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The effect of pectins and xanthan gum on physicochemical properties of egg white protein foams

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ABSTRACT

The study analyzed the influence of the degree of apple pectin methylation and the concentration of xanthan gum on physicochemical properties of fresh wet egg white protein based foams. Molecular characterization of applied hydrocolloids was performed and amino acid composition of proteins was established. First, essential physicochemical properties of the starting solutions, i.e. density, surface tension and hydrophobicity, were analyzed, and electrophoretic analysis of the solutions was carried out. Density and content of the gaseous phase in the continuous phase were determined. The image analysis allowed assessment of the size distributions of gas bubbles and, subsequently, cross compliance of the population of obtained bubbles was performed using the Kolmogorov–Smirnov test. Next, using the maximum likelihood method, three distributions, i.e. Weibull, log-normal and gamma distributions, were matched to one another. The results showed that the log-normal distribution provided the best description of the bubble distribution.

1. Introduction

Foams are a group of systems that play an essential role in the food industry, being applied in dairy, meat and confectionery production (Balerin et al., 2007). Physicochemically, foams constitute a dispersed form of bubbles in the continuous aqueous, semi-aqueous or solid phases and they are classified within an extremely broad group called *soft matter* (Ptaszek, 2013). It is worth noting that the presence of gas affects both mechanical properties and condition of the continuous phase; it determines density of the phase structure, increases spreadability, and causes a more homogeneous appearance and a more uniform distribution of taste (Thakur et al., 2003; Żmudziński et al., 2014).

Thermodynamic instability is the basic property of foams resulting in the disintegration of foams over time (Indrawati et al., 2008). Consequently, surfactants are applied (Campbell and Mougeot, 1999) which ensure reduction of the surface tension as they increase the foam stability through modification of the interface (Dickinson, 2003; Patino and Pilosof, 2011). The efficacy of an emulsifier is also dependent on the rate of its absorption at the phase boundary (Indrawati et al., 2008). Due to the fact that the foam quality depends largely on the emulsifier conformation at the interface, it is essential to open the protein molecule and to activate its hydrophilic and hydrophobic groups in order to obtain stable foams. A good foaming agent should be characterized by good flexibility of its molecules (Kim et al., 2005; Żmudziński et al., 2014). Importantly, improvement of the foam stability, based on the application of a hydrocolloid as an emulsifier, involves increasing the viscosity of the continuous phase (Thakur et al., 2003; Dickinson, 2003; Patino and Pilosof, 2011). Foams are characterized by structural disorder and metastability (Sollich, 1998); in this respect they resemble glasses. The mechanism of relaxation phenomena is stimulated by motions of chains, induced by temperature fluctuations; however, they are not able to bring about complete relaxation of the structure. Due to the fact that the relaxation proceeds very slowly (*slow relaxation modes*), a *soft glassy material* (SGM) theory can be applied to a description of the rheological phenomena (Ptaszek, 2014) occurring during foam shearing (Sollich et al., 1997; Sollich, 1998). In the case of food foams stabilized with hydrocolloids, this behavior is likely to result from the presence of long polysaccharide chains and may indicate that a

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Nomenclature

d	diameter, mm
d_e	equivalent mean diameter, mm
$\langle d \rangle_{32}$	mean Sauter diameter, mm
S	surface area, m^2
V_f	volume of foam, m^3
V_l	volume of liquid, m^3
Greek letters	
ϕ	volume fraction of gas phase
ρ	density, kg m^{-3}
σ	surface tension, mN m^{-1}

viscous mechanism is responsible for the foam stabilization (Żmudziński et al., 2014).

Gas–liquid systems based on egg white protein and whey protein derivates constitute an important group among food foams. In order to avoid the aforementioned process of foam disintegration, appropriate additives such as mono-, di- and polysaccharides are applied in some cases. The use of these supplements allows the formation of expected properties of foams which will best serve their technological purpose. Molecular structure and the ability of a chain to react with a protein used as a foam-forming component are factors determining the application of a particular polysaccharide. Hence, polysaccharides having the characteristics of pectin polyanion and xanthan gum are primarily used in the process of formation of foam mechanical properties. Pectin (P) is a polysaccharide of plant origin (Ovodov, 2009; Yapo, 2011). According to the degree of esterification, commercially used pectins are divided into those with a high methoxyl (HM) degree of methyl esterification (DE $\geqslant$ 50%) and those with a low methoxyl (LM) degree of methyl esterification (DE < 50%) (Lopes da Silva and Rao, 2006). Xanthan gum (XG) is an extracellular polysaccharide produced by *Xanthomonas campestris* (Palaniraj and Jayaraman, 2011). It is an anionic polyelectrolyte and in water solutions adopts a double helix conformation (Morris, 2006). Because of its molecular structure and the presence of electrically charged functional groups, both pectin and xanthan gum are capable of creating stable systems of a complex nature (Lopes da Silva and Rao, 2006; Morris, 2006).

Supplementation with the aforementioned polysaccharides not only influences foam stabilization, but may also affect rheological properties of the system, e.g. viscoelasticity (Żmudziński et al., 2014). Viscoelasticity is closely related to the foam physicochemical properties, such as density and gas volume fraction, which may facilitate prediction of the foam technological attributes (Ptaszek, 2013). Physicochemical properties of the continuous phase as well as the method of foam preparation determine the size distribution of bubbles. The distribution allows a simple visual assessment of participation of the individual bubble fraction in the formation of the whole bubble population. Additionally, based on the distribution, it is possible to estimate both descriptive parameters and mean values for the obtained foam. Bubble size distributions in foams are predominantly obtained by means of image analysis (Germain and Aguilera, 2012). When conducting an analysis of various foams, it is often necessary to verify whether the bubbles belong to the same population, in other words, whether the bubble size distributions for different foams are identical. Moreover, it is often necessary to examine whether the given empirical distribution significantly differs from the theoretical one. Nonparametric statistical tests are useful in considerations of this type of research. Particularly, the Kolmogorov–Smirnov test is helpful in comparison of empirical distribution functions (Fisz, 1963). In the literature, the test was mainly described as useful for the comparison of two empirical distribution functions (for a large number of samples), and allowing the detection of significant differences between them.

The comparison of a larger number of empirical distributions was not possible due to difficulties connected with the determination of critical points.

Böhm and Hornik (2012) presented an accessible algorithm for determination of critical points in order to analyze a larger number of empirical distributions. On this basis, it is possible to verify a hypothesis of equality of several empirical distributions. Another frequently appearing problem is the compatibility of the obtained empirical distribution with the theoretical results. For this purpose, tests applying a χ^2 distribution are used most extensively. The most popular tests of this type include Pearson's χ^2 test; one of its many applications is the comparison of the empirical to the theoretical distribution. Knowledge of the bubble size distributions and their unambiguous characterization allow for an accurate assessment of the impact exerted by the composition of the products used in the foam, as well as by various process parameters (e.g. shape and number of mixer agitators).

The aim of this study was to demonstrate the effects of supplementation with polysaccharides (such as apple pectin with various degrees of methylation and xanthan gum) on selected physicochemical properties of foams based on egg protein. The paper also focuses on analysis of the application of various statistical tests in the description of air bubble distribution in foams.

2. Materials and methods

2.1. Materials

Materials used in this research were commercially available food egg white protein (Ovopol, Poland) and the following food additives: xanthan gum (XG) (Hortimex, Poland) and three apple pectins (indicated in the text as P1, P2 and P3) of a decreasing methylation degree (*de*) (Pektowin Jaslo, Poland).

2.1.1. Protein content

The protein content in egg white determined by the method of Kjeldahl was 83.87 ± 0.10%.

2.1.2. Amino acid analysis

The following instruments were applied for the analyses: vacuum lyophilizer Christ®Alpha1-2 LD Plus (Martin Christ, Germany), chromatographic amino acid analyzer (Ingos, Czech Republic), thermoblock AccuBlock (Labnet, USA), laboratory balance XA 110 (Radwag, Poland), water purifier system Milli-Q Gradient (Millipore, USA).

Amino acid analysis was performed according to the method of Moore and Stein (Davidson, 2003; Smith, 2003). Liquid-phase hydrolysis of powdered samples was performed in 6 M HCl containing 0.5% phenol at 110 °C for 24 h under argon atmosphere. The hydrolysates were lyophilized, dissolved in an appropriate volume of dilution buffer and filtered through a 0.45 μm syringe filter before being applied to an amino acid analyzer. Chromatographic separation of amino acids was performed using an ion-exchange