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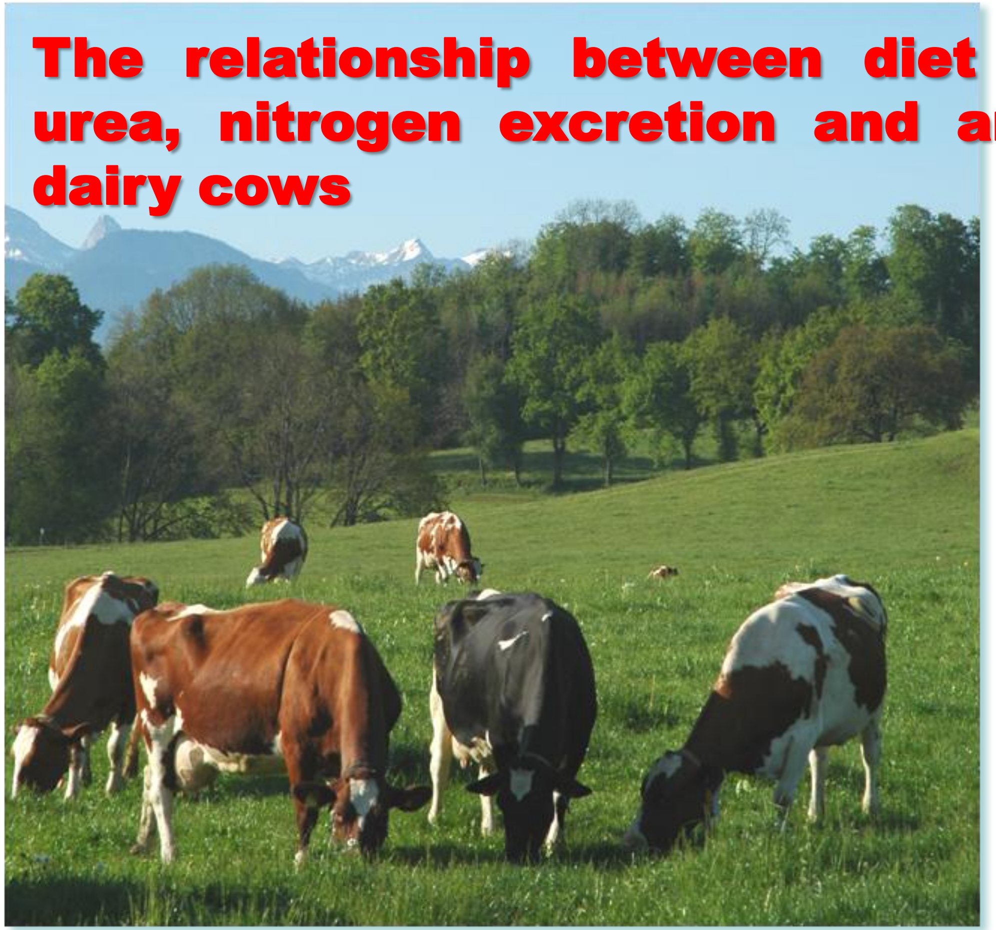
The relationship between diet characteristics, milk urea, nitrogen excretion and ammonia emissions in dairy cows



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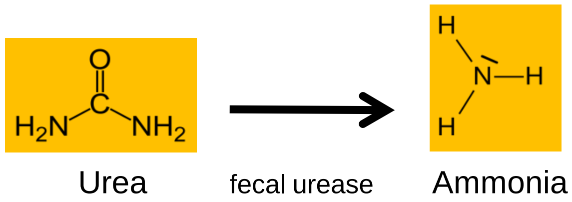
Context

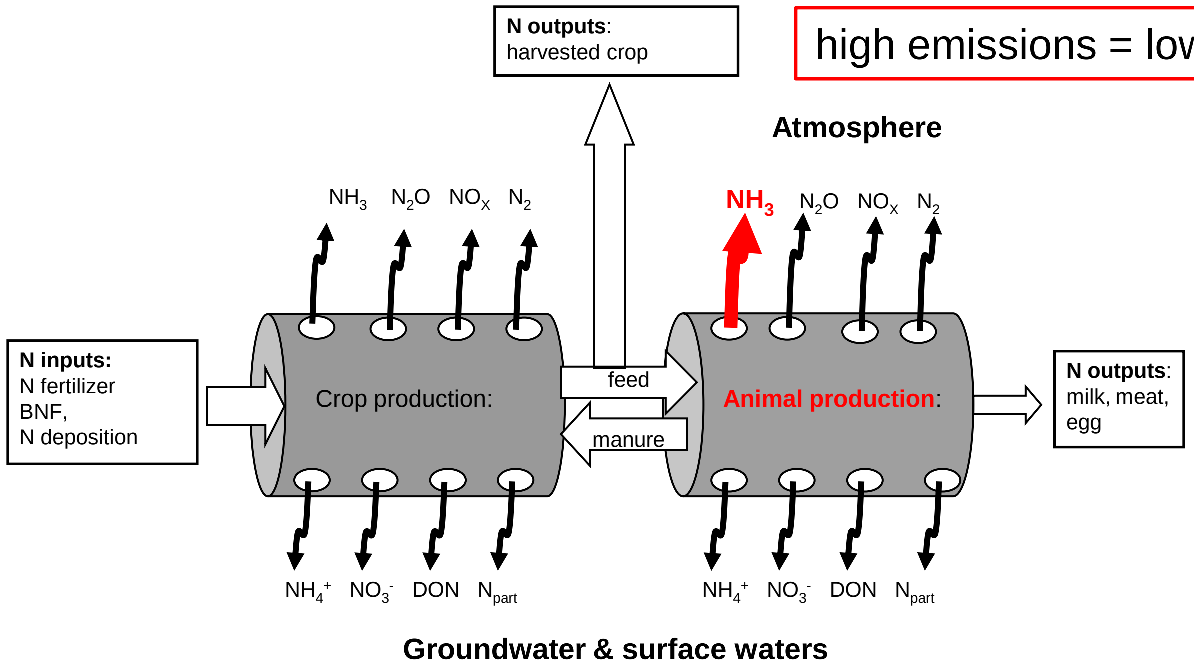
Gothenburg Protocol: emission ceilings for pollutants

- also for ammonia (NH3)
- direct link to N flow
- urea main precursor of ammonia



N flow and N emission in agriculture (after Oenema cited in EPMAN 2009)

high emissions = low efficiency



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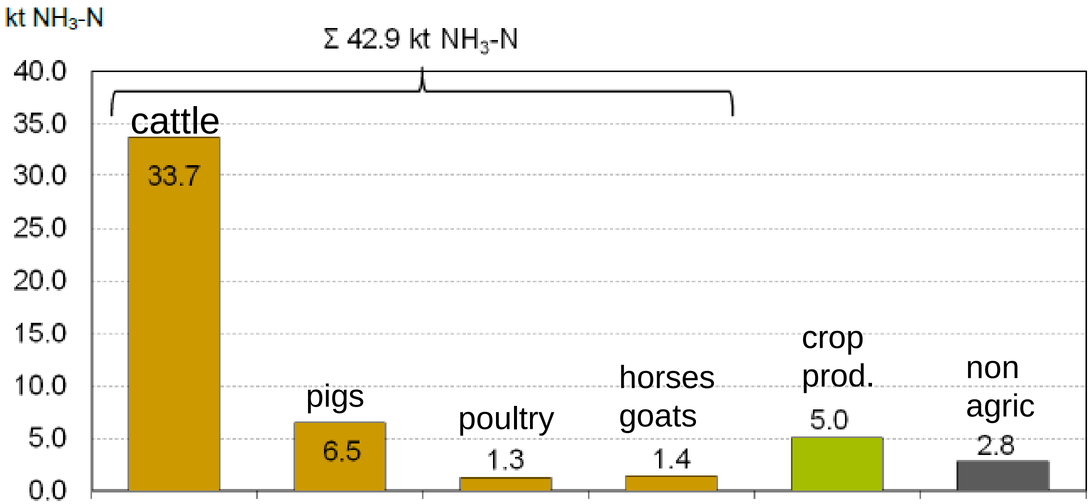
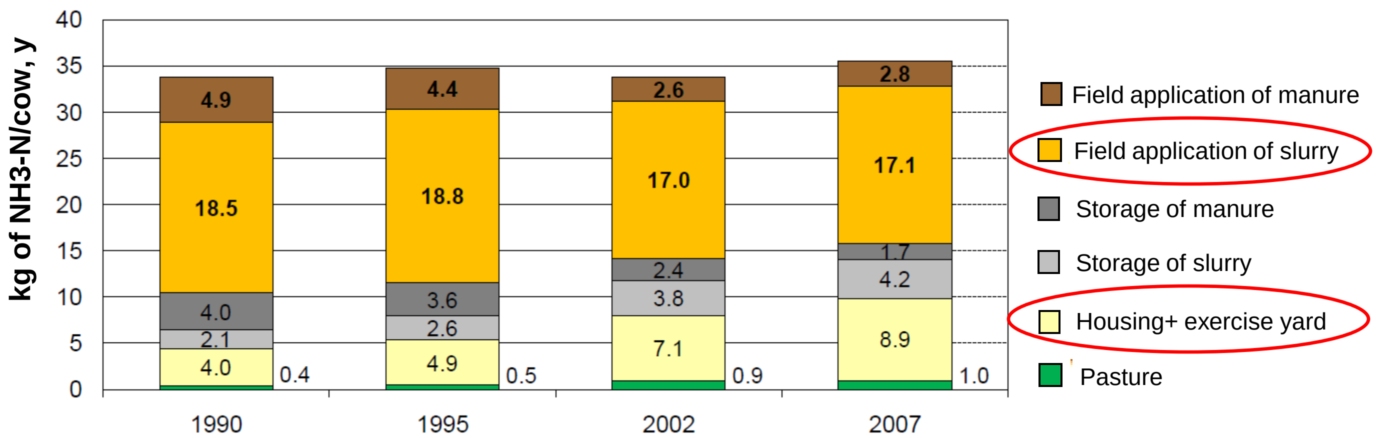
Partition of NH_3 emissions in Switzerland for 2007 (ammonia emission inventory, Kupper 2009)



94 % of agricultural origin
89 % of animal origin
79 % from cattle
→ 65 % from dairy cows

NH_3-N emission sources in dairy cows (ammonia emission inventory, Kupper 2009)



Strategies to reduce NH_3 emissions

1. Reduce N excretion
2. Reduce the volatile N fraction: TAN (total ammonical N), urinary N, urea

Ammonia emission potential = f(excreta quantity, quality)

3. Optimize the chemical-physical environment: housing, storage, field application

Ammonia volatilization = f(emission rate)

Implementation in Switzerland

Cantonal **resource programs**: NH_3 ↓, N-efficiency ↑

- encourage on-farm measures by direct payments:
  for instance field application by trail hose → end-of pipe measure
- planned: feeding measures = begin-of-pipe measure

Objectives and methods

- evaluate potential **feeding measures** in dairy cows to mitigate NH_3 emissions and improve N efficiency
- evaluate possible **indicators** to assess the effect of feeding measures on ammonia emissions (literature review)
- analyze data from **Swiss feeding and N-balance trials** and derive relationships between N-input, N-excretion, diet characteristics and milk urea
- **model calculation** of **N excretions** over lactation cycle
- **model calculation of ammonia emissions**, quantification of feeding measures

→ **the best diet for environmental efficiency, particularly N**

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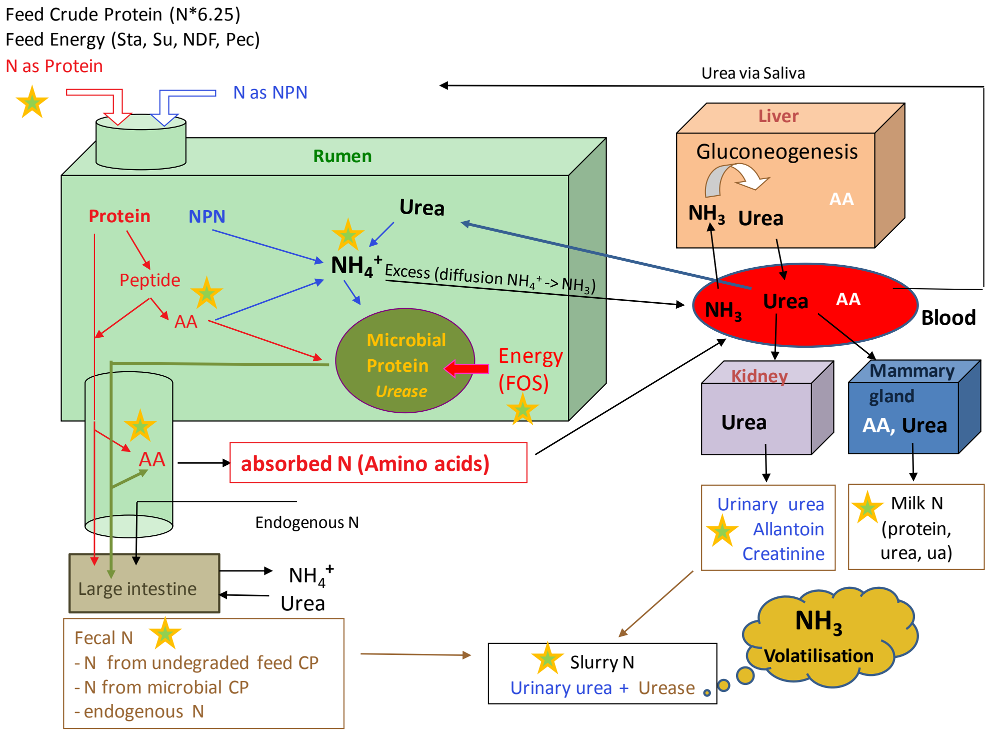
Protein metabolism of ruminants ★ feeding influence



Particularities:

- ruminal feed protein degradation
- energy dependent microbial protein synthesis
- interaction between energy and protein
- diffusion of excess ammonia into blood
- detoxification of blood ammonia in the liver
- urea recycling
- urea main urinary N fraction
- high correlation between blood, urine and milk urea

Causes for high urinary urea excretion

- energy-protein imbalance in the rumen (quantity, timing)
- postruminal protein oversupply
- metabolic losses

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Indicators for high urinary urea

avoidable NH_3+urea sources	dietary indicators
ruminal protein-energy balance	**PMN-PME**, g/kg DM, g/day PMN g/kg DM = CP*[1- {1.11*(1- degCP/100)}] PME g/kg DM = 0.145*FOM FOM g/kg DM = DOM -CP*(1-degCP/100)-at-ST*(1-degST/100)-FP/2 N/DOM, N/FOM, g/kg
cow protein-energy balance	CP/NEL, g/MJ
protein oversupply	CP intake, CP g/kg DM APD supply - APD requirement

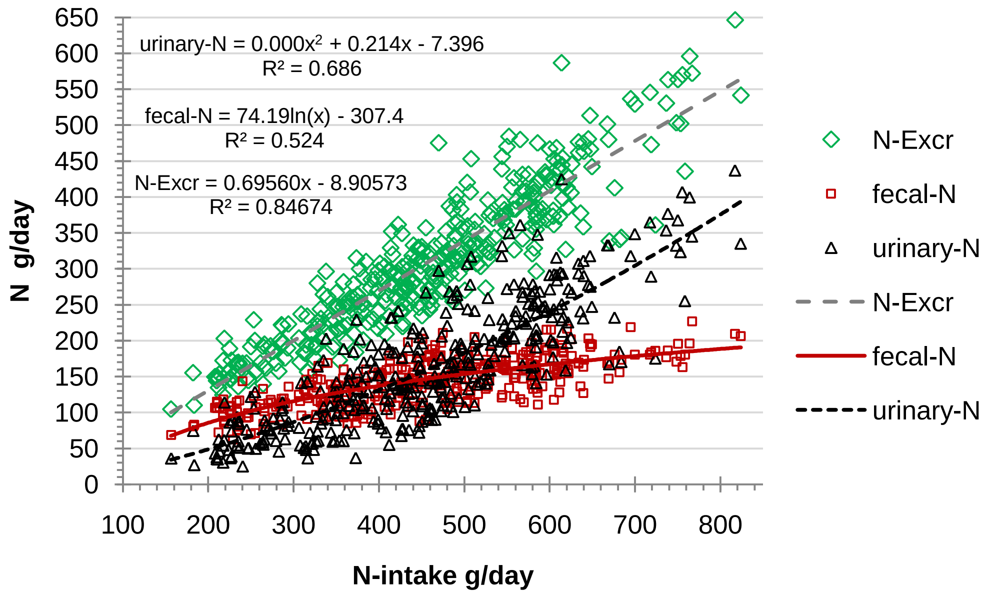
metabolic indicators: milk urea (MUC) mg/dl
blood urea
urinary urea g/l

PMN = microbial protein from ruminal N
PME = microbial protein from ruminal energy → energy intake limits protein synthesis
CP = crude protein
degCP = protein degradability
DOM = digestible organic matter
FOM = fermentable organic matter
APD = absorbable protein at small intestine
NEL = net energy lactation

Analysis of N-balance trials

Group	n	NEL MJ/kg DM	CP g/kg DM	N-intake g/day	fecal-N g/day	urinary-N g/day	urine-N /N-Exkr %	Milk kg ECM	MUC mg/dl
dry cows	31	4.9	109	132.54	54.25	37.16	27.0	-	-
lact cows winter diets	165	6.15	148.3	399.9	144.9	109.9	41.0	23.0	20.0
lact cows summer diets	191	6.61	182.6	515.6	143.7	214.0	58.54	26.6	30.5

Partition of N excretion in lactating dairy cows

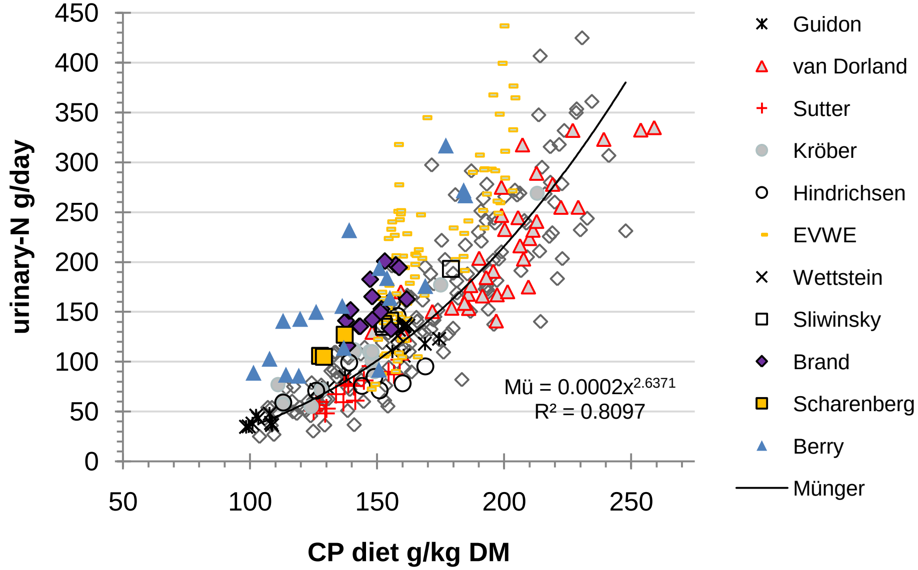


- seasonal influence on N-turnover
- urinary N highly variable
- urinary N evolves quadratically with increasing N-intake
- flat curve for fecal N

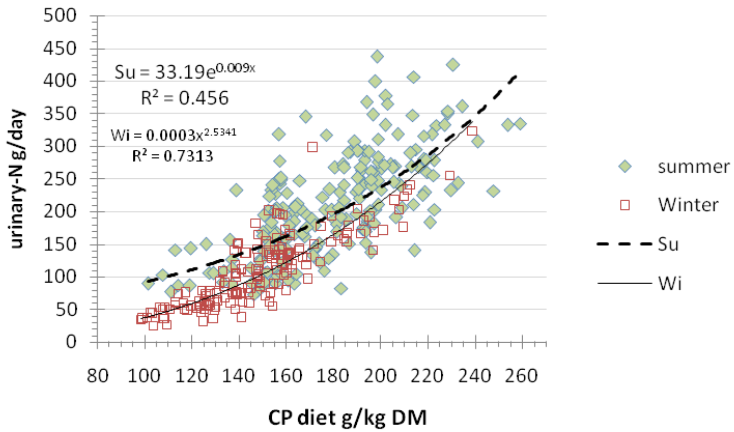
but:

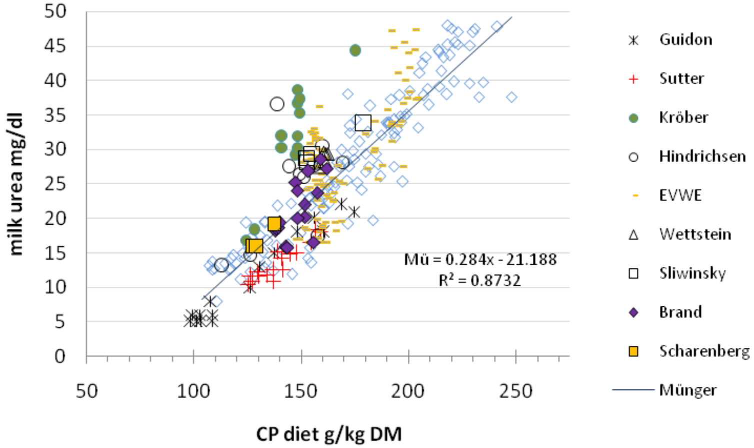
- N intake rarely known on farms

Urinary N, dietary crude protein (CP) and MUC



- urinary N increases with dietary CP content
- level difference between trials
- summer diets (herbage) cause high urinary N excretion
- milk urea correlates with CP ($R^2 = 0.74$)





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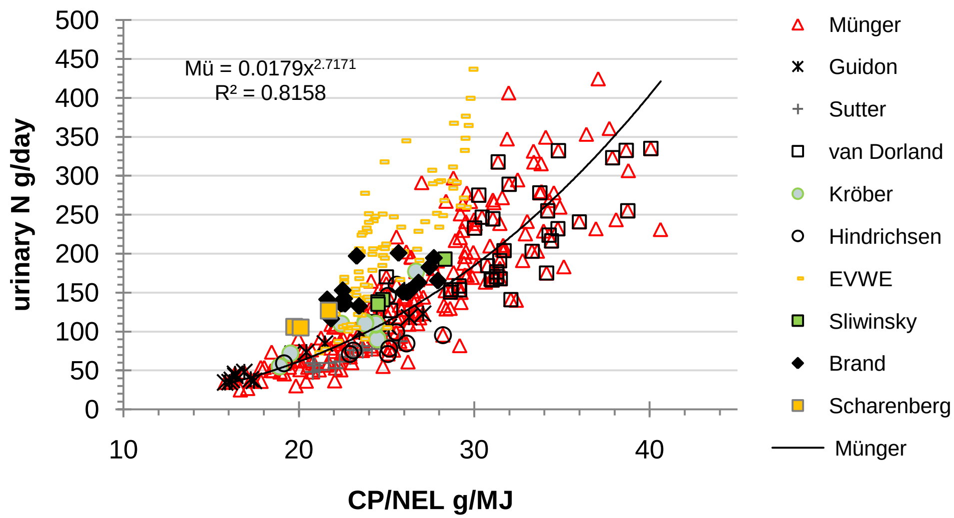
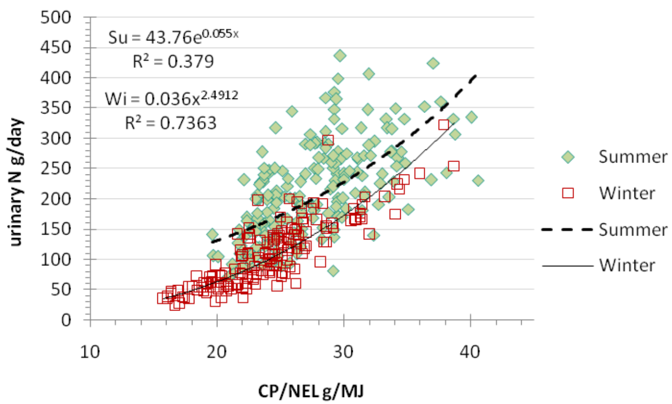
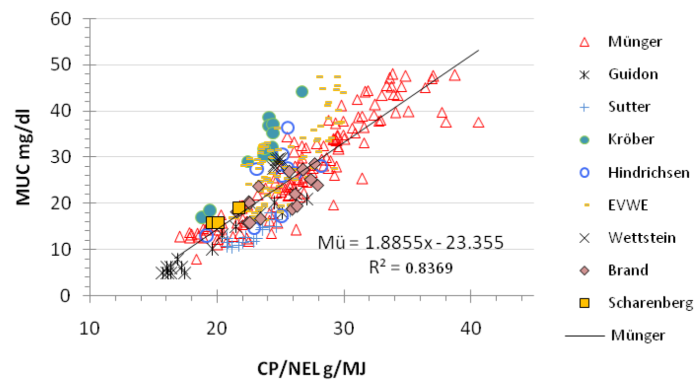
Urinary N, dietary CP/NEL-ratio and MUC



- urinary N increases with dietary CP/NEL ratio
- level difference between trials
- summer diets (herbage) cause high urinary N excretion
- milk urea correlates with CP/NEL ($R^2 = 0.69$)





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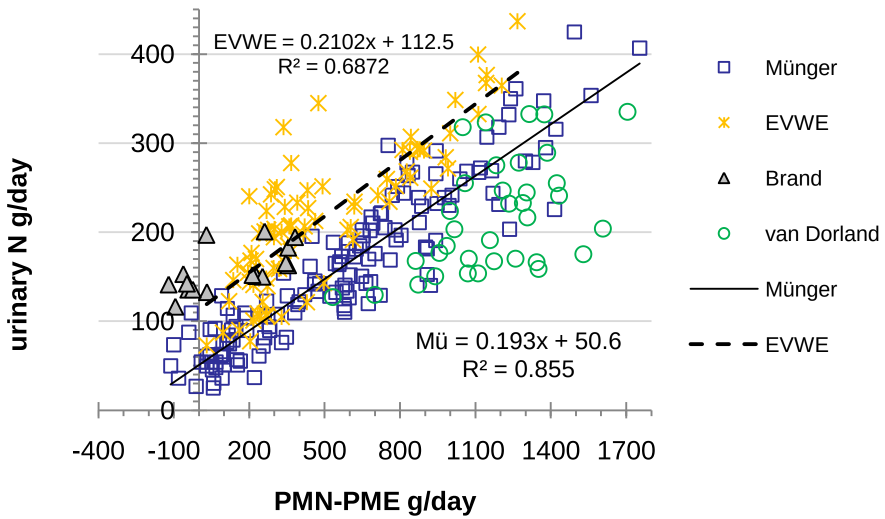
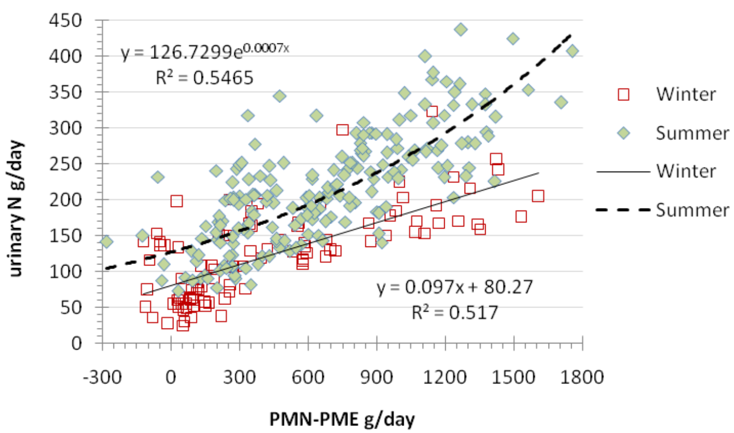
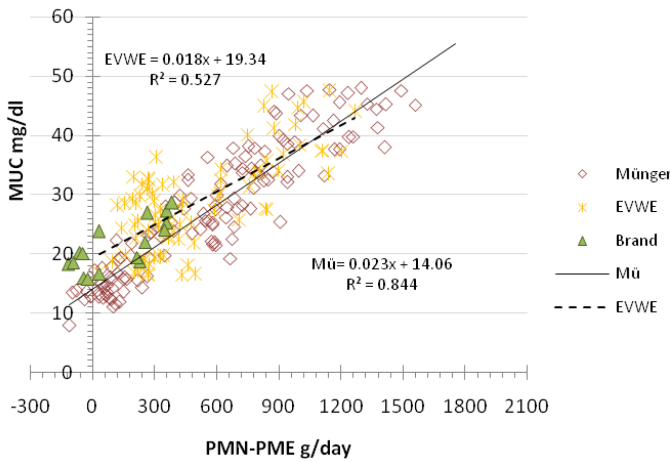
Urinary N, ruminal protein balance and MUC



- urinary N increases with dietary ruminal protein balance
- level difference between trials
- summer diets (herbage) cause high urinary N excretion
- milk urea correlates with PMN-PME (R^2 = 0.74)





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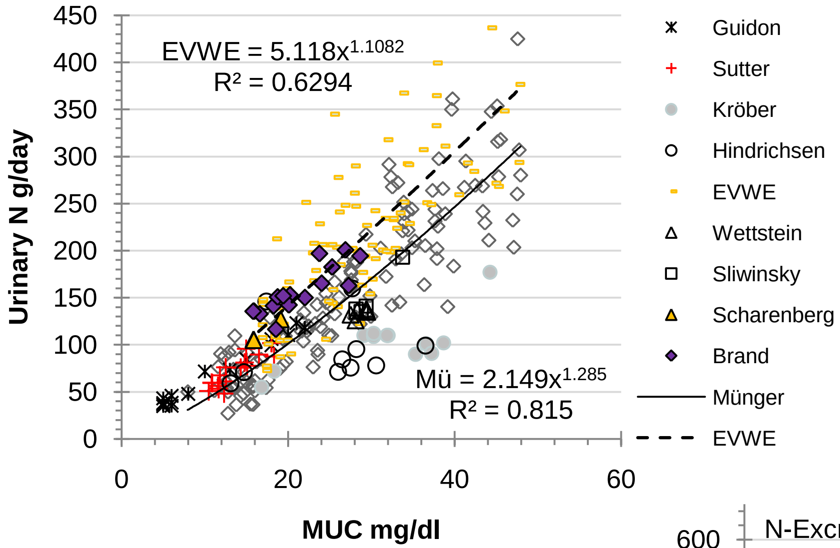
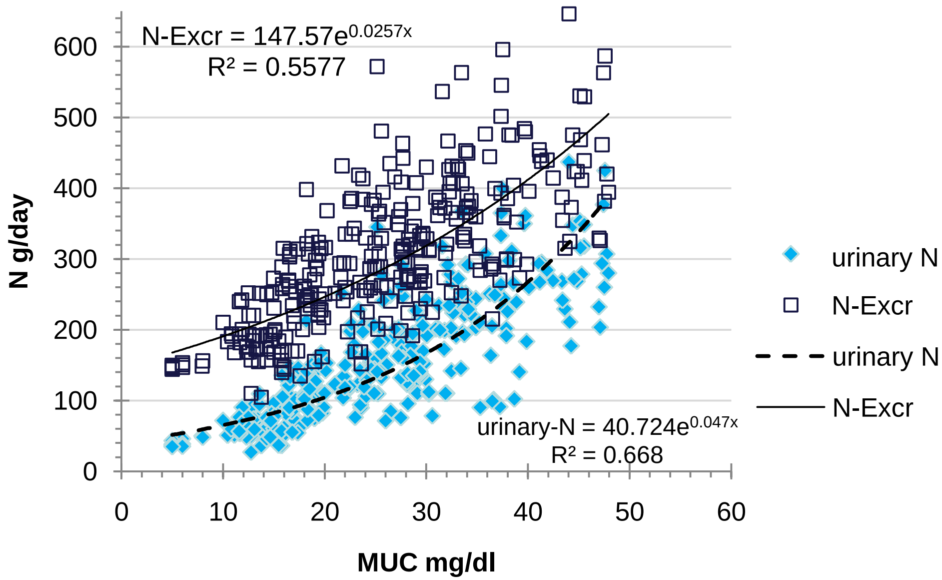
Estimation of N excretion from milk urea

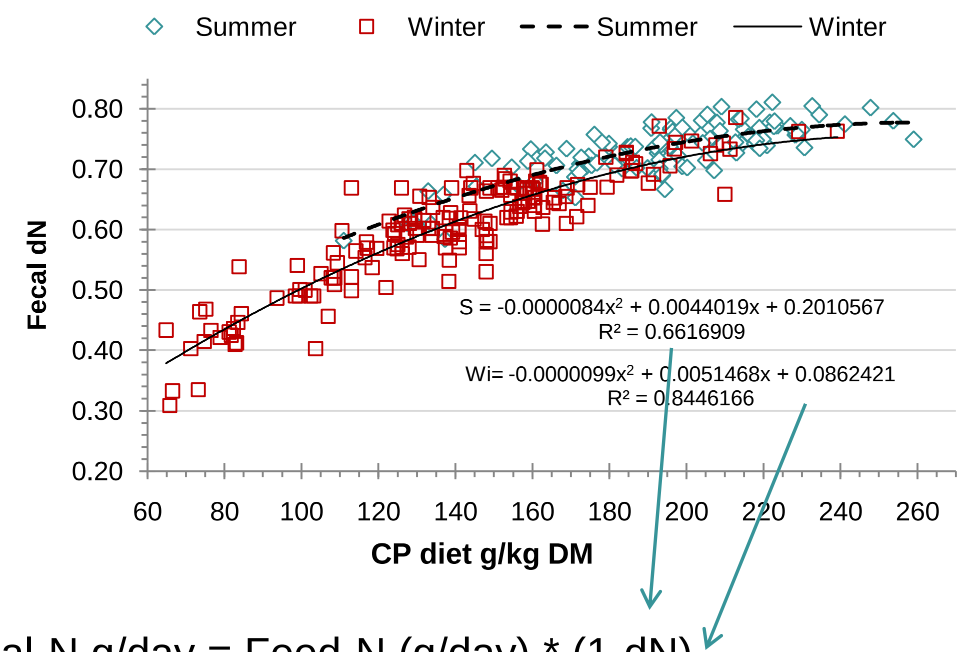


- for practical reasons high interest in MUC
- non invasive, routinely measured in herd book farms
- urinary N increases with MUC
- level difference between trials
- better estimate for urinary N than total N
- good R^2 but still high residual errors
- milk urea unspecific with respect to urea origin



Model calculation of N excretion

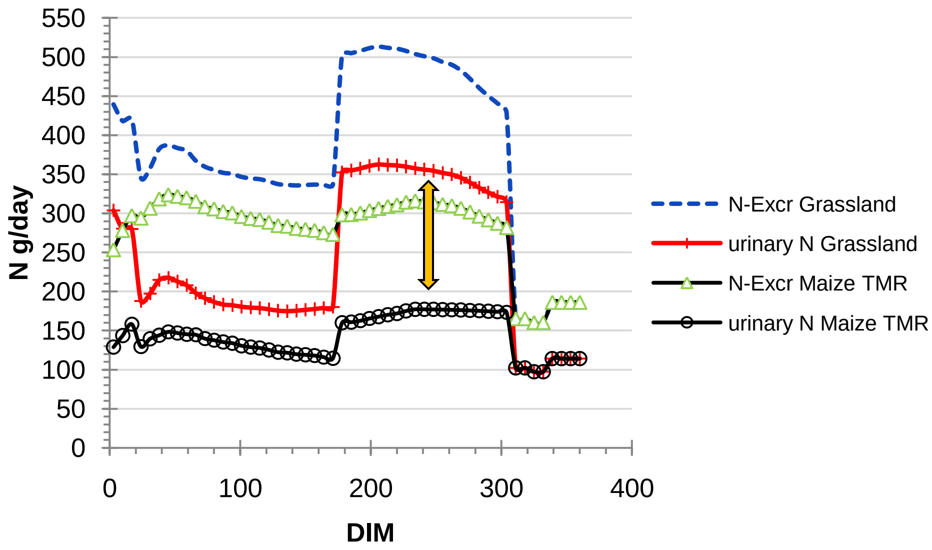
- Lactation curve to predict milk yield on a weekly basis
- Implemented intake curve to predict feed intake, CP and NEL content of diet on a weekly basis



- fecal-N g/day = Feed-N (g/day) * (1-dN)
- urinary-N g/day = Feed-N (g/day) - Milk-N (g/day) - fecal-N (g/day)
- N balance = 0

Grassland based vs maize based feeding

	Grassland based	Maize based TMR
milk yield kg ECM	7000	7000
calving	20. oct	20. Oct
winter diet	Hey (50 %), GS (50 %), conc	MS (40 %), GS, hey, fodder beets, conc
summer diet	100 % grass, 21 % of CP, no suppl	MS (40 %), hey (20 %), grass (40 %)



lactation cycle	grassland	maize
fecal N kg	50.7	49.7
urinary N kg	**87.3**	**52.1**
total N-excr kg	138.0	101.8
CP diet %	18.1	14.2
N-Excr/ECM g/kg	20.1	14.8
N-eff %	19.9	25.1

Input variables for NH_3-emission calculation

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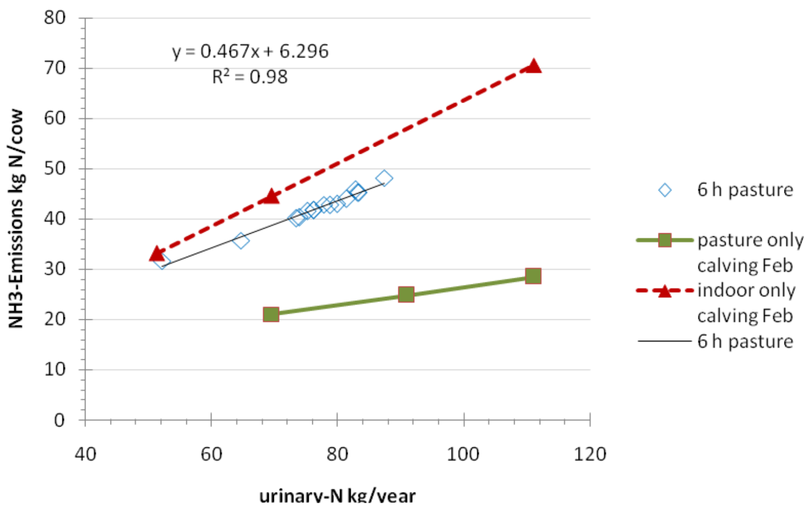
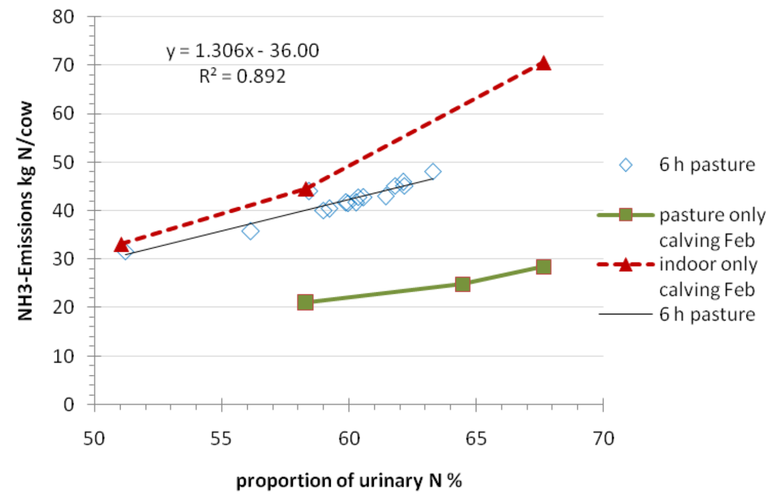
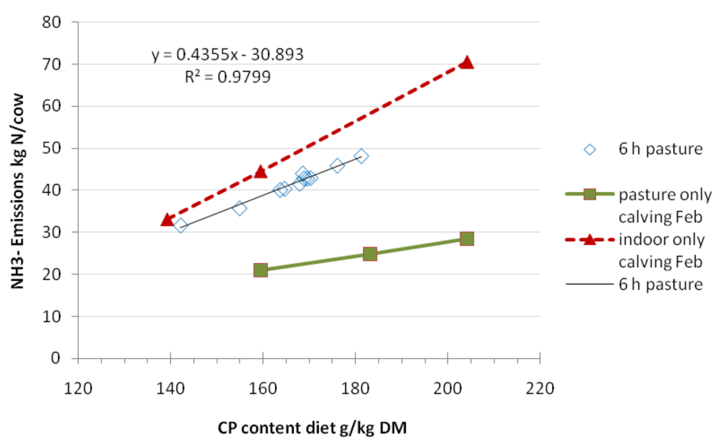
Model calculation of NH_3-emissions per cow and year

Model farm: loose housing, slurry production, excercise yard, no pasture, 6 h pasture or 20 h pasture over 210 days, covered slurry tank, surface spreading, TAN-flow model (http://agrammon.ch).







- for any chosen parameter, lowest NH_3-emissions for pasture only strategy
- **for 6 h pasture strategy**:
  - per kg less urinary N → 0.47 kg less NH_3-N
  - per % less urinary N → 1.3 kg less NH_3-N
  - per g less CP diet → 0.44 kg less NH_3-N
  - per g/MJ less CP/NEL → 2.68 kg less NH_3-N

The best diet for environmental efficiency: an attempt to define guidelines

Diet (at any moment during lactation)

- CP content < 18 %
- CP/NEL ration < 25 g/MJ
- N/DOM ratio < 40 g/kg
- ruminal protein balance < 600 g/day, < 30 g/kg DM (PMN-PME)
- milk production potential of diet adapted to requirement

Feeding technique

- balanced TMR
- Pasture. Supplements to correct N excess and/or adapt grass quality to lactation stage. NH_3-emissions are low but other N-losses may occur and **N-efficiency** at cow and farm level is reduced.

Milk urea

- < 25 mg/dl

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