Physicochemical Effects on Egg Albumen Gel Textural Properties Evaluated by Large-Deformation Studies

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ABSTRACT

The effects of the physicochemical conditions: gelation temperature, albumen concentration, pH, disulfide bond reduction and salt concentration on egg albumen gel texture are evaluated by stress and strain at fracture of gels subjected to uniaxial compression.

INTRODUCTION

The albumen of hen eggs is used singly and in mixes for food applications due to its gelation properties. The major albumen proteins involved in heat induced gelation at temperatures >65°C[1] are ovalbumin, ovotransferrin and lysozyme.

The denatured proteins aggregate and form a particulate gel[2]. The microstructure of albumen gels shows that the molecular network is composed of spherical aggregates embedded in a liquid phase[3, 4]. Both non-covalent (hydrogen and hydrophobic) interactions[2] as well as covalent disulfide bonding are found important for gelation and gel structure[4, 5]. The gel structure is closely related to the textural properties of albumen gels such as the stability against large deformations.

The aim of the present work is to study the effect of physicochemical conditions on egg albumen gel texture.

MATERIALS AND METHODS

Commercially dried egg albumen powder (Sanovo Foods A/S, Odense, Denmark) was dissolved in 50 mM buffers of CH_3COONa at pH 5 or TRIS (tris[hydroxymethyl]aminomethane) at pH 7, 9 or 11 to a final concentration (c) of 80-200 g/l. Disulfide bonds were reduced by addition of DTE to a final c of 20 mM. The effect of salt was studied in the range of 0.001-1 M NaCl and the effect of gelation temperature (T_G) by heating 30 ml samples for 20 min in nylon tubes at 70-100°C in a water bath. The control conditions were albumen c = 100 g/l, pH 9, 0.001 M NaCl, unreduced disulfide bonds and T_G 90°C.

The resulting gels were cooled at 4°C for 18 h. A cork borer and a double blade scalpel were used to cut gel cylinders of the dimensions Ø = 0.015 m and H = 0.015 m.

The gel textural properties was analysed at 20°C by uniaxial compression until fracture by a TA-HD*i* Texture Analyzer (Stable Micro Systems Ltd., Surrey, England) with a 100 kg load cell, 0.001 N detection range, 0.075 m Ø flat probe, and 0.008 m/s compression speed. Force-displacement recordings were converted into axial stress σ (Eq.1) and Hencky strain ε (Eq. 2) with σ_f as stress at fracture and ε_f as strain at fracture.

$$\sigma = \frac{F}{A}\frac{H}{H_i} \quad [\mathrm{Pa}] \tag{1}$$

$$\varepsilon = -\ln\frac{H}{H_i} \quad [-] \tag{2}$$

The equations include A = initial end area (m^2), H_i = initial height (m), H = height (m), and F = force (N).

RESULTS AND DISCUSSION

At a T_G optimum of 89°C the egg albumen gels reach the maximum σ_f and ε_f values, Fig. 1. These textural parameters may be described as functions of T_G by 2nd order polynomials. Gelation at ~100°C results in decreasing textural properties, and the gels appeared more coarse and open in structure, which may be explained by overheating[1].

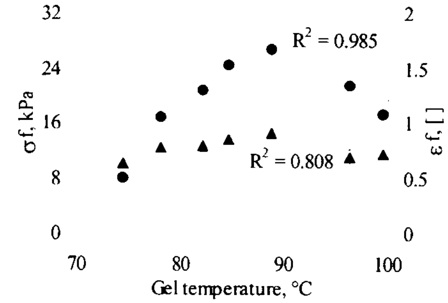


Figure 1. Effect of T_G on σ_f (•) and ε_f (▲) of egg albumen gels, n=3.

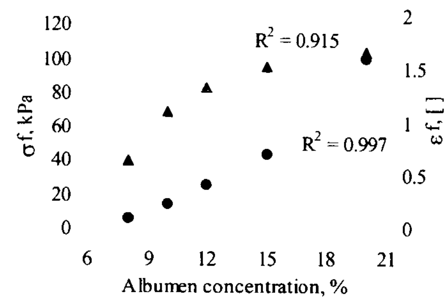


Figure 2. Effect of albumen c on σ_f (•) and ε_f (▲) of egg albumen gels, n=3.

The response of σ_f to albumen c in the range of 80-200 g/l may be described as a power law of c^2-c^3 (Fig.2). This corresponds to small-deformation elastic modulus G' behaviours known for gels of BSA, agarose, gelatine and κ-carregeenan[2]. However, the ε_f in Fig. 2. is described as a log function of c. Previously, albumen protein c is found to decrease with increasing hen age, which results in significantly lower σ_f and ε_f values[6].

In Fig. 3 the effects of pH and reduction of disulfide bonds show some interaction as the native gel possesses the highest textural properties at alkaline pH, whereas gels with 20mM DTE at pH>7 show that disulfide bond reduction results in softer gels than at pH 5. This effect of reduction is similar to the effect obtained by blocking the thiol groups with N-ethylmaleimide, which results in decreased albumen gel strength[5].

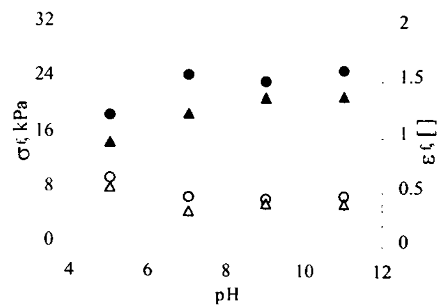


Figure 3. Effect of disulfide bond reduction with 20 mM DTE (open legends) and pH on σ_f (•) and ε_f (▲) of egg albumen gels, n=3.

The increase in textural properties in Fig. 3. of native egg albumen gels with pH correlates to other findings of the maximum protein net charge at pH 9-11, i.e. electrostatic repulsion results in a fine microstructure[3] and a coarser structure at pH 7 analysed by scanning electron microscopy. The present results confirm that the egg albumen gel textural properties are minimal at pH 5-7, where the protein net charges are minimal[7]. However, the repulsive electrostatic interactions must be balanced with attractive forces of hydrogen and hydrophobic interactions to obtain a high stability of the gel[8].

The macroscopically appearance of the egg albumen gels is very dependent on pH, as illustrated in Fig 4. Gels at acidic pH are white and turbid, turning greyish at neutral pH and finally becoming transparent at alkaline pH. Transparent egg albumen gels may also be formed by removing an insoluble coagulum of protein molecules causing the gel turbidity[9], thereby creating gels of smaller deformation at similar force in creep-recovery analysis than turbid gels.

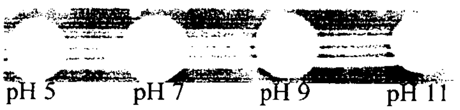
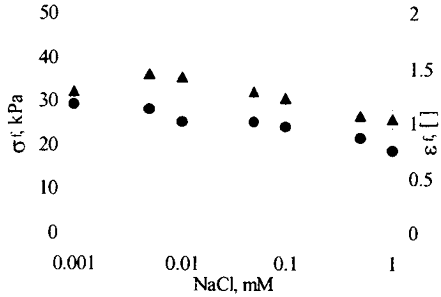


Figure 4. Transparency of egg albumen gels as function of pH, dimensions are Ø = 0.015 m and h = 0.002 m.

Figure 5. Effect of NaCl on



σ_f (•) and ε_f (▲) of egg albumen gels, n=3.

Increasing the ionic strength by addition of NaCl significantly increases the ε_f with an optimum at 5-10 mM NaCl, however without a significant effect on σ_f, see Fig. 5. Previously[10], divalent cations (Mg^{2+} and Ca^{2+}) have been found to improve the rigidity of ovalbumin gels at an optimum ionic concentration of ~5 mM as the cations provide crosslinks between proteins, however, the effect was dependent on the salt type and pH.

CONCLUSIONS

Egg albumen gel texture is affected by physicochemical conditions. High σ_f and ε_f values are obtained at T_G~90°C, albumen c= 200 g/l, alkaline pH and unreduced disulfide bonds. Also, the ε_f increases by 5 mM NaCl, which does not affect the σ_f significantly.

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