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Linseed oil gelled emulsion: A successful fat replacer in dry fermented sausages

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ABSTRACT

Different levels of animal fat replacement by a high omega-3 content carrageenan gelled emulsion in dry fermented sausages were studied in order to improve their fatty acid composition. Percentages of fat replacement were 26.3% (SUB1), 32.8% (SUB2) and 39.5% (SUB3). α-linolenic acid (ALA) content increased up to 1.81, 2.19 and 2.39 g/100 g (SUB1, SUB2, and SUB3 products) as compared to the Control (0.35 g/100 g), implying an increment in polyunsaturated fatty acids (PUFA) supply (up to 10.3%) and reductions in omega-6/ omega-3 ratio (75, 82 and 84%, respectively). Peroxides and TBARs values were not affected ($P > 0.05$) by the fat modification and a slight low formation of volatile aldehydes derived from lipid oxidation was detected. Fat replacement did not cause relevant modifications on the instrumental color properties and no sensory differences ($P > 0.05$) were found between Control and SUB2 products (32.8%) for taste and juiciness, pointing out the viability of this formulation for human consumption.

1. Introduction

Nutrition is an important modifiable determinant of chronic diseases, and changes in the diet have strong effects on health throughout life (WHO, 2003). In response to this fact, dietary guidelines are periodically updated according to current knowledge, being fat particularly affected by these recommendations.

Although fermented meat products have been consumed for centuries in many different parts of the world and constitute one of the most important types of food (Toldrá & Hui, 2014), it is well known that the animal fat used in the elaboration of these products contains a higher proportion of saturated fatty acids (SFAs) than polyunsaturated fatty acids (PUFAs) (Muguerza, Ansorena & Astiasarán, 2004). It has been reported that SFA intake is associated with some of the metabolic syndrome's components, and it has been also suggested that the replacement of these fatty acids by PUFAs decreases coronary heart disease (CHD) risk (Skeaff & Miller, 2009). In consequence, research in this area is attempting to improve the fatty acid profile of these products to comply with current health recommendations.

Numerous strategies have been carried out in order to change fat composition in dry fermented sausages, including the use of different non-animal fats (marine and plant sources). Previous studies have reported that the incorporation of different types of oils improves the lipid profile of these products (Ansorena & Astiasarán 2004b; García-Íñiguez de Ciriano et al., 2009; García-Íñiguez de Ciriano et al., 2010; Jiménez-Colmenero, 2007; Jiménez-Colmenero, Triki, Herrero, Rodríguez-Salas & Ruiz-Capillas, 2013; Muguerza et al., 2004; Ruiz-Capillas, Triki, Herrero, Rodríguez-Salas & Jiménez-Colmenero, 2012; Triki, Herrero, Rodríguez-Salas, Jiménez-Colmenero & Ruiz-Capillas, 2013; Valencia, Ansorena & Astiasarán, 2006).

Most of these studies have been performed using oil in water emulsion (O/W) systems, useful to incorporate components in the lipid phase, (*e.g.*, ω-3 unsaturated fatty acids or antioxidants) with potential health implications in the products. However, stabilization of these emulsions by structural reinforcement is needed to preserve the textural properties of the products (Jiménez-Colmenero et al., 2015). Thus, the use of gelling agents has helped the reformulation processes in mimicking hardness and water holding capacity in different meat products (Jiménez-Colmenero et al., 2013; Marchetti, Andrés & Califano, 2014). In this sense, a gelled O/W emulsion containing 40% of linseed oil and 1.5% of kappa-carrageenan was developed by our group (Poyato, Ansorena, Berasategi, Navarro-Blasco & Astiasarán, 2014) as a pork back fat replacer. Its incorporation in fresh and cooked meat products showed nutritional advantages and did not have a negative influence on the sensory properties of the final products at the concentrations used (Poyato et al., 2014; Poyato, Astiasarán, Barriuso & Ansorena, 2015). However, no studies have been performed to test the viability of this gel in dry fermented sausages, which are characterized by a complex physicochemical ripening process.

The objective of this research was to design a technological strategy able to allow the incorporation of a gelled emulsion as a partial fat

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replacer to improve the lipid content of dry fermented sausages. The technological, nutritional and sensory characteristics, as well as their susceptibility to oxidation were assessed.

2. Material and methods

2.1. Gelled emulsion preparation

Linseed oil (Naturgreen, Murcia, Spain) was obtained in a local market. The fatty acid profile of the linseed oil used, expressed as g 100 g^{-1} of total FA, was as follows: α- linolenic (58.9), linoleic (15.9), oleic (15.8), palmitic (5.13), stearic (3.06).

Carrageenan (κ-carrageenan) was kindly donated by Cargill (San Sebastián, Spain). Polysorbate 80 was obtained from Sigma-Aldrich Chemical Co. (MO, USA). The gelled emulsion prepared contained 40% of linseed oil, 1.5% of carrageenan and 58.5% of water. Gelled emulsion was prepared according to the method described by Poyato et al. (2014). The oil phase (40 g/100 g emulsion) containing the Polysorbate 80 as surfactant (0.12 g/100 g emulsion) was added to the aqueous phase (that included 1.5 g carrageenan/100 g emulsion) and homogenized. Both phases were previously heated separately to 70 °C. After the homogenization process (16.000 rpm, Ultra-Turrax® T25basic), the emulsions were cooled to room temperature in a sealed flask, allowing the κ-carrageenan to polymerize. The gel was kept overnight under refrigeration (4 °C) until being used.

2.2. Dry fermented sausages formulation and processing

Fresh lean pork meat and fresh pork back fat were used as raw materials: these were obtained from a local processor. Lean pork meat was trimmed of fat and pork back fat was separated of adhering skin. They were kept frozen until use (−20 °C).

Four different formulations of dry fermented sausages (6 kg per formulation) were manufactured in a pilot plant according to the general procedure described by Muguerza, Gimeno, Ansorena, Bloukas & Astiasarán (2001). The Control was made using 75% lean pork meat and 25% pork back fat. The other three formulations (SUB1, SUB2 and SUB3) were produced with a substitution of 26.3, 32.8 and 39.5% of pork back fat, respectively, by the gelled emulsion. The substitution levels tested were based on a previous study of our research group, which concluded that sausages with 25% of substitution with pre-emulsified olive oil in O/W systems were acceptable from the sensorial point of view (Muguerza et al., 2001). Calculations were needed to provide the same content of oil in the gelled emulsion. The amount of pork back fat and gelled emulsion used in each formulation is shown in Table 1. The formulations also included the following common ingredients per kilogram of meat mixture: 26 g of sodium chloride, 30 g red pepper, 15 g dextrin, 10 g lactose, 12 g powdered milk, 5 g dextrose, 0.5 g sodium ascorbate, 10 g sodium caseinate, 3 g garlic, 2 g polyphosphates, 3 g curavi (a mixture of NaCl, preservatives E-250, E-252 and antioxidant E-331) and 0.15 g Ponceau 4R (E-124). 200 mg/kg of butylated hydroxyanisole (BHA) were also included in all formulations.

Two technological trials were performed for the processing of dry fermented sausages, that differed on the moment of the incorporation of the gel to the rest of ingredients. In both cases the gelled emulsion was added cut into 1 × 1 cm cubes. In the first trial, the gel was incorporated with the rest of the ingredients into the mincer (chopping step that lasted 50 s), obtaining a meat matrix that was subsequently mixed in a vacuum mixer (blending step that lasted 65 s). In the second trial, all the ingredients except for the gel, were chopped in the mincer, and the gel was incorporated after the chopping step, in the vacuum mixer (blending step). This was performed to observe the possible differences on the final appearance of the dry fermented sausages. In both cases, after blending, the prepared sausage mixture was stuffed into artificial casings (60 mm diameter) of collagen material (Viscofán, Cáseda, Spain). Sausages were fermented and ripened for 30 days in specific conditions (Muguerza et al., 2001) in a drying chamber (STA model W 80XDHG-VEH Noáin, Spain). Once ripening was finished, sausages were stored under vacuum in refrigeration conditions (4 °C), until analysis. As it will be discussed later, results of the first technological trial were not satisfactory, so only one replicate of this experiment was done. The appearance of products in the second technological trial was adequate and hence, the products were elaborated following this technological procedure. The experimental design was carried out in triplicate per each type of formulation (C, SUB1, SUB2 and SUB3). Several sausages from each replicate and formulation were homogenized to obtain a representative sample for analysis. For each parameter, the number of measurements made in the homogenates is indicated below. Data shown in tables are means and standard error of the three replicates.

2.3. Technological and nutritional analysis

pH was measured directly in the sausage with a pH-meter (micropH 2000) using a needle electrode (model pH electrode 52 31, Crison Instruments SA, Barcelona, Spain). Its evolution was controlled during the entire ripening period. Fat, moisture, protein and ash content were analyzed using official methods (AOAC 2002a,b,c,d) in the ripened products. For each type of formulation, three measurements were done per each of the triplicate batches ($n = 9$). Carbohydrates were calculated by difference. The method of Folch, Lees & Stanley (1957) was used for the extraction of fat.

Fatty acid profile was determined in the lipid extracts by gas chromatography (Ansorena, Echarte, Ollé & Astiasarán, 2013). Boron trifluoride/methanol was used for the preparation of fatty acid methyl esters (FAME) (AOAC 2002e). The methylated sample was injected in the gas chromatograph. The gas chromatograph available was Perkin-Elmer Clarus 500 equipped with a capillary column SPTM – 2560 (100 m × 0.25 mm × 0.2 μm) and flame ionization detection. The injector was set at 250 °C and the detector temperature was set at 260 °C. The temperature of the column oven was established at 175 °C for 10 min increasing up to 200 °C at a pace of 10 °C/min, followed by an increase up to 220 °C at a pace of 4 °C/min and finally maintained at that temperature for 15 min. The gas for the flame ionization detector was compressed synthetic gas (O_2-N_2) mixed with hydrogen at a pressure of 20.5 psi. Hydrogen was used as a carrier gas (mobile phase).

The identification of the fatty acid methyl esters was done by comparison of the retention times of the peaks in the sample with those of standard pure compounds and by spiking the sample with each standard individually. The quantification of individual fatty acids was based on the internal standard method, using methyl hepadecanoate.

Table 1
Main ingredients for the 4 types of dry fermented sausages.

Samples	Fat replaced (%)	Pork meat (g)	Pork back fat (g)	Gelled emulsion (g)
C	0	4500	1500	–
SUB 1	26.3	4500	1105.5	394.5
SUB 2	32.8	4500	1008	492
SUB 3	39.5	4500	907.5	592.5

Amounts calculated for 6 kg of each product.