NDC TECHNOLOGIES
a spectris company

White Paper

NIR Measurement of Moisture, Fat and Protein for Quality and Consistency in Dairy Products

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The Need for On-Line Measurements

Moisture measurement and control is very important during the final processing stages of turning liquid dairy concentrate into powder to ensure optimal product quality and operating efficiency. In a world where food yields from manufacturing have become ever more important, improved control of moisture during the final drying stages enables the process to be safely operated closer to the upper specification limit for final moisture, and offers significant financial benefits including:

- Enabling manufactures to produce highly consistent, within specification, top-quality product
- Operating moisture control/drying processes more efficiently to save energy
- Increasing production yields through not over drying (and potentially damaging) the product
- Minimizing production scrap or rework

Simultaneous measurements of fat and protein for confirmatory monitoring of many dairy products allows for a “right first time” approach, further reducing re-work/re-blending, start-up times and energy costs.

Measurement methods for Moisture, Fat and Protein in Dairy Production

Conventional methods for determining moisture, fat and protein

Conventional laboratory analytical approaches for determining moisture, fat and protein content in QC labs use only a very small amount of sample (~5g), and while accurate, the values cannot be considered a truly representative average of the on-going production batch. They require skilled laboratory technicians to perform, taking many hours to complete and are costly to maintain.

For moisture, bench-top loss-on-drying systems featuring a balance and a heating system are available which can be located closer to the production process. While faster than a QC lab oven loss-on-drying method, they still take a significant amount of time (minutes) to determine a moisture reading which again can lead to potentially inefficient operation and poor verification of the processing stage. Good operator skill is again required to generate consistent and reliable moisture values as samples must be very carefully prepared and consistently presented prior to analysis. These manually intensive devices cannot determine fat and protein content in the powder.

Some companies use laboratory-based, bench-top, full-spectrum Near-Infrared (NIR) based systems to measure moisture, fat and protein in dairy powders. However, these require the costly development of complex calibrations on hundreds of customer samples for moisture, fat and protein. These complex instruments are still relatively slow to make a measurement (1 - 2 minutes), and require the services of experienced NIR analysts to develop and maintain calibrations, especially when something goes wrong or an optical component is replaced in the instrument.

The NDC on-line NIR moisture, fat and protein measurement

The NDC Technologies NIR on-line MM710e gauge has been developed from the start to be fit for purpose for use in a demanding production environment and is delivered with in-built linear calibrations ready to measure in real-time moisture, fat and protein in a very wide range of dairy powders right off-the shelf

Figure 1. *MM710e on-line gauge*

On-line measurements of these critical parameters using the MM710e gauge (Figure 1) enables the process operator to see and quantify in real time:

- Any control actions taking place
- If optimal conditions have been reached during startup
- Early warning that the process maybe drifting out of control, producing out-of-specification product

As an example, Figure 2 shows a %Moisture and %Fat trend plot from samples analyzed every 15 minutes over approximately a 14-hour production period (production volume is approximately 3 tons per hour).

Clearly the process is largely under control, but there are significant periods of approximately 1 hour where the moisture content of the powder drops dramatically. Furthermore, %Fat content appears to be increasing steadily over time and spikes significantly during the periods where the %Moisture content drops.

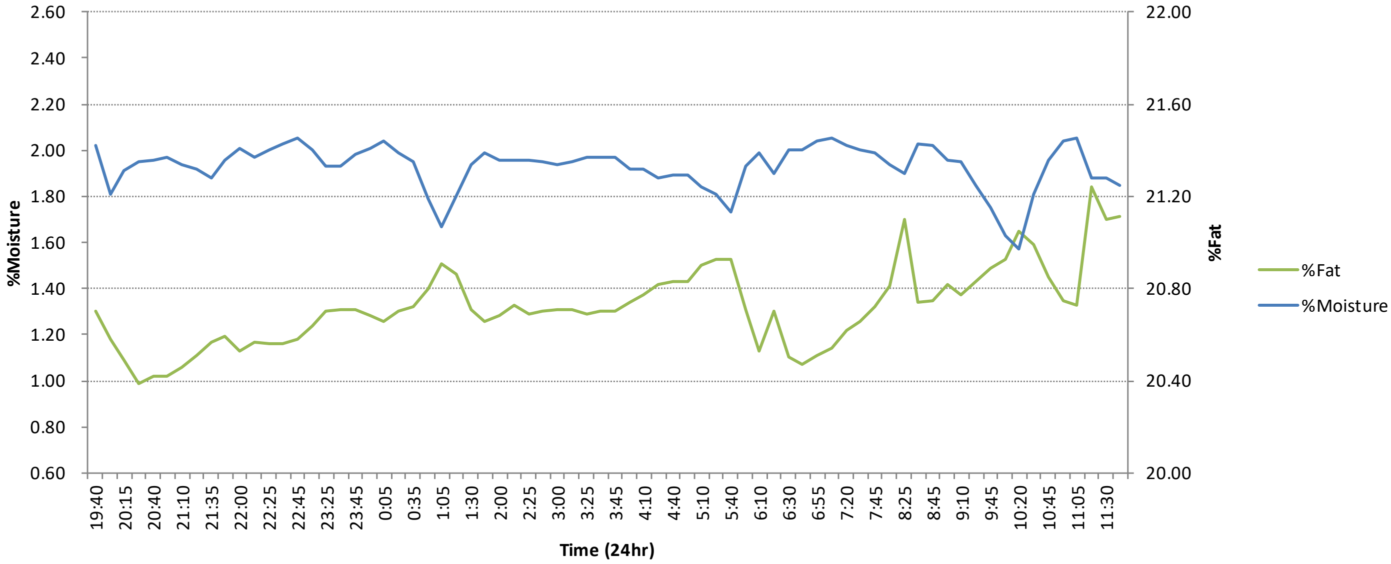


Figure 2. *Moisture and fat trend graph plot*

With real-time measurements using the MM710e, the operator now has early warning that the process is starting to drift out of control, i.e., some part of the process is not operating as expected. So in this example, corrective action can be taken reducing potentially damaging the product by over drying and improving production yields.

A histogram plot of this production data in Figure 3 shows the %Moisture content in the powder is normally distributed around 2.15%.

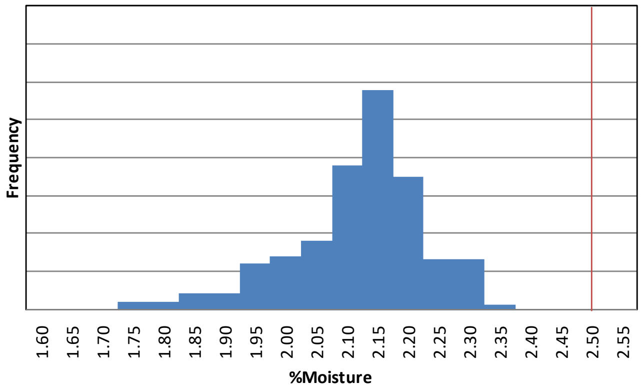


Figure 3. *Histogram for moisture*

However, the target moisture content for this particular product is 2.5%. With real-time measurement, the process can be safely adjusted and maintained at the target moisture content. This offers significant financial benefits from increased production yields and energy savings from a more efficient process operation. As an example, a production site with an annual production volume of 20,000 tons realized an increase in operating profit of $96,000 with a moisture change of 0.2% closer to target.

Measurement locations

The MM710e can easily integrate into the production process via analogue or industrial fieldbus protocols, such as PROFINET, Modbus/TCP, Profibus, and Ethernet IP, for monitoring and closed-loop control. The gauge must be located as close, as practically possible, to the drying stages to provide responsive feedback to the process controller as shown in Figure 6. However, good product presentation to the gauge is important and a measurement location needs to be selected where it is possible to “extract” samples for periodic, comparative checking of the gauge against the site primary reference method. Generally, the gauge will be installed after the final drying process (typically spray drying followed by fluid bed drying/cooling) either:

- At a location where there is a consistent flow of product with measurement through an installed sapphire window.

Figure 4. *Sapphire window*

- Or, by capturing product in the NDC PowderVision sampling cup mounted in gravity-fed pipe work. After measurement, the powder is ejected back into the process with compressed air.

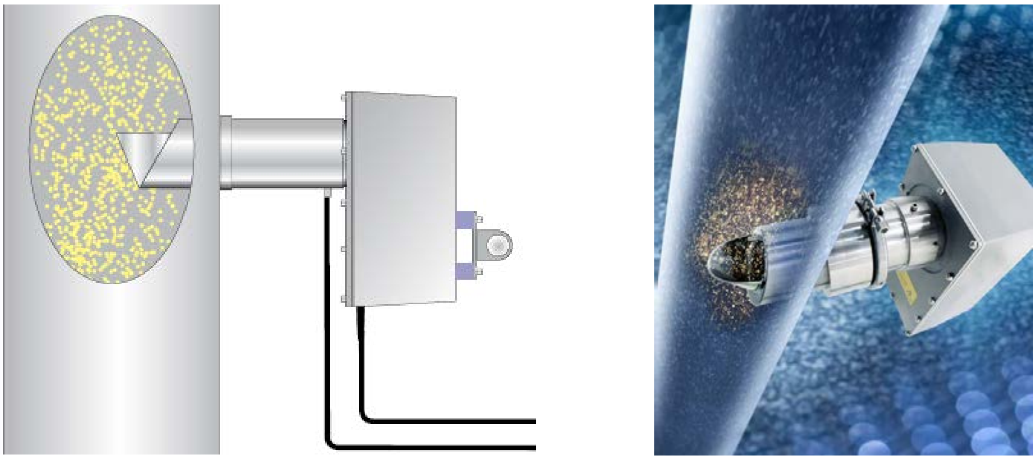


Figure 5. *NDC PowderVision accessory*

Example – potential installation configurations

Figure 6 highlights possible measurement locations after the spray drying process.

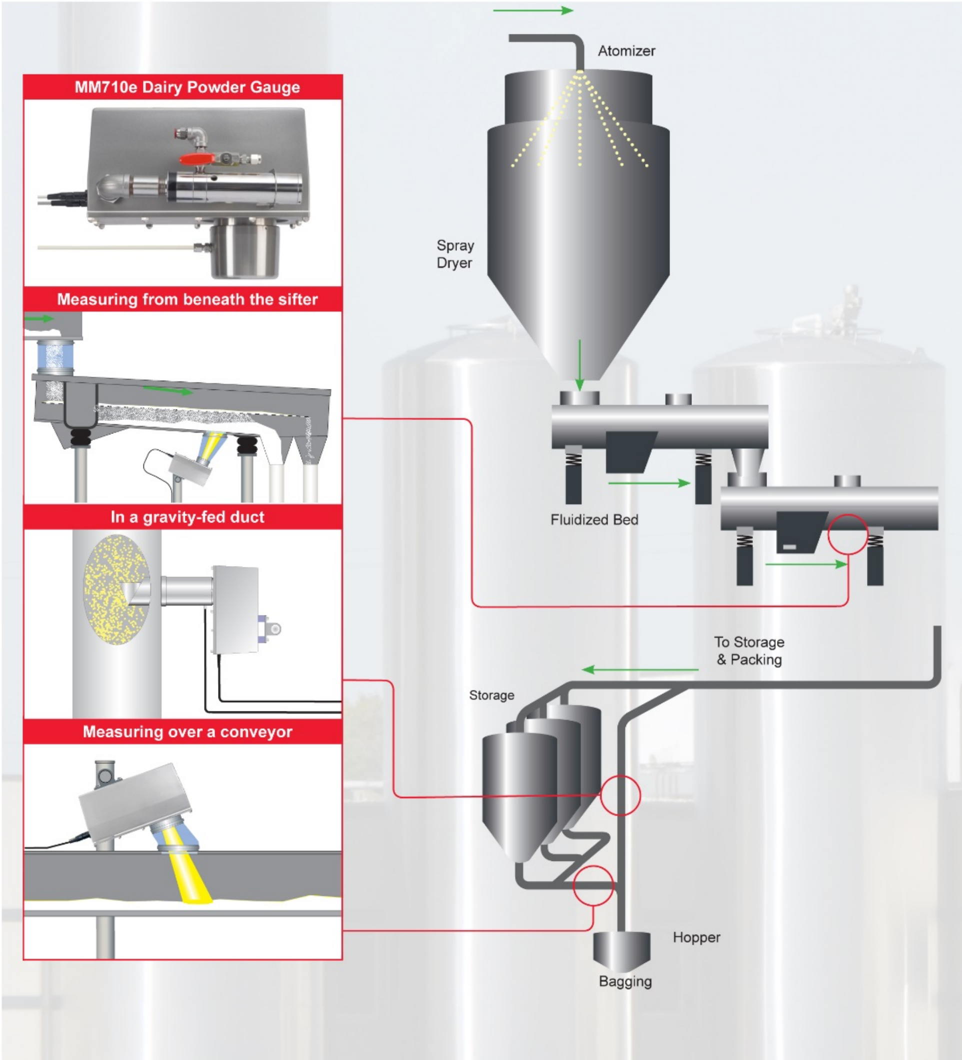


Figure 6. *Optimized product presentation at key measurement locations in dairy powder processing*

NDC measurement performance

The NDC measurements for dairy powders, developed in co-operation with major dairy producers worldwide, are engineered to be:

- Stable -- not prone to measurement drift; desensitised to variations in sample height and particle size
- Fit for purpose -- operates independently of any changes in ambient conditions
- Reliable -- very low cost of ownership
- Desensitized to the effects of seasonal changes

The MM710e gauges are delivered with inbuilt linear calibrations ready to measure fat and protein in diary powders out of the box. As there is no single international standard for measuring moisture or other components in food products, their design makes them extremely simple, with minimal training, to adjust to the customers preferred primary laboratory method. The gauges generate accurate, repeatable and stable measurements that are fit for purpose over the many years the instrument is used.

This is the absolutely crucial part of adopting NIR technology for process control, as low cost of ownership is built into the NDC technology, unlike other gauges which require costly, time-consuming and often specialized calibration to customer samples.

Table 1 and the charts in Figures 7 – 9 demonstrate the NDC measurement performance against a QC oven primary reference method for a variety of products.

Product	Component	Accuracy
Skim, Full Fat, Replacer Fat Powders, Infant Formulation	Moisture 0-5% Fat 10-40% Protein 10-35%	±0.1 ±0.25 ±0.6
Casein Powder	Moisture 5-12%	±0.2
Whey (WPC)	Moisture 0.5-5% Protein 10-35%	±0.2 ±0.2
Lactose Powder	Moisture 0.5-5%	±0.2
Non-Dairy Creamers	Moisture 0-5% Fat 10-40%	±0.1 ±0.3

Table 1. *Representative examples of NDC-developed algorithms*

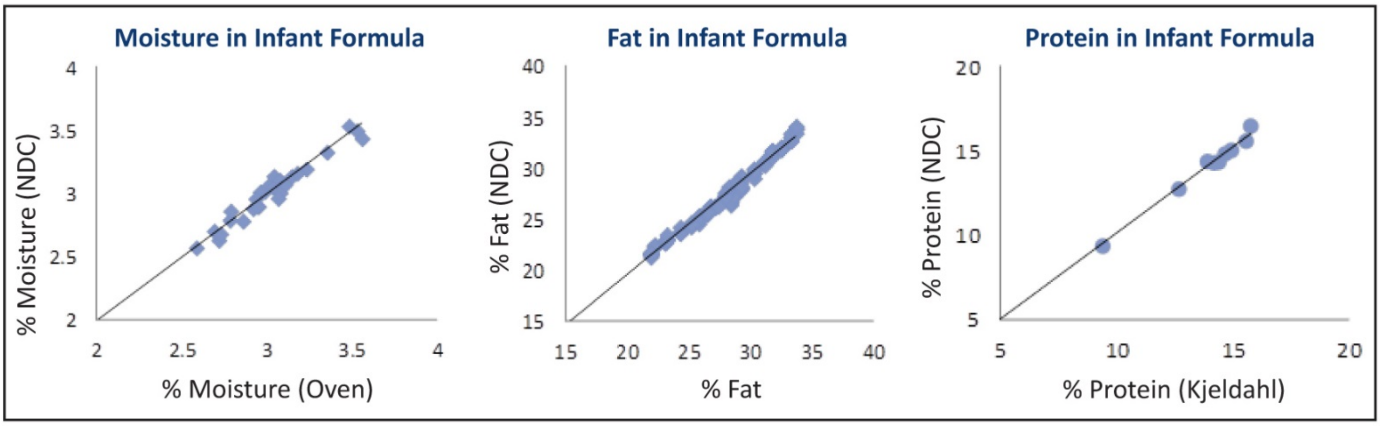


Figure 7. *NDC gauge measurement performance against primary reference methods*

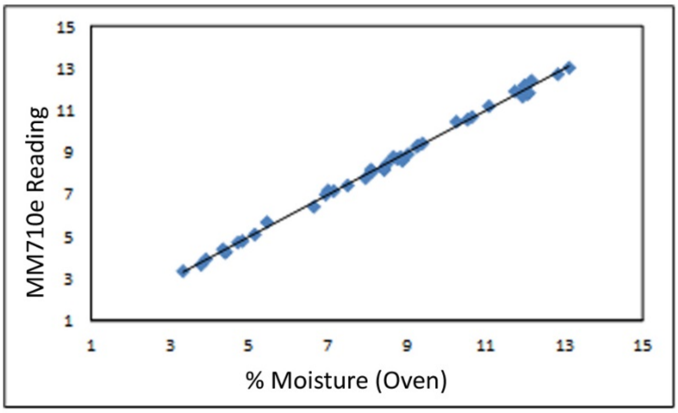
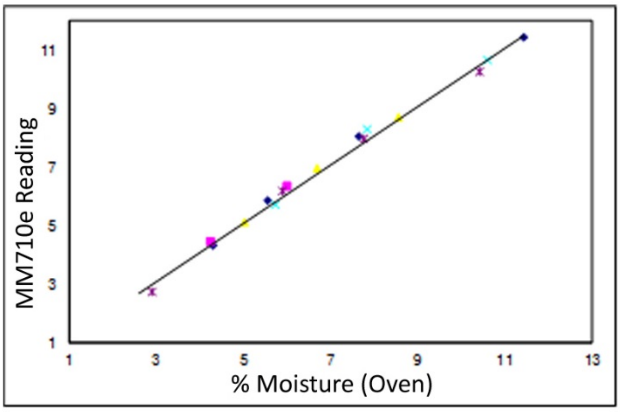


Figure 8. *MM710e vs Oven reference for Rennet Casein*



NOTE: Figure 9 shows five types of caseinate, identified with different symbols. These include sodium caseinate, calcium caseinate, mixed caseinate and granulated caseinate. The plot shows that all types may be measured using a single calibration.

Conclusion: Measureable Benefits

This paper has detailed how NDC's solutions bring measureable process benefits during the final stage of turning liquid dairy concentrate into powder. In particular, they:

- Enable manufacturers to produce a highly consistent, within specification, top-quality product that complies with food safety and other regulatory requirements
- Realise energy savings through efficient operation of the drying processes and reduce the risk of potentially damaging product by not over drying

Furthermore, the financial rewards obtained from good moisture control will rapidly cover the initial cost of the instrument with a low cost of ownership and an early return on investment.

As an example, a dairy powder production site with an annual production volume of 20,000 tons realized an increase in operating profit of $96,000 with a moisture change of 0.2% closer to target.

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