Mechanical Monitoring of Milk Gels during Coagulation for Cheese Manufacturing by ElastoSens™

milk gel formation, cutting time, coagulation kinetics, quality and process control

SUMMARY

Productivity of industrial cheese making process, which is the mass of cheese extracted from unit volume of raw milk, is a key element in the profitability of this industry. This productivity depends, among other parameters, on the cutting time of the milk gel that is formed to produce cheese. The cutting allows the whey to separate from the solid matter. The cutting step can happen at different moments depending on the kind of cheese under production. If the cutting is done too soon or too late, this will dramatically affect the productivity of the process and the quality of the final product. One of the challenges of the industry is to standardize the cutting time in order to optimize productivity. The preparation of cheese involves a viscoelastic change of milk during the gelation kinetic. Depending on the final cheese product, manufacturers will decide to cut the gel at a precise moment corresponding to a certain firmness of the gel. Manufacturers have to take into account the viscoelastic properties of the gel in their product formulation and production process to reach a constant quality and to improve productivity. Today, in plants, this is mostly done by human expertise.

Consequently, there is a need to precisely and reliably measure the viscoelastic properties of milk during the coagulation kinetic. In research and development laboratories, instruments like rheometers are used to characterize the viscoelasticity of milk gels. However, these instruments are not adapted to test the quality of products in production environments. Production plants generally use indirect methods to evaluate the viscoelasticity of milk gels. These methods can consist in the measurement, as function of time, of the acidity (pH) or the optical properties of the product. It can also consist in the use of penetrometers that indirectly reflects the overall stiffness state of a product. From a mechanical point of view, these methods lack specificity, reproducibility and precision. In some cases, the human expertise is the only one able to evaluate the stiffness of milk gels during production. This expertise, which is a part of the art of cheese making, is a qualitative way to control the product that lake reproducibility.

ElastoSens™ X3: Real-time, nondestructive and contactless mechanical monitoring instrument of coagulation, gelation and polymerization kinetics

Rheolution Inc. has developed the ElastoSens™ X3, the first

Rheolution instruments

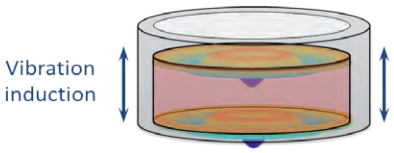

Fig.1 Principle of ElastoSens™ X3: Non-contact and non-destructive measurement of few micrometers amplitude vibrations

instrument to measure in real time, without contact and non-destructively the viscoelastic properties of milk gels during the coagulation process. The patented technological principle behind this instrument is purely mechanical. The liquid is contained into a cylindrical cuvette having a flexible bottom part. A small and gentle vibration (few micrometers) is applied to the sample and its response is measured without contact. Finally, the material response is post processed to obtain the viscoelastic properties of the gel. This process is repeated during the coagulation kinetic.

This study shows how ElastoSens™ X3 allows measuring in real time the viscoelastic properties of milk gels during the preparation of cheese in order to control the product quality and the process productivity.

EXAMPLE

This example shows the measurements of the time evolution of the shear elastic modulus of milk gels during coagulation as function of the temperature. For this experiment, whole pasteurized organic milk with 3.8% fat matter has been used. The volume of milk was 1.8 mL. Rennet solution (90% chymosin, Danisco) diluted in water (0.416 % v/v) has been used to initiate the coagulation of milk. Two levels of temperature have been tested in order to observe temperature effect on the coagulation kinetic. The temperature was set at 34°C and 41°C and automatically controlled by ElastoSens™ X3 with a precision of ±0.5°C. The mechanical measurements were done during 120 minutes with a temporal step of 10 seconds.

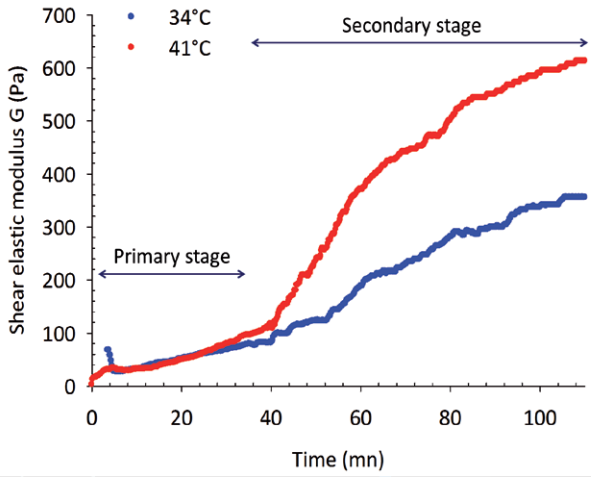

Fig. 2 Effect of temperature on the elasticity of milk gels during coagulation. Measurements done by ElastoSens™ X3.

This example shows the sensitivity of the instrument to measure in real time the elastic modulus of a gel during its formation. It is noticeable that the temperature clearly affects the coagulation kinetic from a mechanical point of view. Indeed, at 41°C the coagulum rapidly reaches an elasticity of 650 Pa comparing to a slow and moderate increase of elasticity at 34°C. The measurements also show that the primary (enzymatic activity) and secondary (aggregation) stages of the enzymatic coagulation process are clearly distinguishable. In this example, one can notice that there is no significant effect of temperature on the primary stage below 30 minutes.

APPLICATIONS OF ELASTOSENS™ X3

The access to the viscoelastic properties during the coagulation kinetic allows calculating information like: gelation time, hardening speed, real time value of elasticity and maximum stabilization stiffness. Cheese manufacturers can then use the ElastoSens™ X3 as a real time measurement tool to decide the most suitable 'cutting time', regarding the final product quality and the targeted productivity. As a precise and reliable measurement tool, ElastoSens™ X3 is a quantitative decision-making tool allowing to reduce the variability in quality and productivity due to qualitative human-based decision.

At-line control of cheese production process

- To automatically set the 'cutting time' at a given elasticity (firmness) value of the gel.
- To reduce variability of productivity due to seasonal variations of raw milk properties.
- To avoid technical accidents and losses due to poorly controlled rheological properties.

Research & Development

- Determination of the optimal stiffness to cut the gel in order to maximize the productivity.
- Determination of the relationship between the elasticity at the cutting-time and the rate of humidity retention of cheese.
- Optimal use (and dosage) of rennet and ferments.
- Optimal parameterization of production process.

	Specifications of ElastoSens™ X3
Mechanical & Physical	
Shear Elastic Modulus	0 Pa to 100 MPa
Precision	0.1 Pa
Simultaneous measurements	3 samples (optional)
Variable sample volume	YES
Programmable Thermal Rampes	
Temperature range	15° C to 70° C (optional 4° to 70° C)
Precision	0.5° C
Temporal	
Selectable temporal resolution	1 second to 120 minutes
Measurements duration	10 seconds to 1200 hours
Software	
Interface	Simple interface with touchscreen
Software	Test settings, post-processing, real time results display, archiving and data transfer
Automation for QC	
Yes	Contactless measurements

Rheolution Inc.
5333 Casgrain Ave., Suite #712
Montreal, QC, H2T 1X3, Canada
+1 514-586-2006 www.rheolution.com informations@rheolution.com