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Effect of modified whey protein concentrate on physical properties and stability of whipped cream

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ABSTRACT

In this research, Whey Protein Concentrate (WPC) conformational structure was modified using thermal treatment at different pHs and heating times. Turbidity, particle size distribution, intrinsic fluorescence properties, and soluble and insoluble aggregates content of WPC were measured. Moreover, physical properties of whipped cream containing modified WPC were studied using RSM design. Analysis showed that thermal treatment at lower pH values and longer time of WPC solutions increased viscosity (whipping cream), firmness and decreased syneresis and overrun of the whipped cream, leading to a better stability in the final products. Our result showed that in the whipped cream containing modified WPC that had been treated at higher thermal treatment time and lower pH values had desirable textural properties. In the case of whipped cream containing WPC heated for 20 min at lower pH values, better stability was observed even at low fat content as compared to the other process conditions.

1. Introduction

In recent years, whey proteins have been used in many food formulations. The use of these proteins is not only due to their unique nutritional properties, but also their functional and technological properties. The major whey proteins, β-lactoglobulin and α-lactalbumin, are about 70% of the total whey proteins responsible for many of the functional properties of whey. These proteins are globular and amphiphilic and they can be adsorbed to the water–oil and air–water interfaces to stabilize emulsions. In this case, the proteins can stabilize emulsions and foams (Nicorescu et al., 2008; Rullier, Axelos, Langevin, & Novales, 2010). Proteins stabilize foams by strongly adsorbing to the air–water interfaces, forming viscoelastic adsorbed layers and leading to a protein network with high viscosity (Rullier et al., 2010).

The functional properties of food proteins are closely related to their structures. Modifying protein structures can enhance their functionalities. Various chemical and physical methods have been used to modify the structure of whey proteins. One of the most commonly used methods for changing the structure of whey proteins is the use of heat treatment and pH (Bryant & Mcclements, 1998; Gago, Nadaud, & Krochta, 1999; Nicorescu et al., 2009; Rullier, Novales, & Axelos, 2008; Zhu & Domodaran, 1994). Thermal treatment leads to aggregation of whey proteins. These aggregates have functionalities different from those of the native ones. Different behaviors in foaming properties and stability of foam have been demonstrated (Rullier et al., 2008; Zhu & Domodaran, 1994). Generally, due to the smaller size of native protein, their ability to diffuse to the interfaces is higher than aggregates. As a result, native proteins have higher foaming properties (leads to higher overrun) than aggregates. In the case of whipped cream, milk proteins play an important role in the formation of foam, and partially crystallized fat globules stabilize the formed foam. In this research, large whey protein aggregates were produced to investigate their effect on replacing a part of fat in whipped cream.

Protein–protein interactions within aggregates can be different (electrostatic, hydrophobic, etc.), which makes the difference in the type of cohesiveness. These interactions affect mobility and the ability to spread at the interfaces are affected and their stabilization ability is increased (Rullier et al., 2008). Zhu and Domodaran (1994) demonstrated that the different ratio of monomer to aggregate could achieve the desired foam.

Whipped cream is one of the most popular dairy products used in desserts, pastries, cakes and ice creams. This product is a complex emulsion-based foam structure in which partially coalesced fat droplets stabilize air bubbles at air–water interface. Stability of this type of cream is very important and several

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studies have been performed on whipped cream stabilization. For example, Smith, Kakuda, and Goff (2000) examined whipped cream structure in the presence and absence of Aertex cream stabilizer (Smith et al., 2000). Camacho, Martinez-Navarrete, and Chiralt (2005) evaluated the effect of different ratios of locust bean gum and carrageenan on the stability of whipped cream (Camacho et al., 2005). Zhao et al., in several research showed the effect of sodium caseinate, whey proteins, hydroxypropyl methylcellulose and Xanthan gum on the stability of whipped cream (Zhao, Zhao, Li, et al., 2009; Zhao, Zhao, Wang, Wang, & Yang, 2008; Zhao, Zhao, Yang, & Cui, 2009). Whipped cream contains about 30–35% fat content. This fat is required for rheological and sensory properties of the final product. Fat replacers are components used to provide all or part of the duties of fat such as texture and sensory properties of a food product, but they have fewer calories when compared to fat. In dairy products, the use of non-dairy additives is limited. Thus, in several researches, dairy-based fat replacers have been considered (Yilsay, Yilmaz, & Bayizit, 2006). Recently, several studies have been done on reducing fat in whipped cream. For example, Padiernos, Lim, Swanson, Ross, and Clark (2009) studied the effect of modified whey proteins using high hydrostatic pressure on low-fat "whipped cream" (Padiernos et al., 2009).

In this research, WPC structure was conformationally modified using thermal treatment at various times and at different pHs. Physical properties of modified WPC such as the amount of insoluble aggregates, turbidity of dispersions, intrinsic fluorescence spectroscopy and particle size distribution were investigated. Then, the effect of modified WPC on physical properties of low fat whipped cream was examined.

2. Material and methods

2.1. Material

Whey protein concentrate powder was purchased from Milei (Milei Co., Leutkirch, Germany) and stored at 4 °C. Composition of the powder was measured using standard methods (81.17 ± 0.04% total protein; 2.34 ± 0.02% minerals; 7.12 ± 0.02% fat). Raw milk and cream were obtained from a local dairy industry (Pegah Dairy Co., Esfahan, Iran). No thermal treatment or other processes such as homogenization had been performed on milk and cream before our experiments.

2.2. Methods

2.2.1. Structural modification of whey proteins

Whey protein concentrate powder was hydrated in deionised water for 2 h at ambient temperature under gentle stirring to prepare 9% w/v whey proteins solutions and then the solution was kept at 4 °C for 24 h to complete hydration. After hydration, the pH of solutions was adjusted to 3.2, 5.2 and 7.2 by addition of 1 N HCL and 1 N NaOH solutions. WPC solutions pH was measured again after 15 min to ensure pH adjustment stability. Then thermal treatment was carried out in a water bath at 80 °C for 5, 12.5 and 20 min. After thermal treatment, the solutions were rapidly cooled down to 4 °C using cold water and stored at 4 °C. Whey protein samples after thermal treatment were freeze-dried (Dena Vacuum, Tehran, Iran) at −45 °C for 24.

2.2.2. Whipped cream production

Fat content of whipped cream samples was adjusted at 25%, 30% and 35% by addition of raw skimmed milk to 40%-fat cream. Then, 1, 2, and 3 wt% of thermal treated whey protein powder was added. Samples were then pasteurized at 85 °C for 5 min in a water bath. Samples were then homogenized at 50 °C and at 3000 RPM for 1 min using Ultra Turex homogenizer (Ultra-Turrax® T18, IKA, Germany). The treated creams were refrigerated for 24 h at 5 °C to promote fat crystallization and support the formation of foam structure during whipping. After cooling, whipping cream was ready for aeration. In the first step, a portion of whipping cream sample was whipped using a classic stand mixer model (Girmi, model SB45, Italy) at different times to find the maximum overrun. Then the rest of each sample was whipped at the optimum time found in the previous step. Then physical properties of samples were studied. All measurements were performed in triplicates.

2.2.3. Physical analysis of modified whey protein solution

2.2.3.1. Amount of insoluble aggregates. To investigate the effect of heat treatment and pH on insoluble aggregate formation in WPC solutions during the process, 15 mL of each sample was centrifuged at 10,000 *g* for 30 min at 20 °C using Hermle centrifuge (Hermle, Z36 HK, Germany). After centrifugation, the soluble fractions were removed and the dry matter content was measured. The insoluble fraction of each sample was obtained by subtraction of dry matter of soluble fraction from total dry mater of the initial sample. This process is suitable for the separation of particles larger than 1 mm. In these particles, the soluble and insoluble proteins are separated (Nicorescu et al., 2009).

2.2.3.2. Turbidity of WPC dispersions. Samples were diluted with distilled water ratio of 1:100 (0.09 mg mL^{-1}). Then absorbance of the dispersions was determined at 600 nm on a UV–Vis spectrophotometer (UV2100, Unico, Shanghai, China). This absorbance was used as an indicator of turbidity (Xu et al., 2010).

2.2.3.3. Intrinsic fluorescence spectroscopy. Samples were diluted with distilled water at ratio of 1:10 (0.9 mg mL^{-1}). The intrinsic tryptophan fluorescence intensity of modified WPC solutions was measured at ambient temperature using Shimadzu fluorescence spectrometer (Shimadzu, FDU-3, Japan). Excitation wavelength and emission wavelength were 290 and 400 nm, respectively (Xu et al., 2010).

2.2.3.4. Laser light diffraction. Particle size distribution in whey protein solutions was measured using static light scattering by Horiba laser particle analyzer (Horiba, LA-930, Japan). Before analysis, modified WPC solutions were diluted with distilled water at ratio of 1:10 (0.9 mg mL^{-1}) and the dried samples were dissolved in distilled water to yield a final concentration of 1% w/v (Nicorescu et al., 2009). For each sample, minimum three repetitions was carried out.

2.2.4. Physical analysis

2.2.4.1. Apparent viscosity of whipping cream. Apparent viscosity was measured using Brookfield rotational viscometer (Brookfield RV DVII, Massachusetts, USA). In this study, viscosity of whipping cream was measured using spindle number 6 at different RPMs (1, 2, 5, 10, 20, 40 and 50 RPM) 24 h (at 4 °C) after production. This time allows completing the crystallization of fat globules. Before analyses, samples temperatures were adjusted at 4 °C.

2.2.4.2. Measurement of overrun. Overrun is mL of air per 100 mL of cream. After the first 30 s whipping, and at 10 s intervals, the overrun was calculated by weighing a fixed volume of unwhipped cream with the same volume of whipped cream using Equation (1) (Emam-Djome, Mousavi, Ghorbani, & Madadlou, 2008):