4 Heat stability of concentrated skim milk on pilot scale

Abstract

Direct steam injection heat treatment on pilot scale as an alternative to lab scale indirect heat treatment was applied to investigate heat stability of concentrated skim milk across a broad range of temperatures from 117 °C to 153 °C and from 0.5 to 13 s holding time, assessing options for heat treatment of concentrated skim milk without a significant amount of protein sediment formation. The relationship between total solids content of concentrated skim milk and temperature-time combinations of heat treatment could be established using minimal heat-induced coagulation as a criterion. Coagulation of destabilized casein micelles was shown to proceed non-linear over heating temperature. Transition of critical temperature-time combinations resulted in a marked increase in sediment formation indicating that preceding reactions, noticeable as the formation of dissociated material, need to take place to some extent to induce coagulum formation. UHT preheat treatment of skim milk prior to concentration was shown to increase heat stability in terms of possible temperature-time combinations without coagulation.

4.1 Introduction

The effect of UHT heating conditions has been studied intensively for unconcentrated milk concerning chemical and physical changes occurring during heat treatment. Physical and chemical changes of whey proteins and casein micelles, degradation of valuable components in the serum phase as well as the inactivation bacterial and endogenous enzymes of bacterial spores were investigated over the last 70 years and comprehensively reviewed (Burton 1984; Dannenberg and Kessler 1988; Bastian and Brown 1996; Claeyts et al. 2003; van Asselt and Zwietering 2006; Chavan et al. 2011; Loveday 2016).

However, regarding the heat stability of concentrated milk under commercial in-line sterilisation conditions, little data exist on possible temperature-time combinations and total solids content of concentrated skim milk (CSM) without causing extensive protein aggregation and sediment formation. Typical temperature-time combinations are rather published as empirical guidelines for evaporated milk manufacture (Muir 1984; Smith and Malmgren 1999). In-line sterilisation of concentrated milk can therefore still be considered as challenging compared to in-container sterilisation. The major problem is that heat stability of concentrated milk can be lower than the processing conditions necessary for inactivation of bacterial spores resulting in coagulation and sediment formation in evaporated milk products. Heat instability of CSM will result in particle formation during heat treatment, gelation, and excessive sediment formation during storage (Muir 1984; Smith and Malmgren 1999; Hinrichs 2000; Kasinos et al. 2014). Preheating, i.e. a preheat treatment of milk prior to concentration and sterilisation of the concentrated milk is widely used for stabilisation of the concentrate against heat-induced physical changes during UHT sterilisation (Muir 1984; Smith and Malmgren 1999; Hinrichs 2000). Newstead et al. (1979) showed that differences in composition of milk as well as the sequence of processing steps affect the effectiveness of preheating. However, no quantitative correlation could be established between physical changes in milk and an increase in heat stability. In addition, the effectiveness of preheating of unconcentrated milk under UHT sterilisation conditions in terms of an increase in heating temperature and duration of concentrated milk without excessive sediment formation has not been assessed so far.

At present, minimally processed microbial stable and safe milk concentrates become increasingly important as intermediate products prior to spray drying or even as an energy efficient alternative to powder manufacture. More recently, it could be shown that heat stability of concentrated milk decreases in terms of heating temperature-time conditions at elevated total solids content (Dumpler and Kulozik 2015). Relatively little is known about the extent and mechanisms of physical changes in concentrates, especially milk concentrated beyond evaporated milk that had undergone temperature-time conditions of UHT heat treatment. Moreover, data regarding the heat effect of direct heat treatment at ultra-high temperature and very short holding times (<1 s) of concentrated milk has not been published to our knowledge.