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Review

Structuring dairy systems through high pressure processing

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ABSTRACT

This review highlights the current knowledge on gelation of hydrocolloids induced by high pressure processing (HPP) of dairy products. Pressure-induced gelation of single systems (casein rich, whey protein rich, gelatin, and polysaccharide solutions) as well as rheological and thermo-mechanical effects of HPP on mixture systems are discussed. The mechanism of dairy protein gelation under pressure, their properties and microstructure, and potential application of HPP to improve physical properties of dairy products (cheese, yoghurt, and ice cream) are included. HPP is a promising tool for future manufacturing of structured dairy products with unique sensorial properties.

Contents

Abbreviations: BSA, bovine serum albumin; CCP, colloidal calcium phosphate; DS, dextran sulphate; G', elastic modulus (Pa); G'', viscous modulus (Pa); HMP, high methoxy pectin; HPLC, high performance liquid chromatography; HPP, high pressure processing; LMP, low methoxy pectin; MC, micellar casein; MPa, mega pascal; MSNF, milk solid non-fat; Pa, pascal; RCT, rennet coagulation time; SEM, scanning electron microscope; SMP, skim milk powder; TEM, transmission electron microscopy; T_{gel}, gelling temperature (°C); T_g, glass transition temperature (°C); T_m, melting temperature (°C); UF, ultra-filtered; WPC, whey protein concentrate; WPI, whey protein isolate; δ, phase angle (°); ΔH_g, enthalpy of gelatinisation (J/kg).

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1. Introduction

1.1. Food gels

Food gels, according to their constructing materials, are classified as either protein gels or polysaccharide gels. Proteins are an essential part in the human diet as they provide essential amino acids and sometimes carry organic minerals. Their ability to form gels makes them ideal to impart structure and texture in foods. They also contribute to colour and flavour developments in foods (Renard et al., 2006).

Polysaccharides can provide soluble dietary fibres in our diet. The amount of polysaccharides required to form gels is five to ten fold lower than that of proteins (Renard et al., 2006). Polysaccharide gels can withstand a wide temperature range of food processing; for example, starch-based fat replacers are added in fat-free bakery goods, meat products, and confections (Drewnowski, 1990). Protein gels, on the other hand, are vulnerable to syneresis and precipitation (Renard et al., 2006). Their incorporation in foods can be a challenge because they tend to aggregate at high temperature; whereas they should imitate the morphology of fat crystals to give creaminess (Kasapis, 2009). Thus, protein-based fat replacers, such as microparticulated proteins, are usually used in products which will not be subjected to further cooking, such as ice cream, margarine, and salad dressings (Drewnowski, 1990). However, in practice, combinations of two or more fat mimetics from two different hydrocolloid groups (i.e., proteins and polysaccharides) are used to replace fat with fine palatability (Chronakis and Kasapis, 1995).

1.2. Gels, gelation, and mixed systems

Gels are systems with the following characteristics: (a) they are composed of a solid dissolved or dispersed in a solvent, (b) they are coherent, meaning both solid and solvent phases of a gel should spread persistently and are interconnected throughout the whole system, and (c) they act as a solid under mechanical forces (Morris, 2007). From a rheological view-point, a gel exhibits both solid-like and liquid-like rheological properties, with an elastic modulus (G') higher than the viscous modulus (G''), throughout the probing frequency range. A gel also must show a plateau of G', in the order between 10^2 Pa and10^8 Pa, with a lower value of G'' (Almdal et al., 1993).

A gelation process is simply defined as a phase transition from sol to gel in which the linkage between the macromolecules is growing from finite to infinite (Djabourov, 1991). When thickening instead of gelation occurs, the resultant system should be categorised as structured or viscoelastic liquid (Clark and Ross-Murphy, 2009). Gelation can be manipulated during food processing to tailor physical properties of gels, i.e., texture, water-holding, and appearance (Morris, 2007).

Rheological investigations have been focused on proteins and polysaccharides because they are always present in food products and contribute to texture and mouthfeel. Therefore, they are suitable components to model food systems, which are more complex. In addition, combination of two or more polymers is a way usually taken for generating gels with improved properties (Morris, 2007). Another approach to change gel properties is by changing the gel formation process. The later substantially affects the morphology of mixed gels and, therefore, can dictate the final properties (Walkenström and Hermansson, 1997b).

1.3. High pressure processing for texturing foods

The effects of high pressure on protein unfolding, denaturation, and aggregation have been extensively summarised by Boonyaratanakornkit et al. (2002) whereas gelling mechanism of starch under pressure was reviewed for example by Knorr et al. (2006) and Kim et al. (2012).

HPP is not a new technology for food manufacture but so far has not been widely applied in the food industry. One of the first scientific reports on HPP applications for food was written by Hite (1899) on shelf-life extension of milk. Since then the application of HPP has been broadened to other food products such as fruit juices and meat products (Heinz and Buckow, 2010). HPP technology can offer a high retention of sensory and nutritional attributes of food products, because the treatment can be performed near room temperature, while ensuring safety and stability during refrigerated storage. Therefore, final products with higher quality than those produced by conventional heat treatments can be obtained. Typically, pressures up to 800 MPa and temperatures between 5 and 40 °C are used in commercial applications (Heinz and Buckow, 2010).

Although HPP of food was initially developed to retain nutritional and sensorial aspects while ensuring safety and stability issues of perishable food products, this technology has attracted attention for modifying macromolecules arrangements such as protein denaturation, starch gelatinisation, or other interactions between food ingredients. Tailoring the functional properties of food systems requires careful consideration of the processing variables in order to obtain the desired characteristics (Knorr et al., 2006).

Studies on the gelation of hydrocolloid mixtures by HPP have been a growing trend for the last two decades (Hemar et al., 2010). HPP offers greater choices of processing variables, i.e., pressure, time, temperature, and pressure release rate; hence, more unique properties can be obtained (Michel et al., 2001).

For successful new product development, it is advisable to conduct quantitative investigations of the resultant gels from rheolog-