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Production and characterization of emulsion filled gels based on inulin and extra virgin olive oil

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ABSTRACT

Emulsion filled gels (EFG) can help food producers to reduce fat content in foods. The present study evaluated the physical, chemical, sensorial and microbiological properties of emulsion filled gels based on inulin, a gel-forming prebiotic carbohydrate, and extra virgin olive oil (EVOO), well-known for its high nutritional value and phenolic antioxidant content. EFG based on inulin and EVOO were produced by means of both mechanical shearing and ultrasound homogenization. Three different ingredient ratios lead to high, medium and low oil content EFG (H, M, L respectively). H EFG had also lower inulin/water ratio. The resulting gels could be considered as a healthy alternative to spreads, rich in fiber, unsaturated fatty acids and phenolic antioxidants. Compared to mechanical shearing, ultrasound homogenization gave more consistent EFG, characterized by lower lightness respect to mechanical processing. Lower coarseness and fusion-like behavior and higher greasiness, perceived by panelists, confirmed the structural and textural differences conferred by ultrasound. Higher inulin content and inulin/water ratios determined consistency increase. The EFG with the best sensory profile (melting, less coarse texture, higher consistency, greasy mouthfeel) was submitted to consumer test and liked by over 70% consumers ($n = 80$). The volatile pattern was characterized by compounds found in fresh oils, mainly 2-hexenal. Oxidized triacylglycerols showed a slight increase in the EFG oil fraction respect to the fresh oil, particularly when using ultrasound homogenization. The residual phenolic compounds were in the range 50–76%, with losses minimized in mechanically sheared EFG. Ultrasound improved the microbiological stability of EFG.

1. Introduction

Reducing the intake of fats, especially saturated ones, is a mandatory target for consumers of developed countries (Utzschneider et al., 2013). Recent recommendations from food safety authorities invite to minimize the assumption of saturated fats (European Food Safety Authority, 2011). This reflects in a challenging task for food producers: reducing the fat content of foods, with special attention to saturated ones, without giving up the fat-related desirable textural properties of food (Abhyankar, Mulvihill, & Auty, 2014). The combined use of gelling agents and oils, in order to obtain emulsion filled gels (EFG) is considered by both researchers and food producers as an effective approach to reach this aim. Both proteins (e.g. soybean or whey protein isolate, gelatin) and polysaccharides (e.g. alginate, agar, k-carrageenan) have been used as gelling agents in studies regarding EFG. Mainly structural, rheological and sensorial properties have been studied as a function of several variables (oil volume fraction, gelling agent type and concentration, droplet size, homogeneity of fat distribution) (Chojnicka, Sala, de Kruif, & van de Velde, 2009; Kim, Renkema, & van Vliet, 2001; Mosca, Rocha, Sala, van de Velde, & Stieger, 2012; Sala, de Wijk, van de Velde, & van Aken, 2008; Sala, van Vliet, Cohen Stuart, van de Velde, & van Aken, 2009).

Inulin is recognized as food ingredient in most countries, and often labeled as dietary fiber (Franck, 2002). A wide literature proves its properties as prebiotic and functional ingredient (Kolida, Tuohy, & Gibson, 2007; Roberfroid, 1999). In fact, due to its chemical structure, inulin is neither hydrolyzed nor adsorbed in the

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small intestine but is extensively fermented by the colon bacteria (Bot, Erle, Vreeker, & Agterof, 2004). Recently Adebola, Corcoran, and Morgan (2013) found an anticytotoxic and antigenotoxic effect of inulin beyond its prebiotic role. Inulin gels are formed by a network of small crystallites of about 100 nm diameter that aggregate to form larger clusters of 1–5 μm, which trap a large amount of water in the network. The properties of this network resemble that of a network of fat crystals in oil. Because of this similarity, inulin has been identified as an interesting ingredient for structuring in low- or zero-fat food products (Barclay, Ginic-Markovic, Cooper, & Petrovsky, 2010; Bot et al., 2004). Recently, inulin has begun to be considered as gelling agent in EFG. Glibowski (2010), considered the behavior of a model EFG obtained homogenizing an inulin solution with hot canola oil, in presence of an emulsifier. Rheometry, hardness, spreadability and structure (by scanning electron microscopy) were the parameters measured. An EFG having similar composition was successively submitted to storage at 8 °C in order to evaluate its microbiological and rheological stability (Glibowski, Kordowska-Wiater, & Glibowska, 2011). Mantzouridou and coworkers evaluated an inulin-based dressing emulsion as a carrier for probiotics (Mantzouridou, Spanou, & Kiosseoglou, 2012). Alimi et al., instead, used inulin together with modified starch in order to obtain a low-fat mayonnaise, that was characterized for microstructure and viscoelastic properties (Alimi, Mizani, Naderi, & Shokoohi, 2013). No other studies seem to be available about the physic–chemical properties of inulin-based EFG.

Moreover, scarce attention has been paid until now to the quality of the oil fraction of these products. Still, potential health benefits could be achieved also by means of the correct choice of the oil to be emulsified, with regard to both the fatty acid composition and minor compounds (e.g. antioxidants, phytosterols) content. To this regard, extra virgin olive oil presents a well-known potential (Aparicio & Harwood, 2013). EFG based on inulin and extra virgin olive oil could constitute potential healthy alternatives to commercial spreadable fatty products. According to European regulations, products containing more than 3 g or 6 g/100 g of fiber can be labeled as “source of fibre” and “high fibre” (Official Journal of the European Communities, 2006).

The present study was aimed to the production of EFG based on inulin and extra virgin olive oil, by means of both mechanical shearing and ultrasound homogenization, and their textural, chemical and microbiological characterization.

2. Materials and methods

2.1. Materials

Inulin (Orafti® HPX, Beneo-Orafti SA, Oreye – Belgium), with degree of polymerization ≥5 accounting for not less than 99.5% of total, and soy lecithin were kindly supplied by Eigenmann & Veronelli SpA (Milan–Italy). Extra virgin olive oil was purchased from a local retailer. All reagents were of analytical grade, from Sigma Aldrich (Steinheim, Germany). Nile Red was supplied by Sigma–Aldrich Chemicals, MO, USA.

2.2. EFG production

Three formulations of EFG were selected after preliminary trials based on the evaluation of consistency and visual homogeneity (data not shown). The ingredients ratios in weight (extra virgin olive oil:inulin:water) were the following: 38:19:43 in high oil content EFG (H); 27:27:46 in medium oil content EFG (M); 21:29:50 in low oil content EFG (L). Lecithin, added as emulsifier, accounted for 2% on the whole in all of three EFG. The inulin/water (i/w) ratio for the three formulations was 0.44, 0.59 and 0.58 respectively.

The EFG were prepared in 200 g batches using three different homogenization technologies:

- Me: mechanical homogenization with Ultraturrax T25 (IKA, Staufen, Germany) for 10 min at 24,000 rpm (final temperature of the emulsion 30 °C);
- US: ultrasonic homogenization with Sonopuls HD 3200 (Bandelin Electronic, Berlin, Germany) with tapered tip KE 76 (6 mm diameter) for 10 min for M and L formulation and 5 min for H formulation (final temperature of the emulsion 55 °C);
- CUS: cold (ice bath) ultrasonic homogenization with the same apparatus and times of US (final temperature of the emulsion 45 °C).

The duration of homogenization corresponded to the time necessary to obtain a homogenous system. No pre-hydration was carried out. After production, the EFG were cooled down at ambient temperature and then kept at 5 °C.

As a whole, nine EFG typologies were produced and compared, as a combination of formulation and homogenization system: L-Me, M-Me, H-Me, L-US, M-US, H-US, L-CUS, M-CUS, H-CUS.

A portion of the formulations was used for sensory, color, volatile compounds and texture analyses; the remaining part was placed at −18 °C for about 4 h to facilitate water crystallization and subsequently lyophilized prior to extract the oil fraction.

Six more spreads were produced, according to a hexagon design, by varying of ±4% the proportions of inulin, olive oil and water respect to the H formulation and using ultrasound (US) homogenization, to be submitted to texture analysis, in order to better assess the relations existing between formulation and textural properties.

2.3. Fluorescence microscopy

Fluorescence microscopy was adopted to obtain information about the morphology of the emulsion formed during homogenization of EFG. To label the oil phase in the EFG, a solution of the fat specific dye Nile Red (0.15%, w/w, in 1,2-propanediol) was added to the extra virgin olive oil at a level of 20 μL/ml. The labeled oil was homogenized with inulin, water and lecithin to produce EFG. The microscopy observations were carried out using a fluorescent microscope (DMLS, Leica) with an excitation filter of 450–490 nm and a barrier filter of 515 nm. Images were acquired at 40× magnification.

2.4. Texture analysis

The texture analysis of the EFG obtained was performed by back extrusion with a 3340 Series Single Column Systems (Instron, Milan, Italy). The test consisted in the penetration of a piston of 40 mm diameter into a sampling tube of 45 mm diameter containing a sample layer of 30 mm of the sample. The penetration occurred for a stroke of 25 mm at a speed of 0.7 mm/s. The area under the load/time curve was calculated and converted in N·mm as a measure of the sample consistency (González-Martınez et al., 2002).

The analysis was carried out on two samples obtained in independent trials for all of fifteen spread formulations.

2.5. Color analysis

Color measurement was carried out by a Minolta Chromameter 2 reflectance colorimeter (Minolta, Tokyo, Japan) equipped with the