Amino acid requirements and updated recommendations for weaned piglets based on a literature review

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Outline

- **Background**
- Requirement of SID lysine (meta-analysis)
- Updated recommendations for SID lysine
- Requirement (literature review) and updated recommendations for SID EAA other than lysine
- Conclusions and future research perspectives

Background

PPS project ‘Voeding op maat’

reduce nitrogen emission in production animals through improved nutrition

REQUIREMENT

= minimum supply of a nutrient to maximize performance

- Feed intake capacity
- Protein deposition capacity

> genotype
> sex
> age

RECOMMENDATION

- Animal’s requirement
- Economic
- Health (risk for diarrhea)
- Environmental, legislation

AA recommendations weaned piglets

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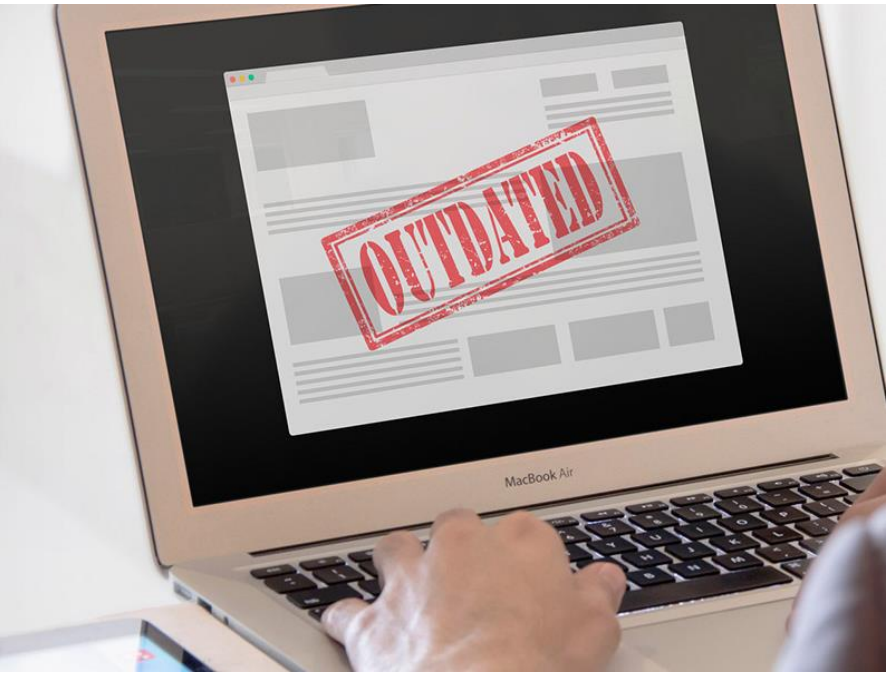
Background



AA recommendations of **growing and finishing** pigs: updated in **2018**
AA recommendations for **weaned piglets** have not been updated since **1996**

- Current recommendations only provided for Lys, Met + Cys, Thr and Trp
- AA requirements may have changed ≈ genetics, feeding, management
- Low protein diets
- Increased availability crystalline AA

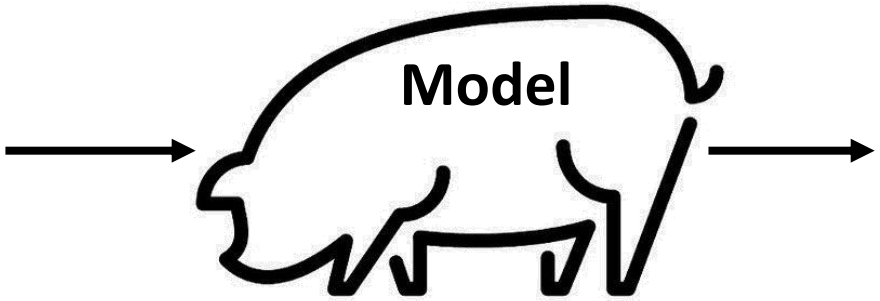
Background

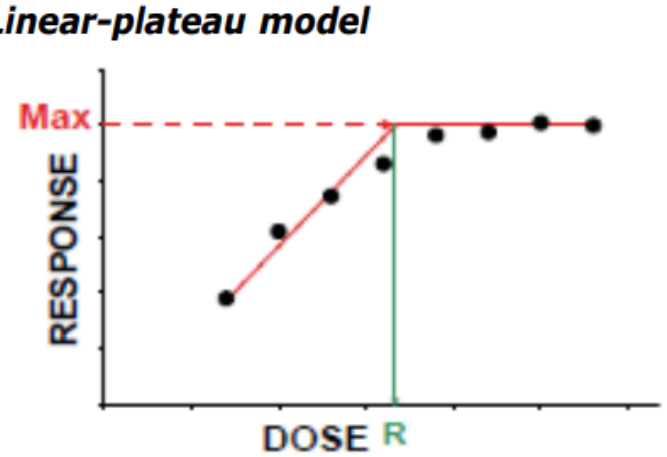
Factorial growth model

lysine requirement

Empirical approach: dose-response studies

lysine requirement: meta-analysis
requirements other EAA: short literature review





Outline

- Background
- **Requirement of SID lysine (meta-analysis)**
- Updated recommendations for SID lysine
- Requirement (literature review) and updated recommendations for SID EAA other than lysine
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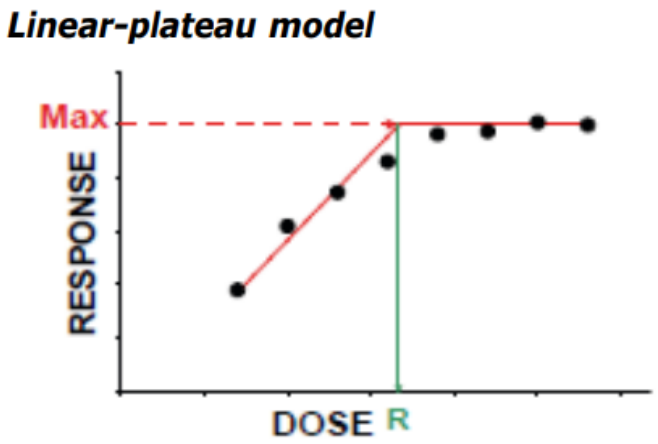
Requirement of SID lysine

MATERIALS AND METHODS

Selection criteria:

- BW range: 5-30 kg
- Dose-response technique: at least 4 levels of lysine
- Animal performance response criteria (ADG, ADFI, FCR or G:F)
- Feed ingredient/nutrient composition of diets
- Lysine should be first limiting nutrient

Y-axis:
- ADG
- ADFI
- G:F



X-axis:
g SID Lys/MJ NE

keywords → abstracts selection → full text selection → final dataset

344 papers

86 papers

37 papers
58 experiments
287 treatment means

24 papers
41 experiments
206 treatment means

AA recommendations weaned piglets

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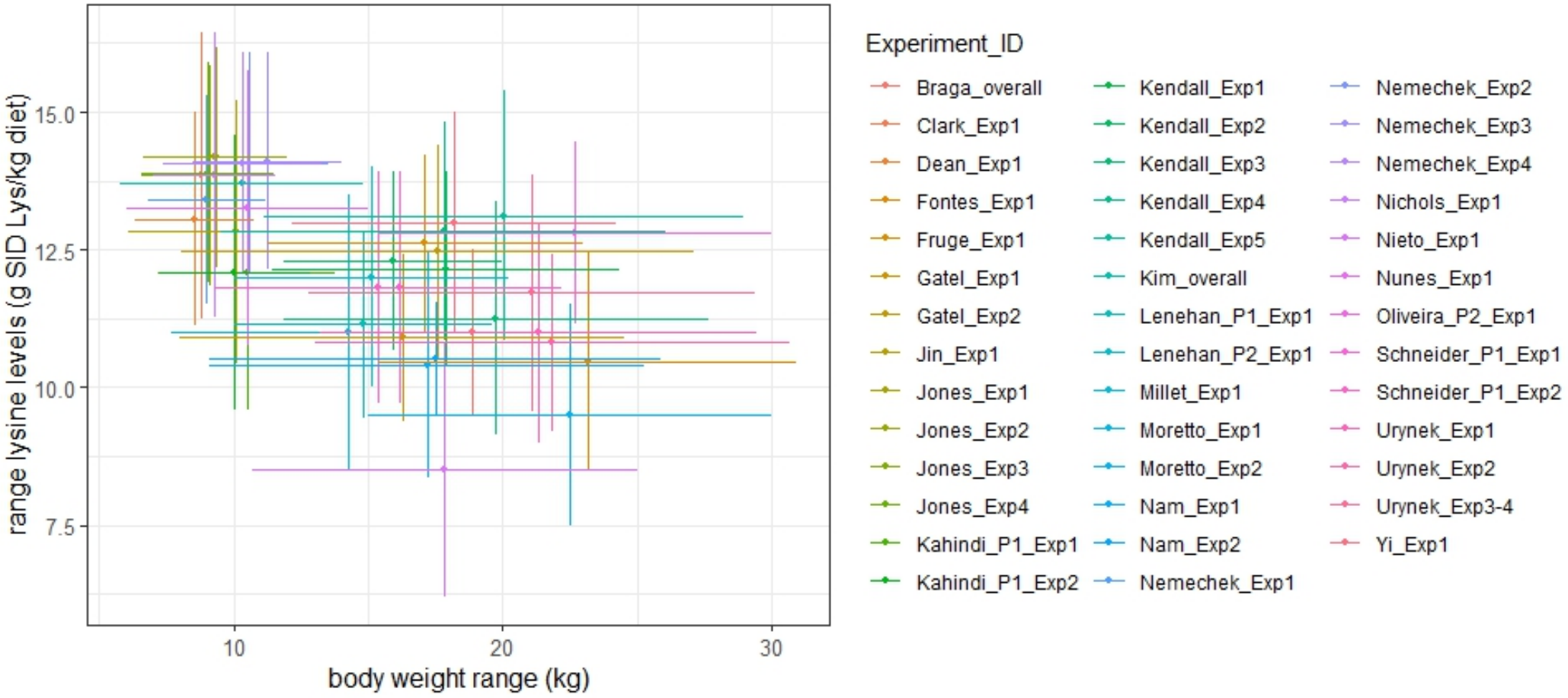
Requirement of SID lysine

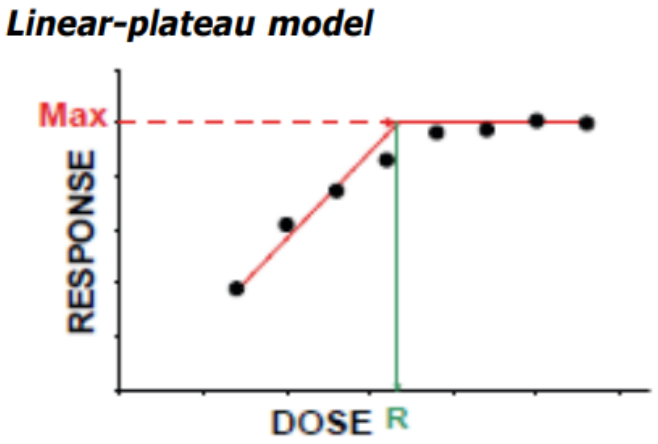
RESULTS



Requirement of SID lysine

MATERIALS AND METHODS

Y-axis:
- ADG
- ADFI
- G:F



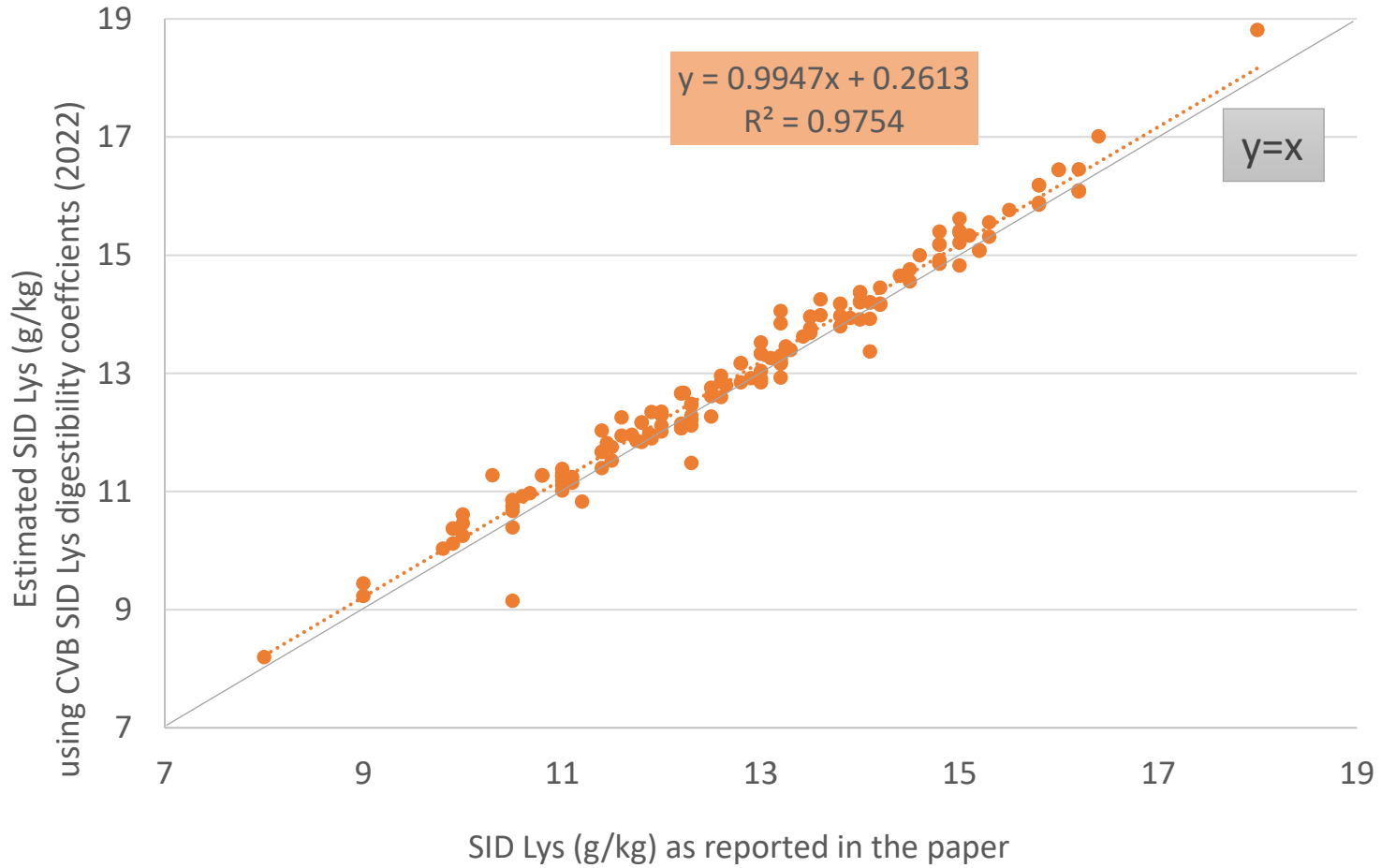
X-axis:
g SID Lys/MJ NE

Calculations:

- energy level: NE (DE, ME, NE, EW)
  based on conversion factors (Noblet et al., 2022)
- lysine level: SID lysine (SID, AID, analyzed total, calculated total)
  based on total lysine levels reported in the paper and CVB SID digestibility coefficients
- crude protein level: SID crude protein (calculated crude protein, analyzed crude protein)
  based on total crude protein level reported in the paper and CVB SID digestibility coefficients

Requirement of SID lysine

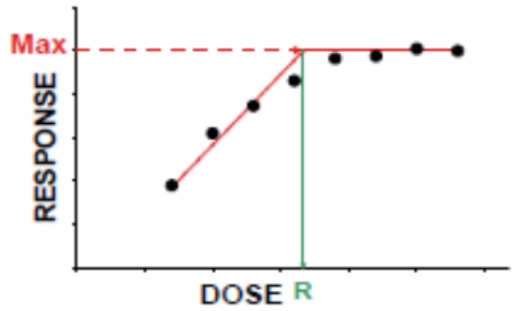
RESULTS



Requirement of SID lysine

MATERIALS AND METHODS

Linear-plateau model



⇒ **Lysine is increased by graded levels of L-lysine HCL and/or protein rich feed materials**
a varying (increase) or constant SID Lys/CP ratio

⇒ **Either or not in combination with the addition of constant or graded levels of one, two or more crystalline EAA**
a constant or varying (decrease) SID EAA/Lys ratio

⇒ **Lysine must be first limiting factor, other nutrients should be non-limiting**

Requirement of SID lysine

MATERIALS AND METHODS

⇒ **Lysine is increased by graded levels of L-lysine HCL and/or protein rich feed materials**
a constant or varying (increase) SID Lys/CP ratio

Item	Content in body protein[d]	Maximum efficiency (k_{AA})[e]
Protein	1.0000	0.81
Lysine	0.0696	0.72
Methionine	0.0188	0.64
Cystine	0.0103	n.a.
Methionine + cystine	0.0291	0.51
Threonine	0.0370	0.61
Tryptophan	0.0095	0.57
Isoleucine	0.0346	0.60
Leucine	0.0717	0.76
Valine	0.0467	0.71
Phenylalanine	0.0378	0.82
Tyrosine	0.0286	n.a.
Phenylalanine + tyrosine	0.0664	0.75
Histidine	0.0279	0.93
Arginine	0.0626	1.54

Van Milgen et al., 2008

160 g CP in diet
SIDC CP = 85% (assumption)
160 g CP x 85% = 136 g SID CP

136 g SID CP in diet
max efficiency = 81%
136 g SID CP x 81% = 110 g SID CP

110 g SID CP will be incorporated in body protein
6.96% is the ratio of lysine in body protein
110 g SID CP x 6.96% = 7.66 g SID Lys

7.66 g SID Lys will be incorporated in body protein
Max efficiency = 72%
7.66 g SID Lys/ 72% = ***10.6 g SID Lys***

10.6 g SID Lys in diet is required to make optimal use of the 160 g CP provided by the diet for protein accretion

In a diet with a CP content of 160 g/kg diet
- **Lys is limiting protein accretion up to a level of 10.6 g SID Lys/kg**
- **When SID Lys level > 10.6 g/kg diet => Lys is probably not used as essential AA**

Requirement of SID lysine

MATERIALS AND METHODS

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Van Milgen et al., 2008

$\frac{100}{0.81}$ ➡ **123.5 g of digestible protein (SID CP)**

$\frac{6.96}{0.72}$ ➡ **9.7 g of digestible lysine (SID Lys)**

$$\frac{9.7}{123.5} = \mathbf{0.0783}$$

Theoretical max ratio of SID LYS:SID CP?

SID Lys:SID CP ratio

- NEAA or nitrogen itself could be first limiting
- For 41 of 58 experiments, all dietary treatments had a ratio < 0.0783
- Ratio < 0.0783 is selection criterium

Requirement of SID lysine

MATERIALS AND METHODS

⇒ **Either or not in combination with the addition of constant or graded levels of one, two or more crystalline EAA**
a constant or varying (decrease) SID EAA/Lys ratio

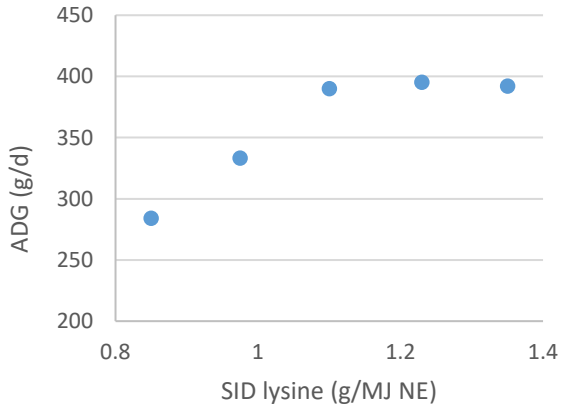
- Estimation of AA profile requires many assumptions
- Very few studies (17) have assumed ideal protein profile
- No selection criterium as such

Requirement of SID lysine

MATERIALS AND METHODS

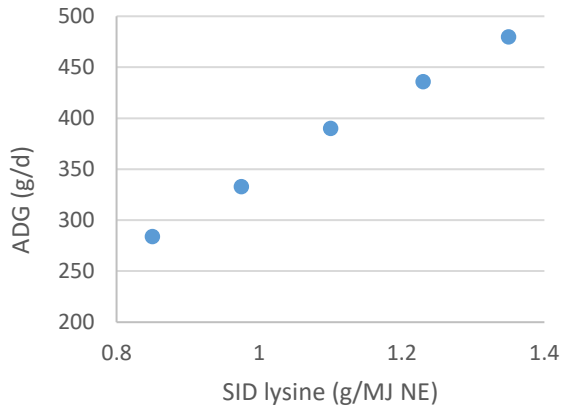
Potential outcome dose-response studies

Linear-plateau



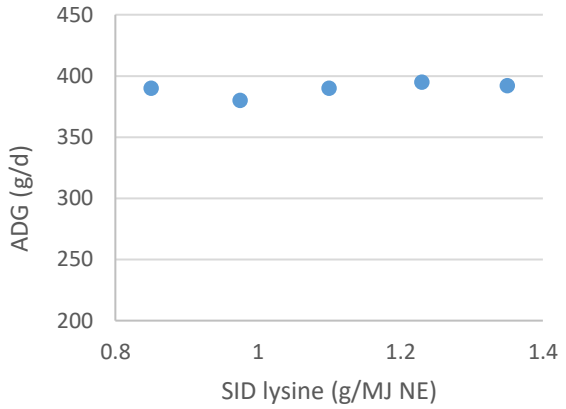
- Exceeding optimal lysine requirement; breakpoint = requirement?
- Other limiting factor?

Linear increase



- Lysine requirement at least the highest tested Lys level?
- Other limiting factor?

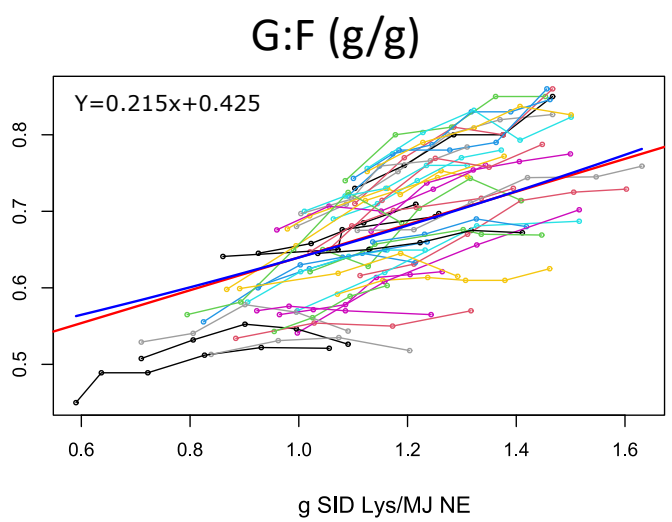
Constant

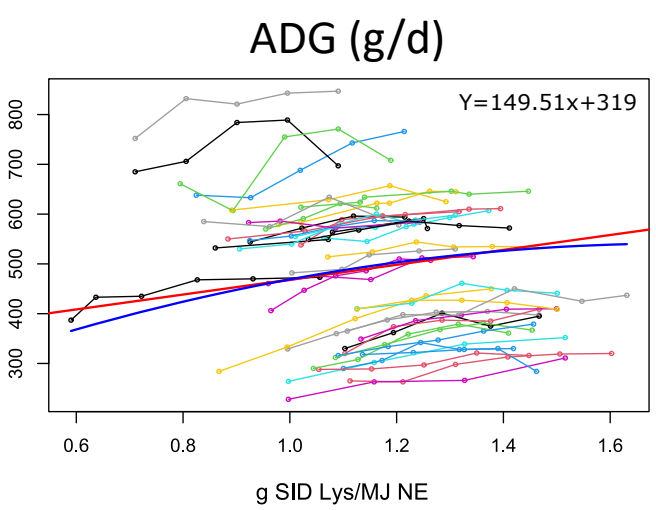


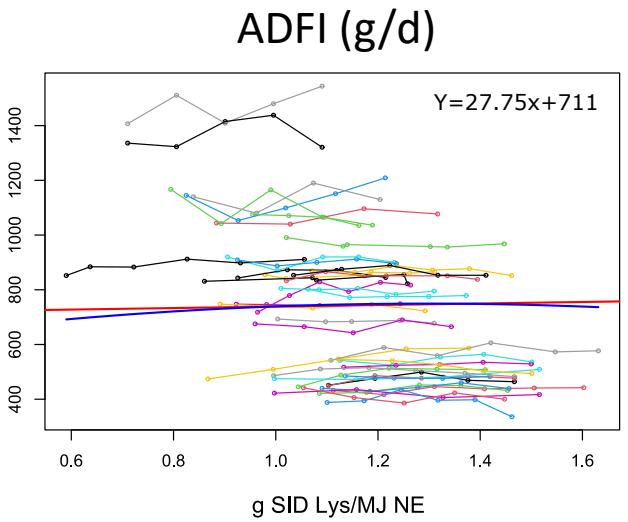
- Tested lysine levels above limiting lysine concentration?
- Other limiting factor?

Requirement of SID lysine

RESULTS







Linear Quadratic

G:F and ADG

No linear-plateau model fit

Response: mainly linear increase

ADFI

Not considerably affected by lysine content

AA recommendations weaned piglets

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Requirement of SID lysine

RESULTS

Individual experiments (17 of 41 experiments assumed to have ideal protein profile)

reference[1,2]	response[3]	model parameters					estimated Lys requirement[4] (g SID Lys/MJ NE)
		linear	quadratic	linear-plateau			
		slope	quadratic term	slope	breakpoint	plateau	
Nieto_Exp1_2015	lin&quad&linp	0.14	-0.415	0.22	0.861	0.522	0.861
Fontes_Exp1_2005	lin&quad&linp	0.2	-0.896	0.36	1.048	0.639	1.048
Lenehan_P1_Exp1_2004	lin&quad&linp	0.21	-0.825	0.32	1.108	0.649	1.108
Kendall_Exp5_2008	lin&quad&linp	0.11	-0.531	0.29	1.197	0.672	1.197
Nemechek_Exp3_2012	lin&quad&linp	0.26	-0.91	0.43	1.342	0.770	1.342
Nunes_Exp1_2008	lin&quad&linp	0.32	-1.007	0.39	1.37	0.787	**1.370**
Nemechek_Exp4_2012	lin&quad&linp	0.21	-0.67	0.29	1.389	0.832	1.389
Oliveira_P2_Exp1_2006	lin&-&-	0.39	-	-	-	-	**>1.091**
Nam_Exp2_1994	lin&-&-	0.3	-	-	-	-	>1.094
Braga_overall_2018	lin&-&-	0.23	-	-	-	-	>1.119
Schneider_P1_Exp1_2010	lin&quad&-	0.18	-0.473	-	-	-	>1.158
Nam_Exp1_1994	lin&-&-	0.07	-	-	-	-	**>1.172**
Gatel_Exp1_1992	lin&-&-	0.22	-	-	-	-	>1.205
Schneider_P1_Exp2_2010	lin&-&-	0.21	-	-	-	-	>1.235
Kendall_Exp2_2008	lin&-&-	0.29	-	-	-	-	>1.242
Lenehan_P2_Exp1_2003	lin&-&-	0.2	-	-	-	-	>1.247
Kendall_Exp3_2008	lin&-&-	0.14	-	-	-	-	>1.251
Millet_Exp1_2020	lin&quad&-	0.34	-0.378	-	-	-	**>1.255**
Kendall_Exp1_2008	lin&-&-	0.22	-	-	-	-	**>1.262**
Fruge_Exp1_2017	lin&-&-	0.31	-	-	-	-	>1.299
Yi_Exp1_2006	lin&-&-	0.08	-	-	-	-	>1.317
Kahindi_P1_Exp2_2014	lin&quad&-	0.31	-0.244	-	-	-	**>1.327**
Kahindi_P1_Exp1_2014	lin&-&-	0.24	-	-	-	-	**>1.327**
Kendall_Exp4_2008	lin&quad&-	0.2	-0.506	-	-	-	>1.336
Jones_Exp3_2014	lin&-&-	0.29	-	-	-	-	**>1.362**
Jones_Exp4_2014	lin&-&-	0.32	-	-	-	-	**>1.363**
Jin_Exp1_1998	lin&quad&-	0.34	-0.433	-	-	-	>1.37
Jones_Exp1_2014	lin&-&-	0.31	-	-	-	-	**>1.376**
Jones_Exp2_2014	lin&-&-	0.36	-	-	-	-	**>1.376**
Nemechek_Exp1_2012	lin&quad&-	0.29	-0.437	-	-	-	**>1.39**
Clark_Exp1_2017	lin&-&-	0.26	-	-	-	-	**>1.506**
Nichols_Exp1_2018	lin&-&-	0.18	-	-	-	-	**>1.547**
Moretto_Exp1_2000	-&quad&-	-	-0.943	-	-	-	-
Moretto_Exp2_2000	-&quad&-	-	-0.911	-	-	-	-
Urynek_Exp3-4_2003	-&quad&-	-	-0.581	-	-	-	-
Dean_Exp1_2007	-&-&-	-	-	-	-	-	-
Gatel_Exp2_1992	-&-&-	-	-	-	-	-	-
Kim_overall_2011	-&-&-	-	-	-	-	-	-
Nemechek_Exp2_2012	-&-&-	-	-	-	-	-	-
Urynek_Exp1_2003	-&-&-	-	-	-	-	-	-
Urynek_Exp2_2003	-&-&-	-	-	-	-	-	-

Linear: 32
Linear & quadratic: 13
Linear & quadratic & linear-plateau: 7

Most studies showed linear increase (without reaching plateau) in tested lysine range

Estimation Lys requirement (g SID Lys/MJ NE)	Number of studies
> 1.0	(14/17) 82%
> 1.1	(13/15) 87%
> 1.2	(12/14) 86%
> 1.3	(10/11) 91%
> 1.4	(2/2) 100%
> 1.5	(2/2) 100%

AA recommendations weaned piglets

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Requirement of SID lysine

CONCLUSION

- **Not possible to determine an accurate value** for the SID lysine requirement of weaned piglets to achieve maximal growth performance
- Analysis of **pooled data** and **individual** dose-response experiments predominantly showed continous **linear increase in G:F and ADG** within the tested SID lysine range
- The results indicate that the **SID lysine requirement is at least 1.3 g SID lysine/MJ NE or higher**.

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- Requirement of SID lysine (meta-analysis)
- **Updated recommendations for SID lysine**
- Requirement (literature review) and updated recommendations for SID EAA other than lysine
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Updated recommendations for SID lysine

Requirement is **> 1.3 g SID lysine/MJ NE**

$$\frac{9.7}{123.5} = 0.0783$$

Max ratio of SID LYS:SID CP?

$$\frac{\textbf{optimal lysine level}\left(\frac{\textbf{g SID lysine}}{\textbf{MJ NE}}\right) * \text{energy content}\left(\frac{\text{MJ NE}}{\text{kg diet}}\right)}{\textbf{optimal crude protein level}\left(\frac{\textbf{g crude protein}}{\textbf{kg diet}}\right) * \text{SID coefficient crude protein (\%)}} * 100 = \text{optimal SID lysine to SID crude protein ratio (\%)}$$

ASSUMPTIONS	85%	10 MJ NE/kg	7.83%

Optimal crude protein level in relation to lysine level	**Optimal lysine level in relation to crude protein level**
Scenario 1: 1.50 g SID Lys/MJ NE => 225 g CP/kg diet	Scenario 2: 170 g CP/kg diet => 11.3 g SID Lys/kg diet

Updated recommendations for SID lysine as function of protein level

Current recommendations, but assumptions of SIDC CP and optimal SID Lys to SID CP ratio should be further investigated

SIDC CP = 90%		
g CP/kg diet	g SID CP/kg diet	g SID Lys/kg diet
160	144	**11.3**
170	153	**12.0**
180	162	**12.7**
190	171	13.4
200	180	14.1
210	189	14.8
220	198	15.5

In bold: SID Lysine values below the estimated lysine requirement of piglets
(under the assumption of a lysine requirement of 1.3 g standardized ileal digestible (SID) lysine/MJ NE and 10 MJ NE/kg diet)

Updated recommendations for SID lysine as function of protein level

Current recommendations, but assumptions of SIDC CP and optimal SID Lys to SID CP ratio should be further investigated

	SIDC CP = 90%		SIDC CP = 85%		SIDC CP = 80%	
g CP/kg diet	g SID CP/kg diet	g SID Lys/kg diet	g SID CP/kg diet	g SID Lys/kg diet	g SID CP/kg diet	g SID Lys/kg diet
160	144	**11.3**	136	**10.6**	128	**10.0**
170	153	**12.0**	145	**11.3**	136	**10.6**
180	162	**12.7**	153	**12.0**	144	**11.3**
190	171	13.4	162	**12.6**	152	**11.9**
200	180	14.1	170	13.3	160	**12.5**
210	189	14.8	179	14.0	168	13.2
220	198	15.5	187	14.6	176	13.8

In bold: SID Lysine values below the estimated lysine requirement of piglets
(under the assumption of a lysine requirement of 1.3 g standardized ileal digestible (SID) lysine/MJ NE and 10 MJ NE/kg diet)

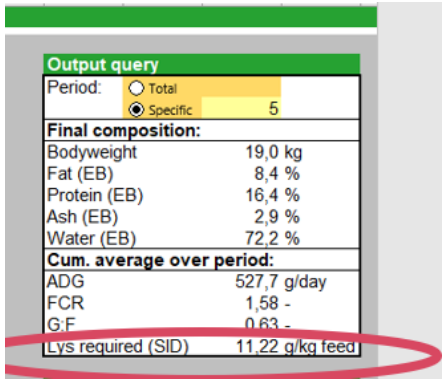
Requirement of SID lysine

Empirical data versus Factorial model

- Value for efficiency of AA utilization
- SIDC for growing pig might differ from piglets
- (Over or under)-estimation of maintenance energy
- Other … ?

> 1.3 g SID Lys/MJ NE

vs



Output query		
Period:	Total / Specific	5
Final composition:		
Bodyweight		19,0 kg
Fat (EB)		8,4 %
Protein (EB)		16,4 %
Ash (EB)		2,9 %
Water (EB)		72,2 %
Cum. average over period:		
ADG		527,7 g/day
FCR		1,58 -
G:F		0,63 -
Lys required (SID)		11,22 g/kg feed

$$Lysine\ required\left[\frac{g\ SID\ Lys}{day}\right] = \overbrace{(turnover + integument)}^{\text{Maintenance}} + \overbrace{endogenous}^{\text{Feed intake}} + \overbrace{\frac{prot.deposition}{efficiency}}^{\text{Protein deposition}}$$

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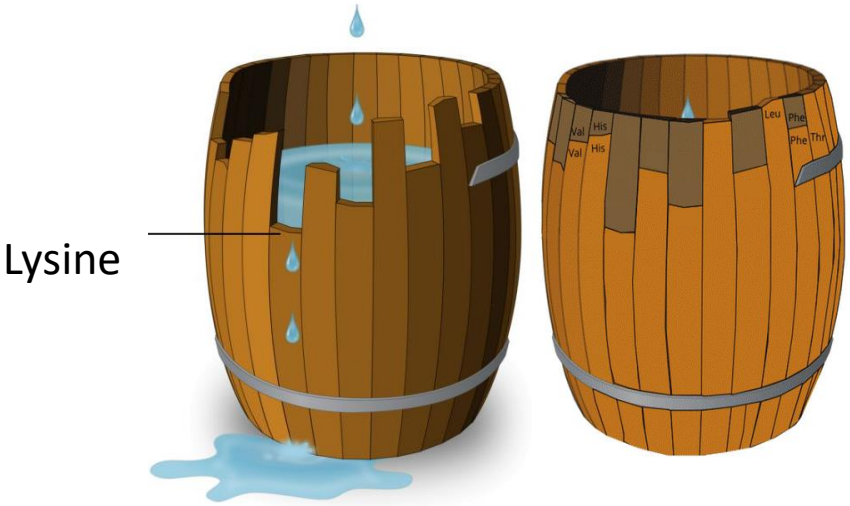
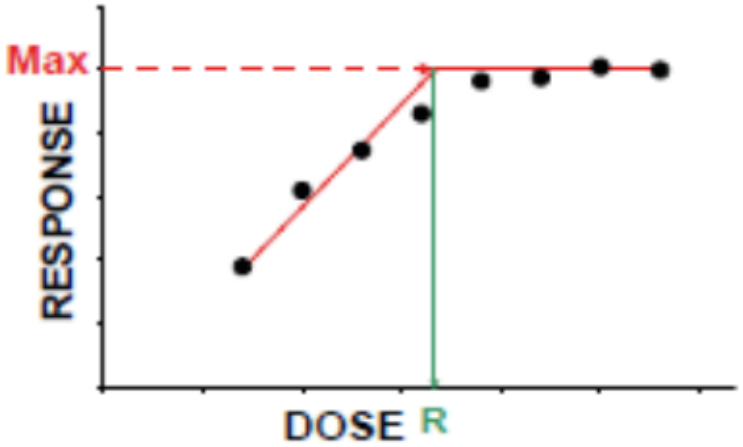
Requirement and updated recommendations for EAA other than lysine

MATERIALS AND METHODS



Literature review:
Reviews + national recommendations
Recent dose-response studies

Linear-plateau model



% EAA/Lys

Requirement and updated recommendations for EAA other than lysine

MATERIALS AND METHODS

- RESPONSE PARAMETER

  maximize **ADG** (especially for AA involved in voluntary feed intake such as **Val and Trp**, lower AA levels could be sufficient to maximize G:F compared to the level that maximizes feed intake and consequently daily gain)

- STATISTICAL MODEL

  Linear-plateau model is mostly best-fitting model. However, for AA negatively affecting performance at excess levels (e.g. **Leu**), quadratic models may show a better fit to the data

- AA INVOLVED IN IMMUNE RESPONSE

  For **Met + Cys, Trp and Thr**, the amino acid requirement might be higher under challenged health conditions

- MARGINAL EFFECT OF AA SUPPLY 10% BELOW (AND ABOVE) THE REQUIREMENT ESTIMATE*

  Deficiency of Ile has higher negative impact on growth performance compared to deficiency of Leu

  *Marginal effect depends on statistical model, not easy to compare and use in the review

Requirement and updated recommendations for EAA other than lysine

	BSAS (2003) UK	NRC (2012) USA	Tybirk et al. (2021) DK	Gloaguen et al. (2013b) FR	CVB (1996) NL	van der Peet-Schwering and Bikker (2018) Starter diet (25-50 kg)
Methionine + Cysteine	59	55	54	60	61	60
Threonine	65	59	62	65	62	66
Tryptophan	19	16	21	22	20	20
Isoleucine	58	51	46-48	52		53
Valine	70	63	62-64	70		67
Leucine	100	100	86-90	101		**100**
Histidine	34	34	28-29	31		**32**
Phenylalanine + Tyrosine	100	93	95	-		**95**

In bold: based on experiments with weaned piglets

AA recommendations weaned piglets

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Requirement and updated recommendations for EAA other than lysine

	Updated recommendations	Variation in ratios in reviewed literature
Methionine [1,4]	33	NA[1]
Methionine + Cysteine [4]	60	54-73
Threonine[4]	65	65-73
Tryptophan[4]	20	17-26
Isoleucine[2]	52	48-54
Valine	67	62-81
Leucine	100	80-111
Histidine	30	27-33
Tyrosine	40	NA[3]
Phenylalanine	54	NA[3]

[1]Based on the advice of a minimum ratio of methionine to methionine+cysteine of 55%

[2]In diets without blood products (non-excess of leucine)

[3]To the best of our knowledge, the study of Gloaguen et al. (2014b) is the only dose-response requirement study conducted for tyrosine and phenylalanine.

[4]Under poor health conditions, the amino acid requirement might be higher

High variation related to

- Statistical model
- Response parameter

e.g. Clarck et al. best fitting model for valine

63 % for ADG, based on linear plateau model
72 % for G:F, based on quadratic model
74% for ADFI, based on quadratic model

Requirement and updated recommendations for EAA other than lysine

	Updated recommendations	Variation in ratios in reviewed literature
Methionine [1,4]	33	NA[1]
Methionine + Cysteine [4]	60	54-73
Threonine[4]	65	65-73
Tryptophan[4]	20	17-26
Isoleucine[2]	52	48-54
Valine	67	62-81
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[4]Under poor health conditions, the amino acid requirement might be higher

	BSAS (2003) UK	NRC (2012) USA	Tybirk et al. (2021) DK	Gloaguen et al. (2013b) FR
Methionine + Cysteine	59	55	54	60
Threonine	65	59	62	65
Tryptophan	19	16	21	22
Isoleucine	58	51	46-48	52
Valine	70	63	62-64	70
Leucine	100	100	86-90	101
Histidine	34	34	28-29	31
Phenylalanine + Tyrosine	100	93	95	-

- Other approach, not based on traditional dose-response studies with EAA as function of lysine
- Recommendation (risk for diarrhea, economic optimum)
- Based on recent studies, have not yet been published in peer-reviewed journals

Outline

- Background
- Requirement of SID lysine (meta-analysis)
- Updated recommendations for SID lysine
- Requirement (literature review) and updated recommendations for SID EAA other than lysine
- **Conclusions and future research perspectives**

Conclusions

- The SID lysine requirement for maximal growth performance seems higher than the level tested in most dose-response studies (> 1.3 g SID Lys/MJ NE)
- Lysine levels (recommendations) should be considered in relation to crude protein levels
- Recommendations for SID EAA other than Lys are similar to most current recommendations, with exception of the Danish recommendations

Future research perspectives

- Determine SID lysine requirement in dose-response studies using a higher SID lysine range
- Determine optimal SID lysine to SID CP ratio
- Requirements versus recommendations including health, environment and economic considerations

Thank you

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