UNIVERSITY OF HOHENHEIM

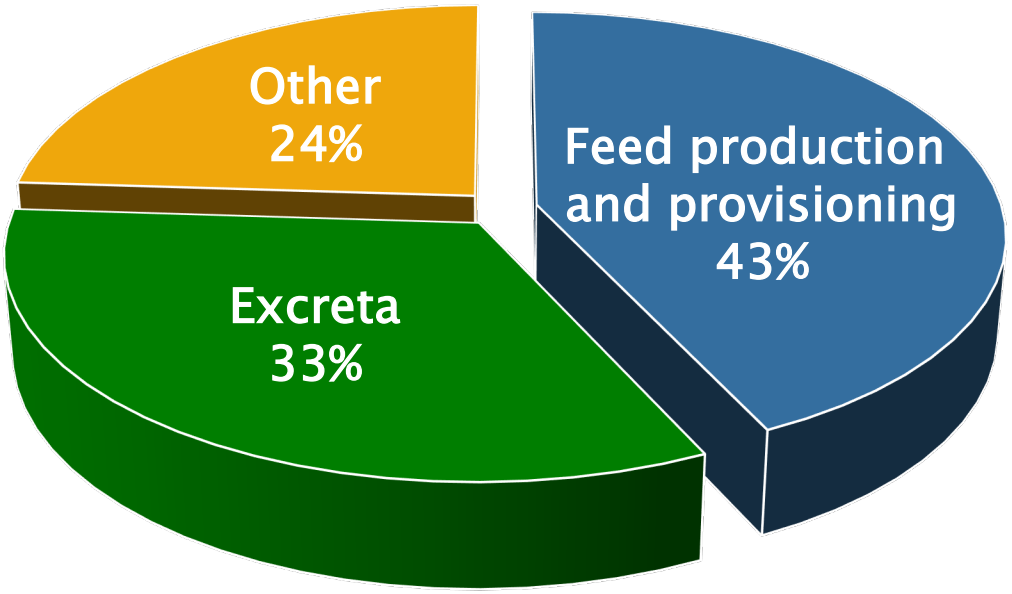
Sustainability and optimal nitrogen nutrition

PD Dr. Wolfgang Siegert
Institute of Animal Science
University of Hohenheim

Current affiliation
Department of Animal Sciences
Georg-August-University Göttingen

Total global greenhouse gas emissions for production of poultry meat and eggs

(kg CO_{2eq}/kg produced animal-based food)

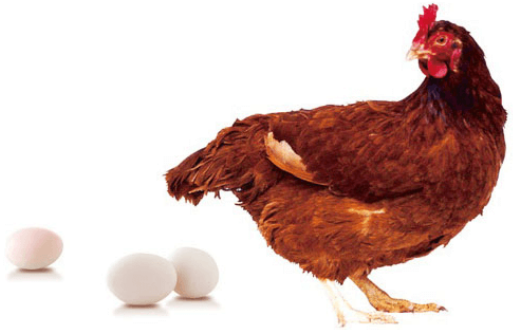


adapted from MacLeod et al. 2013 (FAO)

- Feeding influences substantial proportion of CO_{2eq} emissions
  - More efficient use of feedstuffs
  - Reducing the emissions from excreta

- Optimising nitrogen (N) nutrition
  - More efficient use of feedstuffs
  - Reducing the emissions from excreta
  - → More humans supplied with animal-based food using the same amount of feed
  - → Lower water usage
  - → Reduces N emissions and related environmental issues

Definition of nitrogen utilisation efficiency



2.0 kg Feed → 1 kg Egg mass

17% crude protein (CP) → 12% CP

NUE 35%

340 g CP → 120 g CP

1.6 kg Feed → 1 kg Body mass

20% CP → 17% CP

NUE 53%

320 g CP → 170 g CP

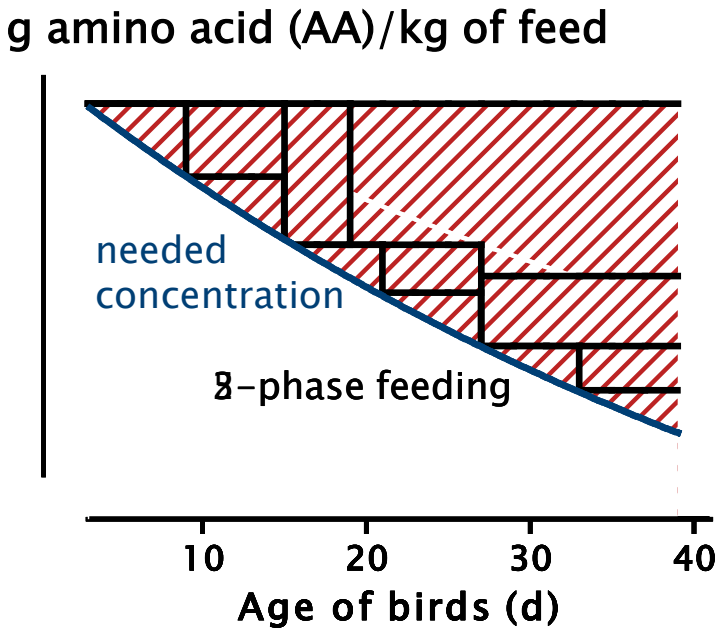
NUE can be increased by decreasing the protein input

Agenda

- Influences on nitrogen utilisation efficiency
  - Phase feeding
  - Increasing knowledge on amino acid requirements
  - Increasing knowledge on amino acid digestibility

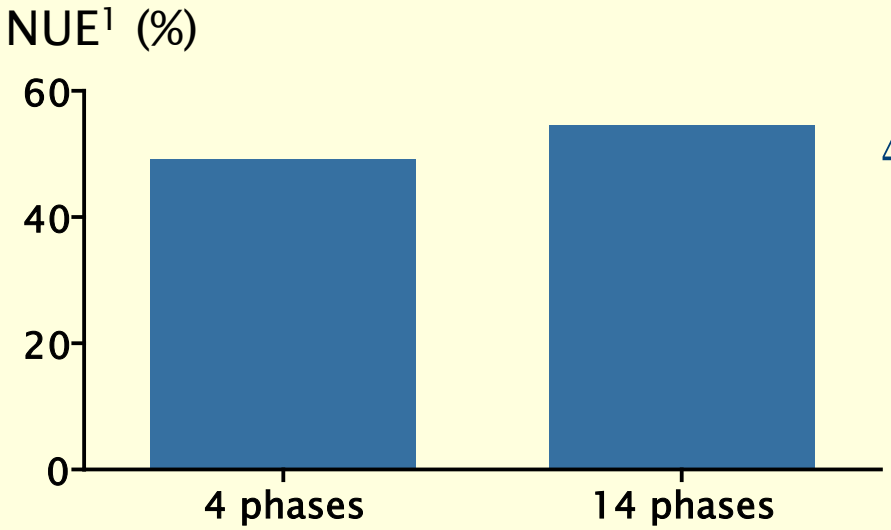
- Conflicts between maximised nitrogen utilisation efficiency and another sustainability goal

Phase feeding



- Impact on NUE decreases with increasing number of phases
- Operational constraints limit implementation of more feeding phases

Impact of increasing the number of feeding phases?



Δ5 %-units

3-10 %-units in most studies

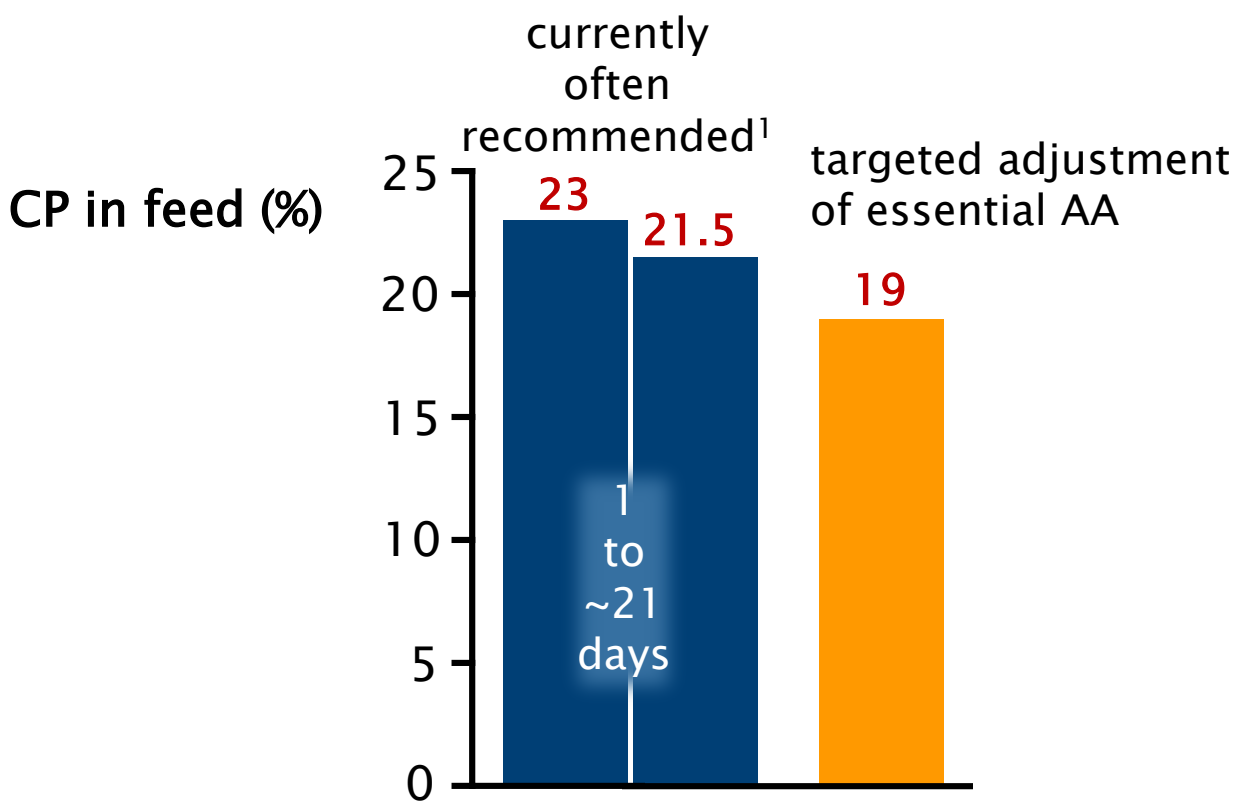
[1] *Hauschild et al. 2015*

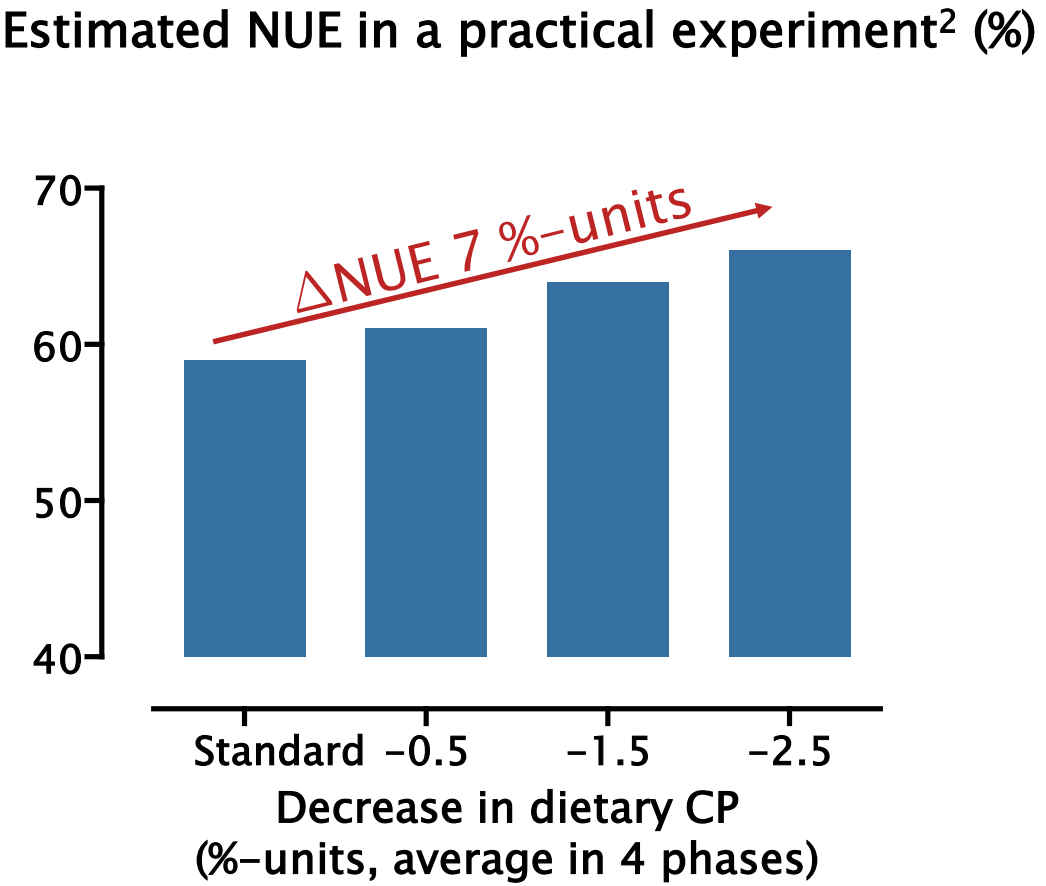
Agenda

- Influences on nitrogen utilisation efficiency
  - Phase feeding
  - Increasing knowledge on amino acid requirements
  - Increasing knowledge on amino acid digestibility

- Conflicts between maximised nitrogen utilisation efficiency and another sustainability goal

Increasing knowledge on amino acid requirements



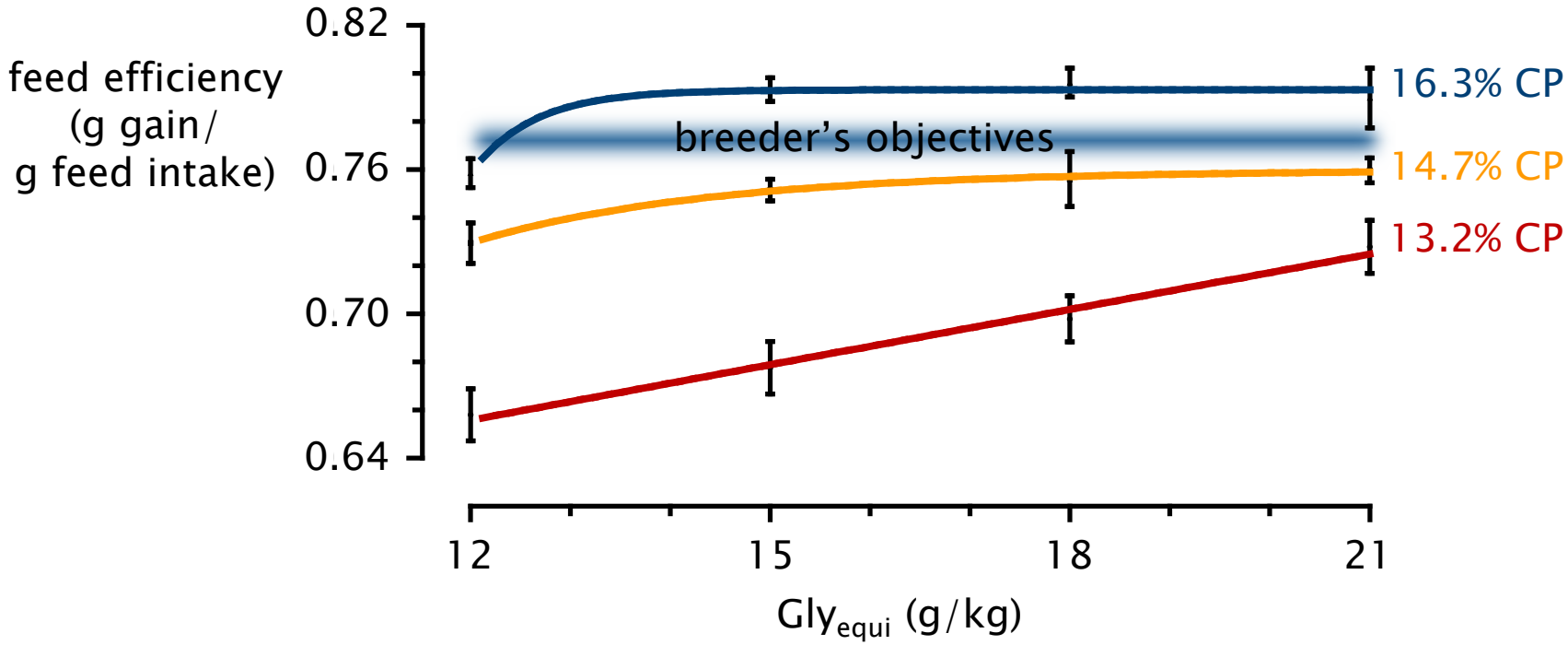


[1]*DLG 2017*

[2]*Lemme et al. 2019*

Current limits of crude protein reduction

Supply with glycine and serine (summarised as Gly_{equi}) limits growth when dietary CP is below 19%[1,2]

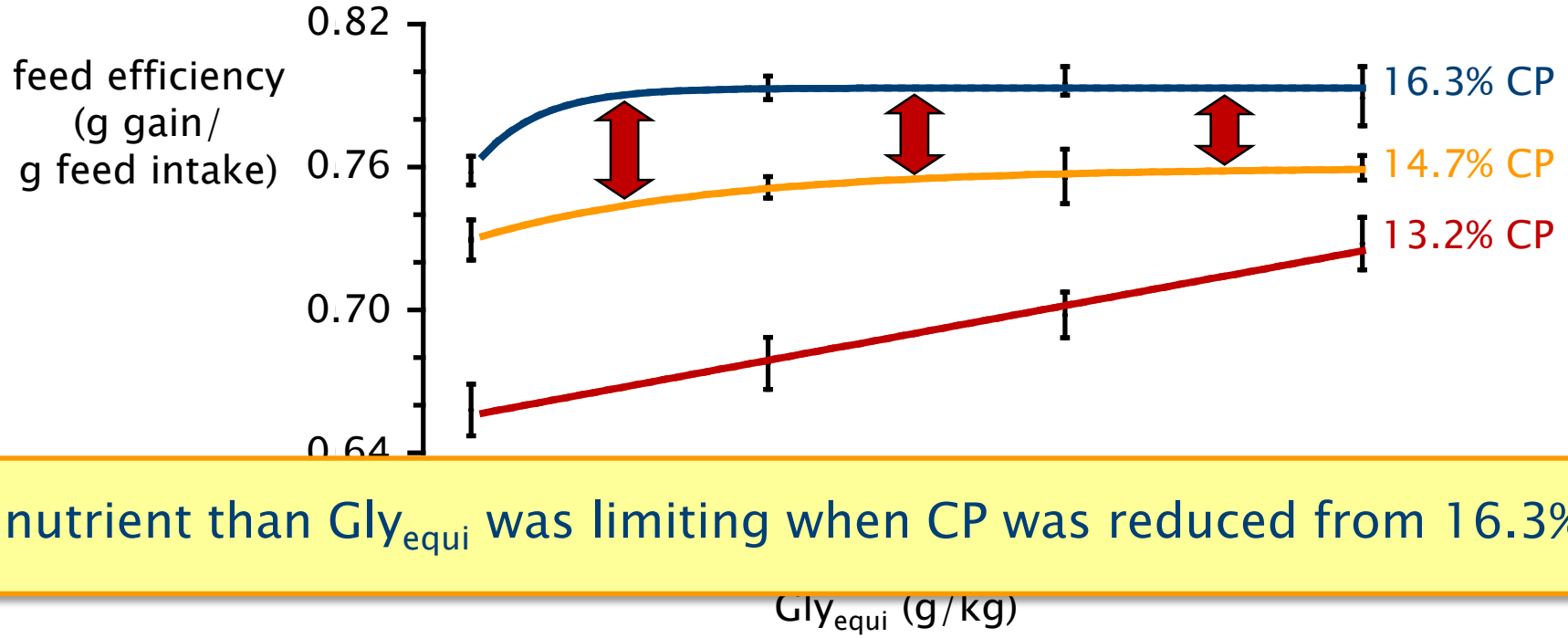


[1]*Dean et al. 2006;* [2]*Siegert and Rodehutscord 2019*

Hofmann et al. 2019

Current limits of crude protein reduction

Supply with glycine and serine (summarised as Gly_{equi}) limits growth when dietary CP is below 19%[1,2]

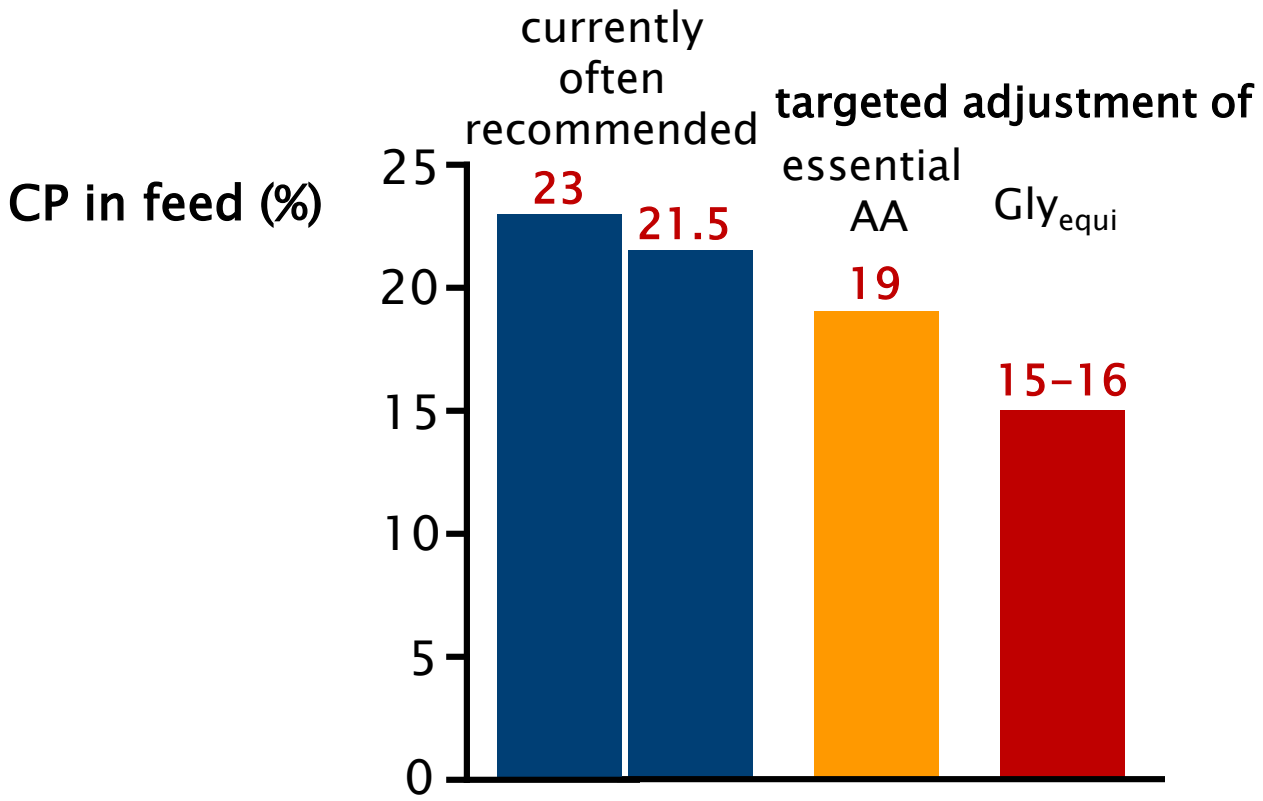


Another nutrient than Gly_{equi} was limiting when CP was reduced from 16.3% to 14.7%

[1]*Dean et al. 2006;* [2]*Siegert and Rodehutscord 2019*

Hofmann et al. 2019

Current limits of crude protein reduction



- NUE of 75% to more than 80% in own recent experiments[1,2,3,4]
- About 20 %–units higher NUE than nowadays standard possible

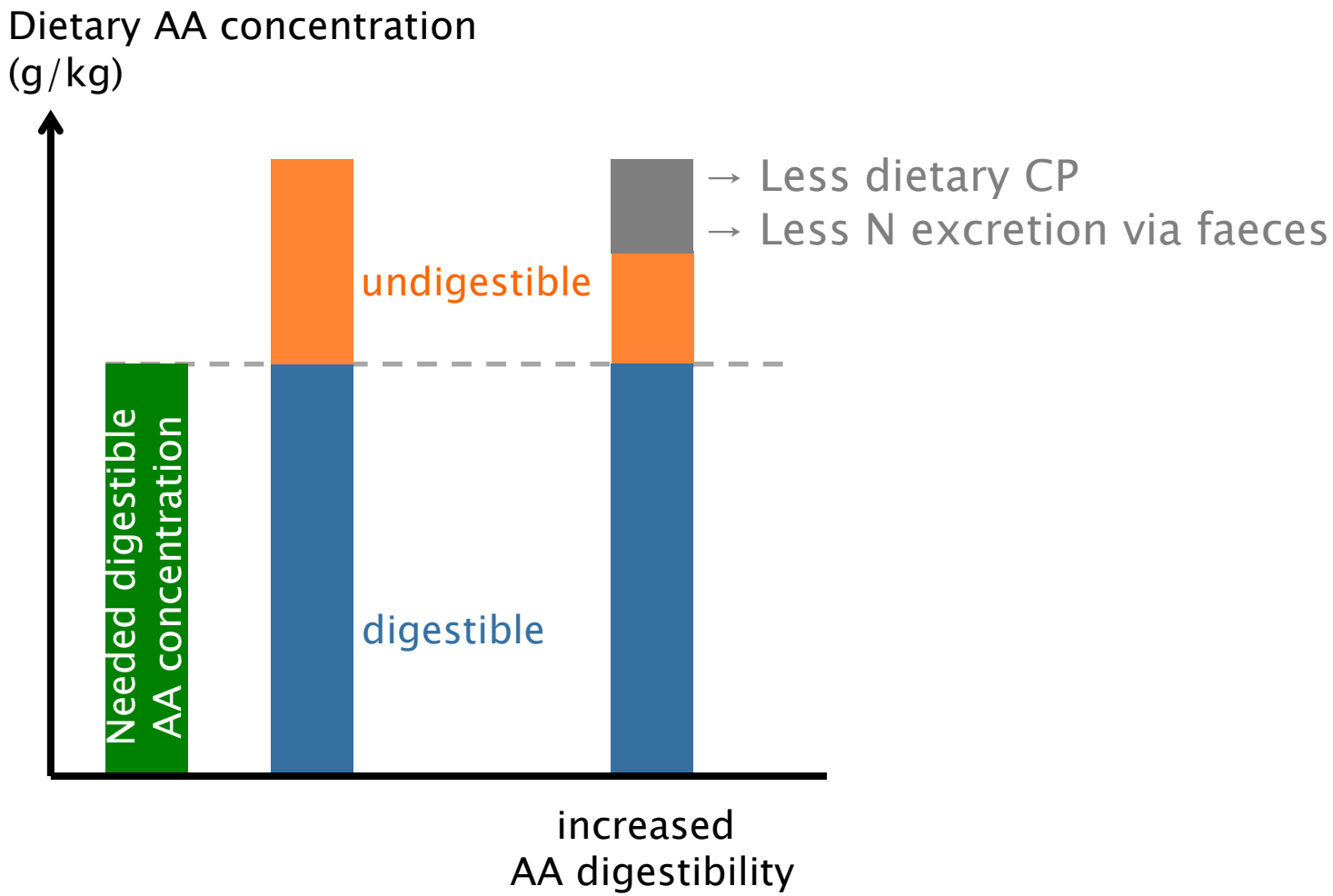
[1] *Hofmann et al. 2020a;* [2] *2020b;* [3] *Ibrahim et al. (submitted);* [4] *Ibrahim et al (unpublished)*

Agenda

- Influences on nitrogen utilisation efficiency
  - Phase feeding
  - Increasing knowledge on amino acid requirements
  - Increasing knowledge on amino acid digestibility

- Conflicts between maximised nitrogen utilisation efficiency and another sustainability goal

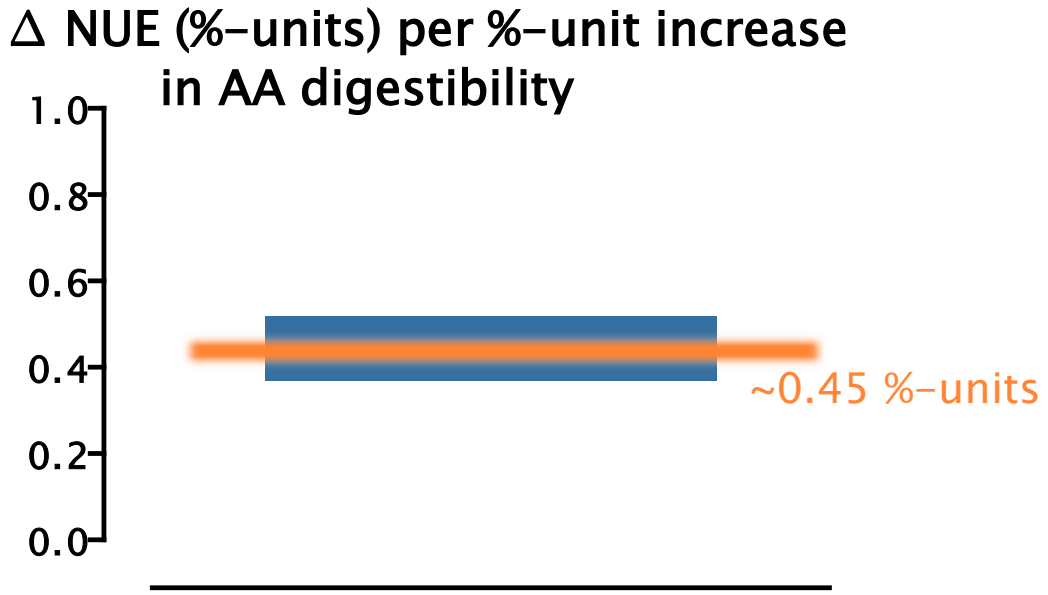
Background of amino acid digestibility

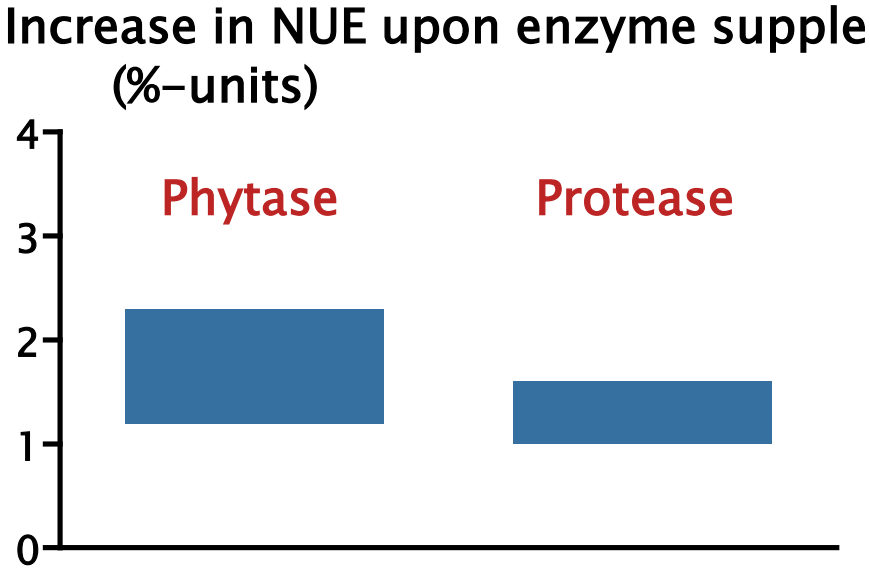


Impact of supplemented feed enzymes on nitrogen utilisation efficiency

Depends on

- N accretion in body mass
- Targeted digestible AA concentration
- Feed intake
- Ratio of the limiting AA relative to CP





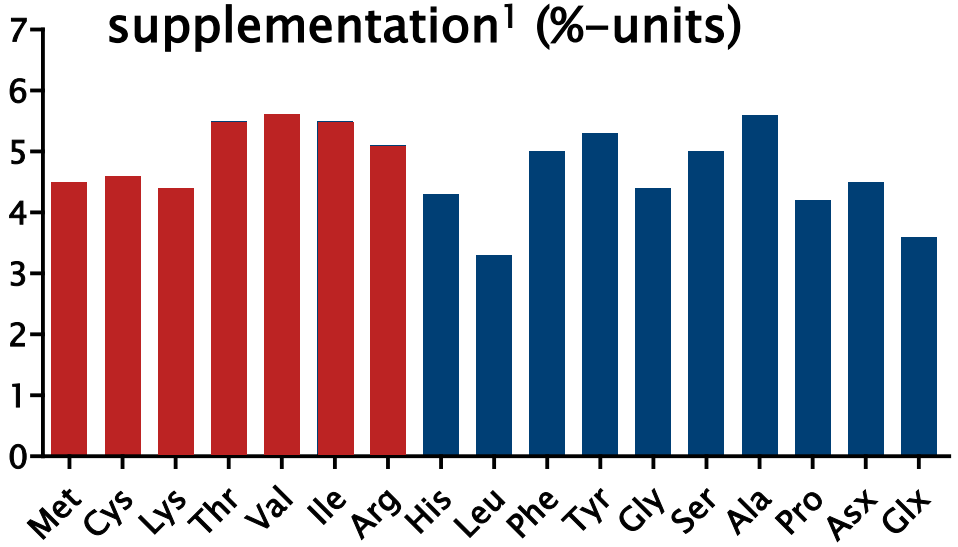
- Effects of enzymes on AA digestibility
  - Bigger effect in some studies
  - No effect in other studies
- In most cases: Range of 0–3 %-units of NUE

Siegert 2022 (Habilitation thesis)

Impact of supplemented feed enzymes on the environmental impact

Only the increase in digestibility of the limiting AA can increase NUE

Increase in AA digestibility upon phytase supplementation[1] (%-units)



- Additionally digested non-limiting AA
  - cannot be accreted
  - contained N needs to be excreted via the urine
  - → Shift in N excretion route from faeces to urine
- Urine-N contributes more to N emissions than faeces-N

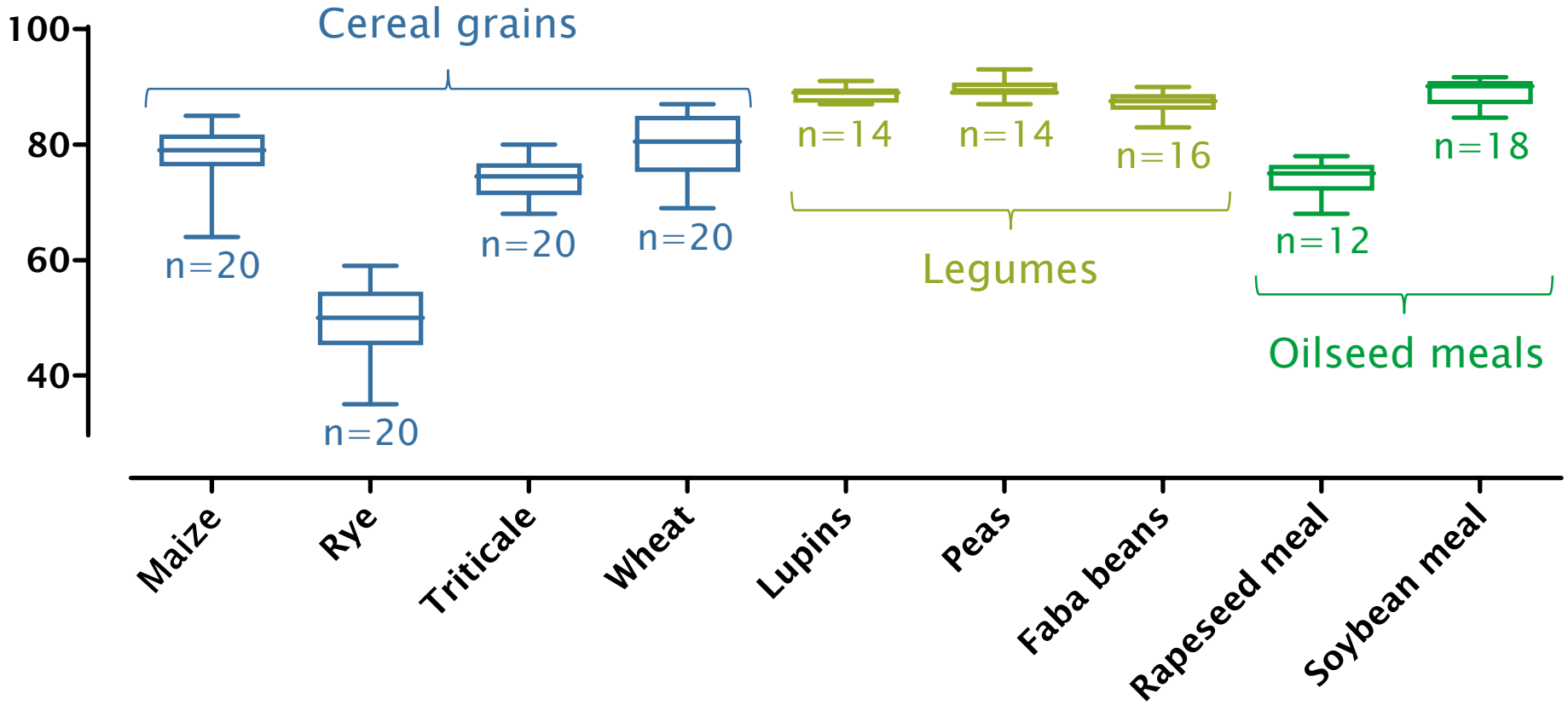
Benefits of higher NUE on the environment ⇔ Bigger emission potential of the excreted N

Supplemented feed enzymes most beneficial on NUE when used together with free AA

[1] *Sieger*

Ranges in digestibility within feed ingredients

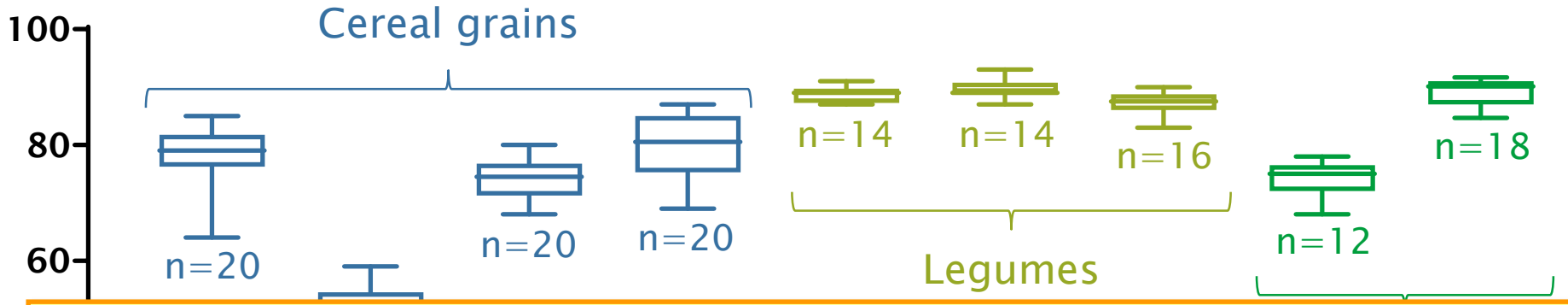
Lysine digestibility in laying hens (%)



Zuber and Rodehutscord 2016, 2017; Zuber et al. 2016ab, 2019; Siegert et al. 2022, 2023

Ranges in digestibility within feed ingredients

Lysine digestibility in laying hens (%)



- Choice of variants can vary the NUE by
  - 5–13 %-units in cereal grains
  - 0–4 %-units in protein-rich ingredients

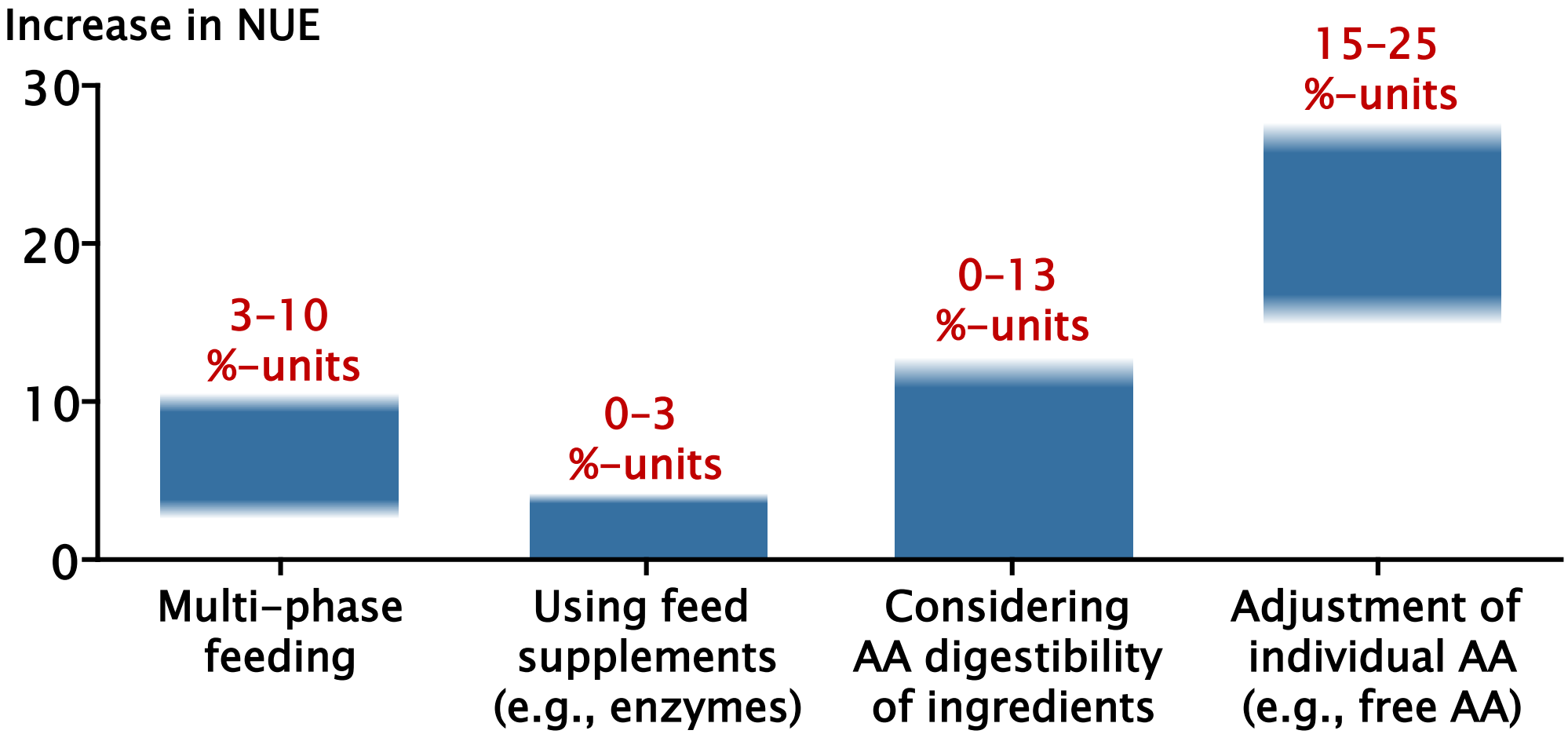
  (model calculations presented in *Siegert 2022, Habilitation thesis*)

- Predictions of AA digestibility not sufficiently accurate

  → Potential of considering digestibility cannot be fully exploited at present

Zuber and Rodehutscord 2016, 2017; Zuber et al. 2016ab, 2019; Siegert et al. 2022, 2023

Current potential to increase NUE via nutritional strategies?



Agenda

- Influences on nitrogen utilisation efficiency
  - Phase feeding
  - Increasing knowledge on amino acid requirements
  - Increasing knowledge on amino acid digestibility

- Conflicts between maximised nitrogen utilisation efficiency and another sustainability goal

  to minimise greenhouse gas emissions

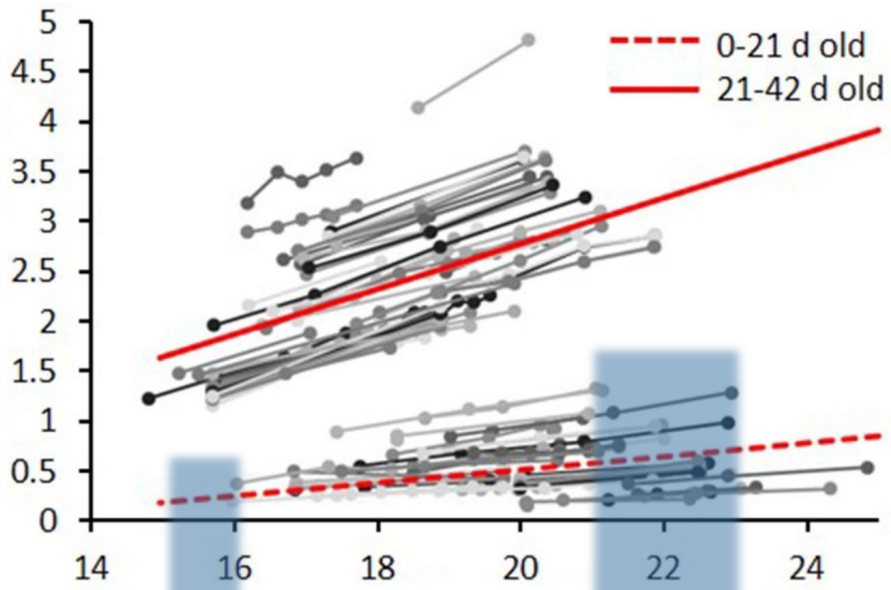
Protein supply and greenhouse gas (CO_{2eq}) emissions

N in excreta → N_2O (CO_{2eq})

Urinary N excretion requires energy → CO_2 in the metabolism

CO_{2eq} for crop production

N excretion by broiler chickens[1] (g/d)



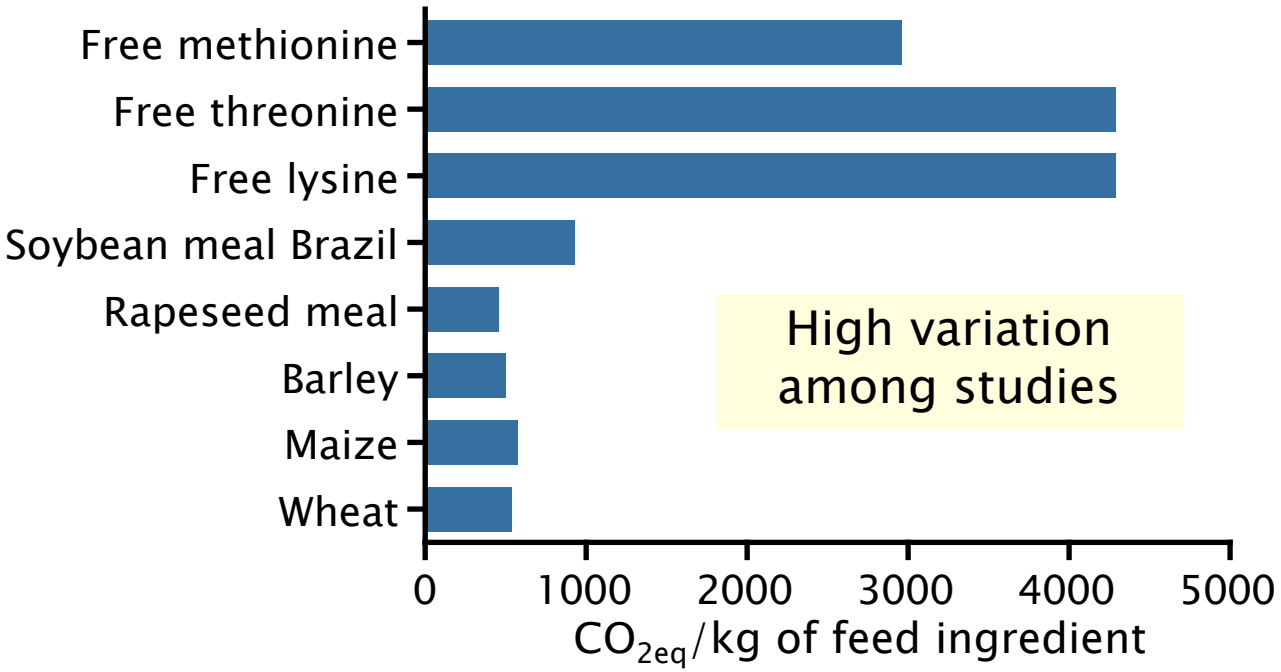
Currently possible[2,3,4]

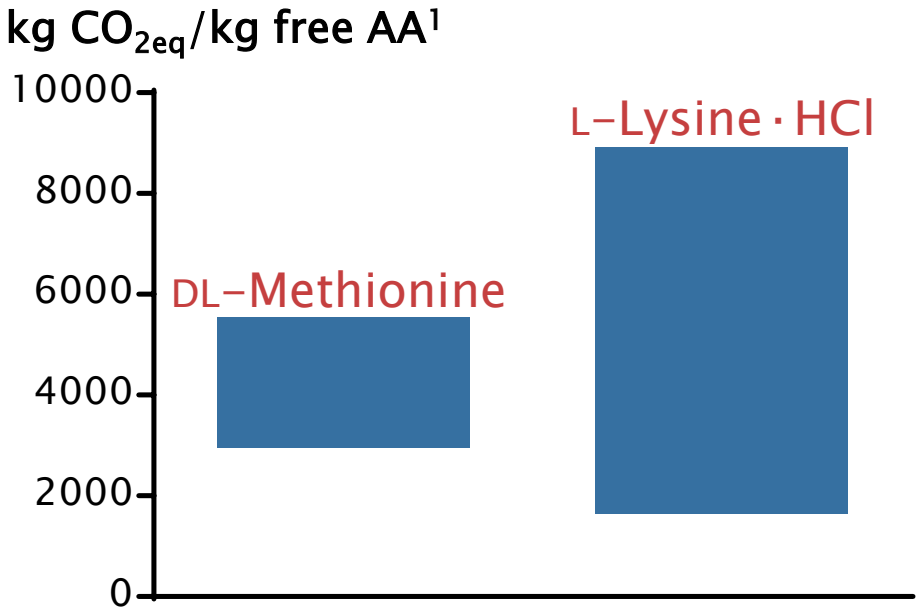
Currently common

[2]Siegert et al. 2016; [3]Hofmann et al. 2019, [4]2020b; [1]Cappelaere et al. 2021

Protein supply and greenhouse gas emissions

Decreasing dietary CP means
- less protein-rich feed ingredients
- more free AA



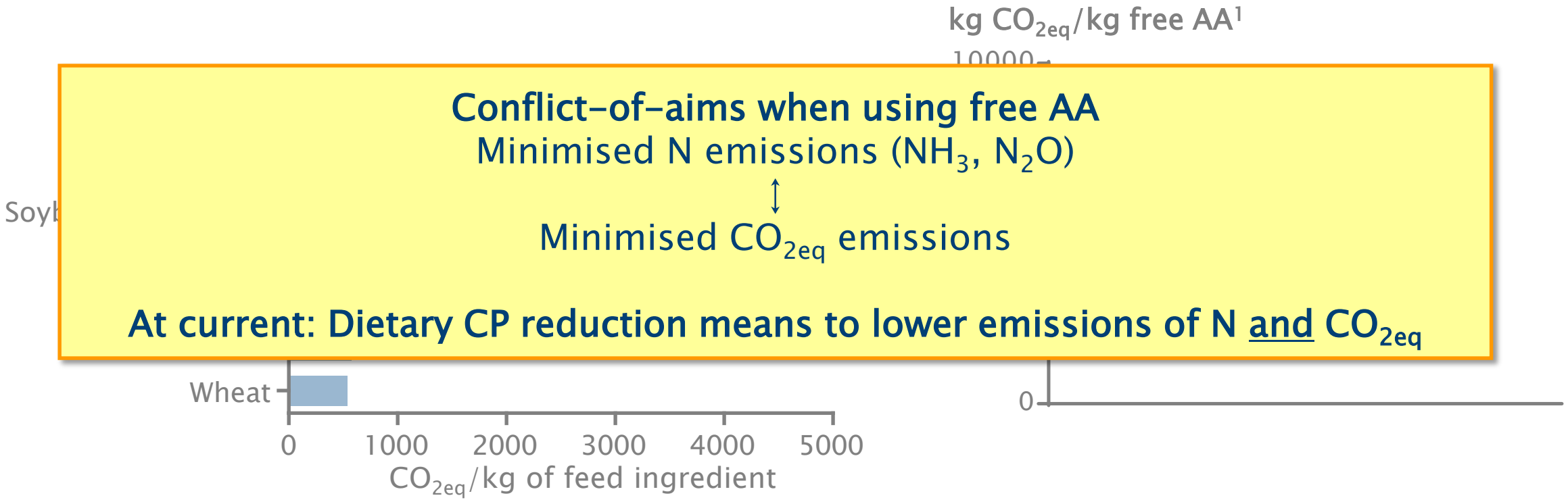


[1] *Marinussen and Kool 2010; Lammers et al. 2011; Mosnier et al. 2011; van Harn et al. 2017*

Mosnier et al. 2011

Protein supply and greenhouse gas emissions

Decreasing dietary CP means
- less protein-rich feed ingredients
- more free AA



Conflict-of-aims when using free AA

Minimised N emissions (NH_3, N_2O)

↕

Minimised CO_{2eq} emissions

At current: Dietary CP reduction means to lower emissions of N and CO_{2eq}

[1] *Marinussen and Kool 2010; Lammers et al. 2011; Mosnier et al. 2011; van Harn et al. 2017*

Mosnier et al. 2011

Summary and conclusions

- Raising NUE can increase sustainability of production of animal-based food
  - Lower environmental impact of N excretion
  - Lower input of field crops
- Future conflict between aims to maximise NUE and minimising greenhouse gas emissions as another sustainability goal of animal farming
- At current, increasing knowledge on AA requirements and using free AA offers the biggest potential to increase NUE
- Increase NUE by increasing AA digestibility may gain relevance once impacts on AA digestibility are more predictable

Thank you for your attention

References (A–M)

- Cappelaere L, J Le Cour Grandmaison, N Martin, W Lambert. 2021. Amino acid supplementation to reduce environmental impacts of broiler and pig production: a review. Frontiers in Veterinary Science 8: 689259.
- DLG (Deutsche Landwirtschafts-Gesellschaft). 2017. DLG-Merkbaltt 406: Haltung von Masthühnern. 2nd ed., DLG e.V., Frankfurt a. M., Germany.
- FAO (Food and Agriculture Organization of the United Nations). 2013. Greenhouse gas emissions from pig and chicken supply chains – A global life cycle assessment. Contributors: MacLeod M, P Gerber, A Mottet, G Tempio, A Falcucci, C Opio, T Vellinga, B Henderson, H Steinfeld.
- Hauschild L, CFD Bueno, A Remus, J de Paula gobi, R Di Giovanni Isola, NK Sakomura. 2015. Multiphase feeding program for broilers can replace traditional system. Scientia Agricola 72: 210–214.
- Hofmann P, W Siegert, Á Kenéz, VD Naranjo, M Rodehutscord. 2019. Effect of very low crude protein and varying glycine equivalent concentrations in the diet on growth performance, excreta characteristics and blood metabolome of broiler chickens. Journal of Nutrition 149: 1122–1132.
- Hofmann P, W Siegert, H Ahmadi, J Krieg, M Novotny, VD Naranjo, M Rodehutscord. 2020a. Interactive effects of glycine equivalent, cysteine, and choline on growth performance, nitrogen excretion characteristics, and plasma metabolites of broiler chickens using neural networks optimized with genetic algorithms. Animals 10: 1392.
- Hofmann P, W Siegert, VD Naranjo, M Rodehutscord. 2020b. Effects of supplemented nonessential amino acids and nonprotein nitrogen on growth and nitrogen excretion characteristics of broiler chickens fed diets with very low crude protein concentrations. Poultry Science 99: 6848–6858.
- Ibrahim A, Á Kenéz, M Rodehutscord, W Siegert. The influence of substituting dietary peptide-bound with free amino acids on nitrogen metabolism and acid-base balance of broiler chickens depends on asparagine and glutamine supply. Submitted to British Journal of Nutrition.
- Lammers PJ, MD Kenealy, JB Kliebenstein, JD Harmon, MJ Helmers, MS Honeyman. 2011. Nonsolar energy use and one-hundred-year global warming potential of Iowa swine feedstuffs and feeding strategies. Journal of Animal Science 88: 1204–1212.
- Lemme A, P Hiller, M Klahsen, V Taube, J Stegemann, I Simon. 2019. Reduction of dietary protein in broiler diets not only reduces N-emissions but is also accompanied by several further benefits. Journal of Applied Poultry Research 28: 867–880.
- Marinussen M, A Kool. 2010. Environmental impacts of synthetic amino acid production. Blonk Milieu Advies BV.
- Mosnier E, HMG van der Werf, J Boissy, J-Y Dourmad. 2011. Evaluation of the environmental implications of the incorporation of feed-use amino acids in the manufacturing of pig and broiler feeds using Life Cycle Assessment. Animal 5: 1972–1983.

References (N-Z)

- Rezvani M, H Kluth, M Bulang, M Rodehutscord. 2012. Variation in amino acid digestibility of rapeseed meal studied in caecectomised laying hens and relationship with chemical constituents. British Poultry Science 53: 665–674.
- Siegert W. 2022. Relevance of amino acid digestibility for the protein utilization efficiency in poultry. Habilitation thesis University of Hohenheim.
- Siegert W, A Ibrahim, W Link, G Lux, K Schmidtke, J Hartung, N Nautscher, M Rodehutscord. 2022. Amino acid digestibility and metabolisable energy of spring and winter faba beans grown on two sites and effects of dehulling in caecectomised laying hens. Journal of the Science of Food and Agriculture 102: 920–930.
- Siegert W, KJ Wild, M Schollenberger, A Helmbrecht, M Rodehutscord. 2015 Effect of glycine supplementation in low protein diets with amino acids from soy protein isolate or free amino acids on broiler growth and nitrogen utilization. British Poultry Science 57: 424–434.
- Siegert W, M Rodehutscord. 2019. The relevance of glycine and serine in poultry nutrition. A review. British Poultry Science 60: 579–588.
- Siegert W, S Kuenz, W Windisch, M Rodehutscord. 2023. Amino acid digestibility and metabolizable energy of soybean meal of different origins in cecectomized laying hens. Poultry Science 102: 102580.
- van Harn J, MA Dijkslag, MM van Krimpen. 2017. Effect of low protein diets supplemented with free amino acids on growth performance, slaughter yield, litter quality, footpad lesions, economical performance and the ecological footprint of male broilers. Wageningen Livestock Research report No. 1033.
- Zuber T, HP Maurer, J Möhring, W Siegert, P Rosenfelder, M Rodehutscord. 2016a. Variability in amino acid digestibility of triticale grain from diverse genotypes as studied in cecectomized laying hens. Poultry Science 95: 2861–2870.
- Zuber T, M Rodehutscord. 2016. Variability in amino acid digestibility of wheat grains from diverse genotypes examined in caecectomised laying hens. European Poultry Science 80.
- Zuber T, M Rodehutscord 2017. Variability in amino acid digestibility and metabolizable energy of corn studied in cecectomized laying hens. Poultry Science 96: 1696–1706.
- Zuber T, T Miedaner, P Rosenfelder, M Rodehutscord. 2016b. Amino acid digestibility of different rye genotypes in caecectomised laying hens. Archives of Animal Nutrition 70: 470–487.
- Zuber T, W Siegert, H Salehi, F Hummel, M Rodehutscord. 2019. Variability of amino acid digestibility of lupin and pea grains in caecectomised laying hens. British Poultry Science 60: 299–240.