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Effects of combined high-pressure and heat treatment on the textural properties of soya gels

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Abstract

SPI, 7S, and 11S globulin at 12% (w/v) protein concentration, at neutral pH, did not form gels when heat-treated (90 °C, 15 min) or when high pressure-treated (300–700 MPa), except for the 11S, which formed a gel when heat-treated. The combination of heat and pressure (that is heating the solutions in a water bath and then pressure-treating at room temperature or the reverse sequence), led to differences: when heat-treatment was before high-pressure treatment, only the 11S fraction formed a self-standing gel; however, when the solutions were pressurised before heat treatment, all the proteins formed self-standing gels. The textural and water-holding properties were measured on the gels formed with the three different soy proteins.

Keywords: High-pressure; Gelling properties; Soy proteins

1. Introduction

The effect of heat on soy seeds and flour has been reported. There are also many reports describing the molecular changes in soy protein isolate (SPI) and the soy globulins 7S and 11S after heating and how they influence the functional properties. High-pressure has also been applied to modify the functional properties of soy products, mainly soymilk (Messens, Van Camp, & Huyghebaert, 1997). However, little is known about the effect of HP on the individual constituents of soy proteins, and this is important if we are to understand the effect on the final product. For example, there is an increasing development, through genetic engineering to develop soybean varieties with only the 7S (Maruyama et al., 1999) or 11S fraction (Liu, Lee, & Damodaran, 1999) but there are few reports about the effect of HP on the functional properties of the different soy fractions. Galazka, Dickinson, and Ledward (1999) reported poorer emulsifying properties of HP 11S (*Vicia faba*) than the native protein and Molina, Papadopoulou, and Ledward (2001) found a great improvement in the 7S and 11S fractions after pressurisation at specific concentrations at neutral pH. Although HP is a very promising technique to produce soy-protein gels with unique textures, previous studies in our laboratory (Molina, Defaye, & Ledward, in press) showed that high-pressure could only form self-standing gels for SPI, 7S and 11S at concentrations of 20%. Lower concentrations did not form self--standing gels. On the other hand, all soy products for food consumption are heated to inactivate antinutritional factors and minimise off-flavours. If heat is applied to produce the gel, concentrations of over 16.7% protein are needed (Okamoto, Kawamura, & Hayashi, 1990). In this work we describe the results of applying heat, before or after high pressure treatment of soy proteins, at a lower concentration (12%), to produce gels and extend the range of products available.

Thus, dispersions of 12% protein concentration were heated (90 °C, 15 min) and pressurised (300–700 MPa) independently or in sequence (heat, followed by pressure or pressure, followed by heat), and the textural properties (TPA profile) and water-holding capacities (WHC) of the gels were determined.

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2. Materials and methods

2.1. Protein extraction

SPI, 7S and 11S were prepared as described previously (Molina et al., 2001). Basically, extraction was a mild procedure to obtain the fractions in their native state. The fractions, SPI and crude extracts of 7S and 11S globulins were freeze-dried and dispersions made in water, adjusting the pH to 6.8 with 1M NaOH.

2.2. Preparation of the gels

Aliquots of 50 ml of 12% protein dispersions (w/v) of 7S, 11S and SPI, pH 6.8, were sealed in Cryovac plastic bags (23-mm dia). One set was heat-treated (HT) (90 °C, 15 min) and then pressurised, the other set was high pressure (HP)-treated and then heated. The heat treatment was in a water bath and the pressure treatment used a 'food lab' high-pressure Rig (Stansted Fluid Power, Essex, UK). Samples were pressurised at 300, 400, 500, 600 and 700 MPa for 15 min at a pressurisation rate of about 250 MPa/min. The initial temperature of the pressure vessel was 20 °C, but due to the adiabatic effect, at the highest pressure used, 700MPa, the temperature rose to 30 °C but within two minutes it fell back to ambient temperature. After treatment, samples were cooled to room temperature and held at 5 °C overnight.

2.3. Texture profile analysis (TPA)

Textural profile analysis (TPA) (Szczesniak, 1963) was used to evaluate the following textural properties: adhesiveness, elasticity and hardness (expressed in N). Discs of gel (23-mm dia.×14-mm height) were compressed twice to 30% of their original height, with a 35 mm diameter probe in a TA.XT2 texture analyser (Stable Micro Systems, Surrey, UK).

2.4. Water-holding capacity (WHC)

Water-holding capacity (WHC) was determined following the method of Parés, Saguer, Saurina, Suñol, and Carretero (1998), using GORE-TEX® filter membrane bags (pore dia 0.45 μm) (W.L. Gore y Asociados S.L.; Barcelona, Spain). WHC was expressed as the percentage of water released/g of sample.

2.5. Statistical analyses

Each treatment was repeated on two different days in triplicate. The analyses (TPA and WHC) were made in duplicate on each sample, and the results are given as the mean ± standard deviation of the results obtained for all samples of each treatment ($n = 12$). ANOVA was used to compare the means.

3. Results and discussion

3.1. General

Dispersions of 12% protein content did not form self-standing gels, either after HP, or after HT (except for the 11S fraction), but if they were heat-treated after pressurisation, they did. This happened with the three proteins tested, soy protein isolate (SPI) and its two major constituents, the 7S and 11S fractions. However, when the same three proteins, at the same pH (6.8) and at the same concentration, were heat-treated and then subjected to pressure, only the 11S formed a gel.

3.2. Textural properties (TPA) and water-holding capacity (WHC) of soy protein gels formed by high-pressure followed by heat-treatment (HP + HT)

Fig. 1 shows the textural properties and water holding capacities for the 7S (Fig. 1, I) and 11S fractions (Fig. 1, II) and SPI (Fig. 1, III). The 7S fraction gave gels in which no adhesiveness was detected at any applied pressure. The elasticity (Fig. 1, Ib) decreased from 300 to 600 MPa, but increased at 700 MPa. Hardness (Fig. 1, Ic) decreased from 300 to 500 MPa, but no significant differences were observed between 500, 600 and 700 MPa. The water retained in the 7S gels (Fig. 1, Id) was higher at higher pressures.

The adhesiveness of the 11S gels (Fig. 1, IIa) was not greatly affected by HP (significant differences were seen only at 700 MPa). The gels tended to decrease in elasticity with increasing pressure, although significant differences were only observed between 300 and 700 MPa (Fig. 1, IIb); they became harder (Fig. 1, IIc) as pressure increased. The water lost (Fig. 1, IId) increased with increasing pressures.

The behaviour of the two main soy globulins differs, as would be expected given their different structures. In the 7S gels, HP denatures the subunits within the trimer, but the concentration is not sufficient to form a gel. After heating the pressurised dispersion, additional cross-links permit the formation of the network of high water content and, as the pressure increases, more water is entrapped. In the 11S gels, the larger more rigid molecules, after heating, permit sufficient protein-protein interactions to occur (aided by a decrease in the pH after HP, bringing it close to its pI), leading to harder gels of lower water contents. The decrease in elasticity of both kinds of gel, may be because the highly denatured proteins give rise to more irregular and coarse gels with decreased elasticity (Parés & Ledward, 2001).

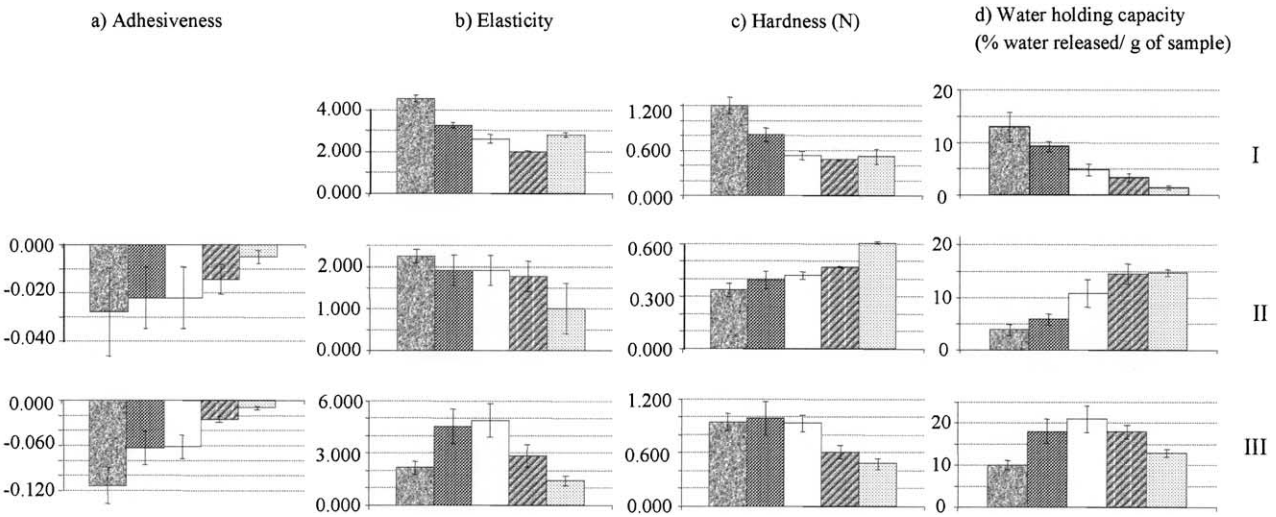

Fig. 1. Textural properties: (a) adhesiveness, (b) elasticity and (c) hardness (expressed in Newtons, N) and (d) water-holding capacity (expressed as the percentage of water released) of different soy protein gels: (I) 7S, (II) 11S and (III) soy protein isolate. Gels are made of 12% protein concentration by heating (90 °C, 15 min) and then by application of high-pressure (300–700 MPa, 15 min.). (▩ 300 MPa; ■ 400 MPa; □ 500 MPa; ▨ 600 MPa; ■ 700 MPa).

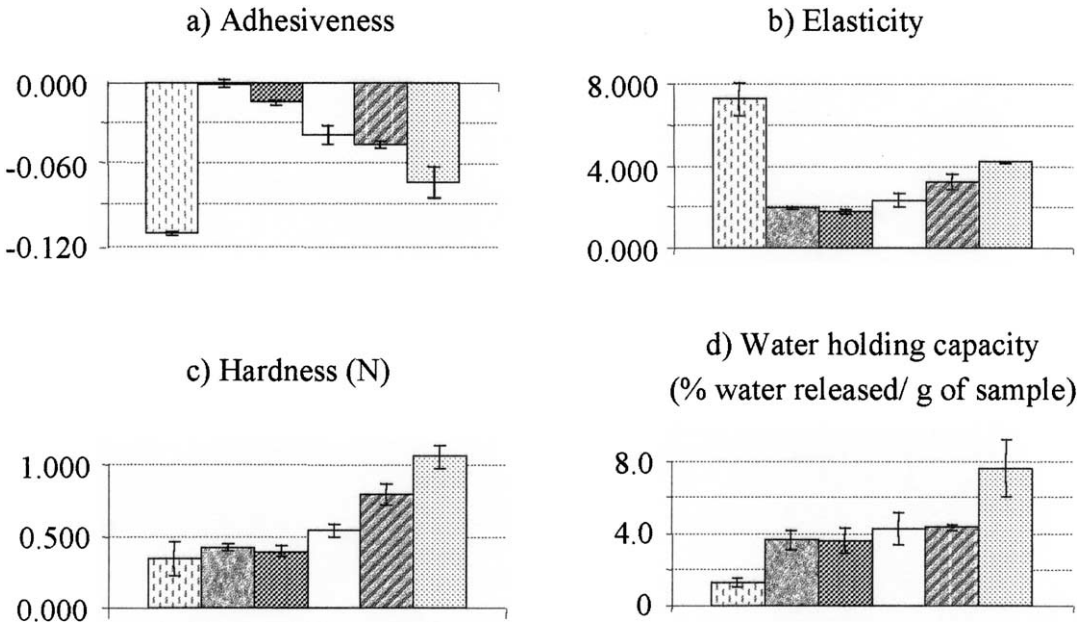

Fig. 2. Textural properties: (a) adhesiveness, (b) elasticity and (c) hardness (expressed in Newtons, N) and (d) water-holding capacity (expressed as the percentage of water released) of 12% protein concentration 11S gels. The gels were obtained by application of high-pressure (300–700 MPa, 15 min.) and then heating (90 °C, 15 min). (□ 90 °C, 15 min; ▩ 300 MPa; ■ 400 MPa; □ 500 MPa; ▨ 600 MPa; ■ 700 MPa).

The adhesiveness of SPI gels (Fig. 1, IIIa) is primarily due to the 11S globulin, but the values are higher than for the 11S gel. It is likely that the presence of the 7S or the other components in the sample enhance the adhesiveness of the SPI gels. This effect is also clearly seen in the WHC (Fig. 1d); for example, 400 MPa induces a 5% loss of water for 7S gels, 10% for the 11S gels, but greater than 20% for the SPI gels.

On pressure treatment, it is generally accepted that protein unfolds or denatures, due primarily to the rupture of electrostatic and hydrophobic linkages, since hydrogen bonds are stable under such circumstances (Galazka & Ledward, 1998). Linkages, though, may well form, involving disulphide groupings and hydrogen bonds and, on subsequent release of pressure, additional hydrophobic and electrostatic linkages may be set up. On subsequent heat treatment the hydrogen bonds initially stabilising the structure will rupture but further disulphide bonds may form and, on subsequent cooling, hydrophobic interactions will be set up well

before any hydrogen bonding network is established. These consideration will be of importance in dictating the textural quality of the 11S and 7S globulins. In the soy protein isolate, similar considerations must apply but, in addition, the possibility of interactions between proteins from the different globulins must be considered.

3.3. Textural properties (TPA) and water-holding capacity (WHC) of soy protein gels formed by heat-treatment, followed by high-pressure (HT + HP)

Only the 11S protein formed a gel under these conditions and this exhibited lower values of adhesiveness than the HT control. There was a decrease in adhesiveness with increasing pressures. The elasticity of the HT + HP 11S gels was increased with increasing pressures, but it never reached the value obtained for the heated sample. Hardness increased, with pressure becoming statistically different from the heated only control at 500 MPa and above. The 12% protein concentration 11S gels, obtained by HT prior to HP, showed poorer retention of water than the heat-only gels (Fig. 2d).

In the heat-set gels the structure will be primarily maintained by disulphide bonds and hydrophobic interactions. However, on subsequent pressure treatment, the hydrophobic linkages will be broken but the disulphide bonds will be maintained and may even increase in number. However, on release of pressure, hydrogen bonds will form prior to the chance of any hydrophobic interaction being set up and thus, not surprisingly, the texture and thus the water-holding capacity will be different. It is likely that it is the relative ratio of the hydrophobic interaction and hydrogen bonds within these gels that dictate their different properties.

These results show that the combination of heat and HP treatments offers a range of possibilities for the development of new products with novel textures. The causes of the differences remain at present to be studied.

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