed values

Feeding trials

N Balance
Exported protein

Requirements

Feed PDI value

Protein in milk

Metabolic efficiency = \frac{\text{Protein in products}}{\text{PDI supply above maint}}

24 trials with 3 PDI levels

PDI above maintenance

N Balance

0

PDI
Global and marginal efficiency
Estimation of requirements

**Maintenance**
3.25 g / kg $P^{0.75}$

**Lactation**
Metabolic efficiency = 0.64
Requirement = Prot Yield / 0.64

24 trials with 3 PDI levels
Tables of nutritional value of feeds

294 fresh forages, 185 silages, 148 hays
27 straws, tubercules

132 feeds (42 different botanical origins):
- cereals and by products, seeds, cakes, dehydrated, milk by products,
- take account of technological treatments
Forages : prediction of DT6 and dsi

dsi: Estimated from the residue of « mobile bag »

<table>
<thead>
<tr>
<th></th>
<th>1988</th>
<th>2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh forage</td>
<td>75</td>
<td>75 - 85</td>
</tr>
<tr>
<td>Silage + Cons</td>
<td>65</td>
<td>65 - 70</td>
</tr>
<tr>
<td>Wilted silage</td>
<td>60</td>
<td>65 - 75</td>
</tr>
<tr>
<td>Hays</td>
<td>70</td>
<td>70 - 80</td>
</tr>
</tbody>
</table>
Feeds materials:
prediction of DT6 and dsi (2007)

DT6:
- Large data set: 584 French data (4 labs)
  + 1305 literature data (172 feeds, 139 publications)

dsi:
- Large data set from mobile bag residues
  388 samples, 15 labs, 72 feedstuffs
- Bag residue ≈ truly indigestible by pass protein
- $dsi = 88.3 + 0.371 \text{ CP} - 0.0037 \text{ CP}^2 - 1.07 \text{ ADL} - 0.3130 \text{ NDOM}$
From the feed tables

<table>
<thead>
<tr>
<th>Code</th>
<th>ENSiLAGE</th>
<th>Energie (g)</th>
<th>Azote (g)</th>
<th>% PDI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ufkg</td>
<td>UPkg</td>
<td>PDA</td>
<td>Prn</td>
<td>PDI</td>
</tr>
<tr>
<td>MF75</td>
<td>55,0</td>
<td>0,82</td>
<td>0,75</td>
<td>22</td>
</tr>
<tr>
<td>MF76</td>
<td>55,0</td>
<td>0,73</td>
<td>0,65</td>
<td>27</td>
</tr>
</tbody>
</table>

From analysis

- CP analysis + Prediction of DOM (FOM), DT6, dsi
- Equations are published to predict
  - DOM from « pcd digestibility »
  - DT6 from dE1 « Enzymatic degradability »
  - dsi from proximal analysis
- software for automation / standardisation
Practical animal feeding
The PDI system allows to rationalize the supply of ruminally degradable N (1)

A deficit of up to 8% do not affect cow performances when the supply of PDIE is correct and will reduce N excreted.
The PDI system allows to rationalize the supply of ruminally degradable N (2)

Diet 1 : 15 kg MS + 2.5 kg Barley + 3.0 kg SBM  
Diet 2 : 15 kg MS + 3.6 kg Barley + 1.9 kg pSBM + 260 g urea  
Diet 3 : 15 kg MS + 3.6 kg Barley + 1.9 kg pSBM + 100 g urea

<table>
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<th>Diet 2</th>
<th>Diet 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>PDIE (g/d)</td>
<td>2101</td>
<td>2095</td>
<td>2095</td>
</tr>
<tr>
<td>PDIN (g/d)</td>
<td>2094</td>
<td>2101</td>
<td>1905</td>
</tr>
<tr>
<td>Expected MY (kg)(^1)</td>
<td>35.5</td>
<td>35.5</td>
<td>35.5</td>
</tr>
<tr>
<td>Expected N excretion (g/kg milk)(^2)</td>
<td>10.0</td>
<td>10.2</td>
<td>8.8</td>
</tr>
</tbody>
</table>

\(^1\) : (PDIE – 395)/48  
\(^2\) : N intake – N milk

all diets provide enough NE to produce 33 kg milk
... and to detect diets having an excess of degradable N

Diet 1 : 15 kg MS + 2.5 kg Barley + 3.0 kg SBM
Diet 2 : 15 kg MS + 1.6 kg Pea + 0.9 kg wheat bran + 3.0 kg SBM
Diet 3 : 13 kg GS + 1.0 kg barley + 5.0 kg maize + 2.0 kg SBM

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<th>Diet 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>PDIE (g/d)</td>
<td>2101</td>
<td>2085</td>
<td>1992</td>
</tr>
<tr>
<td>PDIN (g/d)</td>
<td>2094</td>
<td>2233</td>
<td>2204</td>
</tr>
<tr>
<td>Expected MY (kg)</td>
<td>35.5</td>
<td>35.0</td>
<td>33.3</td>
</tr>
<tr>
<td>Expected N excretion (g/kg milk)</td>
<td>9.6</td>
<td>10.0</td>
<td>13.1</td>
</tr>
</tbody>
</table>

No milk response to an extra supply of PDIN (above PDIE) but urinary N output increased.

No effect of the origin of degradable N on cow performances on normal feeding conditions.
Response of milk yield and urinary N losses to PDIE supply

The supply of MP cannot be reduced to a large extent without an adverse effect of milk yield (and DMI).
An optimum supply of PDIE can be defined

Vérité and Delaby (2001)
Using the PDI system to predict urinary N

Urinary N = 48

+ 0.28 rumen balance \((PDIN – PDIE)\)
+ 0.16 animal balance \((PDI\ supply – PDI\ requirements)\)
+ 3.8 milk yield

\(r^2 = 0.92\)
Main strengths of the PDI system to optimize milk yield / N excretion

| Based on a large diversity of feeding situations | Soundness |
| Coherence between animal requirements and feed value | Allow to rationalise degradable N and MP supply / animal demand |
| Very rich feed tables | Offer a range of solutions |
| Description of the responses curves | Optimise supply considering Milk yield and N excretion responses |
| Predictive methods to calculate value of unknown feeds | On farm evaluation of feeding practices |
| Used since 80’s and regularly upgraded | Take account of returns from on farm evaluation |
| Linked with Fill unit system | Prediction of cows performances |
PDI system: part of the french feeding systems

BCS, Age weight

Cow IC

% conc

DMI

Forage Fill value

PDI supply

NE supply

Milk potential

Milk yield variations

Law of response

Fill Unit system

PDI system

NE system
Main shortcomings of the PDI system to increase feeding efficiency

Effect of high level of feed intake
- FOM, by pass protein, microbial efficiency, dsi ?
- Shift between faecal and urinary N excretion ?

Tolerable deficit in degradable N
- to (re)consider according to the diet (forage) and cows

Variations of metabolic efficiency
- Effect of the profile of absorbed AA (beyond Lys and Met)