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Reducing enteric methane production by finishing beef cattle

Key external stakeholders:

Dept. Agriculture, Food and the Marine, beef farmers, beef industry, policy-makers.

Practical implications for stakeholders:

Greenhouse gas (GHG) emissions from finishing cattle systems reflect the dietary ingredients fed. Diets high in cereal grains increase growth rate and reduce enteric methane emissions compared to forage-based diets. A life-cycle analysis accounting for (a) direct and indirect GHG emissions (carbon dioxide, methane and nitrous oxide) from the cattle production system, (b) carbon sequestration under permanent grassland, and (c) carbon loss where grassland is replaced by cereals or maize, indicates that the beef from cattle finished on a grass silage-based diet had a lower emissions intensity (a.k.a. carbon footprint; kg CO_2e/kg carcass gain) than from a diet based on maize silage, whole-crop cereal silage or *ad libitum* concentrates. The results of this project provide:

- **Farmers** with dietary and management strategies for simultaneously increasing profitability and reducing the emissions intensity of the beef they produce.
- **Policy makers** with the evidence that national GHG inventory systems must account for land use and land use change (LULUC) in addition to the more obvious direct and indirect emissions of GHG.
- **Beef exporters** with a marketing advantage for Irish beef produced from permanent grassland.

Main results:

- Increasing the growth rate of finishing cattle by feeding diets of higher grain content reduced the output of enteric methane.
- A final decision on the efficacy of any strategy for reducing GHG emissions must account for all GHG emitted and for associated changes in the carbon status of the soil. Thus, when soil carbon is assumed to be in equilibrium, cattle finishing systems based on high grain diets have a lower emissions intensity than finishing systems with grass silage-based diets. However, when account is taken of carbon sequestration under permanent grassland and carbon loss where permanent grassland is tilled (to sow small-grain cereals or maize), the estimated GHG emissions intensity of beef is significantly altered such that finishing cattle on grass silage-based diets have a lower emissions intensity.

Opportunity / Benefit:

The results show

- **Farmers** that increasing animal productivity increases profits and reduces GHG emissions intensity.
- **Policy makers** the importance of ensuring that national inventory systems account for changes in soil carbon status in addition to the more standard emissions of GHG.
- **Beef exporters** the opportunity to market Irish beef as generally having a low emissions intensity arising from the permanent grassland based production systems that dominate the Irish cattle sector.

Collaborating Institutions:

University College Dublin (UCD)

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1. Project background:

Increases in atmospheric concentrations of GHG are considered a likely cause of global warming. In Ireland, 29% of our national emissions derive from agriculture, a much higher proportion than occurs in other northern European countries. Since enteric methane produced by ruminants (predominantly cattle) contributes about half of the GHG output from Irish agriculture, mitigating methane output has been the focus of considerable research.

Diets that provide cattle with an increasing proportion of starch (e.g. maize silage harvested at a more advanced growth stage, whole-crop wheat silage of higher grain content, barley grain fed to appetite) are predicted to reduce methane emissions and increase animal growth rate, thereby reducing emission intensity (i.e. kg CO_2e/kg carcass gain; CO_2e is the amount of carbon dioxide that has an equivalent global warming potential as the net amount of carbon dioxide, methane and nitrous oxide released as part of the beef production system). What is unclear is the extent of these effects, the relativity between contrasting feeds and what the overall outcome might be as assessed by a life-cycle assessment.

2. Questions addressed by the project:

- What effect does delaying the harvest date of forage maize (thereby allowing its starch content to increase) have on both the carcass gain and enteric methane output of finishing beef cattle, and how does this compare to a diet based on cereal grain concentrates fed *ad libitum*?
- What effect does increasing the grain content of whole-crop wheat silage (thereby allowing starch content to increase) have on both the carcass gain and enteric methane output of finishing beef cattle, and how does this compare to a diet based on grass silage or cereal grain concentrates fed *ad libitum*?
- What are the relative outputs of methane from these and other comparable feeds when assessed in an *in vitro* rumen digestion system?
- What are the effects on profitability and total GHG emissions intensity of beef produced when the above diets are fed to finishing cattle?

3. The experimental studies:

- Forage maize was harvested and ensiled on four occasions between early September and late October. Groups of 12 beef steers were offered one of these silages (plus 3 kg concentrates per head daily) or concentrates *ad libitum* for 110 days. Feed composition, intake and digestion characteristics were measured together with animal performance, methane production (using the sulphur hexafluoride (SF_6) based technique), and carcass and blood plasma traits.
- Whole-crop wheat silage was separated into grain and straw + chaff fractions and recombined in four ratios - 11:89, 21:79, 31:69 and 47:53. Groups of 15 beef steers were offered one of these mixtures or grass silage (plus 3 kg concentrates per head daily) or concentrates *ad libitum* for 154 days. Feed composition, intake and digestion characteristics were measured together with animal performance, methane production (using the SF_6 based technique), rumen fermentation characteristics, and carcass and blood plasma traits.
- The *in vitro* rumen total gas production technique was used as a rapid screening tool to quantify fermentation characteristics, methane output and dry matter disappearance for a range of feeds including grass, maize and whole crop cereal silages, and wheat, barley and triticale grains stored dry or moist (stored anaerobically).
- A hybrid modeling approach was used to evaluate the physical and financial performance of the production systems corresponding to the finishing diets under investigation and their associated GHG emissions. A bioeconomic model (Grange Beef Systems Model) specified the animal

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production profile, the inputs to and the outputs from the assumed systems, and the associated financial performance. A beef systems greenhouse gas emissions model (BEEFGEM) then calculated (a) direct emissions including those arising from enteric fermentation, agricultural soils and manure management, (b) indirect emissions from ammonia volatilization, nitrate leaching and from the production of inputs utilised in beef production, and (c) GHG emissions or sequestration associated with land use and land use change (LULUC; i.e. permanent pasture vs. tilling). The estimates of carbon sequestration and loss from soils entailed a degree of uncertainty in their calculation.

4. Main results:

- The relatively narrow range achieved in maize maturities meant that that animal performance response to the harvest date of maize was quite small. Nevertheless, the intensity of methane emissions (methane per kg carcass gain) declined with maize silages made from crops harvested at more advanced stages of maturity. In addition, higher performance and lower methane emission intensity occurred when animals consumed concentrates *ad libitum*.
- The wide range achieved in whole-crop wheat silage grain content meant that increasing its grain content increased animal performance and reduced methane emission intensity. Grass silage supported similar performance and methane emission as the 21:79 and 31:69 ratio whole-crop wheat silages, but the highest performance and lowest methane emission intensity occurred when animals consumed concentrates *ad libitum*.
- The methane responses observed in the *in vitro* study contradicted expected *in vivo* trends in methane output, thus challenging the reliability of the *in vitro* technique to usefully determine methane output of feeds differing widely in fibre and starch contents.
- Based on the assumptions made (including accounting for LULUC) in the whole-farm systems modelling exercise, the finishing system based on grass silage supported the highest net financial margin and the lowest GHG emissions intensity.

5. Opportunity/Benefit:

The results show;
Farmers that increasing animal productivity can increase profits and reduce GHG emissions intensity.

Policy makers the importance of ensuring that national inventory systems account for changes in soil carbon status in addition to the more standard emissions of GHG.

Beef exporters the opportunity to market Irish beef as generally having a low emissions intensity arising from the permanent grassland based production systems that dominate the Irish cattle sector.

6. Dissemination:

Main publications:

McGeough, E.J., Crosson, P., Kenny, D.A. and O'Kiely, P. (2012). 'Greenhouse gas emissions from integrated crop - beef finishing systems.' *Journal of Animal Science* (in preparation).

McGeough, E.J., O'Kiely, P., Foley, P.A., Hart, K.J., Boland, T.M. and Kenny, D.A. (2010). 'Methane emissions, feed intake, and performance of finishing beef cattle offered maize silages harvested at 4 different stages of maturity.' *Journal of Animal Science*, 88: 1479-1491.

McGeough, E.J., O'Kiely, P., Hart, K.J., Moloney, A.P., Boland, T.M. and Kenny, D.A. (2010). 'Methane emissions, feed intake, performance, digestibility, and rumen fermentation of finishing beef cattle offered whole-crop wheat silages differing in grain content.' *Journal of Animal Science*, 88: 2703-2716.

Popular publications:

O'Kiely, P., O'Brien, M., McGeough, E., Navarro-Villa, A. and Purcell, P. (2010). 'Reducing methane emissions from cattle.' *TResearch*, 5 (1) Spring :38-39.
http://www.teagasc.ie/publications/2010/6/6_TResearch_201002.pdf

The Investigators (popular science TV documentary series) – Padraig O'Kiely appeared in Programme 2 entitled "Climate Change". http://www.rte.ie/tv/theinvestigators/prog2.html

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Public lecture organized by UCD Earth Sciences Institute, TCD TrinityHaus and Dublin City Council, under the TCD-UCD Innovation Alliance and in collaboration with Business in the Community and the main agencies involved involved in delivering policy (Comhar Sustainable Development Council, Enterprise Ireland, EPA, Geological Survey of Ireland, Marine Institute, Met Éireann, Sustainable Energy Authority of Ireland and Teagasc). The lecture ('Future opportunities to reduce bovine greenhouse gas emissions') given by Padraig O'Kiely can be accessed at
http://www.ucd.ie/earth/newsevents/transformingirelandseminarseries2010/seminar1160310/

7. Compiled by: Padraig O'Kiely, Emma Mc Geough, Paul Crosson and David Kenny

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