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Review

Soy proteins: A review on composition, aggregation and emulsification

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ABSTRACT

Composition of soybean proteins is briefly described. Gels and gelling processes of soybean proteins and other functionalities such as colloidal properties and emulsifying properties are described. The effects of temperature, pH, ionic strength, processing conditions such as high pressure, ultrasonic treatment, utilisation of enzyme, chemical modification are also described since they have been found useful to improve the processing and final product.

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1. Introduction

Soybeans have been cultivated for more than 3000 years in China and other Asian countries, such as Japan and Korea. Some trials to cultivate soybeans have been known in France and England since the 18th century, but have not been developed further. Since 1930, USDA developed the cultivation and now USA has the largest production in the world: USA, 7×10^7 t; Brazil,5.8×10^7 t; Argentine,5.8×10^7 t; China, 1.7×10^7 t; India, 1.0×10^7 t (Kitamura, 2010). Soybeans have been an important protein source in Asian countries and have been utilised in various forms such as tofu (soybean curd), *miso* (fermented soybean paste), *natto* (fermented soybeans covered with mucilagenous substance), *aburage* (fried sheet of tofu) etc (Nishinari, 1988). Recipe books on more than 100 different tofu dishes were published in the Edo era (18th century) in Japan. In addition to these traditional foods, an increased amount of soybean milk is now consumed in Japan and in China due to its expected health benefit. Fibrous texture was also introduced in tofu-like foods, making it resemble meat-like foods. Chen, Yamaguchi, and Ono (2009) recently shed new light upon the formation of *yuba*, a film-like soybean food made from heated soymilk that contains oil bodies, particulate protein, soluble protein, and carbohydrate.

The advantages of soybean proteins are: 1) provides a good balance in amino acid composition, since all the essential amino acids are contained, 2) contains physiologically beneficial components which are shown to lower the cholesterol, and reduce the risk of hyperlipidemia and cardiovascular diseases, 3) has excellent processing ability such as gelling, emulsifying ability and water- and oil- holding capacity.

Soybeans should be heated before use in order to 1) deactivate physiological harmful substances, such as trypsin inhibitor, and hemaglutinin, 2) induce the denaturation of soybean protein, 3) soften the tissue of soybean, 4) remove or reduce the raw soybean odor, 5) to sterilize (Watanabe, Ebine, & Ota, 1991).

In addition to protein and oil, physiologically beneficial effects of daizein, isoflavone in soybeans have been attracting much attention (Kitamura, 2010). Soluble soybean polysaccharides extracted from residue (*okara*) in tofu-curd production have been shown to be a good emulsifier and have been widely used in the food industry (Kitamura, 2010).

2. Main components of soybean proteins

Soybean contains approximately 40% protein and 20% oil on an average dry matter base. By removing oil at lower temperatures, soy protein isolate (SPI) is obtained, and is widely used in the food industry. Whole aqueous extractable soybean proteins can be separated into storage globulin and whey fractions by acidification to pH 4.5–4.8. The acid precipitable fraction includes the major soybean storage proteins, and which is the main material considered in the present paper. The remaining part consists of the minor globulin γ-conglycinin, and relatively large amounts of contaminating proteins, including whey proteins which make up 9–15.3% of soybean protein (Smith, Rackis, Isnardi, Cartter, & Krober, 1966). Whey proteins are composed of lipoxygenase (LOX, 102 kDa), β-amylase (61.7 kDa), lectin (33 kDa), and Kunitz trypsin inhibitors (KTI, 20 kDa) (Iwabuchi & Yamauchi, 1987; Koshiyama, Kikuchi, & Fukushima, 1981; Rackis, Wolf, & Baker, 1986). The proportion represented by these whey proteins in the acid precipitated globulins is unknown (Pearson, 1983; Sorgentini & Wagner, 1999).

SPI is a mixture of various proteins, and the main ingredients are classified into four protein categories according to their sedimentation coefficients 2S, 7S, 11S and 15S which sediment at different gravitational forces when the solution is subjected to a centrifugal field. In the present review, (7S and β-conglycinin) and (11S and glycinin) are used interchangeably, and the history of the name was described in Peng, Quass, Dayton, & Allen, (1984). Among these four proteins, 7S (β-conglycinin) and 11S (glycinin) represent more than 80%, and the ratio 7S/11S has been reported to be about 0.5–1.3 depending on varieties (Saio, Kamiya, & Watanabe, 1969).

7S globulin consists of three subunits α (ca 67 kDa), α′ (ca 71 kDa) and β (ca 50 kDa). 11S globulin is a hexamer, and is made up of five different subunits, each of which consists of an acidic subunit A (acidic pI) with a molecular mass about 35 kDa and a basic subunit B (basic pI) of molecular mass about 20 kDa, linked by a disulfide bond. AB subunits are believed to associate into two hexagonal rings forming a hollow cylinder by electrostatic and hydrogen bondings as shown schematically in Fig. 1 (Badley et al., 1975; Peng et al. 1984). Glycinin (11S) was found to dissociate into 2S, 3S or 7S forms in various pH and ionic strengths (see Fig. 2).

Amino acid compositions of β-conglycinin and glycinin have been analysed, but crystallization was difficult and the three dimensional structure is not well established (Utsumi, Matsumura, & Mori, 1997) in spite of many efforts. The crystal structure of 7S and 11S have been recently studied by X-ray diffraction (Adachi et al., 2003; Maruyama et al., 2001), and the previously proposed picture of 11S was reconfirmed and refined. They proposed that the movement of a mobile disordered region to the side of the trimer, and the dissociation of the hexamer into trimers may be susceptible to proteinases (Adachi et al. 2003). Native glycinin is known to have a compact structure stabilized by disulfide bonds and thus its emulsifying and foaming ability is lower than that of β-conglycinin which lacks disulfide bonds.

Ren, Tang, Zhang, and Guo (2009b) analyzed the aggregation mode of polypeptides in protein particles of soy milk by using ultracentrifugation, gel filtration, and sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE). They proposed the interaction mechanism of polypeptides in heat-induced protein particles of soy milk: The proteins in soy milk dissociated, rearranged, and aggregated to form protein particles when heated. The protein particles of >40 nm in diameter dissociated into protein aggregates with various molecular masses, which were dissociated into monomeric subunits of 7S and 11S protein after treatment by the mixture of 6 M urea and 0.5% SDS. The aggregates were primarily composed of the disulfide-linked basic and acidic polypeptides of 11S, besides a very small amount of α and α subunits of 7S. These aggregates and a part of monomeric subunits of 7S and 11S, as structural units, interact with each other to form protein

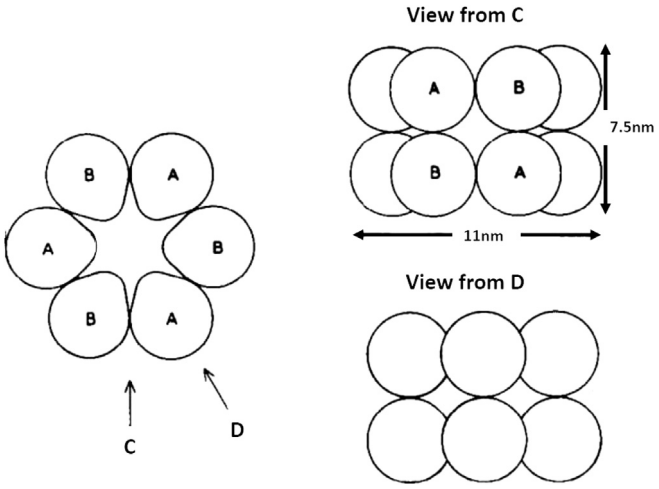

Fig. 1. Schematic diagram of glycinin molecule consisting of acidic, A, and basic, B, subunits. (Badley et al., 1975).