Faecal Near Infrared Spectroscopy (F.NIRS)

An alternative approach to estimate the quality and composition of feed ingested by free-ranging livestock

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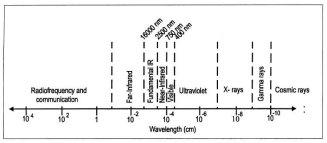
What is near-infrared reflectance spectroscopy (NIRS)?

- Near-Infrared = 750 – 2500 nm
- NIR energy = movements of bonds
- molecule bonds absorb light
- main groups: O-H, C-H, N-H, C=O

Electromagnetic spectrum showing the position of near-IR (Foley et al., 1998)



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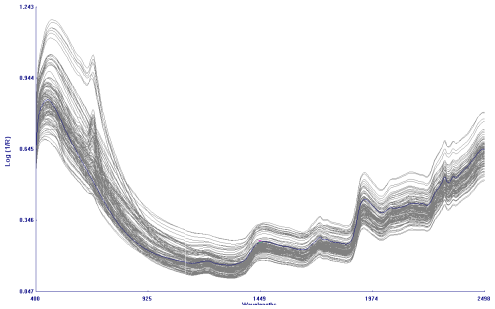
→ **reflectance is measured**

NIR spectra are not only influenced by chemistry of a material, but also by it's physical structure

What is near-infrared reflectance spectroscopy (NIRS)?



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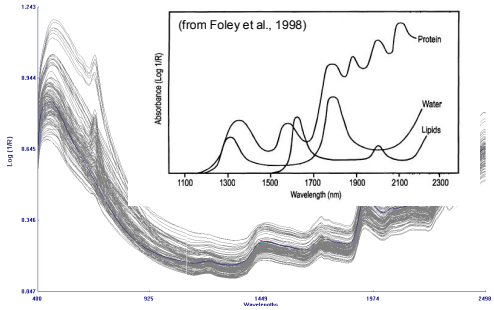


What is near-infrared reflectance spectroscopy (NIRS)?

- measured spectra are combined with "real" information (lab values)
- multivariate analysis methods like Multi linear regression, Stepwise regression or Partial least square regression are used to "translate" the spectra information
- "real" information (measured values) are combined with spectra information = calibration
- calibration equations need to be validated either on independent data sets or by cross-validation procedures
- such equations allow to predict certain characteristics of samples from the spectra only → no need of lab analysis

Advantages of NIRS: non-destructive, small sample sizes, fast, low cost, no chemical wastes

What is near-infrared reflectance spectroscopy (NIRS)?

NIRS in Agricultural Sciences

- first application on protein content of grain in the late 1960's
- used today to assess the chemical composition of feeds and agricultural products, e.g. protein content, fermentation products in silages, fat content in milk, gas production potential in biogas plants, …

→ **Faecal NIRS**

Faecal near-infrared reflectance spectroscopy (NIRS)

F.NIRS – which parameters have been estimated?

3 fields of usage:

- Measure composition of faeces, mixed excreta or of compost
- Estimate animal species and physiology in respect of gender, reproductive status and parasite burden
- Estimate attributes of the diet (chemical composition, digestibility, intake, …)

Faecal near-infrared reflectance spectroscopy (NIRS)

F.NIRS – which parameters have been estimated?

Main objective:
directly relate faecal NIR spectra to attributes of the diet to improve the understanding of the nutrition and ecology of free-ranging animals

important attributes of diets selected by free-ranging animals:

- → nutritional value of selected diet (e.g. crude protein content, digestibility, energy content)
- → voluntary feed intake
- → botanical composition of the diet

Faecal near-infrared reflectance spectroscopy (NIRS)

F.NIRS applied to several animal species:

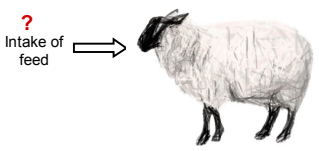
- → successful application in:
  - small ruminants (Leite & Stuth, 1995; Fanchone et al., 2007, Li et al., 2007)
  - cattle (Lyons & Stuth, 1992; Decruyenaere et al., 2002; Boval et al., 2004)
  - deer and elk (Keating, 2005; Showers et al., 2006)
- → use in non-ruminants is rare:
  - donkey (Kidane, 2005) and ostrich (Landau et al., 2006)
  - pig (Schiborra et al., 2010)

Use F.NIRS to estimate DOM and chemical composition of the diet in free-ranging pigs

Research questions:

- How to measure the intake of free-ranging pigs?
- How to assess the chemical composition of the ingested feed?

How to estimate intake of free-ranging animals?



Digestibility = (I-F) / I

Digestibility (%) = (I-F) / I x 100

(**I** = Intake; **F** = **F**aecal output; **D** = Diet **D**igestibility)

How to estimate intake of free-ranging animals?

Digestibility **= (I-F) / I** ↔ **I**ntake **= F / (1-D)**

(**I** = **I**ntake; **F** = **F**aecal output; **D** = Diet **D**igestibility)

to determine intake by this formula, we need to known:

- faecal output
- digestibility of feed ingested

How to determine faecal output?

- total collection using faeces bags

- laborious
- danger that animals lose bags
- feeding behaviour influenced by bags
- skin lesions → animal welfare
- only male animals can be used

How to determine faecal output?

- estimation from external markers

characteristics of marker substances:

- must be indigestible
- must distribute evenly in the gastro-intestinal tract of the animal, no accumulation
- must be recoverable in faeces

external markers: Cr_2O_3, TiO_2, rare earth elements (e.g. Ytterbium), *n*-alkanes, …

→ supplied via capsules, paper pellets, marked fibre, ruminal controlled-release devices, etc.

How to determine faecal output?

- estimation from external markers

$$F = M_d / M_f$$

F = faecal output

M_d = daily dose of marker

M_f = concentration of the indigestible marker in faeces

→ only small amounts of faeces are needed, just enough to allow the analysis of the marker concentration

- observe the animal → take a samples directly after defecation
- take a grab sample directly from the rectum

How to determine digestibility?

generally the **accuracy of intake estimation** is **limited to a greater extend by estimation of digestibility** than of faecal output (Gordon, 1995)

- *In vivo* determination: direct determination of feed intake and faecal output (metabolic cages)
  → not applicable for free-ranging livestock
- *In vitro* determination: laboratory analysis of feed samples (e.g. gas test, Tilley & Terry method, Cellulase method)

problem: how to get representative samples?

→ clipped herbage samples, hand plucked material, extrusa samples from oesophagus fistula

How to determine the digestibility of feed ingested by free-ranging livestock?

several indirect methods are available to estimate organic matter digestibility (DOM) of ingested feed, e.g.:

- Faecal-nitrogen method
  (Boval et al., 2003; Lukas et al., 2005; Wang et al., 2009)
- *n*-alkanes
  (Dove & Mayes, 1991; 2005; Bulang et al., 2010)
- Faecal near-infrared reflectance spectroscopy (NIRS)
  (Leite & Stuth, 1995; Fanchone et al., 2007; Dixon & Coates, 2009)

→ all these methods are based on reliable calibrations with data obtained in *in vivo* experiments

Use F.NIRS to estimate DOM and chemical composition of the diet in free-ranging pigs

Material & Methods

- 210 faecal samples that were obtained in several *in vivo* experiments in Germany, Nigeria and China were available

samples	Kiel	Nigeria	Halle	China	Braunschweig
n	60	30	32	19	69
breed	LW[1] x DL[2]	LW x Duroc	[DL x LW] x Pietrain	LW	LW[1] x DL[2]
weight	~ 30 kg	~35 kg	40-70 kg	~ 35 kg	40-70 kg
no. of diets	8	8	8	3	8
dominant feedstuffs	wheat (w), w gluten, w bran, soybean meal (SEM), corn starch, w bran fibre, rape seed fibre, cassava leaf fibre, cassava root peel fibre	corn, SEM, cassava leaves, cassava peel, fermented, cassava peel, shrimp waste	barley, w bran, molassed beat pulp, barley, soybean meal, lucerne	banana pseudostem, corn, banana leaves	w, barley, peas, DDGS, SEM, corn
in vivo digestibility	76-90%	72-87%	68-89%	31-85%	77-92%

[1] LW = Large White; [2] DL = German Landrace

Material & Methods

- 210 faecal samples that were obtained in several *in vivo* experiments in Germany, Nigeria and China were available
- faecal samples were scanned with a FOSS NIRSystems spectrometer
- reflectance was measured between 400-2500 nm (VIS-NIR), at 2 nm intervals
- cross-validation equations were calculated by modified partial least-squares regression (MPLS) using WinISI software
- 1st or 2nd derivatives were used, scatter correction SNV and detrend procedures were applied

Material & Methods

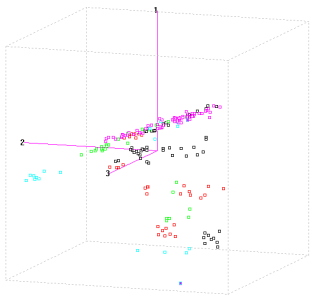
- to assess the quality of the cross-validation equations the following criteria are used:

good prediction = R^2 > 0.9, slope 0.9 - 1.1, RSC > 2

satisfactory prediction = $R^2 \geq 0.8$, slope 0.8 – 1.2, 1.4 ≤ RSC ≥ 2

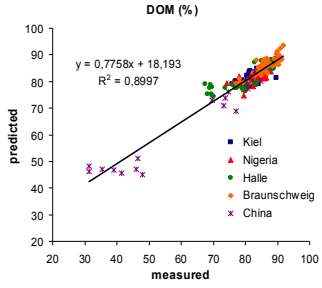
(RSC value = ratio of SD of the laboratory results to SE of cross-validation)

Results



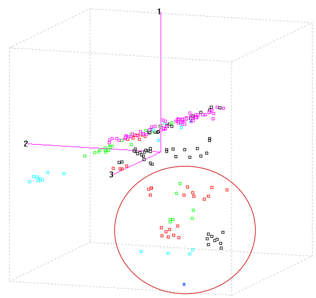
Sample set (n=210) after principle component analysis (PCA) showing the first 3 components

Results



R^2 = 0.9; slope = 0.78; RSC = 2.52

Results



Sample set (n=210) after principle component analysis (PCA)
showing the first 3 components

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Results

→ **Calibration of the reduced data set** (n=169)

excluded:

9 samples from Kiel (cassava leaf diet)

7 samples from Nigeria (cassava leaf diet)

20 samples from Halle (commercial feed)

5 samples from China (basal diet + banana leaves)

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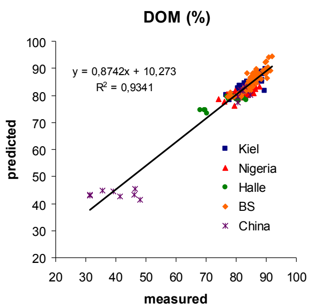
Results



R^2 = 0.93; slope = 0.87; RSC = 3.21

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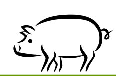
Conclusions

- estimation of DOM by NIRS of faeces from growing pigs is possible with good accuracy
- data are missing of diets with low to intermediate DOM to further improve the equation
- it is not clear yet, if a generally applicable equation can be established
- estimation of chemical composition of the pig's diets from faeces is possible
- quality and robustness of calibrations depends on the quality and size of the data base



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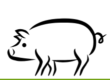

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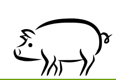

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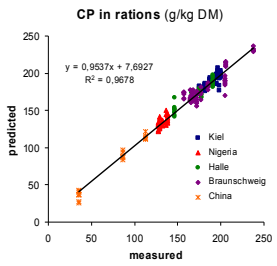
Results

Predicting the crude protein content of the ingested diet from faeces (n=210)



R² = 0.97; slope = 0.95; RSC = 4.42

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Outlook

- validate and extend the established equation for DOM prediction from pig faeces with further *in vivo* data
- test the equation in a field experiment → estimate intake

- explore the possibilities to estimate the botanical composition (= selection) of grazing ruminants by F.NIRS

Thank you for your attention!

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