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Microbiological, Chemical, and Sensory Characteristics of Swiss Cheese Manufactured with Adjunct *Lactobacillus* Strains Using a Low Cooking Temperature

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ABSTRACT

The effect of nonstarter *Lactobacillus* adjunct cultures on the microbial, chemical, and sensory characteristics of Swiss cheese manufactured using the "kosher make procedure" was investigated. The kosher make procedure, which uses a lower cooking temperature than traditional Swiss cheese making, is used by many American cheese manufacturers to allow for kosher-certified whey. Cheeses were manufactured using a commercial starter culture combination and 1 of 3 nonstarter *Lactobacillus* strains previously isolated from Swiss cheeses, *Lactobacillus casei* A26, *L. casei* B21, and *Lactobacillus rhamnosus* H2, as an adjunct. Control cheeses lacked the adjunct culture. Cheeses were analyzed during ripening for microbial and chemical composition. Adjunct strain *L. casei* A26, which utilized citrate most readily in laboratory medium, dominated the *Lactobacillus* population within 30 d, faster than the other adjunct cultures. There were no significant differences in *Propionibacterium* counts, *Streptococcus thermophilus* counts, protein, fat, moisture, salt, and pH among the cheeses. Free amino acid concentration ranged from 5 to 7 mmol/100 g of cheese at 90 d of ripening and was adjunct strain dependent. Lactic, acetic, and propionic acid concentrations were not significantly different among the cheeses after a 90-d ripening period; however differences in propionic acid concentrations were apparent at 60 d, with the cheeses made with *L. casei* adjuncts containing less propionic acid. Citric acid was depleted by the end of warm room ripening in cheeses manufactured with adjunct *L. casei* strains, but not with adjunct *L. rhamnosus*. Cheeses made with *L. casei* A26 were most similar to the control cheeses in diacetyl and butyric/isobutyric acid abundance as evaluated by electronic nose during the first 3 mo of ripening. The 4 cheese types differed in their descriptive sensory profiles at 8 mo of age, indicating an adjunct strain-dependent effect on particular flavor attributes. Adjunct *Lactobacillus* spp. affected the flavor profile and concentration of some flavor compounds in Swiss cheeses produced with the kosher make procedure. Use of adjunct *Lactobacillus* cultures provides Swiss cheese makers using a low cooking temperature with a means to control the dominant *Lactobacillus* strain during ripening, reduce citrate concentration, and modify cheese flavor.

Key words: Swiss cheese, adjunct culture, *Lactobacillus casei*, citrate

INTRODUCTION

The effect of nonstarter lactobacilli on cheese quality can be positive, negative, or neutral depending on the strains that predominate and their roles during ripening (Crow et al., 2001; Swearingen et al., 2001; Kieronczyk et al., 2003). High concentrations of desirable nonstarter lactobacilli in cheese throughout ripening provide balanced flavor development and minimize the possible effects of undesirable nonstarter lactic acid bacteria (Crow et al., 2001); therefore, many cheese makers advocate adding adjunct *Lactobacillus* cultures during cheese making. Experimental cheeses containing adjunct lactobacilli show improved flavor intensity and acceptability and higher levels of free amino acids when compared with control cheeses (Lynch et al., 1997).

In Switzerland, facultatively heterofermentative adjunct *Lactobacillus* spp. are used in the Swiss cheese industry to retard propionic acid fermentation and to prevent late fermentation in Emmental cheese (Fröhlich-Wyder et al., 2002). Although the use of *Lactobacillus casei* as an adjunct culture is common for Swiss-type cheese manufactured in Switzerland, few published reports exist on adjunct use in Swiss cheese and none exist for adjunct use in US-manufactured Swiss-type cheese. Traditional Swiss cheese making involves cooking the curds in the whey at 51 to 58°C (Reinbold,

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1972). With the "kosher make procedure," cooking temperatures must be ≤49°C to allow for kosher certification of whey products derived from cheese making. This alteration in cooking temperature causes changes in the final cheese quality, such as rapid acid development, increased split defects, and high moisture (B. Ramseyer, Holmes Cheese Co., Millersburg, OH; personal communication; G. Hong, Brewster Dairy Inc., Brewster, OH; personal communication). Adjunct culture addition has the potential to reduce vat-to-vat variability within the same manufacturing facility and would allow the cheese maker to control, to some extent, the effect of nonstarter bacteria on cheese quality. The objective of this study was to examine the effect of adjunct *Lactobacillus* strains on the chemical and sensory properties and culture dynamics of Swiss cheeses manufactured using the kosher make procedure.

MATERIALS AND METHODS

Bacterial Strains

Streptococcus thermophilus STC-6, *Lactobacillus helveticus* Lh-32, and *Propionibacterium freudenreichii* ssp. *shermani* PS-4 cultures (Chr. Hansen Inc., Milwaukee, WI) were used as direct-vat-set starter cultures. Adjunct cultures were selected from previously isolated nonstarter lactobacilli based on their citrate utilization properties in broth and on agar plates (Kocaoglu-Vurma, 2005). *Lactobacillus casei* A26 isolated from Swiss Emmental utilizes citrate. *Lactobacillus rhamnosus* H2 and *L. casei* B21 were both isolated from US-manufactured Swiss cheeses and metabolize little or no citrate, respectively, in laboratory medium. The maximum specific growth rates for *L. casei* A26 and *L. rhamnosus* H2 in a basal medium containing 30 m*M* citrate were 0.22 and 0.07 h^{-1}, respectively. Growth was not detected for *L. casei* B21 in this medium (Kocaoglu-Vurma, 2005).

Nonstarter *Lactobacillus* cultures were grown to stationary phase (18 h) in *Lactobacillus* de Man, Rogosa, Sharpe broth (Criterion, Hardy Diagnostics, Santa Maria, CA), washed twice in sterile PBS, and resuspended in sterile water immediately before inoculation into the cheese milk. Cultures were inoculated to approximately 10^3 cfu/mL of milk to achieve $>10^5$ cfu/g of cheese before brining.

Cheese Manufacture

Twelve cheeses (triplicates of 4 treatments) were manufactured in 200-L-capacity pilot-scale cylindrical cheese vats (C. van't Riet Dairy and Process Equipment, Aarlanderveen, the Netherlands) by using the rindless block procedure modified to simulate the kosher make procedure (Reinbold, 1972; Kosikowski and Mistry 1997). The pilot-scale procedure was developed in consultation with 2 Swiss cheese companies that have used this procedure commercially. Milk (100 L) from the Ohio State University Dairy Farm (Columbus, OH) was standardized to a 1:1 true protein-to-fat ratio and pasteurized in the vat by holding at 63°C for 30 min. Before inoculation with starter cultures, the milk temperature was reduced to 34.4°C with gentle to moderate stirring. Nonstarter *Lactobacillus* cultures were added to achieve approximately 10^3 cfu/mL of milk. Starter cultures were added at the levels recommended by the culture supplier. To accomplish this, a 15-g sample of the starter culture pellets was thawed in a sterile container and thoroughly mixed. The recommended amount (STC-6, 60 mg; Lh-32, 120 mg; PS-4, 300 mg) was aseptically removed and inoculated into the milk. Inoculated milk was ripened for 20 min and then set with 8 g of coagulant (Chy-max Extra, Chr. Hansen Inc.) diluted in 40 mL of sterile water. After 25 to 30 min, the curd was cut slowly to fine curd size (6 to 8 mm) by rotating the 2 cutting blade frames (with blades fixed at 37 mm apart) at a gradually decreasing rate over 10 min. The rotation rate for cutting was controlled by using an automated speed control unit. The curds were then heated to 47.5°C for approximately 30 min, and held at 47.5°C with gentle agitation until the target curd pH value of 6.45 to 6.55 was reached. The whey and the curd were pumped into perforated stainless steel vessels dressed with disposable cheesecloth. The whey was drained by gradually adding weight (up to 20 kg) to create approximately 2 kg of pressure/kg of cheese. The cheese was pressed at 37°C until the cheese pH decreased to approximately 5.25. A sample was taken from the center for pH and microbiological analysis. Subsequently, the cheese (approximately 36 × 26 × 8 cm) was divided into 4 equally sized blocks (approximately 18 × 13 × 8 cm) and placed into brine solution (23% salt, 0.001% $CaCl_2$, pH 5.4, 4 to 7°C) for 4 h. After brining, the blocks were vacuum-packaged in 3-mil nylon-polyethylene standard barrier vacuum pouches and stored at 4 to 7°C for 6 d to allow for salt equilibration throughout the block. After this precooling step, blocks were placed into plastic molds and stored in a warm room (21 to 22°C) for *Propionibacterium* growth. After 24 d in the warm room, cheeses were transferred to cold storage at 4 to 7°C for 2 to 8 mo for ripening. One of the 4 blocks was removed for sampling at 6, 30, 60, and 90 d.

In addition to standard cleaning and chemical sanitizing, all cheese-making equipment (milk cans, cheese vats, stirrers, knives, cheesecloth, and pressing tables) was steam-sterilized before each cheese-making session to eliminate or minimize environmental contamination