The effect of rumen dynamics on feed efficiency and profitability of dairy cows

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Feed efficiency important?

Increase
Total world dairy consumption increases strongly

Future
Increasing feed efficiency by producing more milk from the available feeds is the key to the future for dairy farmers

Scarcity of resources
Availability decreasing
Prices increasing

Feed efficiency important?
LESS INPUT
MORE FOOD

Total world dairy consumption, mill t ECM

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Growth of human population

Figure 1. Estimated world population, 1950-2000, and projections: 2000-2050

Margin over feed costs

Prices in USD/100 kg (ECM)
- World milk price
- World feed price

Margin over compound feed costs in USD/100kg
- Margin over compound feed costs (0.3 kg/kg milk)
- Bound - average 2007-2014

Source: IFCN (2015)
Milk price variability per country

Distance to world price September 2015
in USD / 100 kg

- <= -5
- > -5 <= 5
- > 5
- no data

Source: IFCN (2015)
Looking at the SSA situation

### SOUTH AFRICAN RAW MILK PRICE DEVELOPMENT

**Table 2: International calculated standardised raw milk producer prices, 2012 – 2015 (R/litre).**

<table>
<thead>
<tr>
<th>Country</th>
<th>Jan ’12</th>
<th>Jan ’13</th>
<th>Jan ’14</th>
<th>Jan ’15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>3.23</td>
<td>3.94</td>
<td>5.54</td>
<td>3.85</td>
</tr>
<tr>
<td>Germany</td>
<td>3.35</td>
<td>3.84</td>
<td>5.51</td>
<td>3.72</td>
</tr>
<tr>
<td>Denmark</td>
<td>3.35</td>
<td>3.73</td>
<td>5.51</td>
<td>3.82</td>
</tr>
<tr>
<td>Finland</td>
<td>4.14</td>
<td>4.67</td>
<td>5.83</td>
<td>5.47</td>
</tr>
<tr>
<td>France</td>
<td>3.58</td>
<td>3.90</td>
<td>5.68</td>
<td>4.38</td>
</tr>
<tr>
<td>Great Britain</td>
<td>3.47</td>
<td>4.07</td>
<td>5.35</td>
<td>4.69</td>
</tr>
<tr>
<td>Ireland</td>
<td>3.40</td>
<td>3.75</td>
<td>5.25</td>
<td>3.95</td>
</tr>
<tr>
<td>Netherlands</td>
<td>3.55</td>
<td>3.92</td>
<td>5.60</td>
<td>3.84</td>
</tr>
<tr>
<td>New Zealand</td>
<td>3.22</td>
<td>3.15</td>
<td>5.44</td>
<td>3.26</td>
</tr>
<tr>
<td>USA</td>
<td>3.25</td>
<td>3.78</td>
<td>5.13</td>
<td>4.47</td>
</tr>
<tr>
<td>* South Africa</td>
<td>3.10</td>
<td>3.60</td>
<td>4.05</td>
<td>4.45</td>
</tr>
</tbody>
</table>

Source: LTO Nederland
Based on 4% fat-corrected milk
See [www.milkprices.nl](http://www.milkprices.nl) for detailed definition of LTO standardised calculated price.
Exchange rates: Reserve Bank monthly middle rates
* Based on MPO price survey

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Why focus on feed efficiency?

Feed is getting more expensive and prices are variable
It becomes more important to make maximum use of the feed

Maximum production is no longer sufficient
Rising costs with increased productivity

Efficient production is the future!
Dairy cows are quite efficient!

Source: Eshel et al (2014)
Dairy cows are quite efficient!

Feed Efficiency

<table>
<thead>
<tr>
<th>Animal</th>
<th>USA</th>
<th>South Korea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk</td>
<td>0.5</td>
<td>0.1</td>
</tr>
<tr>
<td>Beef</td>
<td>0.9</td>
<td>0.2</td>
</tr>
<tr>
<td>Pigs</td>
<td>3.4</td>
<td>2.0</td>
</tr>
<tr>
<td>Poultry</td>
<td>1.6</td>
<td>1.0</td>
</tr>
</tbody>
</table>

- Can convert non-human-edible protein into valuable protein sources for human nutrition.
- Have never been bred for high feed efficiency.

Gill et al., 2010
Ruminants.....

Can convert non human-edible protein into valuable protein sources for human nutrition
  – Key feature in the future food supply

Have never been bred for high feed efficiency
  – Important and successful breeding target in swine and poultry
  – Target has mostly been higher production, not more efficiency
  – Is there scope for genetic progress?

How can we improve feed efficiency through dietary adaptations improving rumen fermentation?
Amount of milk produced per kg of dry matter intake

**Input**
- Kg x dry matter %

**Output**
- 34% loss = 38 kg milk
- 6% loss = 7 kg milk
- 34% loss = 38 kg milk
- 30 kg milk produced = 26% efficiency

Feed Efficiency = 1.5

20 kg DM 100%
Gross feed efficiency: milk production and dry matter intake

- 305-d production 9000 kg
- average DM-intake 19.8 kg
- average feed efficiency 1.5
# Guidelines for gross feed efficiency (8600 kg FCM)

<table>
<thead>
<tr>
<th>Group</th>
<th>Days in milk</th>
<th>Feed efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>All cows</td>
<td>150 - 225</td>
<td>1,3 – 1,4</td>
</tr>
<tr>
<td>Heifers</td>
<td>&lt; 90</td>
<td>1,5 – 1,6</td>
</tr>
<tr>
<td>Heifers</td>
<td>&gt; 200</td>
<td>1,2 – 1,3</td>
</tr>
<tr>
<td>Older cows</td>
<td>&lt; 90</td>
<td>1,6 – 1,8</td>
</tr>
<tr>
<td>Older cows</td>
<td>&gt; 200</td>
<td>1,2 – 1,3</td>
</tr>
<tr>
<td>Problem cows</td>
<td>150 - 200</td>
<td>&lt; 1,2</td>
</tr>
</tbody>
</table>

An excessive feed efficiency in early lactation may indicate an extremely negative energy balance!
What’s the economical value of improving feed efficiency?

**EXAMPLE CALCULATION**

Improvement of feed efficiency from 1.3 to 1.35 via milk yield results in an economical benefit of over R350 000 Rand a year*

<table>
<thead>
<tr>
<th>Feed Efficiency</th>
<th>Milk production (kg)</th>
<th>Dry Matter intake (kg DM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.30</td>
<td>2082500</td>
<td>1601923</td>
</tr>
<tr>
<td>1.35</td>
<td>2162596</td>
<td>1601923</td>
</tr>
</tbody>
</table>

* Farm size 238 cows, milk yield of 8750 L/yr, milk price 4.5 Rand/L, TMR costs 3 Rand/kg with a DM of 50%
9 billion people
Will need to be fed with dairy products in the future

26%
Of energy is used when FE is 1.5 at an intake of 20 kg DMI and milk yield of 30L/d

200 billion
Tonnes of biomass is available for ruminants to convert but it all depends on rumen fermentation

Provimi
Would like to help you understand what drives Feed Efficiency and how to improve it
Feed Efficiency

- Ration on paper = ration fed
- Avoid deterioration of silage
- Improve rumen fermentation

- Number of feeds per day
- Push up intervals
- Supply feed close to the gate

- Clean and fresh water
- Bunk and pen hygiene
- Bunk and pen space
- Walking distance
Rumen microbial population

**BACTERIA**
- Up to 50% of microbial biomass
- Important source of microbial protein
- Massive range
- Attach to the feed particles and release enzymes

**PROTOZOA**
- 30 - 40% of microbial biomass
- Engulf soluble sugars and starch
- Easily killed by low rumen pH
- Feed on rumen bacteria
- Ruminants can function without protozoa

**FUNGI**
- Make up an important 8% of microbial biomass
- They are Initiators of fibre digestion
- High cellulose and hemicellulose activity
- They also have the ability to solubilise lignin
Nutritional importance of forages

FORAGE MAKES UP A SIGNIFICANT PART OF THE RATION (60-70%)

MAJOR SOURCE OF ENERGY FOR:
– Rumen microbes (metabolism, protein synthesis)
– Animal (end products of the fermentation)

CONVERSION FROM FIBROUS FORAGES, TO MEAT OR MILK IS NOT VERY EFFICIENT
– 10-35% of GE is captured into NE
  • 20-70% of cellulose is not digested

FIBRE DIGESTION HAS BIG IMPACT ON INTAKE
– Voluntary feed intake is dependant on speed of feed clearance
– 1% ▲ NDF Digestibility: DMI 0.17 kg ▲ / Milk yield 0.25L ▲

Source: Oba and Allen (2002)
Composition of plant cell walls

70% of all biomass is plant cell wall, of which:
- 40-50% cellulose
- 20-40% hemicellulose
- 20-30% lignin

Plant cell wall consists of a primary and secondary cell wall:
- Primary cell wall develops in growing cells
- Secondary cell wall develops in mature cells

Source: Paulty and Keegstra, 2008; www.ccrc.uga.edu
Ester and Ether bonds: Lignin

Ester bond

Reactive
Labile in alkali
Broken by esterases

Ether bond

Unreactive
Labile in strong acid
‘anaerobic cleavage of ethers is not known to occur’

Dehydro-ferulate bridge

Lignin

Ester bonds

Cellulose or hemicellulose

Methods to increase forage digestibility

• Stimulation of fungi
  – Nutrients to feed the rumen fungi

• Fungi
  – can degrade a wider range of carbohydrates than bacteria
  – own enzymes that free carbohydrates from lignin!
  – capacity to penetrate primary cell wall and lignified tissues
  – contain extracellular enzymes for breaking down lignin

Gain access to plant materials that is unavailable to other rumen microorganisms

Source: Gordon et al (1985) and Orpin and Joblin (1988)
Particle bound microorganisms do the hard work

<table>
<thead>
<tr>
<th></th>
<th>% of enzyme activity due to particle-bound microorganisms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endoglucanase</td>
<td>88</td>
</tr>
<tr>
<td>Xylanase</td>
<td>91</td>
</tr>
<tr>
<td>Amylase</td>
<td>70</td>
</tr>
<tr>
<td>Protease</td>
<td>75</td>
</tr>
</tbody>
</table>

But cellulolytic bacteria are non-motile: how do they ‘find’ feed particles?
- Mastication, rumination
pH and fibre digestion

Mean daily rumen pH in dairy cows = 5.51 – 6.60 (106 diets, 28 experiments)²

Diurnal variation in pH: example

Is this a critical window: time between feeding and pH 6.0?
Results of a combined buffer

Acetate

% of total VFA

- Control*
- Dose 1**
- Dose 2***

FPCM

kg/day

- Control*
- Dose 1**
- Dose 2***

Milk fat %

Propionate

% of total VFA

- Control*
- Dose 1**
- Dose 2***

Feed Efficiency

kg/day

- Control*
- Dose 1**
- Dose 2***

Cargill Innovation Centre The Netherlands (2012)
# Model Predictions

## PREDICTIONS WHEN ADDITIVE EFFECTS ARE INCLUDED

<table>
<thead>
<tr>
<th>Analyzed</th>
<th>DM: 23.088</th>
<th>0.000</th>
<th>Cost/Hd: $29.33</th>
<th>$0.00</th>
<th>Feasible</th>
</tr>
</thead>
<tbody>
<tr>
<td>AsFedAmount</td>
<td>113.733 kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DryMatterAmount</td>
<td>23.088 kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forage DM Amount</td>
<td>15.800 kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forage %</td>
<td>68.433 %</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy Milk</td>
<td>31.454 kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protein Milk</td>
<td>64.050 kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BLV Gain/Loss:</th>
<th>0.732 kg</th>
<th>Milk Revenue/Hd: 141.545</th>
</tr>
</thead>
<tbody>
<tr>
<td>NFC.RDP:</td>
<td>1.805 Ratio</td>
<td>Income Over Feed Cost/Hd: 112.217</td>
</tr>
<tr>
<td>Sugar (% of SP):</td>
<td>68.716 %</td>
<td></td>
</tr>
<tr>
<td>Feed Efficiency (Milk/DM):</td>
<td>1.362 Unit</td>
<td></td>
</tr>
<tr>
<td>Milk Protein Index:</td>
<td>0.129 Unit</td>
<td></td>
</tr>
<tr>
<td>Feed Cost:</td>
<td>0.875 1 kg</td>
<td></td>
</tr>
<tr>
<td>Income Over Feed Cost:</td>
<td>3.525 1 kg</td>
<td></td>
</tr>
</tbody>
</table>

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**Feed Efficiency**

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Using tools to evaluate

No Additive

50%  35%  15%

Additive

25%  35%  40%
Conclusions

FOCUS ON FEED EFFICIENCY WILL HELP FARMERS!

Feed costs continue to rise; reviewing and judging feed efficiency becomes more important

Feed efficiency is a useful tool to determine how efficiently cows use their feed and provide insight in profitability

Feed efficiency may be used to evaluate new nutritional measures

Two possible nutritional solutions are supporting the rumen pH and specifically rumen fungi

On farm monitoring of expected results should help us focus on doing the right thing for our farmer customers