Modelling the Effects of Forage Composition on Simulated N Excretion and Milk Yield in Dairy Cattle

REDNEX

Ellis et al. (2011) J. Dairy Sci.
(In Press)

SEVENTH FRAMEWORK PROGRAMME

Innovative and practical management approaches to reduce nitrogen excretion by ruminants

Grass Fed Dairy Cattle

REDNEX

- Common nutritional strategy to help keep feed costs down & perceived as 'natural'/ good welfare
- Problem: Inefficient nitrogen (**N**) utilization
  - Sub-optimal milk production or significant N losses through urine & faeces
  - Occurs when rumen microbes lack adequate energy/structural carbon for growth
  - Unable to capture NPN released during breakdown of plant proteins in the rumen

High Sugar Grasses

REDNEX

- Feeding grass with a high water soluble carbohydrate (**WSC**) content has been proposed as a way to address this imbalance
- Increased energy supply → improved capture of dietary N into the rumen microbial biomass
- Proposed benefits:
  - Reduced N excretion in urine
  - Increased milk yield
  - Enhanced N supply for milk production

Problem: Inconsistent results between studies

REDNEX

- *Miller et al. (2001a)* –
  - WSC elevated by 39 g/kg DM (165 vs 126 g/kg DM) at expense of NDF & CP
  - Significant reduction in urine N (25 vs 35, % N intake)
  - Significant increase in milk yield$ (2.7 kg/d) (15.3 vs. 12.6 kg/d)
  - Significant increase in DM digestibility, numerical increase in DMI

$ late-lactation

Problem: Inconsistent results between studies

REDNEX

- *Miller et al. (2000)* –
  - WSC elevated by 40 g/kg DM (234 vs 194 g/kg DM) at expense of CP
  - Significant reduction in urine N (17.8 vs. 26.7, % N intake)*
  - No significant change in milk yield (21.4 vs 21.9 kg/d)$
  - No significant change in DM digestibility or DMI

* Associated with lower N intake on high WSC grass diet due to extra N fertilization on control grass

$ mid-lactation

Problem: Inconsistent results between studies

REDNEX

- *Moorby et al. (2006)* –
  - WSC elevated by 82 g/kg DM* (243 vs 161 g/kg DM) at expense of NDF
  - Significant reduction in urine N (20 vs 27, % N intake)
  - No significant change in milk yield (32.7 vs 30.4 kg/d)$
  - Significant increase in DM digestibility (75 vs. 72%), and in DMI (18.8 vs 16.0 kg DM/d)

* Differences were accentuated by cutting the control grass in the morning and the high WSC grass in the afternoon

$ Early-lactation

Problem: Inconsistent results between studies

REDNEX

- *Tas et al. (2005, 2006)* –
  - WSC elevated by avg. 32.6 g/kg DM at expense of variable proportions of NDF & CP
  - Reductions in urine N associated with reductions in intake N
  - No differences among cultivars in excretion of N in milk/N use efficiency
  - No change in milk yield (kg/d)[$]
  - No change in DM digestibility or DMI

[$] Mid-lactation

Problem: Inconsistent results between studies

REDNEX

- *Cosgrove et al. (2007)* –
  - WSC elevated by 20-40 g/kg DM (Spring)
    - No significant effect on milk yield[$]
  - WSC elevated by 0-9 g/kg DM (Autumn)
    - NS Trend (P = 0.08) for an increase in milk yield[#]

[$] Early-lactation
[#] Mid-lactation

REDNEX

- To attempt to explain the variation in N and milk yield responses of cows fed high sugar grasses using a dynamic mechanistic model with results from the literature and from simulation data.

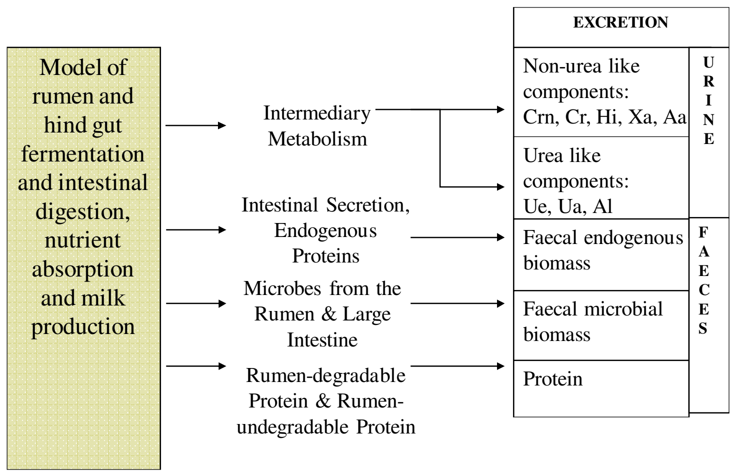
The Model

REDNEX

- **Dijkstra et al. (1992) model**
- Expanded by:
  - *Mills et al. (2001)* – Hind gut fermentation
  - *Reijs et al. (2007)* – N excretion equations
  - *Bannink et al. (2008)* – pH dependent VFA stoichiometry
- **Required inputs:**
  - DMI, NDF, CP, WSC, starch, fat and ash content of diet, digestible/indigestible/soluble fractions
  - Fractional degradation rates

N Excretion – Reijs et al. (2001)

REDNEX



11

Milk Yield Prediction

REDNEX

- Nutrients absorbed from the GIT are classified as:
  - Glucogenic
  - Lipogenic
  - Aminogenic
- Metabolizable energy
- If glucogenic nutrients are 1st limiting, proportion of aminogenic nutrients in excess can be used for gluconeogenesis
- **Milk yield is calculated as the most limiting among these nutrients**

12

The Literature Database – Model Performance Evaluation

REDNEX

- Used to evaluate N excretion, milk yield and NDF digestibility predictions by the model
- Studies that have evaluated the effects of high sugar grasses on N excretion in grazing dairy cows
- 4 studies, 28 treatment averages
  - Moorby et al. (2006)
  - Tas et al. (2005, 2006)
  - Miller et al. (2001)
  - Valk et al. (1996)

Statistics

REDNEX

- Mean square prediction error
  - $MSPE = \Sigma(O_i - P_i)^2/n$
  - Decomposed into:
    - Random error (ED)
    - Error due to bias (ECT)
    - Error due to regression (ER)
- Concordance correlation coefficient
  - $CCC = P \times C_b$
    - P – Pearson correlation coefficient (Precision)
    - C_b – Bias correction factor (Accuracy)

The Simulations/Behaviour Anaylsis

REDNEX

- Three levels of WSC increase in the grass:
  - 20, 60, 90 g/kg DM
- Three possible composition changes within the plant:
  - CP, NDF or a 50:50 split of CP and NDF (**CN**)
- High or low N fertilization level
- Presence or absence of grain feeding

15

REDNEX

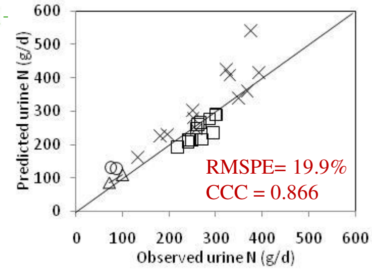
Description	Grass WSC (g/kg DM)	Grass CP (g/kg DM)	Grass NDF (g/kg DM)	DMI (kg/d)
LN/B/0, /G	171	200	501	16.0, 18.0
LN/CP/20, /G	191	180	501	16.0, 18.0
LN/CP/60, /G	231	140	501	16.0, 18.0
LN/CP/90, /G	261	110	501	16.0, 18.0
LN/NDF/20, /G	191	200	481	16.0, 18.0
LN/NDF/60, /G	231	200	441	16.0, 18.0
LN/NDF/90, /G	261	200	411	16.0, 18.0
LN/CN/20, /G	191	190	491	16.0, 18.0
LN/CN/60, /G	231	170	471	16.0, 18.0
LN/CN/90, /G	261	155	456	16.0, 18.0
HN/B/0, /G	121	250	501	16.3, 18.3
HN/CP/20, /G	141	230	501	16.3, 18.3
HN/CP/60, /G	181	190	501	16.3, 18.3
HN/CP/90, /G	211	160	501	16.3, 18.3
HN/NDF/20, /G	141	250	481	16.3, 18.3
HN/NDF/60, /G	181	250	441	16.3, 18.3
HN/NDF/90, /G	211	250	411	16.3, 18.3
HN/CN/20, /G	141	240	491	16.3, 18.3
HN/CN/60, /G	181	220	471	16.3, 18.3
HN/CN/90, /G	211	205	456	16.3, 18.3

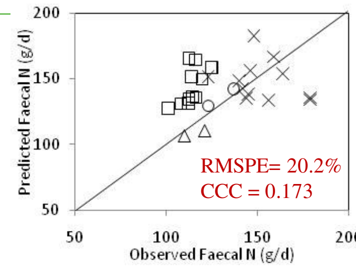
16

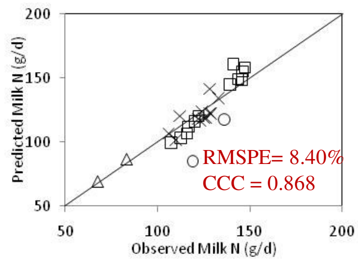
Results

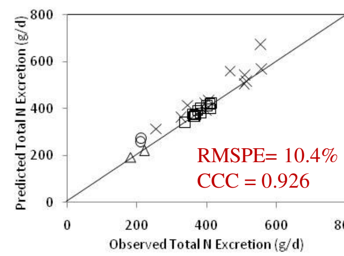
Prediction of N Excretion by the Model

REDNEX







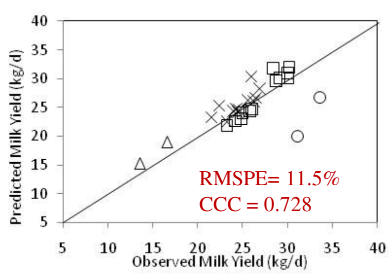


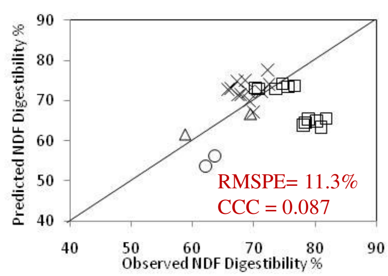
17

Results

Prediction of Milk Yield and NDF Digestibility by the Model

REDNEX





18

Results

N Excretion – Behaviour Analysis (LN)

REDNEX

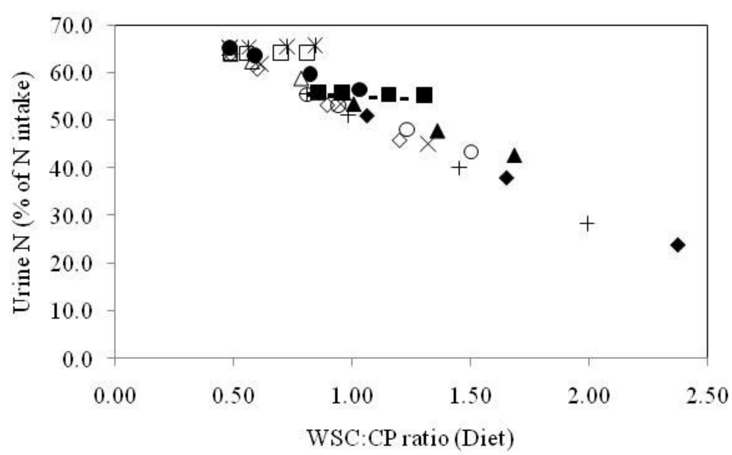
Description	Intake N (g/d)	Urine N (% of N intake)	Milk N (% of N intake)	Total N excretion (% of N intake)
LN/B	512	55.9	15.3	84.7
LN/CP/20	461	51.0	17.8	82.2
LN/CP/60	358	37.9	25.2	74.8
LN/CP/90	282	23.8	33.4	66.6
LN/NDF/20	512	55.7	16.2	83.8
LN/NDF/60	512	55.4	17.8	82.2
LN/NDF/90	512	55.3	18.9	81.1
LN/CN/20	486	53.4	17.0	83.0
LN/CN/60	435	47.7	20.8	79.2
LN/CN/90	397	42.6	24.4	75.6

19

Results

N Excretion – Behaviour Analysis

REDNEX



20

Results

Milk Yield & Digestibility – Behaviour Analysis (LN)

REDNEX

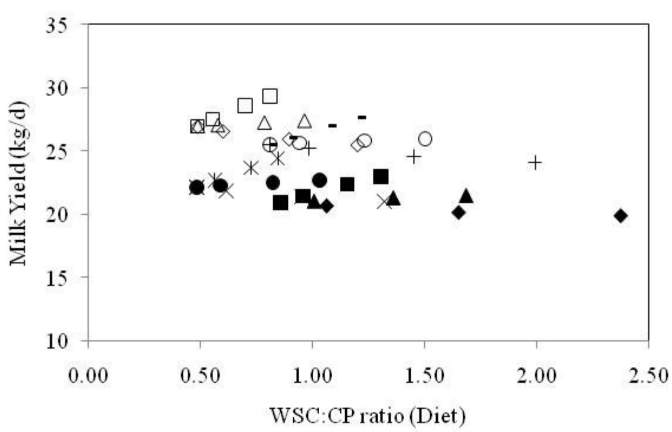
Description	Milk Yield (kg/d)	NDF Digestibility %	CP Digestibility %	Starch Digestibility %	pH
LN/B	20.9	74.1	73.0	97.5	5.99
LN/CP/20	20.7	72.7	70.8	97.5	5.98
LN/CP/60	20.2	68.6	65.6	97.6	5.98
LN/CP/90	19.9	64.7	60.1	97.3	5.97
LN/NDF/20	21.4	75.1	73.7	97.6	5.97
LN/NDF/60	22.4	76.7	74.9	97.7	5.94
LN/NDF/90	23.0	77.6	75.9	97.7	5.92
LN/CN/20	21.0	73.9	72.3	97.6	5.98
LN/CN/60	21.3	73.1	70.6	97.6	5.95
LN/CN/90	21.5	72.1	69.2	97.7	5.94

21

Results

Milk Yield – Behaviour Analysis

REDNEX



22

N Fertilization – Behaviour Analysis

REDNEX

- High versus low N fertilization:
  - Very slight improvement in milk yield response to ↑ WSC
  - Increased levels of improvement in urine N and N utilization ratio on the low N fertilized grass diets

	High N Fert.	Low N Fert.
Milk yield (kg/d)	+ 1.5%	+ 1.7%
Urine N (% N Intake)	- 8.6%	- 15.9%
N utilization ratio	+ 32.6%	+ 38.7%

* values are % change in measure with high WSC grass feeding, average across all simulations, rel. to basal grass

- **Higher levels of improvement on lower quality diets**

23

Results

Grain Feeding – Behaviour Analysis

REDNEX

- Grain versus no-grain:
  - Very slight improvement in milk yield response to ↑ WSC
  - Increased levels of improvement in urine N and N utilization ratio on the no-grain diets

	Grain	No-Grain
Milk yield (kg/d)	+ 1.1%	+ 1.6%
Urine N (% N Intake)	- 11.2%	- 12.3%
N utilization ratio	+ 29.2%	+ 35.7%

* values are % change in measure with high WSC grass feeding, average across all simulations, rel. to basal grass

- **Higher levels of improvement on lower quality diets**

24

Summary – N Excretion & Milk Yield

REDNEX

- N utilization ratio:
  - Most benefit seen when the WSC content of grass increased at the expense of CP, followed by a 50:50 CP and NDF mix, followed by a trade for NDF.

- Milk yield:
  - decreased slightly when WSC increased at the expense of CP, increased slightly when it increased at the expense of a CP and NDF mix, and increased most when WSC increased at the expense of NDF.

Implications

REDNEX

- Highlights the 'uses' of modelling:

  Explanation of experimental results
  sources of variation

  Guidance for future experiment development/design

  A tool for hypothesis testing – CH_4?

This presentation has been carried out with financial support from the Commission of the European Communities, FP7, KBB-2007-1.

REDNEX

It does not necessarily reflect its view and in no way anticipates the Commission's future policy in this area.

SEVENTH FRAMEWORK PROGRAMME

Innovative and practical management approaches to reduce nitrogen excretion by ruminants