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Enhancement of the nutritional status and quality of fresh pork sausages following the addition of linseed oil, fish oil and natural antioxidants

I. Valencia [a], M.N. O'Grady [b], D. Ansorena [a], I. Astiasarán [a], J.P. Kerry [b,*]

[a] Department of Nutrition, Food Science, Physiology and Toxicology, Faculty of Pharmacy, University of Navarra, Irunlarrea s/n, 31008-Pamplona, Spain
[b] Department of Food and Nutritional Sciences, University College Cork, National University of Ireland, Western Road, Cork, Ireland

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ABSTRACT

Fresh pork sausages (pork shoulder, pork back fat, water, rusk and seasoning) were manufactured where 15% of the pork back fat was substituted with linseed oil (LO) or fish oil (FO). Green tea catechins (GTC) and green coffee antioxidant (GCA) were added to both LO (LGTC 200 and LGCA 200) and FO (FGTC 200 and FGCA 200) substituted sausages at a level of 200 mg/kg. Raw and cooked pork sausages were either over-wrapped with oxygen permeable film (aerobic storage) or stored in modified atmosphere packages (MAP) containing 80% O_2:20% CO_2 or 70% N_2:30% CO_2, respectively for 7 days at 4 °C. Effects on fatty acid profiles, lipid oxidation, colour and sensorial properties were investigated. α-Linolenic acid increased from 1.34% (control) to 8.91% (LO) and up to 11.2% (LGTC 200 and LGCA 200). Addition of fish oil increased levels of EPA from 0.05% (control) to 2.83% (FO), 3.02% (FGTC 200) and 2.87% (FGCA 200) and DHA levels increased from 0.04% (control) to a maximum of 1.93% (FGTC 200). Lipid oxidation was low in raw and cooked linseed oil containing sausages. GTC (200 mg/kg) significantly ($P < 0.05$) reduced lipid oxidation in raw fish oil containing sausages after 7 days of storage. Colour parameters in raw pork sausages were unaffected by the packaging atmosphere. L^* lightness values were lower ($P < 0.05$) in LGTC 200 and a^* redness values lower ($P < 0.05$) in LGTC 200 and FGTC 200 after 7 days of storage. Sensory scores of cooked pork sausages were unaffected by linseed oil addition. Flavour and overall acceptability scores in cooked fish oil containing sausages were improved by GTC addition. Results obtained demonstrate potential for the production of nutritionally enhanced fresh pork sausages.

1. Introduction

Meat is considered a vital component of a healthy diet, an excellent source of protein, essential minerals, trace elements and vitamins. Negative concerns regarding meat consumption and its impact on human health have prompted research into development of novel functional meat products (Arihara, 2006). The terms functional food and nutraceutical are used interchangeably and usually defined as any substance that may be considered a food or part of a food which provides medical or health benefits including the prevention and treatment of disease (DeFelice, 1992). Dietary recommendations for humans, favouring the consumption of less saturated fat, have led to an increased interest in meats containing more unsaturated fatty acids. Scientific evidence suggests that certain dietary fats, for example $n-3$ polyunsaturated fatty acids (PUFA's), may prevent and modulate diseases such as coronary heart disease, cancer, hypertension and arthritis (Connor, 2000).

Manipulation of the fatty acid profiles of meat and meat products may be achieved by, feeding animals diets rich in polyunsaturated fatty acids (PUFA's), for example fish oil, linseed oil and soya oil (Monahan, Buckley, Morrissey, Lynch, & Gray, 1992; Raes, De Smet, & Demeyer, 2004) or alternatively, by processing specific lipid ingredients into meat products (Fernández-Ginés, Fernández-López, Sayas-Barberá, & Pérez-Alvarez, 2005). Oils such as linseed oil, fish oil, olive oil, and soya oil alter product fatty acid profiles producing healthier meat products, for example, dry fermented sausages (Ansorena & Astiasarán, 2004; Muguerza, Ansorena, & Astiasarán, 2003, 2004; Muguerza, Gimeno, Ansorena, Bloukas, & Astiasarán, 2001; Severini, De Pilli, & Baiano, 2003; Valencia, Ansorena, & Astiasarán, 2006).

Lipid oxidation is a major quality deteriorative process in muscle foods resulting in a variety of breakdown products which produce off-odours and flavours. Susceptibility to lipid oxidation increases with increased levels of PUFA's. Bryhni, Kjos, Ofstad, and Hunt (2002) reported that supplementation of porcine diets with polyunsaturated fat and fish oil resulted in increased lipid oxidation in whole muscle and sausages. Therefore while oils rich in $n-3$ polyunsaturated fatty acids may contribute to the production of healthier meat, negative effects on meat palatability may be

* Corresponding author. Tel.: +353 21 4903798; fax: +353 21 4270001.
E-mail address: joe.kerry@ucc.ie (J.P. Kerry).

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observed. Lipid oxidation in muscle foods may be controlled using synthetic or natural antioxidants. Concerns regarding the safety and toxicity of synthetic antioxidants have prompted research into natural antioxidants derived from plant sources. In recent times, the functional properties of plant extracts have been investigated due to their potent antioxidant and nutraceutical activity.

Tea catechins are a major group of polyphenolic flavonoids found in green tea. The principle catechins found in green tea (*Camellia sinensis*) are (−) epicatechin (−EC), (−)-epigallocatechin (−EGC), (−)-epicatechin gallate (−ECG), and (−)-epigallocatechin gallate (−EGCG). The antioxidant activity of tea catechins has been demonstrated in a variety of test systems (Huang & Frankel, 1997) and in beef, pork and poultry meats (McCarthy, Kerry, Kerry, Lynch, & Buckley, 2001; Mitsumoto, O'Grady, Kerry, & Buckley, 2005; Nissen, Byrne, Bertelsen, & Skibsted, 2004; Tang, Kerry, Sheehan, Buckley, & Morrissey, 2001). Reported human health benefits of tea catechins include anti-carcinogenic anti-inflammatory and cardioprotective activity (Higdon & Frei, 2003; Sato & Miyata, 2000). Green coffee antioxidant (GCA®) is a commercially available natural chlorogenic acid (>50%) extract derived from raw coffee beans. Green coffee beans are a rich dietary source of chlorogenic acid, an ester of caffeic acid with quinic acid (Clifford, 1999). In addition to antioxidant activity (Charurin, Ames, & Del Castillo, 2002; Daglia et al., 2004), chlorogenic acid may modulate the onset of diabetes in humans (McCarty, 2005) thereby demonstrating human health promoting properties. Also epidemiological and experimental studies have shown positive effects of regular coffee consumption on various aspects of human health such as psychoactive responses, neurological and metabolic disorders, gonad and liver function (Dórea & da Costa, 2005). The antioxidant activity of coffee extract in cooked pork patties has been reported previously (Nissen et al., 2004).

Fresh pork sausages are popular meat products in many European countries and traditionally presented for retail sale either, in trays over-wrapped with oxygen permeable film or sealed into plastic pouches. Martínez, Djenane, Cilla, Beltrán, and Roncalés (2006) packaged fresh pork sausages in modified atmosphere packages (MAP) containing increased oxygen levels and reported a limited positive effect of oxygen level on sausage colour and increased levels of lipid oxidation. In a further study, plant extracts (rosemary, borage, green and pu-erh tea) effectively reduced lipid oxidation and extended the shelf-life of fresh pork sausages stored in MAP (Martínez, Cilla, Beltrán, & Roncalés, 2006). The influence of health promoting green tea catechins (GTC) and green coffee antioxidant (GCA) on the quality of nutritionally enhanced fresh pork sausages stored aerobically (over-wrapped) and in MAP merits investigation.

The objective of this study was to manipulate the fatty acid profile of fresh pork sausages with oils high in $n-3$ PUFA's namely linseed oil (LO) (rich in α-linolenic acid (C18:3($n-3$))) and fish oil (FO) (rich in eicosapentaenoic acid (EPA) (C22:5($n-3$)) and docosahexaenoic acid (DHA) (C22:6($n-3$))). The effects of LO, FO, GTC and GCA on quality parameters such as lipid oxidation, colour and sensorial properties was investigated.

2. Materials and methods

2.1. Materials and reagents

All chemicals used were AnalaR grade and obtained from Sigma Chemical Co. Ltd., Poole, Dorset UK and Merck KGaA, Darmstadt, Germany. Green tea catechins (GTC) (81.43%) were supplied by New Kinglong Natural Products Co. Ltd, Hunan, China and stated by the manufacturer to contain catechin (−C) 4.82%, epicatechin (−EC) 11.51%, epicatechin gallate (−ECG) 16.22%, epigallocatechin (−EGC) 9.64%, epigallocatechin gallate (−EGCG) 37.62% and gallocatechin gallate (−GCG) 1.62%. Green coffee antioxidant (GCA®) was obtained from Applied Food Sciences, LLC, Austin, Texas. GCA, a natural chlorogenic acid extract derived from raw coffee beans, contained >65% total polyphenols and was standardized to contain >50% chlorogenic acid.

Linseed oil (Oxyguard fresh cold pressed) was obtained from Biona, United Kingdom and Fish oil (omega-3 18/12) from LYSI, Reykjavik, Iceland. The fatty acid composition (g/100 g fatty acids) of linseed oil and fish oil was determined by gas chromatography (see Section 2.5). Linseed oil contained lauric (0.02), myristic (0.02), palmitic (4.78), *t*-palmitoleic (0.02), palmitoleic (0.02), stearic (3.87), oleic (19.80), vaccenic (0.40), linoleic (15.01), γ-linolenic (0.20), α-linolenic (55.62) and docosapentaenoic acid $n-3$ (0.11). Fish oil contained lauric (0.16), myristic (7.04), palmitic (17.33), *t*-palmitoleic (0.03), palmitoleic (7.96), stearic (3.50), oleic (8.69), vaccenic (3.11), linoleic (1.26), γ-linolenic (0.22), α-linolenic (1.16), arachidonic (1.14), eicosapentaenoic $n-3$ (16.92) and docosahexaenoic acid $n-3$ (13.44).

Rusk (wheat, flour, salt, E503), sausage seasoning (salt, wheatflour, stabilisers E450 and E451, spice and spice extract, preservative E221, dextrose, flavour enhancer E621, antioxidant E301, flavourings and colour E128) and soya protein isolate were supplied by National Food Ingredients (Limerick, Ireland). Collagen casing was obtained from Devro casings, Moodiesburn, Glasgow, Scotland. Lean pork meat (shoulder) and pork back fat were supplied by Dairygold Ltd., Mitchelstown, Co Cork, Ireland. Pork meat and back fat were minced through a 10 mm plate (Talsa Mincer, Talsabell S. A., Valencia, Spain), vacuum packaged and stored (approximately 1 week) at −20 °C until required for sausage manufacture.

2.2. Sausage formulation and manufacture

A standard fresh pork sausage (~5 kg batch) mixture was formulated to contain 1.63 kg pork shoulder, 1.63 kg pork back fat, 1.00 kg water, 0.63 kg rusk and 0.13 kg seasoning (Control). Batches were manufactured where 15% of the pork back fat was substituted with linseed oil (LO) and fish oil (FO) in an emulsion. Linseed oil (245 g) and fish oil (245 g) were emulsified with 245 g water (50 °C) and 49 g soya protein isolate by mixing vigorously for 2 min and stored at 4 °C prior to use. The natural antioxidants, GTC and GCA were also incorporated into both the LO (LGTC 200 and LGCA 200) and FO (FGTC 200 and FGCA 200) substituted sausages at a level of 200 mg/kg. GTC and GCA were dissolved in the water (1.00 kg) component of the sausage mixture.

Fresh pork sausages were manufactured by mixing and chopping pork meat, back fat, water (0.5 kg) and seasoning for 35 s in a bowl chopper (Seydleman bowl chopper, Burgstallstrabe, Germany). The remainder of the water (0.5 kg), rusk and the emulsion were added and further chopped for 20 s. The sausage batter was subsequently stuffed, using a piston-type sausage filler (Mainca UK Ltd., Berkshire, England), into 21 mm diameter collagen casings and chilled for 1 h at 4 °C prior to further processing and packaging.

2.3. Sausage packaging

Sausages were cooked in a conventional oven by grilling for approx. 15 min at 200 °C. Raw and cooked pork sausages were placed in low oxygen permeable (<1 cm^3/m^2/24 h/atm) polystyrene/ethylvinylalcohol (EVOH)/polyethylene (PE) trays and flushed with 80% O_2:20% CO_2 and 70% N_2:30% CO_2, respectively (modified atmosphere packs (MAP)), using a vacuum sealing unit (VS 100, Gustav Müller and Co. KG, Bad Homburg, Germany) equipped with a gas mixer (Witt–Gasetechnik GmbH and Co. KG, Witten, Germany).