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Effect of antioxidants on stabilization of meat products fortified with $n-3$ fatty acids

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Abstract

The effects of an $n-3$ oil emulsion, with and without added antioxidants, on lipid oxidation in $n-3$ polyunsaturated fatty acid (PUFA)-fortified meat products were studied. An emulsion of $n-3$ PUFAs was prepared (25% algal oil, 2.5% whey protein isolates, 10 mM sodium citrate, 0.2% potassium sorbate, 500 ppm of 70% mixed tocopherols, 100 μM EDTA, pH 3, pasteurized at 75 °C for 30 min) and incorporated into fresh ground turkey, and fresh pork sausage (20% fat) to achieve a concentration of 500 mg $n-3$ PUFA/110 g meat. An antioxidant combination containing rosemary (0.2% w/w; radical quencher), citrate (0.5% w/w; sequestrant) and erythorbate (1 g/kg product; reductant) was prepared and incorporated into ground turkey patties (5 cm dia, 1.5 cm thick) or fresh pork sausages (5 cm dia, 1.5 cm thick). Meat products were stored at 4 °C or −18 °C and analyzed for color (L^*, a^*, b^* values), lipid oxidation (TBARS and lipid hydroperoxides) and $n-3$ PUFA profile. a^* Values of refrigerated ground turkey patties decreased with storage, and an antioxidant combination effect was observed after 4 days ($P < 0.05$). For fresh pork sausages at 4 °C, control + antioxidant (CON + ANTI), and $n-3$ + antioxidant ($n-3$ + ANTI) groups showed greater a^* values than controls (CON) indicating that the antioxidant combination stabilized meat color. TBARS and lipid hydroperoxides of both $n-3$ PUFA-enhanced meat products increased with storage ($P < 0.05$); there were no significant changes in TBARS or lipid hydroperoxides for treatments containing the antioxidant combination ($P < 0.05$). The actual level of $n-3$ PUFA incorporation in both meat products was greater than 87%; $n-3$ PUFA concentrations did not change within any treatment during storage ($P > 0.05$). These results provide support for including antioxidant protection in $n-3$ PUFA fortified meat products.

Keywords: $n-3$ PUFAs; Fortification; Meat color; Antioxidant combination; Lipid oxidation

1. Introduction

The potential health benefits for increasing consumption of dietary $n-3$ polyunsaturated fatty acids (PUFAs) (e.g. α-linolenic acid, C18:3; eicosapentaenoic acid, EPA, C20:5; docosahexaenoic acid, DHA, C22:6) have been well documented (Connor, 2000; Simopoulos, 1997). Dietary $n-3$ PUFAs have been assigned a critical role in pregnancy, and are essential for the proper development of eye and brain function in infants. They have also been demonstrated to decrease coronary heart disease and other cardiovascular diseases including sudden death from heart attack (Connor, 2000; Hu et al., 2002; Simopoulos, 1997). However, the level of PUFAs currently consumed by the general population is considered inadequate (Mantzioris et al., 2000). Consumption trends for foods containing $n-3$ PUFAs are currently static or declining, and there are several populations that would benefit from dietary $n-3$ PUFA consumption (Connor, 2000; Lemaitre et al., 2003).

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Consequently, functional foods containing physiologically significant amounts of $n-3$ PUFAs would be beneficial. The commercial potential of functional foods containing $n-3$ PUFAs appears to be high especially relative to other bioactive food components (Mantzioris et al., 2000; Wallace et al., 2000). Previous researchers have shown that there is an opportunity to incorporate $n-3$ PUFAs into various food systems (Jafar, Hultin, Bombo, Crowther, & Barlow, 1994; Jacobsen et al., 2001).

Muscle food products from terrestrial livestock comprise a significant portion of the average American consumer's diet, and have the potential to be fortified with PUFAs (Mantzioris et al., 2000). Several studies have revealed that $n-3$ PUFAs from fortified foods are readily absorbed and incorporated into tissues (Mantzioris et al., 2000; Wallace et al., 2000). Mantzioris et al. (2000) proposed that $n-3$ PUFA enriched foods would provide a means to achieve desired biochemical effects of these nutrients without the ingestion of supplements, or a change in dietary habits. Many studies have focused on dietary approaches for altering fatty acid profile of meat obtained from monogastric species (i.e. pigs and poultry) (Faustman, 1993, Chap. 8). Approaches for nutritional modification are generally inefficient and highly variable because dry matter intake, nutrient absorption and tissue incorporation can differ substantially among individual animals (Schaefer, Liu, Faustman, & Yin, 1995). An additional challenge for supplementing diets with specific fats is that oxidative quality of the starting material can vary considerably from source to source, and over time from the same source. An alternative and more efficient approach would be to augment the nutrient profile of meat by selected nutrient fortification.

A specific challenge to increasing the tissue concentration of $n-3$ PUFA is the expected increased susceptibility of fortified muscle food products to lipid oxidation. Inclusion of $n-3$ PUFAs to meat has affected flavor (O'keefe, Proudfoot, & Ackman, 1995), and routine meat processing procedures (e.g. grinding, cooking) can exacerbate oxidation. In lipids with high oxidative susceptibility (e.g. $n-3$ oils), it is necessary to utilize multiple antioxidants to control rancidity development (Decker, 1998), and utilization of antioxidants to maintain lipid stability in muscle food products without alteration of the fatty acid profile has been an effective means to delay lipid oxidation (Ahn, Wolfe, & Sim, 1993; Rhee, Krahl, Lucia, & Acuff, 1997; Wilkinson, Sun, Senecal, & Faustman, 2001). It is logical that an antioxidant combination including sequestrants, reductants and radical quenchers would provide the greatest overall benefit for maintaining lipid stability of $n-3$ PUFA fortified meat products through their expected shelf-life relative to any single antioxidant class alone. The objective of the present study was to investigate the effect of an antioxidant combination on lipid oxidation in meat products fortified with $n-3$ PUFA via an oil-in-water emulsion.

2. Materials and methods

2.1. Reagents

Algal oil (Martek Biosciences Co., Columbia, MD), sodium citrate (ADMArcher Daniels Midland Co., Decatur, IL), potassium sorbate (Jungbunzlauer Inc., Newton Center, MA), ethylene diaminetetracetic acid (EDTA, Akzo Nobel Functional Chemicals LLC, Chicago, IL), mixed tocopherol (70%, Covi-ox T-70, Cognis Co., Cincinnati, OH), and whey protein isolates (Davisco Foods International, Inc., Le Sueur, MN) were obtained for emulsion preparation. Thiobarbituric acid (TBA), ethanol, trichloroacetic acid (TCA), butylated hydroxyanisole (BHA), sodium hydroxide, boron trifluoride–methanol (14%), hexane and heptadecanoic acid (C17:0) were obtained from Sigma Chem. Co. (St Louis, MO, USA.). Fatty acid methyl ester standards of heptadecanoic acid, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) were purchased from Nu-Chek Prep, Inc (Elysian, MN). Ultra pure grade (99.999%) helium, compressed air, nitrogen and hydrogen were obtained from Air Gas East (Hartford, CT). Trisodium citrate was obtained from DSM Nutritional Products, Inc. (Belvidere, NJ, USA), and sodium erythorbate was obtained from Continental Seasoning Inc. (Teaneck, NJ, USA). Rosemary extract was obtained from Kalsec Inc. (Kalamazoo, MI, USA). All chemicals were reagent, food grade or purer.

2.2. Preparation of emulsion

An oil-in-water emulsion containing oil-soluble and water-soluble components was prepared according to the procedure of Djordjevic, McClements, and Decker (2004). Algal oil (25% w/w) which contains approximately 40–42% of DHA and whey protein isolate (WPI; 2.5% w/w) were homogenized with 10 mM sodium citrate buffer (pH 3) containing potassium sorbate (0.2% w/w). Five hundred ppm mixed tocopherols (70% stock) and 100 μM ethylene diaminetetracetic acid (EDTA) were used for stabilization. Homogenates were pasteurized for 30 min at 75 °C.

2.3. Preparation of antioxidant combination

An antioxidant combination containing sodium erythorbate (1 g/kg product; reductant), sodium citrate (0.5% w/w; sequestrant) and rosemary extract (0.2% w/w; radical quencher) was prepared according to the