



Effect of seasonal variation on some physical properties and heat stability of milk subjected to ultra-high temperature and in-container sterilisation



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ABSTRACT

Heat stability was evaluated in bulk raw milk, collected throughout the year and subjected to ultra-high temperature (UHT) or in-container sterilisation, with and without added calcium chloride (2 mM), disodium hydrogen phosphate (DSHP, 10 mM) and trisodium citrate (TSC, 10 mM). More sediment was observed following in-container sterilisation (0.24%) compared with UHT (0.19%).

Adding CaCl_2 made the milk more unstable to UHT than to in-container sterilisation, while adding DSHP and TSC made the milk more unstable during in-container sterilisation than to UHT processing, although TSC addition increased the sediment formed by UHT processing.

Better heat stability was observed in autumn and winter than in spring and summer following UHT. However, following in-container sterilisation, samples with added stabilising salts showed significantly improved heat stability in autumn, whereas with added CaCl_2 , the best heat stability was observed in spring. No correlation was found between urea and heat stability.

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1. Introduction

Milk is the most widely consumed dairy product in the UK and accounts for about 50% of total dairy consumption. Currently, UHT (ultra-high temperature) milk is not popular in the UK, but it is in Europe and many other parts of the world. UHT processing was introduced to produce an ambient stable product with less chemical change compared to traditional in-container sterilised milk. Normally, UHT treatment is in the range 135–150 °C with appropriate short holding times (1–10 s) necessary to achieve 'commercial sterility'. Milk destined for UHT processing must be heat stable. The composition and quality of milk can be affected by many factors, such as seasonal variation, breed (Davis et al., 2001), stage of lactation (Othmane, Carriedo, De la Fuente, & San Primitivo, 2002), regional variations (Bony et al., 2005) and diseases (Kitchen, 1981). Recently, Gaucher et al. (2008) investigated the effect of seasonal variation on the suitability of milk for UHT processing. Sweetsur and Muir (1982) reported that winter milk was less stable than summer milk, and after homogenisation it was less easily stabilised by stabilising salts. Our previous research (Grandison, 1988) monitored deposits formed during UHT processing of milk over a 12-month period and noticed that the weight of deposit in

the steam-heated section increased dramatically during the winter months and was lowest during the summer which again elucidate the significant seasonal variation of raw milk during UHT processing. Pouliot and Boulet (1991) reported that seasonal variations in heat stability of concentrated milk at 31% total solids were not significant. However, when they evaluated the stabilising effect of pH adjustment with NaH_2PO_4 , Na_2HPO_4 or NaOH/HCl before sterilisation, the effectiveness of stabilising salts showed seasonal variations, with the effects being greatly increased in summer and decreased in winter.

In-container sterilisation involves lower temperatures (115–120 °C) for longer times (15–30 min), with slower heating and cooling rates, compared to UHT milk. In-container sterilised milk is still produced in the UK, but it is considered by many to be not as palatable as both UHT and pasteurised milk, due to its distinct cooked flavour and brownish colour. No studies on the influence of seasonal variations on heat stability of in-container sterilised milk have been found.

Sediment in UHT milk is one manifestation of poor heat stability. This sediment was found to contain less than 5% minerals on a dry weight basis and the fat/protein ratio was estimated to range between 1.43:1 and 1.67:1. Following UHT treatment, sediment is prevented in goat's raw milk by a moderate reduction of Ca^{2+} concentration, which increases the negative charge on the casein micelles due to the solubilisation of colloidal calcium

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phosphate (CCP) and thus makes them less susceptible to aggregation (Boumpa, Tsioulpas, Grandison, & Lewis, 2008). Sediment formation in UHT or in-container sterilised milk has provided a reliable way of measuring heat stability because the method is less subjective than the classic heat coagulation time method (Chen, Grandison, & Lewis, 2012).

Stabilising salts can be added to raw milk to improve heat stability. Disodium hydrogen phosphate (DSHP) and trisodium citrate (TSC) should be used if the natural pH falls on the acidic side of the heat stability maximum, whereas sodium dihydrogen phosphate (SDHP) or calcium chloride should be used when the natural pH falls on the alkaline side of the heat stability maximum (Sweetsur & Muir, 1980). Phosphate was generally considered to be the most effective stabilising salt. Montilla and Calvo (1997) found that a mixture of SDHP, DSHP, and trisodium mixed phosphate salts was more useful for improving heat stability than pH adjustment by NaOH. Tessier and Rose (1958) reported that addition of both potassium phosphate (pH 6.7) and sodium citrate (pH 6.8) decreased ionic calcium. In contrast, addition of phosphate precipitated calcium, whereas addition of citrate dissolved colloidal calcium.

Comparisons of the heat stability of the same milk subjected to UHT or in-container sterilisation are also rare. There were differences for goat's milk when subjected to these different heat treatments (Chen et al., 2012). Stabilising salts can be added to raw milk to improve heat stability as determined by percentage of dry sediment that have been described in our previous study (Chen et al., 2012). Without added stabiliser, goat's milk showed better heat stability when subject to in container sterilisation than to UHT processing. Small additions of calcium chloride (up to 2 mM) gave similar results. However, additions of DSHP and TSC (6.4 mM) improved the heat stability of UHT milk but had the opposite effect for in-container sterilised milk. However, larger additions of these stabilisers (9.6 and 12.8 mM) resulted in a decrease in heat stability when subjected to UHT processing. Thus, heat stability would appear to be influenced both by the method of heat treatment and the properties of the milk.

The current work is a continuation of our previous study (Chen, Lewis, & Grandison, 2014) and aims to determine the effect of seasonal variations on physico-chemical properties and heat stability of UHT or in-container sterilised milk. In addition, it provides an opportunity to compare heat stability of milk subjected to small changes in pH and ionic calcium, which is now commonly experienced in formulated milk products, and also to investigate whether compositional parameters of raw milk, including urea might influence the heat stability of UHT or in-container sterilised milk.

2. Materials and methods

The raw bulk milk samples (120 L) used in this study were collected over the period August 2011–October 2012 as described previously (Chen et al., 2014). For each of the 25 different batches of raw milk, about 10 L was placed in a freezer (−18 °C) for further study, while some of the residual 110 L was processed into UHT milk and in-container sterilised milk.

2.1. Physico-chemical properties of raw milk

Statistical analysis and methods of determination of pH, ionic calcium concentration, protein particle size and the percentage of dry sediment have been described previously (Chen et al., 2012).

Concentrations of protein, fat and urea, and pH, ethanol stability (ES), rennet coagulation time (RCT), buffering capacity (BC), viscosity and freezing point depression (FPD) were determined according to Chen et al. (2014).

pH was measured using a Sentron 3001 pH meter (Sentron Europe BV, 9351 VD Leek, Netherlands), which was calibrated with standard buffer solutions of pH 4.0 and 7.0.

Ionic calcium was measured using a Ciba Corning 634 ISE Ca^{2+} /pH analyser (Ciba-Corning Diagnostic Limited, Halstead, Essex, UK) (Chen et al., 2012).

Protein particle size was measured using a Zeta Master (Malvern Instruments, Malvern, UK) and the percentage of dry sediment by centrifugation, as described previously (Chen et al., 2012).

2.2. Processing conditions

Raw milk (16 L) was first pre-heated at 60 °C and then subjected to single stage homogenisation (Rannie Homogeniser, 447ADS, Birmingham, UK) at 100 bar. In addition to control milk (no additives), different batches were prepared with addition of disodium hydrogen phosphate (DSHP) or tri-sodium citrate (TSC) at 10 mM, or calcium chloride at 2 mM. These additions were selected to modify pH and ionic calcium within the range that might be found in bulk milk samples destined for heat treatment.

These milk samples were then subjected to indirect UHT using a tubular UHT plant (UHTAC Cook tube génération2, 01480, Fareins, France) with a capacity of about 30 L/h, as described by Omoarukhe, On-Nom, Grandison, and Lewis (2010). The samples were collected in sterile pots (250 mL; Bibby Sterilin Ltd, UK) in a laminar air-flow cabinet. Processing conditions were 140 °C for 5.5 s.

For the in-container sterilisation, milk samples were placed in baby food cans (125 mL capacity), sealed and sterilised under static conditions at 120 °C for 20 min. The come-up time was 5 min and samples were cooled as quickly as possible at the end of the holding period. All UHT or in-container sterilised samples were stored at 4 °C prior to analysis. Analyses were performed on these milk samples prior to heat treatment and following indirect UHT or in-container sterilisation. The pH, ionic calcium concentration, percentage of dry sediment, and protein particle size were all measured in triplicate at room temperature (20 °C).

2.3. Statistical analysis

Details of the statistical analyses, definition of seasons and sample sizes of raw and heat treated milk samples are provided in the study of Chen et al. (2014).

3. Results

Sediment formation has been adopted as the principle method for measuring heat stability as it is less subjective than the classic heat coagulation time procedure and has been shown to be reliable in previous studies (Grimley, Grandison, & Lewis, 2009; Tsioulpas, Koliandris, Grandison, & Lewis, 2010).

3.1. Control milk samples (without any additives)

Overall, there was no significant difference ($p < 0.05$) for the amount of dry sediment formation between UHT milk and in-container sterilised milk. According to Table 1, the range found for UHT was 0.10–0.29%, and that for in-container sterilisation was wider, from 0.02% to 0.56% indicating that overall heat stability was acceptable, as nearly all were below 0.5% (as discussed in Section 3.9). Some of the slightly higher levels of sediment following in-container sterilisation can most probably be attributed to a larger protein particle size, which averaged 326 nm compared with 264 nm after UHT treatment as shown in Fig. 2. These results showed some similarities with observations of Anema and Li

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