The development of global milk powder calibrations

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Milk powder produced by the evaporation and spray drying of liquid milk is a common ingredient commodity used in many foods, as well as being reconstituted to afford liquid products in many countries without ready access to fresh milk. Since 2000 the worldwide production of whole and skim milk powder (WMP and SMP) has increased from 6.3 million tonnes to 7.8 million tonnes[1]. Fonterra Co-Operative Group Ltd, based in New Zealand with milk processing facilities in a number of other countries in the southern hemisphere, is the pre-eminent producer and marketer of milk powder globally.

Near infrared (NIR) spectroscopy has been used routinely for over 20 years to quantify the composition of powdered milk products[2]. Moisture, fat and protein have been analysed routinely on a wide variety of instruments with good accuracy[3]. Traditionally, NIR calibrations for such products have been localized in nature and have used a calibration database of several hundred samples and associated laboratory reference results.

Fonterra has been using NIR spectroscopy to quantify milk powder composition since 1985, and by 1998 had over 40 individual NIR instruments, with more than 300 different calibrations for different types of milk powders. Such a disparate range of instruments and calibrations was both expensive to operate and maintain for a range of reasons:

- Each individual calibration required continued monitoring and adjustment, thus generating a considerable call for laboratory reference testing.
- Each individual calibration required annual updating and validation.
- The number of different instruments and software required much duplication of training and support agreements to different vendors.
- To provide effective support, trained staff was frequently required on all processing sites.

In 2003, Fonterra adopted a strategy to make routine quantification of milk powder composition more efficient. There were four main components of this approach:

- Implement a purchasing strategy for NIR instruments that will be used for milk powder measurement to ensure that optically similar instruments are in place at all processing sites.
- Link all NIR instruments together in a network.
- Adopt generic global calibrations so that single calibrations can be used for WMP and SMP across all processing sites.
- Adopt a single unified system for monitoring calibration performance against laboratory reference testing, across the NIR network.

Table 1. Whole milk powder NIR standard errors of prediction.

Calibration type/year	Number of samples	Fat	Moisture	Protein
MLR & PLS/1998	100–200	0.13–0.31	0.08–0.11	0.12–0.42
PLS/2003	1500	0.18	0.16	0.19
ANN/2003	1500	0.17	0.14	0.17
ANN/2006	7300	0.16	0.09	0.14
ANN/2007	11900	0.16	0.09	0.14
ANN/2008	15750	0.15	0.08	0.13

Since 2005 a network of 15 Foss InfraXact instruments, using the Remote Internet Analysis (RINA) application with artificial neural network based calibrations, has been in place. Alongside this development Fonterra has also implemented RINA based NIR instrument networks for cheese, butter and protein powders based on the same logic.

In 1998 different multiple linear regression (MLR) and partial least squares (PLS) based calibrations on four types of different filter-based and dispersive NIR instruments afforded a range of standard errors of prediction for fat, moisture and protein, as shown in Table 32.1 for WMP. Typically these calibrations used a calibration set of 1–200 samples derived from the specific processing plant with a relatively narrow range of composition for SMP or WMP product (for SMP fat 0.3–1.1%, standard deviation (*SD*) 0.14%, protein 29.5–39.7%, *SD* 1.7%, moisture 3.0–4.7%, *SD* 0.28%, for WMP fat 24.3–29.6%, *SD* 0.89%, protein 22.2–28.5%, *SD* 1.05%, moisture 2.0–4.1%, *SD* 0.35%). Predictive performance varied considerably.

In 2003 some of these calibration sets were combined and similar instruments were used for the same product types. We found that larger PLS-based calibrations, using around 1500 samples in the calibration sets, gave acceptable predictive performance, and a strong indication that reliable global calibrations were feasible for milk powder within Fonterra. The use of ANN models on the same data did not show any significant difference in performance. Following the adoption of the InfraXact instruments from 2005 and gradual increase in calibration and validation set size throughout 2006–2008, we have shown that ANN predictive models can give performance equal to the best site specific calibrations in use ten years prior (Table 32.1).

The challenges of consistently and efficiently measuring milk powder composition across a wide range of processing sites have been successfully overcome by the adoption of a coherent strategy for NIR instrument purchasing, calibration and support and the phased implementation of these tools. We consider that once fully developed, global calibration models of this type offer unique stability over time and confer the ability to support global commodities and brands.

References

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