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Lipid and colour stability of beef from grazing heifers supplemented with sunflower oil alone or with fish oil

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Abstract

The effect of sunflower and fish oil supplementation of grazing heifers on lipid oxidation and colour stability in beef was investigated. For 150 days, heifers were assigned unsupplemented grazing (G) or restricted grazing with 2.5 kg concentrates containing 1250 I.U. α-tocopheryl acetate and 290 g sunflower oil (S1), 415 g sunflower oil (S2), 290 g sunflower + 85 g fish oil (FS1) or 415 g sunflower + 85 g fish oil (FS2). *Longissimus dorsi* muscle was excised 24 h post-mortem and stored at −30 °C prior to analysis. Muscle α-tocopherol in the oil-supplemented groups was higher ($P < 0.05$) than the G group. Lipid oxidation in refrigerated, minced raw or cooked beef was not significantly affected by diet but metmyoglobin was higher ($P < 0.05$) in raw beef from oil-supplemented groups compared to the G group. Lipid oxidation and metmyoglobin formation increased ($P < 0.001$) during refrigerated storage. Vitamin E supplementation together with pasture grazing appeared to offset any potential deleterious effect of oil supplementation on lipid and colour stability.

Keywords: Lipid oxidation in beef; Colour stability; Dietary sunflower and fish oil; Vitamin E

1. Introduction

In recent years there has been an increased interest among consumers in the nutritional composition of food (FSA, 2005). Consumers are becoming more aware of the link between diet and disease and that components of food can have a positive or negative impact on their health. In the wake of dietary recommendations favouring the consumption of less saturated fat (WHO, 2003), modification of animal diets to increase the content of beneficial polyunsaturated fatty acids (PUFA) (C18:3-n-3, linolenic acid; C20:5n-3, eicosapentaenoic acid (EPA); C22:6n-3 docosahexaenoic acid (DHA); conjugated linoleic acid, (CLA)) in animal products has become an area of active research (Chichlowski, Schroeder, Park, Keller, & Schimek, 2005; Raes et al., 2004; Rymer & Givens, 2005; Zotte, Tomasello, & Andrighetto, 2005). The nutritional importance of these n-3 fatty acids in the human diet is well documented (Connor, 2000; Simpoulos, 1999; Whigham, Cook, & Atkinson, 2000).

Increasing the ratio of PUFA to saturated fatty acids (P:S), reducing the n-6:n-3 PUFA ratio and increasing the CLA concentration have also become important targets in the improvement of the nutritional value of beef (Scollan, Dewhurst, Moloney, & Murphy, 2005). Dietary supplementation with oils rich in linolenic acid, linoleic acid (C18:2n-6), EPA and DHA is one strategy employed by animal nutritionists to achieve elevated levels of beneficial fatty acids in beef (Noci, O'Kiely, Monahan, Stanton, & Moloney, 2005; Scollan, Enser, Gulati, Richardson, & Wood, 2003; Vatansever et al., 2000).

While increasing the content of beneficial fatty acids in meat is commendable from a human health perspective, such changes in fatty acid profile may have deleterious effects on the appearance and shelf-life of meat. Increasing the degree of unsaturation of muscle tissue increases its susceptibility to lipid oxidation (Wood et al., 1999), which in

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turn may induce myoglobin oxidation (Monahan, Skibsted, & Andersen, 2005). A challenge to meat scientists seeking to enhance the nutritional composition of beef has been to maintain lipid stability as well as the stability of the desirable bright red colour of fresh beef, in order to retain consumer acceptance.

Dietary vitamin E supplementation plays an important role in improving the antioxidant to pro-oxidant balance in muscle as well as maximising the protection of PUFA against peroxidation (Farrell, 1988). Previous studies have shown that accumulation of α-tocopherol in muscle tissue delays lipid and pigment oxidation (Houben, van Dijk, Eikelenboom, & Hoving-Bolink, 2000; Kerry, Buckley, & Morrissey, 2000; Lee, Kim, Liang, & Kim, 2001; Schwarz, Augustini, Timm, Kirchgeßner, & Steinhart, 1998).

With a view to enhancing the concentration of beneficial fatty acids in beef, grazing heifers were supplemented with different dietary levels of sunflower oil with or without fish oil, in diets fortified with vitamin E (Ermias, Monahan, & Moloney, 2005). The research reported in this paper was conducted to determine if modification of the fatty acid composition of beef affected its shelf-life characteristics, specifically its oxidative stability during refrigerated display. While other studies have also been designed to alter the fatty acid profile of beef by incorporating PUFA rich sources into the diet, the present study is unique because all diets were based predominantly on grass, which is used widely in Irish beef production (O'Kiely, 1994).

2. Materials and methods

2.1. Reagents

All chemicals used were AnalaR grade and obtained from British Drug House, Poole, Dorset, UK; Sigma Chemical Co., Ltd., Poole, Dorset, UK and Rathburn Chemical Co., Ltd., Walkerburn, Peebleshire, Scotland.

2.2. Experimental design and animal management

At Teagasc Grange Beef Research Centre (Dunsany, Co. Meath, Ireland), 60 Charolais crossbred heifers were blocked according to bodyweight (mean initial liveweight 407 kg, sd 31.3) and, within block, assigned randomly to one of 5 dietary treatments ($n = 12$ per treatment): unsupplemented grazing at a grass DM allowance to ensure consumption of 2.5% bodyweight per animal (G) or restricted grazing to ensure similar carcass growth to the unsupplemented grazing group, with an individual daily supplement of 2.5 kg concentrates containing 1250 I.U. vitamin E and 290 g sunflower oil (S1), 415 g sunflower oil (S2), 290 g sunflower oil + 85 g fish oil (FS1) or 415 g sunflower oil + 85 g fish oil (FS2). The vitamin E (α-tocopheryl acetate supplied by vitamin E50, which contained 50% w/w active vitamin E, Roche Vitamins) was added to the concentrate via a vitamin and mineral premix prepared by David Taylor, Animal Nutrition Ltd, Co. Westmeath, Ireland. The supplements were formulated to be isonitrogenous and isoenergetic and to have similar total fat contents, with Megalac protected fat (Volac International Ltd., England) balancing the energy content of sunflower oil and fish oil (Table 1). The groups were rotationally grazed on a predominantly perennial ryegrass sward. Daily grass allowances were achieved by varying the size of the grazing area. Animals were offered a fresh grass allowance every 2–3 days and were not allowed access to the previous day's allowance. Pre-grazing grass mass area was estimated using a plate meter (Filips Folding Plate Meter, Jenquip, New Zealand). Animals receiving supplements along with grass were constrained individually in a specially built mobile feeder in the field until concentrates were consumed (typically 20 min). Samples of grass and concentrates (1 ± 0.1 kg) were collected on a weekly basis throughout the experiment, stored at −20 °C and sub-samples were composited on a monthly basis. The average duration of the feeding period was 150 days from May to October.

2.3. Slaughter and beef sampling

Animals were weighed at the end of the feeding period and slaughtered in 3 groups of 20 animals each, according to block, at weekly intervals at a commercial abattoir (Meadow Meats, Rathdowney, Co Laois, Ireland), within 6 h of removal from Grange Beef Research Centre. Carcasses were weighed and held in a chill for 24 h at 4 °C. Average daily gain was calculated by dividing the liveweight change by the duration on each dietary treatment, cold carcass weight as 0.98 of carcass weight immediately post slaughter and dressing percentage as cold carcass weight divided by final liveweight. The carcasses were cold-boned at 24 h post-mortem and samples of *Longissimus dorsi* muscle were excised from the 10th rib in the posterior direction on one side of the carcass and divided into steaks (2.5 cm thick). Steaks were then vacuum packaged and frozen at −30 °C for subsequent analysis.

Table 1
Composition of concentrate supplements

Ingredients (kg/tonne)	S1	S2	FS1	FS2
Wheat pollard	725	725	725	725
Mineral/vitamin[a]	25	25	25	25
Molasses	50	50	50	50
Megalac	84	34	50	0
Sunflower Oil	116	166	116	166
Fish Oil	0	0	34	34

[a] contained 20,000 I.U. vitamin E (α-tocopheryl acetate)/kg and Ca (28.5%), P (1.6%), Na (5.6%), vitamin A (500,000 I.U./kg), vitamin D_3 (125,000 I.U./kg), cobalt carbonate (42 mg/kg), cupric sulphate (500 mg/kg), calcium iodate (10 mg/kg), iron sulphate (1000 mg/kg), manganese sulphate (5800 mg/kg), sodium selenite (16 mg/kg), and zinc sulphate (7500 mg/kg).