PAT approach for cheese manufacture

Researchers at TEAGASC and UCD are validating a prototype in-line sensor to control and monitor the cutting of milk coagulum at optimum condition during cheese manufacturing.

Ireland exports 85% of all dairy outputs and is the 10th largest dairy exporting nation in the world. Considering the huge contribution of cheese exports to the Irish dairy sector (worth €695 million in 2016), it is essential to ensure the quality and consistency of the cheese being produced. This can be achieved by adoption of process analytical technologies (PAT) in the dairy factory, as it encourages process efficiencies by in-line, real-time monitoring and control of the cheese manufacturing process.

Optimum cutting time for cheese quality

Cheese manufacturing involves several steps that contribute to the quality of the cheese produced. Standardisation of milk and coagulation are the earliest critical points where the quality of the cheese can be monitored and controlled. Ongoing studies at Teagasc Food Research Programme, Moorepark, have focused on the control and optimisation of the coagulation process. Coagulation of milk can be described as the transformation of milk into a semi-solid coagulum by the action of rennet, a proteolytic enzyme (**Figure 1**). Depending on the type of cheese produced, the coagulum formed requires cutting at an optimal firmness linked to a particular curd structure. If the coagulum is cut too early, a soft fragile network is formed. This results in increased curd fines (small particles that are not recovered in the cheese) and fat loss during syneresis (the process where liquid whey is expelled on stirring the cut coagulum), leading to reduced final cheese yield. In contrast, a delayed cutting time produces an overly firm gel, in which the network is unable to rearrange, resulting in retarded syneresis and increased curd moisture, compromising finished product quality. In most cheese plants, the coagulum formed is cut after a predetermined time, whereby optimal coagulum properties have been achieved. It can also be determined subjectively based on evaluation of textural and visual properties of the curd. It is essential to monitor coagulum firmness and cutting time in every cheese vat to ensure a consistent product, which has driven the need for robust in-line PAT to support cheese processes. Several off-line, at-line, on-line and in-line devices have been studied for monitoring both coagulum firmness and prediction of cutting time in the cheese process. Existing PAT, including hot-wire probes and near infrared (NIR) reflectance probe sensors, are used in commercial plants to monitor coagulation kinetics and predict optimal cutting conditions. Although these in-line tools are efficient in predicting coagulation kinetics, it is reported that they have poor prediction accuracy in respect to compositional changes such as varying protein content.

Research using in-line PAT sensor

Current research in Teagasc and UCD is focusing on the validation of a prototype in-line PAT sensor based on combined NIR reflectance and fluorescence probes operating synergistically to monitor coagulation kinetics of milk. Changes occurring in the milk matrix during coagulation correlate with differences in output signals from both probes. NIR reflectance data provide real-time monitoring of particle size distribution and formation of gel structure. As casein

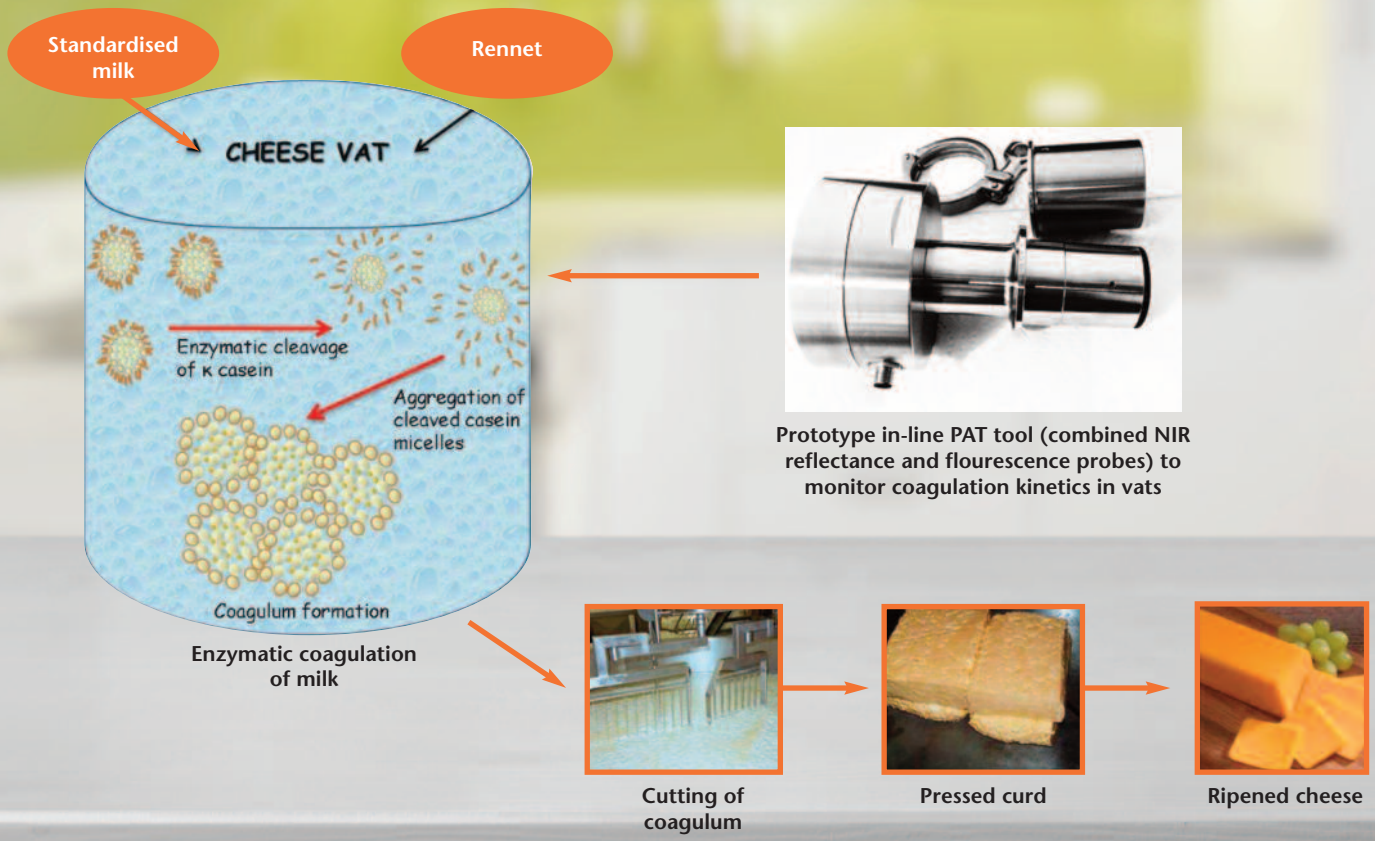

FIGURE 1: Enzymatic coagulation of milk and the PAT tools used to monitor the process.

micelles aggregate forming larger particles, there is a shift in particle size distribution that leads to increased reflectance during coagulation of milk, while the fluorescence probe, which measures the fluorescence emitted by tryptophan, monitors changes in the signal impedance linked to the formation of the coagulum.

Optimum conditions at industry level

Validation of the optimal cutting conditions obtained from the sensor was performed using rheological tests that provide accurate information on optimal cutting characteristics, based on the firmness and strength of the coagulum formed. The time points at which changes were recorded in the output signal from the sensor correlated with the gelation point obtained from the rheological test. The data points from the sensor and rheological method were used in developing a prediction model to predict the optimal cutting time in model systems. Final validation of the sensor at industrial level is underway. With ongoing development of robust prediction models, the in-line PAT sensor, combining NIR reflectance and fluorescence probes, has the potential for optimisation of cutting time, compared to existing technologies, therefore improving batch-to-batch consistency in Irish cheese plants.

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