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Impact of oil and inulin content on the stability and rheological properties of mayonnaise-like emulsions processed by rotor-stator homogenisation or high pressure homogenisation (HPH)

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ABSTRACT

Reduced-fat mayonnaise-like emulsions with varying oil (1.5, 20 and 52 wt%) and inulin (0, 6 and 12 wt%) contents were produced by rotor-stator (RS) homogenisation or additional high pressure homogenisation at 103 MPa (HPH). Emulsions were stored (180 days) and assessed by visual observation and by backscattering, rheological, colour and particle size distribution determinations. Results showed that long-term stable reduced-fat emulsions can be achieved by inulin addition. RS homogenisation is only able to produce stable emulsions (non-creaming and/or non-sedimenting) for the highest tested oil (52 wt%) or inulin (12 wt%) concentrations. When emulsions stability allowed the comparison among RS and HPH samples (non-creamed or sedimented samples), the latest showed increased viscosities and solid-like behaviours. These patterns are similar to the ones showed by commercial and traditional full-fat mayonnaises. The combination of oil and inulin concentrations with HPH can be used to develop stable reduced-fat mayonnaise with a range of rheological properties.

Industrial relevance: High pressure homogenisation (HPH) is an emerging technology with potential application for pasteurisation/sterilisation of liquid products. The results obtained in this study demonstrate this technology could also be suitable for the development of stable reduced-fat emulsions with a range of textures and including functional ingredients such as inulin. HPH also allows a significant reduction in the added inulin which could decrease the costs of production.

1. Introduction

Mayonnaise is one of the most consumed food emulsions. This oil-in water emulsion is mainly formed by oil as the dispersed phase and egg yolk (emulsifying agent), vinegar and optionally spices dissolved or dispersed in the continuous phase (Alimi, Mizani, Naderi, & Shokoohi, 2013). Traditional mayonnaise is a very caloric food product with high contents of oil (an average oil content of 70–80 wt%) (Depree & Savage, 2002). Due to the increasing prevalence of health diseases related to the high-calorie intake, a growing demand of low-calorie foodstuffs has emerged. Food industry is especially interested on reducing fat from products like mayonnaise, and other sauces and emulsions which could satisfy consumer demand.

In general, extensive oil content reductions dramatically affect emulsion physicochemical properties, and therefore their sensory attributes (Chung, Degner, & McClements, 2013). Apart from flavour, texture and emulsion stability are the most affected attributes in reduced-fat emulsions. The presence of smaller amounts of interacting oil droplets and differences in the physicochemical properties between the dispersed and continuous phase generally provoke emulsion separation. This destabilisation phenomenon, known as creaming, results from the oil droplets migration to the upper part of the sample due to differences in density with the continuous phase (McClements, 2005). Increasing viscosity of the continuous phase is the most common strategy to overcome creaming. Hydrocolloids with thickening and stabilising properties such as xanthan gum, guar gum or starch are used with that purpose (Juszczak, Fortuna, & Kośla, 2003; Terpstra, Jellema, Janssen, Prinz, & van der Linden, 2009). However, fat perception can hardly be completely restored. Recently, the use of inulin, a carbohydrate formed by fructose units linked by β(2 → 1) D-fructosyl-fructose bonds (Blecker

Abbreviations: ANOVA, one-way analysis of variance; BS, backscattering; C_{min}, minimum critical concentration; C_p, specific heat capacity; d (0.5), average particle size; DP, degree of polymerisation; G′, storage modulus; G″, loss modulus; HPH, high pressure homogenisation; LDL, low density lipoprotein; PSD, particle size distribution; RS, rotor-stator homogenisation; tanδ, loss tangent; η, viscosity

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et al., 2001), has increased due to the attributed properties as a thickening agent and fat substitute: in dairy desserts (Bayarri, González-Tomás, Hernando, Lluch, & Costell, 2011; Kip, Meyer, & Jellema, 2006; Torres, Tárrega, & Costell, 2010), spreads (Glibowski, Kordowska-Wiater, & Glibowska, 2011) and sauces, including mayonnaise (Alimi et al., 2013; Bortnowska & Makiewicz, 2006).

In contact with water, this ingredient forms small interacting insoluble inulin crystals resulting in a particulate gel structure with a spreadable texture (Franck, 2002). From a structural point of view, inulin particles act similarly to oil droplets in oil-in water emulsions (Bot, Erle, Vreeker, & Agterof, 2004). Additionally, inulin is considered a prebiotic ingredient, a non-digestible fibre (1.5 Kcal/g) (Roberfroid, 1999) with a bifidogenic effect (Meyer & Stasse-Wolthuis, 2009).

Another approach on the development of reduced-fat emulsions is the use of food processing technologies able to modify the emulsion structure. High pressure homogenisation (HPH) applies much higher pressures (up to 400 MPa) than the traditional homogenisers (20–50 MPa) (Dumay et al., 2013). Several works have demonstrated the effectiveness of this technology for the production of emulsions with considerable reduction in fat droplet size and consequently, an increase in the overall viscosity (Cortés-Muñoz, Chevalier-Lucia, & Dumay, 2009; Hebishy, Buffa, Guamis, & Trujillo, 2013; Qian & McClements, 2011). This can permit a substantial decrease in fat content while keeping similar texture than a high-oil-content emulsion. The high forces applied during this process can also modify the molecular structure of some ingredients leading in some cases to the enhancement of their functional properties, as occurs with whey or soy protein (Bouaouina, Desrumaux, Loisel, & Legrand, 2006; Floury, Desrumaux, Axelos, & Legrand, 2002). However, many other ingredients such as thickening carbohydrates (xanthan gum, guar gum, modified celluloses or many starches) experiment the hydrolisation of their molecules and partially lose their ability to increase the viscosity (Augustin, Sanguansri, & Htoon, 2008; Floury, Desrumaux, & Legrand, 2002; Harte & Venegas, 2010; Lagoueyte & Paquin, 1998; Martínez, Ganesan, Pilosof, & Harte, 2011; Villay, Lakkis de Filippis, Cerf, Vial, & Michaud, 2012). In the case of inulin, previous works confirmed that its gelling properties can be improved by HPH processing (Alvarez-Sabatel, Martínez De Marañón, & Arboleya, 2015; Ronkart et al., 2010).

The aim of this work was to study the microstructural impact of oil and inulin content by studying the stability, colour and rheological properties of reduced-fat mayonnaise when two different homogenisation systems, rotor-stator and further high pressure homogenisation, are used.

2. Materials and methods

2.1. Ingredients

Oil was refined winterized sunflower oil (RWSFO) from Cargill España (Spain). Long-chain inulin powder extracted from chicory (Orafti®-HP, degree of polymerisation (DP) > 23) was kindly supplied by Beneo (Belgium). Pasteurized liquid egg yolk was obtained from Calidad Pascual S.A.U. (Spain) and wine vinegar (equivalent acetic acid concentration: 10%) from Ecovinal (Spain).

2.2. Emulsions preparation

Inulin powder was pre-dispersed in ultra-pure water at room temperature under magnetic stirring at 300 rpm. The inulin dispersions were kept at 20 ± 1 °C overnight.

Before mixing, the temperature for the rest of ingredients was equilibrated to 20 ± 1 °C. Three sets of 1500 g of emulsions were prepared, as shown in Table 1, according to the oil content: 1.5 wt% oil, 20 wt% oil and 52 wt% oil. A 75 wt% oil content was used as reference of full-fat emulsions and fat reductions where made considering the European regulations for product labelling (The European Parliament and the Council of the European Union, 2006). The 52 wt% oil content corresponds to a 30% oil reduction and could be labelled as "reduced in fat", the 1.5 wt% is under the threshold provided for "low in fat" claim (no > 3 g of fat per 100 g for solids or 1,5 g of fat per 100 ml for liquids). The 20 wt% oil content was selected as a reference of an intermediate reduction. In each set, three samples with different concentrations of inulin (0, 6 and 12 wt%) were prepared. Fixed amounts of pasteurized egg yolk (4 wt%) and wine vinegar (2 wt%) were added to all the recipes. See Table 1 for recipes and abbreviations.

Emulsions were prepared using a Silverson rotor-stator homogeniser (model LR4, Silverson machines LTD, UK) equipped with a perforated head, at 6000 rpm during 5 min. Egg yolk and vinegar were firstly added to the inulin-water dispersions and sunflower oil was slowly poured for the oil in water emulsion formation. Samples emulsified by rotor-stator homogenisation (RS) were stored in iced-water until a temperature of 3.5 ± 1 °C was reached (approximately 1 h). The final pH of the samples was 3.73 ± 0.06.

2.3. High pressure homogenisation

RS emulsions were high-pressure homogenised with a Micro DeBee (Bee International Inc., USA) device, an air-operated laboratory scale high pressure homogeniser. The basic structure of this homogeniser consists of an orifice-type valve of 1.0 mm diameter. The inlet fluid outlet takes places after impacting with a cone-shaped metallic piece.

The RS emulsions inlet temperature was 3.5 ± 1 °C and the high homogenisation pressure applied was 103 MPa (from the conversion of 15 Kpsi). This pressure is higher than the ones normally applied in the food industry (below 50 MPa). In addition, in previous results the effectiveness of this pressure in the improvement of inulin gelling properties was confirmed (Alvarez-Sabatel et al., 2015). This pressure was also selected to prevent "overprocessing" effects, observed in some of our previous experiments with emulsions and higher pressures, and caused by the temperature rise and the impact on thermosensitive ingredients (e.g. egg yolk). The high pressure homogenised emulsions (HPH) were collected in 125 ml jars and immediately cooled down in an ice-water bath and stored at 4 ± 1 °C until determinations were carried out. Each emulsion was prepared at least twice to check for processing repeatability.

2.4. Emulsion stability

Emulsion stability was followed by visual observation and multiple light backscattering technique. A Turbiscan® Lab Expert (Formulaction, France) optical analyser consisting of a detection head with a pulsed near infrared light source and two detectors for light transmission and backscattering was used. The detection head moves up and down vertically along a flat-bottomed cylindrical glass cell while the backscattering (BS) and transmission detectors receive the light scattered by the sample. When the optical opacity of the samples increases, incident light cannot be transmitted and it is backscattered. The changes in the amount of backscattered light along the test tubes allowed detecting different destabilisation phenomena, such as creaming or sedimentation.

The glass cells (radius 27.5 mm, height 70 mm) used for BS (%) determination were filled with the emulsions up to 40 mm height immediately after processing and stored at 4 ± 1 °C during all the stability test. BS (%) measurements were performed at the same hour at days 7 and 180.

Sedimentation was detected by the appearance of an opaque phase with increased BS (%) at the bottom. Creaming was detected by higher BS (%) at the top part of the tubes with regard to the bottom.

2.5. Colour

The emulsions colour was instrumentally measured using an