Feed-a-Gene

Development of models to predict the nutritional value of feedstuffs and feed mixtures by NIRS

Samantha Joan Noel

(Aarhus University, Denmark)

Objectives

The development of new methodologies for **real-time characterisation** of chemical composition and nutritional value of feeds

- NIRS to predict the nutritive value of animal feed
  - Chemical components (macronutrients and amino acids)
  - Digestible energy and macronutrients, and metabolisable energy in pigs

Rationale

Nutritive value of a feed varies between and within feeds due to factors like genetics, agronomics, harvest, storage and processing

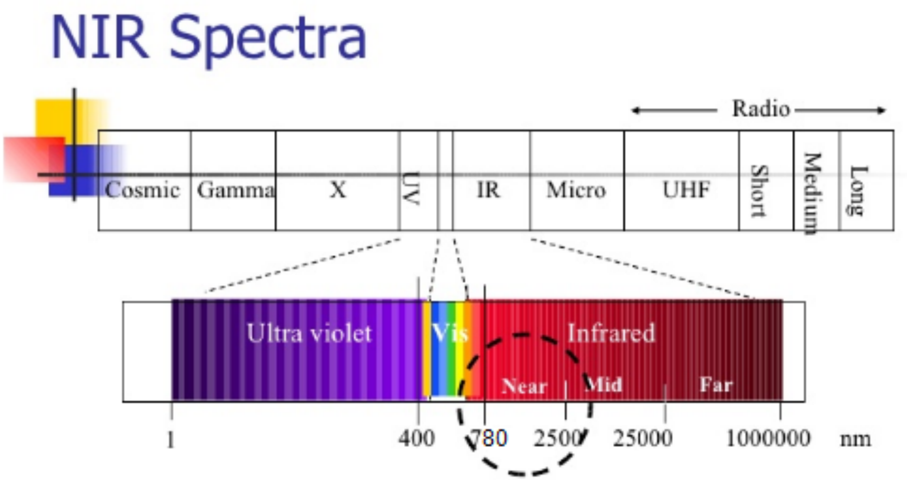
- Chemical analysis of macronutrients is expensive and can't be implemented in real time

The digestibility of the nutrient fractions may vary considerably form feed to feed and from sample to sample

- It is not possible to perform in vivo evaluations of individual batches because of time and cost

There is a need for a quick, reliable and inexpensive methods to evaluate pig feedstuffs

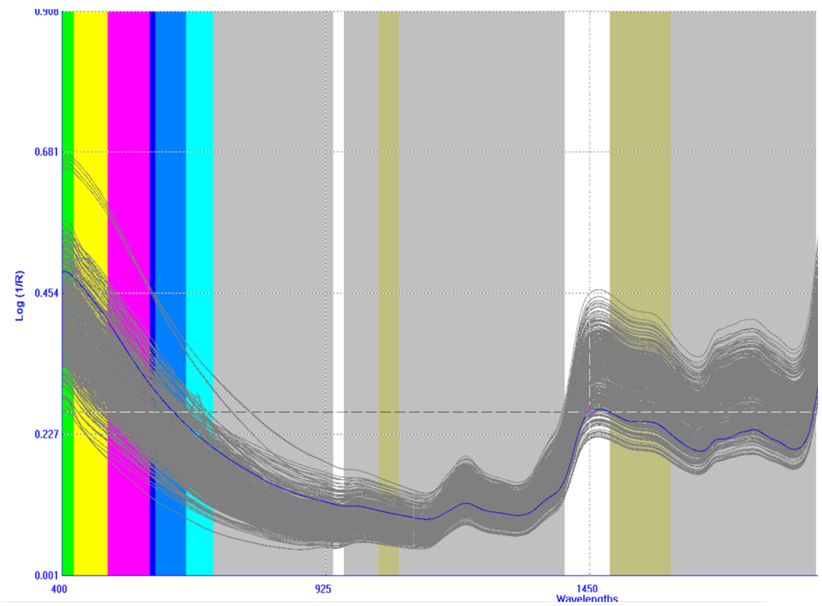
What is Near Infrared spectroscopy (NIRS)

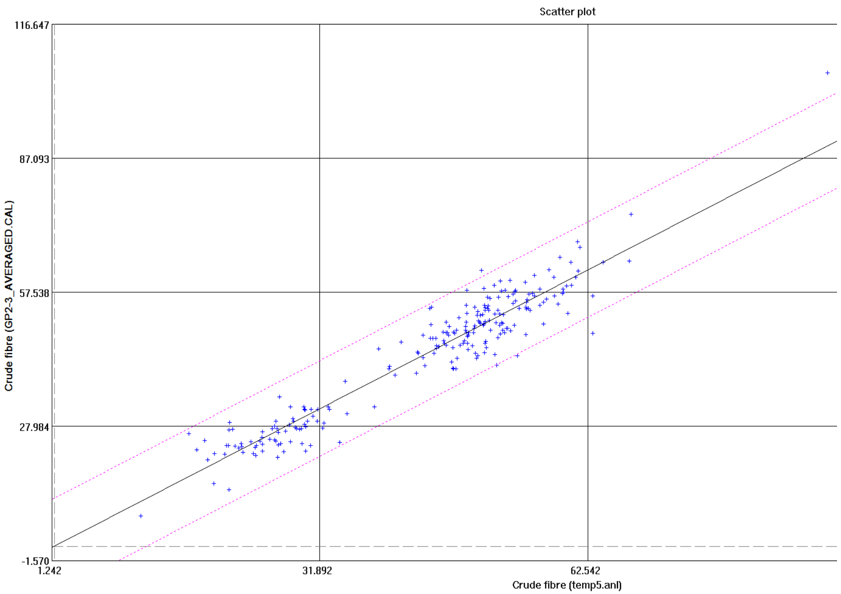


- NIR spectrum is just above the visible region of the electromagnetic spectrum (780-2500nm)
- Measurements in the NIR range in the spectrum contains complex chemical structural information due to differences in the way molecular bonds absorb and reflect energy.

NIRS predictions – reference based technique

- NIRS has been widely used to determine protein, moisture, starch, lipid, and ash content in feedstuffs.
- The spectra is used in combination with reference values to create an model to predict new values
  - Need a large number of samples with measurements





What we are modeling – The feedstuffs and feed mixtures

Samples	Scanned	Scanned and data available
Total	1309	857
Cereals	351	285
Cereal co-products	52	48
Cereal substitute	6	5
Protein concentrate	105	79
Grass meal	7	7
Fiber rich by-products	16	11
~~**Starches and sugars**~~	~~16~~	~~12~~
~~**Roughage**~~	~~5~~	~~5~~
~~**Animal products**~~	~~43~~	~~30~~
Miscellaneous	22	2
Feed mixtures	683	373

What we are modeling – the components

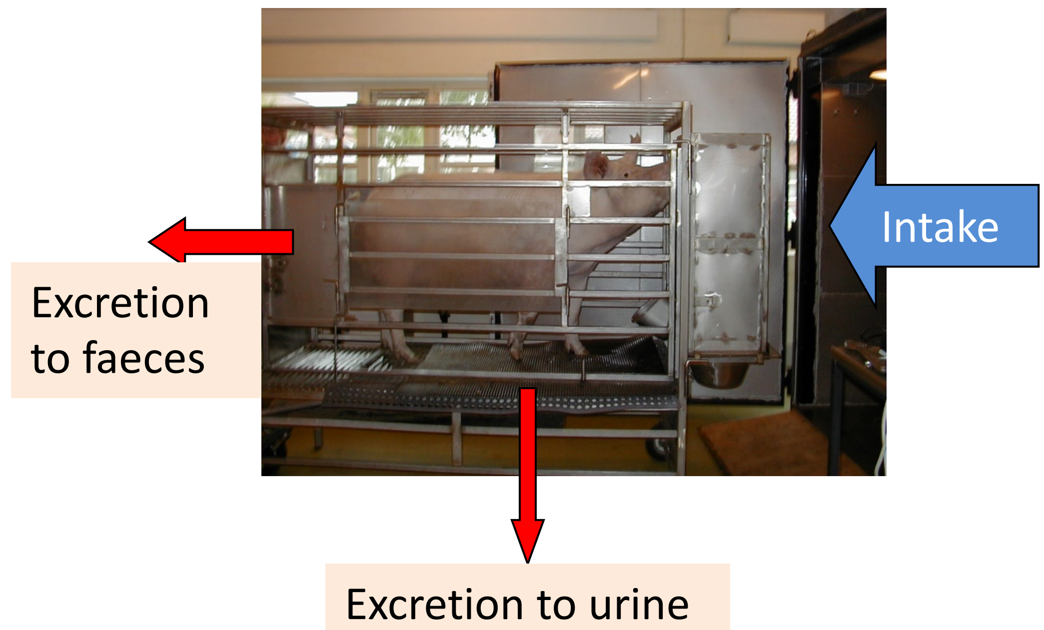
- Chemical components
  - Macronutrients:
    - Ash, Protein, Fat, Crude fibre, Available carbohydrates (starch + sugar), Neutral detergent fibre, Calculated dietary fibre, energy, tannin
  - Specific carbohydrates:
    - Sugars, oligosaccharides, starch, non-starch polysaccharides, cellulose, non-cellulosic polysaccharides, lignin, dietary fibre
  - Amino acids:
    - Lysine, methionine, threonine, ……
  - Minerals:
    - Ca, P, Mg, Na, K, Fe, Mn, Cu and Zn

What we are modeling – in vitro and in vivo data

- In vitro:
  - Enzyme digestible organic matter (EDOM), dry matter digestibility in nylon bags, protein digestibility in nylon bags
- In vivo:
  - Total tract digestibility of dry matter, organic matter, protein (apparent and true), fat, crude fibre, nitrogen free extracts (NFE), neutral detergent fibre, available carbohydrates (starch + sugars), calculated dietary fibre and energy.
  - Metabolisable energy (ME), ME correct to 50% of N retention, ME corrected to 0 N retention
  - Ileal digestibility in combination with total tract digestibility of organic matter, ash, protein, fat, crude fibre, energy, minerals, amino acids

The evaluation of feedstuffs and mixture

The **biological data** were generated in balance experiments with pigs where the total tract digestibility of energy (DE), protein, fat, crude fibre, dietary fibre, neutral detergent fibre, and nitrogen free extracts were determined.
The energy in urine was also determined enabling the determination of metabolizable energy (ME).
The experiments have been performed from 1975 and onward using the techniques described by Just (1982).



Amino acids

	Calibration			Validation		
Constituent	N CAL	RSQ CAL	SECV	N Val	RSQ VAL	SEP
CYS	395	**0.95**	0.44	94	**0.94**	0.44
LYS	395	**0.98**	1.3	94	**0.96**	1.05
MET	395	**0.97**	0.41	94	**0.94**	0.42
THR	395	**0.99**	0.71	94	**0.96**	0.68
TRP	163	**0.93**	0.45	37	**0.87**	0.45
Other AA	369-395	**0.91-0.99**		92-94	**0.92-0.97**	
CP	607	**0.98**	15.73	150	**0.95**	16.87

Model statistics for the digestibility of nutrient fractions

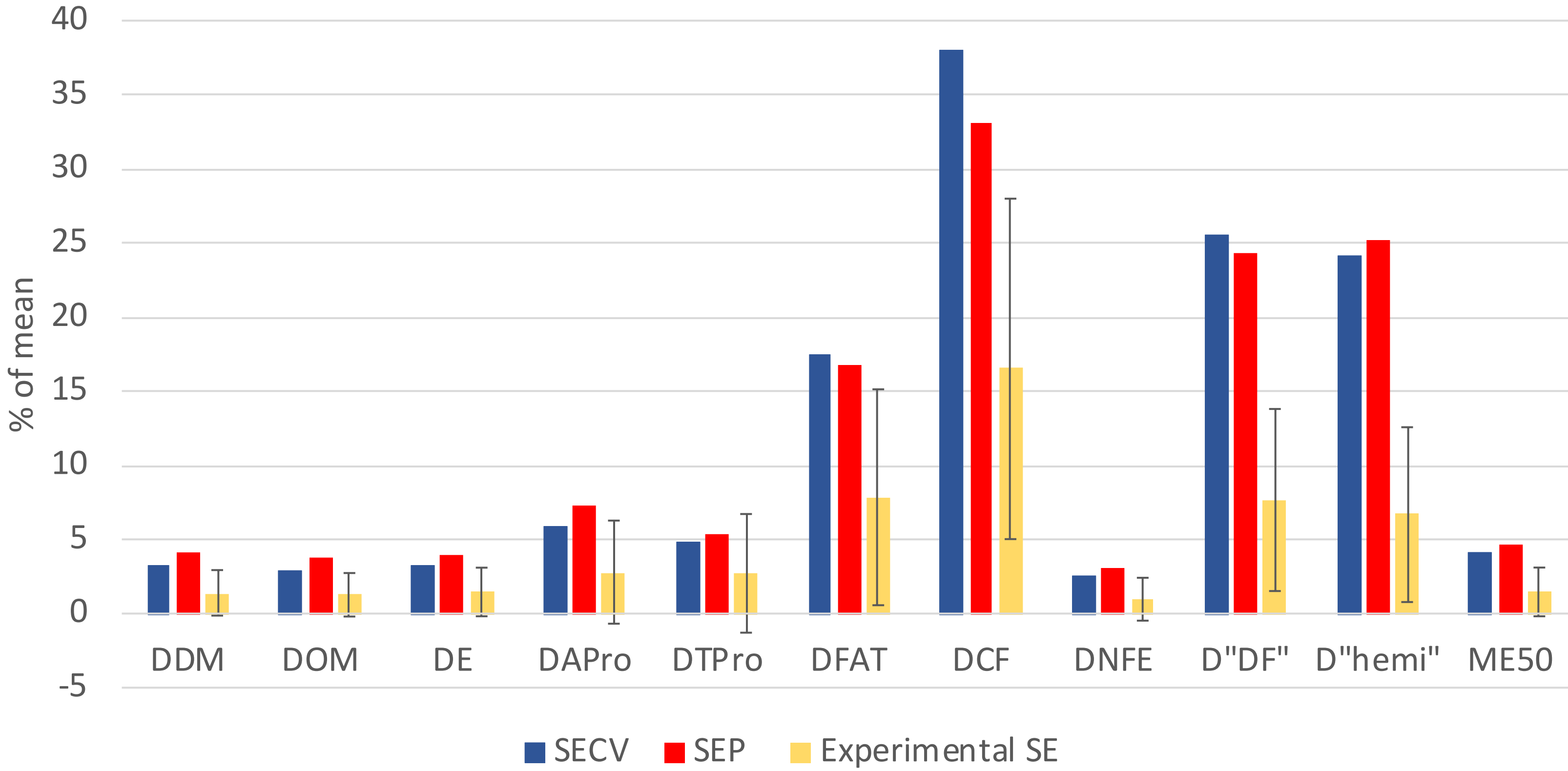
	Calibration					Validation			
Constituent	N	Factors	SEC	**RSQ**	SECV	N	SEP(C)	**RSQ**	RPD
DDM	552	8	2.45	**0.93**	2.68	136	3.36	**0.86**	2.73
DOM	545	10	2.15	**0.95**	2.45	136	3.13	**0.87**	2.94
DE	549	12	2.18	**0.94**	2.67	135	3.24	**0.86**	2.84
DAPro	520	15	3.46	**0.85**	4.62	130	5.66	**0.58**	1.60
DTPro	456	13	2.88	**0.9**	4.03	114	4.34	**0.75**	2.10
DFAT	472	10	7.39	**0.73**	8.99	122	8.63	**0.7**	1.66
DCF	419	9	9.4	**0.7**	11.34	100	9.92	**0.52**	1.73
DNFE	441	15	1.49	**0.97**	2.21	115	2.81	**0.91**	2.94
D"DF"	395	6	10.12	**0.63**	11.18	102	10.63	**0.5**	1.56
D"hemi"	393	4	11.48	**0.53**	12.02	102	12.57	**0.33**	1.34
ME50	528	12	118.23	**0.91**	141.67	130	162.75	**0.84**	2.45

DDM – digestible dry matter (% DM), DOM – digestible organic matter (% OM), DE – digestible energy, DAPro – digestible apparent protein (% AP), DTPro – digestible true protein (% TP), DFAT – digestible fat (% FAT), DNFE – digestible nitrogen free extract (% NFE), D"DF"– digestible calculated dietary fibre[1] (% "DF"), D"hemi" – digestible calculated hemicellulose[2] (% "hemi"), ME50 – metabolizable energy corrected to 50% of protein (KCAL/KgDM).

[1] Dietary fibre calculated by subtracting protein, ash, soluble carbohydrates and fat from dry matter.

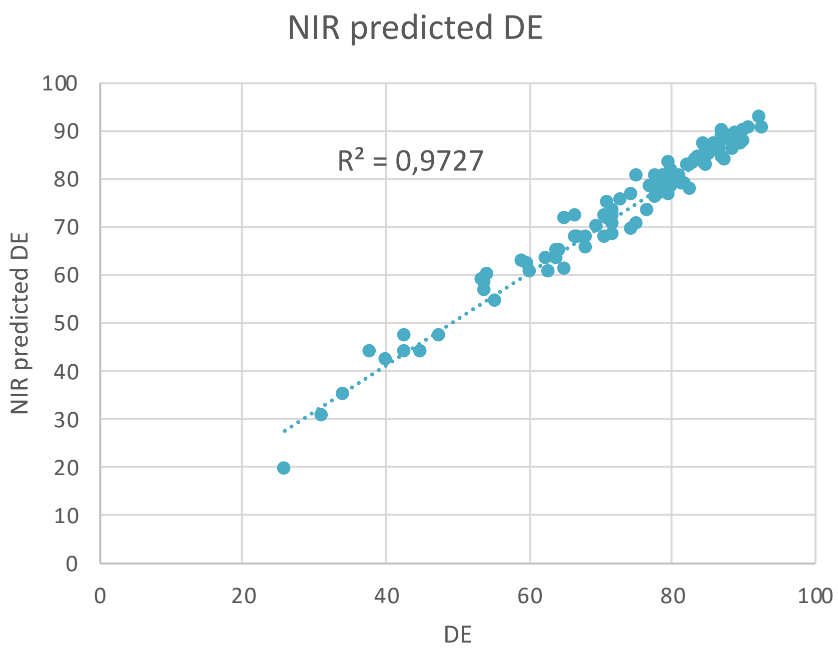
[2] Hemicellulose calculated by subtracting soluble carbohydrates from nitrogen free extract.

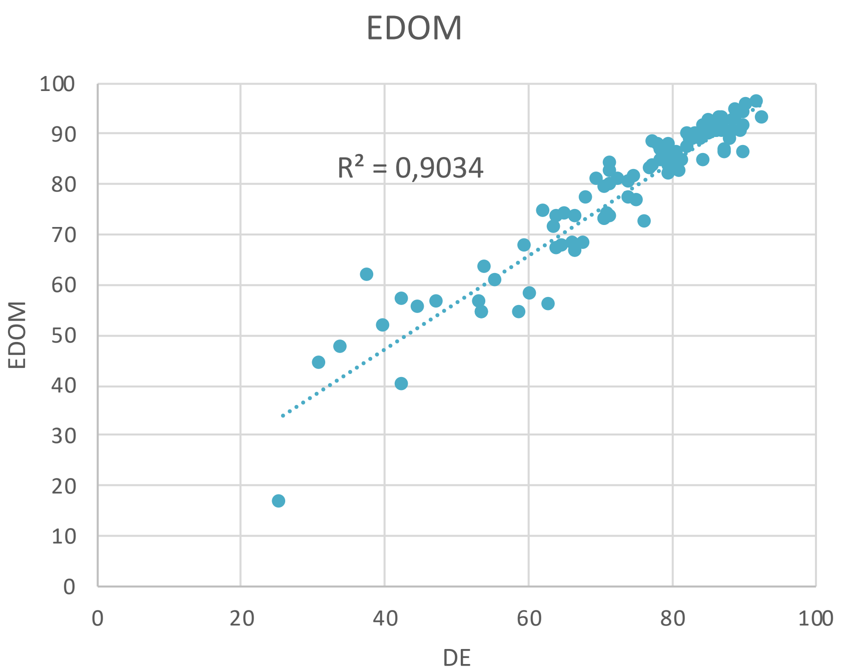
Relative standard error of digestibility of nutrient fractions



Relative standard error of NIR calibrations and measured digestibility values
SECV – standard error of cross validation of the NIR calibration as a percentage of the mean value.
SEP – standard error of prediction of the NIR calibration as a percentage of the mean value.
Experimental SE – average standard error from measured values of digestibility as a percentage of the mean value. Error bars represent ± one SD.

NIR prediction of DE vs EDOM method

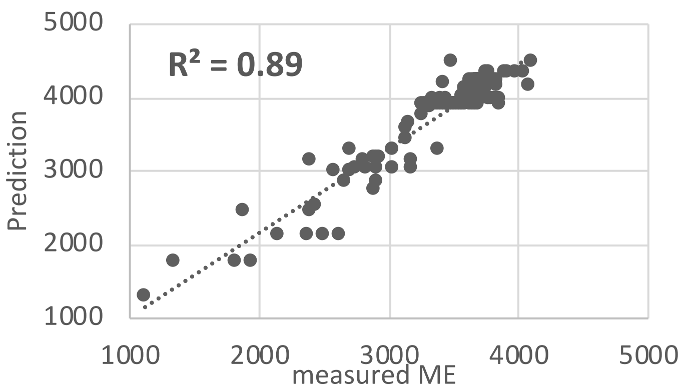




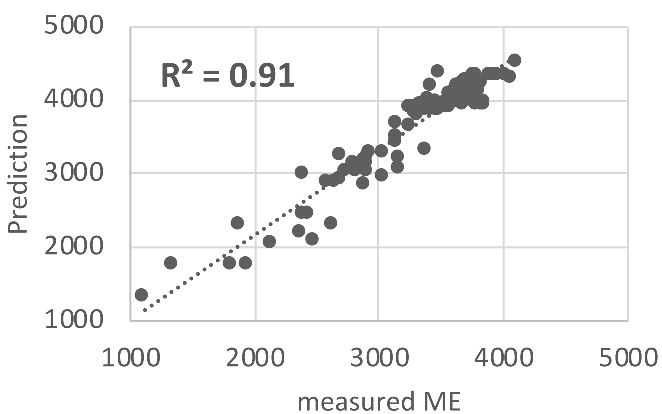
Plots made from the 103 samples that have both DE and EDOM measured values

Metabolisable energy predictions, table values vs NIR

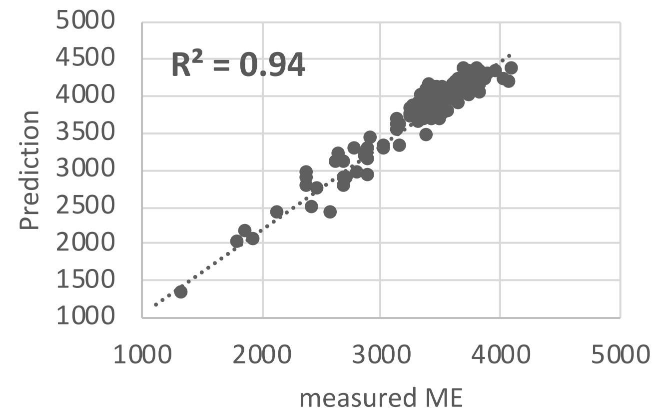
1. eME calculated from table value components and table digestibility estimates



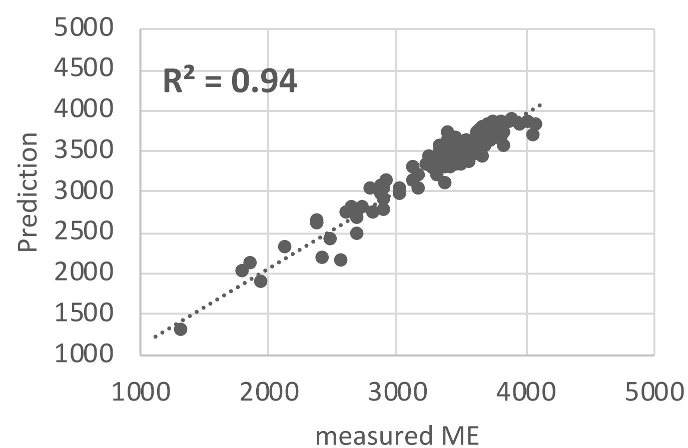
2. eME calculated from measured components and table digestibility estimates



3. eME calculated from NIR estimated components and NIR digestibility estimates



4. ME estimated directly from NIR calibration



Conclusions

- NIRs can be used to estimate both chemical and biological values for pig feed.
- Models are working well for most constituents examined here.
- NIR predictions of digestible energy are better than estimates from in vitro-digestibility (EDOM).
- NIR predictions of metabolisable energy are better than using table values

Future perspectives