FOSS

Application Facts

FOSS ANN meat calibration
- the key to reduced calibration costs

The ANN calibration has a huge advantage compared to other calibration techniques: A very robust calibration can be developed, with no limit as to how many samples can be included in the calibration.

With one ANN calibration it is possible to cover many different products, where you traditionally need to develop and maintain several calibrations. This means reduced calibration development and maintenance costs, as less reference analyses are required.

The purpose of this paper is to show how the ANN-calibration is a superior calibration method and a more cost-effective method compared to PLS.

The content is structured as follows:

- FoodScan measurement principle
- Calibration methods: PLS versus ANN
- The FoodScan ANN calibration for raw meat & meat products
- Case study

1. FoodScan measurement principle

The FoodScan technology is based on Near Infrared Transmittance, NIT, which is an indirect analysis technique. This means that the data (absorbencies at different wavelengths) generated by FoodScan (X) are subjected to a mathematical function, a calibration model, in order to calculate the predicted value (Y).

The calibration model is created from scans of samples of known chemical composition. For every sample analysed on a FoodScan, all the spectral information in the range 850 – 1050 nm (100 measuring points) is used. To produce the calibration model, the relation between the spectral information and the chemical composition (e.g. the fat content determined by the reference method) must be found. This is done using a multivariate calibration technique.

It is generally recognised that a non-linear relationship exists between the fat response and concentration over larger fat ranges (more than 10-15%) as they are often encountered in meat and meat products. Therefore it is not possible to use one PLS calibration for estimating the fat content in such products. It is necessary to use more PLS calibrations – or alternatively one can use the ANN calibration, which can handle non-linear relations.

2. Calibration methods

2.1. PLS calibration

A PLS calibration is a linear function described by the equation:

$$Y = a X + b,$$

which is a straight line, where the dataset is (X, Y), and a and b are calculated as a result of knowledge of the datasets in the calibration.

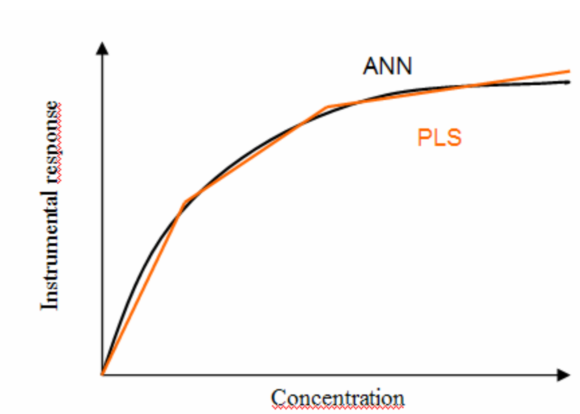
It is possible to use a PLS calibration technique for non-linear relations by developing and using more PLS calibrations (all straight lines).

A PLS calibration is developed for each product. This means that if more products are to be tested on the same instrument, it is necessary to develop a PLS calibration for each product, say a calibration for lean raw meat, another for fatty trimmings, a third for sausages, a fourth for salami etc.

Each calibration is regularly verified via reference analyses (varies from once a week to a couple of times yearly depending on the local regulations and/or company policy).

If a company analyses a large number of different products – say 30 - 40 different products – the annual costs for verification of the calibrations via reference analyses would be significant.

Figure 1. ANN handles non-linear relationships like the fat response over large ranges.



More PLS calibrations are needed for handling non-linear relations – like raw meat with large fat variation.

2.2. ANN Calibration

An Artificial Neural Network (ANN) takes calibrations into a totally different paradigm. First of all the equation used is not linear. It is still a mathematical equation, but whereas PLS ”only” searches for a factor to be multiplied by the value of the energy found in the channels/wavelengths (the X), the ANN mathematics will at the same time calculate if any known mathematical relation can better predict the Y from the known X’s.

This means that an ANN equation based on the same Y and X could for instance look like:

$$Y = (a\,X(1)^{X(2)} + \mathrm{Log}X(3))/e^{X(4)}$$

Actually the calibration equation is much more complicated and will usually take several pages to print.

It is evident, that:

- it takes a lot of software power to calculate the calibration equation in ANN
- it is no longer possible to use the calculated equation for a theoretical explanation

ANN has proven its superiority over the linear calibration methods (MLR and PLS) when a minimum of 1.000 sample sets are in the database.

It is also a proven fact that ANN can make a calibration extremely versatile if you just enter datasets from many different variances into the database.

As mentioned before an example of this non-linear relationship is the fat response over large (more than 10-15%) ranges, as often encountered in meat.

Whereas linear calibrations like PLS must be developed over limited, almost linear ranges in order not to affect accuracy in a negative way, ANN can handle the whole range with the same good accuracy as a PLS.

Likewise, whereas a PLS calibration must be developed on one or very similar products in order to be accurate, the ANN method can handle many different products.

2.3 ANN versus PLS

Any calibration has to be verified regularly to check that the indirect method is accurate, this can take place once a month, once every second month etc. depending on company policy. The verification is done via reference analyses. It is our experience that a minimum of 5 samples are needed for verification of one calibration.

Often the same analyser will be used to test more products. When using PLS calibrations, and if 10 different products are tested, it will normally be necessary to develop and operate 10 PLS calibrations. The minimum samples for verification of the 10 calibrations will be 5 x 10 = 50 samples. The annual samples, if verified monthly, would then be 50 x 12 = 600 samples.

The ANN calibration covers most common meat products (raw meat (beef, pork, poultry etc.), sausages, salami etc.); therefore there is only one calibration to maintain. Consequently the annual number of reference analyses for verification of the calibration would be decimated in the previously mentioned example.

There are also different costs involved when developing the calibrations:

- In case of PLS it would normally be necessary to use minimum 100 reference analyses for building a PLS calibration, and more to validate the calibration (10-30 samples).
- As ANN is a “plug & play” calibration covering most meat products, no new calibration development is required. It is only necessary to validate the calibration – we recommend using 20 samples.

3. The FoodScan ANN Calibration for raw meat & meat products

3.1 Global coverage

The current version (2.0) of the ANN Meat calibration covering the parameters Fat, Moisture, Protein and Collagen was developed using approximately 20,000 spectra collected globally from the more than 700 FOSS dedicated meat analysers installed worldwide since 1989. The huge number of spectra makes the FOSS ANN Meat calibration very robust and offers excellent transferability between instruments. The scope of the FOSS ANN Meat Calibration is shown in the following table.

Parameter	# Calibration objects	Mean	Min	Max	SDev
Fat	20,996	22.4	0.1	88.7	15.95
Moisture	18,811	58.3	9.3	79.7	13.78
Protein	17,650	15.8	1.9	36.8	4.11
Collagen	4,955	2.2	0.1	8.5	0.98

The regions from where the data have been collected are:

- North America - approx. 49 % of the data
- Europe - approx. 48 % of the data
- Australia & New Zealand - approx. 2 % of the data
- Rest of the world - approx. 1 % of the data

3.2 Advantage and benefits of FOSS Meat ANN Calibration

Features	Advantages	Benefits
Global, based on more than 20,000 spectra of meat samples ranging from raw meat to finished products	No need for new calibration development	Start analysing immediately and save time and money spent on reference analysis
	Robust – covers most meat products	Save time and money on calibration maintenance
	High accuracy	Reduced lean meat give-away (improved earnings).
One calibration	Easy verification – few reference analyses needed periodically	Save time and money for reference analyses compared to verification of multiple PLS calibrations
Based on data from more than 700 instruments	Robust, reliable, transferable calibrations	Save money spent on reference analyses for calibration monitoring, expansion and installation of additional units.
Handling of non-linearities, calibrations covering the whole fat range	Less calibrations needed	Cut down on number of calibrations and save money spent on reference analyses for calibration monitoring. Reduce operator errors due to high number of calibrations.
Regular up-date by FOSS	No need to add new data to the calibration – FOSS does this automatically	Save time and money on up-dating calibrations.

4. Case study

A manufacturer of processed meat products uses a FoodScan to test 8 different products: 2 types of raw meat (each with a different level of lean meat content), 4 types of sausages (to measure the intermediate product (from mixer) and the final products), 1 type of salami (to measure the intermediate product and the final product) and 1 corned beef (to measure both the intermediate and the final product).

Total costs for **building PLS calibrations** are shown in table 1.

The parameters tested, the number of PLS calibrations needed and the costs of the periodical number of reference analysis needed for **verification** of the calibrations are shown in table 2.

Table 1. Costs for building 14 PLS calibrations.

Product	No. of reference analyses for building calibrations	No. of samples for verification of calibrations	No. of Constituents (parameters)	Total costs for reference analyses when building calibration (15 US$/constituent)
1. Raw meat trimmings				
a. 90/10	100	20	3	5,400
b. 60/40	100	20	3	5,400
2. Sausages:				
a. Type 1, intermediate	100	20	3	5,400
b. Type 2, do	100	20	3	5,400
c. Type 3, do	100	20	3	5,400
d. Type 4, do	100	20	3	5,400
A. Type 1, final product	100	20	4	7,200
B. Type 2, do	100	20	4	7,200
C. Type 3, do	100	20	4	7,200
D. Type 4, do	100	20	4	7,200
3. Corned beef				
a. Intermediate product	100	20	4	7,200
b. Final product	100	20	4	7,200
4. Salami				
a. Intermediate product	100	20	3	5,400
b. Final product	100	20	3	5,400
Total	**1,400**	**280**	**48**	**86,400**

Table 2. Periodical costs for maintenance of 14 PLS calibrations.

Product	Parameters tested				No. of reference analyses for periodical verification	Costs (15 $ pr constituent /reference analysis)
	Fat	Moist-ure	Pro-tein	Colla-gen		
1. Raw meat trimmings						
a. 90/10	X		X	X	5	225 $
b. 60/40	X		X	X	5	225 $
2. Sausages:						
a. Type 1, intermediate	X	X	X		5	225 $
b. Type 2, do	X	X	X		5	225 $
c. Type 3, do	X	X	X		5	225 $
d. Type 4, do	X	X	X		5	225 $
A. Type 1, final product	X	X	X	X	5	300 $
B. Type 2, do	X	X	X	X	5	300 $
C. Type 3, do	X	X	X	X	5	300 $
D. Type 4, do	X	X	X	X	5	300 $
3. Corned beef						
a. Intermediate product	X	X	X	X	5	300 $
b. Final product	X	X	X	X	5	300 $
4. Salami						
a. Intermediate product	X	X	X		5	225 $
b. Final product	X	X	X		5	225 $
Total					**70**	**3600 $**

In the example it is anticipated that it would be necessary to operate a total of 14 PLS calibrations for testing the 8 types of products, of which some are tested twice in the process (process control and final product control).

As shown in table 1, the total cost for building the 14 PLS calibrations are **86,400 US$,** of which 72,000 US$ are for actually building the calibrations and the remaining 14,400 US$ are for verification of the calibrations.

For each calibration, 100 samples are needed for reference analyses when building the calibration and 20 samples for verification reference analyses.

If the customer already has PLS calibrations, f. inst. when using an Infratec 1265, the customer may wish to continue using these PLS calibrations when switching to the FoodScan. In such case some of the building costs can be saved, as the calibrations can be transferred to the FoodScan.

The total annual calibration maintenance costs for monthly verification of the PLS calibrations would be **43,200 US$** (3600 x 12).

In comparison, the FOSS ANN meat calibration has the potential to cover more or possibly all the products.

In the example shown one would normally expect that 4 versions of the ANN calibration are needed (one for raw trimming, one for sausages, one for corned beef and one for salami). There will be no costs for actually building the calibration – it comes with the FoodScan. It would only be necessary to verify each calibration (for slope & intercept adjustment of the ANN). The total reference analyses costs for verification of the ANN calibration in the example, when four constituents are determined, would be **4,800 US$** (20 x 4 x 4 x15 US$).

Likewise, the total annual costs of maintaining the 4 ANN versions would be **14,400 US$** (12 x 5 x 4 x 4 x15 US$).

Based on the example, the difference in number of reference analyses needed, and the related costs for operation of PLS and ANN can be summarised as shown in table 3.

Table 3. Comparison of PLS and ANN – based on example (table 1 and 2)

	PLS	ANN	PLS	ANN	Savings (US$)
	No. of ref. samples		Costs ($)		
Building calibrations					
- Actual building	1400	0	72,000	0	72,000
- Validation	280	80	14,400	4,800	9,600
Annual maintenance					
(monthly verification)	840	240	43,200	14,400	28,800

5. Conclusion

- **Both when establishing as well as in the annual maintenance of the calibrations, there are huge savings when using ANN.**
- **In many cases what the user saves by going from PLS calibrations to ANN can pay for the FoodScan within 1-2 years or even a shorter period.**
- **Particularly where new PLS calibrations have to be built, huge savings are achieved by using ANN instead.**
- **The higher the number of PLS calibrations used, the higher the savings by switching to ANN.**

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FOSS Electric A/S
69 Slangerupgade
DK-3400 Hilleroed
Company Reg.No. 7339 9815

Tel: +45 7010 3370
Fax: +45 7010 3371
E-mail: info@foss-electric.dk
Web: www.foss.dk