ONLINE BUTTER ANALYSIS BY NIR

Andrew Wallace
Bran+Luebbe Ltd.
Brixworth, Northants
UK

ABSTRACT
The analysis of butter using near infrared (NIR) technology has been carried out in the laboratory or at line since the early 1980s using laboratory type systems. One such system is the Technicon InfraAlyzer (models 260, 360, 400 or 450) which uses selected wavelength filters to measure moisture and salt in butter samples. This technology has wide acceptance in the industry as a rapid and easy to use system. However, it still requires manual intervention and is not able to control any part of the process directly. This was the basis for Bran+Luebbe to investigate the possibility of putting this technology online to control the addition of salt, water, and lactic acid without manual intervention. The major hurdle is sample presentation to the optics of the NIR analyzer without forming a layer of “static” butter on the window. The purpose of this paper is to describe the automation of this analysis, the expected performance, and the potential payback in both financial and productivity terms. It also describes the hardware and software used to control the addition of ingredients using an automated dosing system.

INTRODUCTION
The analysis of butter using near infrared (NIR) technology has been carried out in the laboratory or at line since the early 1980s using laboratory type systems. One such system is the Technicon InfraAlyzer (models 260, 360, 400 or 450) which uses selected wavelength filters to measure moisture and salt in butter samples.

This technology has wide acceptance in the industry as a rapid and easy to use system. However, it still requires manual intervention and is not able to control any part of the process directly. This was the basis for Bran+Luebbe to investigate the possibility of putting this technology online to control the addition of salt, water, and lactic acid without manual intervention. The major hurdle was sample presentation to the optics of the NIR analyzer without forming a layer of “static” butter on the window.

EXPERIMENTAL
The project was initiated in research and development and a graduate from a French university was asked to look at the initial designs and check the flow characteristics of the various proposed designs. Of the various proposals, two designs were selected and prototypes built. These were tested on butter and margarine and appeared to function well in pilot plant situations; however, in depth trials the performance fell off over time and the optics window coated. On the basis of this a further design was produced with a variable gap between the optics window and the flow-diverter. The concept was that a fast flow past the window directed against the window would allow the sample to clean the window as it flowed past.

Once the prototype of the analyzer cell was produced, the next hurdle was calibration of the NIR analyzer. This was accelerated by the use of an existing 360 laboratory system calibration used at a different dairy for the rapid analysis of salt and moisture in salted and unsalted butter. The calibration “F” values were entered in the InfraAlyzer 600 and the analysis started. It was expected that the calibration would need adjusting using the skew and bias software. However, this was not the case and from the very beginning the system produced sensible results that corresponded with the routine test samples which were analyzed using the manual rapid method (driving off the moisture by heat).

The important criteria for the production of butter is a consistent product with the moisture level as close to the maximum 16% as possible. The monitoring of the salt concentration and the lactic acid levels are of less commercial significance. Salt concentration has a maximum of 2%.

This design was installed in a dairy using an APV Pasilac buttermaker for a performance trial (Figure 1).

Figure 1. Butter system schematic.

The paste cell is installed directly after the lobe pump of the buttermaker where the flow of butter ranges between four and six tons per hour. The pipework at this point is 100 mm diameter and had to be reduced to 50 mm through the paste cell, yet remains at 100 mm through the...
by-pass. To ensure that there is sufficient flow past the paste cell window, the valve in the by-pass is adjusted until the output from the analyzer is stable. This set-up is shown in Figure 2.

The system is tolerant to the cleaning in place (CIP) processes used in this dairy which involve steam, hot water, caustic, and a silica based detergent (The latter improves the slip characteristics of the pipework).

The flow of the butter past the cell had no detrimental effect on the butter even though approximately 50% passes through this part of the system. The analysis of the butter is carried out every two minutes, which gives ample warning of any drift in the process. In the case of a system involving closed loop control of the dosing of the water, salt, and lactic acid, an averaging over several analysis cycles is most appropriate.

RESULTS

Figure 3 shows the results from the analyzer over a period of 24 hours and indicates a change from unsalted butter to salted butter (lower dashed trace). The top solid trace indicates the moisture levels, with the X indicating the manual sample results using the rapid method.

Figure 3. Salt and moisture plots with laboratory results (X).
Cleaning Cycle Results

As can be seen from Figure 4, the system responds immediately after the cleaning cycle and the results both before and after correlate well. The online analysis has highlighted the effect of stopping the pump and the changes that occur after a cleaning cycle even though the dosing pump settings have not been altered.

Moisture Results

As shown in Figure 5, the moisture levels are not very constant for two days. During this time, the analyzer was adjusted to give the same reading as the rapid moisture method by applying a bias to the calibration. This helps illustrate the potential improvement that can be achieved by monitoring the moisture more frequently.

Figure 4. Results before and after a cleaning cycle.

Figure 5. Moisture analysis results.
DOSING SYSTEM AUTOMATION

The ultimate aim of any online analyzer is to control the process by direct closed loop control of the controlling system, be it dosing pumps, temperature flow, or any other controllable variable. In this case, the primary control requirement is the control of the dosing of liquid additions at the exit of the buttermaker; i.e., the water, salt, or lactic acid addition. By use of a purpose-designed software package — Autoblend 21 — control of the dosing pumps using the analyzer output is possible (Figure 6). The pumps must be equipped with electric stroke adjusters and also have speed control on the drive motors to enable them to respond to signals from the control PLC. The output of the analyzer in the form of 4–20 mA signals proportional to the concentration of the moisture, salt, etc. are fed into the PLC and these signals then averaged over a predetermined number of analysis cycles and the pumps adjusted accordingly. The setting up of the pump control system involves a recipe sheet so that for each set of conditions the setpoint of the appropriate pump is set at start up. The data in this recipe sheet can involve such things as:

- Fat concentration of cream
- Churn speed
- Temperature of Buttermaker
- Temperature of cream
- Type of butter to be made

The operator can enter this data and on start-up the pumps will be preset to the optimum settings that have been stored from previous runs. During the first ten minutes (this time is determined from the experience of the buttermaker) the output from the analyzer can be ignored, therefore allowing the process to stabilize before adjustments are made. Once the full production batch has commenced, the control of the dosing is automatic thus allowing much tighter control of the water and/or salt addition and therefore achieving a more consistent product.

AN OVERVIEW OF THE PROCESS

Table I shows the steps in the butter making process.

The cream from the silo is fed into the balance tank prior to the buttermaker. The size of the silo is important in that the bigger the better, as it will give a more consistent cream to the buttermaker. Every time the silo changes, the conditions in the buttermaker will change. The temperature of the cream as it enters the buttermaker should be as stable as possible; the cream will pick up both water and heat as it passes down the pipe work. The temperature is then reduced as it enters the buttermaker balance tank. The purpose of the balance tank is to provide a batch of cream that is constant in temperature and fat content, as both these factors influence the quality of the butter. The flow rate from the balance tank to the buttermaker also needs to be constant.

In the churn, the speed of the beater is critical; too fast a speed will create bigger “granules” which hold more moisture while slower speeds produce smaller granules with a larger surface area. The churn speed should be maintained at a constant level to produce a consistent butter with a basic moisture level, i.e. a homogeneous mix.

After this stage the buttermilk is drained off and separation occurs. This separation continues into the first working area, where again the speed of the beater remains constant. In this stage there will be changes in the pressure of the buttermaker and the dosing of water and/or salt occurs.

The second working section is where the whole is blended until a homogeneous mix is achieved, with an even distribution of the moisture in small droplets of about five micron in size.

In the case of the Pasilac system, a vacuum of about 80% of full vacuum is generated at the lobe pump before the butter is discharged. This gives the butter a better consistency; if there is no vacuum then the butter will contain between 4 and 8% air.

RAPID METHOD FOR MOISTURE

A sample of butter weighing approximately 25 grams is extracted from the process line. Approximately ten grams of this sample is placed in a crucible, weighed, and then placed on a tripod over a Bunsen burner. This is heated “gently” using a “cool flame” until the sample stops boiling (which indicates that all the moisture has been driven off). It is then re-weighed and the difference in weight calculated as the moisture loss and then converted to the percent moisture in the butter.
Table I  The Butter Making Process

<table>
<thead>
<tr>
<th>Process Step</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Separation</td>
<td>Centrifuges milk to obtain 40% fat cream</td>
</tr>
<tr>
<td>Pasteurization and</td>
<td>Holds pasteurized cream at 10°C for 12-24 hours</td>
</tr>
<tr>
<td>Aging treatment</td>
<td>Agglomerates butter fat by agitation of cream</td>
</tr>
<tr>
<td>Churning</td>
<td>Removes butter mile and hardens butter fat grains</td>
</tr>
<tr>
<td>Washing</td>
<td>Adds salt to butter fat grains at 1.2-1.4%</td>
</tr>
<tr>
<td>Salting</td>
<td>Disperses salt and moisture droplets; gives texture to butter body</td>
</tr>
<tr>
<td>Working</td>
<td></td>
</tr>
<tr>
<td>Packing</td>
<td></td>
</tr>
</tbody>
</table>

Figure 6. Information flow diagram for the automation of the buttermaker.
BENEFITS OF THE THREE PROPOSED LEVELS OF AUTOMATION

Level One: Online Analysis

At this level, the existing buttermaker has only the InfraAlyzer 600 Paste Cell and bypass incorporated into the production line. An example of this is the Pasilac system installed directly after the lobe pump, as shown in Figure 1.

The display from this analyzer can be in a control room and results will be updated every two minutes. It differs from the “normal” manual system as follows:

- More frequent analysis
- Less delay in getting results
- Multiparameter results (not just moisture) every half-hour or hour
- No operator variation

Advantages:

- More frequent analysis, allowing closer manual control
- No delay in results
- Operator is not involved in analysis
- Tighter control possible

Performance comparison:

- Manual testing every 30 minutes: Average moisture level for period of one week = 15.5%
- Using InfraAnalyzer to adjust dosing (manually): Average moisture level for period of one week = 15.7%

Payback:

- Cost of system with dosing control: £100,000
- Cost benefit of total package: £200,000
- Extra profit in first year: £100,000

Another advantage of this option is the reduction in the influence of inexperienced operators.

Level Two: Online Analysis with Control of Water and Salt Dosing and Linked to the Buttermaker

At this level, the existing buttermaker has the InfraAlyzer 600 Paste Cell and bypass together with a Magflow meter after the bypass incorporated into the production line. After the lobe pump in the case of the Pasilac Buttermaker.

The same benefits as for the analyzer apply, but with the following additional advantages:

- Quicker start-up time – stabilization
- Quicker and more accurate adjustments due to changes in moisture / salt level
- More consistent product
- Higher average moisture levels over the runs (closer to the maximum permissible)

The following has been calculated using theoretical performance data of the dosing pumps and the InfraAnalyzer 600:

- Control level of Moisture = 16% ±0.1
- Accuracy of the analyzer = ±0.1% at 95% confidence
- Set point for control = 15.8%
- Estimated average moisture level = 15.9%
- Benefit above analyzer only option = 0.2% or £100,000 per year.

Payback:

- Cost of system with dosing control: £100,000
- Cost benefit of total package: £200,000
- Extra profit in first year: £100,000

Another advantage of this option is the reduction in the influence of inexperienced operators.

Level Three: Online Analysis with Control of Water and Salt Dosing and Linked to the Buttermaker

This level of closed loop of control at present is only proposed on a theoretical basis as the actual control functions of the buttermaker are not fully understood by Bran+Luebbe. However, it probably is feasible and would lead to a more controlled process.

A total control system would involve the writing of specific control software which would interlace with the dosing control and the analyzer output along with other variable inputs, such as temperature, flow, churn speed, and cream type (fat content). This concept is indicated in Figure 6.

ACKNOWLEDGEMENTS:

Stuart Leslie, Bran+Luebbe Ltd: For his assistance in the setting up and applying the system to the REAL world.

Colin Williams and Staff, St Ivel, Chard: For the use of the buttermaker and his butter making staff, also a thanks for their patience.

Sten Berntsen, APV, Denmark: For the support information on the buttermaker.

REFERENCES