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Healthy fatty acid-enriched fresh beef: implications for shelf-life and flavour

Key external stakeholders:

Beef producers/processors, Bord Bia, Health professionals.

Practical implications for stakeholders:

Strategies to manipulate the fatty acid composition of beef and the implications of the modified beef on shelf-life and flavour were examined.

- The findings will assist the beef industry in the production of beef with enhanced fatty acid composition from a human health perspective, and to prevent any associated deleterious effect on shelf-life or sensory characteristics of beef.
- The findings will also assist the marketing of Irish grass-produced beef.

Main results:

- Muscle lipids of pasture-fed cattle contained higher vaccenic acid, total and c9, t11-conjugated linoleic acid proportions than those from concentrate-fed cattle.
- Supplementation of pasture with plant/marine oils resulted in larger marginal increases in total and c9, t11- conjugated linoleic acid than supplementation of concentrate.
- The shelf-life of the modified beef was unaffected.
- The rather extreme dietary treatments had relatively small effects on shelf-life and sensory characteristics of beef.

Opportunity / Benefit:

The feasibility of producing beef with an enhanced fatty acid composition from a human health perspective, beyond that found in conventionally produced beef was demonstrated. The main challenge to industry is to develop a marketing strategy to capture this potential.

Collaborating Institutions:

UCD, University of Bristol, UK, MTT Finland

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1. Project background:

Typical Irish grass-fed beef has a fatty acid composition more compatible with dietary recommendations for improved consumer health than that of competing European beef. Grass-fed beef also has higher concentrations of CLA (a range of isomers of linoleic acid that have positive health effects relating to cancer, obesity, diabetes and coronary heart disease). To fully capture the added value of Irish grass-fed beef as a healthy, functional food, the concentration of beneficial fatty acids must be optimised such that beef becomes a significant source of these fatty acids in the human diet. There is scope to increase the CLA concentration in grass-fed beef. Dietary management to enhance CLA synthesis prior to grazing together with strategic supplementation during grazing, would likely increase the final concentration in beef beyond that previously observed. The primary route of tissue CLA synthesis is via endogenous desaturation of ruminally-derived trans vaccenic acid (TVA) by delta 9-desaturase. Nutritional regulation of the delta 9-desaturase gene has been demonstrated in rodents but little is known about the regulation of this gene in beef cattle. Up-regulating the expression of the delta 9-desaturase gene, together with an adequate supply of substrate, would increase tissue synthesis of CLA. The targeted increase in CLA concentration may increase the susceptibility of beef lipids to oxidation resulting in the development of unhealthy oxidation products, decreased colour stability and altered flavour. While grass provides antioxidant protection to meat, additional antioxidants may be required when beef is further enriched with polyunsaturated fatty acids. The extent to which natural dietary antioxidants stabilize beef lipids as well as the benefit of supplementary antioxidants needs to be clarified.

2. Questions addressed by the project:

- Will supplementation of grazing cattle with plant/marine oil-based supplements increase the concentrations of CLA and omega-3 PUFA ratio in bovine muscle?
- Will increasing the duration of supplementation increase the concentrations of these fatty acids still further?
- Does supplementation decrease the shelf-life of beef?
- Does supplementation alter the flavour of beef?

3. The experimental studies:

Two beef production studies were carried to test hypotheses concerned with dietary manipulation of the fatty acid composition of beef. In the first experiment, Charolais crossbred heifers (n = 10/treatment) were offered a basal concentrate, unsupplemented or supplemented with a high fatty acid concentrate that contained no additional antioxidant or a low, medium or high concentration of Vitamin E, unsupplemented grazed grass or grazed grass supplemented with a high fatty acid concentrate that contained no additional antioxidant or a medium concentration of Vitamin E. In the second experiment, Charolais crossbred heifers (n = 10/treatment) were offered either a standard ration or a ration designed to enhance CLA synthesis during the winter. Within each group, animals were then offered unsupplemented grazing for 22 weeks, unsupplemented grazing for 11 weeks followed by supplementation with a blend of sunflower oil and fishoil for 11 weeks or supplementation with this oil blend for 22 weeks before slaughter. The cattle were grown at Grange Beef Research Centre and slaughtered in a commercial abattoir. The fatty acid composition of beef was measured using a combination of gas chromatography and high pressure liquid chromatography. Expression of selected genes coding for enzymes involved in lipid metabolism

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was measured in UCD using appropriate molecular biology techniques. Colour and lipid stability was measured in Ashtown Food Research Centre during display of meat in a modified atmosphere while descriptive flavour analysis of cooked beef was carried out using a trained panel of assessors in the University of Bristol.

4. Main results:

Cattle production

Muscle lipids of pasture-fed cattle contained higher TVA, total and c9, t11-CLA proportions; supplementation of pasture resulted in larger marginal increases in total and c9, t11-CLA than supplementation of concentrate; sunflower oil induced a higher enrichment of TVA, total and c9, t11-CLA in muscle relative to sunflower seeds; The predominant CLA isomer in the neutral lipid fraction of unsupplemented grass-fed beef was c9, t11 followed by t11, c13. Supplementation of grass with sunflower/fishoil altered this distribution such that t7,c9 became the second most prominent isomer. Supplementation of concentrates with sunflower/fishoil decreased the proportion of c9,t11 and increased the proportion of t7,c9. There was little effect of vitamin E supplementation on the isomeric distribution of CLA. At least eighteen isomers could be detected in the polar lipid fraction.

With respect to the CLA proportion in muscle lipids, there was no interaction between winter ration composition and subsequent summer ration; increasing the duration of consumption of a fishoil oil/sunflower oil supplement at pasture increased the proportion of CLA in muscle lipids. The highest concentration of CLA was observed in cattle that had been fed a CLA-enhancing supplement in winter and summer.

Gene expression

Delta-9 desaturase mRNA levels were lower in muscle and subcutaneous adipose of grass-fed animals compared to concentrate-fed animals but were unchanged in liver ($P>0.05$). Supplementation of the diet with sunflower oil/fishoil had no effect on delta-9 desaturase gene expression in any tissue examined.

Delta-9 desaturase mRNA levels were higher in muscle from animals that had received wilted grass silage during winter. Delta-9 desaturase mRNA levels were higher after supplementation of grazing heifers with a sunflower oil-containing concentrate for 11 weeks but declined thereafter.

Shelf-life studies

While an increase in vitamin E stabilised lipids it is not required to stabilise colour of grass-fed beef; for concentrate feeding systems, the beneficial effects on redness and saturation of increasing the dietary supply of vitamin E become more apparent as the display period progresses; grazing is as effective as a targeted vitamin E intake of 3,000 I.U.•head^{-1}•d^{-1}on a concentrate-based diet in terms of colour stability; mincing caused increased discoloration and lipid oxidation.

Long term supplementation of grazing heifers with a sunflower oil-containing concentrate increased lipid oxidation. The colour of previously-frozen muscle was less stable than fresh muscle.

Flavour

There were relatively minor differences between pre-slaughter rations and measured flavour attributes; beef from grass-fed cattle was more “greasy” than that from concentrate-fed cattle but overall liking was not affected by the dietary treatments examined.

Toughness was higher in steaks from animals that had received wilted grass silage during winter but they had higher beef flavour intensity and lower abnormal flavour intensity. There were no significant differences in any of the descriptive flavour terms. Steaks from animals that had received oil supplementation for 22 weeks were juicier than steaks from unsupplemented animals but did not differ from those from animals that had received oil supplementation for 11 weeks.

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Steaks from oil-supplemented animals were more greasy and were more preferred than steaks from unsupplemented animals. In general differences, while statistically significant, were small.

5. Opportunity/Benefit:

The data generated on the impact of dietary modification on the fatty acid composition of bovine muscle will assist beef producers in the production of beef with enhanced fatty acid composition from a human health perspective. A comprehensive dataset on fresh colour, colour and lipid stability and on the sensory characteristics of bovine muscle was developed. These data demonstrate the rather small effects of rather extreme dietary treatments on muscle technological characteristics. They therefore provide encouragement to further development of such strategies.

The information obtained on the molecular basis of CLA synthesis adds to the current state of knowledge in this field and may be important in the development of future hypotheses.

Material generated in this project was used in a subsequent project coordinated by Prof. Roche (06RDTCD488) to elucidate the mechanisms underpinning the beneficial effects of beef CLA. From a beef cattle perspective, future strategies will include identification of animals/genotypes that have a greater propensity to accrete fatty acids of benefit to human health and elucidation of genotype by nutrition interactions. The variability in CLA concentration among similar cattle fed a common rations merits research attention and is a potential obstacle to uptake by industry. In addition the likely necessity to produce supporting evidence for a health claim on a functional food product will require further animal model but also human intervention type studies.

6. Dissemination:

Workshops

Moloney A.P. (2008) Presentation at Teagasc event (FarmFest), Athenry.

Moloney A.P. (2008) Recent Advances in Beef Quality, Workshop, Swedish University of Agricultural Sciences (SLU).

Moloney A.P. and Roche H.M. (2009) Relay Workshop Ashtown Food Research Centre.Moloney A.P. (2009) Industry Information Day, Ashtown Food Research Centre.

Main publications:

Moloney, A.P. (2007) 'Enrichment of omega-3 fatty acids and CLA in beef by diet modification' *Irish Veterinary Journal* 60 (3):180-185.

Moloney, A.P., Daly, C.M., Shingfield, K.J. and Monahan, F.J. (2007) 'Fatty acid composition of *longissimus* muscle from grazing or concentrate-fed cattle supplemented with sunflower seeds and fish oil' *Proceedings II International Congress on Conjugated Linoleic Acid*, Sardinia, Italy, p20-22.

Dunne, P.G., Monahan F.J. and Moloney A.P. (2009) 'Long-term supplementation with sunflower/fish oil-containing concentrates in a grass-based beef production system: effects on colour and lipid stability during retail display' *Journal of Animal Science* 87:369.

Popular publications:

Moloney, A. P. (2007) 'Producing beef that meets consumer needs' Hand-out for visit of IASTA to Grange Beef Research Centre, 4 pages.

Moloney, A.P. (2008) 'Producing quality beef for the consumer' In: *Grange Beef Research Centre Open Day Booklet*, 3 pages.

Moloney, A.P. (2009) 'Increasing the healthiness of beef' *Teagasc Beef Newsletter*.

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