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Foaming Properties of Soy Protein Isolates and Concentrates

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Abstract. Soy protein isolates (China 980A, China 880, ISP 974, and ADM 974) and soy protein concentrates (SPC 700 and ARCON S) were used to examine the foaming properties including foaming capacity, liquid percentage, foam maximum density and foaming stability. The effects of whipping time (10-30 min) on the foaming properties were also evaluated. The results showed that the foams soy protein made had foam capacity at 164-1503 mL, maximum density at 0.13-0.44, liquid percentage at 0-85%, and foam stability ranged 1-90%. Whipping time had various effects on foaming parameters. Longer whipping time improved foam capacity by 3-101%, but had no influence on foam stability. However, it decreased liquid percentages of most soy protein foams by 37-88%. Among them, China 980A had the lowest foam maximum density, the best foam capacity and foaming stability.

Keywords: soy protein, whipping time, foam capacity, foam stability

1. Introduction

Soy proteins are widely used in many foods as nutritional and functional ingredients [1], [2]. The US Food and Drug Administration (FDA) has approved a cholesterol-lowering health claim for soy protein indicating that the daily consumption of 25 g of soy protein (6.5 g of soy protein per serving) may lower low-density lipoprotein (LDL) cholesterol in individuals who have high cholesterol and who also adhere to a low-fat diet [3]. Soy protein products have numerous functional properties including solubility, water and fat absorption, water holding capacity, viscosity, foaming, emulsification, and gelling [4]. These functional properties determine the proper applications of soy protein isolates (SPIs) or soy protein concentrates (SPCs) in the food industry.

Many food products possessing an aerated structure are produced by whipping. The major applications of aeration in food industry include egg white and dairy-based products such as cakes, whipped topping, etc. [5]. Foams are of particular interest because they provide desirable textures to the aerated foods. Proteins play a key role both on bubble formation and stabilization [6]. The basic requirements for a protein to be a good foaming agent are the ability to (a) be rapidly adsorbed at the air-water interface during bubbling, (b) undergo rapid conformational change and rearrangement at the interface, and (c) form a cohesive viscoelastic film via intermolecular interactions. The first two criteria are essential for a good foaming ability, whereas the third is important for the stability of the foam [7], [8].

At present, about 10% of Taiwanese identify themselves as vegetarians, among which about 2% are vegan (i.e., consuming no animal or animal-based products). Most bakers in Taiwan use whey protein isolate (WPI) to replace eggs in cake formula for vegetarians [9]. Some try SPIs or SPCs as foaming agents, but the qualities of such cakes are inferior to those of the normal cakes and whey protein ones. Therefore, the objective of this research was to evaluate the foaming properties of four commercial SPIs and two commercial SPCs, and find relationships among their properties. The foaming properties include foaming capacity, liquid percentage, foam maximum density and foaming stability. The effects of whipping time (10-

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30 min) on the foaming properties were also assessed. The information from our study will be beneficial to the application of commercial soy proteins in aerated food systems.

2. Materials and Methods

2.1. Materials

Commercial SPIs including China 980A, China 880, ISP 974, and ADM 974, and SPCs including SPC 700 and ARCON S were chosen for the study. China 980A and China 880 were supplied by Harbin Hi-Tech Soybean Food Co., Ltd., Harbin, China; SPC 700 was from Daqing Celestial Sun Moon Star Protein Co., Ltd., Beijing, China; and ADM 974, ISP 974, and ARCON S were from Archer Daniels Midland Co. (Decatur, IL, USA). The crude protein contents of the SPIs and SPCs were 97.1%-99.4% and 83.5%-88.4% (db), respectively. The moisture contents of the soy protein samples were 5.4%-8.8%. Reagents were analytical grade and were purchased from Sigma Chemical Co. (St. Louis, MO, USA) or Fisher Scientific (Pittsburgh, PA, USA).

2.2. Preparation of Soy Protein Dispersions

The 5% (w/w) protein dispersions were prepared by mixing protein isolate or concentrate in distilled water. HCl or NaOH at 0.1 mol/L was used to make dispersions at pH 7.0. The dispersions were stirred with a magnetic stirrer for 60 min at ambient temperature before measuring foaming properties.

2.3. Measurement of Foaming Properties

The 5% (w/w) protein dispersion was freshly prepared. The dispersion (200 mL) was vigorously whipped for 10, 20, and 30 min in a KitchenAid K5SS mixer (KitchenAid, St. Joseph, MI, USA) set at speed 6. Both the foam volume and liquid volume after whipping were measured. Then, the foam was carefully transferred to a 120-mL glass measuring beaker. The initial and final foam volumes after 30 min were measured.

Three parameters were determined as a measure of the foaming ability. The foam capacity was determined by measuring the foam volume after whipping (Eq. 1). The liquid percentage was determined by measuring the liquid volume not participating in the foam system (Eq. 2). The foam maximum density, a measure of the liquid retention in the foam, was measured by Eq. (3) [10].

The foam stability was determined as the volume of foam that remained for 30 min at room temperature, expressed as a percentage of the initial foam volume (120 mL) (Eq. 4).

$$\text{Foam capacity} = V_{foam}(f) \quad (1)$$

$$\text{Liquid (\%)} = V_{liq}(f)/V_{liq}(i) \times 100 \quad (2)$$

$$\text{Foam maximum density} = (V_{liq}(i) - V_{liq}(f))/V_{foam}(f) \quad (3)$$

$$\text{Foam stability (\%)} = (V_{foam}(f30)/120) \times 100 \quad (4)$$

In these equations, Vfoam(f) is the final foam volume after whipping, Vliq(i) and Vliq(f) are the initial and final liquid volumes, and Vfoam(f30) is the foam volume after standing for 30 min.

2.4. Statistical Analysis

The collected data from all measurements were analyzed with analysis of variance (ANOVA) and Duncan’s multiple-range test ($p < 0.05$) using the SAS program (SAS Institute Inc., Cary, NC, USA). The Pearson product-moment correlation was also used to analyze the correlation of foaming properties.

3. Results and Discussion

3.1. Foaming Properties

The foam capacity, foam maximum density, liquid percentage, and foam stability after standing for 30 min as a function of whipping time are shown in Fig. 1. The foam capacity after whipping for 20 min was in the order of China 980A (1503 mL) > ARCON S (770 mL) ≈ China 880 (731 mL) > ISP 974 (455 mL) > ADM 974 (268 mL) > SPC 700 (164 mL). Compared to the foam capacity after whipping for 10 min, the foam capacity after whipping for 20 and 30 min increased by 7%-47% and 3%-101%, respectively. The improved foam capacity using a whipping effect was more obvious for SPIs (24%-101%) than SPCs (3%-22%).

The liquid percentage after whipping for 20 min was in the order of China 980A (0%) < ARCON S (8.3%) < China 880 (11.7%) < ISP 974 (24%) < ADM 974 (40.1%) < SPC 700 (85%). This indicates that except for China 980A, the other five samples existed as some liquid after whipping. Less liquid after whipping also resulted in a higher foam capacity. Whipping for 20-30 min decreased the liquid percentage for China 880, ISP 974, ADM 974, and ARCON S by 37%-88%, but had no effect on the other two soy protein products.

The foam maximum density after whipping for 20 min was in the order of China 980A (0.13) < SPC 700 (0.18) < ARCON S (0.23) ≈ China 880 (0.24) < ISP 974 (0.33) < ADM 974 (0.44). Most soy proteins with a higher foam capacity had a lower foam maximum density, except for SPC 700. SPC 700 with the lowest foam capacity and a lower maximum density. The whipping time seemed to have diverse effects on the maximum density for SPIs, but little effect on SPCs. It is obvious that longer whipping times increased the maximum density of ADM 974 by 80% and decreased that of China 980A by 25%.

The foam-stabilizing action of protein is largely due to the formation of an adsorbed protein layer at the interface, which stabilizes the foam against breakdown processes such as coalescence and Ostwald ripening [11]. As the standing time lengthened, the foam volume decreased. The foam stability after whipping for 20 min was in the order of China 980A ≈ ISP 974 ≈ ARCON S (90%) > SPC 700 (85%) > China 880 (80%) > > ADM 974 (1%). Most commercial soy proteins had higher foam stability, except for ADM 974. Since ADM 974 foam consisted of smaller bubbles with thicker lamella and/or plateau borders (i.e. the highest foam density), these might have induced faster coalescence and resulted in the poorest foam stability. Moreover, whipping time had no influence on the foam stability for any of these commercial products.

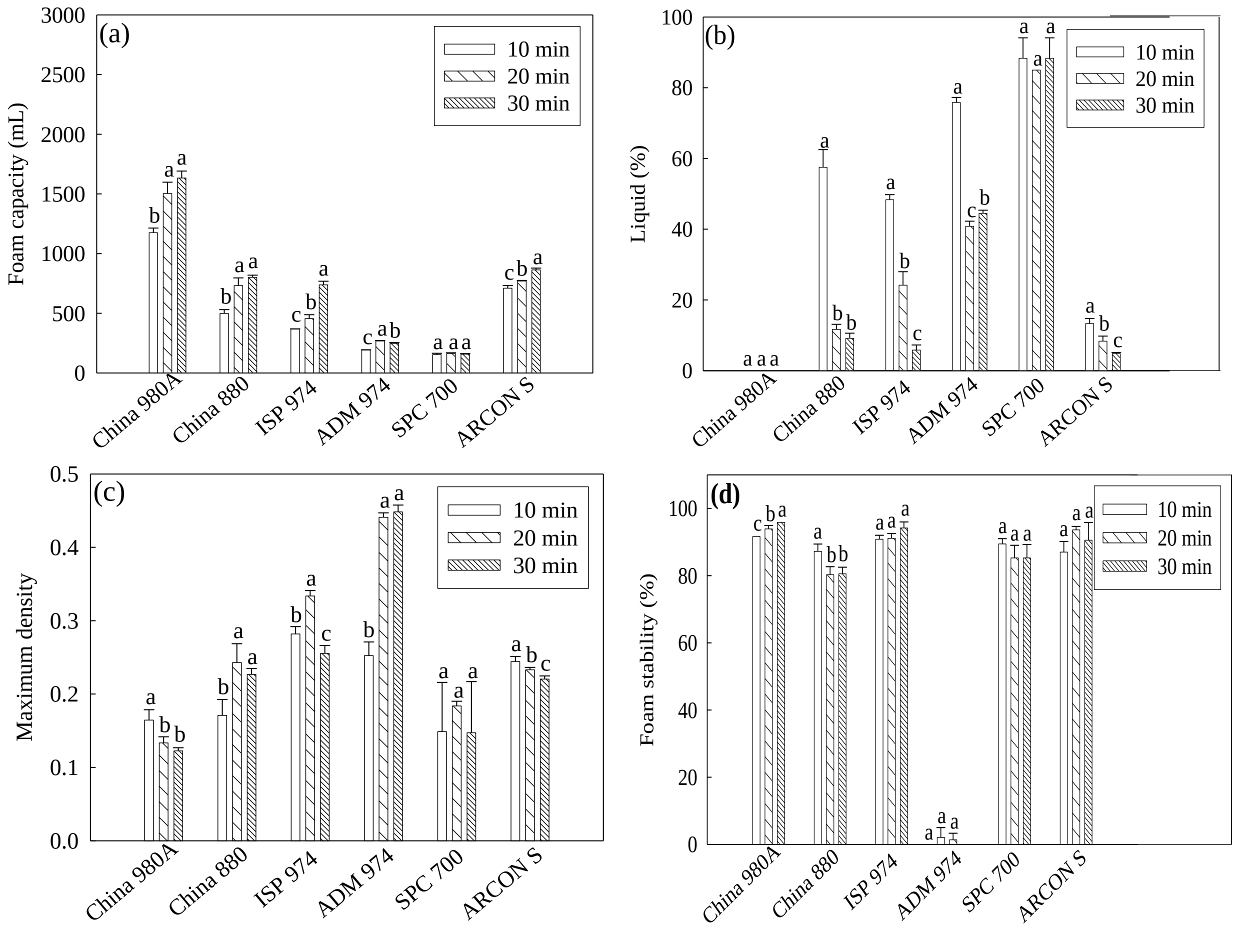

Fig. 1: Effect of whipping for 10, 20 and 30 min on foam capacity, liquid percentage, maximum density and foam stability of soy proteins. The small letters on top of the bar represents the response was significantly different ($p < 0.05$) in each soy protein.

3.2. Correlation Analysis

Correlations among foaming properties of commercial soy proteins are listed in Table 1. Among the four foam properties, the higher liquid percentage not participating in the foam system and the prepared foam with the heavier maximum density would lead to lower foam capacities. The foams with a higher maximum density would also result in an impairment of foam stability through gravitational drainage.

Table 1. Correlation coefficients (R) among foaming properties of soy proteins

Foaming properties	**Foam capacity**	**Liquid percentage**	**Maximum density**	**Foam Stability**
Foam capacity		-0.78***	**-0.60****	
Liquid percentage				
Maximum density				-0.79***
Foam Stability				

P-values below 0.05 (*), 0.01 (**) and 0.001 (***) indicate statistically significant non-zero correlations at the 95%, 99% and 99.9% confidence level, respectively.

4. Conclusions

The six commercial soy proteins had various foaming properties. Among them, China 980A had the lowest maximum density and liquid percentage, and the best foam capacity and foam stability. China 980A was suggested as the best foaming agent in aerated food system. However, SPC 700 had the most of its liquid remained after whipping and possessed a low maximum density and good foam stability, but the least foam capacity. Heat or enzyme modification can be applied to improve its foam capacity in a future study.

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