



Application note | CoaguSens™ Connect

Yield optimization journey – Phase 3: Industrial at-line monitoring of coagulation for yield optimization



COAGUSENS™ CONNECT

BACKGROUND

Cheese is obtained from coagulating milk by separating the milk gel into solid curds and liquid whey. The milk gel is cut into small cubes to increase curds surface/volume ratio and allow whey expelling from curds, a phenomenon called syneresis. The objective of any cheesemaker is to optimize the retention of fat and proteins in cheese while the level of moisture is maintained at a controlled level.

The firmness of milk gel when being cut greatly affects Solids Retention Rate, which is the proportion of solids in milk (everything but water) that is recovered in cheese curds. The Solids Retention Rate specifically measures the performance of milk treatment, recipe formulation, coagulation kinetics as well as the relevance of the selected gel firmness at the cutting step. Contrary to the overall cheese yield that is affected by many factors of the process, Solids Retention Rate measures the efficiency of production at the cheese technology level. The Solids Retention Rate may also be called “vat yield” or “coagulation yield”. It represents the efficiency of an industrial process to convert milk into cheese curds and is easily calculated from Milk Solids and Whey solids. Solids that don't turn into cheese end-up as whey solids losses.

Even though they may be recovered by various processes and turned into whey ingredients, it is in most cases more profitable to retain solids into cheese. For a given milk composition there is an optimal cutting firmness to reach the highest vat yield. Cutting the gel too soft leads to lower vat yield through increased whey fat loss, whereas cutting too firm results in too high curds moisture content and difficult crumbly curds cutting. Suboptimal cutting firmness also alters the ripening process and final product quality.

It is generally known that better profit is made by turning milk solids into cheese compared to reprocessing whey solids to extract fat and proteins. Because whey ingredients have lower value and require extra energy, equipment and staff to be extracted, it is interesting to increase vat yield in order to make more cheese from the same milk volume. In addition, since milk production is responsible for over 90% of cheese making carbon footprint, maximizing vat productivity directly contributes to reducing the environmental impact of the cheese industry.

Presently, in cheese plants, milk gels are cut either: at a fixed time, at a calculated time

from measured flocculation time and/or according to cheesemakers' subjective evaluation of gel texture and appearance. None of these techniques is perfectly accurate nor sensitive enough toward variations of the milk gel firmness. These techniques lead to considerable fluctuations in Solids Retention Rate and combine with many other factors that affect the yield such as seasonal milk variation and complex milk standardizations and treatment.

There is a clear need for objective, quantitative, at-line and real-time measurements of milk gel firmness during coagulation that allow automatic and consistent gel cutting.

This is why Rheolution Inc. developed CoaguSens™ Connect, the first industrial testing instrument that:

- Quantitatively measures milk gel firmness during coagulation.
- Monitors close to the coagulation vat the formation of the curd.
- Automatically triggers cutting when the optimal target firmness is reached by the curd.

This application note presents results obtained in a North-American cheddar cheese plant that deployed the CoaguSens™ Connect to increase Solids Retention Rate.

COAGUSENS™ CONNECT

CoaguSens™ Connect characterizes in real time the evolution of milk gel firmness during coagulation under the action of enzymes (coagulation) or ferments (fermentation). The patented technological principle behind this instrument is purely mechanical: the dynamic response of the milk sample to small and gentle vibrations is first measured using a contact free laser probe and then processed to obtain a quantitative value for gel firmness (elasticity or shear storage modulus G'). CoaguSens™ Connect has the following main specifications:

- Real time elasticity measurement of milk gel firmness.
- Thermal control between 20°C (68°F) and 50°C (122°F).
- Ingress Protection (IP65).
- Communication protocol with PLCs: Modbus TCP/IP.

CoaguSens™ Connect comes with a modular, user-friendly and connected touch-screen-based user interface, called CoaguTouch™, designed to configure the instrument, set and run a test and analyze data. It has been designed for a simple integration with existing PLC-based control systems for automatic process control. CoaguTouch™ provides user-oriented tools and functions to manage, analyze, display, store and transfer data.

IN-PLANT VAT YIELD OPTIMIZATION WITH COAGUSENS™ CONNECT

The objectives of the study were:

1. To use CoaguSens™ Connect to measure and plot milk gel firmness in real-time during coagulation and close to the vats.
2. To increase Solids Retention Rate (vat yield) by determining the optimal cutting firmness of the milk gels.

Solids Retention Rate was calculated from vat Milk Solids (the total amount of solids contained in milk) and vat Whey Solids (the total amount of solids contained in whey sampled after cut and rest time) both measured with a MilkoScan FT2 Infrared Milk Analyzer (FOSS, Denmark). Solids Retention Rate was calculated using the following formula:

$$\text{Solids Retention Rate (\%)} = \frac{\text{Milk Solids Weight} - \text{Whey Solids Weight}}{\text{Milk Solids Weight}}$$

Solids Retention Rate is a better performance indicator of coagulation than overall cheese yield that is influenced by cheese moisture and all production processes that follow milk coagulation. The in-plant study took place in a North-American cheddar cheese plant that uses a highly enriched milk:

MILK COMPOSITION	
Protein content in milk	4.2%
Total solids content in milk	14.5%

The study was structured in 3 phases:

PHASE 1 - LEARNING

During this phase, milk gel firmness at the cutting step was measured using CoaguSens™ Connect on 40 different vats. The cutting time was decided by the cheesemaker following a manual palpation technique to assess the texture of the curd.

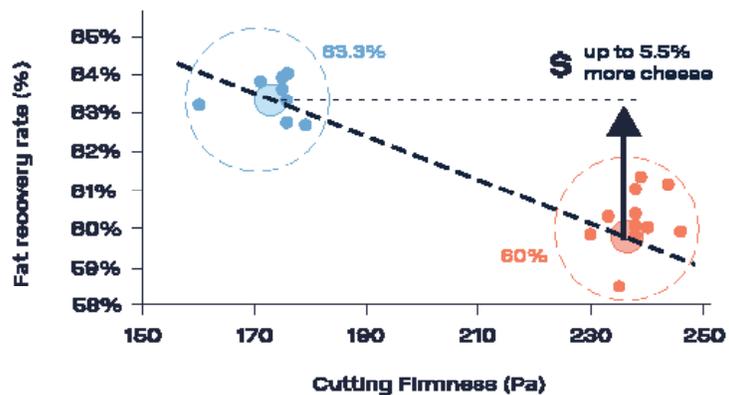
PHASE 2 - STABILIZATION

The average cutting firmness of the 40 vats tested during the learning Phase was calculated (235 Pa) and used as the target cutting firmness for the 40 subsequent vats. This move stabilized the milk gel cutting firmness and the Solids Retention Rate averaged at 60.0%.

PHASE 3 - OPTIMIZATION

The execution of Phase 1 (learning phase) gave interesting indications. Indeed, vats where milk gels were cut at a lower firmness showed higher Solids Retention Rates. So, the target cutting firmness was moved from 235 Pa to 170 Pa. As a consequence, the average Solids Retention Rate moved from 60.0% to 63.3%.

A vat with a capacity of 16,000 L of milk used to deliver 2,324 Kg of cheese at 60% Solids Retention Rate. After changing the target cutting firmness and increasing the Solids Retention Rate to 63.3%, the same vat produced 2,452 kg of cheese. In other words, production increased by 128 kg of cheese per vat at 39% moisture content.



Solids Retention Rate as a function of the cutting firmness of milk gels in a North-American cheddar cheese plant



ECONOMICS & RETURN ON INVESTMENT

By delivering the absolute milk gel firmness in real-time to the cheesemaker, CoaguSens™ Connect uniquely allows perfect at-line control of the cutting step and swift optimization of vat yield. Increasing vat productivity allows producing more cheese from the same milk volume impacting positively many business aspects: need for extra vat investment may be delayed, customer spike orders may be addressed, raw material and energy consumption is less.

By displaying live coagulation kinetics, CoaguSens™ Connect allows quick and early reaction to coagulation defects, human error or equipment failure (culture and rennet lower dosage or poor activity, milk defects, forgotten step or ingredient, equipment breakdown, etc.). Whatever happens, CoaguSens™ Connect tells you anytime what firmness the milk gel is at, so you can make the right decision and save your batch, yield and cheese quality. Return on investment (ROI) in a plant depends on production volumes and varies from 6 to 12 months.

CoaguSens™ Connect has been designed to be operated by cheesemakers (or production operators) who routinely use it to generate data or control coagulation in production. Production or process optimization managers use the data generated by CoaguSens™ Connect to build strategies to optimize yield. CoaguSens™ Connect provides intelligence by enlightening hidden coagulation processes at industrial level.

WHAT TO REMEMBER

The cheese industry needs a technology capable of mimicking milk gel manual palpation, while being more accurate and reliable. Hotwire and light-scattering technologies offered unsatisfactory results because they do not measure milk gel firmness. Since they are installed inside the vats, they are extremely vulnerable to local heterogeneities in terms of coagulant distribution in the vat.

CoaguSens™ Connect, delivers real time measurement of milk gel absolute firmness that compares to human feel. Gel firmness is measured with a high sensitivity and plotted before cheese makers' eyes from renneting to cut and after. These unique features allow to perfectly control coagulation and to quickly react to any drift. It also empowers cheesemakers, R&D and productivity improvement specialists to get the highest vat yield for each of their cheese recipes.

Even for highly standardized milk operations, coagulation kinetics do subtly vary. If curds are cut by the clock, suboptimal firmness at cut will repeatedly occur along with suboptimal yield. In-plant tests described in this study revealed that CoaguSens™ Connect can help increase vat yield. Within weeks, Solids Retention Rate was raised from 60.0% to 63.3% and vat productivity by 5.5%.