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International Dairy Journal 16 (2006) 1119–1131
INTERNATIONAL DAIRY JOURNAL
www.elsevier.com/locate/idairyj

Review

High pressure-induced changes in milk proteins and possible applications in dairy technology

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Received 10 June 2005; accepted 24 November 2005

Abstract

This paper reviews the newest information on the effects of high pressure (HP) on whey proteins, caseins and milk enzymes, and discusses their influence on milk properties. HP treatments cause substantial modification to milk proteins and to the mineral balance of milk. Casein micelles disaggregate into smaller particles or aggregate, depending the intensity and the temperature of the HP treatment. Whey proteins are denatured, possibly interacting with the remnants of the casein micelles, and give aggregated forms different from those produced by heat treatment. These events influence rennet coagulation properties of milk, with micellar disintegration favoring coagulation and whey protein denaturation hindering the aggregation of renneted micelles and enhancing cheese yield. HP treatment of milk favors acid coagulation and produces acid gels whose structure is greatly determined by the different micellar sizes attainable and the degree of whey protein denaturation. Milk gels can also be formed from concentrated milk under HP, providing new structures inaccessible via conventional methods.

Keywords: High pressure; Whey proteins; Casein micelles; Technological properties; Cheese; Yogurt

Contents

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doi:10.1016/j.idairyj.2005.11.007

1. Introduction

The first studies on milk processing using high pressure (HP) date as back as the end or the 19th century (Hite, 1899). However, it was not until 1990 that equipment advances and the consumer demand for minimally processed, high quality foods have lead to a considerable research interest in HP technology. In fact, HP is the only processing technology alternative to heat treatment that has reached the consumer with a variety of products that include fruit jams, jellies, sauces, juices, avocado pulp, guacamole and cooked ham, although there are not, as yet, commercial HP-treated dairy products. Most of the applications take advantage of the fact that HP exerts antimicrobial effects without impairing nutritional quality (Sancho et al., 1999; Sierra, Vidal-Valverde, & López-Fandiño, 2000). However, in addition to satisfying consumer demands for fresh products free from additives, HP may offer a clear competitive advantage in creating unique effects in food that may overcome the constraint of the large capital investment required.

HP treatments specifically influence the functional properties of proteins through the disruption and reformation of hydrogen bonds and hydrophobic interactions and the separation of ion pairs. These changes depend on protein structure, pressure level, temperature, pH, ionic strength, solvent composition and protein concentration (Boonyaratanakornkit, Park, & Clark, 2002; Lullien-Pellerin & Balny, 2002). HP milk processing induces changes in the main milk proteins (whey proteins and caseins) that improve their functional properties for certain uses (Balci & Wilbey, 1999; Datta & Deeth, 1999; Needs, 2002; Trujillo, Capellas, Saldo, Gervilla, & Guamis, 2002). A review on the effects of HP on constituents and properties of milk was recently published in the International Dairy Journal (Huppertz, Kelly, & Fox, 2002). Taking into account the considerable progress in HP research made during the past 5 years, the present paper is aimed to review the newest knowledge on the effects of HP on milk proteins, relating protein modifications with technological improvements that can be of interest to the dairy industry. Special attention was paid to those aspects that provide satisfactory explanations to previously found observations and that have broadenened the potential applications of this technology.

2. Effects of high pressure on milk proteins

2.1. Whey protein denaturation

The main components of the whey protein fraction of bovine milk are β-lactoglobulin (β-Lg), α-lactalbumin (α-La) and bovine serum albumin (BSA). The behavior of these proteins when they are HP treated individually in solution, or combined as part of whey protein products, such as whey protein isolates or concentrates, has been extensively studied and it is dealt with elsewhere (López-Fandiño, 2006).

Treatment of milk at pressures over 100 MPa at 25 °C leads to a progressive β-Lg denaturation, estimated by the loss of solubility at pH 4.6, while α-La and BSA are resistant to pressures up to 400 MPa (López-Fandiño, Carrascosa, & Olano, 1996). Treatments at 200 and 400 MPa, applied at room temperature for 15–30 min, denatured 14–16% and 82–90% of β-Lg, respectively (García-Risco, Recio, Molina, & López-Fandiño, 2003; Huppertz, Fox, & Kelly, 2004a). A pressure of 600 MPa for 15–30 min denatured 15–33% of α-La (Huppertz et al., 2004a; Needs, Capellas et al., 2000).

The extent of denaturation is dependent on the pressure level, treatment time and temperature (Huppertz, Fox, & Kelly, 2004b). As illustrated in Fig. 1, an increase in the temperature of the HP treatment up to 60 °C did not induce β-Lg denaturation at 100 MPa but, at higher pressures, denaturation increased with increasing temperature. In addition, almost 60% of α-La denatured on treatment at 400 MPa and 60 °C (López-Fandiño & Olano, 1998a). Kinetic parameters for the combined effects of pressure and temperature on the denaturation of β-Lg A, β-Lg B and α-La in milk, that allow the prediction of denaturation from the processing profile, have been estimated recently (Hinrichs & Rademacher, 2005).

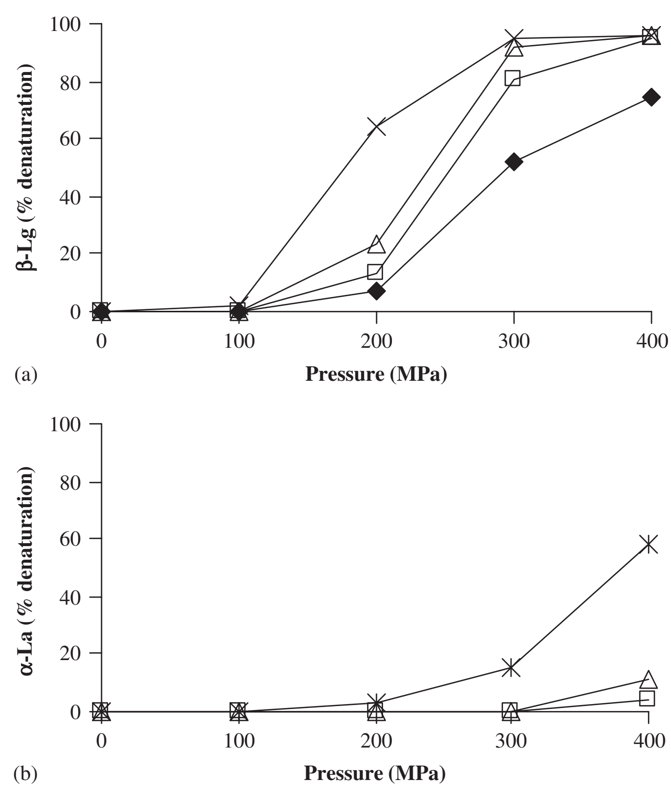

Fig. 1. Effect of pressurization of milk at 25 °C (-◆-), 40 °C (-□-), 50 °C (-△-) and 60 °C (-×-) for 15 min on the percentage of denaturation of β-Lg (a) and α-La (b). The means of three independent experiments are shown. The error bars (±SD) are included in the symbols. Reproduced from López-Fandiño and Olano (1998a, b) with permission.