Smart Dairy Nutrition to Reduce Nitrogen and Phosphorus Excretion: Insights from the Netherlands

Jan Dijkstra - Wageningen University & Research

WAGENINGEN UNIVERSITY
WAGENINGEN UR

Reducing N and P excretion dairy cattle

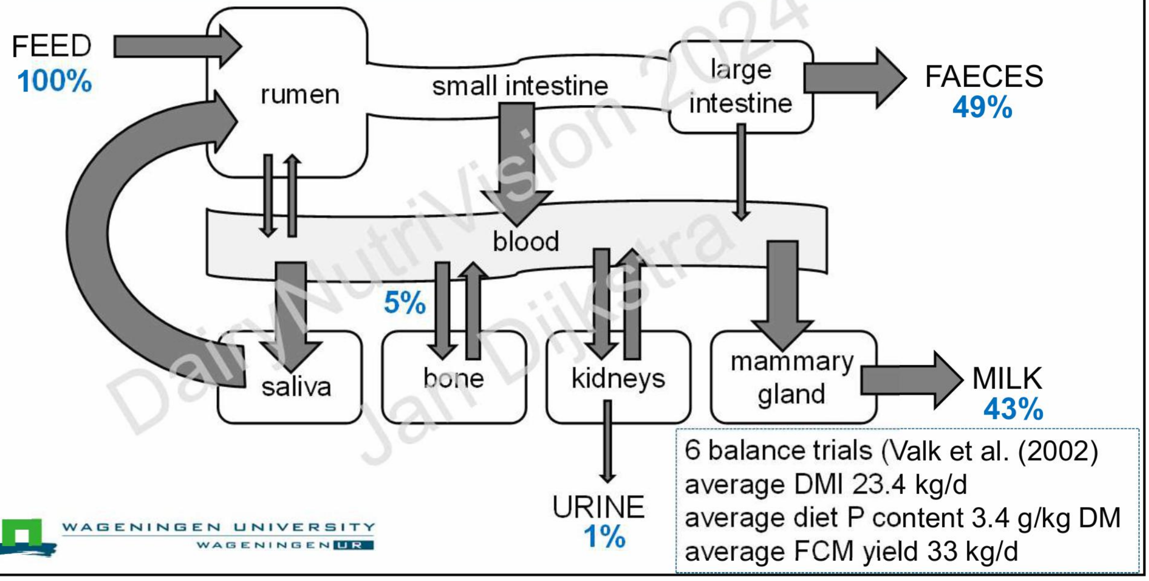
Nutritional approaches to ↓

- phosphorus excretion (P)
- nitrogen excretion (N)

with focus on Dutch dairy sector as a case

WAGENINGEN UNIVERSITY
WAGENINGEN UR

Phosphorus flows cattle



P excretion: meta-analysis

Fecal P excretion (g/d):

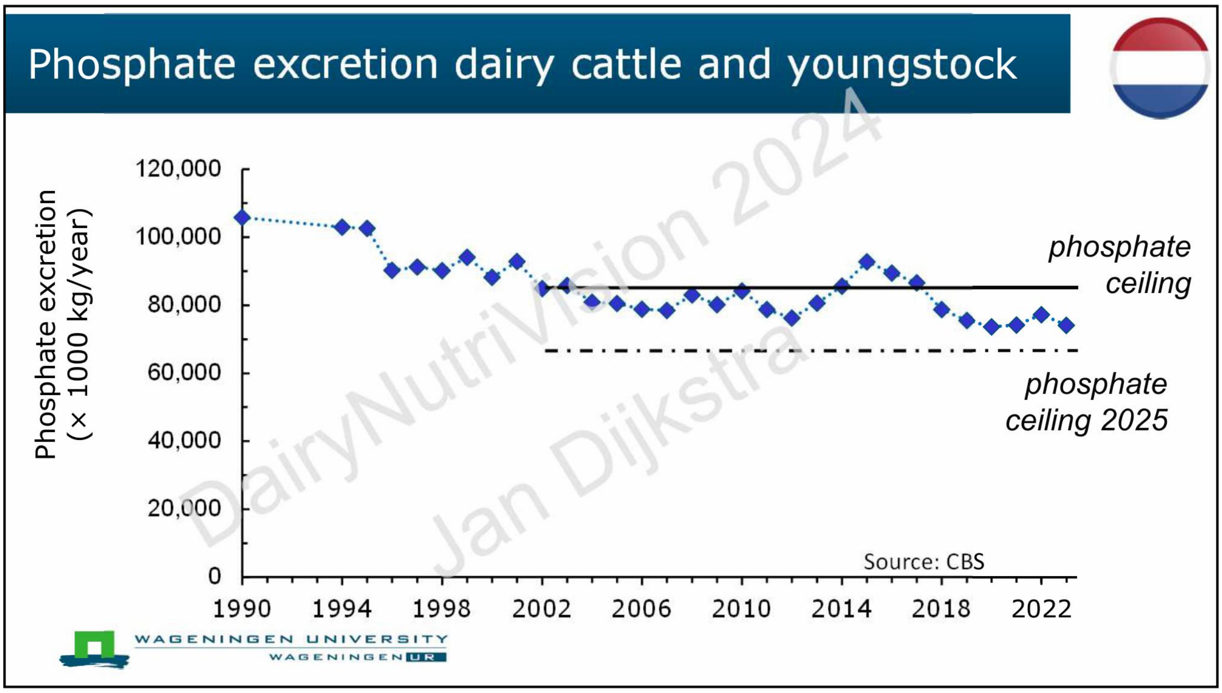
19.9 (±5.1) + 0.79 (±0.06) **P-intake** (g/d) − 1.04 (±0.13) **milk yield** (kg/d)

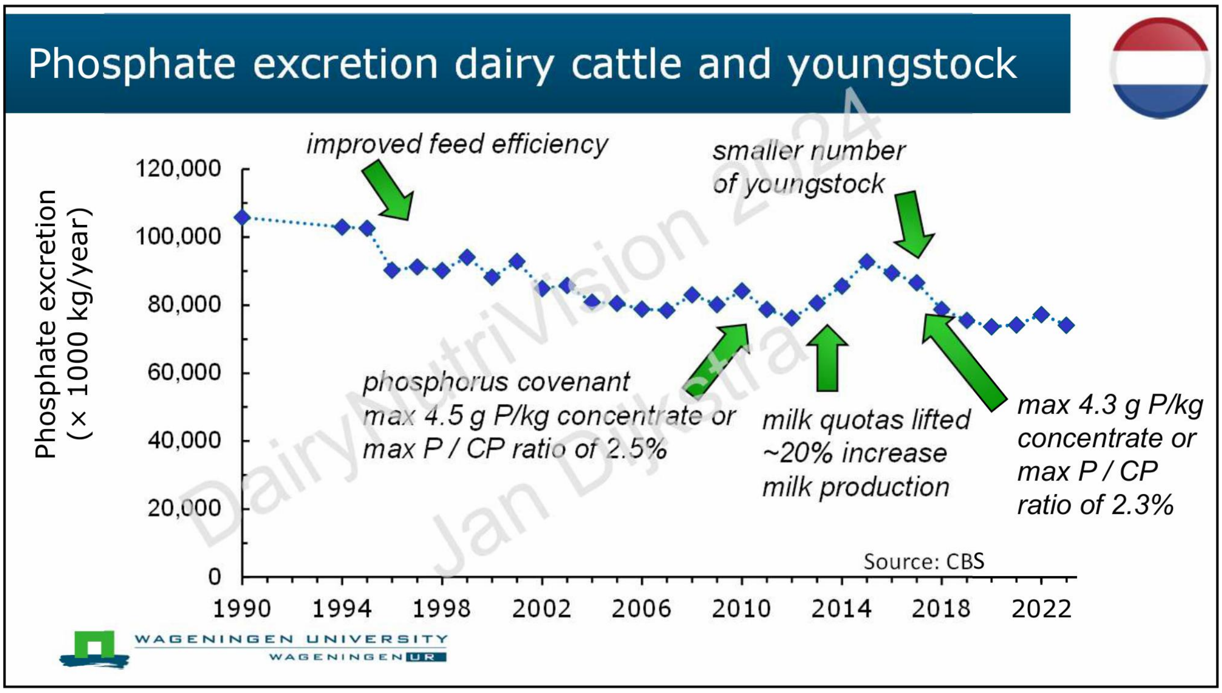
Milk P efficiency (g milk P/g P intake):

0.42 (±0.07) − 0.11 (±0.02) **diet P** (g/kg DM) + 0.23 (±0.02) **FE**

FE: feed efficiency (kg FPCM / kg DMI)

Meta-analysis Klop et al. (2013)
25 studies / 130 treatments


Phosphate excretion dairy cattle and youngstock
Phosphate excretion (× 1000 kg/year)
120,000
100,000
80,000
60,000
40,000
20,000
0
1990
1994
1998
2002
2006
2010
2014
2018
2022
phosphate ceiling
phosphate ceiling 2025
Source: CBS
WAGENINGEN UNIVERSITY
WAGENINGEN UR


Phosphate excretion dairy cattle and youngstock
Phosphate excretion (× 1000 kg/year)
120,000
100,000
80,000
60,000
40,000
20,000
0
1990
1994
1998
2002
2006
2010
2014
2018
2022
improved feed efficiency
smaller number of youngstock
phosphorus covenant max 4.5 g P/kg concentrate or max P / CP ratio of 2.5%
milk quotas lifted ~20% increase milk production
max 4.3 g P/kg concentrate or max P / CP ratio of 2.3%
Source: CBS
WAGENINGEN UNIVERSITY
WAGENINGEN UR

Considerations to reduce P in practice

- Grass herbage / grass silage high P content
- Concentrates / byproducts with low P but adequate protein at a premium
- Concerns about lower dietary P affecting production, transition health, and fertility
- Experiment dairy cattle (*n* = 60)

  (Keanthao et al., 2021)
  - 6 wks antepartum to 8 wks postpartum
  - 2 × 2 factorial design
    - dry period: 2.2 (recommended) or 3.6 (practice) g P/kg DM
    - lactating period: 2.9 (low) or 3.8 (recommended) g P/kg DM

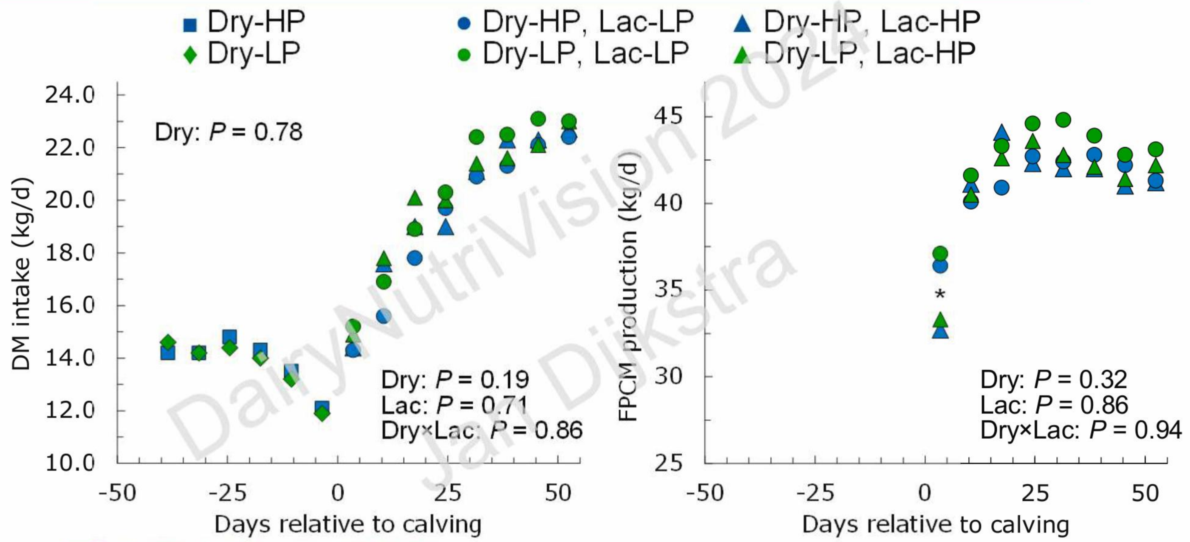

J. Dairy Sci. 104:11646–11659
https://doi.org/10.3168/jds.2021-20488

Effects of dietary phosphorus concentration during the transition period on plasma calcium concentrations, feed intake, and milk production in dairy cows

P. Keanthao,[1]* R. M. A. Goselink,[2] J. Dijkstra,[3] A. Bannink,[2] and J. T. Schonewille[1]
[1]Department of Population Health Sciences, Faculty of Veterinary Medicine, Utrecht University, Yalelaan 7, 3584 CL Utrecht, the Netherlands
[2]Department of Animal Nutrition, Wageningen Livestock Research, PO Box 338, 6700 AH Wageningen, the Netherlands
[3]Animal Nutrition Group, Wageningen University and Research, PO Box 338, 6700 AH Wageningen, the Netherlands

WAGENINGEN UNIVERSITY
WAGENINGEN UR

Effect of P level on DM intake and FPCM production



WAGENINGEN UNIVERSITY
WAGENINGEN UR

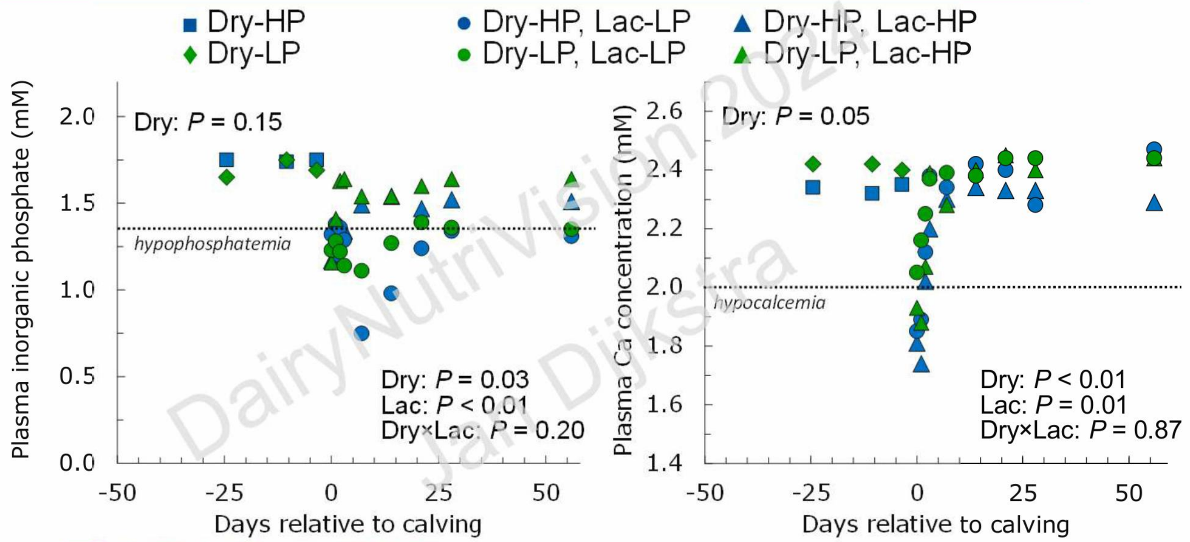
Keanthao et al. (2021)

Impact dietary P level on DMI / milk yield

⊕ recommended
✓ no effect
✗ negative effect

Study	Length experiment	Milk (kg/d)	Diet P content levels (g/kg DM)
Valk and Šebek (1999)	yr 1 / 20 wk	23.9	2.3 --- ✓ --- 2.7 - ⊕ - ✓ -- 3.3
	yr 2 / 40 wk	33.6	2.4 --- ✗ --- 2.8 -- ✓ - ⊕ - 3.3
Wu et al. (2000)	full lact	35.9	3.1 - ⊕ -- ✗/✓ -- 4.0 --- ✓ --- 4.9
Wu et al. (2001)	full lact	40.2	3.1 -- ⊕ - ✓ -- 3.9 --- ✓ --- 4.7
Knowlton et al. (2002)	10 wk	47.9	3.4 - ⊕ -- ✓ -- 5.1 --- ✓ --- 6.7
Tallam et al. (2005)	40 wk	39.8	3.5 -- ⊕ --- ✓----- 4.7
Wu (2005)	10 wk	43.0	3.2 --- ⊕ - ✗/✓--- 4.2
Ekelund et al. (2006)	16 wk	35.8	3.2 --- ⊕ ---✓--- 4.2
Odongo et al. (2007)	2 full lact	35.9	3.5 ⊕ -- ✗/✓ --- 4.2
Puggaard et al. (2014)	wk 2 to 12	34.6	2.3 --- ✗ --- 2.8 -- ✓ -- ⊕ 3.4
	wk 24 to 36	30.4	2.8 --- ⊕ ✓ --- 3.4

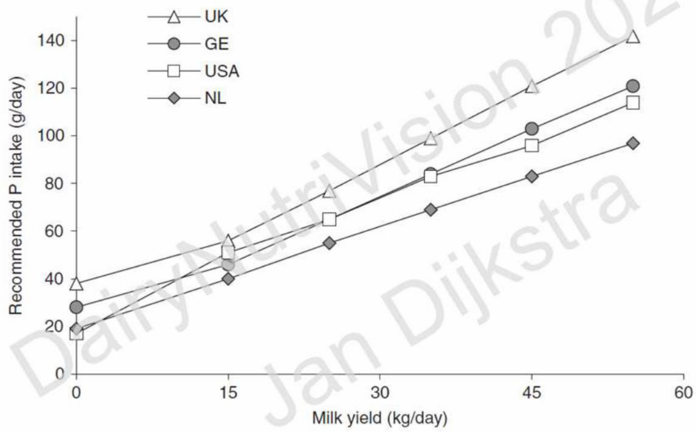
Effect of P level on plasma Pi and Ca concentration



WAGENINGEN UNIVERSITY WAGENINGEN UR

Keanthao et al. (2021)

Recommended P allowance varies widely



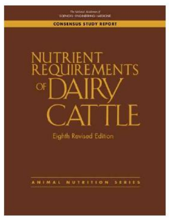
Bannink et al. (2010)

WAGENINGEN UNIVERSITY
WAGENINGEN UR

How to calculate P requirement?

Absorbed P requirements (g/d)		
Maintenance	25	1.0 g P/kg DMI + 0.0006 g/kg BW ?

DMI: 25 kg/d



NASEM (2021)

WAGENINGEN UNIVERSITY
WAGENINGEN UR

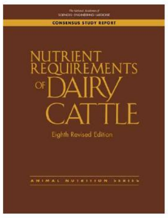
How to calculate P requirement?

Absorbed P requirements (g/d)		
Maintenance	25	1.0 g P/kg DMI + 0.0006 g/kg BW
Growth	1	ADG, BW, mature BW: NRC (2001) eqn
Pregnancy	0 - 5	2 to 5 g/d at 190 to 280 d of gestation (NRC)

DMI: 25 kg/d
ADG: 0.20 kg/d

WAGENINGEN UNIVERSITY
WAGENINGEN UR

NASEM (2021)



How to calculate P requirement?

Absorbed P requirements (g/d)		
Maintenance	25	1.0 g P/kg DMI + 0.0006 g/kg BW
Growth	1	ADG, BW, mature BW: NRC (2001) eqn
Pregnancy	0 - 5	[illegible] estation (NRC)
Milk		[illegible] g P/kg milk
		(0.49 + 0.13 × milk protein %) g P/kg milk

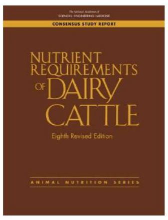
Actual intercept: 0.48

meta-analysis Klop et al. (2013)

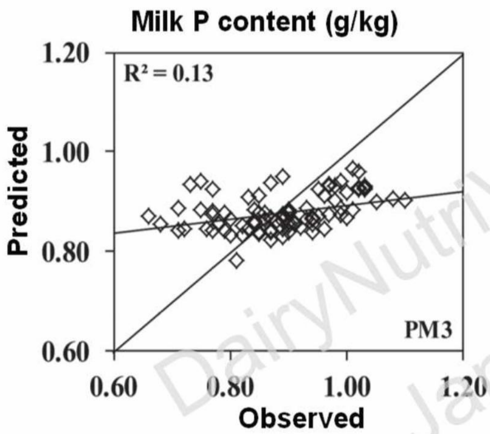
DMI: 25 kg/d
ADG: 0.20 kg/d

WAGENINGEN UNIVERSITY
WAGENINGEN UR

NASEM (2021)



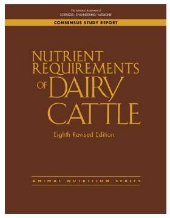
How to calculate P requirement?



1.0 g P/kg DMI + 0.0006 g/kg BW
ADG, BW, mature BW: NRC (2001) eqn
to 5 g/d at 190 to 280 d of gestation (NRC)
0.90 g P/kg milk
(0.49 + 0.13 × milk protein %) g P/kg milk

meta-analysis Klop et al. (2013)

NASEM (2021)



WAGENINGEN UNIVERSITY
WAGENINGEN UR

How to calculate P requirement?

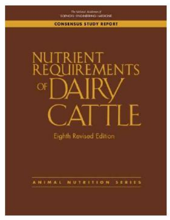
Absorbed P requirements (g/d)		
Maintenance	25	1.0 g P/kg DMI + 0.0006 g/kg BW
Growth	1	ADG, BW, mature BW: NRC (2001) eqn
Pregnancy	0 - 5	2 to 5 g/d at 190 to 280 d of gestation (NRC)
Milk	36	0.90 g P/kg milk
	38 / 41	(0.49 + 0.13 × milk protein %) g P/kg milk

DMI: 25 kg/d
ADG: 0.20 kg/d
Milk: 40 kg/d
Milk protein: 3.55%

meta-analysis Klop et al. (2013)

alternative equation:
meta-analysis Klop et al. (2014)

NASEM (2021)



WAGENINGEN UNIVERSITY
WAGENINGEN UR

DairyNutriVision 2024
Jan Dijkstra

How to calculate P requirement?

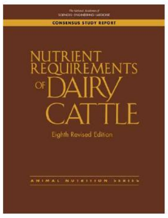
Absorbed P requirements (g/d)		
Maintenance	25	1.0 g P/kg DMI + 0.0006 g/kg BW
Growth	1	ADG, BW, mature BW: NRC (2001) eqn
Pregnancy	0 - 5	2 to 5 g/d at 190 to 280 d of gestation (NRC)
Milk	36	0.90 g P/kg milk
	38	(0.49 + 0.13 × milk protein %) g P/kg milk

DMI: 25 kg/d
ADG: 0.20 kg/d
Milk: 40 kg/d
Milk protein: 3.55%

P required (g/d) = absorbed P requirement / AC

AC: absorption coefficient

AC, default: 0.72
AC, inorganic P: 0.84
AC, organic P: 0.68



NASEM (2021)

WAGENINGEN UNIVERSITY
WAGENINGEN UR

Phosphorus excretion: conclusion

- Reduced P excretion without decreased production volume requires improved feed efficiency and/or lowering dietary P
- Covenant on lower P levels concentrate highly effective
- Recommended dietary P levels may be too high
  - low P dry period helpful to smoother transition
- Required P levels depend mainly on DMI and milk yield
  - milk P content varies

WAGENINGEN UNIVERSITY
WAGENINGEN UR

Reducing N and P excretion dairy cattle

Nutritional approaches to ⬇
- phosphorus excretion (P)
- nitrogen excretion (N)

with focus on Dutch dairy sector as a case

WAGENINGEN UNIVERSITY
WAGENINGEN UR

Nitrogen – hot topic

DW Made for minds.

TOP STORIES MEDIA CENTER TV RADIO LEARN GERMAN
GERMAN ELECTION CORONAVIRUS WORLD BUSINESS SCIENCE ENVIRONMENT

ENVIRONMENT

Dutch farmers angry about nitrogen restrictions

The Netherlands is under pressure to reduce its nitrogen emissions – gases proven to be 300 times worse for global warming than CO2. That means the country's agriculture has to change. But the restrictions the government is proposing aren't going down well with Dutch farmers.

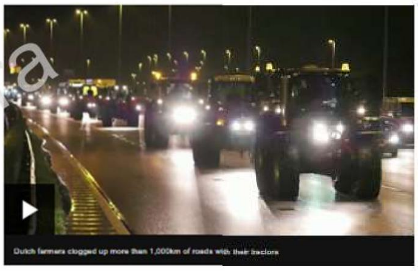
BBC NEWS

Home | Video | World | UK | Business | Tech | Science | Stories | Entertainment & Arts
World | Africa | Asia | Australia | Europe | Latin America | Middle East | US & Canada

Dutch tractor protest sparks 'worst rush hour'

1 October 2019

Climate change



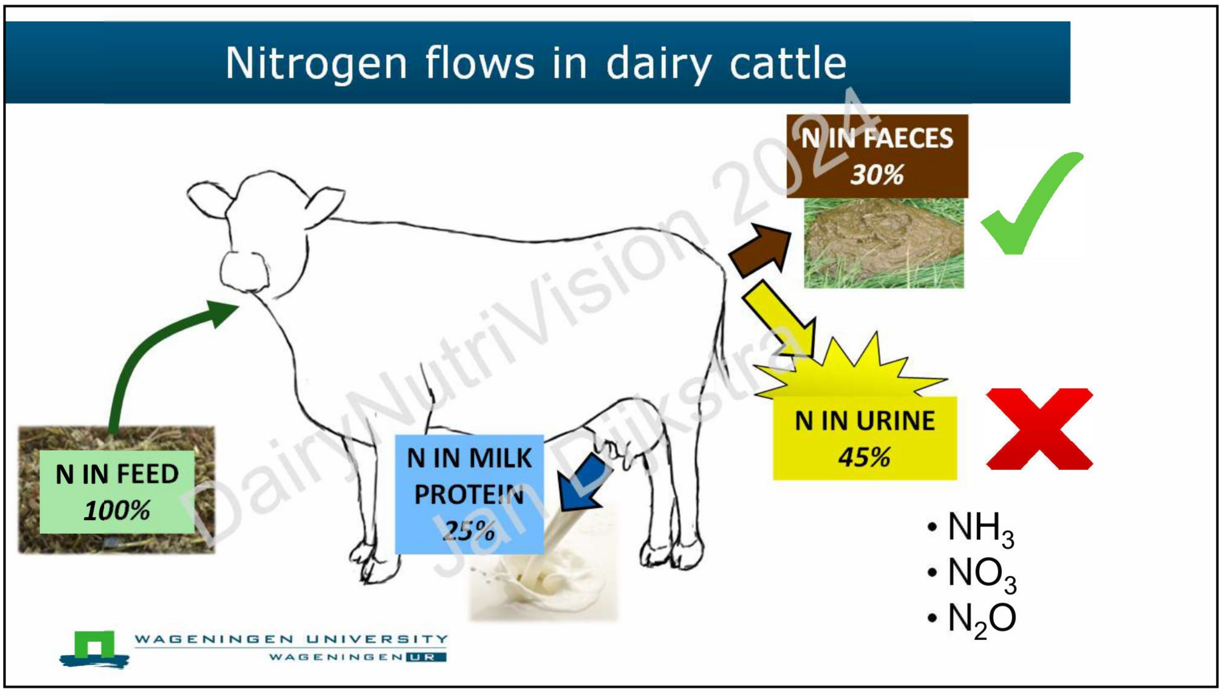
Dutch farmers clogged up more than 1,000km of roads with their tractors

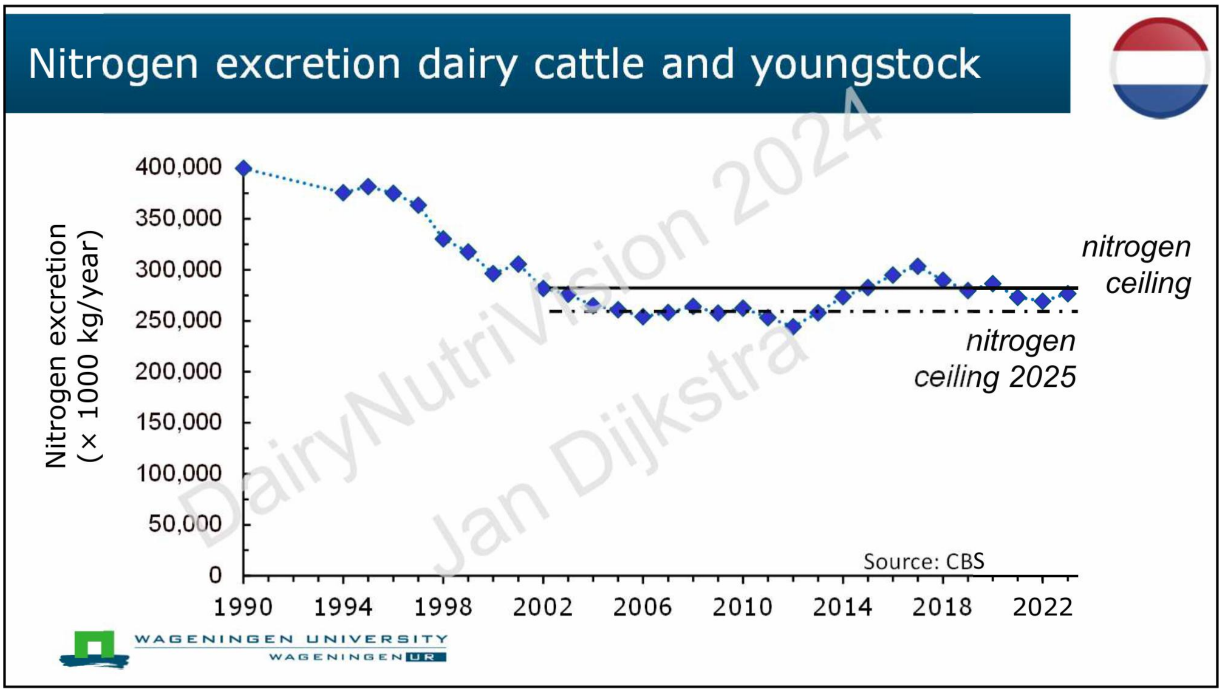
Tractor-driving farmers taking to the streets to demand greater recognition caused the worst ever Dutch morning rush hour on Tuesday, according to motoring organisation ANWB.

There were 1,136km (700 miles) of jams at the morning peak, it said.

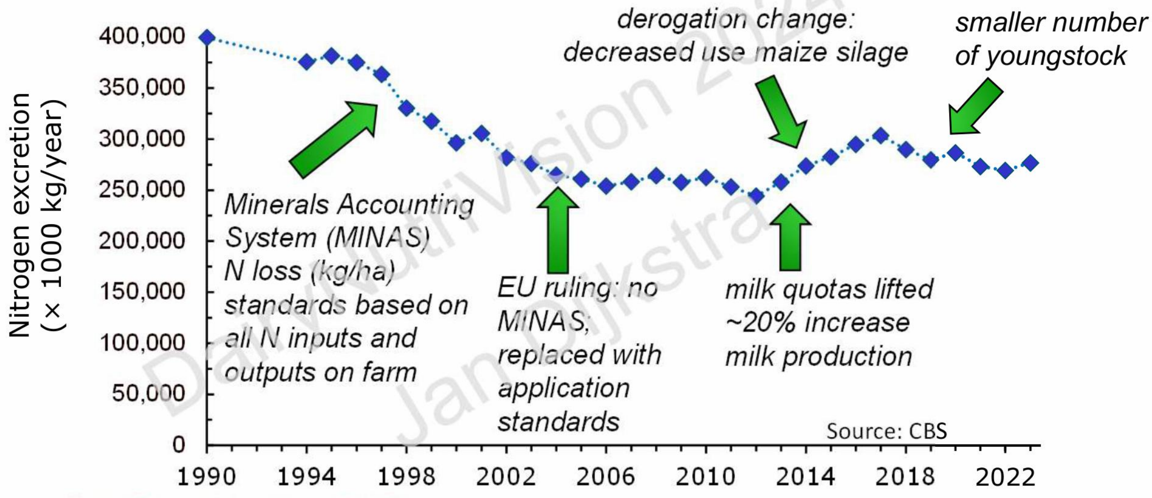
Farmers reacted angrily to claims that they were largely responsible for a nitrogen oxide emissions problem.

WAGENINGEN UNIVERSITY
WAGENINGEN UR


Nitrogen flows in dairy cattle
N IN FAECES
30%
N IN URINE
45%
N IN FEED
100%
N IN MILK
PROTEIN
25%
• NH_3
• NO_3
• N_2O
WAGENINGEN UNIVERSITY
WAGENINGEN UR
DairyNutriVision 2024
Jan Dijkstra


Nitrogen excretion dairy cattle and youngstock
Nitrogen excretion
(× 1000 kg/year)
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1990
1994
1998
2002
2006
2010
2014
2018
2022
nitrogen
ceiling
nitrogen
ceiling 2025
Source: CBS
WAGENINGEN UNIVERSITY
WAGENINGEN UR
DairyNutriVision 2024
Jan Dijkstra

Nitrogen excretion dairy cattle and youngstock



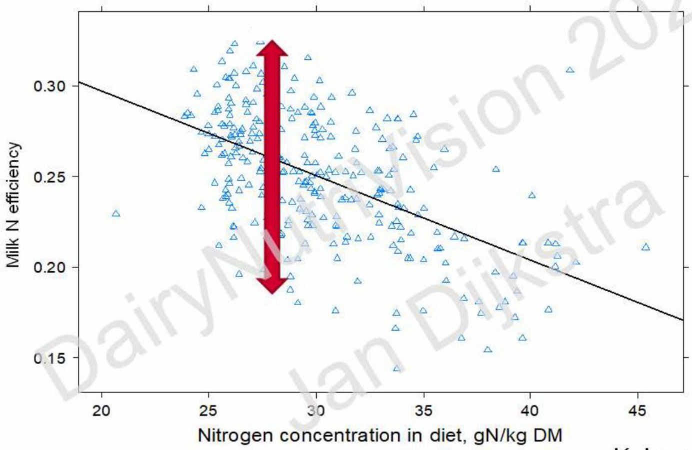
WAGENINGEN UNIVERSITY
WAGENINGEN UR

Smart dairy nutrition to reduce N excretion

- Keep N intake as low as possible to minimize N excretion
- Maximize the proportion of N intake that is partitioned into milk

WAGENINGEN UNIVERSITY
WAGENINGEN UR

Large variation in milk N efficiency



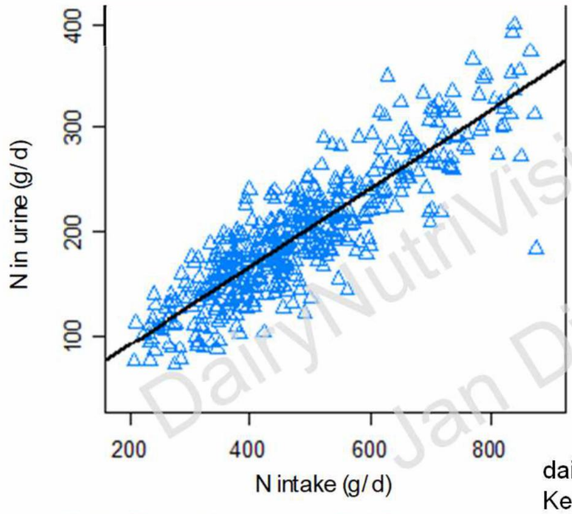
Kebreab et al. (2010)

Variation in milk N use efficiency

	Milk N efficiency cluster				
	NE22 *n* = 20	NE27 *n* = 31	NE30 *n* = 31	NE36 *n* = 18	*P*-value
Milk N efficiency (% N intake)	22.1[a]	26.9[b]	30.0[c]	35.8[d]	<0.01
CP (g/kg DM)	16.0[a]	15.3[a]	15.1[ab]	14.2[b]	<0.01
NDF (g/kg DM)	39.4	39.1	36.4	36.8	0.03
Starch (g/kg DM)	14.1[b]	14.6[b]	19.6[a]	20.3[a]	<0.01
NE_L (MJ/kg DM)	6.10[b]	6.19[b]	6.40[a]	6.44[a]	<0.01
RDP (g/kg DM)	108[a]	104[a]	101[ab]	93[b]	<0.01
FCM (kg/d)	28.8[b]	31.3[ab]	32.0[a]	32.9[a]	<0.01
Milk urea (mg/dl)	28.2[a]	24.4[b]	25.3[ab]	23.8[b]	0.02

100 dairy farms Quebec (Canada); Fadul-Pacheco et al. (2017)

N intake is principal driver of N excretion, but…



Urine N (g/d):
$20_{(20.0)} + 0.38_{(0.039)}$ N-intake

Prediction significantly better with energy intake included

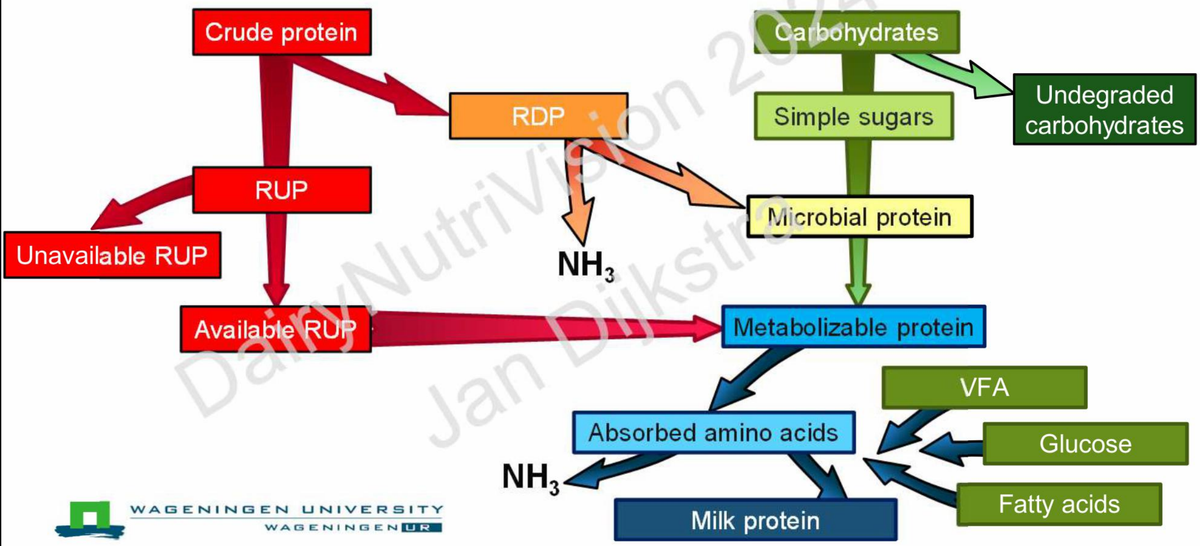
Urine N (g/d):
$48_{(20.1)} + 0.56_{(0.030)}$ N-intake $- 71.4_{(12.20)}$ ME-intake

N-intake, g/d
Metabolizable Energy (ME) intake, MJ/(kg$^{0.75}$ d)

dairy cattle (*n* = 470)
Kebreab et al. (2010)

WAGENINGEN UNIVERSITY
WAGENINGEN UR

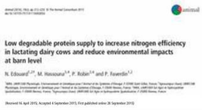
Metabolizable amino acids: N and energy



WAGENINGEN UNIVERSITY
WAGENINGEN UR

Rumen Nitrogen Balance (RNB) as low as possible

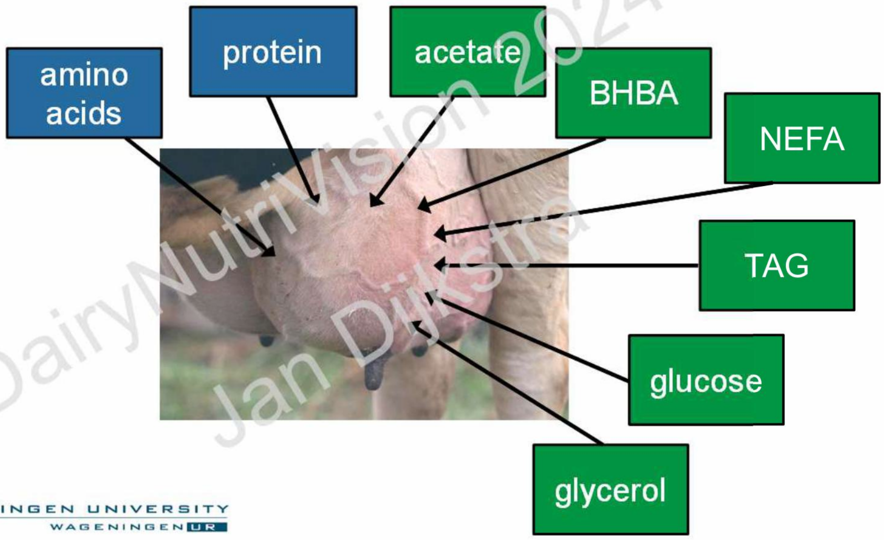
	Low CP	High CP	*P*-value
CP (g/kg DM)	122	176	-
MP (g/kg DM)	96.4	99.0	-
RNB (g/kg DM)	-2.0	2.4	-
DM intake (kg/d)	20.6	21.4	<0.01
Rumen degr. protein balance (g/d)	-260	325	-
ECM yield (kg/d)	28.1	29.1	0.13*
N milk (g/d)	129	136	<0.01
Milk N efficiency (%)	31.1	21.7	<0.01
N urine (g/d)	65 (~*130*)	243 (~*330*)	<0.01



Edouard et al. (2016)

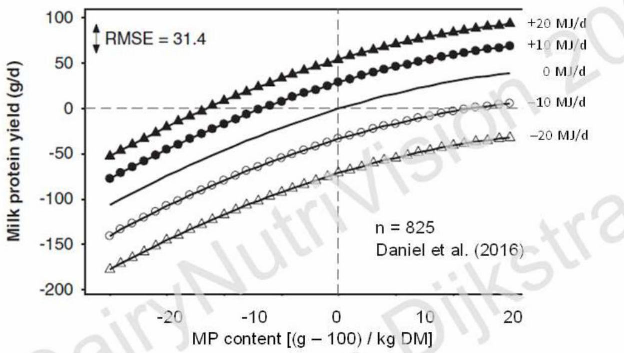
WAGENINGEN UNIVERSITY WAGENINGEN UR

Balanced protein and energy supply udder



WAGENINGEN UNIVERSITY WAGENINGEN UR

Response to change in NE_L and MP



animal

Milk yield and milk composition responses to change in predicted net energy and metabolizable protein: a meta-analysis

J. B. Daniel, N. C. Friggens, P. Chapoutot, H. Van Laar and D. Sauvant

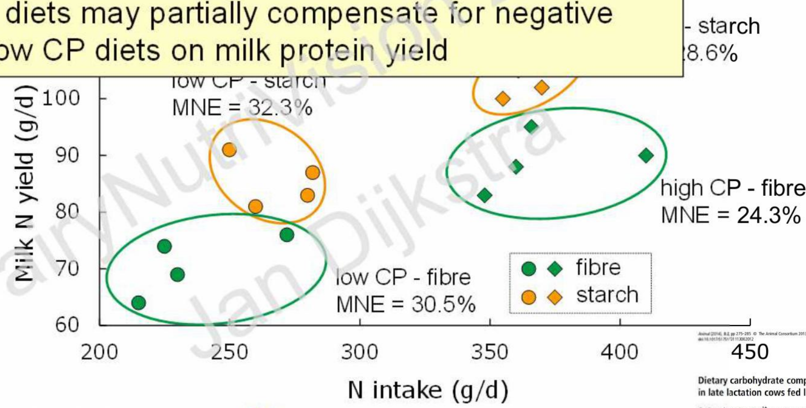
Response to dietary metabolizable protein content depends on dietary net energy content

- increase in NE_L content may balance impact of decrease in MP content and reduce urinary N excretion

WAGENINGEN UNIVERSITY

Energy components: fibre vs. starch

- starch-rich diets improve milk N efficiency compared with fibre-rich diets
- starch-rich diets may partially compensate for negative effects of low CP diets on milk protein yield



animal

Dietary carbohydrate composition modifies the milk N efficiency in late lactation cows fed low crude protein diets

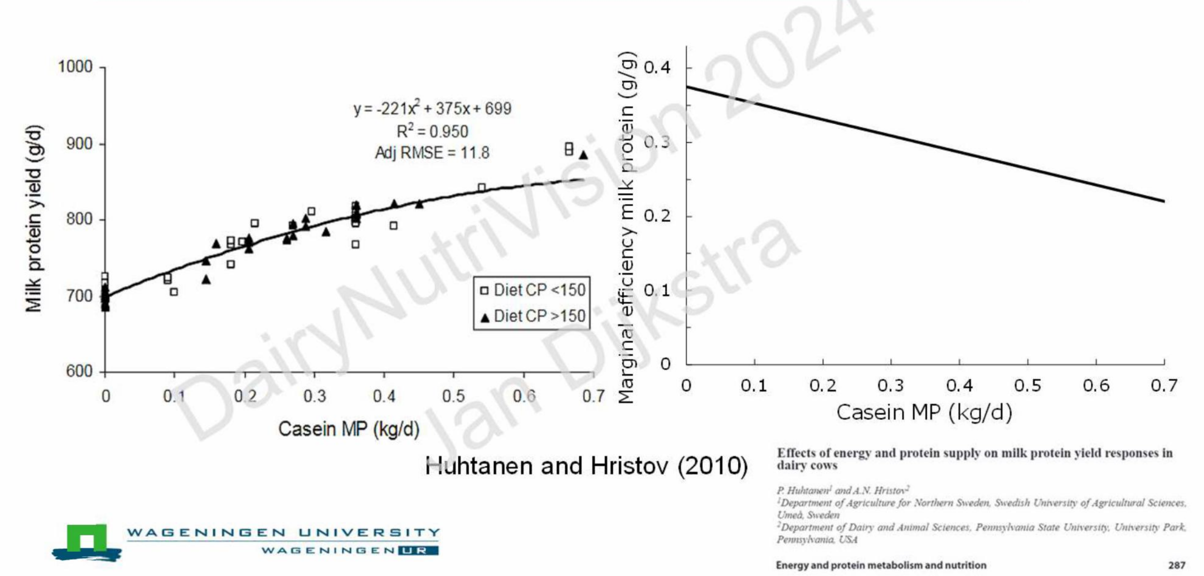
G. Cantalapiedra-Hijar, J. L. Peyraud, S. Lemosquet, E. Molina-Alcaide, H. Boudra, P. Nozière and I. Ortigues-Marty

WAGENINGEN UNIVERSITY
WAGENINGEN UR

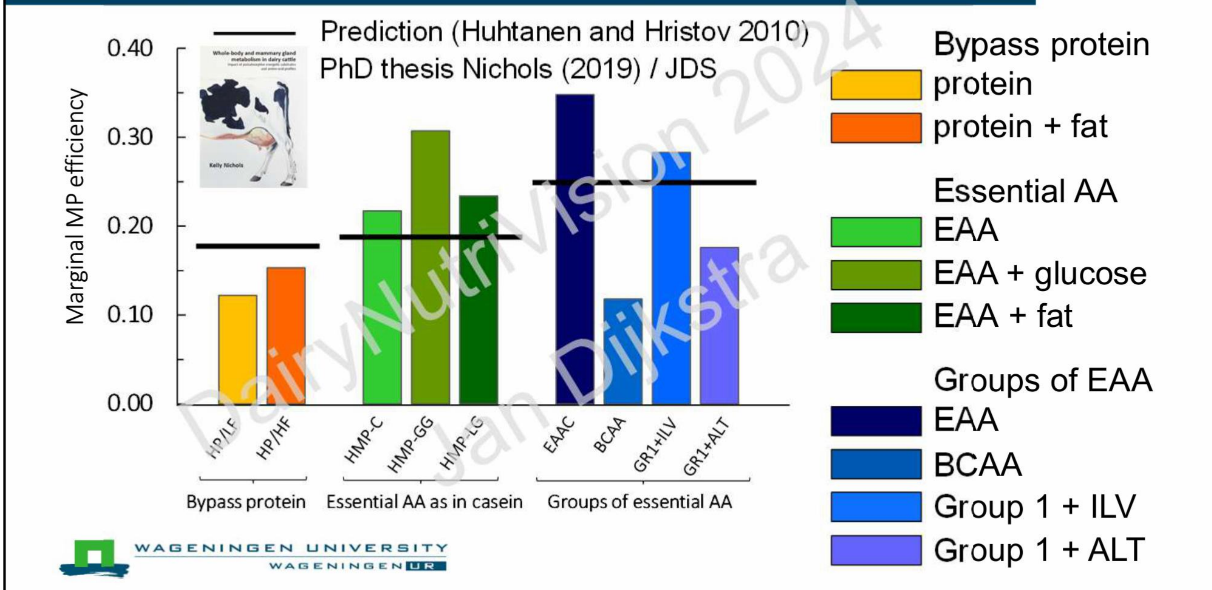
REDNEX

Cantalapiedra-Hijar et al. (2014)

Response to abomasal casein infusion



Response to nutrient supplementation



Mammary flexibility in using individual amino acids

Milk protein yield limited by single amino acid?

Unlikely, because:

- ✓ mTOR (major signalling pathway in ribosomal protein synthesis) responds independently and additively to several essential AA and energy compounds
- ✓ milk protein yield is stimulated by mutually exclusive sets of essential AA
- ✓ equal losses in milk protein yield when individual AA are subtracted from duodenal essential AA supply

WAGENINGEN UNIVERSITY
WAGENINGEN UR

Mammary flexibility in using individual amino acids

Milk protein yield limited by single amino acid?

Additive and independent responses to nutrients

- size of leak depends on mix of nutrients
- plugging any crack may help

WAGENINGEN UNIVERSITY
WAGENINGEN UR

Nitrogen excretion: conclusion

- Mineral accounting system (inputs and outputs of N) central to reducing N excretion
- Decreasing dietary protein level *per se* is not major goal
  - proper balance between dietary protein and level / type of energy at rumen / post absorptive level
- Minimize rumen degradable protein balance
  moderate ↑ milk protein efficiency; large ↓ urinary N excretion
- Efficiency of post-absorptive utilization nutrients is not fixed
  - focus quantitatively and qualitatively: as groups, not individual

WAGENINGEN UNIVERSITY WAGENINGEN UR

thank you *jan.dijkstra@wur.nl*