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Emission measurements in a naturally ventilated dairy housing: How does the crude protein level of the diet affect ammonia and nitrous oxide emissions?

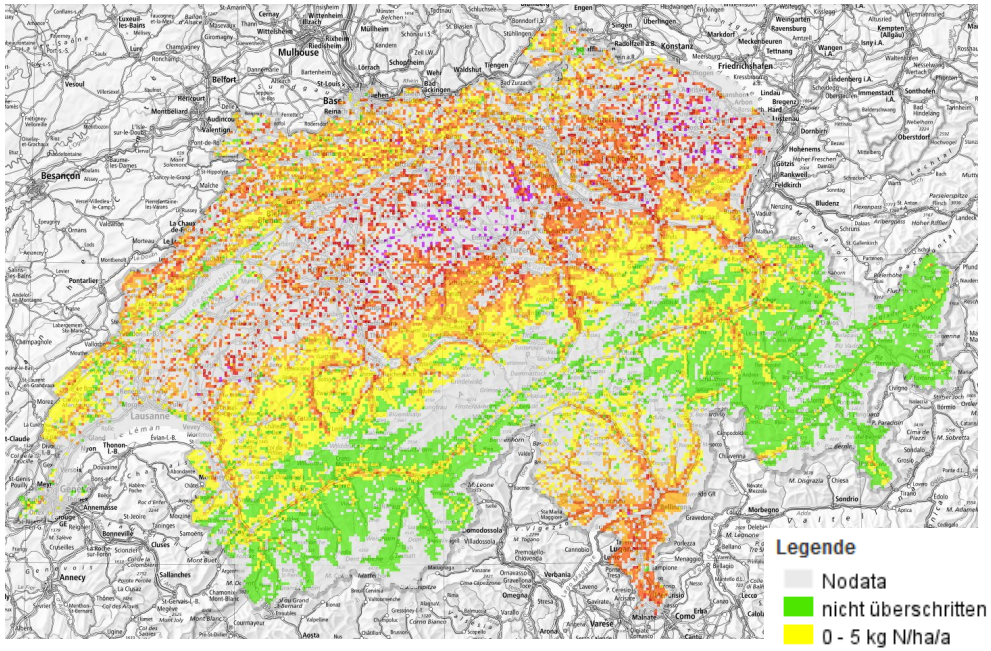
S. Schrade, K. Zeyer, J. Mohn, M. Zähner

75th EAAP Annual Meeting, Florence, 1-5 September 2024

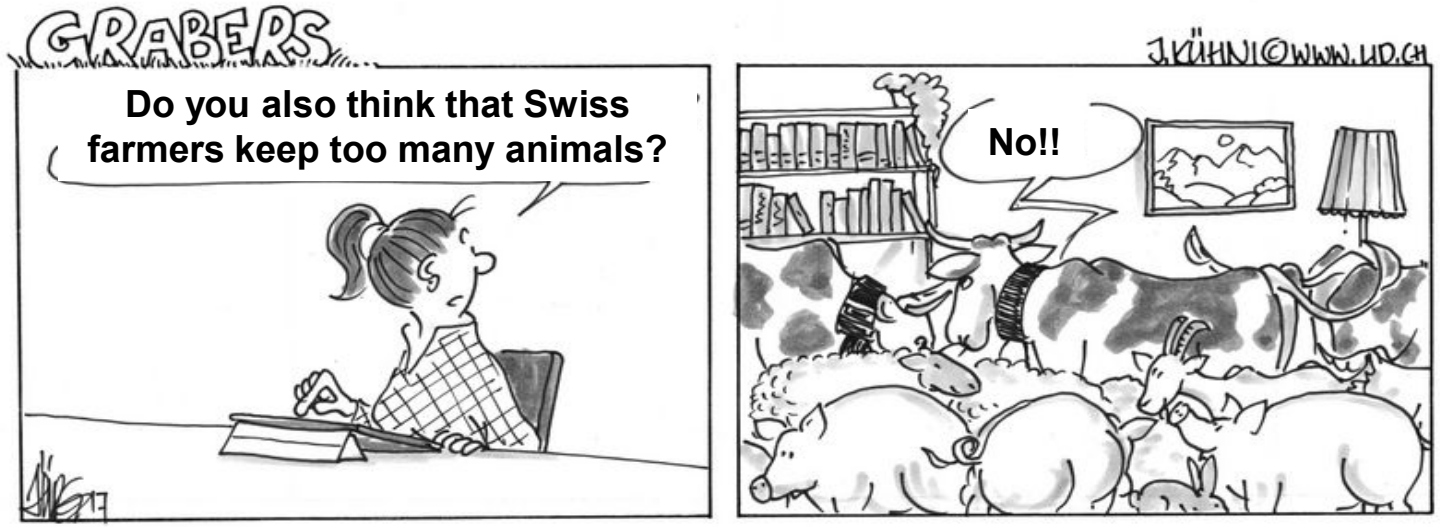
Emission situation Switzerland

Critical loads for nitrogen (N) exceeded
➔ Swiss Environmental Targets Agriculture:
40% ammonia (NH_3) reduction

Swiss Climate Strategy Agriculture:
➔ GHG reduction of around one third (2050)



[Source: Federal Office of the Environment, 2020]



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Correlations: Dietary crude protein (CP) content
➔ urinary nitrogen excretion/milk urea content
➔ NH_3 emissions

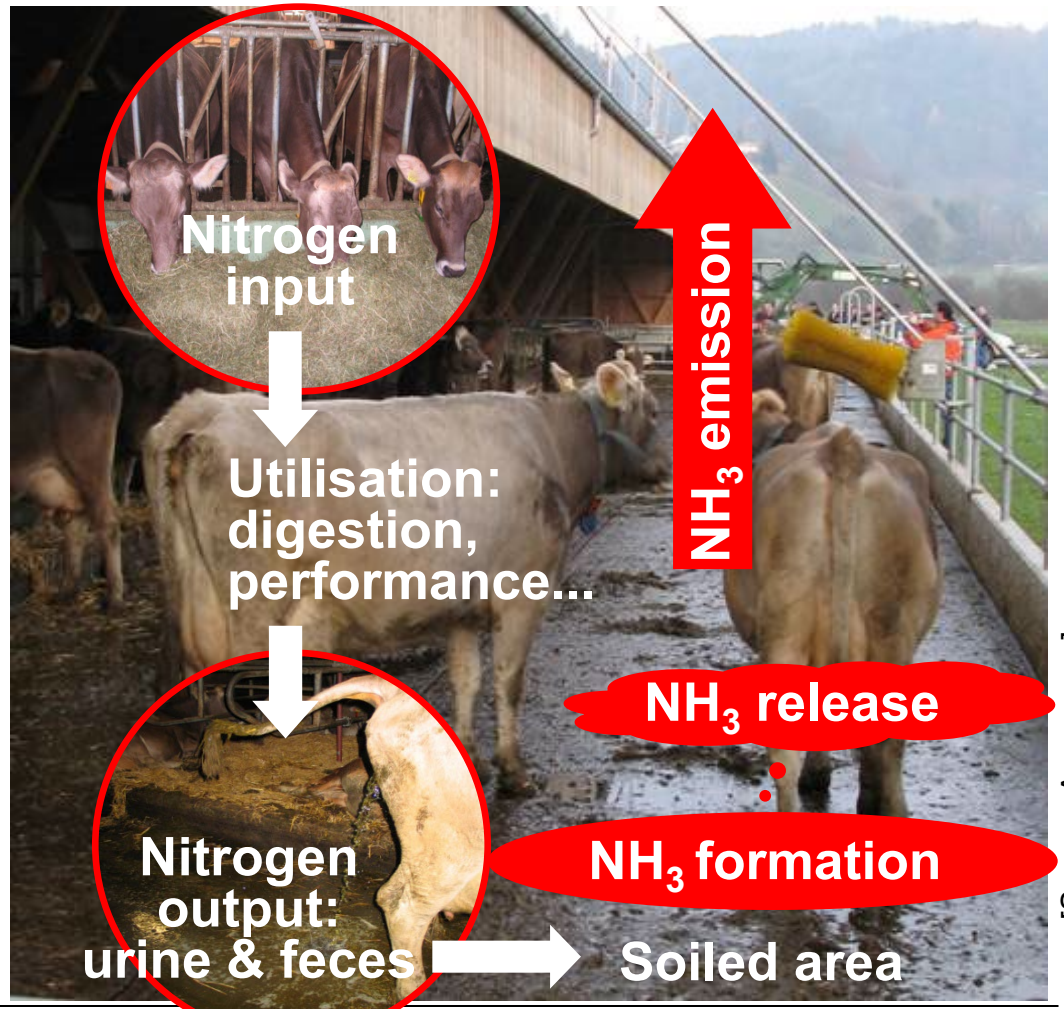
Measurements on a practical scale:
Van Duinkerken et al. 2005, 2011;
Powell et al. 2008;
Schrade et al. 2012;
Edouard et al. 2019

Literature review:
Bracher 2011

➔ **Aim: balanced and needs-based diet**

➔ **Milk urea content as an indicator of nitrogen utilisation and excretion**

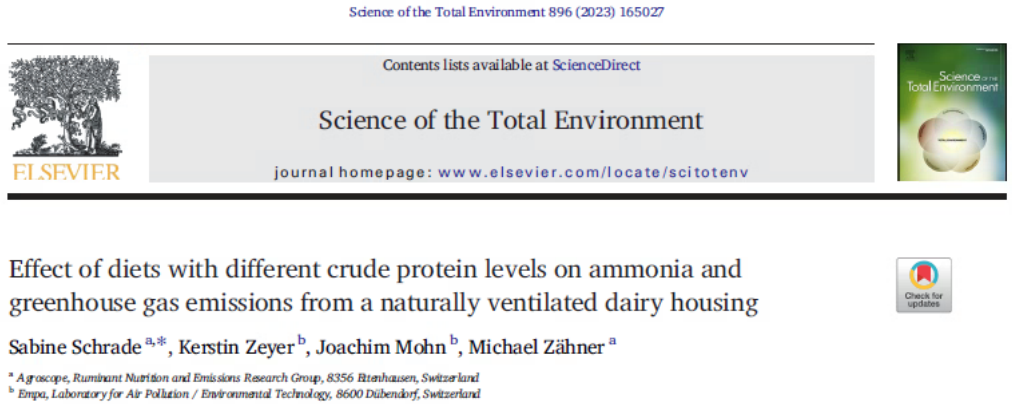
Reduction of CP in the diet = less CP has to be supplied from other sources?!



[Source: Agroscope]

Research questions

- How does a high CP content compared to a low CP content of the diet affect NH_3 and nitrous oxide (N_2O) emissions in the dairy housing (practical scale)?
- What are the significant factors influencing emissions?
- Can the milk urea content be used as an indicator for N excretion and thus also for the NH_3 emission potential?
- Do the diets (‘CP content high’ ⇔ ‘CP content low’) influence milk yield and milk contents?


Science of the Total Environment 896 (2023) 165027

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Effect of diets with different crude protein levels on ammonia and greenhouse gas emissions from a naturally ventilated dairy housing

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http://dx.doi.org/10.1016/j.scitotenv.2023.165027

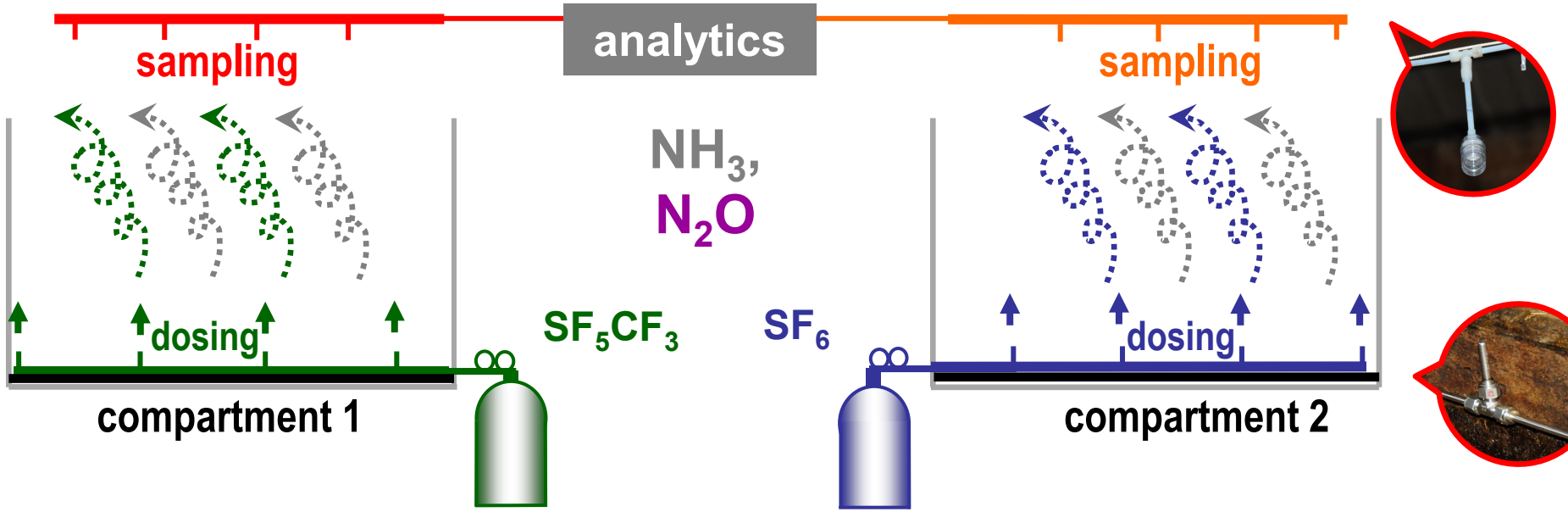
Dual tracer ratio method in the experimental dairy housing for emissions measurements with two compartments

[Schrade et al. 2012, Mohn et al. 2018]

Picarro (CRD spectroscopy) ➔ NH_3

QCLAS ➔ N_2O

GC-ECD ➔ SF_5CF_3, SF_6



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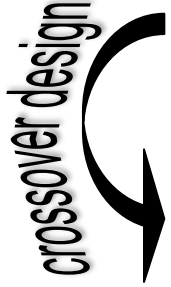
Comparable measurements using a «crossover design»

[Photos: Agroscope]



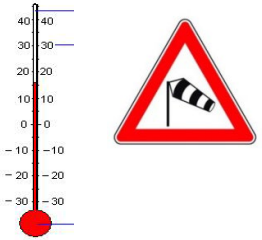
	Compartment 1	Compartment 2
Adaptation (10 days)	CP content low	CP content high
Measurement (6 days)	CP content low	CP content high
Adaptation (10 days)	CP content high	CP content low
Measurement (6 days)	CP content high	CP content low

Measurements were carried out during the cooler season: February to March

Accompanying parameters

➔ Description of the measurement situation, factors influencing emissions

- **Feed and leftovers**
  Masses: daily, herd level
  Contents: analysis of pool samples over 6-day measurement
- **Animal data**
  Milk yield (daily, individual animal), live weight (individual animal),
  Eating and rumination behaviour (10 focus animals)
- **Milk samples**
  3 days per measurement in the morning and evening (individual animal, pool sample herd)
- **Urine samples**
  2 days per measurement in the morning (9 focus animals per herd)
- **Weather data**
  Temperature, wind speed, relative humidity, precipitation etc.
  (inside the compartments and outside)



[Photos: Agroscope]

Diets

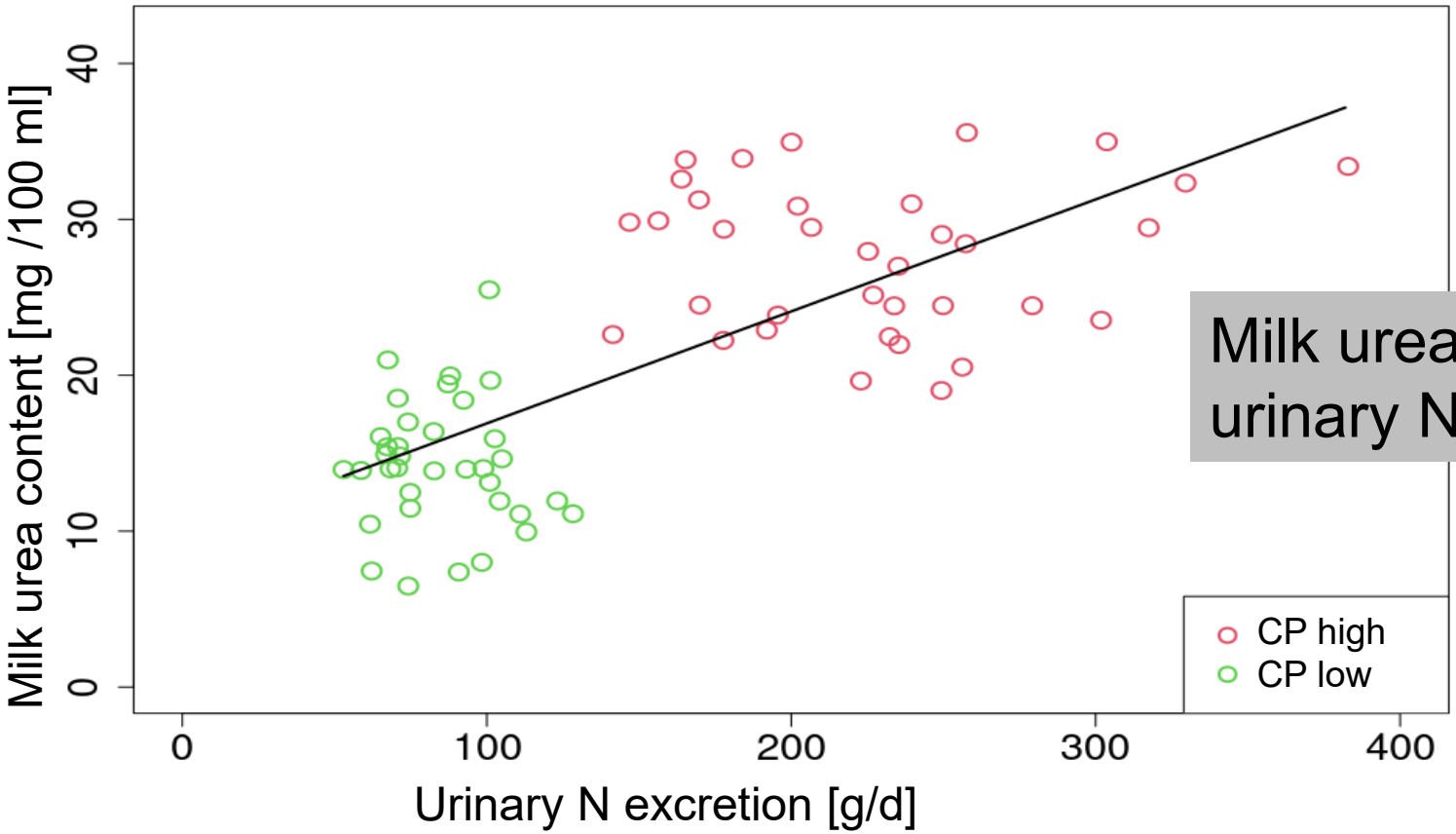
	CP low		CP high
Feed components in the diet	Grass silage, maize silage, hay, sugar beet pulp silage, concentrate rich in energy, dextrose, salt, mineral feed		Grass silage, maize silage, hay, sugar beet pulp silage, concentrate rich in protein, urea, concentrate rich in energy, salt, mineral feed
Crude protein [g / kg DM]	**115**	**<**	**169**
Crude fibre [g / kg DM]	239	>	195
NEL [MJ / kg DM]	6.3	=	6.4

Aim

Comparison of NH_3 and N_2O emissions from typical Swiss partial mixed ration with different CP contents

➔ Reduction of CP in the diet also means optimisation of protein self-sufficiency

Milk urea content und urinary nitrogen excretion



Milk urea content und urinary N excretion (R = 0.71)

Further correlations

CP content diet and urinary N excretion (R = 0.84)

CP content diet and milk urea content (R = 0.82)

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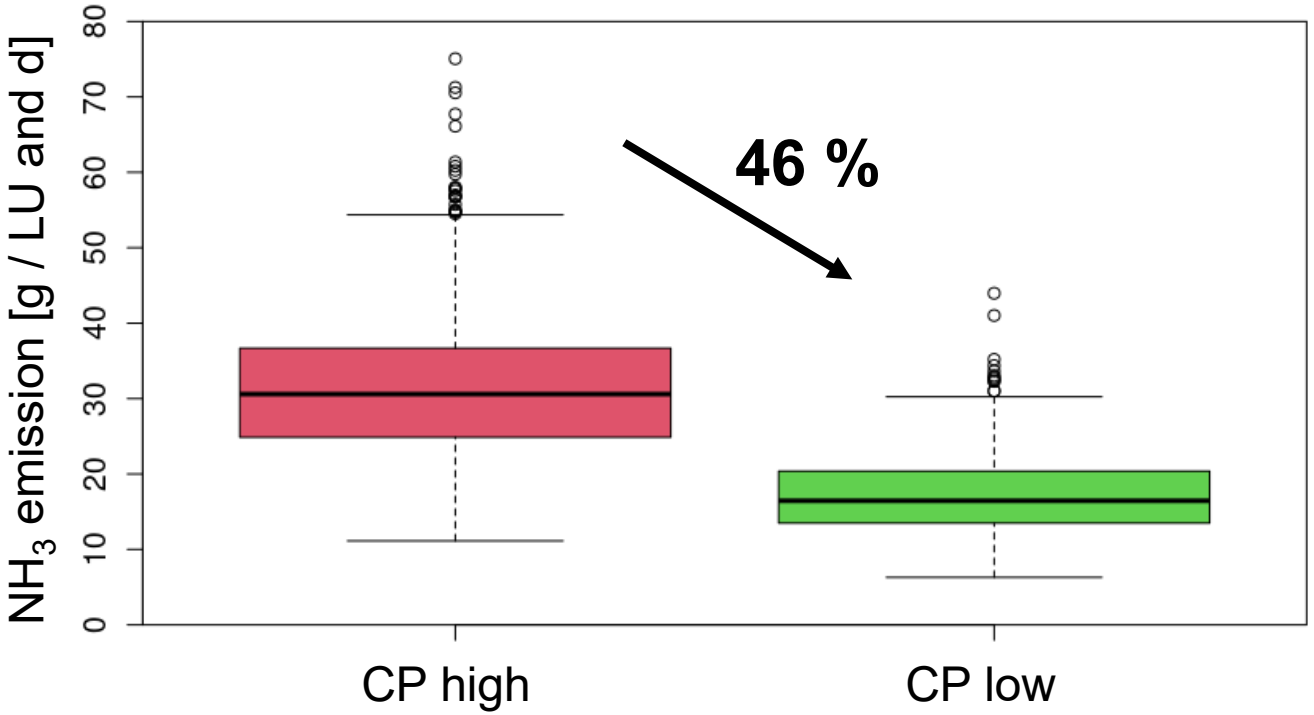
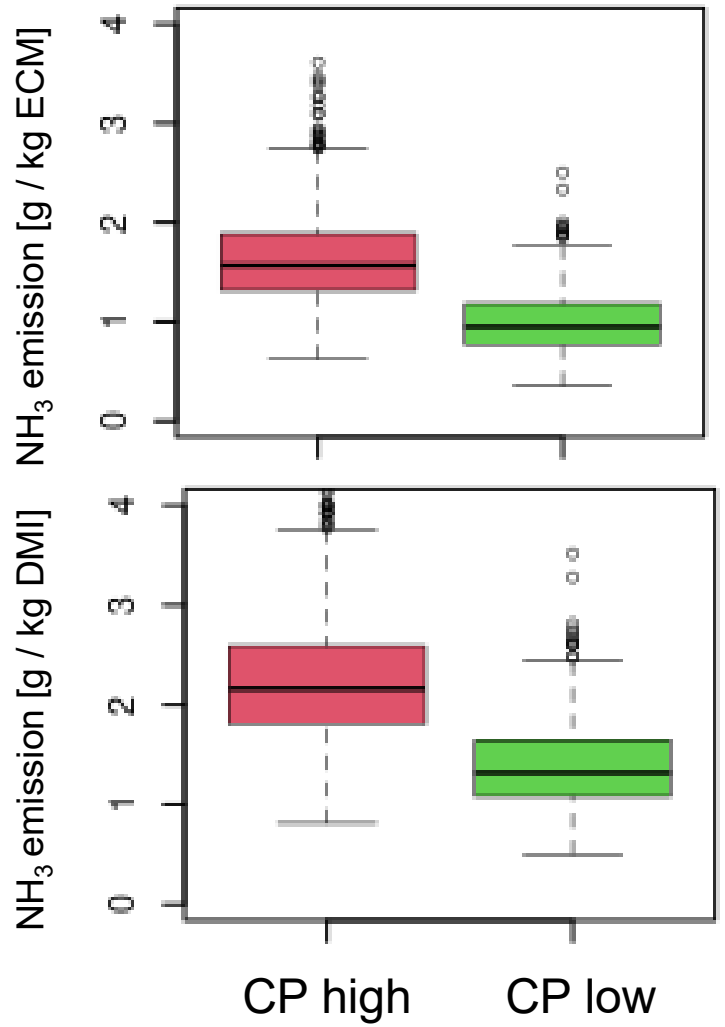
NH_3 emissions

per livestock unit (1 LU = 500 kg live weight)
milk yield (ECM) and dry matter intake (DMI)

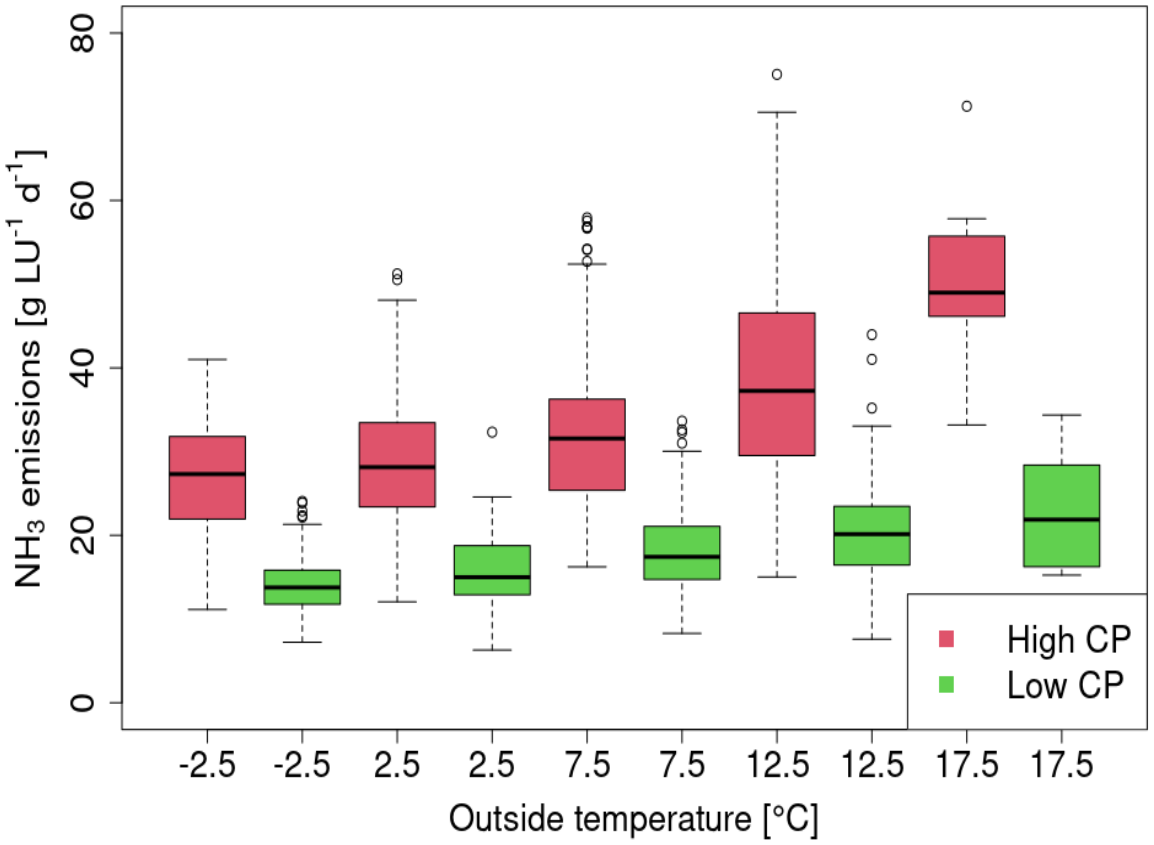




Factors influencing NH_3 emissions

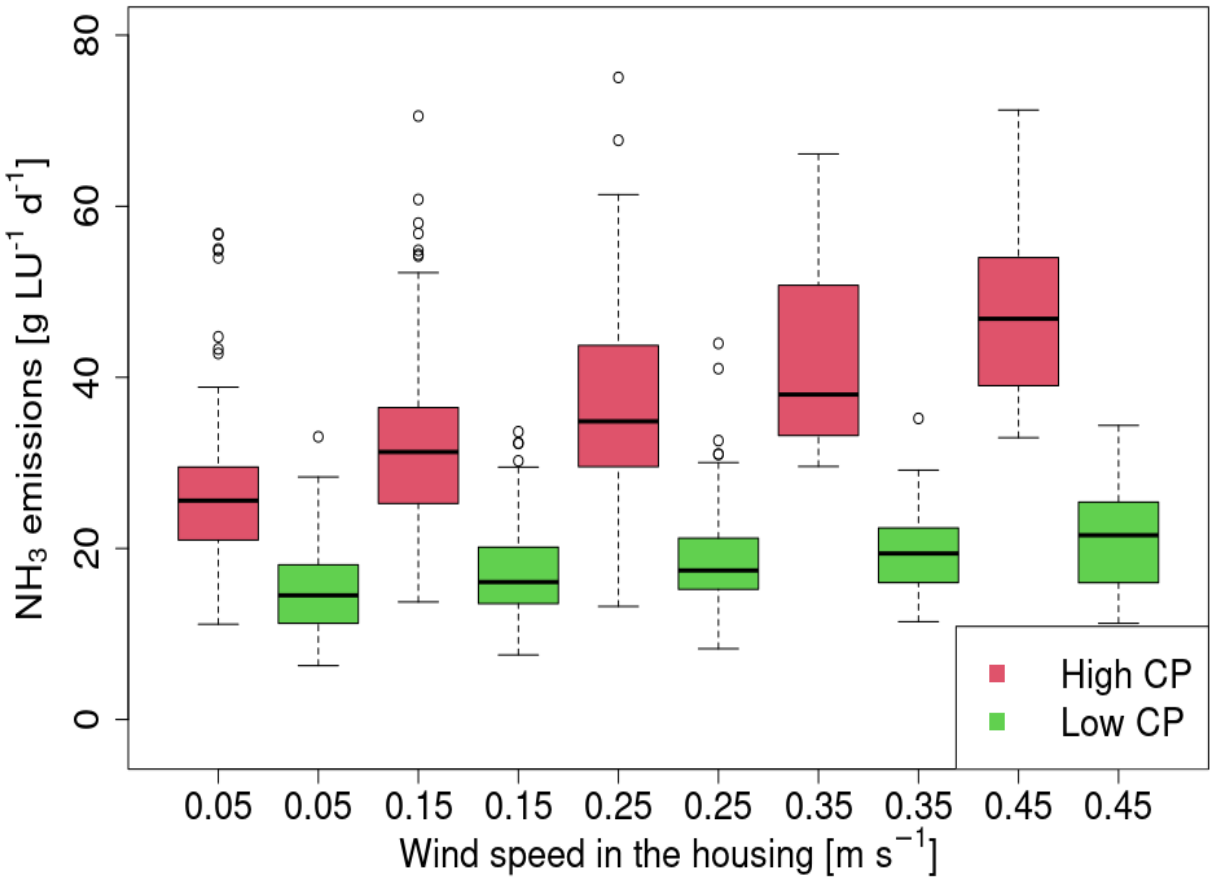
Diet ($p<0.001$), outdoor temperature ($p<0.001$), wind speed in the housing ($p<0.001$)

Effect on NH_3 emissions: Outdoor temperature



Temperature effect on NH_3 emissions is more pronounced with higher CP content.

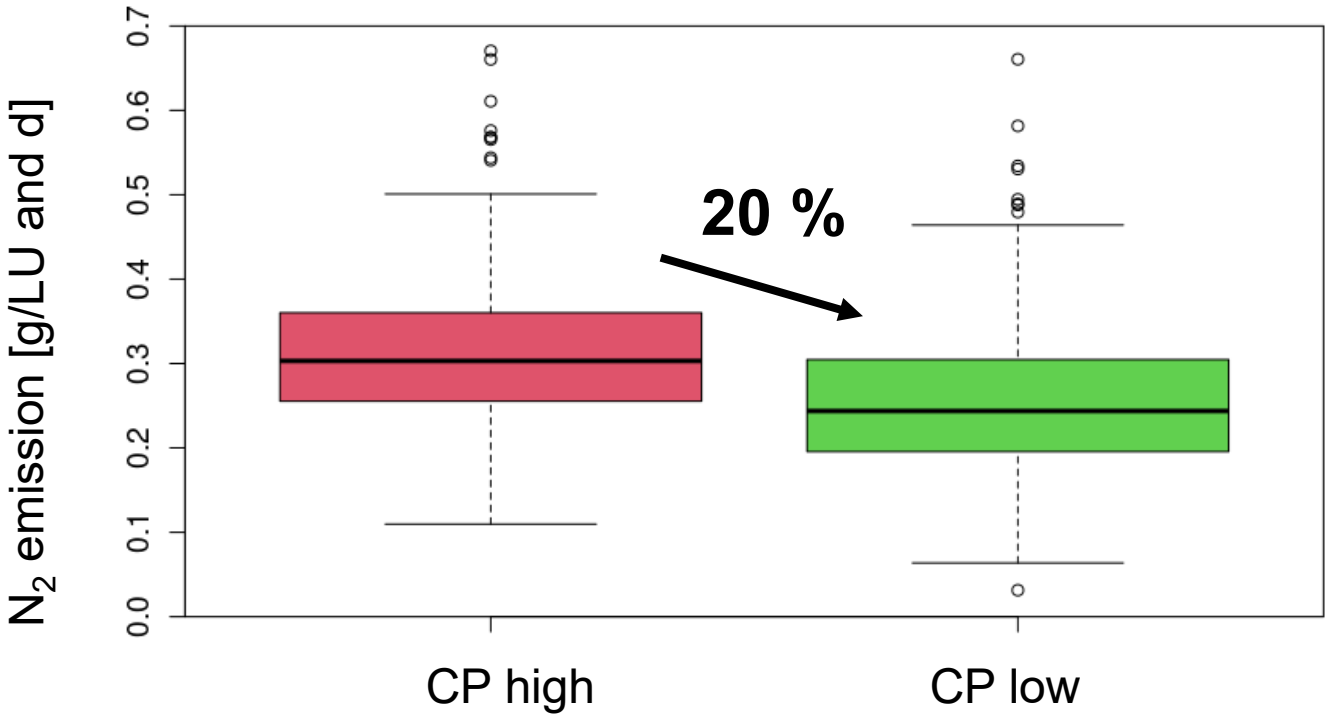
Effect on NH_3 emissions: Wind speed in the housing

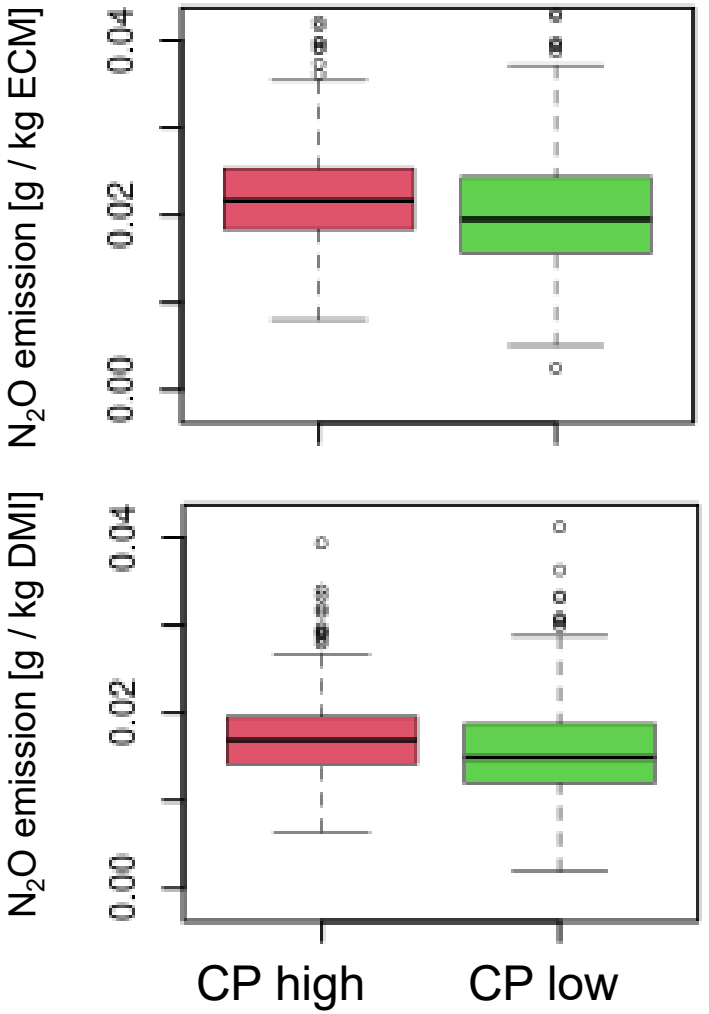


Effect of wind speed in the housing on NH_3 emissions is more pronounced with higher CP content.

N_2O emissions

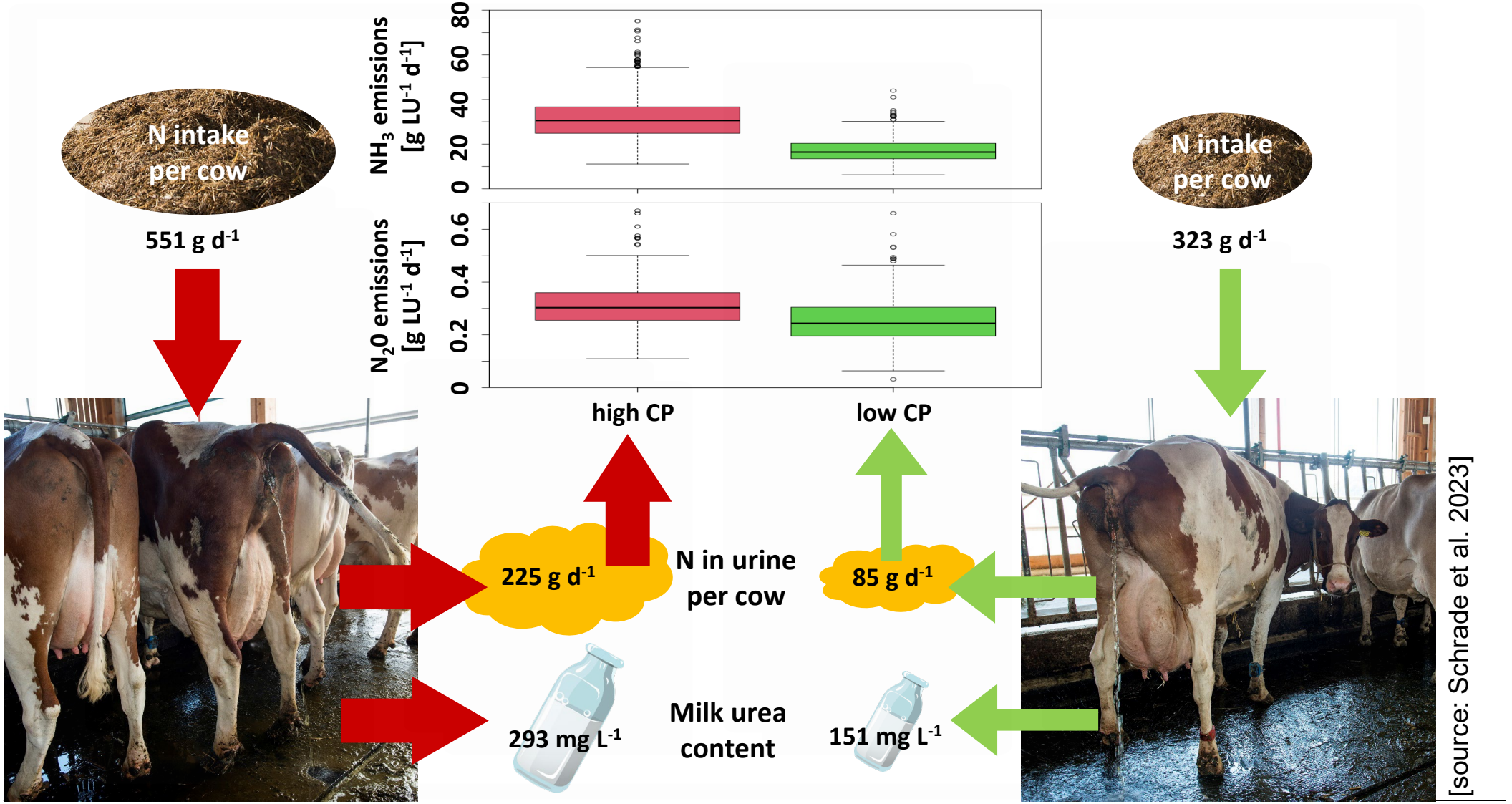
per livestock unit (1 LU = 500 kg live weight)
milk yield (ECM) and dry matter intake (DMI)





Differences in N_2O emissions per livestock unit are more pronounced than in relation to milk yield in ECM and dry matter intake (DMI)

Summary


N intake per cow
551 g d-1
NH3 emissions [g LU-1 d-1]
0 20 40 60 80
N2O emissions [g LU-1 d-1]
0 0.2 0.4 0.6
high CP
low CP
N intake per cow
323 g d-1
225 g d-1
N in urine per cow
85 g d-1
293 mg L-1
Milk urea content
151 mg L-1
[source: Schrade et al. 2023]

Conclusions

Comparison of NH_3 and N_2O emissionen of two diets for dairy cows with high CP content (17 %) and low CP content (12 %) measurend in practical scale:

- ✓ Low CP content ➔ lower NH_3 and lower N_2O emissions
- ✓ Signifikant factors influencing NH_3 emission:
  Diet, outside temperature, wind speed in the housing
- ✓ Strong correlation between dietary CP content, urinary nitrogen excretion and milk urea content
  ➔ Milk urea content can be used as an indicator for urinary nitrogen excretion and therefore also for the NH_3 emission potential

➔ Optimising the dietary CP content takes place at the beginning of the nitrogen chain and offers great potential for implementation in agricultural practice, as neither constructional changes to buildings nor additives are necessary.
















Thank you for your attention

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Agroscope good food, healthy environment
www.agroscope.admin.ch












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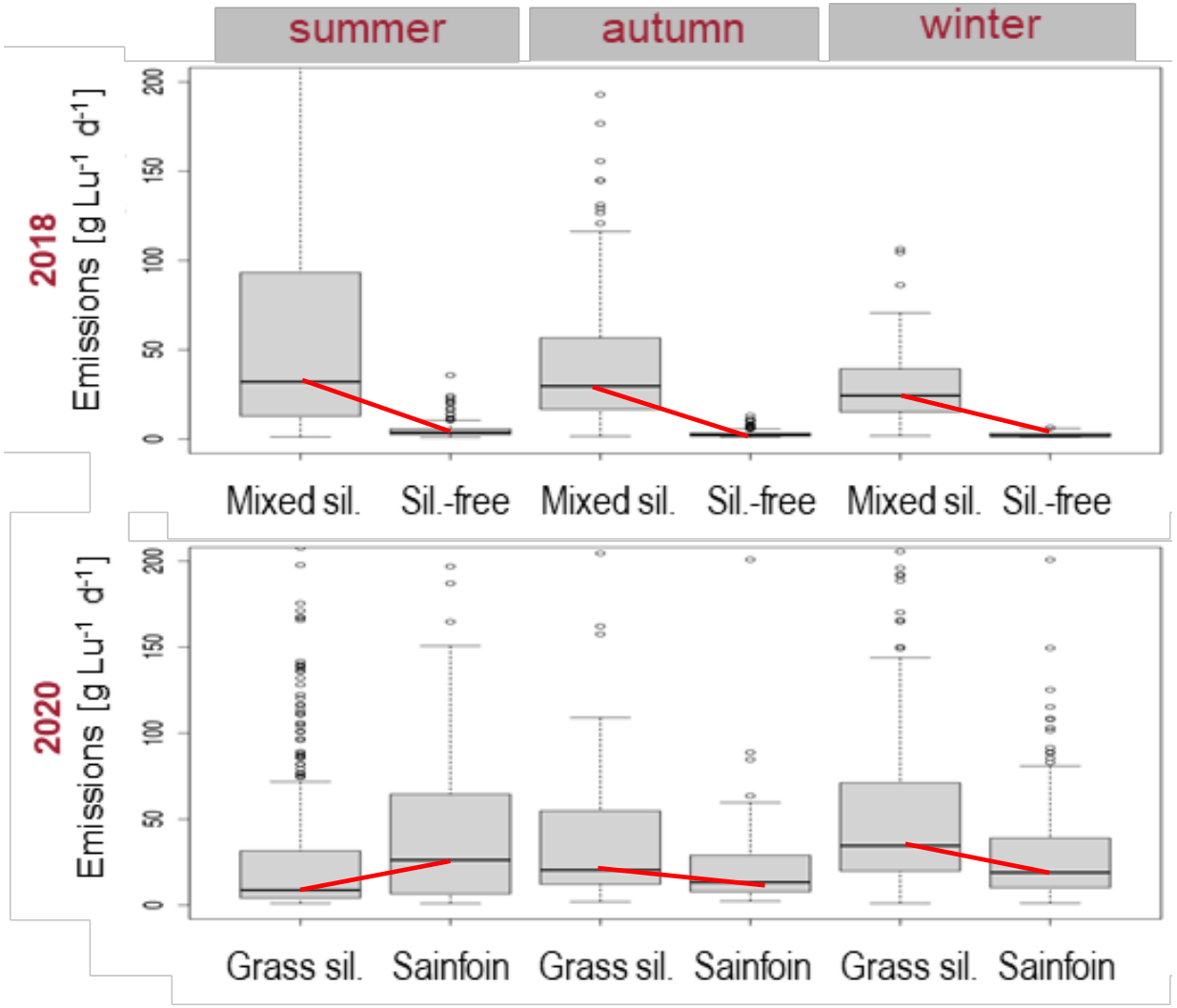
Diets and performance

	CP low		CP high
Feed components in the diet	Grass silage, maize silage, hay, sugar beet pulp silage, concentrate rich in energy, dextrose, salt, mineral feed		Grass silage, maize silage, hay, sugar beet pulp silage, concentrate rich in protein, urea, concentrate rich in energy, salt, mineral feed
Crude protein [g / kg DM]	**115**	**<**	**169**
Crude fibre [g / kg DM]	239	>	195
NEL [MJ / kg DM]	6.3	=	6.4
Dry matter intake [kg]	17.6	<	20.4
ECM per cow and day [kg]	24.8	<	27.8
Milk urea content [mg/L]	151	<	293

Effekt auf die NH_3-Emissionen: Milchharnstoffgehalt - Vergleich mit Literaturwerten

Referenz	Milchharnstoff-gehalt [mg/L]	Änderung der NH_3-Emissionen bei Erhöhung des Milchharn-stoffgehalts um 10 mg/L	Bemerkungen
Van Duinkerken et al. (2005)	200 bis 400	ca. 2 %	Liegeboxenlaufstall, perforierte Laufflächen
Van Duinkerken et al. (2011)	200 bis 300	2.5 bis 3.5 %	Liegeboxenlaufstall, perforierte Laufflächen, 8.5 h Weide
Powell et al. (2011)	210 bis 300	5 bis 7 %	Abgeleitet von 5 Betrieben mit unterschiedlichen Haltungssystemen
Schrade et al. (2023)	151 vs. 293	6 %	Liegeboxenlaufstall, planbefestigte Laufflächen

Results NMVOC emissions



Statistical analyses

over 3 seasons per year
using linear mixed-effects models

➔ significant effects on NMVOC emissions of

- the **diet**
  (2018: $p<0.001$, 2020: $p<0.001$)
- the **air temperature**
  (2018: $p<0.001$, 2020: $p<0.001$)

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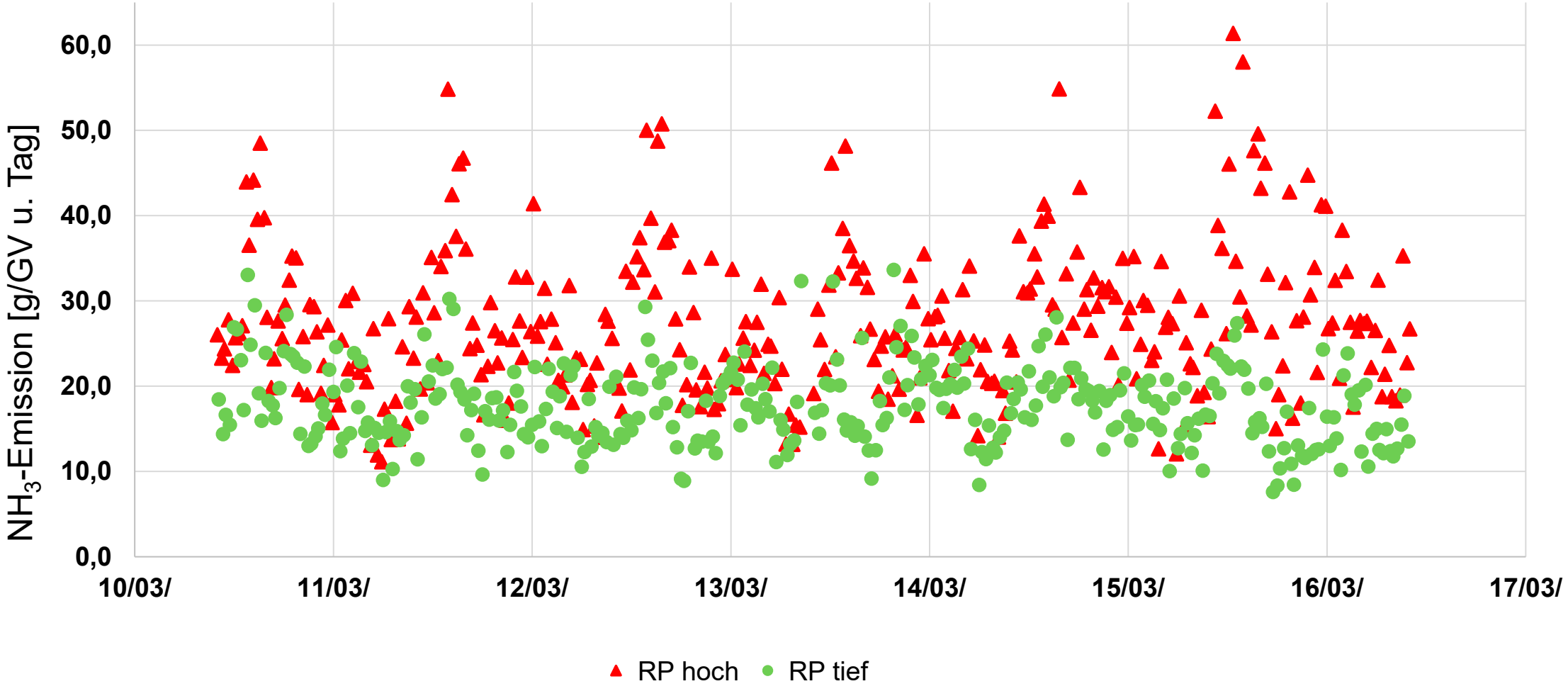
Beispiel Verläufe NH_3-Emissionen



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Situation NH_3- und N_2O-Emissionen Schweiz

~94 % der NH_3-Emissionen aus der Landwirtschaft (2019), v. a. Tierhaltung

~63 % der N_2O-Emissionen aus der Landwirtschaft (2020)

1990

2015

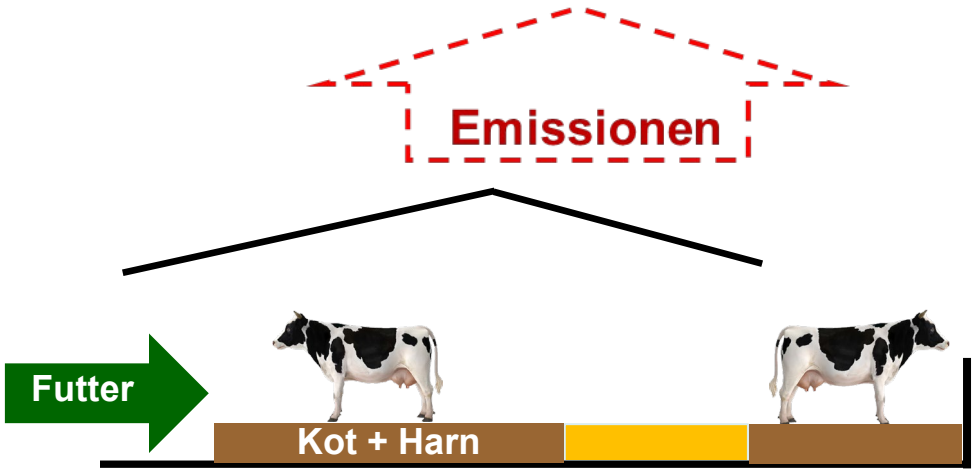
[BAFU 2007, 2022, Kupper et al. 2018, 2022]

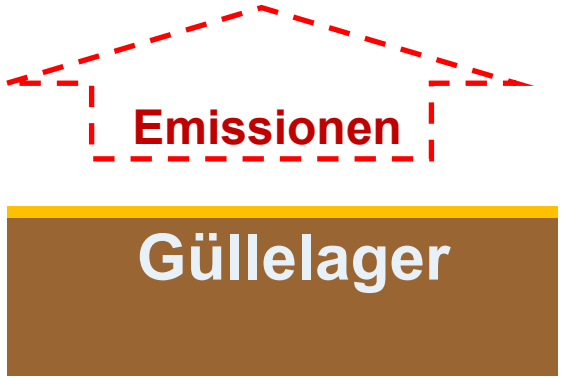
<u>Umwelt- und Klimaziele Landwirtschaft</u> [BLW u. BAFU 2008, BLW 2011]

➔Zur Einhaltung der Critical Loads für NH_3-N Reduktion auf ~25‘000 t Stickstoff pro Jahr

➔Reduktion der Treibhausgase aus der Landwirtschaft um mindestens ein Drittel bis zum Jahr 2050

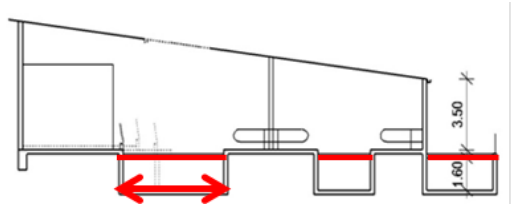
Stickstoff-Kette und NH_3-Emissionen



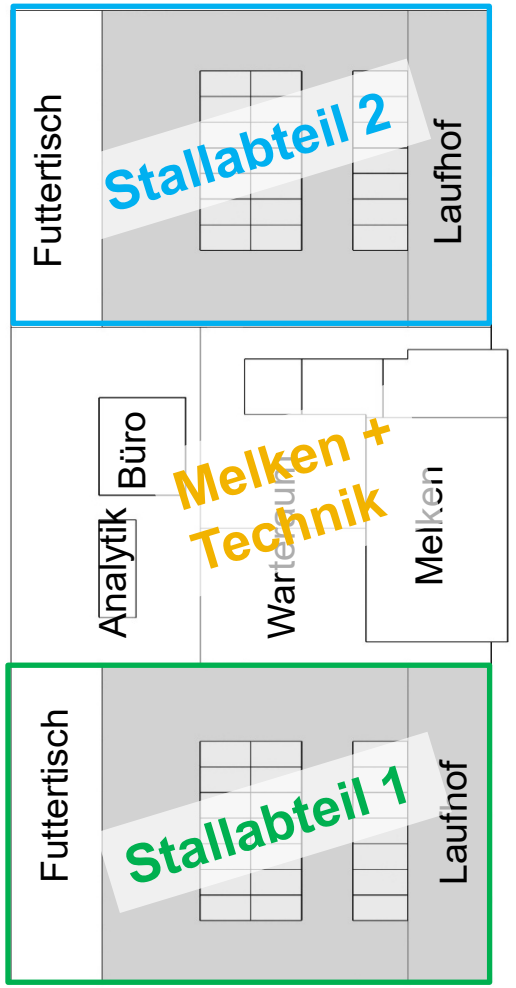


Stall und Laufhof → Hofdünger-Lagerung → Hofdünger-Ausbringung

Emissionsversuchsstall



- Liegeboxenlaufstall mit zwei Stallabteilen für je 20 laktierende Kühe und getrennten Güllesystemen
- Variable Anordnung und Abmessungen
- Modulartige Bauweise
- Weitere spezielle Versuchseinrichtungen



- ➢ Vergleichbare klimatische Bedingungen in beiden Stallabteilen
- ➢ Praxismassstab («Ebene Stallabteil/Herde»)
- ➢ Tieraktivität unbeeinflusst
- ➢ Eingriff in betriebliche Abläufe gezielt