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Oil bulking agents based on polysaccharide gels in meat batters: A Raman spectroscopic study

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ABSTRACT

A Raman spectroscopic study was performed to determine protein and lipid structural properties in meat batter containing oil bulking agents as pork backfat replacers. Meat batters were prepared with pork backfat (MB-PF) or with a combination of olive oil, sodium alginate, $CaSO_4$, sodium pyrophosphate and dextrin (MB-A/D) or inulin (MB-A/I) as a fat replacer. Proximate composition, pH, cooking loss (CL), colour and texture were evaluated. MB-A/D and MB-A/I both showed lower ($P < 0.05$) CL and a^* values, higher ($P < 0.05$) L^* and b^* values, and higher ($P < 0.05$) hardness and chewiness. MB-A/I showed the highest hardness and chewiness. Enhancement of the β-sheet structure was observed in MB-A/D and MB-A/I, more so in MB-A/I. There was increased disorder in the oil acyl chains, which involve lipid–protein interactions, in both MB-A/D and MB-A/I. Structural characteristics in proteins and lipids may be associated with specific water and fat binding properties and textural characteristics of meat batters.

1. Introduction

In recent years there has been growing interest in the consumption of foods that are perceived as healthier (including meat-based foods), and the trend is expected to continue over the next ten years. Because of their health implications, lipids are among the components that have received the most attention in developing healthier foods. Their importance lies in the connection between the amount and type of fat in the diet and the risk of major chronic diseases in our society, such as cardiovascular diseases, cancer and obesity. Because of their composition and prevalence of consumption, meat and meat products are amongst the foods that contribute most to dietary lipid intake. If we consider that in many cases, the characteristics of meat lipids are not exactly those considered most recommendable, it is understandable that the development of strategies designed to achieve quantitative and qualitative modification of their lipid profiles, to bring them more into line with health recommendations is desirable (Jiménez-Colmenero, 2007). One of the strategies that has received the most attention involves reformulation processes designed to replace animal fat with other fats of plant and/or marine origin, which comply better with health recommendations. These fats have been incorporated in meat products in liquid and solid forms, encapsulated or as oil-in-water emulsions (Jiménez-Colmenero, 2007). Strategies for the incorporation of healthy oils in a gel-like matrix to form oil bulking agents (in which this new ingredient acts as an animal fat replacer) could offer new possibilities for improving the fat content of meat products. In this regard, healthy oils in a konjac matrix have been used to improve the fat content in meat products (Ruiz-Capillas, Triki, Herrero, Rodríguez-Salas, & Jiménez-Colmenero, 2012; Salcedo-Sandoval, Cofrades, Ruiz-Capillas, Solas, & Jiménez-Colmenero, 2013). With similar purposes, our group recently developed two different polysaccharide gel matrices containing olive oil, prepared using mixed biopolymer systems of alginate with inulin or dextrin showing optimal characteristics for use as animal fat replacers. The technological and structural properties of these new oil bulking agents highlight the possibilities to use such matrices as potential fat replacers in the development of meat products.

To properly develop healthier meat products of this kind, it is essential to examine aspects of the reformulation processes that affect technological properties (water and fat binding properties, colour, texture, etc.), and to gain an understanding of the complex relationship between these properties and the different structural characteristics of the components of the meat matrix. Further investigation of this structure/function relationship would help to elucidate the mechanisms that act on them, to establish criteria for adjusting them, and criteria for assessing aspects relating to factors of processing and composition and their impact on various physicochemical properties of the complex meat system. In this context, Raman spectroscopy offers a powerful tool with which to address such questions. As a technique it has numerous advan-

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tages, among them the fact that it is a direct (non-invasive) method capable of simultaneously furnishing structural and analytical information on the different components (proteins, lipids, etc.) of meat and their derivates. Moreover, Raman spectroscopy requires only small sample amounts (Böcker et al., 2007; Damez & Clerjon, 2008; Herrero, 2008a, 2008b; Herrero, Carmona, Jiménez-Colmenero, & Ruiz-Capillas, 2010; Pedersen, Morel, Andersen, & Engelsen, 2003; Yang & Ying, 2011). In the literature there are several references regarding the use of Raman spectroscopy coupled to chemometrics (multivariate analysis) to predict different physico-chemical properties (protein solubility, apparent viscosity, water holding capacity, fatty acid composition, instrumental textural methods, etc.) in meat systems (Damez & Clerjon, 2008; Herrero, 2008a, 2008b; Herrero et al., 2010; Pedersen et al., 2003). On the other hand, Raman spectroscopy has also been used specifically to study protein structural changes in meat batters, induced by thermal treatment or by salt, soy protein or cold-set binding agents (Herrero, Carmona, López-López, & Jiménez-Colmenero, 2008; Herrero, Carmona, Cofrades, & Jiménez-Colmenero, 2008; Herrero, Cambero, Ordóñez, de la Hoz, & Carmona, 2009). Some authors have also demonstrated that Raman spectroscopy is a useful tool for obtaining direct information on the secondary and tertiary structural changes occurring in proteins of meat batters, as a result of addition of different lipids (pork fat, soybean oil and dairy butter) and thermal treatment (Shao, Zou, Xu, Wu, & Zhou, 2011). These studies revealed some connections between the protein structure and the technological properties of the product, such as texture and water binding (Herrero, Carmona, Cofrades et al., 2008; Herrero, Carmona, López-López et al., 2008; Herrero et al., 2009; Shao et al., 2011).

A better understanding of the structural changes induced in meat batters by incorporation of polysaccharide gels as oil bulking agents to replace animal fat, and of their relationship with some of the physico-chemical characteristics of the batters, could be helpful in optimising the development of healthier meat products. The primary aim of this work was therefore to examine changes in physico-chemical properties (colour, water and fat binding properties and textural characteristics) produced in meat batters by utilisation of oil bulking agents based on polysaccharide gels as animal fat replacers, and changes in protein and lipid structures of these meat systems, using Raman spectroscopy. The secondary aim was to elucidate the relationship between the physico-chemical properties and the protein and lipid structures of these meat batters.

2. Materials and methods

2.1. Materials

Fresh post-rigor pork meat (mixture of *Musculus biceps femoris*, *Musculus semimembranosus*, *Musculus semitendinosus*, *Musculus gracilis* and *Musculus adductor*) and pork backfat were obtained from a local meat market. The meat was trimmed of fat and connective tissue and the pork fat was passed through a grinder with a 0.4 mm plate. Lots of approximately 1 kg were vacuum packed and stored at −20 °C until use, which took place within 2 weeks.

Ingredients used for preparation of polysaccharide gels as oils bulking agents included: olive oil (13% SFA, 79% MUFA and 8% PUFA) (Carbonell Virgen Extra, SOS Cuétara SA, Madrid, Spain); sodium alginate (90% carbohydrates) (Tradissimo, TRADES S.A., Barcelona Spain); calcium sulfate (Panreac Química, S.A. Madrid, Spain), tetra-sodium pyrophosphate anhydrous (STP) (Manuel Riesgo, S.A. Madrid, Spain), inulin consisting mainly of chicory inulin (>90% inulin) with a molecular weight of 1650 g/mol (TRADES S.A., Barcelona Spain) and white maize dextrin (molecular weight average approximate between 10 and 20 glucose molecule per polymer) (CARGILL S.L.U- CTS Rubi, Barcelona, Spain).

Sodium chloride (Panreac Química, S.A. Barcelona, Spain) and sodium tripolyphosphate (ST) (Manuel Riesgo, S.A. Madrid, Spain) were also used as ingredients.

2.2. Preparation of olive oil bulking matrices based on polysaccharide gels

Two different types of polysaccharide matrices with olive oil were considered: a combination of olive oil with sodium alginate, $CaSO_4$, STP and dextrin (A/D) or inulin (A/I). These matrices were prepared by mixing with water (40%) in a homogenizer (Thermomix TM 31, Vorwerk España M.S.L., S.C, Madrid) SA (1%), $CaSO_4$ (1%), STP (1%) and dextrin (2.25%) or inulin (2.25%) to prepare A/D or A/I respectively. The mixtures were prepared at 1500 rpm for 20 s. Olive oil (55%) was gradually added to this mixture with the homogenizer running (1500 rpm). Matrices of each type were stuffed into metal moulds under pressure to compact them and avoid air bubbles, and stored in a chilling room at 2 °C for 24 h until analysis. The preparation of each type of oil bulking agent was performed in duplicate using two metal moulds for each type of sample. These polysaccharide matrices with olive oil were used as pork backfat replacer in the formulation of the meat batters.

2.3. Preparation of meat batters

Three different meat batters were prepared as reported in Table 1: a control meat batter formulated with meat and pork backfat (MB-PF) and two reformulated samples in which the pork backfat was replaced by an equal amount of oil bulking agents, A/D or A/I to formulate MB-A/D and MB-A/I, respectively. Briefly, raw meat material was homogenised and ground for 1 min in a chilled cutter (2 °C) (Stephan Universal Machine UM5, Stephan Machinery GmbH & Co., Hameln, Germany). Half of the pork backfat or polysaccharide gel-based olive oil bulking matrices (A/I or A/D, depending on the formulation), NaCl and sodium tripolyphosphate (previously dissolved in the added water) were added to the ground meat and the whole mixed again for 1 min. The rest of the additives, the pork backfat or the polysaccharide matrices with olive oil as fat replacer were added and the whole homogenised for 1 min. Finally the whole meat batter was homogenised under vacuum conditions for 2 min. Mixing time was standardized at 4 min. The final batter temperature was below 12 °C in all cases. Portions of each meat batter (approximately 70 g) were placed in plastic containers (diameter 3.5 cm, height 7 cm), which were hermetically sealed. They were then heated in a water bath at 70 °C for 30 min. Thermocouples connected to a temperature recorder were used to establish the thermal conditions required to reach an internal temperature of 70 °C (Yokogawa Hokushin Electric YEW, Mod. 3087, Tokyo, Japan). Samples were stored in a chilling room at 2 ± 2 °C until analyses. Each formulation was prepared in duplicate.

2.4. Proximate analysis and pH

Moisture and ash contents of the cooked meat batters were determined (AOAC, 2000) in triplicate. Protein content was measured in triplicate with a LECO FP-2000 Nitrogen Determinator (Leco Corporation, St Joseph, MI, USA). Fat content was evaluated in triplicate (Bligh & Dyer, 1959).

The pH was determined on a Radiometer model PHM 93 pH-metre (Meterlab, Copenhagen, Denmark) at room temperature on homogenates in water in a ratio 1:10 (w/v) of meat batters, pork