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Rheology, Microstructure, and Functionality of Low-Fat Iranian White Cheese Made with Different Concentrations of Rennet

A. Madadlou,[1] A. Khosroshahi,[2] and M. E. Mousavi[1]
[1]Department of Food Science and Engineering, Faculty of Agricultural Biosystem Engineering, University of Tehran, Iran
[2]Department of Food Science and Technology, Faculty of Agricultural Engineering, University of Urmia, Iran

ABSTRACT

A batch of full-fat (23% target fat) and 3 batches of low-fat (6% target fat) Iranian white cheese with different rennet concentrations (1-, 2-, and 3-fold the normal usage) were produced to study the effect of fat content reduction and promoted proteolysis on the textural and functional properties of the product. Cheese samples were analyzed with respect to their rheological parameters (uniaxial compression and small amplitude oscillatory shear), meltability, microstructure, and sensory characteristics. Reduction of fat content from 23 to 6% had adverse effects on the texture, functionality, cheese-making yield, and sensory characteristics of Iranian white cheese. Fat reduction increased the instrumental hardness parameters (storage modulus, stress at fracture, and Young's modulus of elasticity), decreased the cheese meltability and yield, and made the microstructure more compact. Doubling the rennet concentration reduced values of instrumental hardness parameters, increased the meltability, and improved the sensory impression of texture. Although increasing the rennet concentration to 2-fold the normal usage resembled somewhat the low-fat cheese to its full-fat counterpart, it appeared to cause more reduction in yield. Increasing the rennet concentration 3-fold the normal usage produced a product slightly more elastic than the low-fat cheese with normal concentration of rennet. Increasing the rennet concentration to 2-fold the normal usage was useful for improving the textural, functional, and sensory properties of low-fat Iranian white cheese.
(**Key words:** Iranian white cheese, low fat, rheology, microstructure)

Abbreviation key: FFC = control full-fat cheese, **G′** = elastic modulus, **IMCU** = international milk clotting units, **LFC1C** = control low-fat cheese with normal concentration of rennet, **LFC2C** = low-fat cheese with double concentration of rennet, **LFC3C** = low-fat cheese with triple concentration of rennet, **MNFS** = moisture in nonfat substance, **M:P** = ratio of moisture to protein.

INTRODUCTION

Fat reduction in the diet is important based on the scientific evidence linking diets that are high in fat to obesity, arteriosclerosis, coronary heart disease, elevated blood pressure, tissue injury, and certain types of cancer (Rudan et al., 1999; Guinee and Law, 2002). Hence, dietary fat intake reduction is an effective means of decreasing the risk of coronary heart disease (Hynes et al., 2001) and the other mentioned health problems. Reduced-fat dairy products are the most widely consumed reduced-fat foods (Drake et al., 1996); among these, the production of reduced- and low-fat cheese has significantly increased since 1980 (Koca and Metin, 2004). The fat in food carries much of its flavor and gives it a satisfying characteristic texture; removal of fat from cheese produces undesirable texture and appearance, altered rheological parameters, lack of flavor, poor keeping quality, and poor meltability and stretching property (Ustunol et al., 1995; Perry et al., 1997; Paulson et al., 1998; Rodríguez, 1998; Sipahioglu et al., 1999; Koca and Metin, 2004). Low-fat cheeses are characterized as having rubbery body and flavors that are atypical of corresponding full-fat varieties (Mistry, 2001); therefore, new ingredients and knowledge are needed (McKenna, 2003) to manufacture a product that is similar in flavor, melt, firmness, and texture to full-fat cheeses (Metzger and Mistry, 1995).

As the percentage of fat fraction is reduced, the proportions of protein and moisture fractions are increased. The protein-dominated microstructure of low-fat cheese (Sipahioglu et al., 1999) causes textural defects, such as rubberiness (Metzger and Mistry, 1995) and hardness. The bacterial population in curd is directly related to the fat content of cheese, and fat reduction leads to fewer starter cells than found in full-fat cheese (Laloy et al., 1996). Conversely, a high moisture content in low-fat cheese and lower salt concentration

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Corresponding author: A. Madadlou; e-mail: ashkan.madadlou@gmail.com.

in the moisture fraction can enhance the activity and growth of microorganisms, including retained starters. Therefore, the peptide profile of low-fat cheese may become different from full-fat varieties (Ardö and Gripon, 1995).

Before they are renneted, the casein micelles in milk show no tendency to aggregate (Dalgleish, 1997). When milk is renneted, casein micelles aggregate (Walstra, 1999), providing a clear transition from a stable dispersion to a flocculated and gelled preparation (De Kruif, 1999). A large portion of the rennet is lost in the whey during cheese making (Gouda, 1987), depending on the pH at wheying (in the case of calf rennet, not microbial rennets) and the proportion of whey retained in the curd (Holmes et al., 1977; Lawrence et al., 1987; Fox, 1989). In general, only about 6% of the rennet added to cheese milk is retained in the curd (Fox, 1989); however, it is an important factor in the development of texture and flavor in the most aged cheese types because of its high proteolytic activity. Perhaps the main consequence of proteolysis is the conversion of the rubbery texture of initial curd to the smooth-bodied finished cheese (O'Keeffe et al., 1976). One may expect improvement of the textural and functional characteristics of low-fat cheese by the addition of higher rennet during cheese making, which leads to the higher retention of active rennet in the cheese curd (Holmes et al., 1977), and therefore, the higher rate of proteolysis. Ernstrom et al. (1958) reported for pasteurized- and raw-milk Cheddar cheese made with one-half the normal amount of rennet and Kindstedt et al. (1995) reported for low-moisture, part-skim Mozzarella made with 100, 80, and 60% of normal usage of rennet, that rennet concentration significantly influenced the rate of proteolysis. However, no significant differences were detected in the flavor and body of Cheddar and the rheological characteristics and meltability of Mozzarella cheeses. Nevertheless, Dave et al. (2003) found that relative firmness (reported as the dynamic complex modulus) of full-, reduced-, and nonfat Mozzarella cheese was influenced by the level of rennet (0.25-, 1-, and 4-fold). In general, higher fat contents promoted more melting as did higher coagulant concentration. Cremoso Argentino soft cheeses without active rennet were hard and crumbly, but cheeses with a normal dose were soft and crumbly (Hynes et al., 2001).

Iranian white cheese is a brined cheese that is produced traditionally and industrially throughout Iran. Its characteristic flavor, body, and texture are developed at the ripening period of several weeks to months (Ehsani et al., 1999). The objective of the present study was to improve the textural, functional, and sensory properties of low-fat Iranian white cheese by increasing the rennet concentration 2- and 3-fold the normal usage.

MATERIALS AND METHODS

Treatments, Cultures, and Rennet

The 4 cheese treatments were as follows: control full-fat cheese (**FFC**), control low-fat cheese with normal concentration of rennet (**LFC1C**), low-fat cheese with double concentration of rennet (**LFC2C**), and low-fat cheese with triple concentration of rennet (**LFC3C**). Cheese batches manufactured using 50 kg of standardized milk for each treatment. Cheeses were manufactured in triplicate; each replicate was produced in 2 d. Two lyophilized direct-to-vat mixed cultures (R-704 and FRC-60; Chr. Hansens Dairy Cultures, Denmark) were used as starter. Culture R-704 contained *Lactococcus lactis* subsp. *cremoris* and *Lactococcus lactis* subsp. *lactis.* Culture FRC-60 contained *Lactococcus lactis* subsp. *cremoris, Lactococcus lactis* subsp. *lactic, Streptococcus thermophilus,* and *Lactobacillus delbrueckii* subsp. *bulgaricus.* As a coagulant, chymosin, derived by fermentation [standard rennet; Chy-Max; Chr. Hansen Inc., Denmark; 183 international milk clotting units (**IMCU**)/mL (International Dairy Federation, 1997)], was used at 3 different concentrations: 4.5 IMCU of Chy-Max/kg of milk for FFC and LFC1C, 9.0 IMCU of Chy-Max/kg of milk for LFC2C, and 13.5 IMCU of Chy-Max/kg of milk for LFC3C. Rennet was diluted 30-fold with cold water then added to each 50-kg batch of milk.

Cheese-Making Procedure

Raw skim milk (<0.025% fat) was standardized with cream of determined fat content to 3.1% fat for FFC and to 0.6% fat for low-fat cheeses. Standardized milk was batch-pasteurized at 64°C for 30 min in a stainless steel vat placed in a water bath, cooled to 35°C, and supplemented with 0.1 g of $CaCl_2$/kg of milk. After inoculation of cultures, milk was held at 35°C for approximately 55 min for starter maturation before the addition of rennet. The curd was cut crossways in cubes of 2 cm^3 when firm (approximately 55, 40, and 25 min for 1, 2, and 3× rennet concentrations, respectively). After being cut, the curd was allowed to settle for 3 to 5 min and then was gently agitated at a gradually increasing rate for 10 min to avoid fusion of freshly cut curd cubes and facilitate whey expulsion. This was followed by whey draining and wrapping the drained curd within a cheesecloth. Following this stage, the curd was pressed for 3 h (under a gradually increasing pressure up to approximately 2200 Pa at the first 1.5 h) to complete draining. After pressing, the curd was cut in blocks (4 cm × 9 cm × 9 cm). The blocks were stored at