Use of Global Equations to Predict Forage Quality

Presented at the:

NIRS Forage and Feed Testing Consortium

Annual Conference, February 10 – 12, 2004

Madison, Wisconsin, USA

Bo Büchmann, FOSS Analytical A/S, Denmark

Ian Cowe, FOSS Analytical A/S, UK

Stefan Lundgren, FOSS Scandinavia, Sweden

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Subjects

- NIR for forages: Scope, constraints, and drivers
- NIT for grains: The inspiration.
- The Global Forage Board
- The Global Forage Models
- Test results from the Nordic Countries
- Summary

Scope

To further the development of universal Near Infrared (NIR) solutions for the main quality parameters in forages that may be used irrespective of location or botanical species.

NIR for Forages: Present Constraints

- **Location of instruments:** NIR is still used in labs, not where forages are grown, traded, and fed.
- **Calibration support:** Development and maintenance of NIR calibrations is still costly and complex.
- **Lack of uniformity:** Results differ due to imperfect standardisation and calibration model differences.
- **Reference methods:** Poorly harmonised or incomparable reference methods compound the problem of lacking compatibility between instruments.

NIR for Forages in Future: Expected Drivers

- **Expert systems:** Analyses of forages and ingredients as part of expert systems for farmers.
- **Quality insurance:** Forage crops traded as commodities over long distances.
- **Optimisation:** Fine tuning of supplementary feeding to ruminants based on frequent analyses.
- **Environmental monitoring:** Monitoring the nutrient balance on the individual dairy farms.
- **NIR devices:** Mounted on harvesters and mixer wagons.

Inspiration

- **Global solution for grain:** FOSS' unique experience with truly global calibrations for protein and moisture by NIT in cereals such as wheat and barley.

- **Large datasets:** Huge, amalgamated databases derived from different parts of the world in combination with advanced chemometrics such as Artificial Neural Networks (ANN).

NIT Networks for Grain: The Beginning

- **Infratecs:** The Infratec family is used world-wide for cereals, pulses, maize, and soybeans.

- **Networks:** Satellite instruments are organised in networks and controlled from a master by modem.

- **PLS:** Until 1996, all calibration models were based on linear calibration models (PLS = Partial Least Squares).

- **ANN:** Co-operation in Europe led to common ANN models in 1996; later data from North America and Australia were added.

- **Data sharing:** The vast improvements with ANN were possible because of data-sharing.

NIT Networks for Grain: A Global Scenario

USA 1800	Canada 300	Australia 900	Japan 80
Austria 70	France 1000	Germany 350	Hungary 75
Lithuania 60	Italy 100	UK 100	Sweden 45
Denmark 250	Finland 20	South Africa 25	China 6
Ukraine 25	South America 20		

USA, Canada are using ANN and PLS; all other countries mainly ANN.

The Global Forage Board

- **Neal Martin,** USDA, USA (Chairman)
- **Pierre Dardenne,** CRAGx, Belgium
- **Dan Undersander,** Univ. Wisconsin, USA
- **Peter Flinn,** Agriculture Victoria, Australia
- **Christian Paul,** FAL, Germany
- **Paolo Berzaghi,** Univ. Padua, Italy
- **Fernando Mazeris,** DeLaval
- **Jonas Carlgren,** DeLaval
- **Bo Büchmann,** Foss Tecator

The Technical Forage Group

- **Pierre Dardenne**
- **Peter Flinn**
- **Paolo Berzaghi**
- **John Shenk & Mark Westerhaus,** ISI, USA
- **Martin Lagerholm, Ian Cowe, and Bob Schumann,** Foss Analytical, Sweden, UK, and USA.

Global Forage Models: Parameters

- The following parameters have wide acceptance as regards reference methodology: Protein, Dry Matter, and Neutral Detergent Fibre.
- Laboratory methods for estimating digestibility, voluntary intake, and energy content describe “properties” that are not globally harmonized.

Global Forage Models: Historical Datasets

- Fresh corn
- Corn silage and stover
- Haylage
- Alfalfa (Lucerne)
- Grasses
- Hays

Data from: Australia, US, Canada, Germany, Italy, Belgium, Sweden. Only dried and ground samples.

Global Forage Models: Datasets

Set	Open/Close	# Spectra	# DM	# CP	# NDF
Calibration Set		19495	11399	16390	8079
Validation Set	Closed	6496	3823	5412	2719
Validation Set IT02	Open	211	209	211	207
Validation Set Ival	Open	1885	1885	1846	1912
Validation Set Sval	Open	1861	1861	1860	1660
Validation Set Ring-test	Open	60	60	60	60
Total:		30008	19237	25779	14637

osed denotes a validation set from the same population as the calibration set.

pen denotes a validation set from a different population as the calibration set.
pen sets not standardized to calibration set.

Calibration techniques considered so far

- **ANN:** Artificial Neural Networks. Non-linear algorithm requiring vast computing power and large data sets. (Lagerholm).
- **LOCAL:** Each prediction based on its own PLS model generated from spectra like the unknown, selected from a common data set. (Shenk).
- **MPLS:** Modified PLS. An optimised version of PLS, where the results from a series of PLS models of increasing complexity are averaged. (Dardenne).

Independent Evaluation: Nordic Participants

- **Maria Hellamäki**, Valio Oy, Finland
- **Gustav Fystro**, Planteforsk, Norway
- **Lambert Sørensen,** Steins Laboratorium A/S, Denmark
- **Leif Brohede,** AnalyCen Nordic AB, Sweden

Nordic Samples: Forage types

Forage type	N
Grass	58
Mix	5
Hay	31
Haylage	2
Grass Silage	119
Corn Silage	3
Legume Silage	3
Legume Hay	3
Whole Crop Barley	8

Nordic Samples: Sample Preparation

Country	Drying	Grinding
Norway	60 °C / 48 hrs	1 mm screen
Finland	50 °C / 18-20 hrs	1 mm screen
Sweden	50 °C / 12-18 hrs	0.8 mm screen
Denmark	80 °C / 16 hrs	1 mm screen

Nordic Samples: Reference Method CP

Country	Method	Equipment
Norway	Kjeldahl	ChemLab Auto
Finland	Kjeldahl	FOSS Kjeltec 2400
Sweden	Kjeldahl	FOSS Kjeltec 2400
Denmark	Dumas	LECO

Summary: Crude Protein

- Global models show some slope and bias effects
- Global ANN model gives best performance on the whole test set, relative to aggregate local models
- Global models could cope with samples where individual models were not available (not shown here)
- Results look very encouraging

Nordic Samples: Reference Methods NDF

Country	Method	Equipment
Norway	Van Soest	FOSS Fibertec 1010
Finland	Van Soest	FOSS Fibertec 1020
Sweden	Modified van Soest	FOSS FiberCap/Ankom?
Denmark	Van Soest	FOSS Fibertec

Summary: NDF

- Global models shows slope and bias effects
- Norwegian results comparably poor for global models. Predictions appear to be non-linear.
- Danish predictions with global models have very high bias, compared to those with individual models. Needs further investigation into the cause for this.
- Overall SEP(C) for global ANN and MPLS models close to acceptable limit of 2.50 (Svensk Mjölk)

Nordic Samples: Reference Methods DM

Country	Method	Equipment
Norway	Drying to constant weight at 104-105 °C	
Finland	Drying at 105 °C for 10-20 hrs	
Sweden	Drying at 103 °C for 5 hrs	
Denmark	?	

Summary: DM

- No individual models for comparison
- Reference data is for dry matter of pre-dried, stored materials, whereas global model is based on dry matter from fresh materials
- Finnish results are reasonable; Norwegian results show three low samples predicted poorly; Swedish results are poor; no results from Denmark.
- Global ANN and MPLS models are performing equally well; very little range in population.

Conclusions

- Similar tests are planned for in Australia and the US.
- Global models for dried, ground forages are possible at least for simple parameters.
- Global models presently are not quite as accurate as individual ones, but have merit when analysing atypical samples.
- When amalgamating large, historical databases many sources of instrument variation cannot be traced and removed; the key issue is to ensure correct datasets for evaluation.
- Both ANN and MPLS allow all forage types to be analysed with a single equation….so you don't need a Ph. D. In botany.
- Global equations will never totally replace local, sophisticated equations, but may form the backbone of NIR analyses of forages in the future.