Milk gel formation by combined acidification and renneting: New insights into coagulation dynamics and mechanisms

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Rationale & Methodology

The subject of milk gel formation by combined continuous acidification and renneting has been noticeably under-researched despite its important bearing on the technology of a number of cheeses.

A comprehensive study was conducted to determine the effects of varying the proportion of acidifying starters *vs.* rennet enzymes on milk gel formation and viscoelastic properties. Qualitative and quantitative analyses were carried out. The effects of milk pre-treatment (*e.g.*, pre-heating and/or concentration) were also studied insofar as they provided insights into coagulation mechanisms.

Four starter levels (C/8, C/4, C/2, C/1) and 4 rennet levels (R1, R4, R8, R16) were used. Reconstituted skim milk (standard and pre-treated RSM) was set at 25, 30 and 40°C. For each combination of C/*i*-R*j*, gel development was monitored using small deformation dynamic rheometry (Nametre and Carri-Med rheometers for gel 'consistency', and dynamic moduli and loss tangent, respectively), with complementary measurements of pH and κ-casein hydrolysis (by SDS-PAGE) over time (1, 2).

Results & Discussion

1. On the qualitative side:

Three distinct patterns of coagulation and a clear gradation among them:

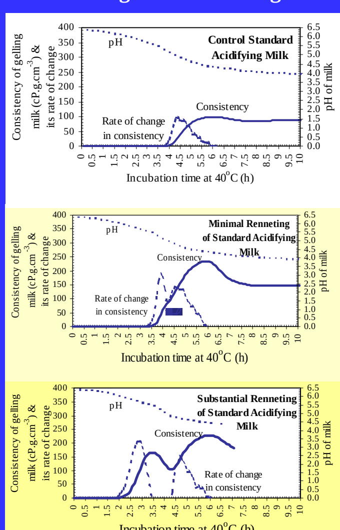

Fig. 1.

Note the usefulness of rheo-kinetic analyses (plots of rate of change in consistency, dC(t)/dt). Time-derivative curves emphasize subtle changes in the shape of the primary gelation curves. This helped us to identify common (homologous) features in the gelation curves and to classify coagulation behaviour and mechanisms.

Interpretation:

Pattern (1):

Acidifying starter with NO rennet (R0) → Coagulation by acidification alone

Mostly continuous firming of gel (NB: irregular rate of firming)

Pattern (2):

Acidifying starter + low level of rennet (R1) → Coagulation by **simultaneous** acidification & renneting

A shoulder appears midway through enhanced firming of gel (irregularity in firming rate intensifies)

Pattern (3):

Acidifying starter + High level of rennet (≥ R4) → Coagulation by **sequential** renneting then acidification (demineralization of casein gel)

Clear 'Maximum-minimum' in the evolution of gel firmness ('bimodal' evolution of firming)

In other words, rennet concentration has a predominant influence on gel development.

Increasing rennet concentration modifies the sequence between acid production and renneting.

This gives rise to a gradation in coagulation behaviour and to distinct mechanisms of acid-rennet coagulation (1, 2).

2. On the quantitative side:

Effects of varying the concentrations of rennet and acidifying starter on characteristic coagulation parameters:

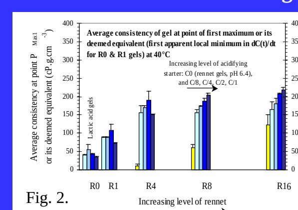

Fig. 2.

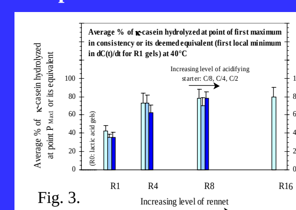

Fig. 3.

Systematic quantitative analyses also showed that rennet concentration had a major influence on characteristic coagulation parameters, including coagulation time; values of consistency (C, Fig. 2), elastic modulus (G'), pH, κ-casein hydrolysis (Fig. 3) and time at different stages of gel development; maximum rate of consistency and G' development; and loss tangent (G''/G') (1). As illustrated in Figures 2 and 3, this influence leveled off above rennet concentration R4-R8.

3. Tentative modeling:

A probabilistic approach to modeling coagulation profiles:

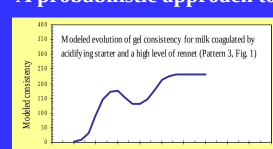

Fig. 4.

We are investigating whether experimental coagulation profiles can be modeled using a probabilistic approach. This approach derives from the Item Response Theory (IRT) and from the study of variables which affect item parameters in the IRT. Four-parameter logistic (4PL) models were used (3).

In the figure above (preliminary results), gel consistency, C(t), is modeled as a combination of three probability functions (p*i*, three 4PL functions): C(t) = p1*p2*p3. [Research in progress.]

Technological Relevance & Perspectives

Our work sheds new light on a well-known aspect of cheese-making, *i.e.*, how cheese milk coagulates has a lot to do with synchronizing acidity development & rennet action. The results have a direct bearing on cheese process control, incl. optimization of yield & quality of cheeses such as cottage cheese (rennet level ≈ R1) and Cheddar (≥ R4). We showed that simple rheo-kinetic analyses of milk gel formation (combined use of gel consistency or elastic modulus & time-derivative thereof) provide useful insights into coagulation dynamics and phenomena. As discussed by Tranchant (1,2), these insights may enable more precise control of critical points such as curd cutting time. Research is underway to model gelation curves and patterns.

References

1. **Tranchant, C.C. (2000).** *Coagulation behaviour of differently acidified & renneted milk and the effects of pre-treatment of milk.* Ph.D. Thesis, University of Guelph, Guelph, ON, Canada.
2. **Tranchant, C.C. *et al.* (2001).** Different coagulation behaviour of bacteriologically acidified and renneted milk: the importance of fine-tuning acid production and rennet action. *Int. Dairy J.*, 11, 483-494.
3. **McDonald, R.P. (1967).** Nonlinear factor analysis. *Psychometric Monographs*, 15, p. 67.

Thank you for your interest!