Introduction updated CVB SID-AA Table of feedstuffs for pigs

Machiel Blok

June 1st (ILVO Dier, Melle) and 2nd 2023 (WUR, Wageningen)

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Scheme of the presentation

- Introduction
- Basal Endogenous Losses
- Apparent versus standardized ileal digestibility
- New database with observations
- Development of new table
- Conclusions

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Determination of ileal digestibility

- Intake of feed
- Collection of chyme at terminal ileum
- No quantitative collection
- Use of indigestive marker to relate amount of ileal chyme to amount of feed

Protein/Amino Acids in ileal chyme:

- Undigested feed protein/amino acids
- Endogenous protein/amino acids
- ➢ Measurement of *apparent digestibility*

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Sources of endogenous protein / amino acids (AA) at terminal ileum

- **Basal endogenous protein / AA loss**

  Minimum (*inevitable*) loss of protein/AA - related to the *physical flow of feed DM through the digestive tract*, and not influenced by dietary composition
- **Specific endogenous protein / AA loss**

  Specific losses are induced by specific feed ingredient characteristics, e.g., contents and types of fiber and antinutritional factors

A large part of the endogenous protein is digested before reaching the end of the ileum.

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Description of ileal digestibility

- **Apparent digestibility (AID) of AA**

  AID, % = [(AA intake - Ileal AA outflow)/(AA intake)] × 100

- **Standardized digestibility (SID) of AA**

  SID, % = {[AA intake - (Ileal AA outflow + basal endogenous ileal AA)]/(AA intake)} × 100

  or

  SID, % = AID + [(Basal Endogenous Loss AA / AA diet) × 100]

- **True digestibility (TID) of AA**

  TID, % = {[AA intake - (Ileal AA outflow + total endogenous ileal AA)]/(AA intake)} × 100

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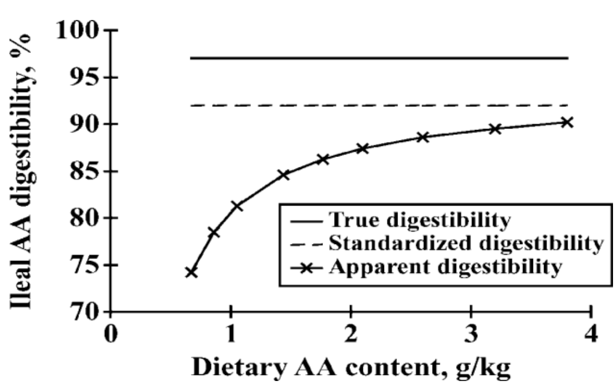
Graphic representation of different ways of expression of ileal digestibility



- From Stein et al. (2007).
  Digestibility obtained with the direct method

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Techniques to measure Endogenous Losses at the terminal ileum

Basal Endogenous Loss (BEL) of Crude Protein and AA:

- Protein-free diets (most often used)
- Feeding a highly digestible purified diet (e.g., casein)
- Peptide alimentation technique (enzymatically hydrolyzed casein)
- Regression technique

Total endogenous loss (basal + specific) of CP and AA:

- Homoarginine technique
- Isotope dilution technique

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CVB Database with observations on BEL in N-free diets, Casein diets and Regression method

	CP	ARG	HIS	ILE	LEU	LYS	MET	PHE	THR	TRP	VAL	ALA	ASP	CYS	GLU	GLY	PRO	SER	TYR
	N-free diets																		
Number	172	187	187	187	187	187	183	187	187	145	187	186	183	164	182	181	155	183	151
Average	**17.3**	**0.6**	**0.2**	**0.4**	**0.6**	**0.4**	**0.1**	**0.4**	**0.6**	**0.1**	**0.5**	**0.6**	**0.8**	**0.2**	**1.1**	**1.5**	**4.3**	**0.6**	**0.3**
STDEV	6.3	0.3	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.1	0.2	0.3	0.3	0.1	0.5	0.7	3.2	0.3	0.1
Minimum	6.8	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.1	0.0	0.1	0.2	0.0	0.1	0.1
Maximum	48.6	2.1	3.1	1.2	1.7	1.4	0.8	1.3	1.5	0.6	1.5	2.1	2.6	0.7	3.4	4.3	20.1	2.1	0.9
	Highly digestible protein diets (Casein)																		
Number	21	24	26	26	26	26	24	26	26	12	26	19	19	21	19	18	19	19	17
Average	**14.0**	**0.5**	**0.4**	**0.5**	**0.7**	**0.5**	**0.1**	**0.3**	**0.7**	**0.1**	**0.6**	**0.6**	**0.9**	**0.3**	**1.6**	**1.1**	**2.8**	**0.8**	**0.4**
STDEV	5.0	0.3	0.5	0.2	0.2	0.2	0.0	0.1	0.3	0.1	0.2	0.2	0.3	0.2	0.5	0.7	2.4	0.3	0.4
Minimum	5.3	0.2	0.1	0.2	0.3	0.2	0.1	0.2	0.3	0.1	0.2	0.1	0.4	0.0	0.9	0.1	0.5	0.3	0.0
Maximum	22.8	1.2	2.4	0.9	1.1	0.9	0.2	0.6	1.2	0.4	1.1	1.0	1.7	0.8	2.8	2.5	9.1	1.3	1.8
	Regression method (without observations obtained with IRA technique)																		
Number	19	18	17	19	19	19	17	16	19	9	19	18	18	15	18	18	17	18	13
Average	**14.7**	**0.8**	**0.2**	**0.5**	**0.8**	**0.5**	**0.2**	**0.5**	**0.7**	**0.2**	**0.7**	**0.7**	**1.0**	**0.4**	**1.7**	**1.2**	**2.0**	**0.7**	**0.3**
STDEV	9.1	0.8	0.2	0.4	0.7	0.5	0.2	0.4	0.5	0.2	0.6	0.6	0.8	0.3	1.8	0.9	1.6	0.4	0.3
Minimum	3.1	0.2	0.1	0.1	0.3	0.2	0.0	0.2	0.2	0.0	0.2	0.1	0.3	0.1	0.3	0.3	0.3	0.3	0.0
Maximum	46.6	3.3	0.9	1.7	3.3	2.3	1.0	1.7	2.5	0.7	2.7	2.9	3.8	1.0	7.8	3.6	5.4	2.3	1.1

Highest average of the three methods   Lowest average of the three methods

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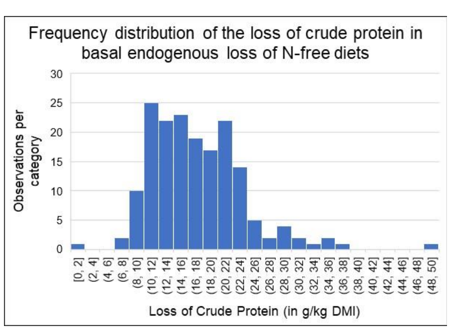
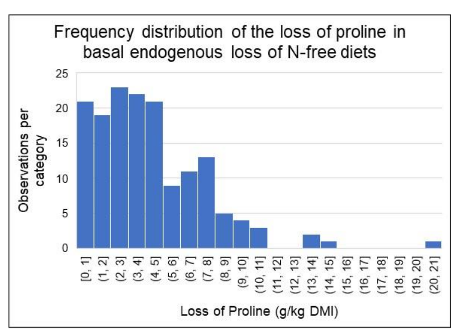
Frequency distribution of BEL of Crude Protein and Proline obtained with N-free diets





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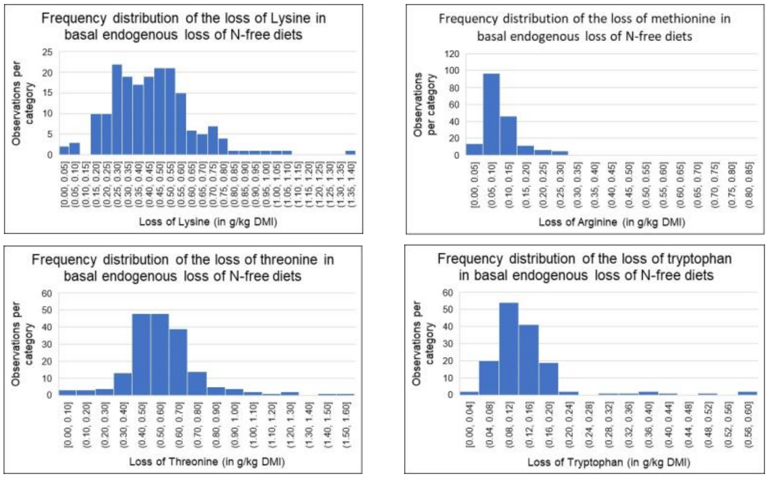
Frequency distribution of BEL of LYS, MET, THR and TRP obtained with N-free diets



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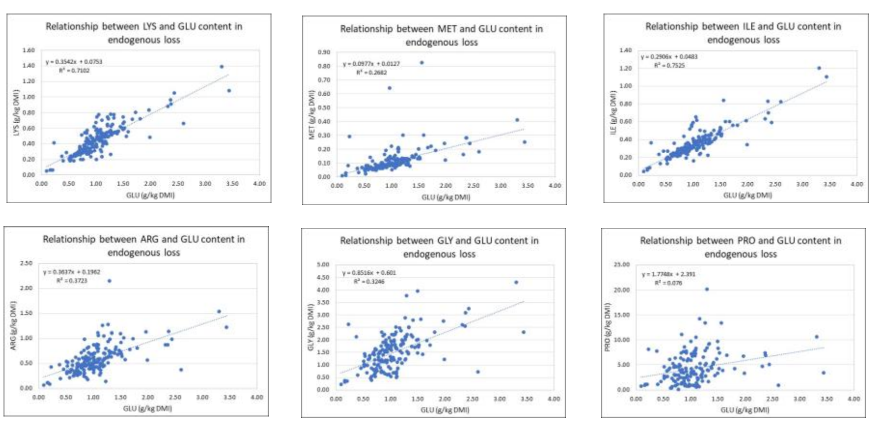
Relationships between LYS, MET, ILE, ARG, GLY and PRO to GLU in BEL of N-free diets



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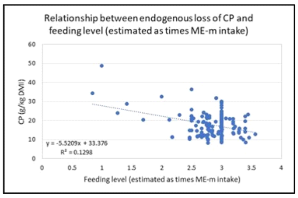
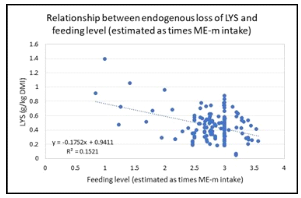
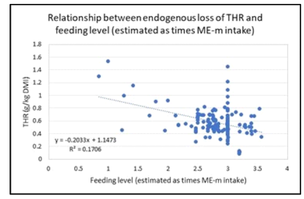
Relationship between BEL of some AA and 1) Feeding Level and 2) Body weight at start experiment

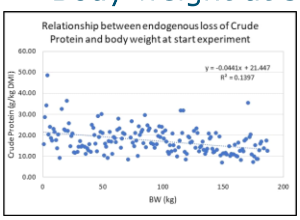
- Feeding Level

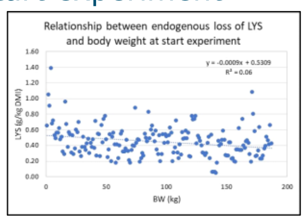


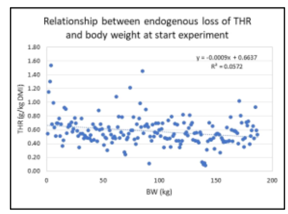




- Body weight at start experiment







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Factors affecting BEL after feeding N-free diets

- Feed Intake (Furuya and Kaji, 1992; Moter and Stein, 2004):
  Data indicate that BEL increases at low FI levels
- Body weight (no conclusive literature data):
  Difficult to evaluate in CVB dataset. BW mentioned at start experiment but not when chyme is collected
- Diet composition:
  No effect of fiber (cellulose) or fat level
- Energy source (Adedokun et al., 2019):
  High sugar levels gave in higher BEL for 60% of the AA
- Adaptation time (Adedokun et al., 2019)
  Adaptation for 6-7 d. resulted in higher BEL for CP, ARG, ALA, GLY and PRO than 3-4d adaptation.

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Are Basal Endogenous Losses of CP and AA (especially PRO) obtained with N-free diets artefacts?

- Suppose: BEL of CP and AA obtained with N-free diets are artefacts, due to the absence of protein in the diets.
- Consequence: These artefacts are absent when feeding a protein containing diet.
- Can this be tested?
  - Yes, if there are independent studies examining both the AID of a certain protein source as well as the BEL by feeding a N-free diet.
- As the CVB database contained such experiment for Corn, we tested the above hypothesis.

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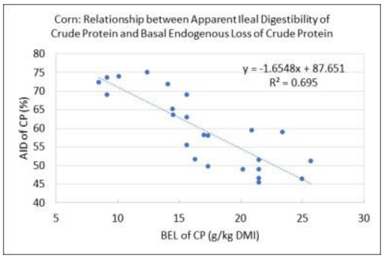
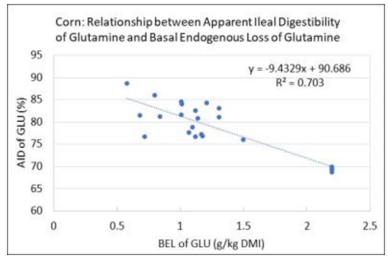
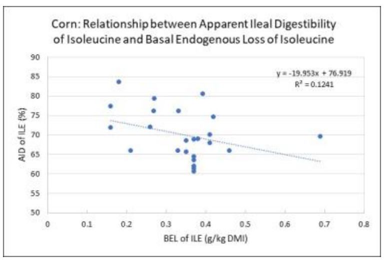
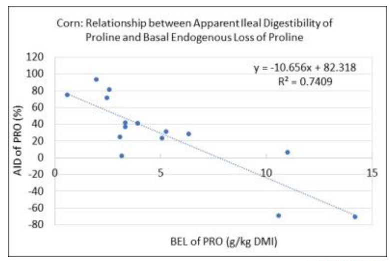
Relationship between AID of CP and some AA in Corn and the corresponding BEL in N-free diets in the same experiment









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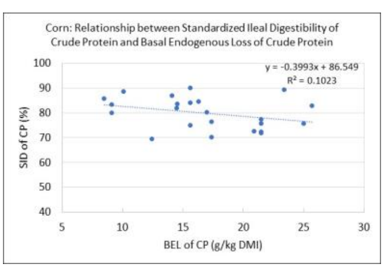
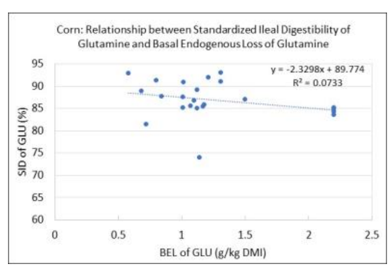
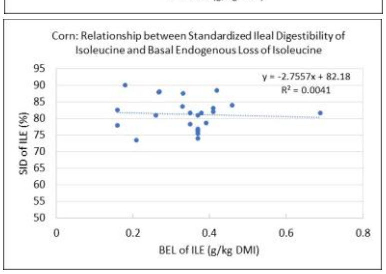
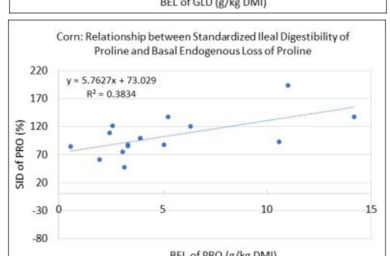
Relationship between SID of CP and some AA in Corn and corresponding BEL in N-free diets in same experiment









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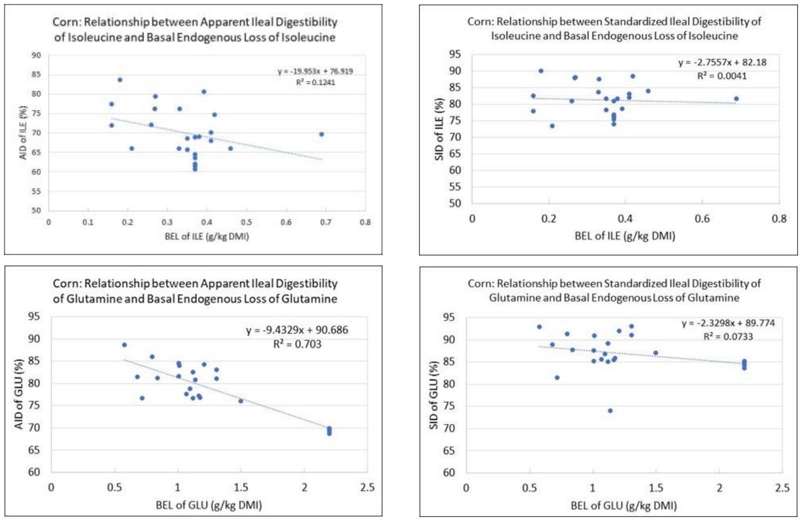
Comparison of relationships of AID and SID of corn to BEL: Isoleucine and Glutamine



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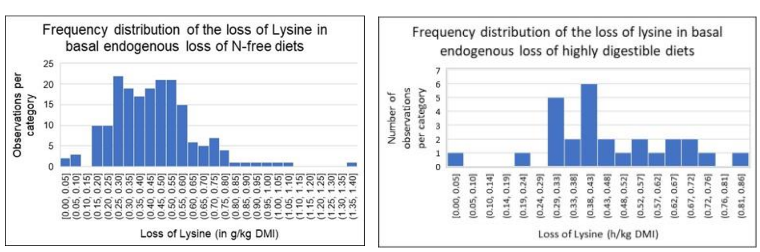
High BEL of CP and AA obtained with N-free method are no artefacts

1. High experiment specific BEL values for AA result in low AID values
2. BEL of CP and AA (e.g., lysine), determined with diets with highly digestible protein (casein) or with the regression method also show (very) large variations.



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Basal Endogenous Loss of CP and AA is experiment specific

- AID is related to BEL, whereas SID is not.
- Consequences:
  - SID is correct standard for ileal digestibility of CP / AA
  - Most correct way to calculate SID is with experiment specific BEL values.
- What to do with studies publishing AID without experiment mentioning experiment specific BEL?
  - SID calculated with average BEL pattern
  - Arguments:
    - Most observations for BEL are around average value
    - BEL effect on SID is relatively limited for high protein feedstuffs
    - Loss of too much observations for certain feedstuffs

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New CVB Table on ileal digestibility of CP and AA in feedstuffs for growing pigs

- Current Table:
  - Based on literature study of former ILOB-TNO in 1996
  - Subsidized by Degussa (now Evonic) and placed at the disposal of CVB
  - In 2006 transition from AID to SID
- Since 1996 numerous studies on ileal digestibility of CP and AA were published in peer reviewed journals
- As many studies as possible collected, published in the period 1970 – 2020
- Studies that fulfilled a set of criteria were inserted in a database

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Criteria to incorporate studies in CVB database (1)

- Peer-reviewed publications (obligatory)
- Author(s), scientific journal, year publication (obligatory)
- Chemical composition of the test ingredient(s):
  - *Dry matter (obligatory, or reliable estimate)*
  - *Crude protein (obligatory)*
  - *Crude fiber, NDF and/or ADF*
  - *Crude ash, Starch, Sugars*
  - *Separate runs S-containing AA and TRP: yes/no*
- Animal data:
  - *Genotype, sex, body weight/age (obligatory), housing system, experimental set up, number of replicates*

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Criteria to incorporate studies in CVB database (2)

- Method to determine ileal digestibility (obligatory)
  - Direct method (one protein source in diet)
    - SID or AID
  - Indirect (basal diet and experimental diet = x% basal diet and (100-x)% test ingredient)
    - SID or AID
  - Regression method

- Experimental aspects:
  - Diets: incorporation rate of test ingredient (obligatory)
  - Feeding method: ad lib / restricted (feeding level)
  - Exclusion of data from diets containing enzymes

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Criteria to incorporate studies in CVB database (3)

Experimental aspects (continued):
- Marker: Cr_2O_3 / Acid insoluble Ash / TiO_2
- Chyme collection:
  - Collection technique (obligatory):
    - *Cannulation (and type of cannula)*
    - *Ileal rectal Anastomosis (IRA)*
    - *Slaughter technique*
  - Adaptation period before chyme collection
  - Duration and number of chyme collections (obligatory)

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CVB Database and sub-databases

As different experimental methods were applied, data were incorporated initially in several sub-databases:

1. Direct method and SID
   - *Experiment specific BEL in publication*
   - *An experiment specific BEL used but not published*
   - *BEL pattern from literature or from institute*
2. Direct method and AID*
3. Indirect method and SID
4. Indirect method and AID*
5. Regression method

*: Recalculated to SID with standard BEL pattern

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Development of new table on ileal digestibility of CP and AA in feedstuffs for growing pigs

- Sub-datasets combined in one large database (>1500 observations).
- Table for growing/finishing pigs – no separate table for piglets
- Removal of outliers from datasets of individual feedstuffs:
  - Outliers concerning AA content (in g/16g N):
    - *Removal values deviating >2*STDEV from average*
    - *Removal entire observation when ≥ 5 AA are an outlier*
  - Outliers concerning SID of AA (in % units):
    - *Removal values deviating >2*STDEV from average*
    - *Removal entire observation when ≥ 5 AA are an outlier*
- SID-PRO: often deviating –> average SID of 17 remaining AA

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Further evaluation of datasets of individual feedstuffs (general approach)

- After removal outliers, correlation matrices were made:
  - Is variation in SID (%) related to chemical parameter (e.g., Crude Protein, Crude Fiber, NDF, ADF)
  - If so, regression equations were developed to estimate SID as function of certain parameter
- For (almost) all relevant feedstuffs sufficient data were available to determine new and robust SID values
- No new observations for several feedstuffs of minor practical importance: current evaluation maintained

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Feedstuffs where variation in SID of crude protein and amino acids was related to Crude protein, Crude fiber or NDF content

Feedstuff	Chemical parameter
Cotton seed meal, solvent extracted	CP
DDGS, Wheat	NDF
Rapeseed expeller	CP
Rapeseed meal, solvent extracted	NDF
Soybeans, heat treated	NDF
Wheat by-products dry milling	CF / NDF

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Comparison of new SID values with current SID values: DDGS Corn and Wheat

DDGS Corn																			
Item	**SID (%)**																		
	CP	**ARG**	**HIS**	**ILE**	**LEU**	**LYS**	**MET**	**PHE**	**THR**	**TRP**	**VAL**	**ALA**	**ASP**	**CYS**	**GLU**	**GLY**	**PRO**	**SER**	**TYR**
N	75	82	83	83	80	80	83	82	82	79	81	78	82	82	79	79	68	74	56
Average SID	73.9	83.6	77.9	76.3	84.7	62.6	82.4	81.8	70.7	73.8	75.8	80	69.2	73.2	81.5	66.6	75.5	77.1	82.5
STDEV *	4.8	4.47	4.31	4.11	2.84	6.94	3.34	3.17	4.34	8.45	4.08	3.51	4.58	4.11	3.72	8.69	11.8	4.3	3.14
Min	63.5	74.1	69.8	66.5	77.8	46.5	73.9	74.4	60.6	53.2	67.3	71.7	59.4	65.9	71.2	51	51.5	63.4	74.6
Max	82.9	92	85.9	84.2	91.3	75.4	89.2	88.7	81.9	86.9	86.2	86.4	79.1	80.6	88.7	87	109.1	86.6	90.1
	After conversion to an integral number																		
SID	74	84	78	76	85	63	83	82	71	74	76	80	69	73	82	67	76**	77	83
	SIDC values in the CVB Feed Table 2021																		
SID	73	84	78	79	86	58	86	85	73	77	80	82	67	66	84	60	67	84	-

WHEAT																			
Item	**SID (%)**																		
	CP	**ARG**	**HIS**	**ILE**	**LEU**	**LYS**	**MET**	**PHE**	**THR**	**TRP**	**VAL**	**ALA**	**ASP**	**CYS**	**GLU**	**GLY**	**PRO**	**SER**	**TYR**
N	50	56	52	56	57	57	51	53	57	34	57	53	54	37	50	53	47	51	40
Average SID	90.1	91.1	90.1	89.6	89.9	82.2	89.4	91.0	85.0	86.7	87.7	84.0	83.8	89.6	95.7	90.0	103.3	91.1	91.7
STDEV *	4.4	4.4	3.9	4.2	3.8	7.8	3.5	4.1	5.7	5.3	4.3	6.3	5.8	2.8	1.7	7.8	10.4	3.3	5.4
Min	83.0	83.0	83.5	79.4	79.6	69.0	84.0	82.3	70.2	74.0	78.1	71.3	73.4	84.7	91.7	75.1	71.7	82.9	79.6
Max	98.6	99.9	98.3	96.7	97.0	95.7	97.8	97.9	98.2	94.6	96.8	93.9	93.2	95.1	98.4	106.3	129.7	98.0	100.1
	After conversion to an integral number																		
SID	90	91	90	90	90	82	89	91	85	87	88	84	84	90	96	90	89 **	91	92
	SIDC values in the CVB Feed Table 2021																		
SID	89	90	90	90	90	84	90	90	86	88	88	83	83	90	96	87	96	92	91

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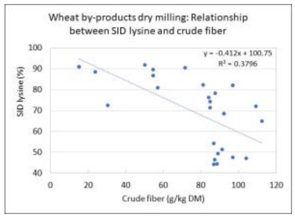
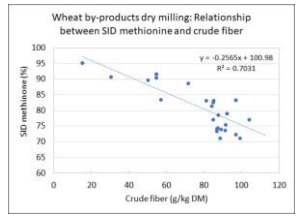
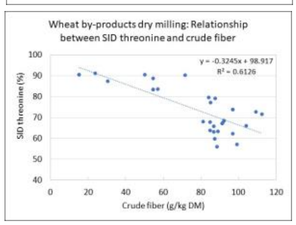
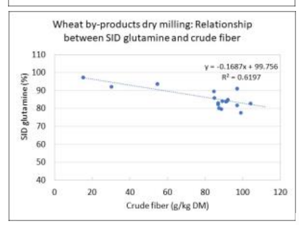
Regression analysis on dataset wheat by-products from dry milling: relation between SID to Crude Fiber

- Wheat flour – feed flour – feed meal – middling's – bran
- SID (%) of CP and AA negatively related to Crude Fiber.









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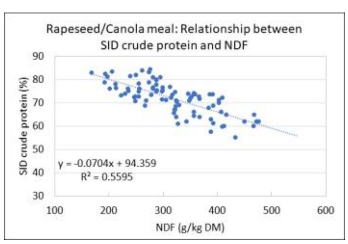
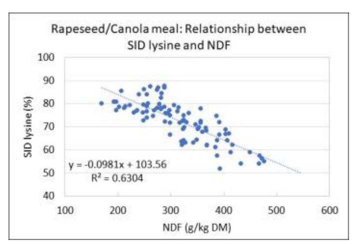
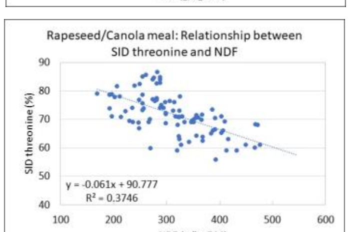
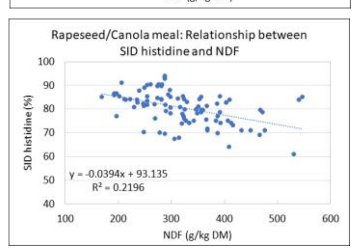
Regression analysis on dataset rapeseed / canola meal solvent extracted: relation between SID to NDF









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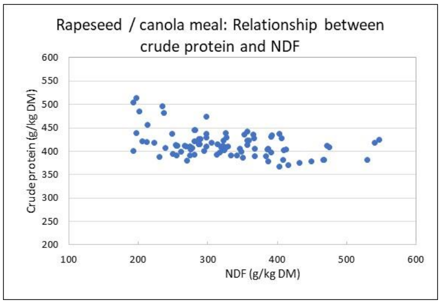
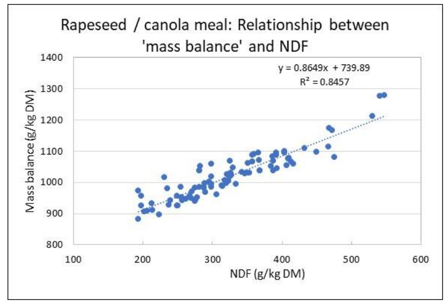
Relationship between crude protein and NDF in rapeseed/canola meal





- NDF is an artefact

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Level of crude protein in NDF in 5 samples of German rapeseed meal

Rapeseed meal: CP, aNDF and CP in NDF in 5 rapeseed meal samples differing in NDF content (Messerschmidt et al., 2014)

Item (g/kgDM)	Rapeseed meal with different glucosinolate levels				
	RSM15	RSM14	RSM10	RSM6	RSM5
Glucosinolate[a]	15	14	10	6	5
CP	409	408	405	396	369
aNDF[b]	328	325	343	388	413
CP in NDF	78	79	86	114	109

[a]: in µmol/g DM

[b]: aNDF with heat stable amylase and expressed inclusive ash

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CVB voor waardevolle veedervoorden

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SID of crude protein and amino acids in soybean meal solvent extracted (1)

a. Total number of observations: 208
b. Observations without information about TIA content: 92
c. Removal 4 observations with TIA > 8 mg/kg DM.
d. Remaining observations after step b. and c.: 112
e. Year of publication (improvement technology): no effect
f. Effect BW at start experiment on SID: removal 29 observations with BW at start < 10 kg
g. Remaining number: 83
h. Removal of 8 observations with NDF > 150 g/kg DM
i. Further processing of the remaining 75 observations to calculate average SID's crude protein and amino acids

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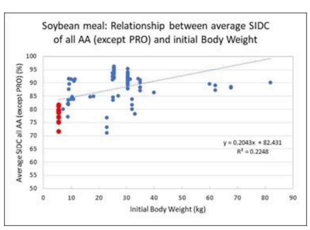
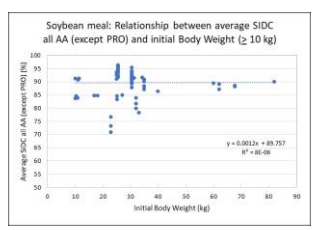
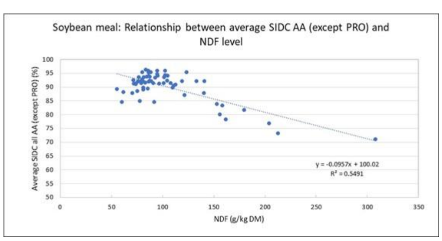
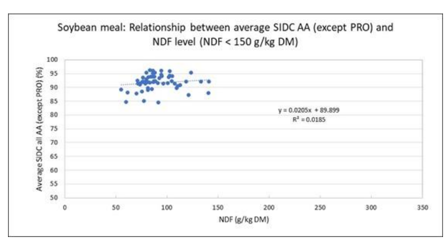
SID of crude protein and amino acids in soybean meal solvent extracted (2)









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SID of crude protein and amino acids in soybean meal solvent extracted (3)

SOYBEAN MEAL SOLVENT EXTRACTED																			
Item	SID (%)																		
	CP	ARG	HIS	ILE	LEU	LYS	MET	PHE	THR	TRP	VAL	ALA	ASP	CYS	GLU	GLY	PRO	SER	TYR
N	61	65	65	63	64	65	64	65	65	60	64	65	65	58	64	65	36	64	63
Average SID	92.4	96.5	92.9	91.8	91.4	91.5	93.2	92.0	89.3	93.4	90.4	90.8	89.9	86.5	91.3	95.3	126.9	93.2	91.5
STDEV*	2.78	1.70	2.04	2.42	2.38	2.05	2.43	2.06	2.93	2.50	3.01	2.81	2.26	3.84	2.21	5.02	11.40	2.56	2.26
Min	86.9	92.6	88.1	84.3	83.7	86.7	86.5	85.4	82.7	86.6	82.8	84.1	84.4	78.7	85.7	84.5	93.8	86.7	85.1
Max	97.4	99.6	96.2	95.6	95.2	95.4	96.6	95.4	95.2	97.1	95.3	95.4	94.5	94.0	95.4	104.4	142.1	97.8	95.2
	After conversion to an integral number																		
SID	92	97	93	92	91	92	93	92	89	93	90	91	90	87	91	95	92**	93	92
	Soybean meal, solvent extracted crude fibre < 45 g/kg, Crude Protein > 485 g/kg																		
SID	88	94	91	89	88	90	91	90	86	89	88	87	88	84	91	87	93	90	89
	Soybean meal, solvent extracted crude fibre > 75 g/kg																		
SID	86	92	89	87	86	88	89	88	84	87	86	85	86	82	89	85	91	88	87

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Comparison new and current SID's in some feedstuffs

Feedstuff	Difference (in %) for EAA		
Barley	-3.2	-	+5.2
Biscuit, ground/Bread remains	**-7.4**	**-**	**-23.9**
DDGS, Maize	-5.0	-	+8.6
DDGS, Wheat	-21.1	-	+1.3
Linseed meal, solv. extr.	-19.5	-	+8.0
Maize	-4.7	-	+3.9
Rapeseed expeller	**+1.3**	**-**	**+15.5**
Rapeseed meal	-3.8	-	+8.9
Soybean meal, solv. extr.	**+2.2**	**-**	**+4.5**
Sunflower meal, solv. extr.	-3.8	-	+1.2
Wheat	-2.4	-	+1.1
Wheat feed flour	-1.1	-	-6.1
Wheat middling's	**-8.3**	**-**	**-26.9**

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Scheme of the presentation

- Introduction
- Basal Endogenous Losses
- Apparent versus standardized ileal digestibility
- New database with observations
- Development of new table
- Conclusions

Conclusions

New CVB table on ileal digestibility of CP and AA

- Based on SID values, mainly calculated with experiment specific BEL values
- Based on very large dataset: >1500 observations published in between 1970 and 2020
- For some feedstuffs variation in SID related to chemical parameter (CP, CF, NDF)
- Biscuit meal en bread remains as well as wheat by-products with higher fiber levels have lower SID's
- SID's of EAA in soybean meal increase 2.2 – 4.5%; those of Rapeseed expeller with 1.3 – 14.5%.
- For several less relevant feedstuffs no new data
- New table much more robust than current CVB table

Thank you for your attention.

Questions?

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