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Physical properties of ultrasound treated soy proteins

Anet Režek Jambrak [a,*], Vesna Lelas [a], Timothy J. Mason [b], Greta Krešić [c], Marija Badanjak [a]

[a] Faculty of Food Technology and Biotechnology, University of Zagreb, Zagreb, Pierottijeva 6, Croatia
[b] Sonochemistry Centre, Faculty of Health and Life Sciences, Coventry University, Priory Street, Coventry CV1 5FB, UK
[c] Faculty of Tourism and Hospitality Management, Department of Food and Nutrition, University of Rijeka, Primorska 42, P.O. Box .97, 51410 Opatija, Croatia

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ABSTRACT

The aim of this study was to examine the effect of ultrasound treatment on physical properties of soy proteins. For this purpose, soy protein isolates (SPI) and soy protein concentrate (SPC) were treated with ultrasound 20 kHz probe and ultrasound baths (40 and 500 kHz) system. In this study ultrasound treatment affected significant changes in texture of model systems prepared with soy protein concentrates, that gelled during ultrasound treatment with probe 20 and 40 kHz bath for 15 min. Model system prepared with SPI creamed during ultrasound treatment with probe 20 kHz for 15 min. Treatment with 20 kHz probe ultrasound lead to significant changes in conductivity, increased solubility for SPC, significantly increased specific surface area that is of interest in food texture and increased values of emulsion activity index. Weight mean diameter and volume–surface average diameter decreased significantly for all samples and all treatments. Flowing behaviour of SPI and SPC model systems has been greater influenced by ultrasound treatment. There was no improvement in foaming and emulsifying properties of soy protein model systems after 500 kHz bath treatment.

1. Introduction

Application of ultrasound in food industry is attracting much attention nowadays. The basic idea of application of ultrasound and sonochemistry in food processing lies in the fact that power ultrasound can cause changes in some properties (chemical, functional, physical etc.,) that may be of interest as technological benefit. Ultrasound represents mechanical waves, i.e. a variation of pressure or density with frequencies above the human hearing threshold (ca. 18 kHz) (Mason, 1998). Ultrasound can be classified in two categories: low-intensity (high frequency-low power), and high intensity (low frequency-high power) ultrasound. The low-intensity ultrasound uses very small power levels, typically less then 1 W cm^{-2}, with the frequency range of 5–10 MHz (McClements, 1995; Mason, 1998). It is generally used in diagnostic analysis of food materials. At high intensities (the high intensity ultrasound uses much higher power levels, typically in the range of 10–1000 W cm^{-2}, with the frequency of 20–100 kHz (Mason, 1998)), ultrasound has a lethal effect on microorganisms, and so has potential as a food preservation treatment (Entezari et al., 2004). High-intensity ultrasound is used in many food applications, such as emulsifying, sterilizing, extracting, degassing, filtrating, drying, and enhancing oxidation (Leadley and Williams, 2002; Mason, 1998). High intensity ultrasound generated by periodic mechanical motions of a probe, transfers ultrasonic energy into a fluid medium and triggers extremely high alterations in pressure leading to the formation of small rapidly growing bubbles (cavities) (Mason, 1990), which expand during the negative pressure excursion, and implode violently during the positive excursion generating high temperatures, pressures and shear forces at the probe tip (Suslick, 1988). This phenomenon is known as cavitation. During implosion, very high temperatures (approximately 5500 K) and pressures (approximately 50 MPa) are reached inside these bubbles (Mason, 1990; 1998; Suslick, 1988) that is consequently causing several reactions around imploding bubble.

Soy protein isolates (SPI) and soy protein concentrate (SPC) are used in many food products. The major components of soy proteins are storage proteins known as *β-conglycinin* and *glycinin*, which account for 65–80% of total seed proteins (Nielsen, 1997). According to their rate of sedimentation during centrifugation, soy proteins can be classified as 2S, 7S, 11S, and 15S. Form of isolate used in a specific food application varies according to its characteristics such as solubility, gelation, emulsification, dispersibility, viscosity (Orthoefer, 1978; Richert and Kolar, 1987; Soy Protein Council, 1987). Soy proteins are high in the amino acids glycine and arginine, which decrease cholesterol and lower insulin levels (Burrington, 2000). Soy proteins regulate appetite/satiety, weight control, enhance immune defences, prevent cavities, decrease chances of heart disease, decrease menopausal symptoms, increase mental alertness, develop and maintain healthy bones, decrease chances of developing cancer and also the protein samples are low in fat/fat-free, cholesterol free and lactose free (Russell, 2004).

* Corresponding author. Tel.: +385 1 4605 035; fax: +385 1 4605 072.
E-mail address: arezek@pbf.hr (A.R. Jambrak).

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There are few papers that deal with whey proteins (Wang et al., 2008; Jambrak et al., 2008; Guzey et al., 2006), but none that deals with functional properties of soy proteins with ultrasound treatment used in food industry. Ultrasound was used very successfully in modifying solubility, foaming and other functional properties of whey proteins (Jambrak et al., 2008). Industrial implication could include ultrasound processing in the way of producing creams, pastes and other kind of product based on soy proteins. The fact that this procedure is less time and energy consuming ensure one of the possible usages of this technology in food industry. The aim of this study was to examine the effect of ultrasound treatment on physical properties of soy proteins. Namely, solubility, rheological, foaming and emulsifying properties, as well as specific surface area and specific diameters of particles have been measured with the aim to examine the influence of ultrasound treatment.

2. Materials and methods

2.1. Materials

Protein powders were purchased as declared by manufacturer. Protein powders were: *Soy protein isolates* (SPI, SUPRO® 595, Solae™) and *Soy protein concentrates* (SPC, ARCON® S, Solae™). According to the manufacturers, the typical composition of these powders was for soy protein concentrate: protein 66%, fat 3%, carbohydrate 21%, ash 4% and moisture 5%, and for soy protein isolate: protein 90%, fat 1%, carbohydrate 0%, ash 4%, and moisture 5%.

2.2. Sample preparation

The model systems marked as SPI and SPC were aqueous suspensions of powdered soy protein isolate and soy protein concentrate containing 10.0% (w/w) of dry matter. For this purpose appropriate amount of sample were dispersed in distilled water in volume of 100 ml by vigorous hand mixing until homogenous suspensions were obtained.

Soy protein model systems were marked as follows:

No ultrasound (A); 20 kHz probe – 15 min (B1); 20 kHz probe – 30 min (B2);

40 kHz bath – 15 min (**C1**); 40 kHz bath – 30 min (**C2**);

500 kHz bath – 15 min (**D1**); 500 kHz bath – 30 min (**D2**).

2.3. Ultrasound treatment

2.3.1. Ultrasound treatment with 20 kHz probe

Samples for ultrasound treatment with probe (20 kHz) were placed in 100 ml flat bottom conical flask. Samples were treated for 15 and 30 min with power ultrasound, high intensity and low frequency, 20 kHz probe (Model: V1A, power 600 W, Sonics & Materials Inc. Danbury CT, USA), attached to the transducer (Jencons Scientific Ltd. – Ultrasonic processor, Leighton Buzzard, United Kingdom) so that high power intensity can be obtained. Probe has a vibrating titanium tip 1.2 cm and is immersed in the liquid and the liquid is irradiated with an ultrasonic wave directly from the horn tip.

2.3.2. Ultrasound treatment with 40 kHz bath

Samples were placed in 100 ml flat bottom conical flask for ultrasound treatment with bath (40 kHz). Samples were treated for 15 and 30 min, where Erlenmeyer flask was immersed into a 40 kHz bath (Model SO375T, HF-Pk-power 300 W- overall dimensions: 370 × 175 × 250 mm; internal dimensions: 300 × 150 × 150 mm, Sonomatic, Warrington, UK). The treatment times were selected according to the significance of effect which was observed in preliminary research conducted in our Laboratory. An ultrasonic transducer was attached to the outer surface of the liquid container and the liquid was irradiated with an ultrasonic wave from the surface of the liquid container.

2.3.3. Ultrasound treatment with 500 kHz bath

Samples (100 ml) were placed in 250 ml Erlenmeyer conical flask for ultrasound treatment with high frequency bath (500 kHz). Samples were treated for 15 and 30 min with 500 kHz (512 kHz) bath (Model ES01/06/92, power 100 W, Undatim Ultrasonics S.A., Nivelles, Belgium).

2.3.4. Determination of ultrasound power and intensity

Ultrasonic power, which is considered as mechanical energy, would partly lose in the form of heat when ultrasound passes through the medium (Thompson and Doraiswamy, 1999). Since the ultrasonic irradiation of a liquid produces heat, recording the temperature as a function of time leads to the acoustic power estimation (in W) by the equation (Margulis and Malt'sev, 1969; Margulis and Margulis, 2003).

$$P = m \cdot c_p \cdot \left(\frac{dT}{dt}\right) \quad (1)$$

where: m – is the mass of the sonicated liquid (g), c_p – specific heat of medium at a constant pressure dependent on composition and volume of medium (J $(gK)^{-1}$), dT/dt – slope at the origin of the curve.

Ultrasound intensity is expressed in watts per unit area of the emitting surface, (W cm^{-2}), or in watts per unit volume of the sonicated solution (W cm^{-3}).

Ultrasonic intensity has been measured by calorimetry by thermocouple (model: HI 9063, Hanna Instruments Ltd. Leighton Buzzard LU7 4AD, UK) and expressed in W cm^{-2}.

2.4. Determination of electrical conductivity and temperature changes of soy protein model systems

Changes in electrical conductivity were determined using a calibrated PTI-8 Digital Electrical conductivity Meter (PTI-8 Digital Electrical conductivity Meter, Scientific Industries International Inc. UK) described in details elsewhere (Jambrak et al., 2008).

During ultrasound treatment temperature has been controlled by thermocouple, and the average temperature increase was expressed related to the room temperature (untreated sample-A) (model: HI 9063, Hanna Instruments Ltd., Leighton Buzzard LU7 4AD, UK).

2.5. Specific surface area and diameters determination

Specific surface area and diameters determination were carried directly after ultrasound treatment, when the particles were still dispersed in the collection fluid, by laser light scattering (Malvern Mastersizer 2000 equipped with a 100 mm lens, Malvern Instruments Limited, Malvern – Worcestershire, UK with Hydro MU sample dispersion unit).

2.6. Determination of soy proteins solubility

After ultrasound treatment soy protein were lyophilized in freeze dryer (Che ml ab Instruments Ltd., Hornchurch, Essex, UK; Model SB6CB) by freezing for a minimum of 3 h to temperature of −45 °C. Lyophilized protein powders were dispersed (1% w/w) in deionized water. The solubility of protein was determined at pH 7.0 by the method described by Smith et al. (1985). The concentration of proteins was determined using bicinchoninic acid (BCA) protein assay kit (Pierce Biotechnology, Rockford, IL, USA). Stock