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Production and human health benefits of beef enriched with conjugated linoleic acid (CLA)

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 the health of the consumer were examined.

- The findings will assist the beef industry in the production of beef with enhanced fatty acid composition from a human health perspective.
- The findings will also assist the marketing of Irish grass-produced beef.

Main results:

- Supplementation of grazing cattle with plant/marine oils increased the levels of total and the *cis*9, *trans*11 isomer of CLA in beef.
- The shelf-life of the modified beef was unaffected.
- Beef derived CLA was beneficial in increasing insulin sensitivity in a rodent model of obesity.

Opportunity / Benefit:

The feasibility of increasing the nutritional value of Irish beef beyond that found in conventionally produced beef was demonstrated. This, together with evidence that nutritionally enhanced beef had beneficial effects in a mouse model of human disease provides an opportunity for the development of functional beef and beef products. The future challenge is to develop production strategies to enhance the nutritional value still further and marketing strategies to capture this potential value to the producer and the consumer.

Collaborating Institutions:

UCD, TCD, MTT Finland

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1. Project background:

Irish grass-fed beef has higher concentrations of omega-3 polyunsaturated fatty acids (PUFA) and conjugated linoleic acid (CLA) than beef produced in competing European countries. Increased consumption of omega-3 fatty acids is advised by the medical profession. The optimum achievable concentration of beneficial fatty acids is not known but the higher the concentration, the greater the competitive advantage of Irish beef as a significant source of these healthy fatty acids. Medical research has shown a number of positive health effects of chemically synthesised CLA, which indicates that it may have therapeutic potential with respect to common diet-related health conditions including cancer, obesity, coronary heart disease and diabetes. Little is known about the bioavailability and efficacy of naturally produced CLA such as that found in beef. Enrichment of Irish beef with natural CLA may confer a marketing advantage if it was also demonstrated that beef CLA had therapeutic effects relevant to human health.

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?
- Is the shelf-life of beef from supplemented animals affected?
- Would consumption of modified beef influence the health of the consumer?

3. The experimental studies:

Cattle production

For 150 days prior to slaughter, heifers were assigned unsupplemented grazing (G) or restricted grazing with 2.5kg concentrates containing 1250 I.U. alpha-tocopheryl acetate and 290g sunflower oil (S1), 415g sunflower oil (S2), 290g sunflower + 85g fish oil (FS1) or 415g sunflower + 85g fish oil (FS2). After slaughter, samples of the *longissimus dorsi* (striploin) muscle were collected and the fatty acid composition measured by gas chromatography and high pressure liquid chromatography.

Shelf-life studies

The oxidative stability of muscle lipids and myoglobin in raw or cooked minced beef, during display in modified atmosphere packaging, was determined. In parallel, the concentration of vitamin E in muscle was determined.

Studies with a rodent model of diabetes/obesity

Samples of beef muscle and adipose tissue were collected from animals with normal or high measured CLA concentrations and included in the diet of ob/ob mice, which is an accurate model of human obesity, diabetes and insulin resistance. The treatments were: low CLA beef, high CLA beef, low CLA beef + synthetic CLA, low CLA beef + synthetic vaccenic acid. Biomarkers of lipid metabolism and insulin resistance (plasma cholesterol, triacylglycerol, insulin and glucose concentrations, body weight and composition) and molecular markers of hepatic lipid metabolism, insulin and glucose metabolism were measured.

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4. Main results:

Cattle production

The neutral lipid fraction of muscle from G, S1, S2, FS1 and FS2-fed cattle had 1.29, 1.80, 2.18, 2.32 and 2.44 (sem 0.132) g c9,t11CLA /100g fatty acids, respectively. The corresponding values were 0.66, 0.44, 0.42, 0.42 and 0.47 (sem 0.030) for alpha-linolenic acid. The phospholipid fraction of muscle from G, S1, S2, FS1 and FS2-fed cattle had 0.59, 0.88, 1.12, 1.35 and 1.20 (sem 0.101) g c9,t11CLA /100g fatty acids, respectively. The corresponding values were 4.61, 2.21, 2.35, 2.19 and 2.53 (sem 0.258) for alpha-linolenic acid, 3.76, 1.98, 1.75, 2.37 and 2.31 (sem 0.250) for eicosapentaenoic acid and 0.15, 0.06, 0.02, 0.35 and 0.61 (sem 0.053) for docosahexaenoic acid.

Shelf-life studies

Muscle α-tocopherol in beef from 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.

Studies with a rodent model of diabetes/obesity

While neither diet had an effect on plasma cholesterol and triacylglycerol levels, the CLA enriched beef diet effectively reduced plasma glucose and NEFA levels ($P<0.05$), which would indicate improvements of the diabetic phenotype. Adiponectin levels were increased ($P<0.05$) and IL-6 levels were decreased ($P<0.05$) in the animals receiving the CLA diet compared to the low CLA beef and low CLA beef + vaccenic acid diets.

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. Data from the shelf-life study demonstrate the rather small effects of rather extreme dietary treatments. They therefore provide encouragement to further development of such strategies.

While the data with a rodent model suggest that beef enriched with CLA may have beneficial effects on glucose metabolism, insulin sensitivity and inflammation, the results need further clarification. However they do provide positive information in relation to the feasibility of nutritionally enhancing Irish beef and the development of functional beef and beef products.

6. Dissemination:

Workshops

Moloney A.P. (2009) Industry Information Day, Ashtown Food Research Centre.

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

McMonagle J., Toomey S., Moloney A. and Roche H.M. (2007). Feeding a diet with CLA enriched beef improves the diabetic phenotype in ObOb mice. Presented at Nugo course – Diabetes: from individual genes to the systems level, Munich, Germany. 4-7 July 2007.

Main publications:

Ermias, E., Monahan, F.J. and Moloney, A.P. (2005) 'The fatty acid composition of Longissimus muscle from grazing cattle supplemented with sunflower oil and fish oil' *Journal of Animal Science* 83 (Suppl. 1): 240. Available: http://www.fass.org/2005/abstracts/05abs239.pdf

Daly, C.M., Moloney A.P. and Monahan, F.J. (2007) 'Lipid and colour stability of beef from grazing heifers supplemented with sunflower oil alone or with fish oil' *Meat Science* 77: 634-642.

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Morine, M.J, McMonagle, J., Toomey, S., Reynolds, C.M., Moloney, A.P., Gormley, I.C., Ó Gaora, P. and Roche, H.M. (2010) 'Bi-directional gene set enrichment and canonical correlation analysis identify key diet-sensitive pathways and biomarkers of metabolic syndrome' *BMC Bioinformatics*, 11:499. Available:http://www.biomedcentral.com/1471-2105/11/499

Popular publications:

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.

7. **Compiled by:** Dr Aidan Moloney

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