Rheological Behaviour of Urea Denatured Soybean Protein

Jun-Fen Wu[1*], Rui-Min Zhang[2], Yun Chen[2], Cui-Yu Yin[2]

[1]*Tianjin Municipal Key Laboratory of Fiber Modification & Functional Fiber*
[2]*Tianjin Polytechnic University, Tianjin, 300160 P. R. China*

***Abstract*:** This paper reports the study of rheological properties of the urea denatured soybean protein in concentrations of 10 % after 0 mol L^{-1} ～ 10 mol L^{-1} urea treatment using a programmable control revolving viscometer (Brookfield RVDV-II+/SSA-SCL27). A theoretical foundation is provided in this paper to study the exploitation and application of soybean protein. The results show that after urea denaturation the soybean protein solution was a typical pseudoplastic fluid while before it was a Bingham character fluid. The viscosity of both decreased with shear rates and increased with urea contents. The change was much obvious at the urea concentration of 4 mol L^{-1}～6 mol L^{-1}. After urea denaturation, the non-Newtonian index of soybean protein solution increased from 0.17 to 0.3 ~ 0.4 at 20 ℃, which was still fairly low. The stabitily of fluids was pretty bad. The viscosity dropped with temperature significantly.

Keywords: Soybean protein, urea, denaturation, rheological properties.

1. Introduction

Soy is a renewable plant resource, soybean protein obtained from soybean seeds through the process of extraction cannot only be developed from food products, as a biological macromolecule, it contains a variety of reactive groups that can be modified through the chemical and physical denaturations as a new environmental-friendly material, it also can be used in pharmaceutical, chemical, construction, packaging, textile and many other areas, its research and use have become an increasing focus for scientists of materials from our country and abroad [1-2].

Kinsella and other researchers pointed out urea was an effective protein denaturant.. Since urea molecule has oxygen atoms and hydrogen atoms, which could react with hydroxide radical of soybean protein molecule, and break the hydrogen bonds of the protein system, changing the molecular conformation, thus some fragments in the polypeptide chain would present to be a state of stretching, namely, denaturation[3-5].

Urea-denaturation changed the structure of protein molecules, that this in turn changed its rheological behavior. Therefore, the study of rheological behavior would not only contribute to the study of molecular structure, but also have the directive significance of its extrusion process, forming mechanical design, correct operation and optimal control. Numerous studies were carried out abroad on the rheological behavior of various modified soybean protein. [6-8], but the domestic research is few, especially the study about the rheological properties system before and after urea-denaturation hasn't been reported in the literature. In this investigation, by using a programmable control revolving viscometer we reported the rheological behavior of 10 wt% aqueous solution of soybean protein, where soybean protein was denaturated by urea concentration of 0 mol L^{-1} ~ 10 mol L^{-1}, this provided a theoretical base to protein-based polymer extrusion processing and functional modification.

2. Experiment

2.1 Materials and reagents

Urea (CH_4N_2O), analytically pure, was produced by Tianjin Kermel chemical reagents and development centers.

Soybean protein isolate(SPI) was obtained from Shandong Dongying Wonderful Plant Protein Technology Co., Ltd., its protein content was over 92%, fat content was over 0.1%, moisture was 4.5%, ash was 3.2% and crude fiber content was 0.2%.

2.2 Test equipment and experimental methods

2.2.1 Denaturation of soybean protein solution

In the flask with three necks, a 10 wt% of the isolated soybean protein was prepared by adding urea concentration of 0 mol L^{-1} ~ 10 mol L^{-1}, mechanical stirring at room temperature for 20 minutes was done, and then filtered, vacuumed to remove the impurities and air bubbles.

*Corresponding author's email: yincuiyu@tjpu.edu.cn

2.2.2 Rheology test of soybean protein solution

Rheology was achieved by using a revolving viscometer (Brookfield r RVDV-II+/SSA-SCL27), the torsion was from 0 to 7187×105N·cm, at 20 ℃.

The results were described by an empirical Ostwald-de-Waele relationship linking the shear stress σ, the shear rate $\dot{\gamma}$, the consistency index *k*, and the pseudo plastic index n:

$$\sigma = k\dot{\gamma}^n \quad (1)$$

According to Eq. (2) the apparent viscosity η_a, of the analyzed dispersions decreased with the increase in the shear rate:

$$\eta_a = k\dot{\gamma}^{n-1} \quad (2)$$

3. Results and discussion

3.1 Effect of urea denaturation on the type of the soybean protein solution fluid

Figure 1 and figure 2 show the rheological curves obtained for the soybean protein solution processed by urea concentration of 0 mol L^{-1} ~ 10 mol L^{-1}. We can find that the shear stress and shear rates curve of the non-denaturated protein aqueous solution was approximately a straight line, as shown in figure 1a, the curve did not cross the origin, it intercepted on the vertical axis, having a yield stress, so it was Bingham-behaviour fluid; in concentration of 10 wt%, non-denatured protein molecules had more opportunities of contacts cross-linking, in this condition protein formed a network structure with gaps through the combination reaction of hydrophobic bonds and disulfide intermolecular bonds, this was also called protein-water gel form of the protein solution; at the same time it looked like a paste, with the protein kept in the globular structure. Many studies came to the conclusion that the rheology yield stress extrapolated by the law of Bingham behaviour fluid equation could be used to predict the theoretical size of solid particles permanently suspended in a liquid [9]. With the increase of shear rate, apparent viscosity decreased rapidly, the flow became less stable (as shown in figure 2a), which resulted in easy breakage of the hydrophobic groups and sulfhydryl groups surface of glycinin under the action of the shear force.

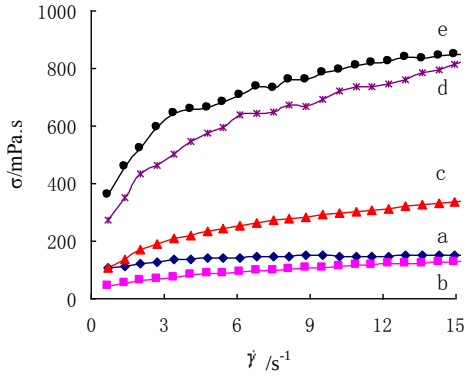

Figure1 The effect of shear rates on shear stress of urea denatured soybean protein.
a-0 mol L^{-1} Urea, b- 2 mol L^{-1} Urea, c- 4 mol L^{-1} Urea, d- 6 mol L^{-1} Urea, e-10 mol L^{-1} Urea(20 ℃ SPI 10 wt%).

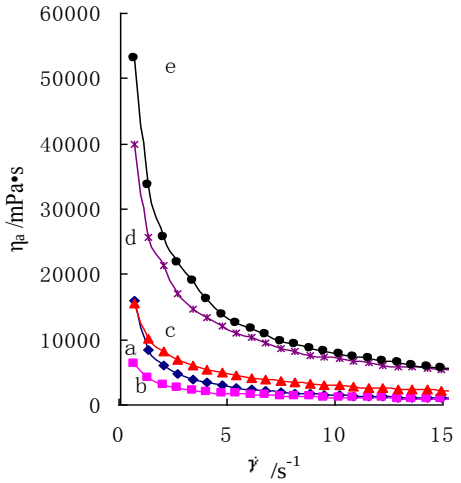

Figure 2 The effect of shear rates on apparent viscosity of urea denatured soybean protein.
a-0 mol L^{-1} Urea, b- 2 mol L^{-1} Urea, c- 4 mol L^{-1} Urea, d- 6 mol L^{-1} Urea, e-10 mol L^{-1} Urea(20 ℃ SPI 10 wt%).

3.2 Effect of urea denaturation on the viscosity of soybean protein solution

With the increase of the urea concentration, the relationship curves of shear rates and shear stress is shown in Figure 1 and Figure 2 curve b, c, d and e bent downward, this increasing trend made the fluid present more characteristics of pseudoplastic fluid which was also known as shear-thinning type behavior, apparent viscosity decreased with the shear rate increase. That is to say, with the urea concentration increasing, the hydrogen bonds in the protein had been destroyed, some of the peptide fragments extent