Rheolution AGRI-FOOD

Application note | CoaguSens™ Connect

Solids Retention Rates and Coagulation: A pilot plant correlation study

COAGUSENS™ CONNECT

BACKGROUND

This application note describes a study performed at the cheese pilot plant of the R&D center of the Canadian department of agriculture & agri-food (Agriculture & Agri-Food Canada) in Saint-Hyacinthe (QC, Canada). The study aimed to measure the influence of the curd firmness and coagulation speed at the time of cutting on the retention rates of fat, protein and solids in cheddar cheese. The CoaguSens™ Connect (Rheolution Inc, Canada) was used to conduct this study.

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)

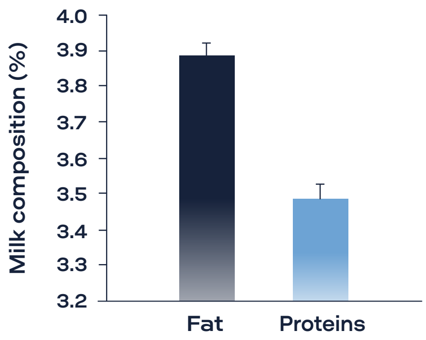
— Ingress Protection (IP65)

— Communication protocol with PLCs: Modbus TCP/IP

CoaguSens™ Connect comes with a modular, user-friendly and connected touchscreen-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.

CONTEXT

This study aimed to measure the effect of cutting milk gels (produced by enzymatic coagulation) at four (04) different curd firmnesses on fat, protein and solids retention rates. The type of cheese produced in this study was cheddar. The project also aimed to measure the effect of coagulation speed at cutting time on the different retention rates.



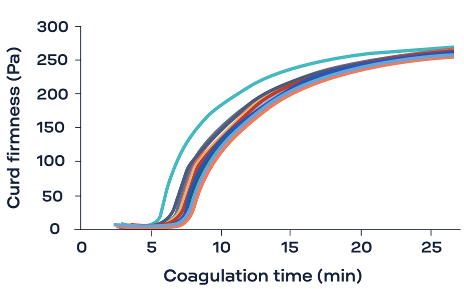
Fat and protein content of the standardized milk used in the study

For that purpose, 3 randomized repetitions were performed for each of the four (04) cutting firmnesses. A total of 12 vats were tested from Nov. 2016 to March 2017. 1 vat that showed extreme retention rates (outliers) was withdrawn from this study.

PROTOCOL

The parameters and conditions of the experimental study are summarized in the following table:

Production Conditions	
Vats	Three 100 L double-O vats were used at each of the 4 production days
Period	From Nov. 2016 to March 2017
Experimental plan	4 productions, 3 vats per production. The 4 levels of cutting firmnesses were randomly tested over the 4 production days.
Milk Standardization and Technological Parameters	
Milk fat	Standardized at 3.88% (±0.04%)
Milk protein	Standardized at 3.48% (±0.04%)
Milk solids	Standardized at 12.85% (±0.08%)
Milk pH	Adjusted to 6.7 with lactic acid
Culture	Lactococcus lactis ssp cremoris (AAC collection) inoculated at (1.28 ± 0.7) x 10^7 CFU per mL of milk.
Coagulant	CHY-MAX Extra (Chr. Hansen A/S, Denmark) at 7200 IMCU/100 L of milk
Calcium Chloride ($CaCl_2$)	26 mL per 100L of milk (at a dilution of 35% w/w)
Coagulation temperature	32°C (90°F)
Renneting pH	Renneting initiated at pH 6.45
Curd cutting and drainage	
Curd cutting	Manual (harp)
Tested cutting firmnesses	190, 210, 230 and 260 Pa (as measured by CoaguSens™ Connect)
Whey draining pH	Drainage initiated at pH 6.10
Milk and whey analysis	
Fat and Solids in milk and whey	MilkoScan FT-120 Infrared Milk Analyzer (FOSS, Denmark)
Protein in milk and whey	Kjeldhal (Kjeltec 1030 – Tecator)



Coagulation kinetics of the 12 vats tested in this study. The variability of coagulation kinetics (due to the variability of the experimental conditions) was precisely measured by CoaguSens™ Connect.

PARAMETERS MEASURED BY THE COAGUSENS™ CONNECT

CoaguSens™ Connect was used to measure the following parameters by sampling milk from each of the 12 tested vats :

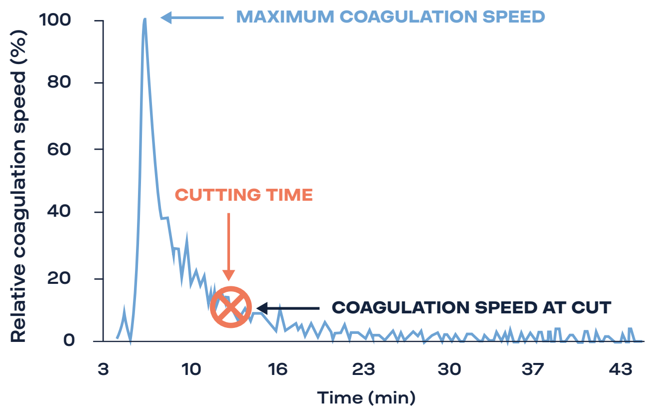
- Coagulation kinetics: curd firmness as a function of time.
- Curd firmness at cutting time.
- Coagulation speed at cutting time V_{cut}
- Maximum coagulation speed V_{max}

The relative coagulation speed at cutting time was calculated based on the time evolution curves of the speed of coagulation as follows:

Where:

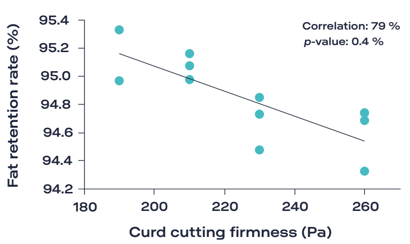
$$\textbf{Relative Coagulation speed (\%)} = \frac{\textbf{Coagulation speed at cut}}{\textbf{Maximum coagulation speed}}$$

- The coagulation speed at cut is the speed at which milk coagulates (measured in Pa/s) at the exact time where the curd cutting was initiated.
- The maximum coagulation speed is the maximum of the coagulation speed curve that represents the milk gel maximum forming rate at the beginning of the coagulation kinetics.

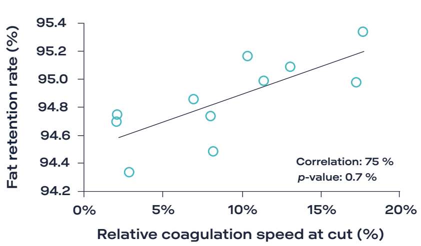


Fat, protein and solids retention rates were calculated with the following formula (example of calculation on fat):

$$\textbf{Fat recovery rate (\%)} = \frac{\textbf{Milk fat weight - Whey fat weight}}{\textbf{Milk fat weight}}$$



Fat retention rate strongly increases when curd is cut at lower firmness levels.



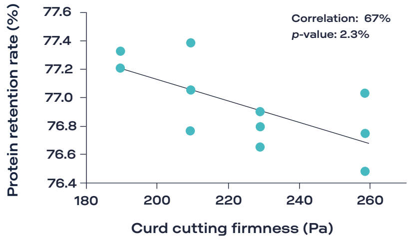
Fat retention rate strongly increases when curd cut happens at higher gel organization speeds.

RESULTS & CONCLUSIONS

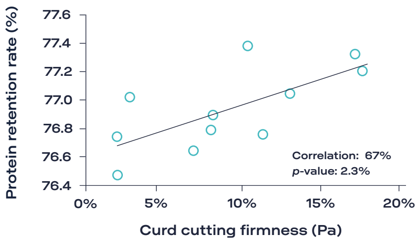
The results of this study clearly show how cutting firmness affects the retention rate of fat, protein and solids in cheese. The losses are also, as a consequence, significantly affected by the cutting firmness and the milk gel speed of organization. It is noticeable in this study that a lower cutting firmness induced higher retention rates of all valuable ingredients in cheese. The methodology developed in this study may be translated to industrial scale in order to optimize the coagulation kinetics as well as the curd firmness at the critical cutting step.

FINANCIAL IMPACT

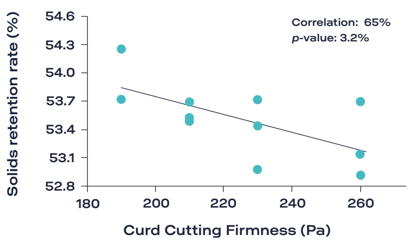
The below financial calculations were made based on the results and conclusions of the study performed by Agriculture & Agri-Food Canada (AAC-R&D Center in Saint-Hyacinthe, QC, Canada). The financial calculations below are intended to simulate the savings that a typical large size plant could generate over a year if the retention rate of fat, protein and solids is optimized thanks to a better control of the curd cutting firmness.



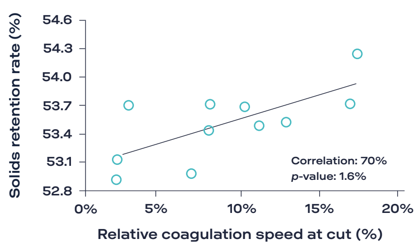
Protein retention rate strongly increases when curd is cut at lower firmness levels



Protein retention rate strongly increases when cut happens at higher gel organization speeds



Solids retention rate strongly increases when curd is cut at lower firmness levels



Solids retention rate strongly increases when cut happens at higher gel organization speeds

PROFILE OF A TYPICAL PLANT (Example)			
Type of cheese		Cheddar	
Number of vats produced per year		14,000	
Cheese moisture (%)		39	
Milk density		1.033	
Milk Volume per Vat (L)		20,000	
Milk Weight per Vat (kg)		20,660	
CHEDDAR MARKET PRICE			
Canada (CA$/kg)		8	
USA (US$/kg)		4	
Europe (€/kg)		3.8	
MILK COMPOSITION (Example)			
	Fat	Protein	Solids
Milk composition (%)	3.88	3.48	12.85
Weight per vat (kg)	802	719	2,654
Minimum retention rate (%)	94.6	75.0	53,2
Maximum retention rate (%)	95.2	76.0	54.0
Weight at the minimum retention rate (kg)	759	759	1,412
Weight at the maximum retention rate (kg)	764	547	1,433
EXAMPLE OF SHORTFALL (Example)			
Average Solids (Dry Matter) in Cheddar (%)			61%
Cheese weight at the minimum retention rate (kg)			2,315
Cheese weight at the maximum retention rate (kg)			2,349
Average cheese weight (kg)			2,332
Average Shortfall per Vat (Kg) (Difference between average and maximum weight of cheese per vat)			17
Average annual shortfall (Kg of cheese)			238,000
ANNUAL FINANCIAL SHORTFALL DUE TO BADLY CONTROLLED COAGULATION PROCESSES			
Canada (CA$)			1,904,000
USA (US$)			952,000
Europe (€)			904,400

Rheolution AGRI-FOOD

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