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Utilizing whey protein isolate and polysaccharide complexes to stabilize aerated dairy gels

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ABSTRACT

Heated soluble complexes of whey protein isolate (WPI) with polysaccharides may be used to modify the properties of aerated dairy gels, which could be formulated into novel-textured high-protein desserts. The objective of this study was to determine the effect of polysaccharide charge density and concentration within a WPI-polysaccharide complex on the physical properties of aerated gels. Three polysaccharides having different degrees of charge density were chosen: low-methoxyl pectin, high-methoxyl type D pectin, and guar gum. Heated complexes were prepared by heating the mixed dispersions (8% protein, 0 to 1% polysaccharide) at pH 7. To form aerated gels, 2% glucono-δ-lactone was added to the dispersions of skim milk powder and heated complex and foam was generated by whipping with a handheld frother. The foam set into a gel as the glucono-δ-lactone acidified to a final pH of 4.5. The aerated gels were evaluated for overrun, drainage, gel strength, and viscoelastic properties. Without heated complexes, stable aerated gels could not be formed. Overrun of aerated gel decreased (up to 73%) as polysaccharide concentration increased from 0.105 to 0.315% due to increased viscosity, which limited air incorporation. A negative relationship was found between percent drainage and dispersion viscosity. However, plotting of drainage against dispersion viscosity separated by polysaccharide type revealed that drainage decreased most in samples with high-charge-density, low-methoxyl pectin followed by those with low-charge-density, high-methoxyl type D pectin. Aerated gels with guar gum (no charge) did not show improvement to stability. Rheological results showed no significant difference in gelation time among samples; therefore, stronger interactions between WPI and high-charge-density polysaccharide were likely responsible for increased stability. Stable dairy aerated gels can be created from WPI-polysaccharide complexes. High-charge-density polysaccharides, at concentrations that provide adequate viscosity, are needed to achieve stability while also maintaining dispersion overrun capabilities.
Key words: whey protein, polysaccharide, foam, aerated gel

INTRODUCTION

As a byproduct of cheese manufacturing, whey protein can be an economic and environmental burden when unused. Alternatively, its high biological value protein content and unique properties make it a promising food ingredient (Smithers, 2008). Whey protein is commonly added to dairy foods such as yogurt, ice cream, and cheese to increase total protein content, alter textures, or replace more costly ingredients (Singleton, 1973; Kinsella and Whitehead, 1989; Sodini et al., 2005). Understanding whey protein functional properties that allow it to support different food textures is crucial to expanding its use to new applications in the food industry.

There is an opportunity to expand the use of whey protein in nutritionally focused products. As consumers look for more healthful food choices, they have an interest in foods that are more filling with fewer calories. Putting whey protein into an aerated system can address consumer's desire to lower caloric intake in 2 ways. Proteins as a class are more satiating than carbohydrates or fat, and whey protein may suppress gastrointestinal hormones to further improve satiation (Hall et al., 2003; Veldhorst et al., 2009). Additionally, adding bubbles to snack foods such as chocolate or cheese puffs introduces a novelty factor (Campbell and Mougeot, 1999) and has been shown to decrease energy intake by increasing the total food volume per calorie (Osterholt et al., 2007). Potential benefits of aerated gels could include flavor encapsulation or release (or both), delivery of bioactive molecules, control of satiety, and creation of gastronomic structures (Zúñiga and

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Aguilera, 2008, 2009). Using in vitro gastric conditions, Tomczyńska-Mleko and Mleko (2014) revealed that aerated gels could be used in controlled release of minerals. Although whey protein foaming and gelation properties are well understood, little research has been done on aerated whey protein gels.

Aerating foods has a long history through several methods including fermentation, whipping, gas injection, or frying. Many aerated foods such as soufflés, ice cream, and whipped cream rely on fat molecules to support the aerated network (Campbell and Mougeot, 1999; Allen et al., 2006). In a nutritionally focused product, fat content may be undesirable so additional stabilization mechanisms are needed. The functional properties of whey protein can be exploited to prevent system destabilization such as drainage, coalescence, or disproportionation.

In a foam system, stability can come from increased dispersion viscosity, increased interfacial elasticity, or control of bubble size. The amphiphilic nature of whey protein allows it to interact with both the air and water phase of the foam interface. Native whey proteins are able to adhere quickly to the interface to increase stability during the foaming process. In aerated gels, whey protein concentrate has been shown to produce elastic aerated gel by first forming gels and then whipping to form aerated gels (Tomczyńska-Mleko, 2010; Tomczyńska-Mleko et al., 2014). Zúñiga et al. (2011) used β-LG to increase gas volume and decrease air bubble size in aerated gelatin gels. When heated, the whey proteins form aggregates or polymers, resulting in slower interfacial adsorption due to their larger size. However, they are better able to stabilize the foam by increasing the interfacial elasticity which increases resistance to deformation forces (Davis and Foegeding, 2004; Schmitt and Turgeon, 2011). Heated whey protein isolate formed at different pH and heating conditions produced aerated gels with different microstructural and textural properties (Orrego et al., 2015).

The introduction of polysaccharides (**PS**) into the foam dispersion can work in conjunction with either native whey protein or whey protein polymers to further stabilize the foam. Polysaccharides increase the dispersion viscosity that contributes to foam stability; however, their electrostatic charge also plays an important role. By interacting with oppositely charged regions on the protein, the PS can modify its function at the interface within a range of pH (Schmitt and Turgeon, 2011).

Further research on the relationship of whey protein and PS focuses on their properties when co-heated as a complex. Typically in a mixed system with 2 charged polymers such as whey proteins and PS, they will either segregate into a bilayer system, or attract and form insoluble aggregates (de Kruif and Tuinier, 2001). However, when dispersions of native whey protein and PS are heated together at a pH above the protein isoelectric point, the positive patches of the protein that are exposed during unfolding are able to interact with the negatively charged PS to form a heated soluble complex. A study of whey protein foam properties found that heating the whey protein with λ-carrageenan led to increased foamability and increased drainage time. These changes are attributed to protein-PS interactions improving elasticity and film viscosity of the foam (Wang et al., 2015).

Whey protein-PS heated soluble complexes have also been applied to acid-induced gelation. When whey proteins in dispersion are subjected to gradually lowering pH, the change in the net electric charge of the aggregates allows them to interact and form a gel network (Alting et al., 2002). The addition of PS to the system can be used to alter gel properties and microstructure (Cavallieri and Cunha, 2009). Several PS chemical properties have an effect on the gel microstructure; charge density has the largest effect, followed by molecular weight and chain stiffness (de Jong and van de Velde, 2007). Recent works have shown that acid-induced gels formed from heated whey protein-PS complexes have improved water-holding capacity (**WHC**) and gel strength compared with those from whey protein polymers with added PS (Zhang et al., 2014; Zhang and Vardhanabhuti, 2014).

We investigated whether heated whey protein-PS complexes could be applied to stabilize aerated whey protein gels by combining their properties in improving both foam and acid-induced gels. To evaluate the effect of both PS concentration and electrostatic charge on the final foam and gel properties, 2 pectins were chosen for this study. Low-methoxyl pectin (**LM12**) is manufactured with a high degree of esterification and has a high negative charge. High-methoxyl type D pectin (**HM D**) has a lower degree of esterification and a lower charge but a similar molecular weight to LM12 (~160 kDa). Guar gum was also included in this study as a control PS with a neutral charge.

The objective of this study was to investigate the effect of heated whey protein-PS complexes on low pH aerated skim milk gel. Several PS were used in the system to look at the roles charge density and PS concentration play on the stability of the aerated system during the acid-induced gelation process. A greater understanding of how heated complex addition can be used to maintain product stability while manipulating properties such as overrun and yield stress will allow the dairy industry to create successful novel-textured products.