J. Dairy Sci. 101:1–12
https://doi.org/10.3168/jds.2017-13905
© American Dairy Science Association®, 2018.

Vibration-induced particle formation during yogurt fermentation—Effect of frequency and amplitude

Adrian Körzendörfer,*[1] Philipp Temme,† Eberhard Schlücker,† Jörg Hinrichs,* and Stefan Nöbel*
*Institute of Food Science and Biotechnology, University of Hohenheim, Garbenstr. 21, 70593 Stuttgart, Germany
†Department of Chemical and Biological Engineering, Friedrich-Alexander University Erlangen-Nürnberg, Cauerstr. 4, 91058 Erlangen, Germany

ABSTRACT

Machinery such as pumps used for the commercial production of fermented milk products cause vibrations that can spread to the fermentation tanks. During fermentation, such vibrations can disturb the gelation of milk proteins by causing texture defects including lumpiness and syneresis. To study the effect of vibrations on yogurt structure systematically, an experimental setup was developed consisting of a vibration exciter to generate defined vibrational states and accelerometers for monitoring. During the fermentation of skim milk, vibrations (frequency sweep: 25 to 1,005 Hz) were introduced at different pH (5.7 to 5.1, step width 0.1 units) for 200 s. Physical properties of set gels (syneresis, firmness) and resultant stirred yogurts (visible particles, rheology, laser diffraction) were analyzed. Vibrational treatments at pH 5.5 to 5.2 increased syneresis, gel firmness, and the number of large particles ($d > 0.9$ mm); hence, this period was considered critical. The particle number increased from 34 ± 5 to 242 ± 16 particles per 100 g of yogurt due to vibrations at pH 5.4. In further experiments, yogurts were excited with fixed frequencies (30, 300, and 1,000 Hz). All treatments increased syneresis, firmness, and particle formation. As the strongest effect was observed by applying 30 Hz, the amplitude was set to vibration accelerations of $a = 5$, 10, 15, 20, and 25 m/s^2 in the final experiments. The number of large particles was increased due to each treatment and a positive correlation with the amplitude was found. We concluded that vibrations during gelation increase the collision probability of aggregating milk proteins, resulting in a compressed set gel with syneresis. Resultant stirred yogurts exhibit large particles with a compact structure leading to a reduced water-holding capacity and product viscosity.

Received September 27, 2017.
Accepted January 8, 2018.
[1]Corresponding author: adrian.koerzendoerfer@uni-hohenheim.de

Key words: fermented milk product, sonication, graininess, texture

INTRODUCTION

Yogurt and related fermented dairy products are manufactured by microbial acidification of milk with lactic acid bacteria (Lee and Lucey, 2010). Texture attributes as appearance, flow behavior, and mouthfeel play a major role in consumers' acceptance (Jaworska et al., 2005). Texture defects such as low viscosities, graininess, or whey separation are undesired (Lucey, 2004). Milk is either fermented in the retail container (set-style yogurt) or more commonly in large fermentation tanks for the production of stirred yogurt. In the latter case, the gel is broken up in the tank at approximately pH 4.6 and cooled. Before packaging, ingredients such as fruit, color, and so on can be added (Mokoonlall et al., 2016a). Stirred yogurt can be described as a microgel suspension consisting of protein particles that are suspended in acid whey. Typically, the particle size ranges from 2 to 100 μm (van Marle et al., 1999; Weidendorfer and Hinrichs, 2010). Depending on the microstructure, the mouthfeel can become rough due to particles >150 μm (Cayot et al., 2008; Krzeminski et al., 2013). Apart from these microgel particles, particles of a size that are visible to the unaided eye can cause lumpiness and a gritty texture. Such defects can be corrected by mechanical postprocessing (Walstra et al., 2006); however, this will result in structure losses (Lucey and Singh, 2003; Mokoonlall et al., 2016a). Whether a product is rated smooth or lumpy is subjective. To evaluate the texture objectively, a method based on image analysis has been developed (Nöbel et al., 2016b).

There is several potential reasons for excessive particle formation, including protein composition (Isleten and Karagul-Yuceer, 2006; Nöbel et al., 2016a), heat treatment of milk (Remeuf et al., 2003; Küçükçetin, 2008), fermentation temperature, and starter cultures (Küçükçetin et al., 2009; Buldo et al., 2016). Moreover, mechanical damage to the gel during fermentation

disturbs the gelation of the milk proteins and results in an inhomogeneous, lumpy texture showing visible particles. During fermentation, mechanical stress to the coagulating milk can be caused by vibrations that are generated by surrounding machines such as pumps and homogenizers (Körzendörfer et al., 2016). In addition, cleaning and sterilization steps generate vibrations due to high flow velocities and a phenomenon called water hammer (Swidersky, 2013; Kaliatka et al., 2014). Vibration measurements in a dairy factory showed various sources of vibrations that are transferred through pipelines to the fermentation tanks. Compared with the idle state, the mean vibration acceleration at a running rotary piston pump was increased by a factor of 7. The frequency spectrum measured at the running pump ranged from 10 to 10,000 Hz with the highest amplitudes between 100 and 1,000 Hz (Körzendörfer et al., 2016).

In the first experiments, a temporary ultrasound treatment (45 kHz, 5 min) during fermentation at pH 5.4 to 5.1 resulted in a stirred product with numerous large particles (Nöbel et al., 2016b). In a previous study, an experimental setup was developed to run fermentation experiments under defined vibrational states. Low-frequency vibrations up to 1,000 Hz as primarily existing in industry also caused the formation of visible particles (Körzendörfer et al., 2016). The vibrational treatment of a fermentation tank (20 L) was carried out by means of a vibration exciter. However, not much is known about the effect of low-frequency vibrations on particle formation and further texture properties. We hypothesize that the effect of a specific vibration depends on its characteristics (i.e., occurring frequencies and respective amplitudes) because these parameters determine the sound energy. An increasing sound energy results in increased particle motions and should cause more disturbances during gelation (Müller and Möser, 2013). This study focuses on 3 subtopics. (1) Yogurts were short-term vibrated (200 s, 25 to 1,005 Hz) at different pH during the fermentation to define a critical pH range. (2) Various frequencies were applied during the acquired critical pH. (3) A single frequency was set and different amplitudes were tested. After fermentation, set gels were examined first and then processed into stirred yogurt for further analyses.

MATERIALS AND METHODS

Milk Pretreatment and Starter Culture

Fresh bovine raw milk was provided by the agricultural experiment station (Meiereihof, University of Hohenheim, Germany) and skimmed at 55°C (SA 10, Frautech S.r.l., Schio, Italy). The protein content was standardized to 3.40 ± 0.01% (wt/wt) using reconstituted ultrafiltered skim milk permeate, which consisted of 5.2% (wt/wt) permeate powder (Bayolan PT, BMI e. G., Landshut, Germany) and demineralized water. Protein and fat contents were analyzed with an FTIR spectrometer (LactoScope FTIR Advance, Delta Instruments, Drachten, the Netherlands). Milk was heated to 95°C for 256 s to denature whey proteins (>90%) and subsequently cooled to 6°C using a pilot plant (150 L/h; Asepto GmbH, Dinkelscherben, Germany). Before every experiment, a quantity of 250 g of the frozen starter culture YC-471 (Chr. Hansen, Hørsholm, Denmark) was diluted with 1,000 g of skim milk (6°C) to ensure a homogeneous distribution of the 2 species *Lactobacillus bulgaricus* and *Streptococcus thermophilus*. The stock solution (20% wt/wt) was thawed at room temperature with occasional stirring before use.

Yogurt Fermentation

Cylindric polypropylene containers (d = 102 mm, l = 155 mm) were filled with a quantity of 900 g of preheated milk (45°C) and put in a water bath (Julabo ED, Julabo Labortechnik GmbH, Seelbach, Germany) at 42°C. After temperatures had equilibrated, milks were inoculated with 2.25 mL of starter culture stock solution (i.e., 0.05% in total) and fermented at 42°C until pH 4.6. Acidifications were continuously monitored with pH sensors (SE555X/2-NMSN, Knick Elektronische Messgeräte GmbH & Co. KG, Berlin, Germany; software: DAQ Factory Express, Azo Inc., Memphis, TN). During fermentation, yogurt samples were temporarily treated with a vibration exciter as described in the section below. To negate any effects of moving the containers to the vibration exciter, controls were also taken out of the water bath at the same time and put back like the vibrated samples. Additionally, one yogurt sample remained in the water bath during the complete acidification (reference). Fermentations were stopped at pH 4.6 by immersing the containers in iced water for 60 min. Samples were stored overnight at 10°C until further analysis. The number of independent repetitions of the experiments was $i \geq 3$.

Applying Vibrations

Vibrations are generated by an electrodynamic vibration exciter/shaker (TV 51110, Tira GmbH, Schalkau, Germany), which is powered by an amplifier (BAA 60; Tira GmbH). The frequency range of the shaker is 2 to 7,000 Hz, and the rated force is 100 N. The vibration

Download English Version:

https://daneshyari.com/en/article/8501210

Download Persian Version:

https://daneshyari.com/article/8501210

Daneshyari.com