REDNEX

PRIFYSGOL ABERYSTWYTH UNIVERSITY

IBERS

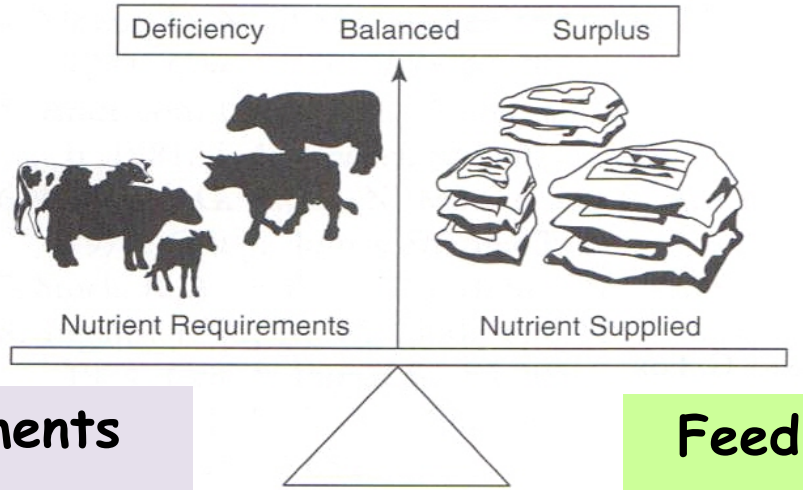
Prediction of CP concentration and rumen degradability by Fourier Transform Infrared Spectroscopy (FTIR)

Belanche A., G.G. Allison, C.J. Newbold, M.R. Weisbjerg and J.M. Moorby

EAAP meeting, 27 August, Bratislava (Slovakia)

Introduction

Optimize the ruminant nutrition



Animal requirements

-In:
- -Energy
- -Protein (digestible)

-Depends on:
- -Physiological state (Mant. Grow. Preg.)
- -Animal performance
- -Others (BW, °C, activity, etc.)

-Estimation
- -"*Trial and error*" (production data)
- -Tables (INRA, AFRC, NRC, etc)

Feed nutritional value

-Tables of feed evaluation
- -Ingredients in the diet?
- -Broad approach

-Chemical analysis
- -Expensive
- -No degradability data

-*In situ* degradability

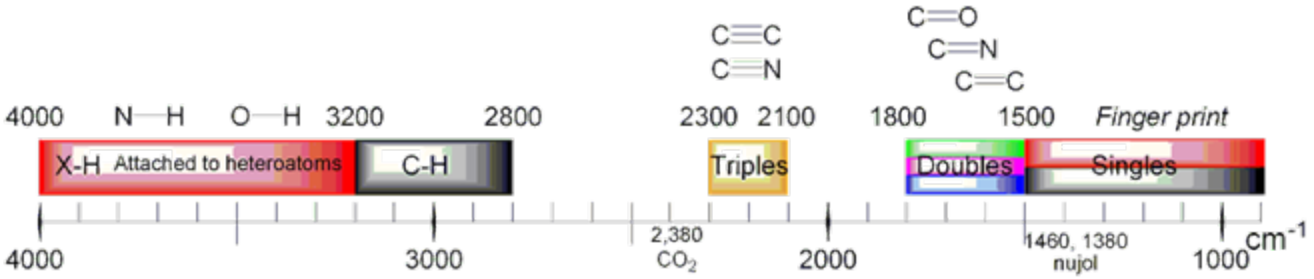
-Alternatives
- -Accurate prediction
- -Simple and cost-effective

Infrared Spectroscopy

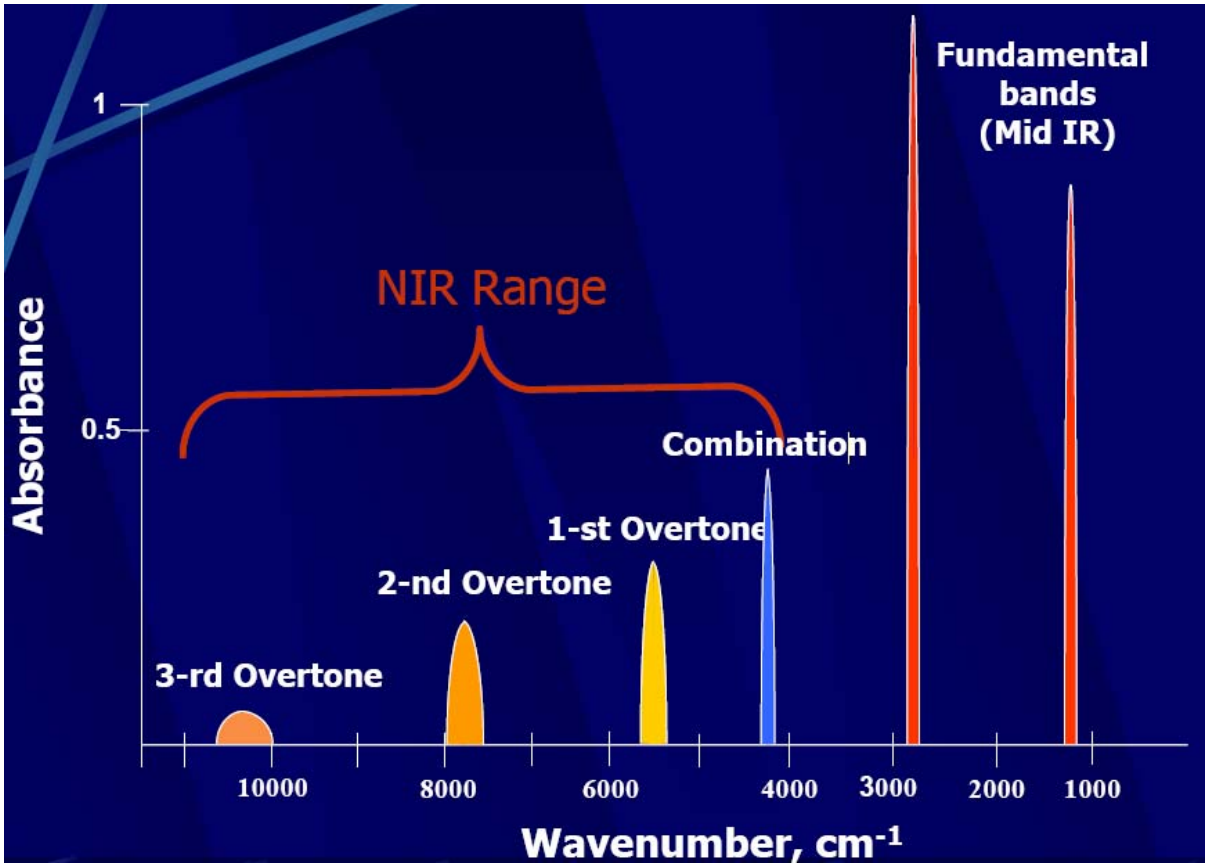
neurologists

volcanologists

nutritionists



NIR vs. FTIR



Objectives:

1) Investigate whether FTIR spectra differ between feeds

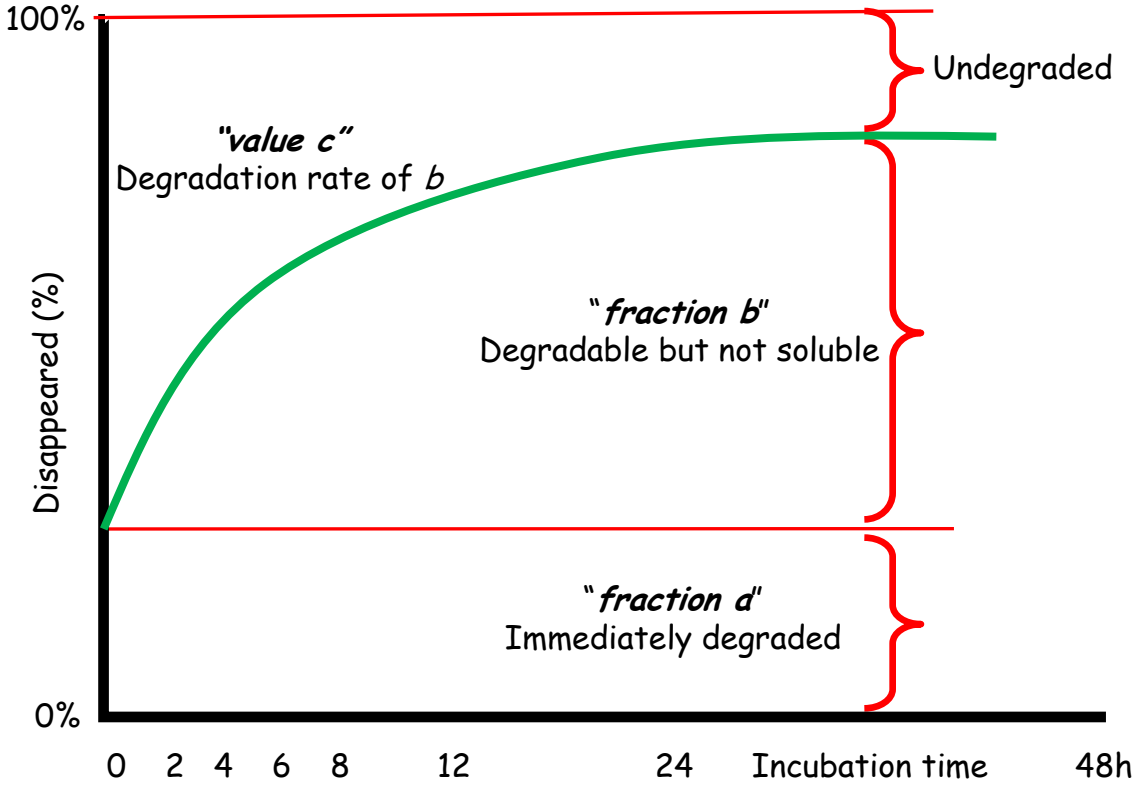
2) Evaluation the potential of FTIR spectrometry to predict the CP concentration and rumen degradability

Dataset = 786 samples (80 different feeds)

38 Barley-wheat forage	**111 Grass-clover forage**	**39 Legume forage**	**200 Oil by products**
10 Barley whole crop	36 Grass-clover forage	12 Lupinus whole crop	112 Rapeseed
10 Winter wheat whole crop	26 Grass silage	7 Lucerne forage	42 Soybean
8 Winter wheat silage	16 Grass-clover silage	5 Peas whole crop forage	25 Sunflower
4 Barley whole crop silage	14 Grass forage	4 Peas whole crop silage	12 Cotton seed
4 Green barley forage	7 Artificial-dry grass	4 Galega forage	2 Soypass
2 Barley straw	8 Clover forage	4 Field beans whole crop	2 Treated soybean meal
	2 Grass straw	2 Artificial dry lucerne	4 Others
	2 Festulolium forage	1 Peas straw	
18 Mill by products	**63 Cereal grains**	**18 Legume seeds**	**17 Protein products**
7 Maize gluten feed	30 Barley	7 Peas	7 Guar meal
4 Maize feed meal	12 Wheat	3 Soybean	5 Malt sprouts
3 Wheat gluten feed	7 Rye	3 Toasted soybean	3 Brewers grains
2 Wheat bran	5 Triticale	2 Rapeseed	2 Potato protein
2 Amyfeed	4 Oat	2 Lupinus	
	3 Maize	1 Field beans	
	2 Grain mix		
22 Maize silage	**32 Maize forage**	**22 Beets**	**35 Distillers**
22 Maize silage		14 Dry sugar beet pulp	28 Corn distillers
2 Maize silage with pulp		6 Fodder beets	5 Wheat distillers
		2 Beet pulp	2 Barley distillers
16 Soybean hulls	**127 Concentrate mix**	**19 Total mixed ration**	**9 Tropical feeds**

Protein nutritional value of feeds

Parameter	Abbreviation	Method
Crude protein	*CP*	Kjeldahl
Water soluble CP	CP_{WS}	Water
Total tract CP digestibility	CP_{TTD}	Mobile bag (Duodenum-faeces)
Rumen degradation pattern	*a, b, c* and CP_{ED}	*In situ* or *in sacco* method



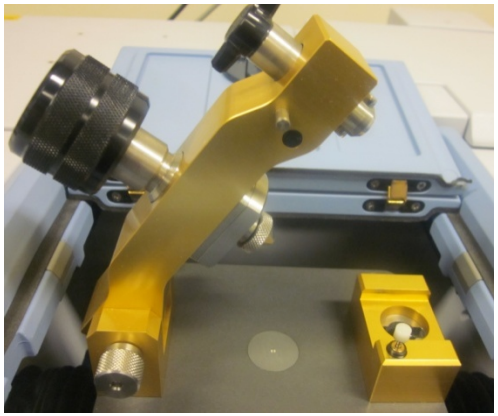
Effective degradability

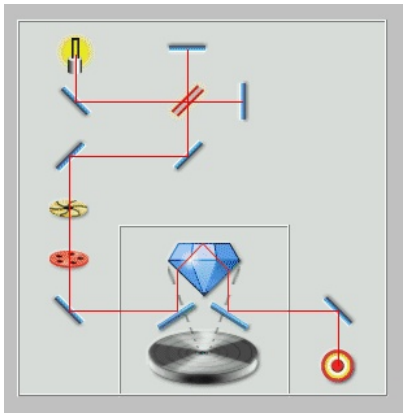
$CP_{ED} = a + b\,[c / (c + k)]$

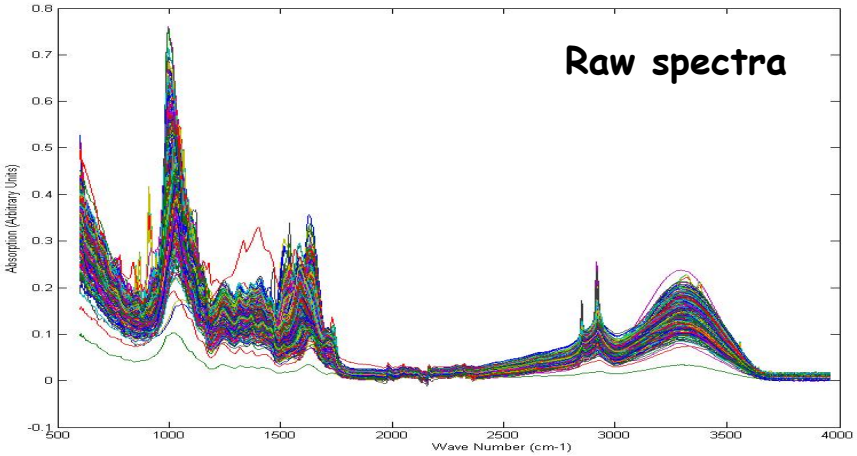
k= rumen outflow rate = 5%/h
RRT=20h

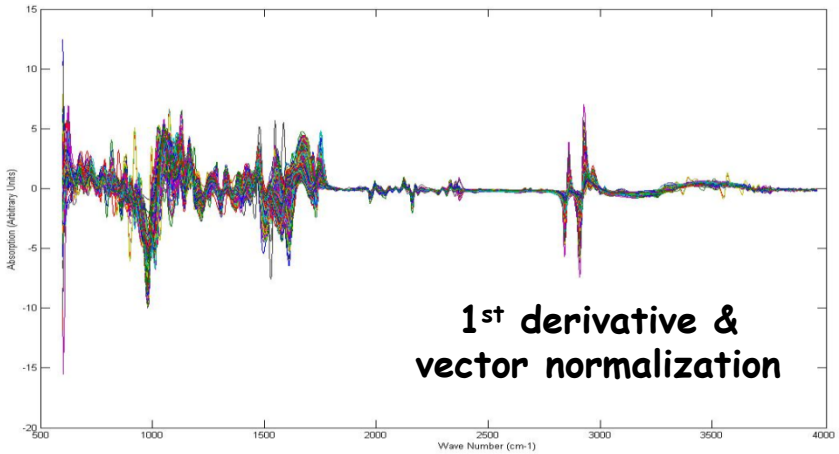
FTIR analysis

- **Sample preparation:**
  - Dry at 60°C and milled at 1.5 mm diameter
- **FTIR analysis:**
  - Equinox 55 FTIR spectrometer fitted with a Golden Gate ATR accessory
  - Wavelength: 500 to 4000 cm^{-1} (resolution $2cm^{-1}$)
  - 64 scans per sample in duplicate









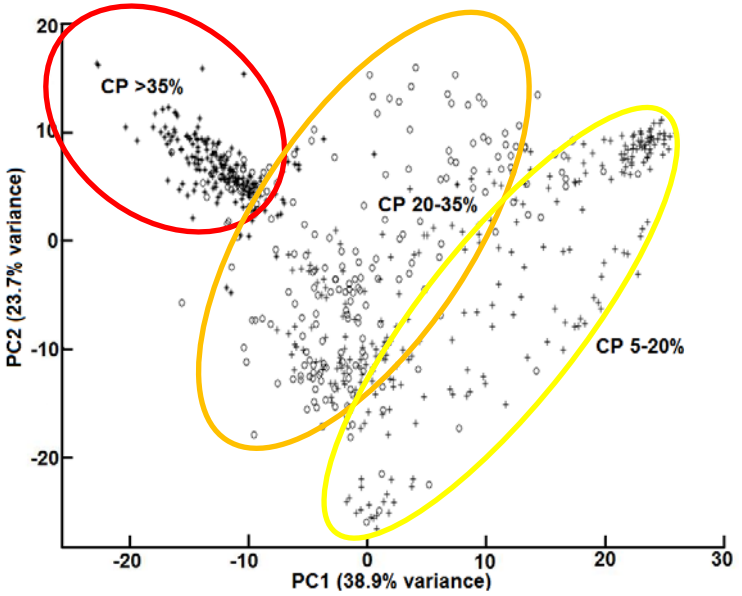
Modelling

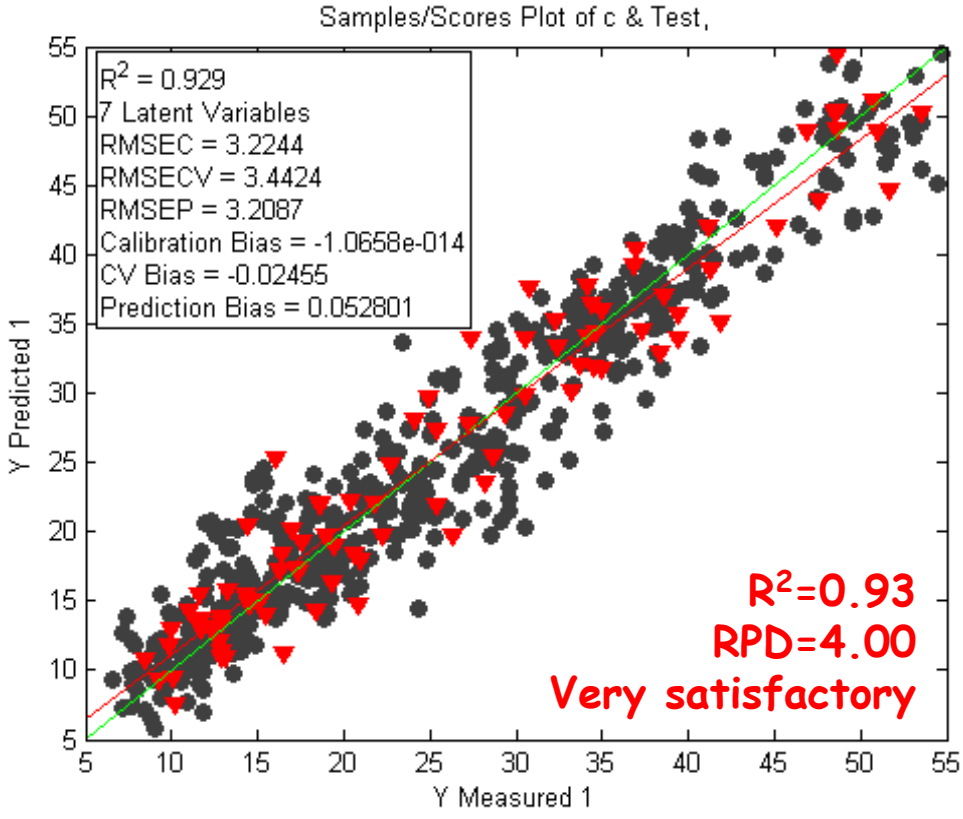
- **Metadata (*n*=663)**
  - Mean centre scaled
- **Spectral data**
  - Calibration dataset (85% samples)
  - Validation dataset (15% samples)
- **Prediction models**
  - Partial Least Squares (PLS-Matlab)
  - Data transformation (de-trend, SNV, MSC)
    - 1st or 2nd derivative
    - Vector normalized (mean=0, variance=1SD)
    - Mean centre scale
  - Outliers (high hotelling, Q residuals, >3SD)
  - Cross validation ("Venetian Blinds")
  - Number of LV chosen to minimize RMSECV
  - Model accuracy (R^2 & RPD=SD/SEP)
    - Very satisfactory $R^2 > 0.90$ & RPD > 3.0
    - Satisfactory: $R^2 > 0.80$ & RPD > 2.5
    - For screening: $R^2 > 0.70$ & RPD > 2.0
    - Inaccurate: $R^2 < 0.70$ & RPD < 2.0

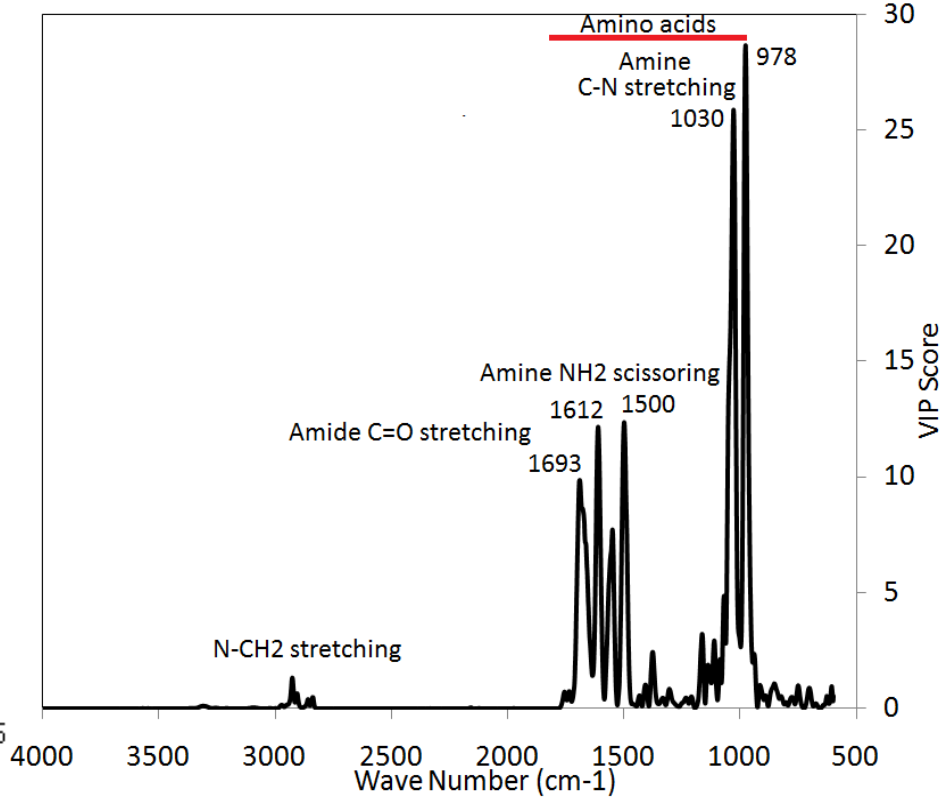
Universal model

% CP

(*n* = 655)



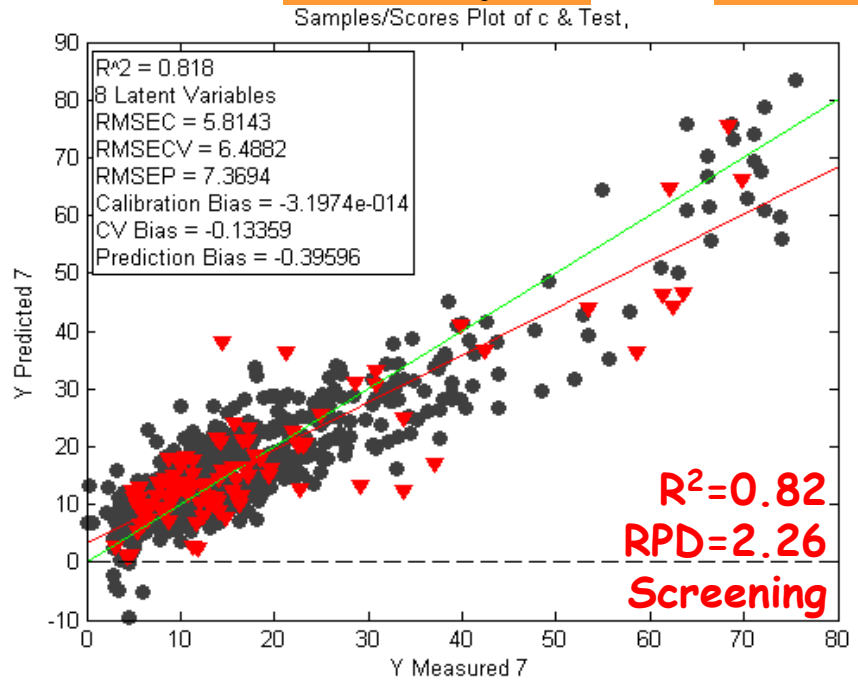


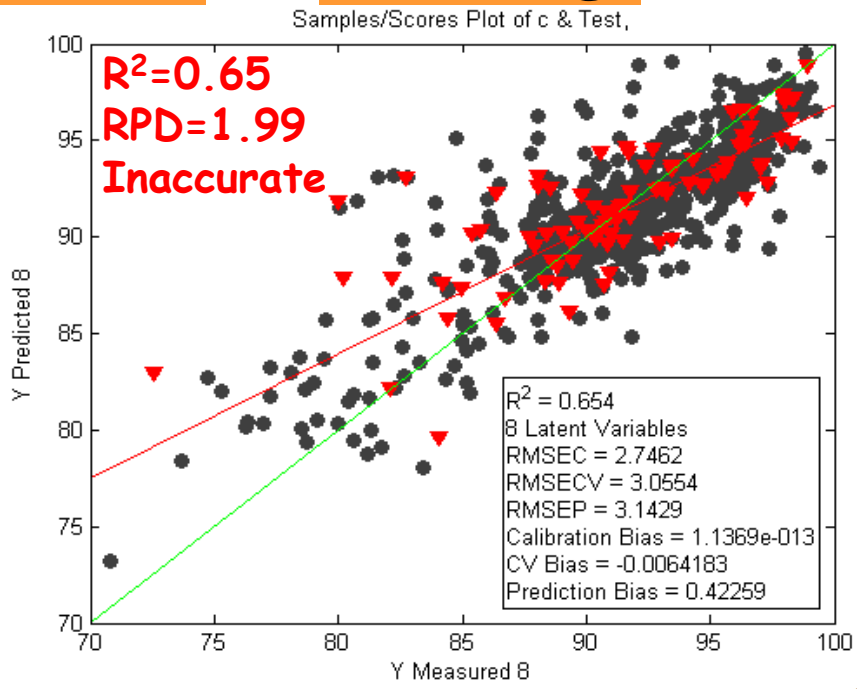


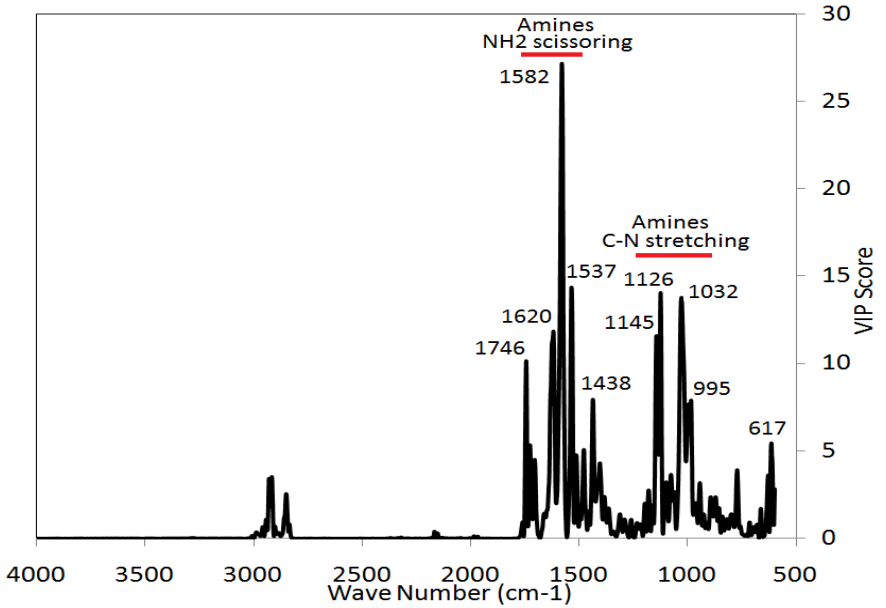
CP_{WS}

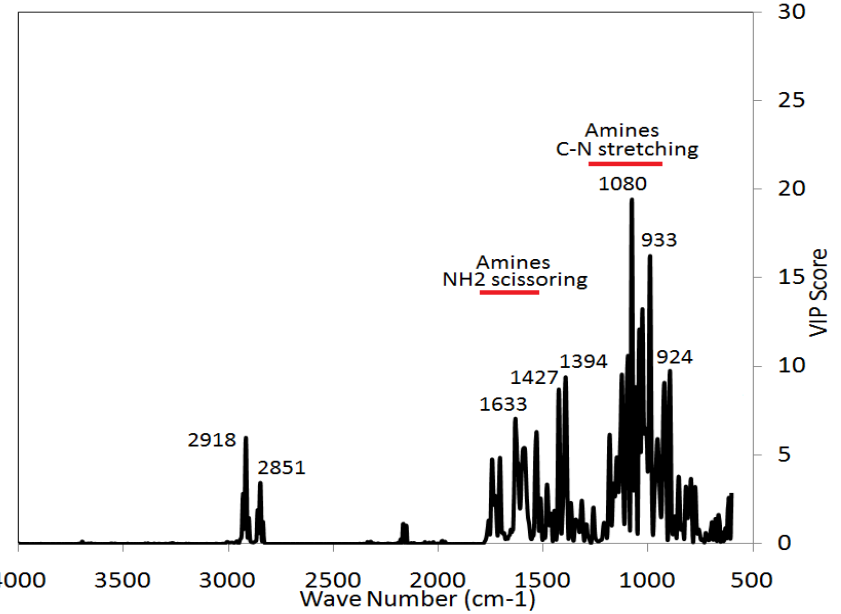
Universal models (n =655)

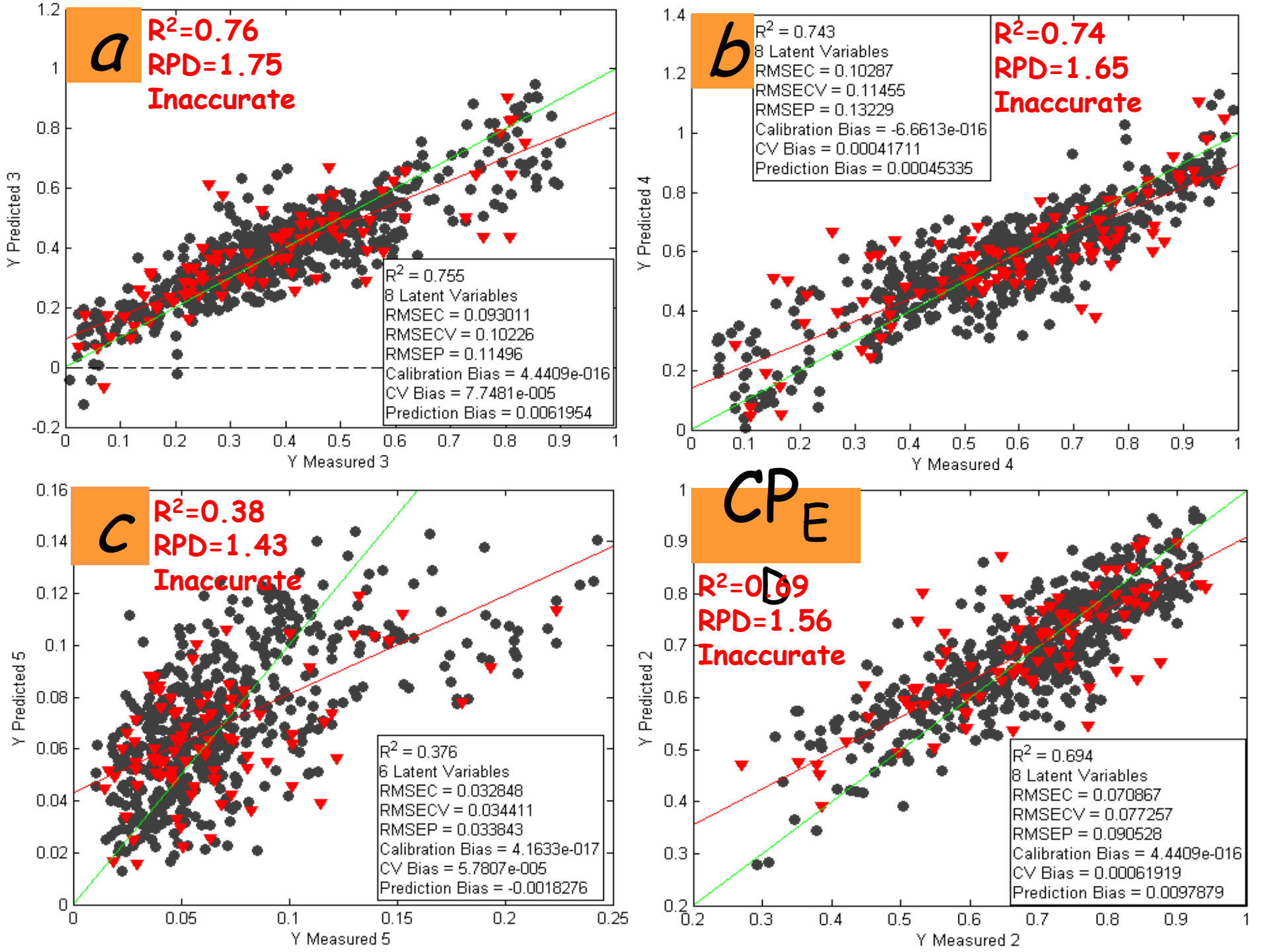
CP_{TTD}



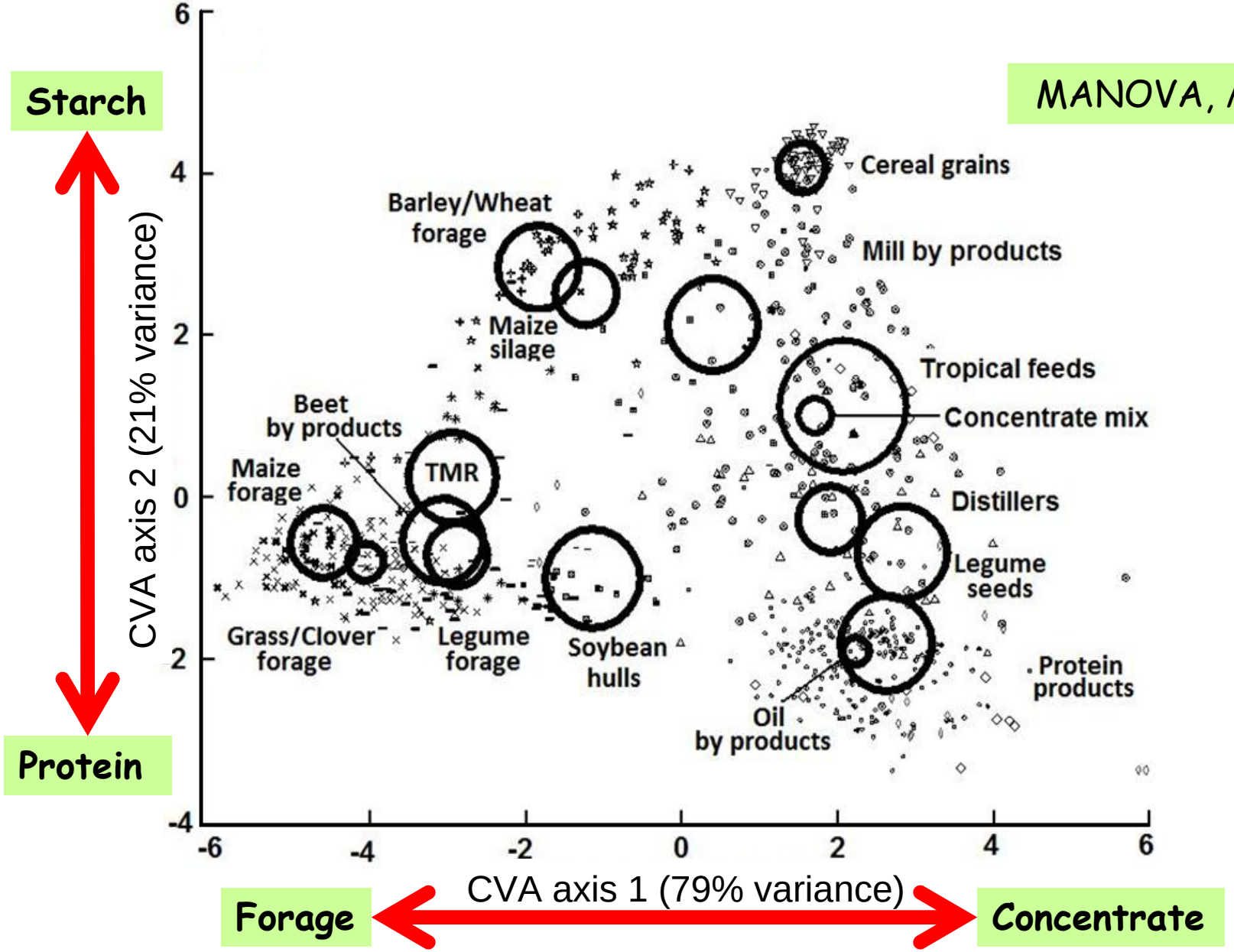




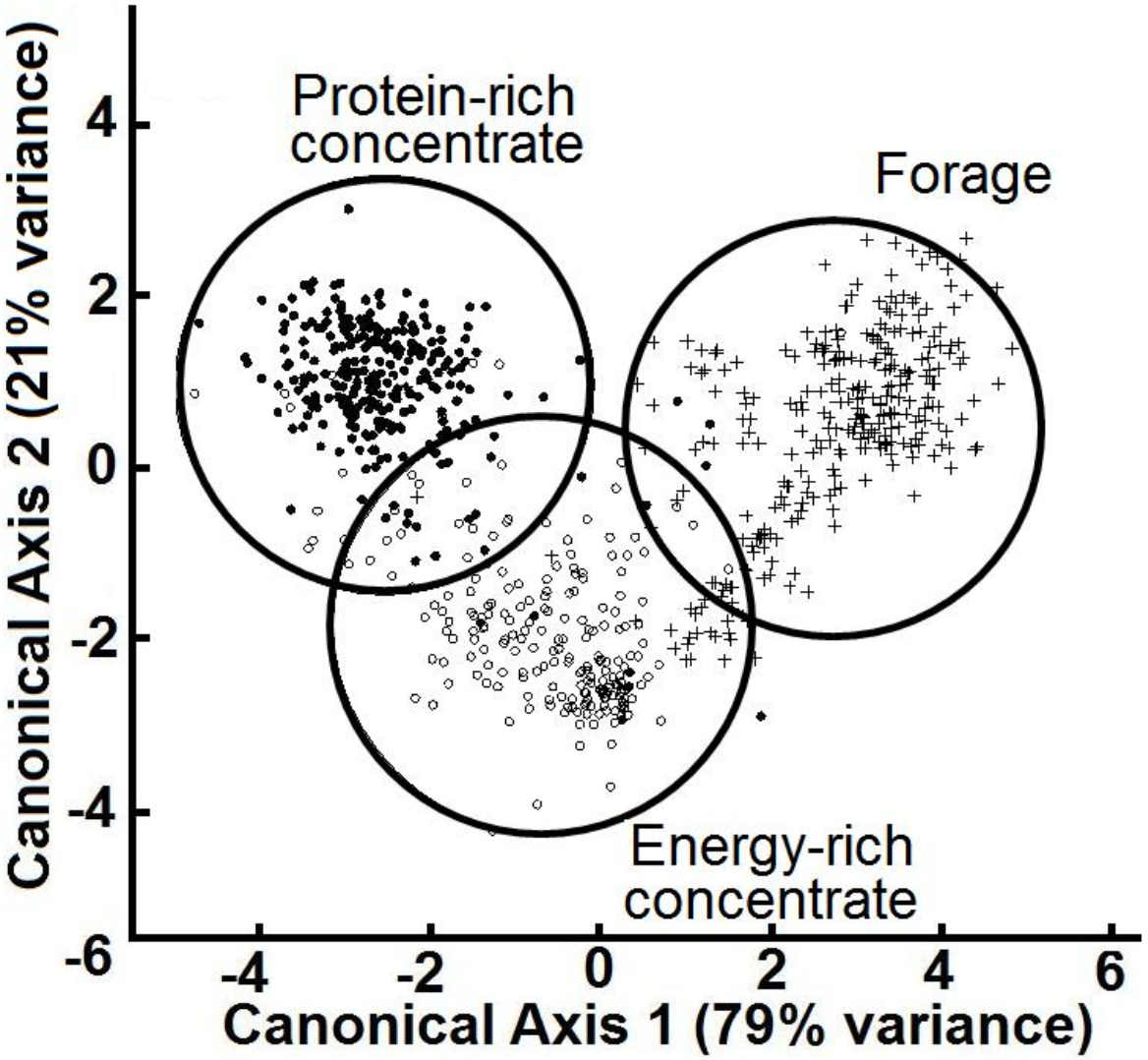



a
R²=0.76
RPD=1.75
Inaccurate
R² = 0.755
8 Latent Variables
RMSEC = 0.093011
RMSECV = 0.10226
RMSEP = 0.11496
Calibration Bias = 4.4409e-016
CV Bias = 7.7481e-005
Prediction Bias = 0.0061954
Y Predicted 3
Y Measured 3
b
R² = 0.743
8 Latent Variables
RMSEC = 0.10287
RMSECV = 0.11455
RMSEP = 0.13229
Calibration Bias = -6.6613e-016
CV Bias = 0.00041711
Prediction Bias = 0.00045335
R²=0.74
RPD=1.65
Inaccurate
Y Predicted 4
Y Measured 4
c
R²=0.38
RPD=1.43
Inaccurate
R² = 0.376
6 Latent Variables
RMSEC = 0.032848
RMSECV = 0.034411
RMSEP = 0.033843
Calibration Bias = 4.1633e-017
CV Bias = 5.7807e-005
Prediction Bias = -0.0018276
Y Predicted 5
Y Measured 5
CP E
R²=0.69
RPD=1.56
Inaccurate
R² = 0.694
8 Latent Variables
RMSEC = 0.070867
RMSECV = 0.077257
RMSEP = 0.090528
Calibration Bias = 4.4409e-016
CV Bias = 0.00061919
Prediction Bias = 0.0097879
Y Predicted 2
Y Measured 2

Canonical analysis of variance (10 PCs = 90%var)



Feeds classification



FORAGES

Barley-wheat forage

Grass-clover forage

Maize forage

Legume forage

Total mixed ration

Soybean hulls

Beets

ENERGY-RICH concentrates

Cereal grains

Mill by products

Tropical feeds

Concentrate mix

PROTEIN-RICH concentrates

Legume seeds

Protein products (>30%CP)

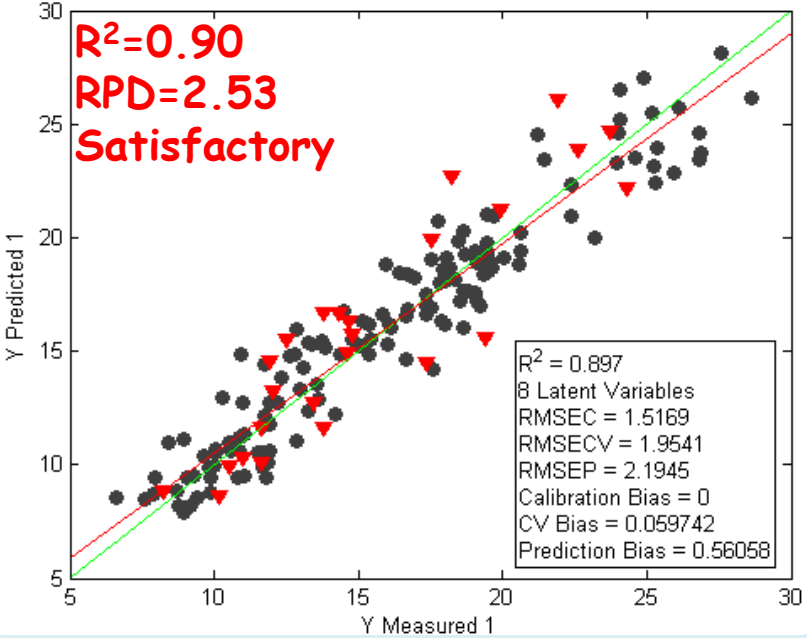
Oil by products

Dried distiller grains (DGGS)

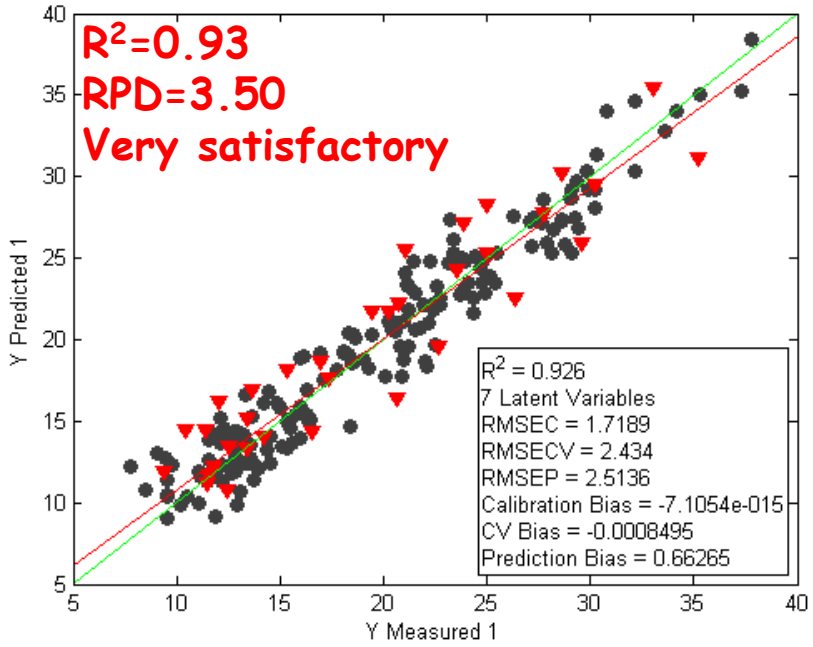
% CP

Crude protein

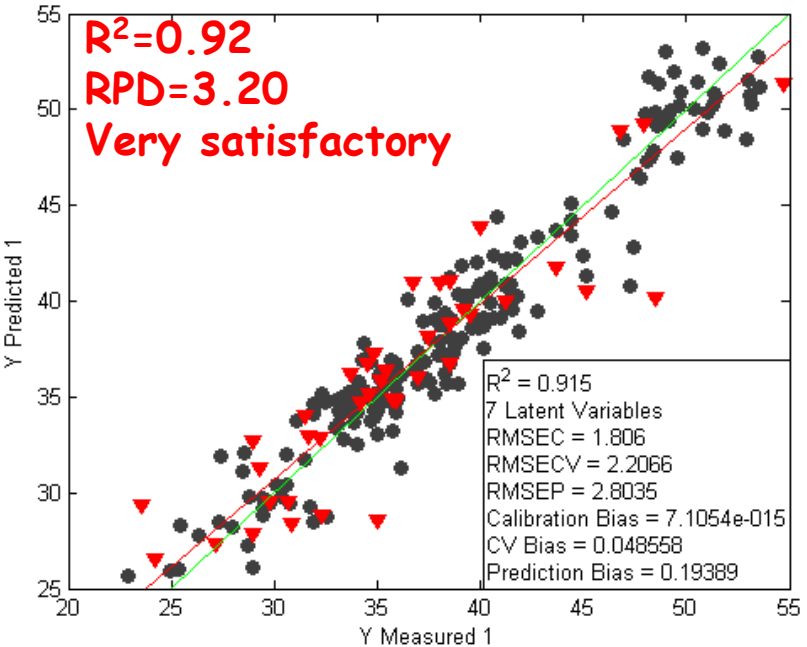
FORAGES
(*n* =183)



ENERGY-RICH concentrates
(*n* =215)



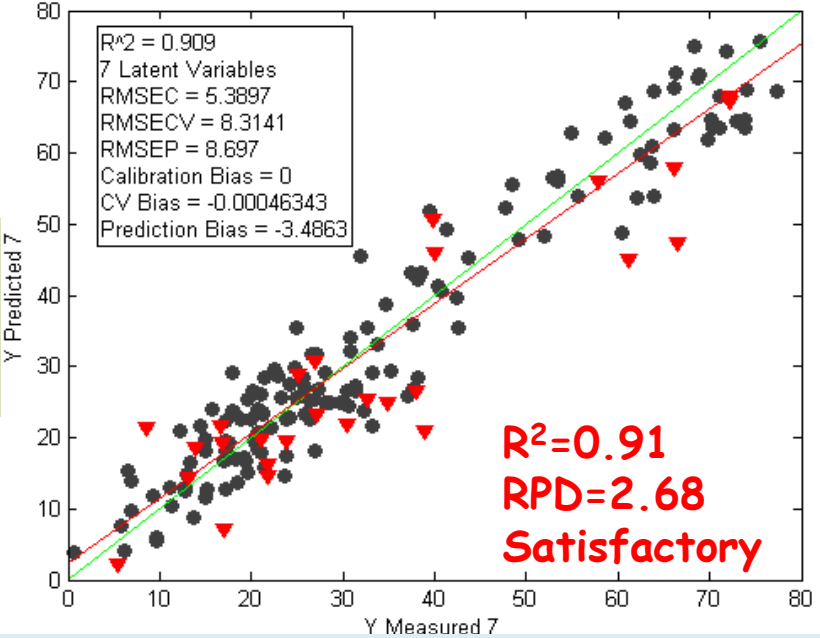
PROTEIN-RICH concentrates
(*n* =266)



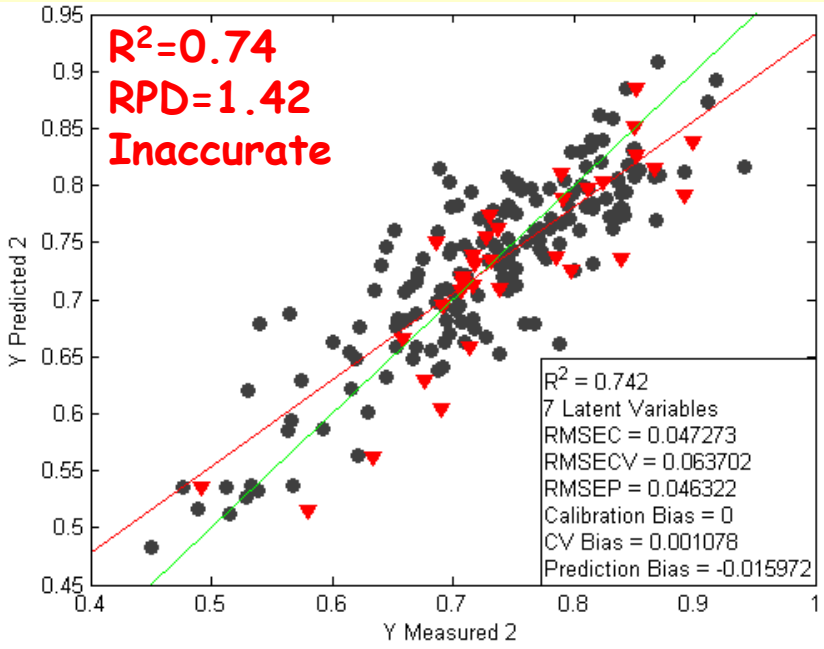
CP_{ws}

Water soluble CP

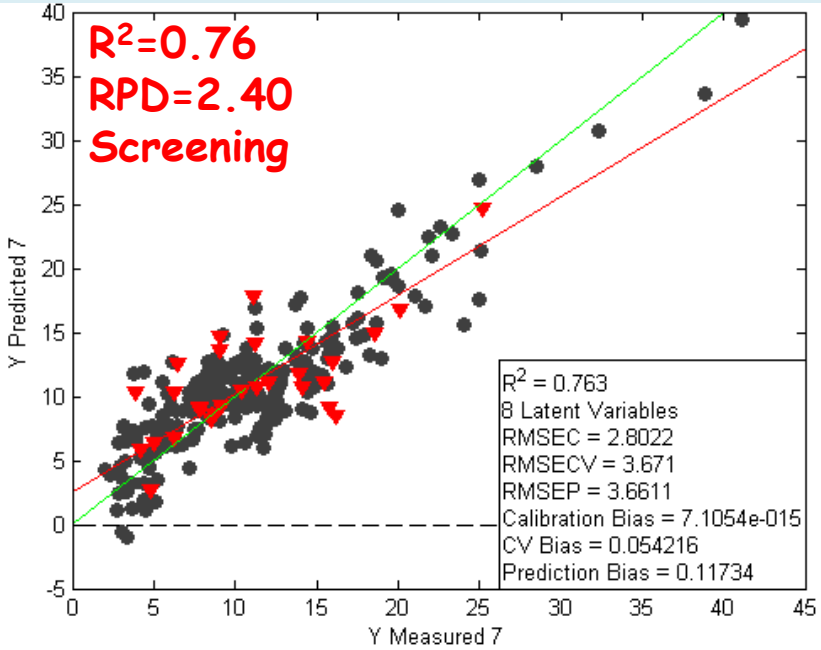
FORAGES
(*n* =183)



ENERGY-RICH concentrates
(*n* =215)



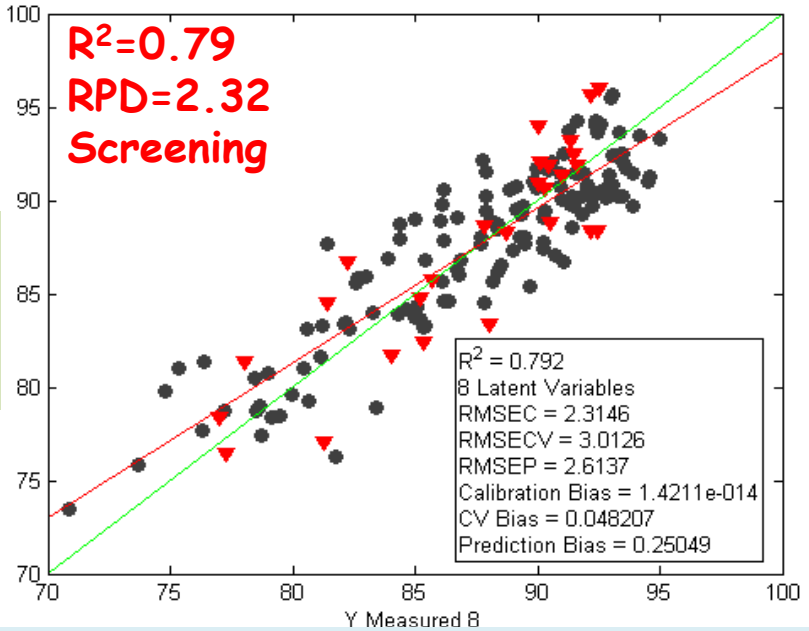
PROTEIN-RICH concentrates
(*n* =266)



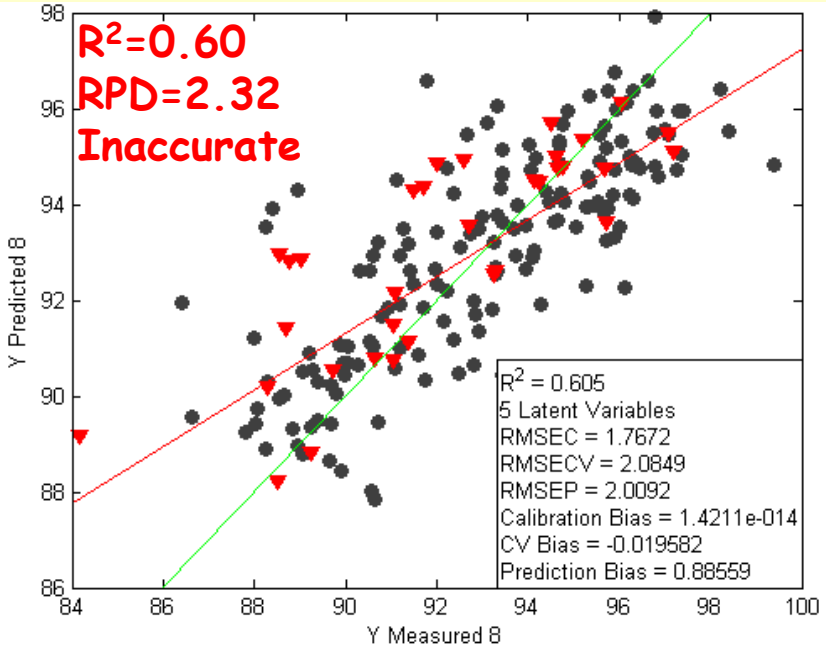
CP_{TTD}

Total tract digestible CP

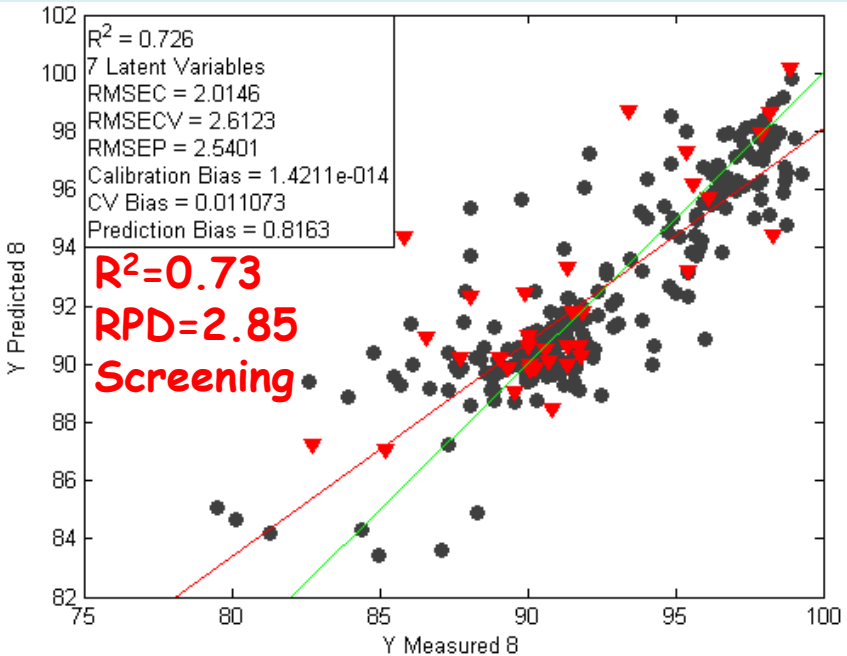
FORAGES
(*n* =183)



ENERGY-RICH concentrates
(*n* =215)



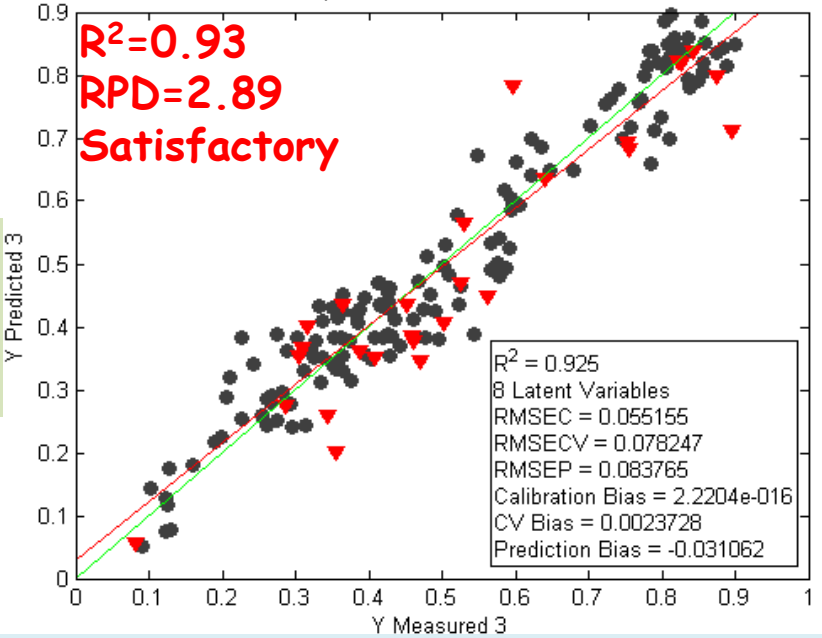
PROTEIN-RICH concentrates
(*n* =266)



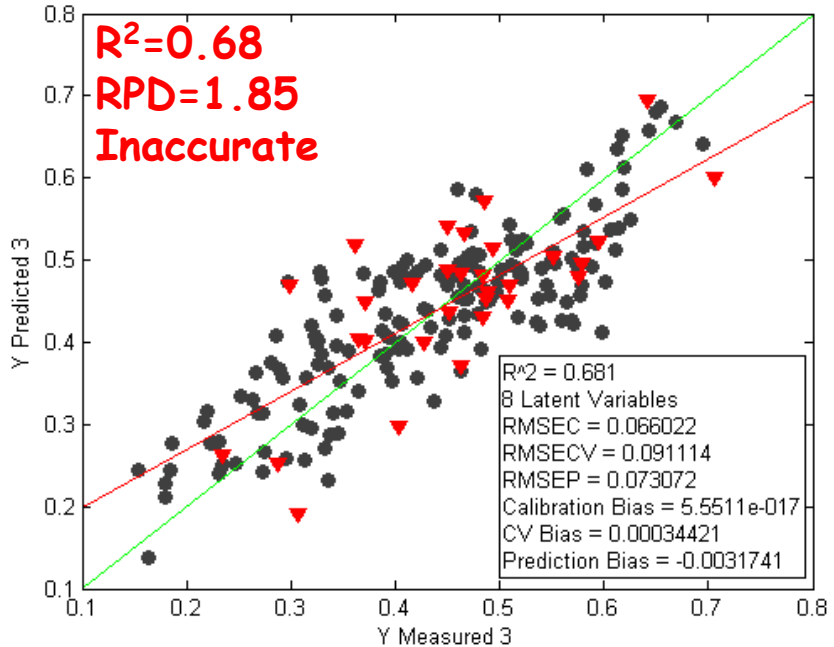
Fraction *a*

Immediately degradable CP

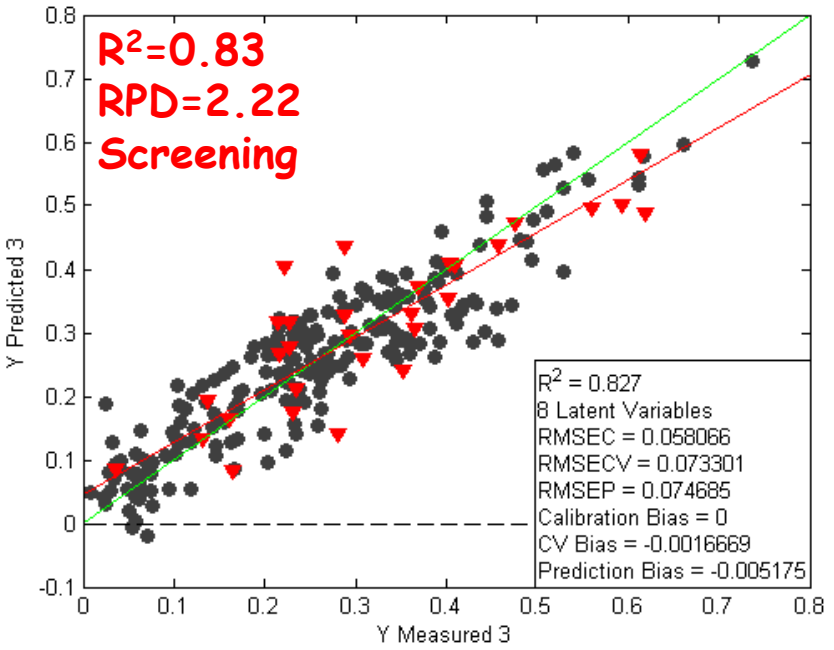
FORAGES
(*n* =183)



ENERGY-RICH concentrates
(*n* =215)



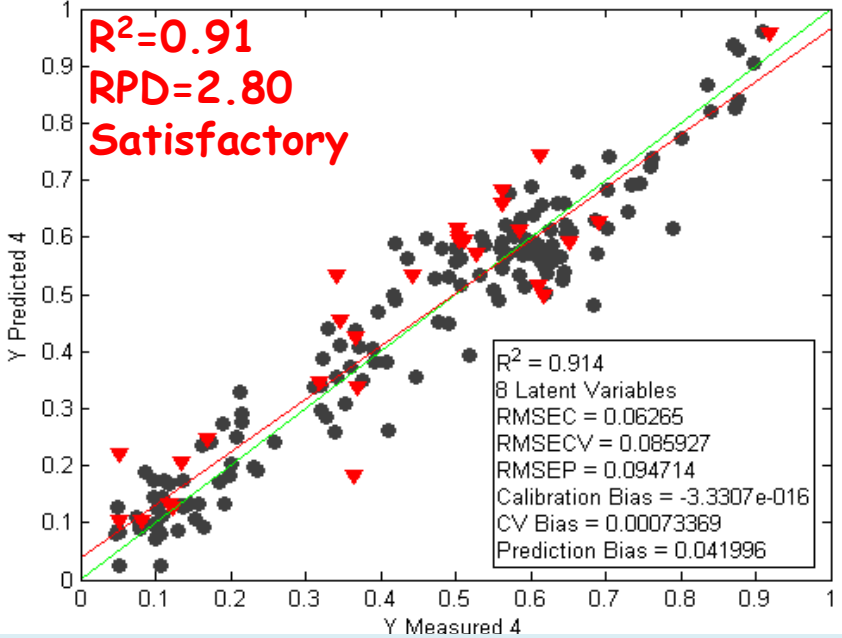
PROTEIN-RICH concentrates
(*n* =266)



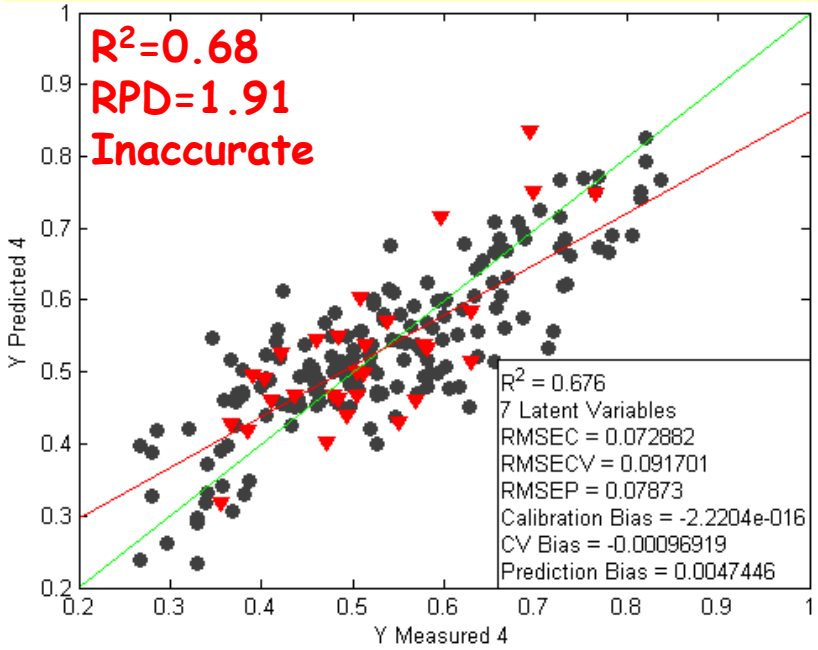
Fraction *b*

Degradable but not soluble CP

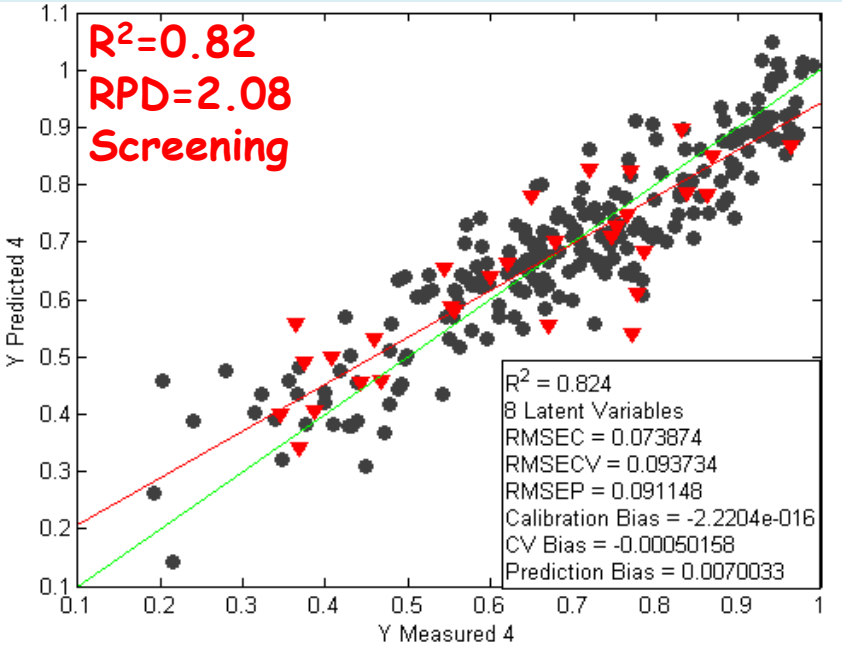
FORAGES
(*n* =183)



ENERGY-RICH concentrates
(*n* =215)



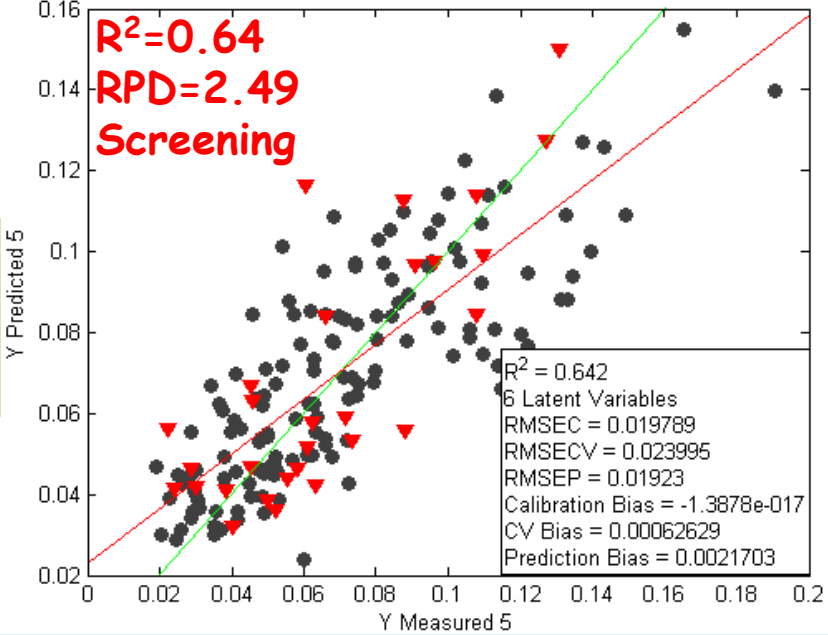
PROTEIN-RICH concentrates
(*n* =266)



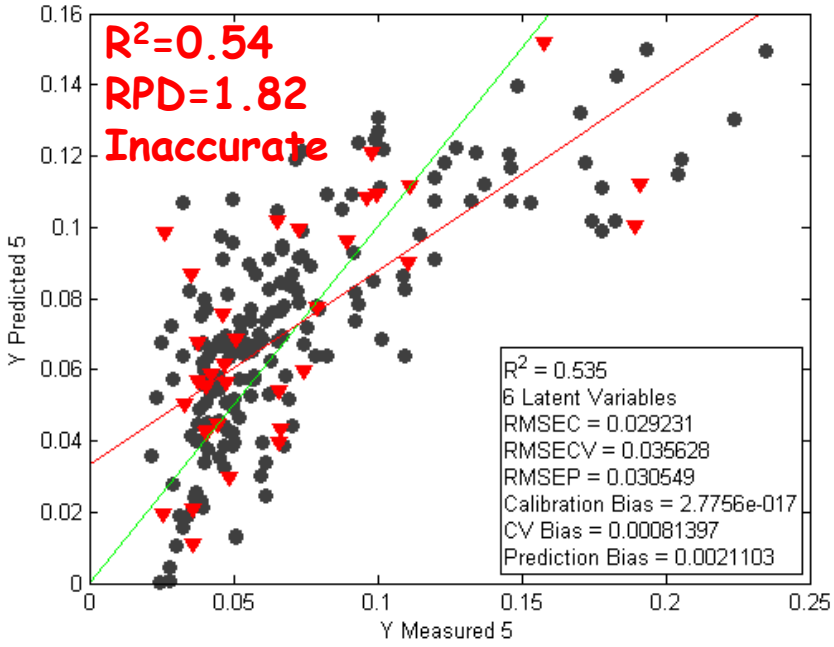
Value *c*

Degradation rate of *b*

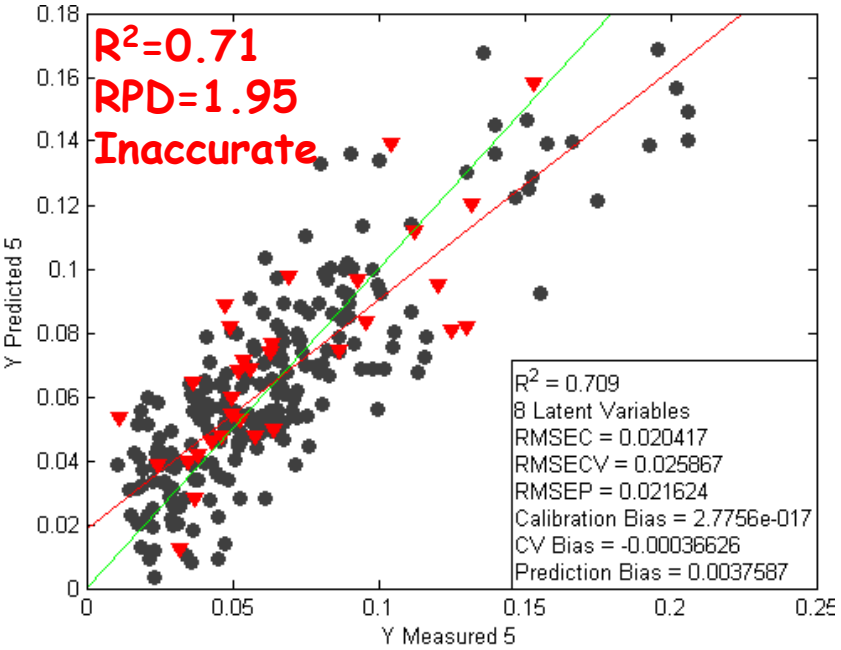
FORAGES
(*n* =183)



ENERGY-RICH concentrates
(*n* =215)



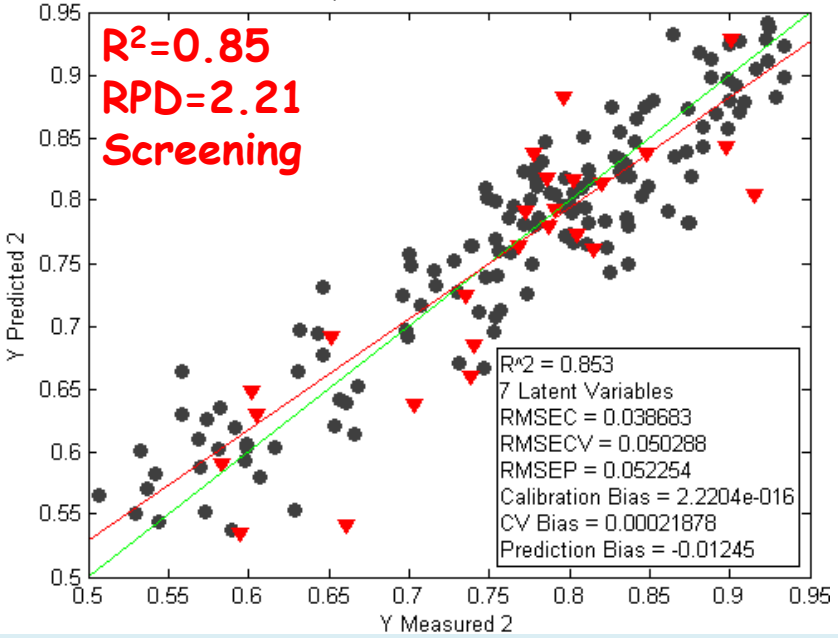
PROTEIN-RICH concentrates
(*n* =266)



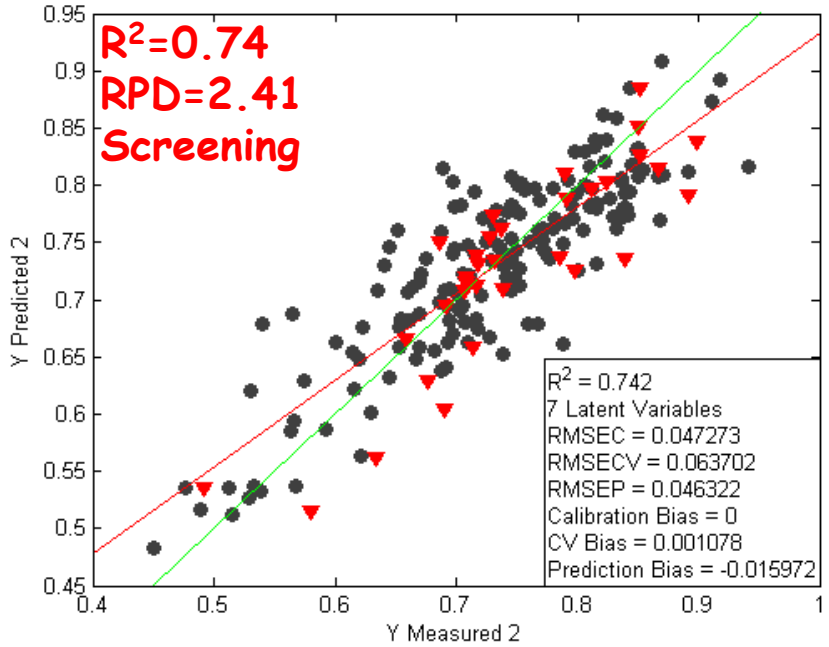
CP_{ED}

Effective digestible CP

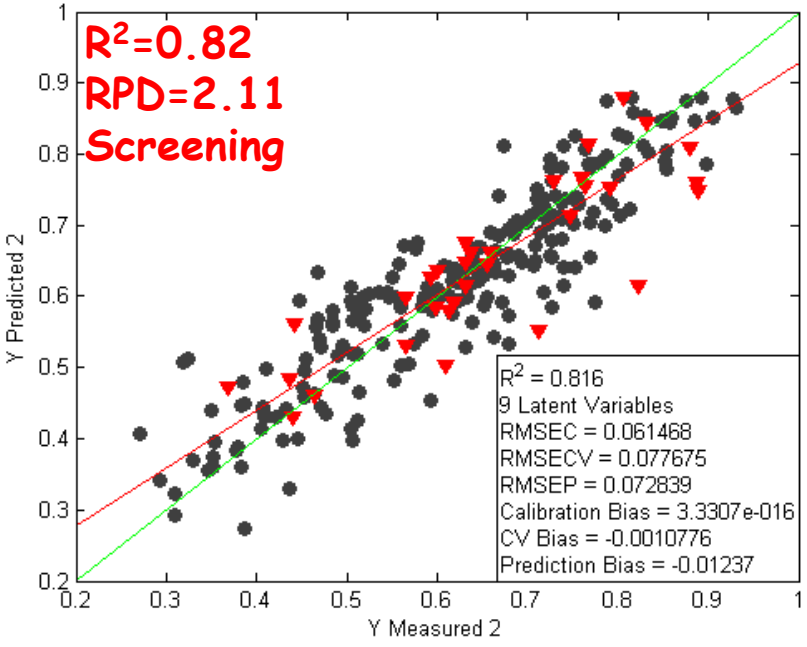
FORAGES
(*n* =183)



ENERGY-RICH concentrates
(*n* =215)



PROTEIN-RICH concentrates
(*n* =266)



Conclusions

- Mid-infrared spectra allows to classify feeds according to the nutritional value
- **UNIVERSAL** equations:
  - Quantification: CP
  - Screening: CP_{WS}
- Equations for **FORAGES**:
  - Quantification: CP_{WS}, "*a*" and "*b*"
  - Screening: CP_{TTD} , CP_{ED} and "c"
- Equations for **PROTEIN-RICH concentrates**:
  - Screening: CP_{WS}, CP_{TTD} , CP_{ED} , "*a*" and "*b*"
- Equations for **ENERGY-RICH concentrates**:
  - Screening: CP_{ED}

This study has been carried out with the financial support from:
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The Welsh Government

REDNEX

Thank you for your attention !!

SEVENTH FRAMEWORK PROGRAMME

Innovative and practical management approaches to reduce nitrogen excretion by ruminants