Journal of Food Engineering 91 (2009) 140–145

Contents lists available at ScienceDirect

Journal of Food Engineering

journal homepage: www.elsevier.com/locate/jfoodeng

Rheological properties of dairy desserts prepared in an indirect UHT pilot plant

F. Depypere [a,*], D. Verbeken [a], J.D. Torres [b], K. Dewettinck [a]

[a] *Faculty of Bioscience Engineering, Department of Food Safety and Food Quality, Laboratory of Food Technology and Engineering, Ghent University, Coupure Links 653, 9000 Gent, Belgium*

[b] *Department of Food Technology, Universidad Politécnica de Valencia, Camino de Vera s/n, 46022 Valencia, Spain*

ARTICLE INFO

Article history:
Received 22 April 2008
Received in revised form 7 August 2008
Accepted 19 August 2008
Available online 26 August 2008

Keywords:
UHT dairy desserts
Kappa-carrageenan
Modified starch
Oscillation measurements
Penetration tests

ABSTRACT

The Viscolab (Tetra Pak), an indirect ultra-high treatment (UHT) pilot plant, was used to prepare dairy desserts containing kappa-carrageenan, skimmed milk powder (SMP), adipate cross-linked acetyl-substituted waxy maize starch, sucrose and water. Effects of varying concentrations of carrageenan, milk powder and starch on the dessert rheology were studied, while the sucrose and water content were kept constant. The rheological measurements included both small amplitude oscillation tests and large deformation penetration tests. To investigate the influence of shear during the process, the scraped-surface heat exchangers of the UHT pilot plant were run at two rotation speeds. At a low rotation speed of 70 rpm, both the complex modulus and gelation temperature were found to increase with increasing carrageenan content and upon substitution of SMP by starch. These findings are in line with the previously reported exclusion effect of starch, demonstrated by the authors for lab-scale and sterilized dairy desserts. However, more intense shearing at 350 rpm mainly affects the starch granules, which results in a lower complex modulus and gelation temperature of dairy desserts containing high amounts of starch. Where starch granules seem to considerably contribute to small oscillatory deformation measurements, they appear to contribute little to the gel strength. Compared to earlier reported lab-scale experiments, the dessert preparation in an UHT pilot plant involves a more intense heat treatment. As a result, a more extensive whey protein denaturation and subsequent complexation with casein micelles is believed to contribute to the rheological properties of the UHT desserts.

1. Introduction

A broad range of ready-to-eat milk based desserts is nowadays available, offering a wide variety of textures, flavours and appearances. The hydrocolloids used in these dairy desserts are typically starch and carrageenan, a linear sulphated polysaccharide obtained from red seaweeds (de Vries, 1992; Rapaille and Vanhemelrijck, 1992; Therkelsen, 1993; Piculell, 1995; Mleko, 1997; de Wijk et al., 2003; Tarrega et al., 2004). Starch imparts body and mouthfeel to the product while carrageenan provides the desired texture, depending on the type and the concentration used (Trius and Sebranek, 1996; Imeson, 2000; de Vries, 2002).

Upon heating and subsequent cooling, iota- and kappa-carrageenan form thermoreversible gels in the presence of gel-promoting cations. In dairy desserts however, carrageenan gelation is importantly affected by the presence of milk proteins and starch. The interaction between carrageenans and milk proteins and its influence on the formation and the rheological properties of carrageenan gels have been the subject of numerous studies (Snoeren et al., 1975; Dalgleish and Morris, 1988; Drohan et al., 1997; Tziboula and Horne, 1998, 1999a,b; Bourriot et al., 1999; Langendorff et al., 2000; Schorsch et al., 2000; Puvanenthiran et al., 2001, 2003; Hemar et al., 2002; Sedlmeyer et al., 2003; Trckova et al., 2004). In general most authors agree that at temperatures below the coil–helix transition temperature carrageenan associates with casein micelles through an electrostatic interaction between its negatively charged sulphate groups and a positively charged region of κ-casein. This interaction was mostly found to decrease the carrageenan concentration necessary for gelation and to increase the mechanical strength of the obtained carrageenan gel. Carrageenan gelation in the presence of starch has been reported to be mainly governed by the exclusion effect of swollen granules, concentrating carrageenan in the continuous water phase (de Vries, 1992; Lai et al., 1999; Tecante and Doublier, 1999).

The considerable amount of literature available on the influence of milk fractions and starch on the gelation of carrageenan has one important thing in common: gels are always formed following a heat treatment during which temperatures do not exceed 95 °C, presumably out of practical considerations. This is however in

* Corresponding author. Tel.: +32 0 9 264 61 67; fax: +32 0 9 264 62 18.
E-mail address: Frederic.Depypere@UGent.be (F. Depypere).

0260-8774/$ - see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jfoodeng.2008.08.017

contrast to the fact that intensely heated desserts with a long shelf life and specifically ultra-high temperature (UHT) treated desserts dominate the European market of ready-to-eat neutral dairy desserts (Rapaille and Vanhemelrijck, 1992). Therefore, in this work an indirect UHT pilot plant equipped with scraped-surface heat exchangers was used with the specific aim to study the rheological properties of dairy desserts that were subjected to processing conditions (temperature, shear) comparable to the ones applied in industry. It was investigated whether findings from previous lab-scale research (Verbeken et al., 2004, 2006) could be confirmed by pilot-scale produced UHT desserts. Furthermore, this research differentiates from other studies in the complexity of the investigated products. Instead of dealing with simplified model systems that show little resemblance to commercial products, five-component desserts with practically relevant compositions were studied using an experimental mixture design approach (Depypere et al., 2003; Verbeken et al., 2004, 2006). In this way, the influence of variations in the concentration of carrageenan, starch, and milk components on the rheological properties was investigated and translated back to the microstructure of the UHT prepared dairy desserts.

2. Materials and methods

Dessert composition. Medium-heat skimmed milk powder (SMP) was supplied by Friesland Foods (Belgium), adipate cross-linked acetyl-substituted waxy maize starch by Tate & Lyle Europe (Belgium) and an alcohol-precipitated κ-carrageenan isolate from Cargill Texturizing Solutions (Belgium). Furthermore, desserts were also composed of demineralised water and sucrose. The dessert compositions used in this work were based on that of a typical vanilla-flavoured dessert (Rapaille and Vanhemelrijck, 1992), as well as on earlier work of the authors where an experimental design approach was used (Verbeken et al., 2004, 2006). The concentration of water and sucrose, not being directly involved in microstructure build-up, was kept constant at 77.45 and 12.00 wt%, respectively. As a result, the sum of the respective concentration of SMP, starch and carrageenan always equals 10.55 wt% (Verbeken et al., 2004, 2006). Table 1 shows the concentration of SMP, starch and carrageenan in each of the investigated UHT desserts in this work. Taking into account the large production scale of pilot plant desserts, five dessert mixtures corresponding to the most diverging compositions, i.e., the four corners and the center point, of the constrained, three-component experimental mixture design region covered in previous work (Verbeken et al., 2004, 2006) were studied in this paper. Fig. 1 shows a graphical representation of the five dessert compositions chosen for the pilot-scale tests in the mixture design region. The results of this paper are based on two independent pilot-scale production runs of each of the five dessert compositions.

Gelation of κ-carrageenan has been shown to be importantly affected by the type and amount of cations present (Hermansson et al., 1991; Drohan et al., 1997; Puvanenthiran et al., 2001; Hemar et al., 2002). As changes in composition lead to changes in the cation content of the desserts, salts (calcium phosphate, potassium chloride, sodium choloride and magnesium chloride) were added in order to keep the cation content constant and consequently minimize cation effects on the dessert properties. The approach was especially chosen to be able to ascribe possible effects of a changing SMP content to the action of milk proteins and rule out the influence of the milk salts.

Table 1
Different dessert compositions applied in this research

Composition	Carrageenan (wt%)	SMP (wt%)	Starch (wt%)
A	0.05	5.00	5.50
B	0.05	10.00	0.50
C	0.50	5.00	5.05
D	0.50	9.55	0.50
E	0.27	7.39	2.89

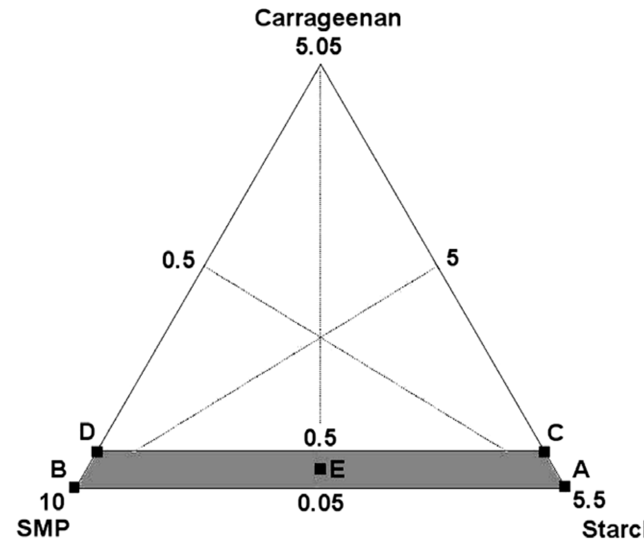

Fig. 1. Graphical representation of the five dessert compositions (A–E), selected for the pilot-scale tests, in the experimental design region (grey) (Verbeken et al., 2004, 2006).

Pilot-scale dessert preparation. SMP was dissolved in distilled water and stored overnight at 4 °C allowing milk proteins to become fully hydrated. Appropriate amounts of starch, κ-carrageenan and sucrose were added to the cold milk and stirred until homogeneity. Dairy desserts were prepared using the Viscolab (Tetra Pak, Lund, Sweden), an indirect UHT pilot plant especially designed for the production of viscous products. A Viscolab experiment usually starts with the sterilization of the process equipment system to avoid additional contamination of the product before heating and especially recontamination of the product during subsequent cooling and filling. Sterilization is carried out by circulating hot water of 130 °C through the entire system for 30 min. At the beginning of an experimental run, fresh tap water is run through the Viscolab while all instrument parameters are set for production. At steady state the water supply is stopped and the dessert mix is introduced into the system. Each experimental run is followed by a cleaning step to remove product remnants left behind in the system. The Viscolab is equipped with a cleaning-in-place or CIP system consisting of a separate tank, pump, and heat exchanger which are not used for production. A typical cleaning procedure consists of five steps, consecutively using water, alkali, water, acid and again water as rinsing medium (Tetra Pak, 2003).

An overview of the Viscolab configuration used in this research is given in Fig. 2. After introducing the dessert mix into the feed tank (1), the dispersion is pumped through the system by the action of the feed pump (2) at a flow rate of 250 l/h. Firstly, preheating with hot water to 70 °C is performed in a shell and tube heat exchanger (3) consisting of one outer pipe surrounding four small inner tubes that contain the product. Hot water is generated by pumping (4) around water in a closed circuit along a plate heat exchanger (5), fed with low-pressure steam. When leaving the shell and tube heat exchanger the preheated dessert mix passes through a high-pressure homogenizer (6) operating at a homogenization pressure of 50 bar (Rapaille et al., 1988; Rapaille and Vanhemelrijck, 1992). Following, the dessert mix is further heated in a scraped-surface heat exchanger or contherm (SSHE, 7) consisting