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Effect of whey and pea protein blends on the rheological and sensory properties of protein-based systems flavoured with cocoa

A. Tarrega [a,*], M.O. Ramírez-Sucre [a,b], J.F. Vélez-Ruiz [b], E. Costell [a]

[a] Physical and Sensory Properties Laboratory, Instituto de Agroquímica y Tecnología de Alimentos, CSIC, Avda. Agustín Escardino 7, 46980 Paterna (Valencia), Spain
[b] Chemical, Food and Environmental Engineering Department, Universidad de Las Américas Puebla, Sta. Catarina Mártir, Cholula, Puebla CP 72820, Mexico

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ABSTRACT

Whey and pea protein combined in different proportions (100W:0P, 75W:25P, 50W:50P, 25W:75P, 0W:100P) were used to prepare protein-based systems flavoured with cocoa and containing κ-carrageenan or κ-carrageenan/xanthan gum as thickeners. Steady and dynamic shear rheological properties of samples were measured at 10 °C and sensory differences were evaluated. Protein-based systems exhibited a shear-thinning flow behaviour that was fitted to the simplified Carreau model. Samples showed different viscoelastic properties, ranging from fluid-like to weak gel behaviour. For both types of system (with and without xanthan gum) viscosity, pseudoplasticity and elasticity rose on increasing the pea protein proportion in the blend. The sample with only whey protein obeyed the Cox–Merz rule, while in the rest of the samples complex viscosity was higher than apparent viscosity. Regarding sensory properties, the protein blend ratio mainly affected sample thickness, which rose as pea protein proportion increased. However, at the same time, the chocolate flavour and sweetness decreased and the off-flavour increased.

1. Introduction

Protein concentrates and isolates are now being used to fortify food products and to produce a variety of snacks, shakes, soups and creams for meal replacement or as protein supplementation for groups with such a dietetic requirement (elderly people, sportsmen, vegetarians or cancer patients).

Whey proteins are globular proteins, mainly β-lactoglobulin, α-lactalbumin, albumin, immunoglobulin, and several minor proteins and enzymes (Bordin et al., 2001). Whey protein concentrates and isolates are widely used in the manufacture of many food products as a texture modifier because of their ability to form gels (Kinsella and Whitehead, 1989) and to facilitate moisture retention during processing and cooking (Hayes et al., 2005). Whey protein is used to increase the nutritional value of food products in enriched-protein products or to produce meal replacement bars and beverages (Childs et al., 2007) and protein supplement drinks (Keowmaneechai and McClements, 2002). These products are mainly formulated with whey protein although the proportion of products with soy protein or with whey and soy protein is increasing on the market (Childs et al., 2007; Moreira et al., 2010). Consumers interested in products with protein from a vegetable source are not only vegetarians, but also those interested in a balanced ratio of vegetable/animal protein intake and consumers that associate specific health benefits with specific protein types (Russell et al., 2006). Although soybean protein isolates dominate the market of vegetable proteins, the protein extracted from pea (*Pisum sativum* L.) constitutes an alternative source for such applications (Sun and Arntfield, 2011a).

Pea protein contains albumins and two major globulin proteins, namely legumin (11S) and vicilin (7S). Pea protein products exhibit similar functional properties to soybean protein products (water retention, emulsifying, foaming, gelling) (Boye et al., 2010) probably due to the analogies between pea legumin and soy glycinin and between pea vicilin and β-conglycinin (O'Kane et al., 2004a,b). In recent years, the rheology of pea protein systems has been studied, mainly focusing on the gelation mechanisms and characteristics of the gels formed at different pH and ionic strength (Andrade et al., 2010; Musampa et al., 2007; Sun and Arntfield, 2011a,b). Pea protein forms weak gels, which according to some comparative research studies are weaker and less elastic than soy gels (O'Kane et al., 2005; Shand et al., 2007).

Apart from its ability to modify the texture, protein can affect the flavour of the product. Off flavours, especially bitterness has been found in products enriched with a high amount of protein. According to Carunchia Whetstine et al. (2005), whey protein isolates and concentrates can contribute with dairy flavours like sweet aromatic, cooked/milky but also with some flavours not generally associated with fresh fluid milk like cardboard, animal or cucumber. Proteins from vegetable sources, such as soy, are

* Corresponding author. Tel.: +34 96 3900022; fax: +34 96 3636301.
E-mail address: atarrega@iata.csic.es (A. Tarrega).

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considered by consumers to have an inferior flavour than whey proteins (Russell et al., 2006). Heng (2005) described the volatile and non-volatile compounds responsible of the off-flavour of pea protein products. They found that the intensity of the perceived bitterness was related with the saponin concentration in the pea protein preparation (Heng et al., 2006).

Hydrocolloids are included in the formulation of food products to control their structure, texture and stability. They are especially useful to compensate the lack of structuring components in the formulation of dietetic products like low-fat products or nutritional supplements. κ-carrageenan is a polysaccharide widely used for its gelling, thickening, stabilizing and suspending properties in dairy and non dairy products (Guiseley et al., 1980; Langendorff et al., 2000; Yanes et al., 2002). κ-Carrageenan has been shown to increase the apparent viscosity in whey protein solutions (Gustaw and Mleko, 2003) and to exhibit a synergistic effect with whey proteins (Schmidt and Smith, 1992) and with pea protein (Ipsen, 1997). The use of κ-carrageenan is suitable for the formulation of gelled desserts enriched with pea protein (Nunes et al., 2003). On the other hand, xanthan gum is a non-gelling polysaccharide, used particularly as a stabilizer, thickener and suspending agent in dressings and beverages. It has been shown effective to improve the gelling properties of whey proteins (Bryant and McClements, 2000; Bertrand and Turgeon, 2007; Sanchez et al., 1997) and pea protein (Makri et al., 2005) though Nunes et al. (2003) did not find a significant effect of xanthan gum in the texture of pea protein/starch gelled desserts.

With a view to evaluating the potential of combining whey and pea protein isolates in protein-based product formulations, this work aimed to characterise the rheological properties of cocoa flavoured protein/carrageenan and protein/κ-carrageenan/xanthan systems containing different whey/pea protein blends, and to make a preliminary comparison of their sensory properties.

2. Materials and methods

2.1. Materials

Whey protein isolate Prolacta 90 (Lactalis, Bourgbarré, France), pea protein isolate Pisane C9 (Cosucra, Warcoing, Belgium), κ-carrageenan Satiagel ADF 23 (Cargill, Barcelona, Spain), xanthan gum (Kalys, Bernin, France), commercial sucrose, granular sucralose (Splenda, Decatur, IL, USA) and cocoa powder S-5310.02 (Natra Cacao, Valencia, Spain) were used in this study.

2.2. Sample preparation

Chocolate flavoured model systems containing 10% protein were studied. Samples of 800 g were prepared varying the whey protein (W) to pea protein (P) ratio (100W:0P, 75W:25P, 50W:50P, 25W:75P, 0W:100P). All samples included fixed amounts of κ-carrageenan (0.1%), commercial sucrose (6%), sucralose (40 ppm), cocoa powder (2%), and vanilla aroma (0.008%). Two sets of samples were prepared: one without xanthan gum and other with 0.2% xanthan gum. For each sample, ingredients were weighed in a flask and mixed for 10 min using a paddle stirrer (Heidolph RZR 1, Schwabach, Germany). The flask was placed in a water bath at 90 ± 1 °C and stirred constantly (paddle stirrer, Heidolph RZR 1, Schwabach, Germany) for 10 min. After the heating process the amount of evaporated water was replaced gravimetrically. The sample was cooled down in a water bath at 25 ± 1 °C. The sample was transferred to a closed flask and stored under refrigeration (4 ± 1 °C) for 24 h. Two batches of each composition were prepared.

2.3. Rheological measurements

All rheological measurements were carried out in a controlled stress rheometer RheoStress 1 monitored by the Rheowin Pro Software v. 3.1 (Haake, Karslruhe, Germany), using a parallel-plates sensor system (6 cm diameter and 0.5 mm gap). During the measurements, temperature was kept constant at 10 ± 1 °C using a Phoenix P1 Circulator device (Thermo Haake). One measurement was performed on each batch in order to obtain two replicates for each composition:

(1) *Steady shear test*: Flow curves were obtained from stepped shear stress ramp (steady state approximation: 1 min per point). Different ranges of shear stresses, in logarithmic distribution, were used in order to obtain shear rates between 10^{-4} and 10^{3} s^{-1}, approximately. Data were fitted to the simplified Carreau model (Eq. (1)) using the Rheowin Pro software:

$$\eta_{ap} = \eta_0/(1 + (\dot{\gamma}/\dot{\gamma}_c)^2)^m \qquad (1)$$

where η0 (Pa s) is the limit viscosity at low shear rates, $\dot{\gamma}_c$ (s^{-1}) is the value of shear rate at the start of the pseudoplastic region and m is a parameter related to the slope of this latter region.

(2) *Shear stress decay test*: The flow time dependence was analysed measuring shear stress at a constant shear rate of 100 s^{-1} for 1200 s. Experimental data were fitted to the Weltmann (1943) model (Eq. (2)) using the Rheowin Pro software

$$\sigma = A - B \ln t \qquad (2)$$

where *A* represents the initial shear stress and *B*, the time coefficient of thixotropic breakdown.

(3) *Dynamic rheological test*: Viscoelastic properties were measured using oscillatory shear tests. First, to determine the linear viscoelastic region, stress sweeps were run at 1 Hz. Then the frequency sweeps were performed over the range *F* = 0.01–10 Hz and the values of the storage modulus (G'), the loss modulus (G''), the loss tangent angle ($\tan\delta$) and the complex viscosity (η^*), as a function of frequency, were calculated using the Rheowin Pro software.

According to Cox and Merz (1958) complex viscosity (η^*) values are similar to the apparent viscosity (η_{ap}) values at equal values of frequency and shear rate. The validity of this empirical relationship, called the Cox–Merz rule (Eq. (3)), was studied for each sample by comparing the experimental values η_{ap} versus $\dot{\gamma}$ and those of η^* versus ω in a double logarithmic plot:

$$\eta^* = \eta_{ap}|_{\omega=\dot{\gamma}} \qquad (3)$$

2.4. Sensory analysis

Sensory tests were carried out in the morning in a standardised test room (ISO, 2007). Samples (30 mL) were served at 10 ± 1 °C in white plastic cups coded with random three-digit numbers. Mineral water was provided for mouth-rinsing. Data acquisition was performed using Compusense Five v.4.6 software (Compusense Inc., Guelph, Canada). Ranking tests (ISO, 2006) were used to study the differences in sensory properties among samples with different blend ratio. Two set of samples were analysed in two separate sessions. The first set was evaluated by 44 assessors and included the five samples without xanthan gum and with the different protein blends (100W:0P, 75W:25P, 50W:50P, 25W:25P, 0W:100P). The second set was evaluated by 44 assessors and included the samples