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Formulation of mayonnaises containing PUFAs by the addition of microencapsulated chia seeds, pumpkin seeds and baru oils

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ABSTRACT

There is an increasing demand for healthier foodstuff containing specific compounds such as Polyunsaturated Fatty Acids (PUFAs). In the case of PUFAs, protection against oxidative degradation is challengeable and microencapsulation emerges as an alternative. Mayonnaises containing microencapsulated oils could be a source of PUFAs. The objective was to formulate mayonnaises containing microencapsulated chia seeds oil, pumpkin seeds oil or baru oil. Micrometric particles with high encapsulation efficiency were produced and thermal analyses indicated an increased thermal stability of all oils after encapsulation. Rheology studies highlighted an increase in the mayonnaise viscosity when microparticles containing chia and pumpkin seeds oil were added. Mechanical texture was not affected by the presence of microparticles in the mayonnaise in all formulations tested. Nevertheless, samples containing microcapsules up to 5%wt were not distinguished from the base-mayonnaise in the sensorial test. Overall, enriched mayonnaises were successfully produced and encapsulation was efficient in protecting oils from oxidation.

1. Introduction

Mayonnaise is an oil-in-water emulsion stabilized by emulsifying agents present in the egg yolk and egg white (Rahmati, Tehrani, & Daneshvar, 2014). It has a low-pH and a high lipid content (Di Mattia et al., 2015) and the base components are oil, water, egg yolk and vinegar. Mayonnaise is one of the most common emulsion-based foods and effort have been made to improve it nutritional value and to reduce its caloric content (Alvarez-Sabatel, Martínez de Marañón, & Arboleya, 2018; Chivero, Gohtani, Yoshii, & Nakamura, 2016). Partial substitution of fat is also reported in the literature using microparticulated whey protein (Sun et al., 2018). In all cases, texture and rheological behavior are important factors that could affect sensory perception, physical stability and consumer satisfaction (Di Mattia et al., 2015).

The growing number of health-oriented consumers is pressuring the food industry to develop healthier foodstuff or foods that containing functional components (Miele, Di Monaco, Cavella, & Masi, 2010). The addition of oils containing polyunsaturated fatty acids (PUFAs) to staple, well-accepted foods like mayonnaise may be an alternative to improve the dietary intake of omega 3 (n-3) and omega 6 (n-6). The contents of these fatty acids are associated with nutritional aspects and consumption of monounsaturated fatty acids is recommended to reduce cardiovascular risk (Wood et al., 2004). Recent findings showed that n-6:n-3 ratio may affect the selectivity of the lipid cytotoxic activity towards normal or tumor cells (Mansara, Deshpande, Vaidya, & Kaul-Ghanekar, 2015). Also, it is reported that the imbalance of n-6 and n-3 in diet is closely related to metabolic disorders and chronic diseases (Simopoulos, 2008).

PUFAs are found in a variety of vegetable oils such as chia seeds oil, pumpkin seeds oil and baru oil. Chia (*Salvia hispanica* L.) seeds have high content of oil, proteins, antioxidants, and minerals. Its health reputation is mainly associated with a high content of unsaturated fatty

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acids (Timilsena, Vongsvivut, Adhikari, & Adhikari, 2017). Pumpkin (*Cucurbita maxima*) seeds oil is an excellent source of antioxidants like polyphenols, tocopherols, carotenoids, and PUFAs, contributing to disease prevention and health promotion (Siano et al., 2016). Pumpkin seeds have an average lipids concentration of 35–45%, and their fatty acids composition comprise oleic (23.9%) and linoleic (53.3%) acids (Jiao et al., 2014). Baru (*Dipteryx alata*) oil, obtained from barueiro chestnut, has excellent food parameters and high nutritional value and can be used in food, pharmaceuticals and cosmetics (Silva et al., 2015).

It is well known that oils rich in polyunsaturated fatty acids are susceptible to oxidation and degradation, which may decrease sensory quality. In addition, some oxidation products may be harmful to human health. The presence of oxygen, free fatty acids, mono and diacylglycerols, transition metals, pigments and thermally oxidized compounds directly influence the oxidative stability of oils (Ixtaina et al., 2011). Differential Scanning Calorimetry (DSC) is a remarkable tool to evaluate the oxidation of lipid materials due to the exothermic character of the lipid oxidation reaction. Also, DSC is a very fast analysis and requires only small amounts of sample when compared to conventional techniques like Rancimat tests. In addition, it has been demonstrated that results of Rancimat and DSC present high correlation degree (Ostrowska-Ligeza et al., 2010). DSC was used to evaluate the oxidative stability of toogga oil (Gardette & Baba, 2013), mustard (Litwinienko & Kasprzycka-Guttman, 1998), canola, corn and soy (Adhvaryu, Erhan, Liu, & Perez, 2000), chia seeds and linseed (Grampone, Irigaray, Rodríguez, & Sammán, 2013) and also blackberry and raspberry (Micić et al., 2015).

Integral isoconversional methods such as the classical method proposed by Ozawa, Flynn and Wall (OFW) (Ozawa, 1970), are able to provide the activation energy and pre exponential Arrhenius factor involved in lipid oxidation reaction. The oxidation temperature (T) is determined from the inflection point of the "heat flow versus temperature" curve obtained at a constant heating rate. The activation energy in initial instants of reaction is considered sufficient to allow the comparison between samples submitted to same experimental conditions (Litwinienko & Kasprzycka-Guttman, 1998). Also, it is assumed that the oxidation reaction follows a pseudo first-order kinetics when oxygen in excess is used. A constant conversion is assumed for every onset oxidation temperature at different heating rates (Ostrowska-Ligeza et al., 2010).

Microencapsulation is defined as a process where a compound is surrounded by a wall material forming micrometric particles. This method has shown promising results in the encapsulation and protection of lipids, vitamins, peptides, fatty acids, antioxidants, minerals, and probiotics. It is efficient to prevent evaporation, chemical degradation, migration of substances to food, preservation and stabilization (Dordevic et al., 2015). Encapsulation is a viable approach to obtain oils in a powder form, facilitating manipulation and incorporation of oils in foodstuff. It may also protect lipids from atmospheric exposure, protecting them from oxidation and degradation and avoiding the formation of undesirable flavors and odors. In the case of mayonnaise, encapsulation could be a feasible way to prevent oil oxidation (Campo et al., 2017; Raudsepp, Brüggemann, Lenferink, Otto, & Andersen, 2014).

To the best of our knowledge, no studies have been found in literature dealing with the incorporation of microencapsulated oils into mayonnaise. Microencapsulation may be an alternative to prevent the oil to be perceived sensorially and also to avoid oil oxidation which can impact negatively on physico-chemical properties, food processing and storage. Therefore, the aim of this work was to obtain mayonnaises containing microencapsulated chia seeds oil, baru oil and pumpkin seeds oil.

2. Materials and methods

2.1. Materials

Chia seeds, baru seeds and pumpkin seeds oils (Veris do Brasil Ltda) were stored at −10 °C and protected from light until use (oils did not contain any kind of added antioxidants). Distilled water was used as the continuous phase to produce the microparticles. Stearic acid (Sigma-Aldrich, analytical grade) and sodium caseinate (Sigma-Aldrich, analytical grade) were used as wall material and stabilizer, respectively. Neutral ether-alcohol solution (2:1, v:v); phenolphthalein (Dinâmica, analytical grade) solution (1%, w:v); sodium hydroxide (Dinâmica, analytical grade) solution 0.01 mol.L^{-1}; methyl tricosanoate (23:0 Me, Sigma-Aldrich, chromatographic standard); isooctane (Dinâmica, chromatographic grade); esterifying reagent, methanolic sodium hydroxide solution 0.5 mol.L^{-1} and saturated sodium chlorate solution were used in the characterization analyzes. Fatty acids methyl esters (FAME) Mix C14-C24 (Sigma-Aldrich) was used as standards in gas chromatography. Synthetic air (79% N_2, 21% O_2) and nitrogen were used in the calorimetric experiments. KBr (Sigma-Aldrich, spectroscopic standard) was used in the FTIR analyses. Commercial mayonnaise was acquired from local market.

2.2. Microparticles production

Microparticles were obtained using the procedure described by Guimarães-Inácio et al. (2018). Briefly, the aqueous phase was prepared dissolving sodium caseinate (0.275 g) in distilled water (250.0 g) that was thereafter heated up to 75 °C under gentle stirring (0.10 dispersed to continuous phase ratio, 10% solids content and 33%wt oil in the lipid phase). Separately, a jacketed borosilicate flask was connected to a thermostatic bath at 75 °C and used to firstly melt stearic acid (16.75 g). Oils (chia seeds, pumpkin seeds or baru) (8.25 g) were then added to the flask under gentle stirring. After 1 min, the aqueous phase was added to this mixture using a high efficiency disperser (Ultraturrax IKA, T25 equipped with a S25N10G probe) at 8600 rpm during 5 min. At the end of this step, the obtained dispersion was poured into an ice bath for quick quenching and solidification of the microparticles. Microparticles were freeze-dried (Liotop 101, −50 °C and 100 μmHg) and stored at −10 °C protected from light. The same procedure also was carried out to obtain microparticles without oil (blank microparticles) in order to evaluate the influence of oils on the particles properties.

2.3. Oils and microparticles characterization

Physico-chemical parameters (acidity and humidity index) of oils were determined in triplicate according to the methodologies described by the Adolfo Lutz Institute (2008). Fatty acids were determined and quantified by Gas Chromatography with Flame Ionization Detection (GC-FID, DANI model GC 1000, Milan, Italy), after *trans*-esterification procedure previously described (Barros et al., 2013), this procedure was performed in triplicate. Separation was performed in a Macherey–Nagel column (50% cyanopropyl-methyl-50% phenylmethylpolysiloxane, 30 m × 0.32 mm i.d. × 0.25 μm d_f, Düren, Germany), with the following temperature ramp: initial temperature 50 °C, held for 2 min, 30 °C.min^{-1} ramp to 125 °C, 5 °C.min^{-1} ramp to 160 °C, 20 °C.min^{-1} ramp to 180 °C, 3 °C.min^{-1} ramp to 200 °C, 20 °C.min^{-1} ramp to 220 °C and held for 15 min. Hydrogen was used as the carrier gas, using a flow rate of 4.0 mL.min^{-1} (0.61 bar), measured at 50 °C. Split injection (1:40) was carried out at 250 °C. Fatty acid identification was performed by comparing the relative retention times of FAME standards (Supelco 37 Component FAME Mix, Sigma-Aldrich, St. Louis, MO, USA) with the samples. The results were expressed in relative percentage of each fatty acid.

Differential Scanning Calorimetry (DSC) was used to evaluate the thermal properties of the microparticles at a Perkin Elmer 4000 equipment at nitrogen flowrate of 50 mL.min^{-1} and 20 °C.min^{-1} from 0 °C to 440 °C. Samples (approximately 10 mg) were put in closed aluminum sample holders. FTIR spectra were acquired using a Fourier Transform Infrared Spectroscopy (FTIR Shimadzu IR Affinity-1) working in transmittance mode at 2 cm^{-1} resolution from 4000 to