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Promotion of foam properties of egg white protein by subcritical water pre-treatment and fish scales gelatin

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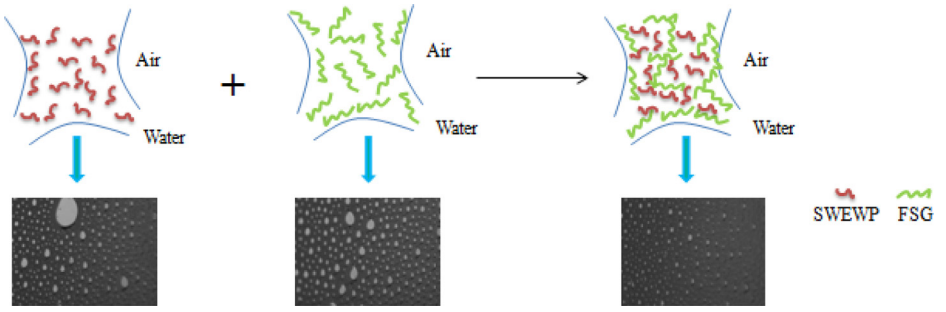
HIGHLIGHTS

- SW could improve the foam-ability, but decrease the foam-stability of EWP obviously.
- Addition of FSG could enhance the foam-ability and foam-stability of SWEWP.
- SWEWP-FSG formed stronger mechanical film and showed higher foam properties.

GRAPHICAL ABSTRACT



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ABSTRACT

The aim of this work was to study the effect of fish scales gelatin (FSG) on the foam and interfacial properties of subcritical water (SW) treated egg white protein (EWP) systems. The foam ability of the SW treated EWP (SWEWP) system was obviously better than that of untreated EWP system, although the former had poorer foam stability. The foam ability of the SWEWP system was further enhanced by the addition of FSG by reducing the surface tension. FSG seemed to build an interfacial viscoelastic network at the air – water interface with the increased surface dilational rheological behavior, causing the low drainage of liquid and inhibiting the bubbles coalescence of complex systems. Moreover, variations of surface elasticity matched the foam stability as the FSG concentration increased. This study described the effect of the biopolymer mixing ratio on the foam properties of SWEWP and FSG. This study also offered the possibility to design the production of protein powder with an outstanding capacity for foams formation and stabilization.

1. Introduction

Egg white protein (EWP) is frequently used as a foaming agent in the food industry to improve and maintain the quality (texture and volume) of aerated food, such as meringues, beverages, fermentation, cakes, whipped creams and chocolate mousses [1–3].

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However, thermodynamic instability is a basic property of foams, thereby leading to their disintegration over time and their large surface area, this instability could significantly influence the final quality of the products [1,4].

Several techniques have been employed to improve the foaming properties of EWP, such as heat [5,6], high pressure [7,8], pulsed electric fields followed by heat treatment [9], irradiation [10–12] and acylation [13]. Nevertheless, high pressure treatment has several limitations during mass production and may increase the production cost [12]. Irradiation produces unattractive odors [14], whereas chemical modifications may generate hazardous substances. Therefore, a novel method should be developed to improve the foaming properties of EWP.

Subcritical water (SW) is defined as hot water at high temperatures ranging from 100 to 374 °C under high pressure to maintain water in the liquid state. SW is an extraordinary medium or solvent for various chemical reactions and the extraction of different compounds [15]. SW is also an alternative to the traditional methods of protein hydrolysis because water is an environment – friendly reaction medium does not need acids or enzymes [16,17]. SW has been used to produce products with excellent foam stability from soy meal [18]. To the best of our knowledge, information is available on the foaming mechanism SW – treated protein.

Moreover, the synergistic effect of blending proteins and hydrocolloids generally produces a more significant improvement of the functional properties of several foods than those of proteins and hydrocolloids alone [19]. Gelatin, low in calories, is normally applied in foodstuffs to enhance protein levels, and is especially useful in stabilizing foamed food products because of its excellent surface-active and gelling properties upon cooling [20,21]. Nevertheless, concerns over bovine spongiform encephalopathy, vegetarianism and religious beliefs have driven the concerted efforts to find alternative protein sources that can provide similar functions for food systems [22]. Fish gelatin has been regarded as a promising alternative in the food industry, because of its similar properties with mammalian gelatin [23]. The foaming [24] and interfacial properties [25] of mammalian gelatin or casein glycomacropeptide (CMP) – mammalian gelatin [21] have been studied. However, the influence of fish gelatin on the foaming properties of other food proteins has been rarely reported. In our previous work (Fig S1), FSG enhanced the foaming properties of untreated EWP and SW – treated EWP systems, the latter presented better foaming capacity and foaming stability.

At present, many studies on surface dilational rheology of various surfactant at the air – water interface have been published to better understand the interfacial behavior of a film [26,27]. Therefore, the present work was performed to study the foaming and interfacial properties of EWP as influenced by pre-treatment with SW and the addition of FSG. The foaming mechanism of protein systems was explored, to develop a process that can produce protein powder product with high foaming properties, which has a potential in future expand the application of FSG and EWP through an industrially applicable process.

2. Materials and methods

2.1. Materials

Fresh eggs (Lao nan gou) were bought from local market in Nanchang, China. Liquid EWP with protein content of 10.21 ± 1.12% [28] was prepared by separating egg white and yolk manually. FSG was extracted from bighead carp scales as described in our previous study [23]. The crude protein content of lyophilized gelatin was 90.21 ± 1.23% with molecular weight of 30–200 kDa [23]. Double-distilled water (with conductivity of 0 ms/cm) was used throughout all the experiments.

2.2. Methods

2.2.1. Preparation of SW treated EWP

Fresh liquid EWP was mixed with distilled water at a ratio of 1:4 (w/w) for 0.5 h at room temperature to obtain a homogenous mixture. The SW treatment was performed at 140 °C for 1 h. After the reaction, the treated EWP solution was rapidly cooled by submerging the reactor in an ice bath for 5 min. The treated and untreated EWP solutions were collected and sprayed for further analysis.

2.2.2. Preparation of single and complex protein systems

Single system: The EWP and SW treated EWP (SWEWP) powders were dissolved with deionized water in a water bath (55 °C, 1 h, ~400 rpm) to prepare the protein solutions (10 mg mL^{-1}, pH 6.5). The gelation of gelatin was hindered because the critical concentration for gelation is 20 mg mL^{-1} [21]. To discriminate the foaming properties of gelatin from its gelling properties, the max FSG concentration was 6 mg mL^{-1}. The single system was named as EWP, SWEWP and FSG, respectively

Complex systems: The SWEWP- FSG systems were prepared by adding FSG to the prepared SWEWP solution. The concentrations of FSG were 2, 4 and 6 mg mL^{-1}, the mixtures were incubated in a water bath (40 °C, ~400 rpm) until complete dissolutions, and were named as SWEWP-FSG1, SWEWP-FSG2, and SWEWP-FSG3, respectively

2.2.3. Measurements of foam properties

The foam properties of single and complex systems were characterized based on their foam formation and stability on a Foamscan instrument (IT Concept, Teclis Co., France) according to the method of Zhang et al. [29] with some modifications. The foam ability, foam stability and drainage from the foams were determined by conductivity measurement of the foam column. The change of the bubbles was observed by a CCD camera which photographed every 5 s. The size and distribution of the bubbles were analyzed from the foam pictures with a CAS software. Briefly, the foams were generated by blowing air at a constant flow rate of 200 mL min^{-1} through a porous glass filter at the bottom of a glass tube, where 60 mL of prepared protein solution was located. The blowing of air was immediately stopped when the foam volume reached 100 mL. The blowing time "t" was defined as the foamability. The time of foam volume decays "$t_{1/2}$" was recorded as the foam volume decayed from 100 mL to 50 mL. The quantity of the liquid that remained after foaming and that was drained out from the foam was measured by a pair of electrodes at the bottom of the glass column. The volume of the liquid in the foam was measured by conductimetry with three pairs of electrodes along the glass column. Each sample was performed in triplicate at room temperature.

2.2.4. Measurements of surface tension

The surface tension of various solution systems were carried out on the interface expansion rheometer (Tracker, TECUS-IT Concept, France) using pendant drop method. The average values of surface tension were obtained in triplicate at room temperature.

2.2.5. Measurements of surface dilational viscoelasticity

The parameters of surface dilational viscoelasticity of the systems with various components were measured using the oscillating bubble rheometer (Tracker, TECUS-IT Concept, France) as reported by He et al. [30] with few modifications. The dilational viscoelasticity measurements were started after a pre-equilibrium period of 2 h. The prepared bubble was expanded and compressed sinusoidally with a small amplitude (3%) and oscillational frequency