Current Opinion in Colloid & Interface Science 28 (2017) 120–128

Contents lists available at ScienceDirect

Current Opinion in Colloid & Interface Science

journal homepage: www.elsevier.com/locate/cocis

Soybean lipophilic proteins — Origin and functional properties as affected by interaction with storage proteins

Yasuki Matsumura [a,*], Jiraporn Sirison [b], Toya Ishi [a], Kentaro Matsumiya [a]

[a] Graduate School of Agriculture, Kyoto University, Gokasho, Uji, Kyoto 611-0011, Japan
[b] Faculty of Agro-Industry, King Mongkut's Institute of Technology Ladkrabang, Ladkrabang, Bangkok 10520, Thailand

ARTICLE INFO

Article history:
Received 6 September 2016
Received in revised form 19 April 2017
Accepted 19 April 2017
Available online 25 April 2017

Keywords:
Soy protein isolate (SPI)
Lipophilic proteins (LP)
Glycinin
β-Conglycinin
Defatted soybean meal
Solubility
Emulsifying properties
Oil body
Oleosin
Nitrogen solubility index (NSI)

ABSTRACT

Soy protein isolate (SPI) is a typical commercial product of soybean, widely used as a food ingredient. SPI has long been thought to consist of two major storage proteins, namely, glycinin and β-conglycinin. However, the finding of new protein fractions, lipophilic proteins (LP), which occupy about 30% of SPI, requires us to reconsider the composition and functional properties of SPI. In this review, we consider the origin of LP and its interaction with the two storage proteins referring to recent results on the solubility of LP, glycinin, β-conglycinin, and SPI. The importance of the interaction between LP and the storage proteins is also highlighted by comparing our results with those previously published on the emulsifying properties of LP. The major component of LP is a complex of oleosin-phospholipids, and this complex forms a strong membrane surrounding the oil body in soybean seeds. The possibility of using the oil body as an emulsifying agent is also discussed, and the importance of the interaction between LP and storage proteins is highlighted.

1. Introduction

Soybean is a major crop that is a traditional part of food culture in East and South-East Asia. Traditional soybean products, such as natto (fermented soybean), tofu (soybean curd), miso (soy paste), and shoyu (soy source) are still much consumed in this area, and this is gradually spreading throughout the world. Despite the long history of soybean production and utilization in East-Asia, the major countries producing soybean are now Brazil, USA, and Argentina (the production from these countries accounts for 81% of the total production) [1], and Asian countries, including China and Japan, import most of the domestically consumed soybean. Approximately 80% of soybean is used for extracting oil, resulting in the production of large amounts of residues. Not all of these residues are utilized effectively, and most of them are dumped as waste or are fed to animals. Since soybean and its residues contain high levels of protein following oil extraction, with relatively high amino acid scores [2], protein fractions have been isolated and used as food ingredients. For example, soy proteins are very often added to animal meat products or fish products in order to improve physical properties, since the proteins possess good water-holding properties and the ability to bind meat pieces [3]. However, the application of soy proteins and peptides has not been expanded to other types of food, such as beverages, because of their relatively low solubility and beany flavor [4•].

Interest in soybeans has gradually increased, even in countries (e.g., in the West) where soybeans have not traditionally been highly regarded, apart from for oil production. The National Cancer Institute of USA launched the “Designer Foods Project” in the 1990s and placed soybean at the top level of the “Designer Foods Pyramid” in which the cancer preventative effects of 40 foods were listed [5]. In addition to its cancer preventing effects, there has been an increasing number of reports on other health benefits of soybean and its components, which has enhanced peoples' understanding of the importance of soybean intake. Although traditional soybean products have not yet become popular, there is interest in the components of soybean, which are sometimes used as ingredients as functional foods or supplements. Fig. 1 shows the major components and food products from soybean. Isoflavone and saponin are contained in the hypocotyl. Isoflavone is known for its function as a selective estrogen receptor modulator [6]. This polyphenol is also known to reduce the risk of lung cancer [7], prostate cancer [8], and cerebral and myocardial infarctions [9]. Saponin is a surface-active compound with a bitter taste and astringency [10]. The biological functions of saponin have been noted, and include such effects as reducing serum cholesterol [11], damaging colon cancer cells [12], and radial-scavenging activities [13].

---

* Corresponding author.
E-mail address: matsumur@kais.kyoto-u.ac.jp (Y. Matsumura).

http://dx.doi.org/10.1016/j.cocis.2017.04.004
1359-0294/

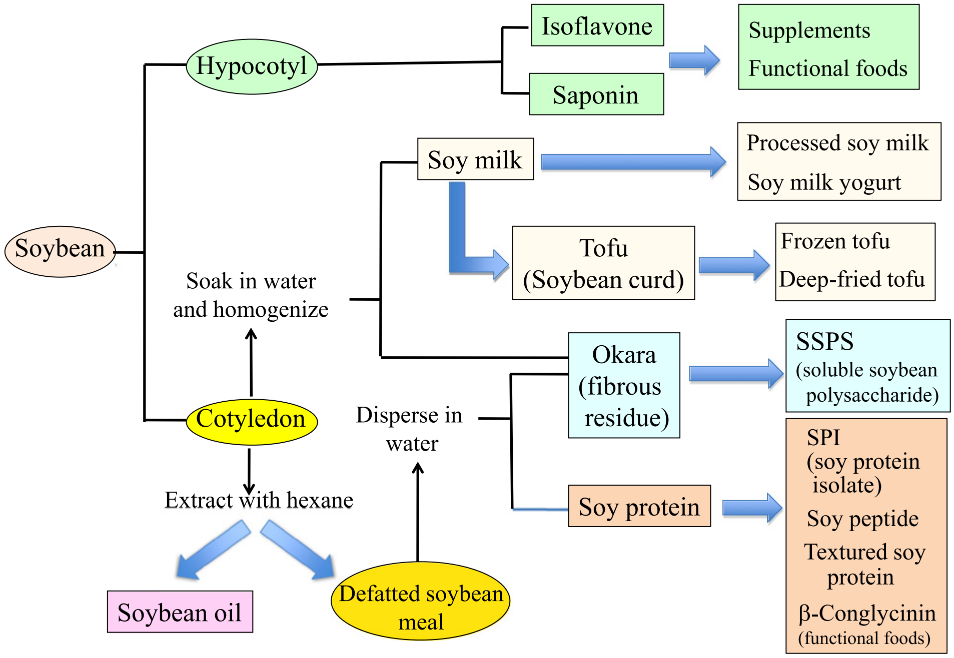

Fig. 1. Major components and food products of soybean. Black arrows indicate key processes for further separation of components. Blocked arrows indicate final products of soybean.

The cotyledon part is homogenized after soaking soybean in water to produce "soy milk", which is transformed to "tofu" in traditional processing and now through mass production. In addition to the traditional processes used in soy milk and tofu production, dried soybean is treated with hexane to produce soybean oil and "defatted soybean meal". The defatted soybean meal is added to water and homogenized, followed by centrifugation, generating a supernatant containing proteins and precipitated fibrous residues, so called "Okara". Protein recovered from the supernatant is available in the market as soy protein isolate (SPI). Okara is inevitably generated in the traditional production process of soy milk and tofu, as well as in the defatted soybean flour process, and is the final and most difficult by-product to utilize. However, soluble soybean polysaccharide (SSPS) is now prepared from Okara and this process has been commercialized [14]. SSPS has various functions relating to food processing, which include the stabilization of protein dispersions [15], emulsification [16], and anti-sticking effects for starch [17]. Biological and physiological functions [14] have also been reported, such as anti-microbial action, dietary fiber, and the prevention of lipid oxidation [18]. For proteins, SPI is known to improve lipid metabolism, that is, to decrease the serum cholesterol [19] and triacylglycerol levels [20], resulting in the reduction of body fat [21], which is approved as a health claim by the FDA.

As described above, soybean is rich in components with superior functions and has the potential to create attractive and useful food products by utilization of its separated components. Therefore, we can state that the status of soybean in 'Eastern' food culture is equivalent to that of milk in the 'Western' food culture, because milk is also rich in nutritious proteins and fat, and includes various components with biological functions and is a source of diverse food products, although lacking in fiber. However, soybean research is not as comprehensive and widespread compared to the work that has been done on milk, which has a much longer history of research and development. To explore new products in order to meet the diverse needs of consumers, there is a necessity collect additional data about each of the components of soybean. In this review, the authors focus on soy proteins. Although fundamental information on the molecular structure and physicochemical properties of the major soy protein components is already available [22•], the colloidal aspects of the components remain to be studied as thoroughly as required. As shown in Fig. 1, SPI is produced in several steps, and may suffer from damage caused by heating, drying, and homogenization, which leads to a change in its colloidal behavior. Importantly, the proteins originally separated from each other in the different seed compartments encounter each other during processing, which might affect their colloidal dispersability and thereby modify the functional properties of the protein mix, such as solubility, foaming, and emulsifying capacity. In this context, we target the behavior of lipophilic proteins (LP) originally present at the surface of oil bodies, especially their interaction with the major storage proteins, glycinin and β-conglycinin.

2. Reconsideration of the composition and function of SPI (the presence of LP)

Fig. 2(A) shows the process of SPI production from defatted soybean meal. It has long been believed that SPI consists of two storage proteins, namely, glycinin and β-conglycinin [23••,24]. Glycinin has a complex hexameric structure, in which six intermediary subunits with a molecular mass of approximately 50 kDa are associated by non-covalent bonds [25]. The intermediary subunit can be further divided into one acidic and one basic polypeptide by a reducing agent such as 2-mercaptoethanol, indicating that these two polypeptides are linked via disulfide bonds to form the intermediary subunit. Glycinin is known to have a prominent gelling ability [26•,27] and plays a dominant role in the formation of soybean curd: tofu [28]. On the other hand, β-conglycinin is a trimer glycoprotein composed of three subunits, α, α', and β, with a molecular mass of 50–70 kDa [29]. Gelling properties of β-conglycinin are inferior to those of glycinin, but β-conglycinin exhibits better emulsifying properties [30,31•]. The saccharide chain attached to the polypeptide is believed to contribute to the stability of oil droplets emulsified by β-conglycinin [32].

As described above, it has been generally accepted that glycinin and β-conglycinin account for 60–70 and 30–40% of SPI, respectively, widely varying depending on soybean cultivars and isolation procedures. The characteristics and functional properties, such as gelation and emulsification, are therefore believed to be dependent on the interactions between the individual proteins. Based on this theory, numerous studies have been carried out to investigate the structure, physicochemical properties, and functional properties of glycinin and β-conglycinin alone and mixtures of the two proteins, plus SPI. In those studies