Application of Faecal Near Infrared Spectroscopy to Measure Nutrient Utilisation in Horses, Cattle and Sheep

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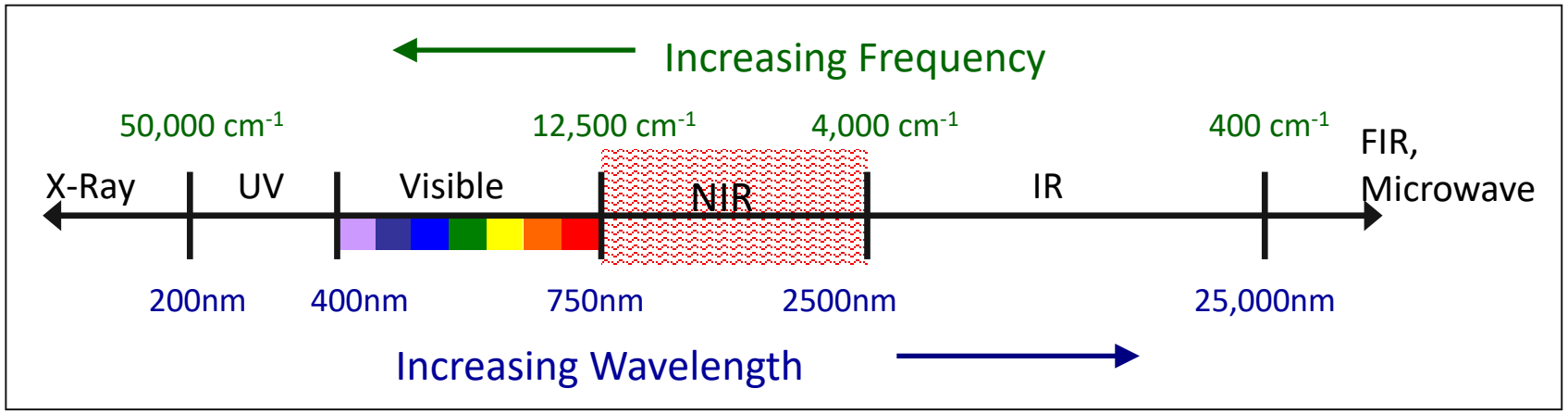
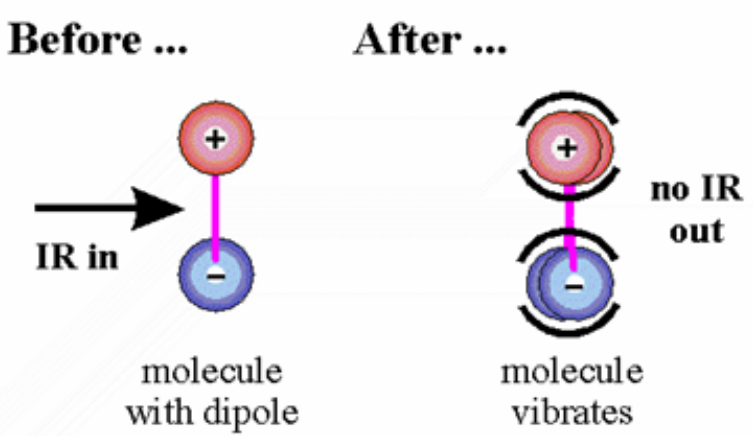
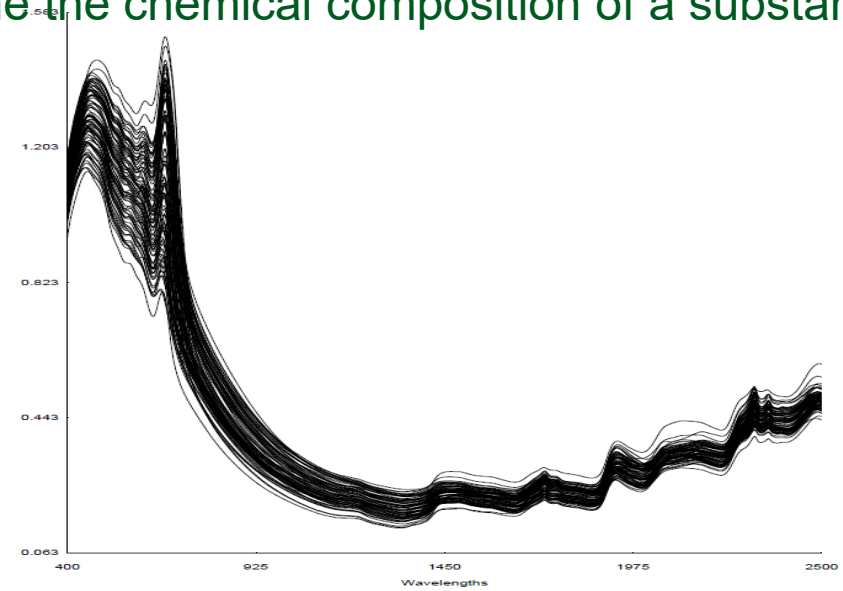
Near Infrared Reflectance Spectroscopy (NIRS)



- Interaction of materials with light in the NIR region
- Indirect method to determine the chemical composition of a substance





Spectra recorded as *'peaks and troughs'*

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Applications of Faecal NIRS

Previous Applications

- Focus on ruminant nutrition few studies on equines
- Compositional analysis
- Dietary intake
- Digestibility
- Species identification
- Monitor physiological status

Multispecies Calibrations

- Single calibration model applied to multiple species
- Previously considered species dependent
- Successful multispecies calibrations developed
- Compositional analysis of forages
- Determination of faecal N and P

Implications

- On-farm analysis in mixed grazing
- Improved livestock management practices
- Promote more economical and sustainable practices

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Objectives

- To develop NIRS calibrations to predict nutrient composition including dry matter (DM), organic matter (OM), neutral detergent fibre (NDF), acid detergent fibre (ADF) and crude protein (CP) in faeces of ruminant and non-ruminant animals

- To develop new calibration models to determine the nutrient composition of equine faeces

- To develop multispecies calibration models to determine the nutrient composition of faeces of animals with varying digestive anatomies

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Sample Preparation

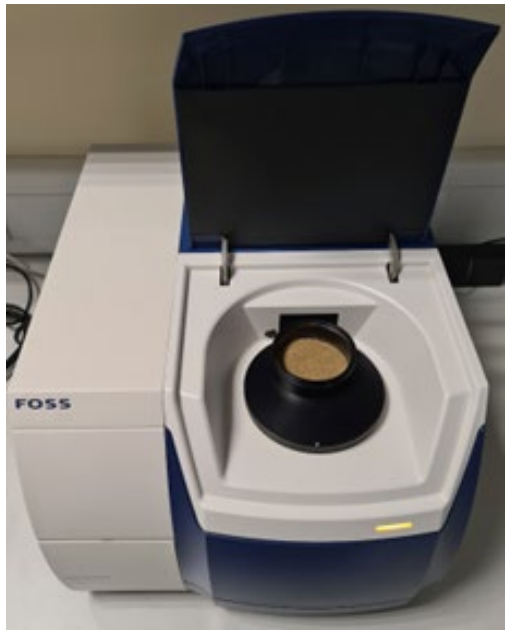
- Freshly voided faecal samples
  - Bovine n = 89
  - Equine n = 93
  - Ovine n = 80

- All animals on predominantly grass-based diets
  - Range of age, sex, physiological status

- All samples milled to a particle size of 1 mm

- Wet chemistry for reference data
  - Dry matter
  - Ash/organic matter
  - NDF and ADF
  - Crude protein
    - Conversion factor x 6.25

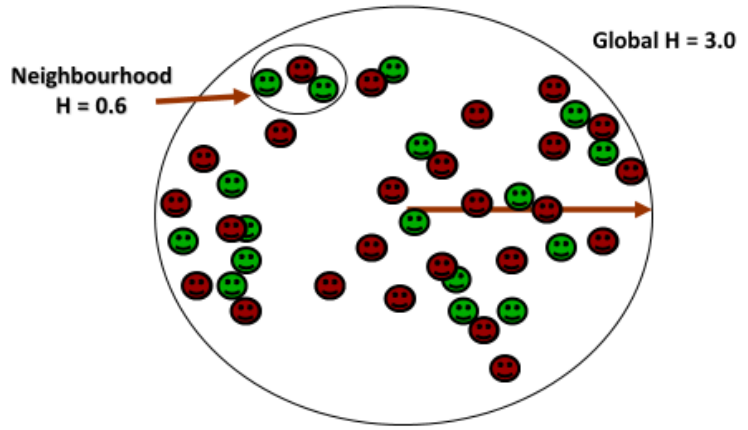
Spectral Data Acquisition



- Foss NIRS DS2500
- Reflectance mode
  - VIS-NIR region (450 – 2500 nm)
  - 0.5 nm intervals
- Quartz ring cup
  - Residual moisture removal
  - Uniform packing density
- Scanned 7 times and an average spectrum produced

Calibration Development

- WinISI 4.0 software
- Modified partial least squares regression
- Divided into calibration and validation data sets
  - Mahalanobis Distance
    - GH = 3 and NH = 0.6



- Spectra pre-processing techniques used to reduce the effects of scattering, noise and sample preparation methods

Scatter corrections

Standard normal variate (SNV)

Detrend (DT)

Combination of SNV and DT

None

Mathematical treatments

1,4,4,1	2,6,4,1
1,8,6,1	2,8,6,1
2,4,4,1	2,8,8,1
2,4,4,2	3,5,5,1
2,5,5,1	

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Calibration and Validation Performance Criteria

Selection of the best predictive equation

- Lowest standard error of cross validation (SECV)
- Highest coefficient of determination of calibration (R^2_{cal})
- Highest 1 minus variance ratio (1-VR)

Validation

- Samples excluded from the calibration model

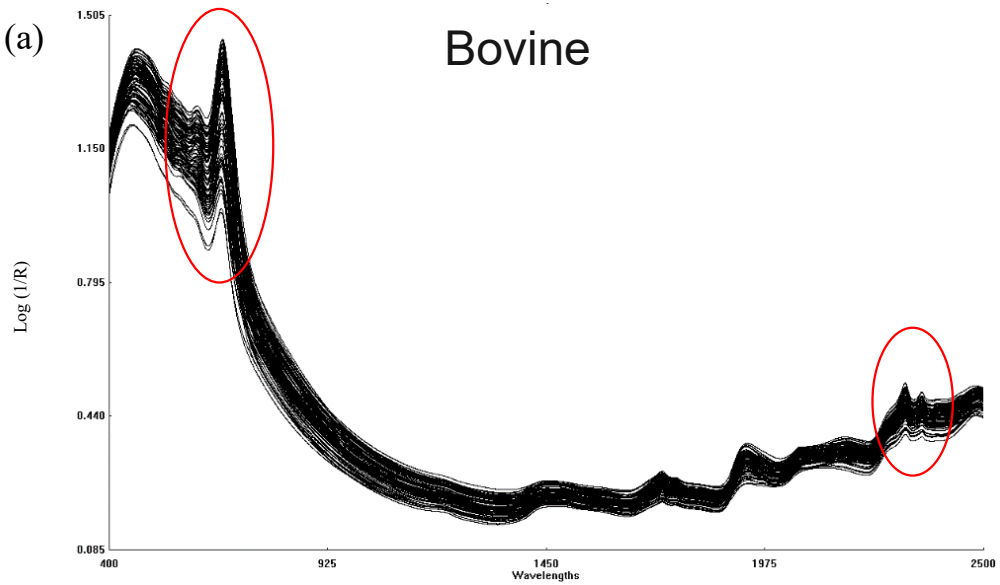
Evaluation of the validation statistics

- Highest coefficient of determination of validation (R^2_{val})
- Highest ratio of performance deviation (RPD)
- Lowest standard error of prediction (SEP)

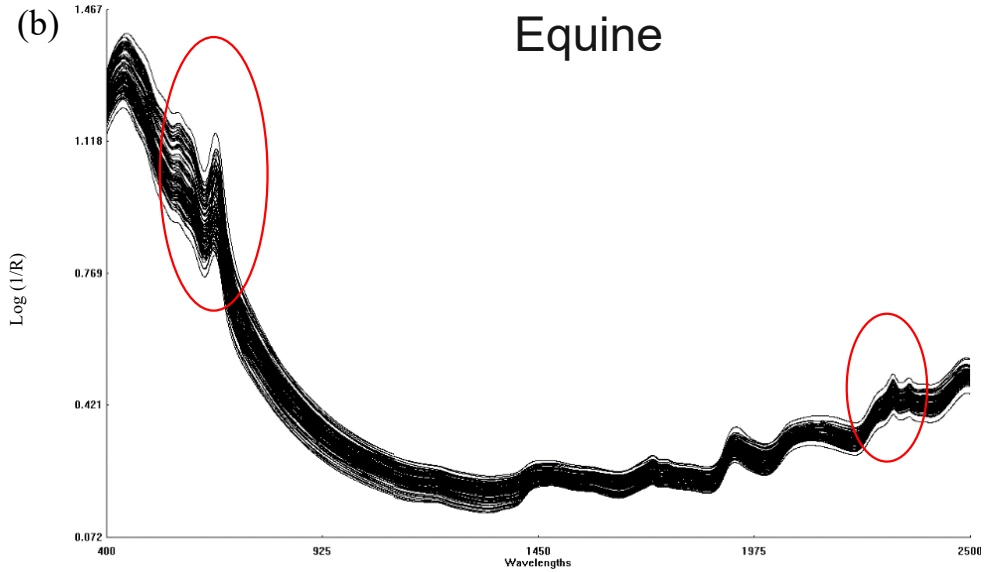
Results

Spectra of Faecal Samples Presented as Log(1/R)

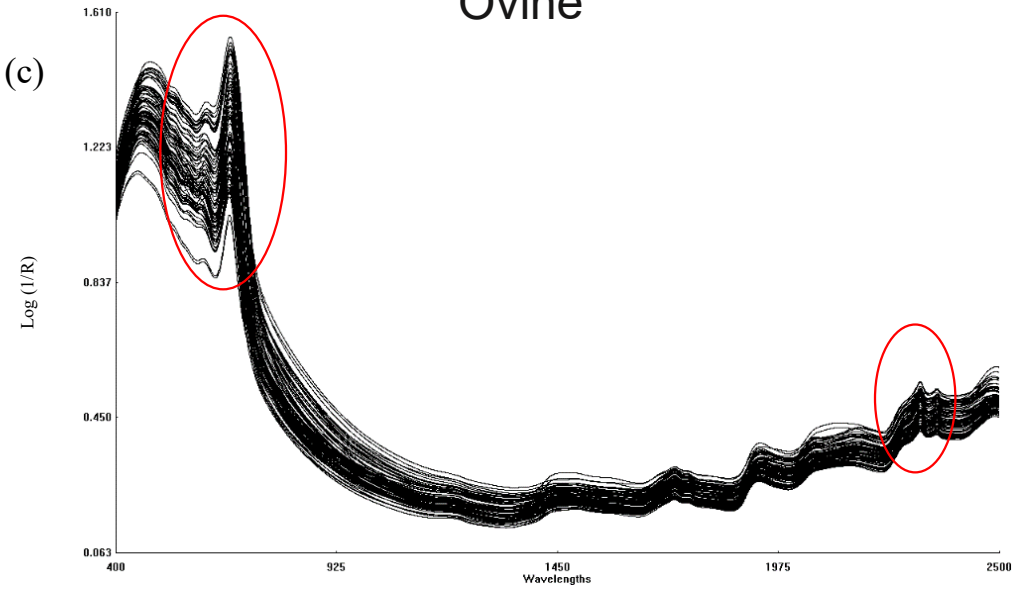
(a) Bovine



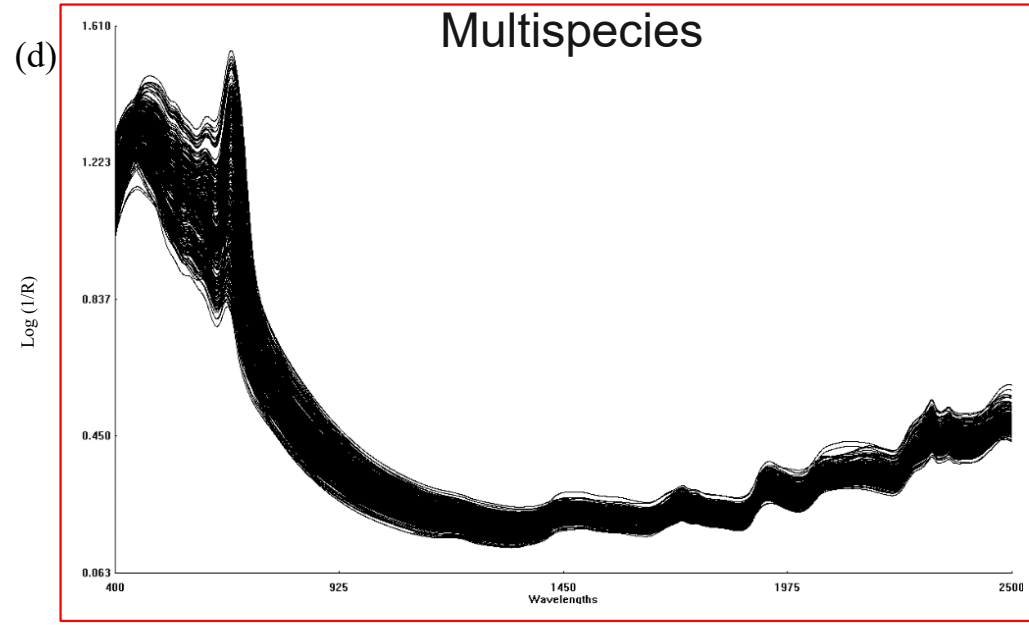
(b) Equine



(c) Ovine



(d) Multispecies



Individual Species and Multispecies **Calibration** Statistics for Prediction of Faecal Composition

Species	Constituent (gkg^{-1} DM)	No. of Samples	MT	SC	Mean	SEC	R^2_{cal}	SECV	1-VR
Bovine	DM	45	2551	DT	117.07	3.86	0.98	13.48	0.71
	OM	45	1441	SNV-DT	797.96	9.71	0.92	14.38	0.81
	NDF	45	2881	SNV-DT	494.81	26.88	0.82	31.77	0.74
	ADF	44	2442	SNV	295.17	9.59	0.94	20.73	0.73
	CP	46	2881	DT	187.51	3.02	0.99	6.3	0.96
Equine	DM	56	1861	NONE	162.55	8.98	0.79	11.61	0.65
	OM	56	1441	SNV-DT	859.29	6.38	0.97	8.74	0.94
	NDF	58	1441	NONE	609.78	7.3	0.98	10.34	0.97
	ADF	56	1441	NONE	346.23	7.6	0.95	11.94	0.87
	CP	56	1861	SNV	114.76	3.54	0.98	4.44	0.97
Ovine	DM	46	2441	SNV	199.85	13.25	0.84	21.96	0.54
	OM	43	1861	SNV	806.00	5.16	0.99	7.36	0.98
	NDF	44	1441	SNV	493.12	21.15	0.84	26.74	0.74
	ADF	44	1441	DT	246.1	11.14	0.96	17.06	0.90
	CP	43	2861	NONE	185.97	1.91	0.99	3.97	0.98
Multi-Species	DM	126	2881	SNV-DT	157.52	12.16	0.93	21.9	0.76
	OM	123	2881	SNV	816.96	5.11	0.99	9.86	0.96
	NDF	121	2551	SNV	528.03	16.47	0.96	21.86	0.93
	ADF	126	1441	SNV	294.82	16.39	0.93	18.85	0.91
	CP	122	1861	SNV-DT	164.18	3.48	0.99	4.38	0.99

Criteria for best calibration:

Lowest SECV

Highest R^2_{cal}

Highest 1-VR

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Individual Species and Multispecies **Validation** Statistics for Prediction of Faecal Composition

Species	Constituent gkg-1	No. of Samples	R^2	Slope	Bias	SEP	RPD
Bovine	DM	40	0.38	0.52	9.55	23.86	0.95
	OM	40	0.81	1.03	-2.82	16.46	2.26
	NDF	40	0.48	0.75	11.09	39.77	1.28
	ADF	40	0.51	1.03	14.54	29.26	1.25
	CP	40	0.94	1.02	0.99	7.09	4.02
Equine	DM	34	0.74	0.92	2.29	9.75	1.93
	OM	34	0.90	1.01	-2.80	12.48	3.19
	NDF	34	0.97	0.99	2.80	10.56	5.47
	ADF	34	0.81	0.82	0.45	14.34	2.09
	CP	34	0.97	1.01	-1.44	4.57	5.22
Ovine	DM	33	0.57	0.91	3.60	22.76	1.52
	OM	33	0.70	0.96	-1.62	23.84	1.85
	NDF	33	0.65	0.78	0.02	39.93	1.595
	ADF	33	0.66	0.78	3.84	30.54	1.62
	CP	33	0.88	1.01	3.01	13.33	2.81
Multi-Species	DM	130	0.61	0.81	4.46	24.36	1.51
	OM	130	0.87	1.05	-2.35	17.46	2.78
	NDF	130	0.80	0.87	10.09	38.28	2.05
	ADF	130	0.86	0.88	6.29	22.55	2.45
	CP	130	0.97	0.99	-0.03	7.40	6.01

Evaluation criteria for validation statistics:

Low SEP

High R^2val

High RPD

RPD > 2 = Good

RPD ≥ 1.4 = Acceptable

RPD < 1.4 = Unreliable

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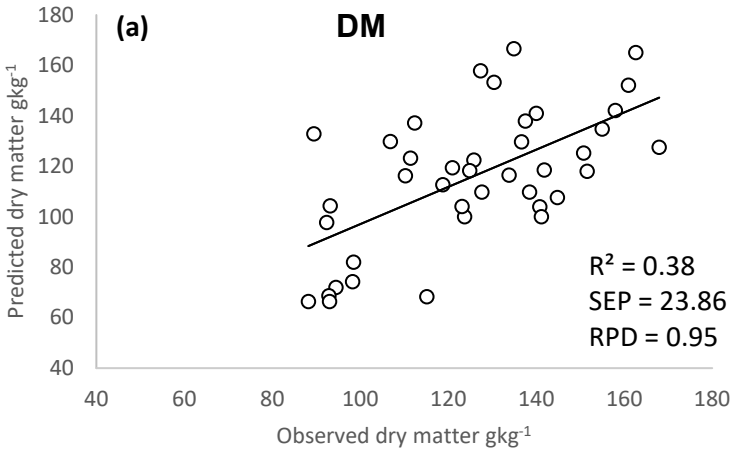
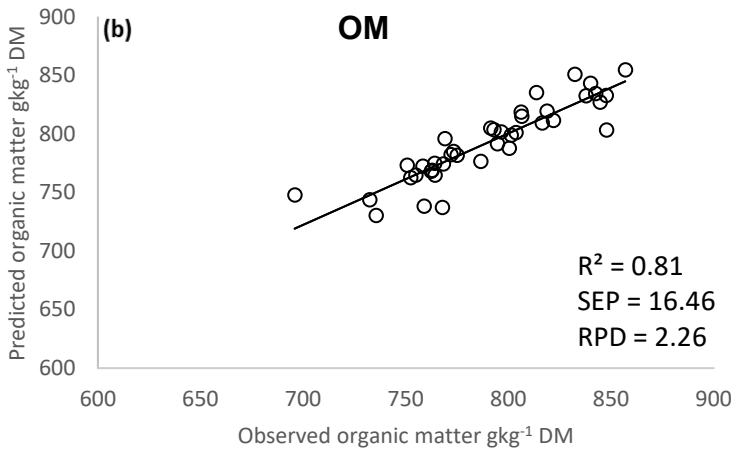
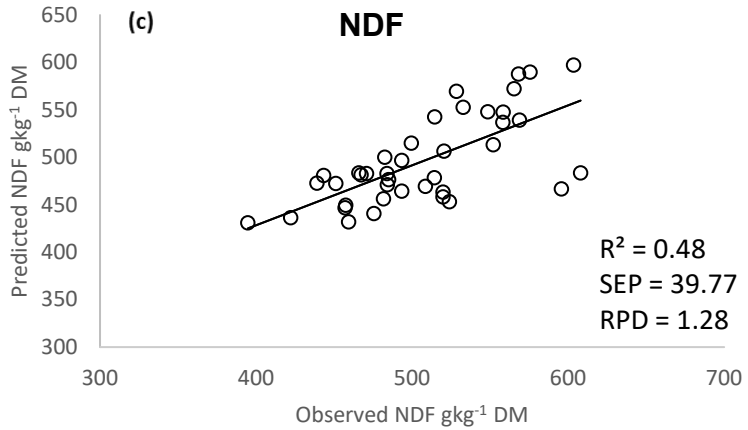
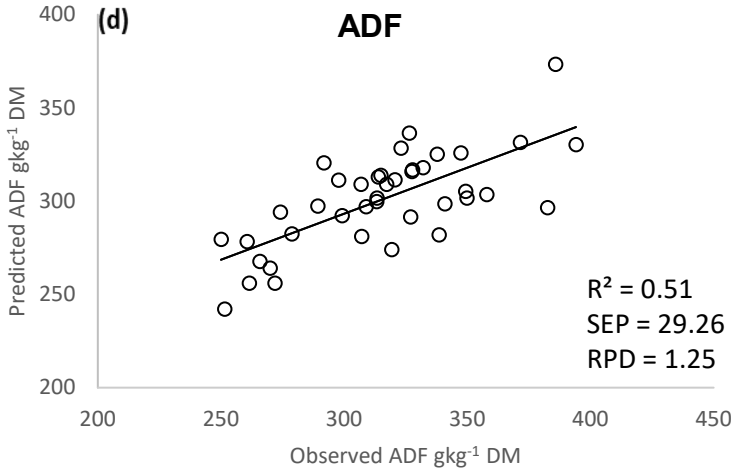
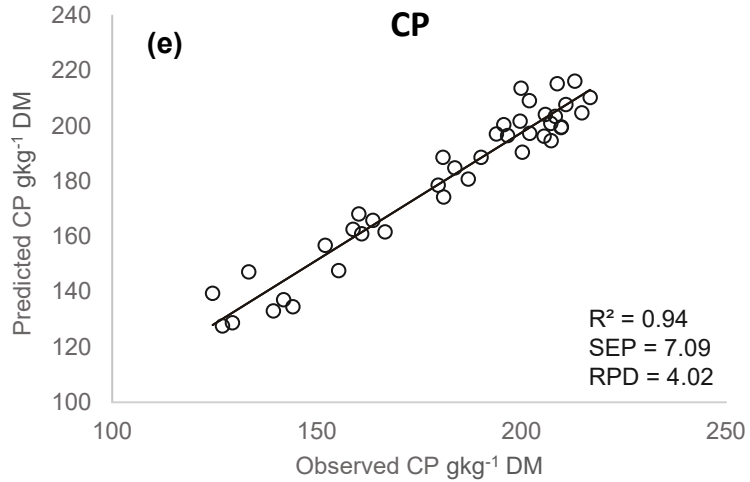
Comparison of Reference Values and NIRS Predicted Values for **Bovine** Faeces











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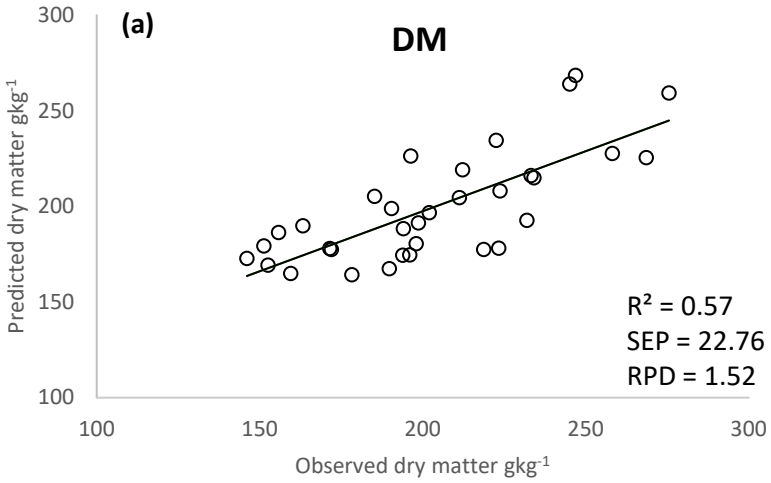
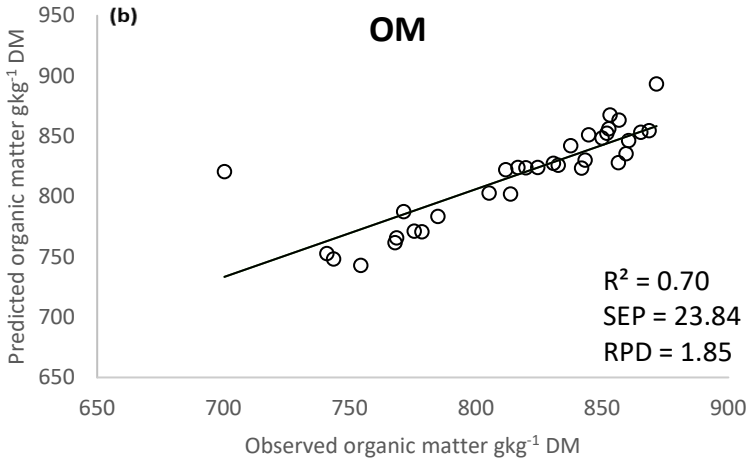
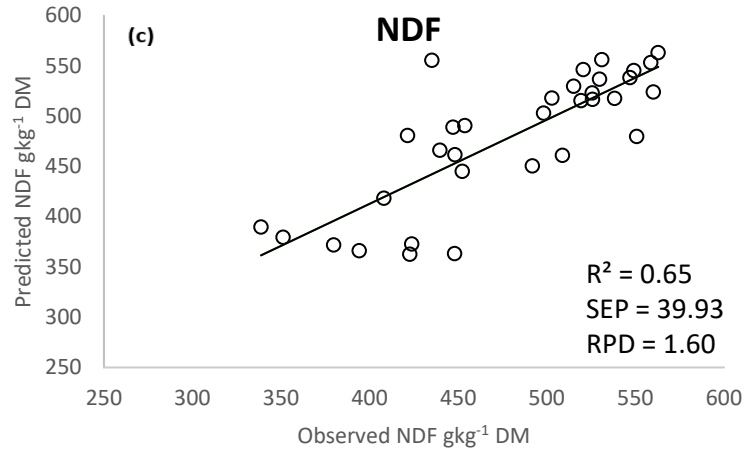
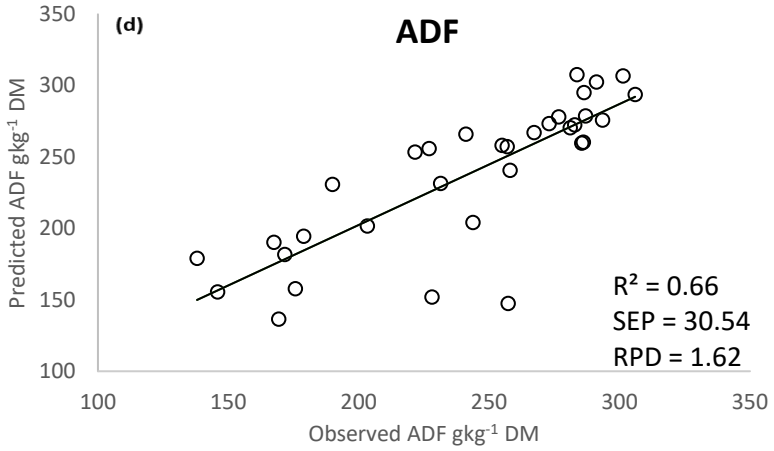
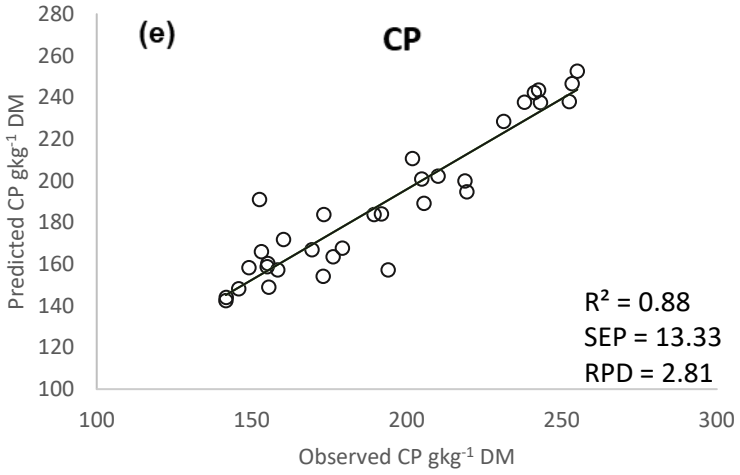
Comparison of Reference Values and NIRS Predicted Values for **Ovine** Faeces











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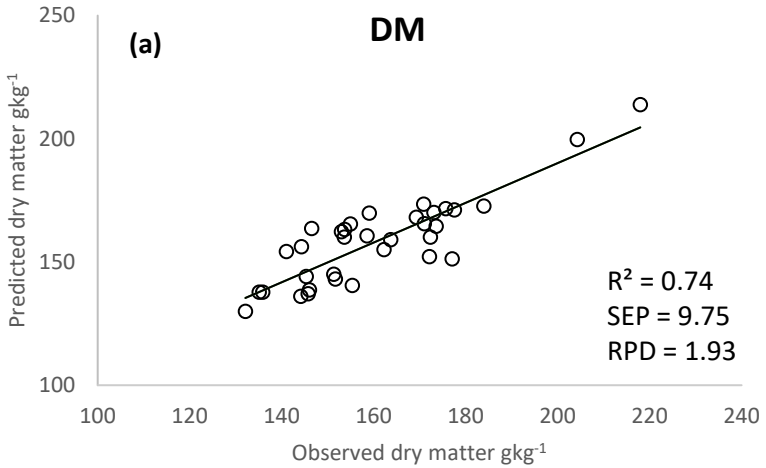
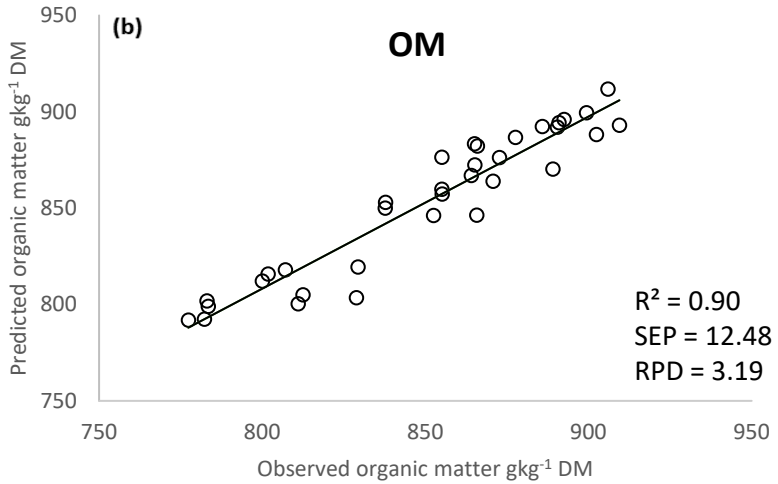
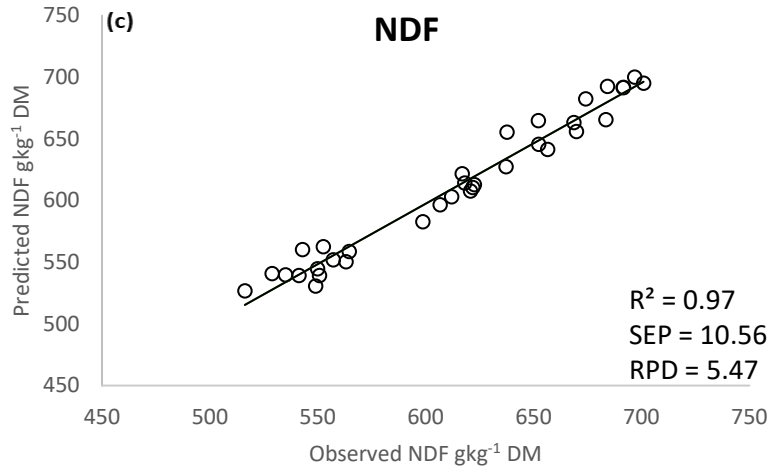
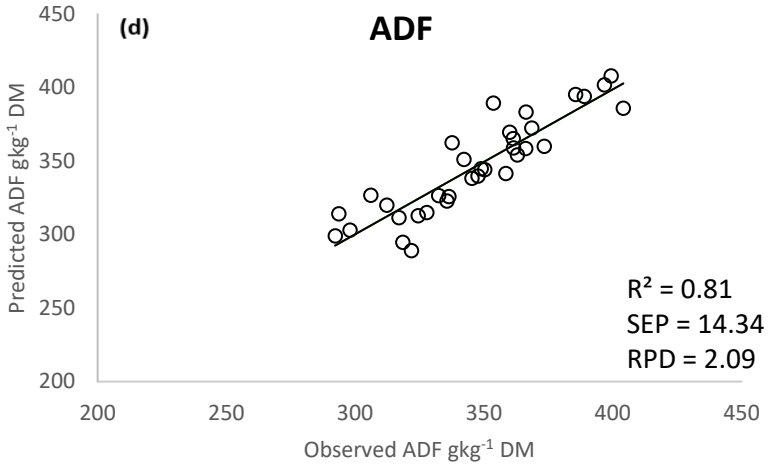
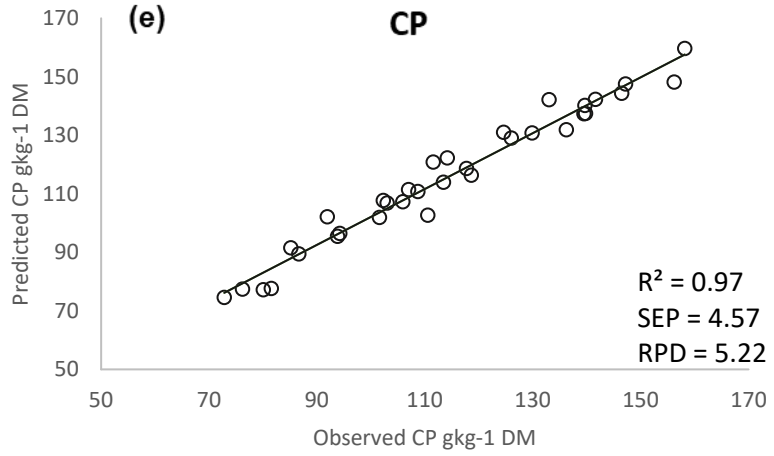
Comparison of Reference Values and NIRS Predicted Values for **Equine** Faeces











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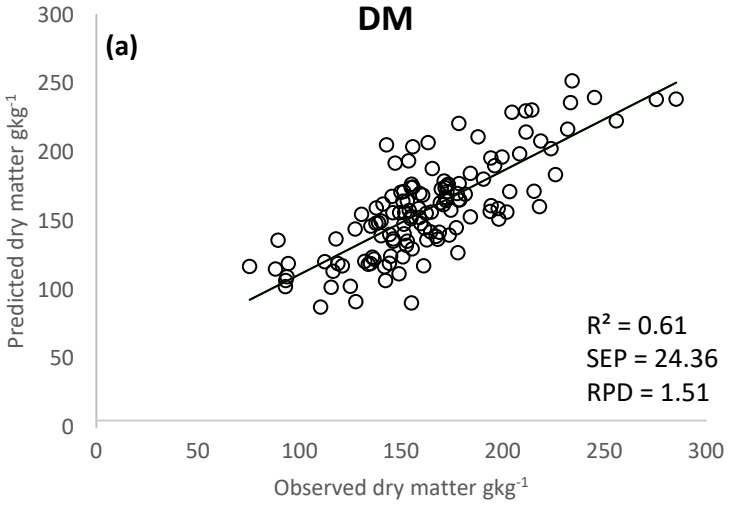
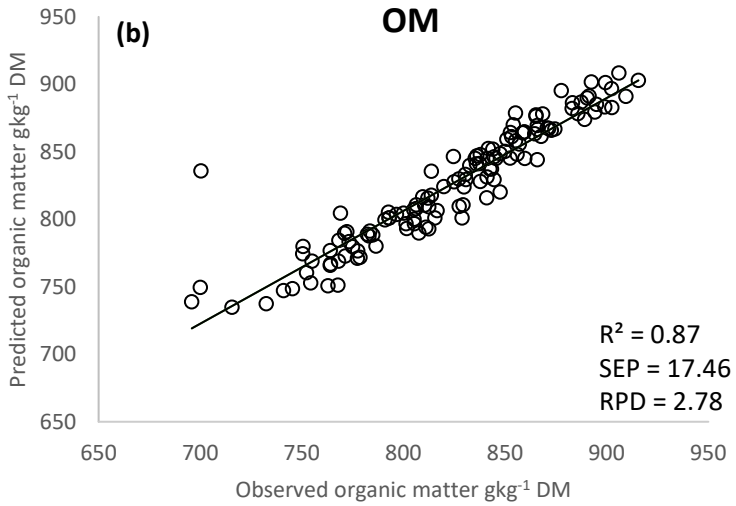
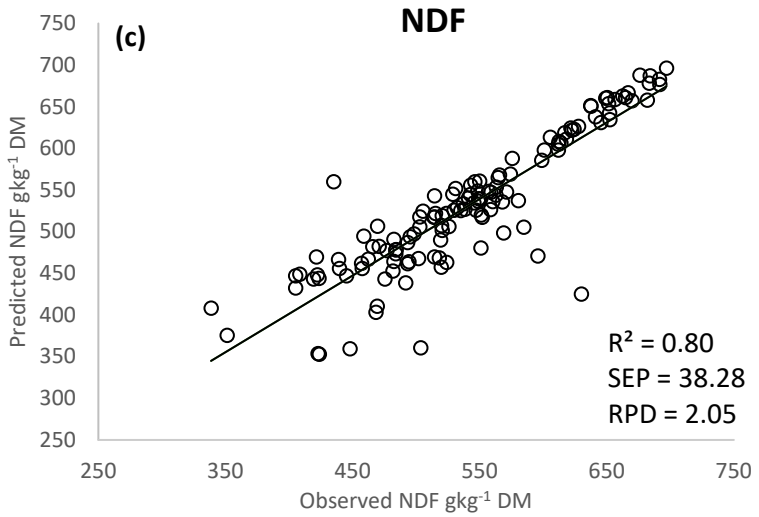
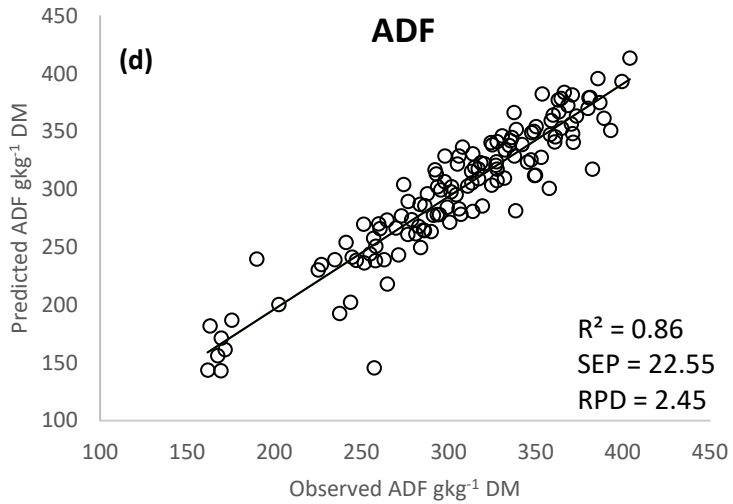
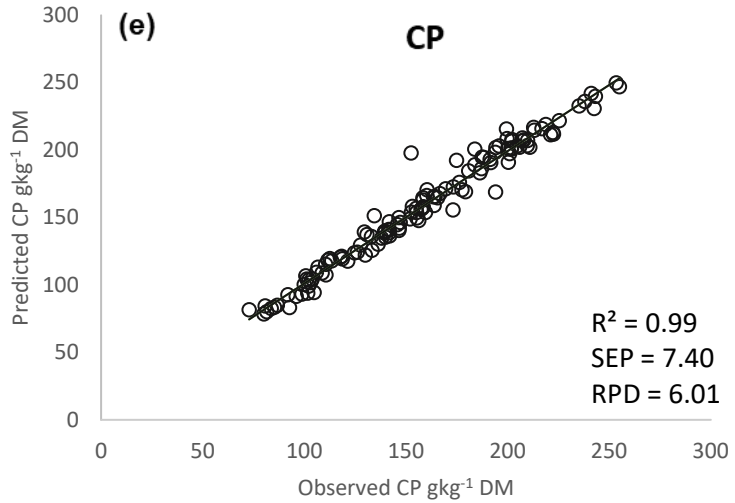
Comparison of Reference Values and NIRS Predicted Values for **Multispecies** Model











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Conclusion

- Crude protein calibration models showed excellent predictive accuracy for all species
- Calibration models for equines produced superior validation statistics compared to calibration models for ruminants
- Multispecies calibration models for all constituents were acceptable. Excellent to very good predictive ability associated with organic matter and crude protein models
- Multispecies calibration models are suitable for the prediction of faecal composition of ruminant and non-ruminant animals

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Acknowledgements

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