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Stability of milk protein concentrate suspensions to in-container sterilisation heating conditions

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ABSTRACT

Milk protein concentrate (MPC) powders, ranging from 35 (MPC35) to 87 (MPC90)% protein, were reconstituted to 8.5% protein and assessed for heat stability at 120 °C, Ca-ion activity, heat-induced dissociation of κ-casein, and heat-induced gelation of serum-phase proteins in ultracentrifugal supernatants of unheated MPC suspensions. Heat stability of MPC suspensions depended on the protein content of the powder from which the suspensions were prepared. MPC70 had excellent heat stability compared with MPC35; however, MPC80, MPC85 and MPC90 were highly unstable to heating. Ca-ion activity increased with increasing protein content of the MPCs, whereas the extent of heat-induced dissociation of κ-casein and gelation of serum-phase proteins decreased. Increased heat stability with increasing protein content from MPC35 to MPC70 was attributed to decreased κ-casein dissociation and reduced gelation of serum-phase proteins. Despite these stabilising factors, excessively high Ca-ion activity caused MPC80, MPC85 and MPC90 to have very poor heat stability at pH 6.3–6.8, 6.3–7.1 and 6.3–7.3, respectively.

1. Introduction

The heat stability of milk protein concentrates (MPCs) reconstituted to 3.5% protein was previously investigated by Carr (1999) for MPC85 at 120 °C and Crowley et al. (2014) for MPC35 (i.e., skim milk powder), MPC50, MPC60, MPC70, MPC80, MPC85 and MPC90 at 140 °C. Carr (1999) demonstrated that increasing the level of whey protein denaturation up to 86% in MPC85 had a negligible effect on heat stability, while further increases to ≥90% had a negative effect. Crowley et al. (2014) reported that MPC suspensions became less heat-stable when prepared from MPC powders with high protein contents, due primarily to increased Ca-ion activity. The results of these studies are useful for predicting and controlling the heat stability of unconcentrated MPC suspensions during thermal processing (e.g., in-container sterilisation, UHT treatment).

To further expand knowledge pertaining to the stability of MPCs during thermal processing, the present study investigated the stability of concentrated MPC suspensions under heating conditions resembling those of in-container sterilisation. In-container sterilisation involves the application of a lower temperature (typically ~120 °C) and a longer treatment time (typically 10–20 min) than UHT, and is widely applied to concentrated milk (Singh, 2004). Sterilisation is also commonly used in the manufacture of ready-to-drink beverages with high protein contents (~5–10% protein), which is a product category in which high-protein MPCs (i.e., MPC80, MPC85, MPC90) are increasingly being used as ingredients.

It is well known that the heat stability of milk protein systems is concentration-dependent. Concentrated milk has a lower heat stability than unconcentrated milk, which can be improved considerably by pre-heating the milk or by the addition of Ca-binding agents (De Kort, Minor, Snoeren, van Hooijdonk, & van der Linden, 2012; Rose, 1961; Singh, 2004). The highest heat stability in concentrated milk tends to occur at a lower pH (6.4–6.6) than in unconcentrated milk (6.6–6.8) and heat-induced changes generally proceed to a less advanced degree (Singh, 2004). This study evaluated the stability of a range of MPC powders when reconstituted to 8.5% protein and heated at 120 °C. Measurement of protein distributions, Ca-ion activity and serum-phase protein

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gelation were used to develop a mechanistic understanding of observed pH-dependence of heat stability of the concentrated MPCs. The heat stability profiles of two MPC80s with differing degrees of whey protein denaturation were also compared, to investigate if pre-heating influences the heat stability of concentrated MPCs.

2. Materials and methods

2.1. Production and composition of milk protein concentrates

MPC powders of different protein contents used in the present study were the same as described by Crowley et al. (2014), with the additional inclusion of a medium-heat MPC80 (MH-MPC80), produced from milk heated at 95 °C for 45 s, as described by Gazi, Vilalva, and Huppertz (2014), instead of 72 °C for 15 s. Composition of the 8.5% protein MPC suspensions (Table 1) was estimated from measured values of the powders (Crowley et al., 2014). MPC suspensions were prepared from powders as described by Crowley et al. (2014).

2.2. Heat coagulation time

Heat coagulation time (HCT) of the MPC suspensions was determined for three independently prepared suspensions of each MPC at 120 °C as a function of pH (6.3–7.3) using the method of Davies and White (1966), as described by Crowley et al. (2014).

2.3. Heat-induced gelation of serum-phase proteins

Ultracentrifugal supernatants (1 h at 100,000 × *g* at 20 °C) from two independently-prepared 8.5% protein suspensions of MPC35, MPC60, MPC80 and MPC90 at pH 6.8 were heated in an oil bath at 120 °C, for the time equivalent to the HCT of the whole MPC suspension at pH 6.8 (see Section 2.2). In unheated MPC suspensions, ultracentrifugation separates casein micelles from the proteins in the serum phase, with the latter being comprised primarily of whey proteins and minor levels of casein. The resultant supernatant was considered a system representative of the serum-phase of the complete MPC suspension. To investigate the gelation of serum-phase proteins, the supernatants were assessed for visual indicators of heat-induced changes (i.e., coagulation, particulation/flecking and thickening). In addition, the particle size distribution (PSD) of the heated supernatants was determined with a Malvern Mastersizer S (Malvern Instruments, Malvern, UK). PSD was calculated using a generalised polydisperse model using a particle and dispersant refractive index of 1.46 and 1.33, respectively, and an absorption coefficient of 0.1.

2.4. Ca-ion activity and heat-induced κ-casein dissociation in MPC suspensions

Ca-ion activity of unheated MPC suspensions was determined in duplicate as a function of pH using a Ca-ion selective electrode as described by Crowley et al. (2014). Protein profiles of ultracentrifugal supernatants of heated (30 min at 90 °C) suspensions (8.5% protein) of MPC35, MPC60, MPC80 and MPC90 at pH 6.5, 6.8 or 7.1 were determined in duplicate using reversed-phase HPLC, as described by Hinz, Huppertz, and Kelly (2012).

3. Results

3.1. Heat stability of MPCs

Suspensions of MPC35, MPC50, MPC60 and MPC70 showed distinct maxima in their pH–HCT profiles (Fig. 1), as is typically observed for concentrated skim milk (Singh, 2004). Both the pH at which the maximum occurred (from 6.6 to 6.9) as well as the HCT at the maximum (from 13 to 74 min) increased with increasing protein content of the MPC. For MPC80, MPC85 and MPC90, HCT increased with increasing pH. For these samples, HCT was <2 min (i.e., within the heating period to reach 120 °C) at pH values ≤ 6.7, 7.1 and 7.2, respectively; notable heat stability was only observed at higher pH values (Fig. 1). The heat stability of MPC90 was exceptionally low across the entire pH range, with MPC85 having a HCT which was nearly 10-fold higher than that of MPC90 at pH 7.3. Due to a more intense pasteurisation treatment (95 °C for 45 s), MH-

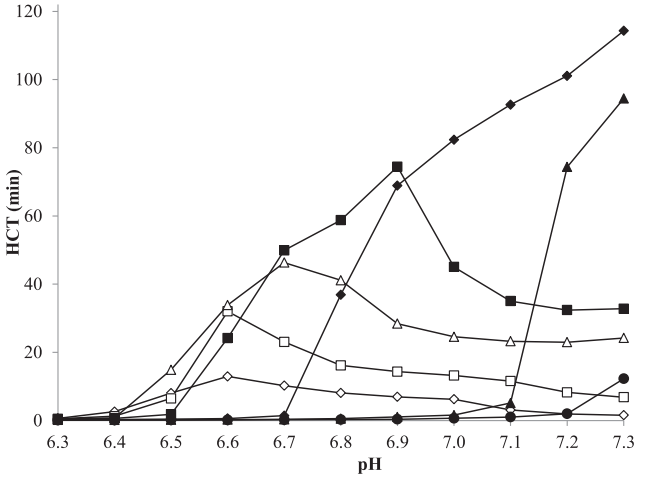

Fig. 1. pH-heat coagulation time (pH–HCT) profiles at 120 °C for MPC35 (◇), MPC50 (□), MPC60 (△), MPC70 (■), MPC80 (◆), MPC85 (▲) and MPC90 (●) reconstituted to 8.5% (w/w) protein. Values are the means of duplicate data from three independent trials.

Table 1
Composition of reconstituted milk protein concentrate (MPC) powders calculated from measured values for MPC powders.[a]

MPC	Non-protein nitrogen (%, w/w)	Lactose (%, w/w)	Ash (%, w/w)	Solids (%, w/w)	Calcium (mg g^{-1})	Inorganic phosphorus (mg g^{-1})
MPC35	0.08	11.9	1.94	23.2	3.28	2.04
MPC50	0.04	6.10	1.31	16.4	2.94	1.53
MPC60	0.02	3.42	1.09	13.4	2.77	1.29
MPC70	0.02	2.23	1.00	12.0	2.72	1.21
MPC80	0.01	0.68	0.83	10.2	2.57	1.00
MPC85	0.01	0.19	0.75	9.64	2.57	0.87
MPC90	0.00	0.05	0.75	9.50	2.57	0.87

[a] All powders were reconstituted to 8.5% (w/w) protein; data were calculated based on the values reported by Crowley et al. (2014).