Optimising Cheese Brining Times

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Industry Representatives:
J. L. Simpson,
Fonterra Co-operative Group Ltd, Hautapu, New Zealand.

Problem Moderators:
S. T. P. Psaltis,
Science and Engineering Faculty, QUT, Queensland, Australia.
J. E. F. Green,
School of Mathematical Sciences, University of Adelaide, South Australia, Australia.

Fonterra runs the only brine cheese plant in the Southern Hemisphere, dissolving 750 tonnes of salt and 50 tonnes of calcium in a 3.5 million litre brine bath. At maximum capacity the plant processes 81,000 litres of milk per hour which makes about 3.5 tonnes of cheese. Brine salted cheese is formed in the presence of whey and will therefore usually have a higher moisture content than dry salted cheese, giving it a more supple, smooth texture suitable for slicing and shredding.

Brine salted cheese is formed in a similar manner to dry salted cheese up to the stage of treating the curds. Rennet and starters are added to vats of standardised and pasteurised milk which are then given time to set before being cut, washed and cooked to form curds and whey. The curds and whey are then pumped into towers where the whey is drained and the curds are pressed and cut to form blocks. The blocks are then further pressed to remove more whey before being removed from their moulds and submerged into a brine solution where they cool and absorb salt. Brining time can take between 48 and 55 hours. After the cheese has reached the desired level of salt, the blocks are removed from the brine solution, washed, dried and vacuum packed to continue further ripening. The salt levels within the block of cheese affect the cheese quality during the ripening time - influencing the flavour and texture profile by controlling the breakdown of the protein and fat, as well as inhibiting micro-organisms. Thus the salt content is of critical importance to the final product produced.

Currently brining times are estimated based on cheese specification, the desired final product salt content, initial cheese moisture and manufacturing experience. Brine bath concentration and temperature are monitored over the entire brining period, while samples of cheese are analysed when the estimated brining time is approaching. The current prediction and monitoring routine is generally sufficient to ensure the cheese is manufactured within specification and within predicted operating time-frames. However, if the

Initial Moisture %	Brine Time (hours)	Final Moisture %	Final Salt	Predicted Moisture %	Predicted Salt
46.03	12	44.12	1.78	44.22	0.976
44.48	45	42.87	1.67	41.22	1.8
38.08	13	37.02	0.78	36.84	0.78

Table 1: Predicted final salt and moisture levels from Model 1, compared with actual values from measurements by Fonterra.

expected brining times or salt uptake times do not adhere to the expected time-frames, the operation of the cheese plant can be severely impacted.

During the week of the MISG there were two main areas of focus. One part of the team investigated the data provided by Fonterra, using statistical analysis to ascertain whether any trends relating salt content and brining time could be observed. However, no trends were, in fact, discernible, and it was concluded that the data reflected natural variation in composition, with the cheese-makers exhibiting good control of their process to achieve the required outcome.

The rest of study group team aimed to develop a model which would predict the salt and moisture content of the cheese after a given brining time. After considerable discussion of potentially relevant transport mechanisms, we focused on diffusive transport of both salt and moisture. Different approaches to the problem were pursued by sub-groups within the team, resulting in three models, which are described in detail below.

Model 1 - Interstitial diffusion

An important experimental observation is that the diffusion coefficient for salt through cheese is approximately one fifth of the diffusion of salt through water. This is because salt is not able to diffuse effectively through the protein and fat globules in the cheese. This effect was included in the model by introducing the concept of the interstitial volume, or pore volume of the cheese - *i.e.* the fraction of the cheese volume through which salt diffusion occurs. We postulated that the total interstitial volume is made of up a fraction occupied by salt and a fraction occupied by moisture. Hence it can decrease as moisture is removed from the cheese. The resulting model consisted of two nonlinear diffusion equations for the salt and moisture concentrations, coupled with an algebraic equation for the interstitial volume. A code was written in Matlab® to perform numerical simulations of the model in a one-dimensional geometry. We parameterised the model with diffusivity values from the literature and calculated partial molar volumes, and the brine conditions provided by Fonterra were utilised for our boundary conditions. Furthermore, we estimated the initial interstitial volume using data from Fonterra for the initial moisture content of cheese. For a given initial moisture content, we ran our simulations for the specified brining time and found encouraging agreement between the predicted and actual final salt and moisture content (see Table 1).

Model 2 - Nonlinear salt diffusion

This group observed from the data that the moisture content of the cheese could be very accurately predicted by a linear function of the salt concentration. Hence, the problem could be simplified to developing a model for the salt concentration alone (once this is known, the moisture concentration can then be calculated). They proposed a nonlinear diffusion equation for the salt concentration. However, the difficulty is then to determine the correct form for the salt diffusion coefficient, which is assumed to depend on salt concentration. Unfortunately, it was not possible to determine a form of diffusion coefficient that gave a good fit to the salt data by the conclusion of the study group.

Model 3 - Reaction-diffusion or 'Maturity' model
This model postulated that cheese becomes 'mature' when salt binds to the cheese matrix (protein and fat content) in an irreversible reaction. It introduces a variable which measures this degree of binding, or 'maturity', which is coupled to a diffusion equation for the salt concentration. A numerical code was written to simulate the model, which displayed travelling wave type behaviour, as salt travelled into the cheese. However, owing to time constraints, we were not able to undertake any detailed analysis, or fitting of data for this model.

An important issue in comparing the model results with the existing data available is that whilst the models were formulated as partial differential equations, providing predictions of spatial variations in salt and moisture content, the testing process homogenises a sample through the depth of the cheese, so the spatial information is lost. We can compensate for this by similarly averaging the model concentrations; however, spatial data, if it could be obtained, would provide a more rigorous validation of the models developed. After discussions with the plant manager, the Industry Representative now hopes to be able to undertake testing to obtain this spatial data in the near future. The lack of spatial data notwithstanding, the interstitial diffusion model developed in this work produced results that in general were in close agreement with the observed data. This model could be used to generate a look-up table to give the brining time required to achieve a desired salt content for a given initial moisture content.