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Is it possible to produce a low-fat burger with a healthy n − 6/n − 3 PUFA ratio without affecting the technological and sensory properties?

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ABSTRACT

Burgers subjected to lipid reformulation were made by replacing 50% of the fat component by microparticles containing chia (CO) and linseed (LO) oils obtained by external ionic gelation. The microparticles presented high n − 3 PUFAs levels and were resistant to the pH and temperature conditions commonly used in burger processing. The lipid reformulation did not affect hardness and improved important technological properties, such as cooking loss and fat retention. In addition to reducing the fat content of burgers by up to 50%, the lipid reformulation led to healthier PUFA/SFA and n − 6/n − 3 ratios, and lower atherogenicity and thrombogenicity indices. The burgers with CO microparticles showed a higher lipid oxidation and a lower sensory quality compared to the other treatments. However, the substitution of pork back fat by LO microparticles did not impair the sensory quality of burgers. Therefore, the microencapsulation of n − 3 PUFA-rich oils by external ionic gelation can be considered an effective strategy to produce healthier burgers.

1. Introduction

Burger is a meat product widely consumed in several countries. However, its nutritional quality is questioned by health experts, since it contains a high amount of animal fat (up to 30%). Besides increasing the energy value, animal fat also increases the saturated fatty acid (SFA) concentration of the processed products. Thus, frequent consumption of burgers may increase the incidence of obesity, cardiovascular disease and some cancers (Kaeferstein & Clugston, 1995). In addition, the n − 6/n − 3 ratio is higher in animal fat due to the higher content of n − 6 PUFAs rather than n − 3 PUFAs (Valencak, Gamsjäger, Ohrnberger, Culbert, & Ruf, 2015). This imbalance of PUFA levels may lead to the onset of several chronic diseases (Beecher, 1999).

Lipid reformulation by replacing a portion of the animal fat by fat substitutes containing n − 3 PUFA-rich oils may provide healthier characteristics to the food product, thus meeting the demands of health-conscious consumers. Due to their low SFA content and healthy n − 6/n − 3 ratio (Ayerza & Coates, 2005; Rubilar et al., 2012), chia and linseed oils may be an interesting alternative to improve the nutritional quality of burgers. However, the use of liquid oils rich in n − 3 PUFA in meat products may impair important technological and sensory attributes (Valencia, O'Grady, Ansorena, Astiasaran, & Kerry, 2008), as well as reducing the shelf life of the product due to increased lipid oxidation (Juárez et al., 2012; Triki, Herrero, Rodríguez-Salas, Jimenez-Colmenero, & Ruiz-Capillas, 2013).

Microencapsulation is an effective technique to increase oxidative stability and to prevent thermal degradation of fatty acids in n − 3 PUFA-rich oils (Bakry et al., 2016). This technique consists basically in the production of microparticles by coating the core material with a microencapsulating agent (Champagne & Fustier, 2007). Studies have shown that microencapsulation by external ionic gelation using alginate as microencapsulating agent allowed the production of microparticles resistant to high temperatures (Onwulata, 2013) and with controlled release of the active compounds in the human intestine (Soliman, El-Moghazy, El-Din, & Massoud, 2013).

In spite of the features of oil microencapsulation, only a few studies have been proposed using microencapsulation as a way to incorporate n − 3 PUFA-rich oils into meat products. Pelser, Linssen, Legger, and Houben (2007) used microencapsulated fish and linseed oils in dry fermented sausages. The use of fish oil microparticles was also studied by Josquin, Linssen, and Houben (2012) and Lorenzo, Munekata, Pateiro, Campagnol, and Domínguez (2016) in fermented meat products and by Keenan et al. (2015) in burgers. Those authors have shown that the use of microencapsulated oils may be a viable alternative of

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enriching food products with n − 3 PUFAs. However, those studies have not evaluated the effect of the heat treatment on the fatty acid composition and lipid oxidation. Therefore, n − 3 PUFA-rich oil (chia and linseed) microparticles were produced by external ionic gelation for use as a fat substitute in burgers. The encapsulation efficiency, proximate composition, fatty acid profile, thermal resistance, and stability of the microparticles under different pHs were assessed. The oxidative stability and the technological, nutritional, and sensory quality of the raw and cooked burgers were also evaluated.

2. Material and methods

2.1. Production of microparticles

The microparticles were produced by the external ionic gelation technique, according to Liserre, Ré, and Franco (2007) and Etchepare et al. (2016) with adaptations. In this way, 25% chia oil (T1) and linseed oil (T2) were mixed with 2.0% sodium alginate solution. Then, the mixture was atomized in 0.1 M $CaCl_2$ solution using a dual fluid atomizer nozzle (0.1 mm) at a distance of 12 cm from the solution, under air pressure of 0.125 kg/cm. After atomization, the microparticles were kept under constant stirring for 30 min, and then sieved in a wire mesh sieve (150 μm in diameter) and washed with sterile distilled water.

2.2. Analysis of oil microparticles

2.2.1. Encapsulation efficiency

The encapsulation efficiency (EE%) was calculated in triplicate according to Eq. (1). The total oil content (TO) in the microparticles was quantified according to the methodology described by Bligh and Dyer (1959), and the extractable oil (SO), commonly referred to as surface oil, was determined according to the methodology of Davidov-Pardo, Roccia, Salgado, Leon, and Pedroza-Islas (2008).

$$EE = \frac{(TO - SO)}{TO} \times 100 \quad (1)$$

2.2.2. Proximate composition, pH, and a_w

The proximate composition, pH and a_w of the microparticles were determined in triplicate. Moisture, ash and protein contents were determined according to AOAC (2005). The lipid content was determined by the method of Bligh and Dyer (1959). The pH values were measured using a pH meter (130 MA; Mettler Toledo, SP, Brasil), and a_w was measured using an Aqualab apparatus (Decagon Devices Inc., Pullman, USA).

2.2.3. Fatty acids profile

The fatty acid profile of both the microencapsulated oils and liquid chia and linseed oils was determined in triplicate. The lipids were extracted according to Bligh and Dyer (1959) method, and then 50 mg of sample was subjected to methylation as described by Hartman and Lago (1973), based on the saponification with a 0.4 M of NaOH methanolic solution (100 °C for 10 min) and acid-catalyzed esterification using 1 M H_2SO_4 methanolic solution (100 °C for 10 min). The fatty acid methyl esters (FAME) were quantified using a gas chromatograph equipped with a flame ionization detector (GC-FID, Varian Star 3400CX, Walnut Creek, USA). Aliquots of 1 μL were injected in split mode at a 50:1 ratio in 250 °C. The carrier gas was hydrogen at a constant pressure of 15 psi. The FAMEs were separated on CP-Wax 52 CB capillary column (Agilent, Middelburg, The Netherlands, 50 m × 0.32 mm × 0.20 μm). The initial column temperature was 50 °C, remaining for 1 min, increasing to 180 °C at 10 °C/min, with an increase rate of 2 °C/min after 200 °C, and then 10 °C/min until reaching 230 °C, which temperature was maintained for 5 min. The detector was maintained at 240 °C.

The FAME identification was performed by comparing the retention times of the analytes with FAME Mix-37 standards (P/N 47885-U; Sigma-Aldrich, St. Louis, USA). The results were expressed in grams/100 g of fatty acids. The atherogenicity (AI) and the thrombogenicity (TI) indices were calculated according to Ulbricht and Southgate (1991), as shown in Eqs. (2) and (3), respectively.

$$AI = \frac{C12{:}\,0 + (4{*}C14{:}\,0) + C16{:}\,0}{(\Sigma PUFA) + (\Sigma MUFA)} \quad (2)$$

$$TI = \frac{C14{:}\,0 + C16{:}\,0) + C18{:}\,0}{(0,5{*}\Sigma MUFA) + (0,5{*}\Sigma n - 6) + (3{*}\Sigma n - 3) + (\frac{n-3}{n-6})} \quad (3)$$

2.2.4. Thermal stability

To verify whether the microparticles would remain intact in the burgers when subjected to conditions similar to those used during preparation, test tubes containing approximately 10 g microparticles were heated in a water bath set to 80 °C until reaching the internal temperature of 72 °C, which was maintained for 20 min. Subsequently, the integrity of the microparticles were analyzed under an optical microscope. This analysis was performed in triplicate.

2.2.5. Resistance of microparticles at different pH values

The resistance of the microparticles at different pH values was determined in triplicate according to the methodology proposed by Holkem et al. (2016). The microparticles were mixed with phosphate (pH 7.5 and 6.0) and acetate (pH 4.5) buffers. The solutions with the microparticles were stirred at 150 rpm at 37 °C in a shaking incubator (TE-421, Tecnal, Piracicaba, SP, Brazil). Aliquots were removed after 60, 120, and 180 min to determine the release of the microencapsulated oil. The integrity of the particles was monitored by light microscopy before and after buffer addition.

2.3. Burgers formulation and processing

Beef (*rectus femoris*) (moisture: 72.9%; protein: 21.7%; and fat: 4.5%), pork back fat (moisture: 11.6%; protein: 8.5%; and fat 80.3%), and spices were purchased from local market. Chia and linseed oils were obtained from Giroil S.A. (Santo Ângelo, Brazil). Three burger formulations were processed in a pilot plant, as follows: a control treatment was produced with beef (78.4%), pork back fat (20.0%), salt (1.5%), and garlic (0.1%), and the modified treatments (T1 and T2) were prepared by replacing 50% of pork back fat with microparticles containing chia (T1) and linseed (T2) oils.

To produce the burgers (5 kg per batch), beef and pork back fat were ground separately (Model PJ22, Jamar Ltda, São Paulo, Brazil) using a 3 mm disc. Beef was then mixed with salt to extract myofibrillar proteins. Subsequently, the remaining ingredients were added and the mixture was mixed until complete homogenization. Burgers (100 g), 11 cm in diameter and 2.5 cm thick were produced using a burger machine (HP 112, Picelli, São Paulo, Brazil). The burgers were immediately frozen and stored at − 18 °C until analysis. Some measurements were performed in both raw and cooked burgers. The samples were cooked in an electric grill (Multi Grill, Britânia, São Paulo, Brazil), preheated to 150 °C, until reach an internal temperature of 72 °C in the geometric center of each burger, which was measured by a spit thermometer (HM-600, Highmed, São Paulo, Brazil) inserted in the center of each burger.

2.4. Physicochemical evaluation of burgers

The proximate composition (moisture, protein, lipids, and ash), pH, and a_w of raw and cooked burgers were determined in triplicate using three samples for each treatment according to procedures described above.

The color of the raw and cooked burgers was measured just after