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# Effects of spray drying conditions and the addition of surfactants on the foaming properties of a whey protein concentrate

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ABSTRACT

Whey is the main waste by-product from dairy industry and at the same time is the major source of globular proteins. These proteins are concentrated mainly through spray drying, but high temperatures affect the foaming properties of globular protein. The addition of surfactants can have a protective role against thermal effects. The aim of this work was to optimize the spray-drying condition and surfactant concentration to obtain a whey protein concentrate (WPC) to be used in hot beverages according to the industry criteria for foaming stability. Three temperatures and three surfactant concentrations were applied, and the optimization was conducted using response surface analysis. Sensory analysis was applied to the WPC obtained under optimal conditions. The results showed that the foaming stability according to industrial criteria was attained when the spray drying was performed at 210 °C with surfactant concentration of 1.50 g/100 g. This resulted in foaming capacity of 3.80 mL, moisture content of 1.82 g/100 g and apparent density of 0.181 g/cm$^3$. The sensory analysis suggested that aroma was related to dairy, cooked and whey and taste was related to sweet and dairy notes. In conclusion, temperature and surfactant concentration played an important role in the foaming capacity and stability of WPC.


## 1. Introduction

Whey protein concentrate (WPC) is the main source of globular proteins, which are used in the food industry for their emulsifying and foaming properties (Bernard, Regnault, Gendreau, Charbonneau, & Relkin, 2011). Proteins have been recognized as foaming agents in the food industry, with applications in the baking, hot beverages, confectionery and other industries, especially when the gas phase is dispersed by beating or whipping. The most common commercial foaming ingredients are egg white proteins (EWP) and milk proteins, with WPC being the most effective (Nicorescu et al., 2011). Due to their surface properties, which involve a decrease in the interfacial tension, globular proteins alone or mixed with caseins have been shown to adsorb at the droplet surface and stabilize oil-in-water emulsions (Dickinson, 2001; Sourdet, Relkin, Fosseux & Aubry, 2002). Damodaran (1997) reported that the capacity of whey to form and stabilize foams is due mainly to the relationship between monomeric and polymeric species. The monomeric form would contribute to the foaming capacity, and the polymeric forms would contribute to foam stabilization.

Several studies have been conducted to understand the effect of heat treatments on whey proteins either in solution or after incorporation into an emulsion. According to the literature, heating whey proteins in solution or in an emulsion at temperatures higher than 70 °C induces denaturation, resulting in the unfolding of the whey protein molecules and the exposure of their reactive sites (Galani & Apenten, 1999; Millqvist-Fureby, Elofsson, & Bergenståhl, 2001; Relkin, 1996), which affect on foam and emulsion stabilization (Livney, Corredig, & Dalgleish, 2003; Millqvist-Fureby et al., 2001; Relkin, Bernard, Meylheuc, Vasseur, & Courtois, 2007; Sourdet, Relkin, Fosseux, & Aubry, 2002).

According to Master (1979) and Nath and Satpatthy (1998), spray drying transforms a liquid or pasty food into a powder through the disintegration of the liquid in atomized small particles of a high-pressure spray after contact with hot air.

Compared with other drying methods, this process is noted for its applicability in heat-sensitive products such as food due to the rapid evaporation of water, which reduces the temperature of the gesticulate and keeps the drying time very short, which reduces the

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thermal damage and ensures that good quality food is produced. All of these outcomes are due to the establishment of a large exchange surface between the liquid spray and the surrounding gas (Zhartha & Palacio, 2009). However, this process is often considered as a process that can affect negatively the protein properties due to high temperatures that commonly are applied. For this reason, the effect of surfactant a protection agent during thermal process has been extensively studied. Also in other research fields, like pharmaceutical area, surfactants are suitable candidates as protectors because they are mainly present on the particle surface, avoiding thermal damage of enzymes and other proteins (Alder, Unger, & Lee, 2000; Yoshii et al., 2008). Also, surfactants have been identified as agents that can control mass transfer during spray drying depending on their characteristics. For example, insoluble surfactant monolayer can form a solid film on the particle surface which acts like diffusional barrier. In the case of soluble surfactants forming a Gibbs monolayer, such barrier effect is usually not presents (Frey & King, 1986).

Fang, Rogers, Salomulya, and Dong Chen (2012) reported that lactoglobulin provided more stability than casein (a milk protein) when both were dried at different temperatures in a spray dryer. Oldfield, Taylor, and Singh (2005) reported that spray-drying temperatures ranging from 160 to 200 °C for the inlet and 89–101 °C for the outlet did not significantly affect the denaturation of β-lactoglobulin. Písecký (2005) observed that the production of WPC powder is an attractive alternative for processing whey because the product has a high value on the market. It is used mainly as a component of baby food and for protein fortification in various food formulations. The standard product for the market contains 35, 60–80 or 90 g protein/100 g.

The effect of heat treatment on whey protein has been widely studied and it is known that temperatures of 70 °C induce protein modifications related with unfolding and exposure of active sites. These alterations increase the probability of droplet flocculation and coalescence affecting negatively the foaming properties (Bernard et al., 2011). This temperature effect can be overcome through the use of surfactants, which can interact with active sites avoiding droplets flocculation and coalescence.

The aim of this work was to study the optimal conditions of both, spray drying and surfactant concentration, to obtain a whey protein concentrate powder to be applied in hot beverages according to optimize response based on industry criteria for foaming stability.

## 2. Materials and methods

### 2.1. Materials

The whey concentrate process was performed under licensee of COLANTA S.A (Medellin, Colombia). The whey was concentrated until reaching 40°Brix, pH 6.0 and an acidity of 0.90. The surfactant Tween 60 was obtained from PROES (Productos Especiales), Medellin, Colombia.

### 2.2. WPC powder preparation

After the whey protein was concentrated, it was mixed at 200 rpm with the surfactant Tween 60 at three concentrations: 1.50, 2.25 and 3.00 g/100 g. Then, to get the powder, WPC with different surfactant concentrations was dehydrated in a laboratory-scale spray dryer (BUCHI Mini Spray Dryer B-290, Flawil, Switzerland). Samples were pulverized with a co-current airflow produced by a blower. The airflow rate was 830.8–1051.75 L $h^{-1}$, and the humidity level of the air was 18 g water (kg dry air)$^{-1}$. The samples were dried for 3 h at three temperatures: 170, 190 and 210 °C. Finally, the WPC-surfactant powder was characterized as follows.

### 2.3. WPC powder characterization

The WPC powder characterization involved the determination of the moisture content, apparent density and particle size. The moisture content was determined according to 930.15 AOAC (1990). The apparent density of the WPC-surfactant powder was measured using the pycnometer method proposed by Caparino et al. (2012). Briefly, 5.0 g of the WPC-surfactant powder was placed into a 25 mL graduated glass cylinder, which was tapped manually by lifting and dropping the cylinder under its own weight until a negligible difference in the volume measurements was observed. The mass ($m$) and the apparent (tapped) volume ($V$) of the powder were used to calculate the powder density as $m/V$ (kg/m$^3$).

The particle size distribution of the WPC-surfactant powder was obtained from the velocity of the distribution of particles suspended in a dispersion medium using a particle size analyzer Microtract S3500 (Microtract Inc, Montgomeryville, PA, USA). This equipment has a tri-laser technology with a measurement capability from 0.0024 to 2800 μm.

### 2.4. Foaming properties

#### 2.4.1. Foaming capacity and stability

To produce the foam, 4.00 g of the WPC-surfactant was placed into a 250 mL beaker with 85 mL of distilled water at 80 ± 1 °C. The resulting solution was whipped with a mechanical blender (Hamilton Beach) for 2 min at medium rate.

The foaming capacity was measured according to the method proposed by Constant (1991), with some modifications. After formation, the foam was added to a 100 mL graduated glass cylinder. The foaming capacity was obtained by measuring the height of the foam in the cylinder at 25 °C. The foam stability was evaluated according the visual method based on the modified methodology proposed by Wilson and Mundy (1984) at 80 ± 1 °C. The collapse of the foam into the graduated glass cylinder was observed, and the volume of the liquid drained over time was recorded. Then, the time required to collapse all of the bubbles present in the foam was measured and considered to represent the stability time of the foam.

### 2.5. Sensory analysis

The foam forming solution that was obtained after the optimization underwent sensory measurements by nine trained panelists. The sensory analysis was performed based on the NTC3929 (NTC, 2009), approved by ISO6564:2005, where 0 is absence, 1 is very weak, 2 is weak, 3 is moderate, 4 is strong and 5 is intense. The panelists measured the attributes related to flavor and aroma. The panelists received a sample of the foam solution under the same conditions described in the foam formation section. The sensory study was conducted in the Food Sensory Analysis Laboratory at the Universidad de Antioquia, Colombia.

### 2.6. Statistical analysis

To estimate if temperature during drying process or surfactant concentration or a combination of both affect on the moisture content, apparent density, foaming capacity and foam stability whey protein powder were studied by a multifactorial statistical analysis ($3^2$ with two replicates) performed at 95% of significance (Table 1). In specific, two factors were considered: temperature ($X_1 = T$) during spray drying and surfactant concentration ($X_2 = C$).