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Effects of Exopolysaccharide-Producing Cultures on the Viscoelastic Properties of Reduced-Fat Cheddar Cheese*

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ABSTRACT

The objective was to study the influence of different exopolysaccharide (EPS)-producing and nonproducing lactic cultures on the viscoelastic properties of reduced-fat Cheddar cheese. Changes in the viscoelastic properties were followed over a ripening period of 6 mo. Results showed that the elastic, viscous, and complex moduli were higher in reduced-fat cheeses made with EPS-nonproducing cultures than in full-fat cheese. No differences in the viscoelastic properties were found between young reduced-fat cheese made with a ropy strain of *Lactococcus lactis* ssp. *cremoris* (JFR1) and its full-fat counterpart. Interestingly, the changes in viscoelastic moduli in both full-fat cheese and reduced-fat cheese made with JFR1 during ripening followed the same pattern. Whereas the moduli increased during the first month of ripening in those 2 cheeses, a dramatic decrease was observed in all other cheeses. Slopes of the viscoelastic moduli as a function of frequency were lower in the full-fat than in reduced-fat cheeses. The creep test showed that fresh reduced-fat cheese made with JFR1 was less rigid and more deformable than that made with EPS-nonproducing cultures. The creep and recovery properties of young reduced-fat cheese made with JFR1 and the full-fat type were similar. No differences were found in the viscoelastic properties between reduced-fat cheese made with no EPS and those made with EPS-producing adjunct cultures of *Streptococcus thermophilus*. After 6 mo of ripening, cheeses made with EPS-producing cultures maintained lower elastic and viscous moduli than did those made with no EPS.

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(**Key words:** reduced-fat cheese, Cheddar, exopolysaccharide, viscoelastic properties)

Abbreviation key: %Crp = percentage creep recovery, **EPS** = exopolysaccharide, **FFC** = full-fat control cheese, **G′** = elastic modulus, **G″** = viscous modulus, **G*** = complex modulus, **MNFS** = moisture in nonfat substance, **RFC** = reduced-fat control cheese, **RF-JFR1** = reduced-fat cheese made with the ropy culture *Lactococcus lactis* ssp. *cremoris* JFR1.

INTRODUCTION

Fat reduction is associated with many textural and flavor defects in Cheddar cheese; the texture of reduced-fat Cheddar cheese is described as rubbery, dry, and grainy (Mistry, 2001). To overcome such defects, the moisture in nonfat substance (**MNFS**) in reduced-fat cheese is increased to a level similar to that in the full-fat type. The high levels of moisture in reduced-fat cheeses produce pasty cheese that is difficult to shred. Stabilizers such as carrageenan increase the water-binding capacity of reduced-fat Cheddar cheese and increase the gel strength (Ma et al., 1997). However, there is often a need for using natural additives to comply with food legislation that imposes severe constraints on materials that can be used. Lactic acid bacteria are found naturally in all cheese varieties; they have "generally recognized as safe" status, and are used in making fermented dairy products. Exopolysaccharide (**EPS**)-producing cultures have been used in yogurt, sour cream, Mozzarella cheese, soft cheese, and whipped toppings to improve rheological properties, prevent syneresis, and replace stabilizers (Hassan et al., 1996; Perry et al., 1998; Broadbent et al., 2003; Hassan et al., 2004). Recently, EPS-producing cultures were used to produce reduced-fat Cheddar cheese with textural and melting characteristics similar to those of its full-fat counterpart (Awad et al., 2005b).

The viscoelastic properties of cheese are a function of its composition, microstructure, macrostructure, and the physicochemical state of its components (Guinee, 2002). Such properties comprise a large part of the total sensory score by cheese graders (Prentice et al., 1993).

The objective of this work was to study the effect of different EPS-producing and nonproducing lactic cultures on the viscoelastic properties of reduced-fat Cheddar cheese.

MATERIALS AND METHODS

Cultures

An EPS-producing *Streptococcus thermophilus* CHCC 3534 and its EPS-negative genetic variant *Streptococcus thermophilus* CHCC 5842 (Chr. Hansen, Denmark), a capsule-forming nonropy *Streptococcus thermophilus* (Hassan et al., 1995), and a ropy *Lactococcus lactic* spp. *cremoris* (JFR1; Hassan et al., 2003) were used in this study. Culture preparation was done as previously described (Awad et al., 2005a). Commercial Cheddar starter culture (DVS 850) was obtained from Chr. Hansen (Milwaukee, WI).

Cheese Making

Raw milk was obtained from the Dairy Research and Training Facility at South Dakota State University. Cheddar cheese was manufactured from standardized (2% reduced fat or 3.6% full fat), pasteurized (63°C for 30 min and cooled to 31°C) milk (100 kg) according to Awad et al. (2005a). The following 6 treatments were used: 1) **FFC**, full-fat control cheese made using the commercial Cheddar starter culture (DVS 850; 0.015% wt/wt), 2) **RFC**, reduced-fat control cheese made using the commercial Cheddar starter culture (DVS 850; 0.015% wt/wt), 3) **RF-JFR1**, reduced-fat cheese made with the ropy strain *Lactococcus lactis* spp. *cremoris* JFR1 (2% vol/wt), 4) RF-Slab, reduced-fat cheese made with a capsule-forming nonropy *Streptococcus thermophilus* (0.4% vol/wt) plus the commercial culture (0.011% wt/wt), 5) RF-3534, reduced-fat cheese made with EPS-producing *Streptococcus thermophilus* CHCC 3534 (0.4% vol/wt) plus the commercial culture (0.011% wt/wt), and 6) RF-5842, reduced-fat cheese made with the EPS-negative genetic variant of CHCC 3534 (*Streptococcus thermophilus* CHCC 5842; 0.4% vol/wt) plus the commercial culture (0.011% wt/wt). Curd was cooked to 39°C and held at this temperature for 30 min. The milling pH was 5.4 and salt level was 1.7%.

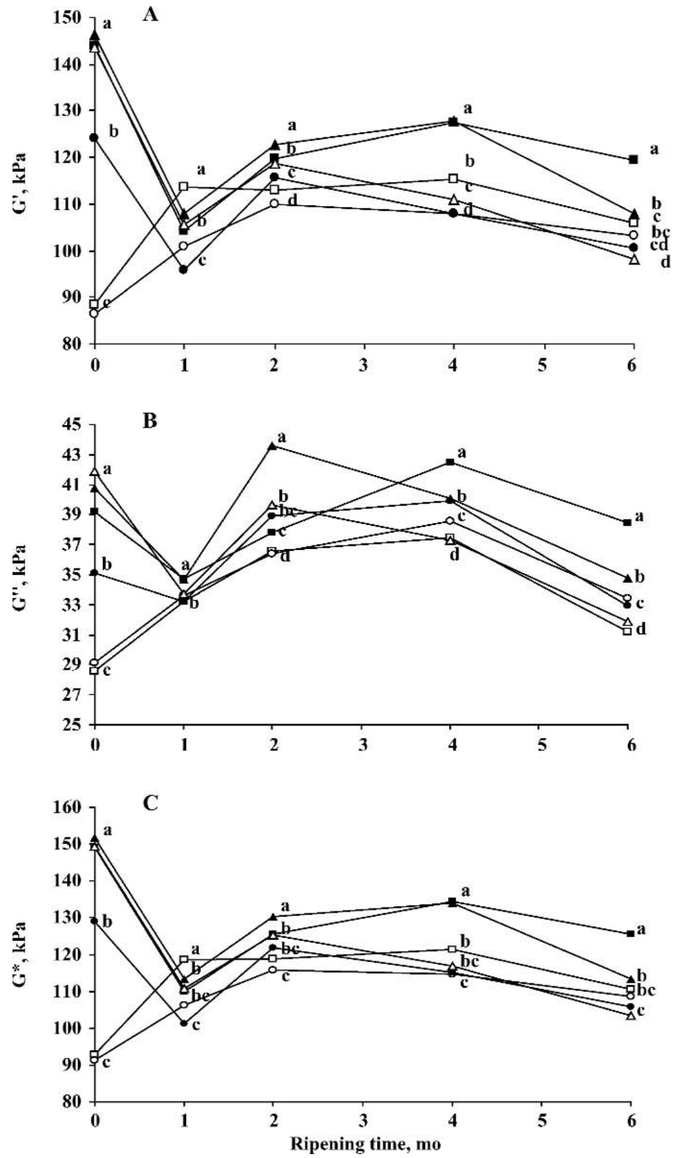

Figure 1. Changes in viscoelastic moduli during ripening of full-fat and reduced-fat Cheddar cheeses: A) Elastic modulus (G′), B) Viscous modulus (G″), and C) Complex modulus (G*). ○ = FFC (full-fat control), ■ = RFC (reduced-fat control), □ = RF-JFR1 (reduced-fat cheese made with the ropy culture *Lactococcus lactis* ssp. *cremoris* JFR1), ● = RF-Slab (reduced-fat cheese made with the capsule-forming nonropy strain *Streptococcus thermophilus* Slab), △ = RF-3534 (reduced-fat cheese made with the EPS-producing moderate ropy strain *Streptococcus thermophilus* CHCC 3534), and ▲ = RF-5842 (reduced-fat cheese made with the EPS-nonproducing strain *Streptococcus thermophilus* CHCC 5842). Different letters indicate significant differences ($P < 0.05$) within the same ripening period.

Viscoelastic Measurements

Cheeses were sliced into thin disks (~2 mm thick and 28.5 mm in diameter) with a cheese slicer, placed into plastic bags to prevent dehydration, and stored at 20°C for 1 h before analysis. Dynamic oscillatory experiments were performed using a Viscoanalyzer (ATS Rheosystems, Rheologica Instrument Inc., Bordentown, NJ) equipped with an MP parallel plate geometry (plate diameter = 30 mm). The gap between the 2 plates was set to the thickness of the sample to allow good contact between the sample and the plates without deforming the cheese. Cheeses were allowed to rest for about 1 min after loading to relax stress caused by sample