Modelling primary proteolysis in cheddar cheese in commercial cool stores

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ABSTRACT

One issue identified as a possible problem during the manufacture of cheddar cheese is the possibility of producing a non-uniform product. It was proposed that a pallet of cheese experiencing different time-temperature histories, depending on the position within the pallet, could cause the heterogeneity. This work involved the investigation of that issue.

The level of primary proteolysis observed in cheese was measured over time in cheeses of different compositions, stored at different temperatures. The remaining intact α_{s1}casein was measured using reverse phase high performance liquid chromatography. Several trends were observed during maturation. High temperatures caused a faster rate of disappearance of α_{s1}casein. The temperature relationship followed Arrhenius law. High moisture content caused a faster rate of the disappearance of α_{s1}casein. The level of rennet added to the milk during production had a directly proportional effect on the rate of the disappearance of α_{s1}casein. Salt had no observable effect in the range investigated here. From the data a kinetic model was developed that described the rate of disappearance of α_{s1}casein in terms of the temperature, the moisture content, and the level of rennet in the cheese.

The heat transfer occurring in the commercial pallet of cheese was mathematically modelled and solved numerically. The heat transfer model was then applied to produce data describing the time-temperature profile throughout a pallet of cheese for a variety of possible industrial storage conditions. The kinetic model developed was then used to predict the extent of proteolysis in each case.

It was found that there would be significantly different levels of proteolysis within a pallet of cheese that had undergone chilling. A 10% difference in the level of proteolysis between the surface and the centre was observed after chilling for 40 days. During freezing the difference in the level of proteolysis after freezing was complete ranged from 10-25%. It was found that the heterogeneity was reduced during the thawing process and that the greatest reduction in non-uniformity was observed when thawed at lower temperatures.

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It has been said that the search for knowledge is like a blind man searching for a black cat in a darkened room. I thought I heard it meow, but that may have been the walls closing in. As they say however: It's *all* good. It is true also, that this project would not have been possible without the help (and patience) of a number of people.

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CHAPTER 1

PROJECT OVERVIEW

1.1 BACKGROUND AND PROBLEM DEFINITION

New Zealand produced approximately 245000 tonnes of cheese in the 1997/1998 season (Johnston, Luckman, Lilley, & Smale, 1998). As it is such a large part of New Zealand industry it is important that the process is understood and optimised.

Cheese making is a dehydration concentration process. Cheese curd is produced from standardised milk by destabilising the casein micelles present in the milk causing them to aggregate and precipitate out of solution. Destabilisation is carried out by acidulation or an enzymatic reaction transforming kappa casein proteins into non-stabilising para-kappa casein. The casein gel formed is then cut and cooked causing it to release water present in the gel as "whey". This leaves behind concentrated casein and milk fat that forms cheese curd. Once the whey is drained from the curd, it is dry salted to the desired level and cheddared. The curd is left until the pH reaches approximately 5.2 and then pressed. Once pressed, the cheese is put in chillers to mature, between 2-18 months for mild to tasty cheese respectively (Fox, 1989).

During maturation one of the reactions occurring is the proteolysis of α_{s1}-casein. As the protein is broken down this changes the functional properties of the cheese. The flavour and odour also change as breakdown products of the proteolysis process begin to appear. The rate at which the maturation occurs is a function of the cheeses composition. For example the salt content effects the rate at which enzymes can work. The rate is also a function of temperature (Law et al. 1979). In some applications the functional properties of the cheese are important. (e.g. processed cheese). As an ingredient some of the cheese used is required to have a low level of α_{s1}-casein breakdown in order to provide the desired functionality.

Production of cheese that has a low level of proteolysis is possible by manipulation of those factors that effect the rate of proteolysis. That is; adjusting the composition or temperature at which the cheese is stored. In addition to this, when cheese is made it is packed into $\cong 1m^3$ pallets and then chilled or frozen. This leads to the possibility of non-homogeneous time-temperature histories depending on the position in the pallet. It is not known whether this could cause a significantly non-homogeneous product in terms of the level of proteolysis or functionality.

The challenge therefore is twofold. Firstly, to determine a method that can be used to estimate the ripeness of cheese given different compositions and chilling regimes. Secondly, characterise the extent of and offer possible solutions to the problem of a non-uniform cheddar cheese after storage.

1.2 PROJECT OBJECTIVES

The solution to the problem outlined above is the development of a method to control the rate of proteolysis in cheddar cheese. This requires the understanding of a number of things including:

- The cheese composition. The influence of cheese composition and how this may effect the cheese and its ripening properties. (i.e. the aim of this work is to determine the impact of salt, rennet, and moisture on rate of proteolysis in the early stages of proteolysis).
- Low temperature during the early stages of proteolysis. This includes an understanding of the effects of low temperatures and freezing on the rate of proteolysis. This understanding would allow prediction of the level of proteolysis for any given cheese under any given time-temperature profile and would allow for the prediction of maximum storage times for these cheeses in terms of the amount of remaining intact α_{s1}-casein.
- The extent of the heterogeneity of the level of proteolysis throughout a pallet of cheese caused by variations in the temperature time history. This can be achieved through modelling the heat transfer through a pallet of cheese and combining this with the understanding of the rate of proteolysis.

1.2.1 SPECIFIC OBJECTIVES

To achieve the understanding outlined above the following objectives were proposed.

1) Experimentally measure the rate of proteolysis in cheddar cheese by measuring the rate of disappearance of α_{s1}-casein with time. The reaction rate was to be described mathematically in terms of temperature and composition. This work has been covered in chapter 2.
2) To collect data on the thermophysical properties of cheddar cheese in the chilling and freezing range 15°C to -40°C. The results of this investigation are given in chapter 3.
3) To construct and validate a mathematical model to predict the time temperature relationship with position in a pallet of cheese undergoing chilling or freezing. This would use the thermophysical properties described in chapter 3. The formulation and testing of that model is presented in chapter 4.
4) To combine the chilling/freezing model for a pallet of cheese produced in chapter 4 with the proteolysis work carried out in chapter 2. This was to allow the prediction of positional variability of the level of primary proteolysis in a pallet of commercial cheese and identification of possible ways to control this variability. This work is outlined in chapter 5.