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ScienceDirect
Food Hydrocolloids 21 (2007) 174–179
FOOD HYDROCOLLOIDS
www.elsevier.com/locate/foodhyd

Gelation behavior of wheat gluten by heat treatment followed by transglutaminase cross-linking reaction

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Received 30 August 2005; accepted 21 March 2006

Abstract

Improvement in the functional properties of food proteins using microbial transglutaminase (TGase) has been the subject of recent studies in food field. However, changes in functional properties of wheat gluten as affected by cross-linking with TGase have not been well studied. Gelation of wheat gluten treated by TGase was investigated in this present study. Obvious decrease in the minimum concentration for gelation of the heated gluten (16%) was found compared with 22% of the original gluten. The surface lysine and glutamine residues of the gluten increased with heating, the formation of ε- (γ-glutamyl)lysyl cross-links increased markedly in the gelation of heated-gluten treated by TGase. Significant ($P<0.05$) improvements in rheological properties, water-holding capacity and texture properties of the TGase-induced gluten gels were observed, particularly, for gels of TGase-induced glutens treated by pre-heating. It indicated that TGase had significant ($P<0.05$) effect on gelation capacity and gel properties of wheat gluten proteins.

Keywords: Wheat gluten; Microbial transglutaminase; Protein cross-linking; Minimum concentration for gelation; Rheological properties; Water-holding capacity; Texture properties

1. Introduction

Wheat gluten and wheat starch are economically important coproducts produced during wet processing of wheat starch. Wheat gluten includes two components, glutenins and gliadins. They are highly polymorphic polypeptides, consisting of more than 60 different molecular mass species ranging in *M*r from 30,000 to 90,000 kDa (Payne, Nightingale, Krattiger, & Holt, 1987; Shewry, Halford, & Tatham, 1992). In food industry, wheat gluten is traditionally used as an additive to improve the baking quality of flour. For industrial applications, the wheat gluten is readily available in large quantities and at low prices. Application of the wheat gluten has gained much interest in the past decade (Cook & Shulman, 1998; Gennadios & Weller, 1990; Gontard, Guilbert, & Cuq, 1992; Gontard & Ring, 1996; Larré, Desserme, Barbot, & Gueguen, 2000).

The expanded utilization of wheat gluten proteins in food and non-food industrials has been limited by lack of some desirable functional properties, such as solubility and emulsifying properties. Therefore, modifications have been made to extend the range of available functional properties (Bietz & Lookhart, 1996; Lens, Mulder, & Kolster, 1999). Food proteins can be modified by physical (Apicharts-rangkoon, Ledward, Bell, & Brennan, 1998; Haschemeyer & Haschemeyer, 1973), chemical (Lens et al., 1999; Wall, Friedman, Krull, Caving, & Beckwith, 1968), and enzymatic methods (Larré & Schwenke, 1996). Only physical and enzymatic methods are used in foods, chemical modification of proteins is very well suited to improve properties required for nonfood applications.

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doi:10.1016/j.foodhyd.2006.03.006

Enzymes including mammalian and microbial transglutaminase (TGase) have been applied in food processing. TGase (protein–glutamine: amine γ-glutamyltransferase, EC 2.3.2.13) catalyzes a protein cross-linking reaction through an acry transferase mechanism involving protein-bound glutaminyl residues (acyl donor) and primary amines (acyl acceptors), including ε-amine group of lysine residues in certain proteins. The enzyme has been used for improving the functional properties of various proteins including soy proteins, myosin, globulin, casein and whey proteins (Abourmahmoud & Savello, 1990; Faergemand, Otte, & Qvist, 1997; Ikura, Sasaki, & Motoki, 1992; Motoki, & Seguro, 1998; Siu, Ma, Mock, & Mine, 2002).

Cross-links among wheat gluten proteins by TGase are of particular interest because of their high glutamine content. However, only limited information is available on changes in functional properties of the gluten proteins caused by TGase treatment. Some reports indicated that the physicochemical and rheological properties of wheat flour dough modified by microbial TGase had great change (Larré, Papini, & Popineau, 2000; Tseng & Lai, 2002). Koksel, Sivri, and Steffe (2001) found that complex modulus values of TGase-treated wheat doughs, and doughs blended with bug-damaged wheat flour increased significantly. This indicated that TGase substantially rebuilt structure of dough hydrolyzed by wheat bug proteinase enzymes. Bauer, Koehler, Wieser, and Schieberle (2003a, b) demonstrated that the use of TGase could improve dough properties and baking performance for flours with weak gluten and poor baking performance. Sequence analysis of peptides from a thermolytic digest of the insoluble residue revealed that high molecular weight subunits of glutenin and α-gliadins were predominantly involved in cross-links formed by TGase treatment.

In this present study, the effect of heat treatment followed by microbial TGase cross-linking reaction on the gelling behavior of insoluble wheat gluten proteins was investigated. Moreover, the rheological and texture properties of the gels formed by the modified glutens catalyzed by TGase were also probed.

2. Materials and methods

2.1. Commercial wheat gluten

Commercial wheat gluten was used. The gluten contained 71.5% (m/m, dry basis) protein, 6.8% moisture.

2.2. Transglutaminase (EC 2.3.2.13)

Purified microbial TGase (derived from *Streptoverticillium sp*. No. 8112) was kindly provided by Ajinomoto Co., Inc. (Japan) and stored at −20 °C. Microbial TGase was with TGase activity of approximately 100 U/g. Unless otherwise stated, all reagents in this study were of analytical grade.

2.3. Heat treatment of gluten

A 2% of wheat gluten dispersion was heated in thin test tubes at 100 °C for 30, 60 and 120 s. The gluten was then cooled, freeze-dried and stored at −20 °C until use.

2.4. TGase cross-linking reaction

The defined concentration of the original gluten and the heat-treated gluten were reacted with TGase. Soluble TGase at enzyme/substrate [*E*/*S*] ratios of 10 U/g gluten was used in the cross-linking experiments. The reaction was carried out in a jacketed bioreactor for 3 h at 40 °C with continuous circulation. The enzyme was inactivated by *N*-ethylmaleimide (0.1 mL, 0.1%) according to the method of Kato, Wada, Kobayashi, and Motoki (1991). The cross-linking glutens were freeze-dried and then stored at −20 °C for further use.

2.5. Gel preparation

The suspensions of the original gluten and modified glutens (heat-treated gluten and heat-treated/TGase-modified gluten) were prepared in distilled water. 10 mL of various concentrations of dispersions was transferred into a beaker and then were heated in a boiling water bath for 1 h, followed by rapid cooling at the ice bath. The test beakers were further cooled at 4 °C for 2 h. The minimum concentration for gelation was determined as the concentration when the sample from the inverted beaker did not slip or fall.

When determination of water-holding capacity (WHC) and texture properties of gels were made, 12% of sample was used to prepare gel except of the original gluten.

2.6. Determination of lysine and glutamine residues

The number of lysine residues on the surface of gluten molecules was determined according to the TNBS method (Fields, 1972) using 0.2% gluten solution. The number of glutamine residues was determined by TGase-catalyzed labeling of glutamine residues of gluten with dansylcadaverine that was known to bind effectively with the ε-amino groups of lysine in donor proteins (Lorand et al., 1968).

2.7. Determination of ε-(γ-glutamyl)lysine cross-links

The contents of ε-(γ-glutamyl)lysine formed by TGase reaction were determined according to the method of Griffin, Wilson, and Lorand (1982).

2.8. Determination of rheological properties of gels

The storage (G') and loss (G'') modulus of the suspensions of the original and modified glutens (12%) by heat/TGase were investigated by small oscillatory measurements performed by a CarriMed SL 100 rheometer (TA