Food Institutional Research Measure

Final Report

Irish Meat and Eggs: their fundamental role in promoting vitamin D nutrition and contribution to health and well-being [EnhanceD meats and eggs]

DAFM Project Reference No: 11/F/021
Start date: 1/4/2013
End Date: 30/9/2016

Principal Coordinator and Institution: Professor Kevin Cashman, University College Cork
Email: k.cashman@ucc.ie

Collaborating Research Institutions and Researchers:
University College Cork [Professor Kevin Cashman and Professor Joe Kerry]
University College Dublin [Professor John O'Doherty and Dr. Alan Kelly]

Please place one “x” below in the appropriate area on the research continuum where you feel this project fits

<table>
<thead>
<tr>
<th>Basic/Fundamental</th>
<th>Applied</th>
<th>Pre-Commercial</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3 X 5 6 7</td>
</tr>
</tbody>
</table>

Please specify priority area(s) of research this project relates to from the National Prioritisation Research Exercise* (NRPE) report:

| Priority Area(s) | (I) Sustainable Food Production and Processing | (H) Food for Health |

Key words/terms: (max 4): Vitamin D deficiency, Vitamin D-biofortified meat, Vitamin D-biofortified eggs
1. Rationale for Undertaking the Research

It is well-established that prolonged and severe vitamin D deficiency leads to rickets in children and osteomalacia in adults\(^1\), while more marginal vitamin D deficiency may be associated with increased risk of a wide range of other chronic diseases\(^2\). Of concern, we have recently shown that in our nationally representative National Adult Nutrition Survey, 12% and 46% of Irish adults aged 18-84 years had severe and marginal vitamin D deficiency, respectively, with similar average prevalences being reported for Europe\(^3,4\).

In humans, vitamin D is obtained primarily through dermal biosynthesis in the presence of ultraviolet B sunlight, and also from the diet. However, in the absence of sufficient sun exposure for dermal synthesis (e.g. during the 5 months of extended winter and increasingly even in summer, as a consequence of sun awareness/avoidance campaigns), dietary supply of vitamin D takes on major importance. However, due to the limited number of vitamin D-rich foods, the mean daily intakes of vitamin D by Irish adults (aged 18+ y) is relatively low at only \(\sim 4 \mu g/d\)\(^5\). Thus, there is a significant gap between current intakes in Ireland (and elsewhere) and recommended intakes for vitamin D (15 and 20 \(\mu g/d\), for those aged 1-70 and 70+ years, respectively\(^1\)).

Thus, there is an urgent need for food-based strategies for increased vitamin D intake so as to minimise risk of vitamin D deficiency in our populations. Meat and eggs have important potential as two of these food-based strategies\(^6\). Specifically, this project was undertaken to provide evidence that meat and eggs, already significant sources of vitamin D and its major metabolite [25-hydroxyvitamin D]\(^7\), could be enhanced further and in this way, can help improve vitamin D status of Irish individuals. In particular, improvements in the 25-hydroxyvitamin D content of foods would be of importance to human nutrition, as it is has been shown in an intervention study in older Irish adults to be five times more effective at raising serum 25(OH)D [the biochemical marker of vitamin D status] compared to an equivalent amount of vitamin D\(_3\) consumed\(^8\). This approach of increasing the vitamin D activity of meat and eggs, and potentially other foods of animal origin, by increasing the dietary vitamin D/25-hydroxyvitamin D level in the feedstuffs of the animal has been referred to as biofortification\(^6\). Such scientific data would underpin and support positive messages on meat and egg consumption, their fundamental role in the diet as well as their contribution to health and well-being.

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\(^7\)Cashman KD. The role of vitamers and dietary-based metabolites of vitamin D in prevention of vitamin D deficiency. Food Nutr Res. 2012;56.

2. Research Approach

The research approach employed in this multi-disciplinary, trans-Institutional project included use of animal/hen dietary feeding trials, food vitamin D analytics, sensory evaluation studies, dietary modelling of the impact of vitamin D-enriched foods on Irish population intakes of vitamin D as well as a dietary intervention study in older Irish adults. A core aim of the EnhanceD project was the provision of proof that vitamin D₃ and 25-hydroxyvitamin D content of Irish eggs and meat (pork and beef) could be improved above their normal nutritionally significant levels (i.e., bio-fortified). This was tested in a series of novel feeding studies in hens, pigs and beef heifers, conducted in the UCD Lyons Research Farm. In the hen trials, laying hens were fed either a control diet (with vitamin D₃ at just half the EU upper allowable level; i.e., 1500 IU/kg diet) or an experimental diet in which the vitamin D₃ and/or 25-hydroxyvitamin D content was increased to the maximum allowable EU limit (3000 IU/kg diet). In the pig trials, pigs were fed either a control diet (with vitamin D₃ at the EU upper allowable level; i.e., 2000 IU/kg diet) or an experimental diet in which the vitamin D₃ was replaced with vitamin D₃ plus 25-hydroxyvitamin D or 25-hydroxyvitamin D only (2000 IU/kg diet). In both hens and pigs, use of 25-hydroxyvitamin D in animal feedstuffs is permissible, but not for cattle feeds. In the beef heifer trial, cattle were fed either a control diet (with no vitamin D₃) or an experimental diet in which the vitamin D₃ content was increased to the half and the maximum allowable EU limit (2000 and 4000 IU/kg diet, respectively). The eggs, pork meat, and beef steaks obtained at the end of these feeding trials were tested for their vitamin D and 25-hydroxyvitamin D contents to show that their levels were increased. This was done using state-of-the-art liquid chromatography tandem mass spectrometry methodology. The effects of extra vitamin D compounds on animal growth and performance as well as quality aspects of the meat/eggs were also assessed. It was also important to check that this increased vitamin D did not cause alterations in the sensory acceptance of the meat and eggs by the consumer and thus a series of sensory evaluation tests (using between 18 and 40 naïve assessors) were conducted in University College Cork (UCC) and in accordance with the ISO standard.

A separate pilot trial in cattle was conducted to test whether the vitamin D₃ and/or 25-hydroxyvitamin D content of beef at point of sale (and following the usual processing conditions) decreased from the peri-mortem levels, which is a good reflection of that in muscle in vivo.

Finally, a randomised, double-blind, food-based dietary intervention trial was conducted in older adults to show that vitamin D-biofortified Irish eggs can increase serum 25(OH)D levels in older Irish adults during winter and thus produce critical evidence of the effectiveness of vitamin D-biofortified foods. This UCC-based intervention trial used vitamin D-enhanced eggs supplied in a separate follow-up hen feeding study in UCD Lyons Research Farm which used the optimal vitamin D treatments as identified in the first feeding trial. While originally planned to be, the pork and beef from the feeding trials were not included in the human intervention trial for logistical reasons (i.e., a pig feeding trial in the time running up to the human study was delayed thus pork was not available; in terms of beef, because the eggs and pork from hens and pigs, respectively, fed the 25-hydroxyvitamin D-containing diets were envisaged being used in the human intervention trial, that the beef would not come from 25-hydroxyvitamin D (as not allowable in the EU at present; only vitamin D) led to a decision that it should not be included in the human trial from a design perspective). However, data on the impact of these biofortified meats on preventing vitamin D nutritional inadequacy has been modeled in the Irish adult population by use of data from the relevant pig and cattle tasks coupled to the new data from our human intervention study with eggs in a dietary modelling approach developed in the EU-funded ODIN vitamin D project (coordinated by UCC).
3. Research Achievements/Results

The project completed all animal/hen feeding studies, the pilot peri-/post-slaughter study of changes in vitamin D content of meat, all the sensory panel trials, the human intervention trial, and the dietary modelling of the impact of biofortified eggs and meat on the intake of vitamin D in the Irish diet.

The following is a concise summary of the main results achieved in these various elements:

- **The hen feeding trials** showed that inclusion of 25-hydroxyvitamin D, followed closely by 25-hydroxyvitamin D plus vitamin D\(_3\), and vitamin D\(_3\) only (all at the EU allowable limit of 3000 IU/kg) achieved eggs with total vitamin D activity in the range of 5.1 to 3.8 \(\mu g/\text{egg}\), respectively, compared to 3.8 \(\mu g/\text{egg}\) for eggs from hens receiving the 1500 IU/kg vitamin D diet.

- **The sensory evaluation studies of boiled and fried eggs** (using 22 and 18 sensory panellists) showed that there were no significant (P>0.05) differences in hedonic or intensity sensory scores between any of the four treatment groups, suggesting the consumer acceptability of vitamin D-biofortified eggs was equivalent to non-biofortified eggs.

- **The winter-based dietary intervention study of older adults** (n=55) showed that weekly consumption of 7 vitamin D-biofortified eggs, produced by hens provided with feed containing 25-hydroxyvitamin D\(_3\) or vitamin D\(_3\) at the allowable EU maximum content, prevented the typical decline in serum 25(OH)D concentration during winter and any incidence of vitamin D deficiency (i.e., serum 25(OH)D <25 nmol/L). The control group in the study, who were requested to consume weekly up to a maximum of 2 commercially available eggs, had a significant decline in serum 25(OH)D over the 8 weeks of winter, and 22% had vitamin D deficiency at endpoint.

- **The pig feeding trials** showed that pork meat from pigs fed 25-hydroxyvitamin D (equivalent to 2000 IU/kg diet) had the highest total vitamin D activity (~1.7-fold higher than that from pigs fed 2000 IU vitamin D\(_3\)/kg diet), largely arising from the increase in 25-hydroxyvitamin D content. The meat vitamin D content reflected a similar trend evident in pig serum 25(OH)D. Data from this trial also suggest no adverse effect of the vitamin D-enhanced diets on the performance and characteristics of the animals or on other quality aspects of the pork meat.

- **The beef heifer feeding trials** showed that there was a stepwise increase not only in vitamin D\(_3\) but in 25-hydroxyvitamin D with increasing level of addition of vitamin D\(_3\) to the feedstuffs (from 0 to 2000 to 4000 IU/kg). This resulted in a stepwise increase in total vitamin D activity, with the beef from animals fed 4000 IU vitamin D\(_3\)/kg diet having the highest total vitamin D activity (~2.5-fold higher than that from animals fed 0 IU D\(_3\)/kg diet). The meat vitamin D content reflected a similar trend evident in heifer serum 25(OH)D concentrations.

- **Data from these trials also suggest no adverse effect of the vitamin D-enhanced diets on the performance and characteristics of the animals or on other quality aspects of the beef.**

- **While the analytical Warner Bratzler shear force measurements of the meat suggest increased tenderness in beef from animals feed the highest level of vitamin D (but one that is allowable under EU regulation), data from the sensory panel trial (with 40 naïve assessors) showed that vitamin D\(_3\) supplementation had no impact (P>0.05) on any of the sensory
parameters evaluated, although a numerical improvement was seen for most of the parameters. The lack of statistical difference in the sensory scores across treatments compared to the WBFF findings is quite possible due to the greater sensitivity of the instrumental Warner Bratzler measurements relative to those of sensory panel perception.

- The vitamin D activity of bio-fortified pork and beef (as above) was used in modelling the impact of consumption of such pork within the Irish adult population (using food consumption data from the National Adult Nutrition Survey). These on their own are unlikely to have a major impact but when combined as part of a wider vitamin D (bio)fortification strategy (including eggs but also continuation and extension of dairy fortification) could be important.

These new data highlight that use of biofortified foods, together with other traditional vitamin D-fortified foods, can have an important impact in terms of tackling low vitamin D intakes and high prevalence of low vitamin D status in the population. Food-based strategies for improvement of vitamin D status have been prioritized by many expert groups, and thus this project is now providing much needed data.

4. Impact of the Research

- The project has added to the research base in terms of it leading to the development of more highly-skilled researchers in both UCC and UCD in the area of biofortification of Irish eggs, pork and beef. Thus, there has been an increase in the critical mass of expertise in the area of biofortification of Irish eggs and red meat.
- The project has also added to the research base in terms of the analytical capabilities required to verify the vitamin D content of Irish eggs and red meat as well as in the sensory assessment capabilities required to verify the consumer acceptability of such biofortified produce.
- The project has also led to the development of more highly skilled researchers in the area of conduct of food-based intervention studies in healthy human volunteers, which are a critical requirement in terms of provision of evidence of efficacy.
- The data in relation to the effect of increased level of inclusion of vitamin D₃ and/or 25-hydroxyvitamin D (as applicable) into hen and animal feedstuffs on resulting increased content in eggs and red meat from the project will be relevant to animal nutrition feed producers, egg, pork and beef producers, European Commission's Panel on Additives and Products or Substances used in Animal Feed (FEEDAP), the Food Safety Authority of Ireland, Safefood as well as other agencies (nationally and internationally) briefed with development of healthy eating guidelines as well as the academic community.
- The consumer could ultimately benefit from the findings of this project should the meat and egg producers require of their animal feed suppliers to include vitamin D and/or 25-hydroxyvitamin D at the EU upper allowable level. This will ensure the richest supply of total vitamin D in the produce, and thus improving consumer vitamin D intakes, a key priority highlighted by most expert groups.
- The international scientific community will have benefited from the research undertaken in this project and in particular with the publication of its findings in high calibre peer reviewed journals, such as the American Journal of Clinical Nutrition, Proceedings of the Nutrition Society, Meat Science and Innovative Food Science and Emerging Technologies, thus far as well as their presentation at key international conferences/symposia.
➢ The meat industry has benefited from this project in terms of providing some of the groundwork for some of the activities of the Enterprise Ireland-funded Meat Technology Centre (see below).

➢ The delivery of the project on its stated aims as well as its findings align closely with the Meat Industry's Strategic Research Agenda (SRA) (as part of Food Research Ireland) which suggests the following priorities:

“The Research community can assist our sector in delivering solid Food & Health science-based findings that provide positive messages on meat consumption, its fundamental role in the diet as well as its contribution to health and wellbeing.” as well as ‘To determine the relationship between animal nutrition and health, productivity and product quality’, ‘Development of new processes to produce safer, healthier and flavoursome traditional meat products’, ‘Mining of new bioactives in meat systems’ and ‘Development of functional meat products’, all of which would have an expected impact in terms of improvements in food and health, and thus clearly of relevance to Irish society.

4(a) Summary of Research Outcomes

(i) Collaborative links developed during this research

The project has fostered an ongoing and extended collaboration between UCC and UCD in terms of Food and Health research, which is in line with the research strategy of both institutions. The project has also fostered further collaboration between Professor Cashman of the Cork Centre for Vitamin D and Nutrition Research at UCC and Dr. Jette Jakobsen of the Danish Technical University in terms of food-based solutions for tackling vitamin D deficiency.

The project has facilitated collaborative links to be established between the Cork Centre for Vitamin D and Nutrition Research and partners of the newly established Enterprise Ireland-funded Meat Technology Centre (Professor Cashman is the Programme lead for Meat & Health research) (see http://www.mti.ie).

(ii) Outcomes where new products, technologies and processes were developed and/or adopted

While the project was very much an applied type one within the research continuum, it was still pre-commercial. The project produced key new data in terms of development of vitamin D-biofortified eggs and red meat, and in particular provided the analytical data to show the foods were indeed enriched in vitamin D, with an absence of any adverse food quality or consumer acceptability findings, and including proof of efficacy of the eggs in a human dietary intervention study. These findings provide a major underpinning evidence-base for relevant industry stakeholders to adopt within their current practises so as to generate vitamin D-biofortified foods.

(iii) Outcomes with economic potential

The project generated outcomes with economic potential in terms of facilitating foods enriched in vitamin D, which together with other vitamin D (bio)fortified foods, could help tackle the prevalence of vitamin D deficiency in Ireland, with associated cost savings to the health care costs. Recent cost-effectiveness and budget impact data from the UK suggests that treating all individuals aged 60 years plus with vitamin D supplements could lead to a net saving of £420 million to the health-care system [Poole et al 2017l BMJ Open 2015;5:e007910]. This is based on falls-related outcomes only and use of vitamin D supplements. Use of a foods-first approach is likely to be much more cost-effective and will reach those in the population of all ages, important in terms
of potential vitamin D-related outcomes beyond just bone. While this is of clear importance to society from a public health perspective, it also provides key data for the Irish meat and egg sector to underpin its product development and marketing. Thus, the project can support and boost the competitiveness of these segments of the Irish food industry.

(iv) Outcomes with national/policy/social/environmental potential
The findings of this project are of relevance in terms of improving health and quality of life of citizens and potential cost-saving to the Irish health-care budget as well as that of others internationally, by improving vitamin D nutrition. The cost of non-communicable diet-related disease is subject to various colossal estimates, in the realm of trillions, but a consistent finding is that budget allocations to disease prevention are much lower than to treatment of chronic disorders, typically by pharmaceutical or surgical interventions, that are lifestyle or dietary in origin.

4 (b) Summary of Research Outputs
(i) Peer-reviewed publications, International Journal/Book chapters.


This paper was included in the recently released ‘The Top 18 Vitamin D Papers in 2015-2016’ (source: Orthomolecular Medicine News Service, February 13, 2017).


**Book Chapters:**


(ii) Popular non-scientific publications and abstracts including those presented at conferences

**Conference abstracts**


(iii) National Report. Nil

(iv) Workshops/seminars at which results were presented:
K. Cashman (UCC) highlighted the projects' activities in the following presentations at national and International meetings/conferences during the lifetime of the EnhanceD project:

- Vitamin D and Human Health: From the Gamete to the Grave, London, UK May 2014. Plenary lecture entitled: Vitamin D requirements and potential of fortification.
- 17th International Vitamin D Workshop, Chicago, USA; June 2014. Plenary lecture entitled: Vitamin D: dietary requirements and food fortification as a means of helping achieve.
- Conjoint Fresenius-INDI symposium for Dieticians, Dublin, Dec 2014. Plenary lecture entitled: Recommended dietary intakes for vitamin D.
- Best Brains Exchange - a dedicated conference jointly hosted by Health Canada and the Canadian Institutes of Health Research to inform their policy makers on pending changes in the fortification approach for their national food chain (Vitamin D fortification of the food supply: Are changes to the existing vitamin D policy warranted?; Ottawa, Canada, March 2015. One of the four-invited plenary presentation entitled: Vitamin D fortification to achieve public health targets: a European perspective.
- 12th European Nutrition Conference (FENS), Berlin, Germany, October 20-23rd 2015. Plenary presentation entitled: Critical micronutrients in Europe: Vitamin D?
- 19th International Vitamin D Workshop, Boston, MA, USA. March 2016. Poster entitled: Vitamin D biofortified eggs have a winter vitamin D status protective effect in older adults and meet with consumer acceptability.
- 4th International Vitamin Conference, Copenhagen, Denmark. May 2016. Keynote speaker providing presentation entitled: Modelling of serum 25-hydroxyvitamin D and other potential biomarkers to inform approaches towards improving population vitamin D status by dietary strategies.
- International Congress of Endocrinology (ICE) and the China Society of Endocrinology (CSE), Beijing, China, August 31–September 4, 2016. Plenary presentation entitled: Reconciling observational studies of vitamin D with randomized control trials - Why the difference and how to proceed?
Plenary presentation entitled: Vitamin D food fortification: Effectiveness ? and lessons for LMICs. and 29th March 2017. Plenary presentation entitled: Vitamin D bio-addition to food: Scope for use in LMICs ?


- 3rd International Congress Hidden Hunger, Stuttgart, Germany, March 2017. Invited plenary presentation entitled: Vitamins D and K: Micronutrient deficiencies of public health significance or just hype ?

A. Hayes (UCC) highlighted the projects' activities in the following presentations at national and International meetings/conferences during the lifetime of the EnhanceD project:


- EU ODIN project One-day symposium 'Implications of New Research Data on Vitamin D from the ODIN project for public health policy and food innovation in Europe, DG Research and Innovation', EC Commission, Brussels. 3rd March 2016. Invited presentation entitled: Vitamin D-biofortified eggs: protective against vitamin D deficiency?

- Specialised Workshop on Vitamin D Food-based Solutions within the "Vitamin D & Health in Europe: current & future perspectives" international conference, University College Cork 5th and 6th September 2017 (and see under (vi) below). Invited presentation entitled: Biofortified eggs.

S. Duffy (UCD) highlighted the projects' activities in the following presentations at national and International meetings/conferences during the lifetime of the EnhanceD project:


- 67th Annual meeting of the European Federation of Animal Science, Belfast, August 2016. Oral presentation entitled: Vitamin D₃ supplementation in heifers, on blood serum 25-OH-D₃ and beef Vitamin D₃ concentration.

- 18th World Food Congress of Food Science and Technology (IUFoST 2016), Dublin, August 2016. Oral presentation entitled: The effect of vitamin D₃ and 25-hydroxyvitamin D supplementation in laying hen diets, on total egg vitamin D and total antioxidant capacity.

beef heifers, to increase beef vitamin D content and improve beef tenderness and sensory evaluation.

Alan Kelly (UCD) highlighted the projects' activities in the following presentations at national and International meetings/conferences during the lifetime of the EnhanceD project:


J. O'Doherty (UCD) highlighted the projects' activities in the following presentations at national and International meetings/conferences during the lifetime of the EnhanceD project:

- Specialised Workshop on Vitamin D Food-based Solutions within the "Vitamin D & Health in Europe: current & future perspectives" international conference, University College Cork 5th and 6th September 2017 (and see under (vi) below). Invited presentation entitled: Biofortified beef and pork.

Other presentations highlighted the projects' activities in the following presentations at national and International meetings/conferences during the lifetime of the EnhanceD project:

- Dr. Maurice O’Sullivan (UCC). Specialised Workshop on Vitamin D Food-based Solutions within the "Vitamin D & Health in Europe: current & future perspectives" international conference, University College Cork 5th and 6th September 2017 (and see under (vi) below). Invited presentation entitled: Consumer acceptability of biofortified meat and eggs.

- Professor Mairead Kiely (UCC). 3rd International Conference "Vitamin D - minimum, maximum, optimum" held in Warsaw in September 22 - 23, 2017, under the auspices of the European Vitamin D Association (EVIDAS). Invited presentation entitled: Proof of efficacy that food-first approaches can prevent vitamin D deficiency throughout life.

(v) Intellectual Property applications/licences/patents **Nil**

(vi) Other:

There was a 'Special Workshop (Novel food-based approaches for prevention of vitamin D deficiency)' within the recent ODIN Vitamin D & Health in Europe: Current and Future Perspectives conference at UCC on the 5-6th September 2017. This was co-jointly organised by the European Commission-funded ODIN project and this FIRM-funded EnhanceD project (see [http://www.odin-vitd.eu/files/Insert%20Programme%20ODIN_Final.pdf](http://www.odin-vitd.eu/files/Insert%20Programme%20ODIN_Final.pdf)).

5. Scientists trained by Project

Total Number of PhD theses: **2**


Total Number of Masters theses: 0

6. **Permanent Researchers**

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<th>Number of Permanent staff contributing to project</th>
<th>Total Time contribution (person years)</th>
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<td>University College Dublin</td>
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7. **Researchers Funded by DAFM**

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8. **Involvement in Agri Food Graduate Development Programme**

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<th>Names and Dates of modules attended</th>
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<tr>
<td>Aoife Hayes (UCC)</td>
<td>'Science writing and presenting' AFGD module October 22-24th, 2013</td>
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9. Project Expenditure

Total expenditure of the project: €434,460

Total Award by DAFM: €484,608

Other sources of funding including benefit in kind and/or cash contribution (specify): €0

Breakdown of Total Expenditure

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10. Leveraging

This project helped UCC (as overall ODIN project coordinators) and UCD (as ODIN partners) to leverage a large-integrated €6 million European Commission Framework 7-funded project called ‘Food-based solutions for optimal vitamin D nutrition and health through the life cycle’ [ODIN] (Project Ref: FP7-613977). The work and existence of EnhanceD was highlighted in our ODIN submission and the fact that the coherence of the work between the two projects would bring added value.

This project helped UCC to leverage additional national funding through its involvement in the Meat Technology Centre (http://www.mti.ie), as mentioned above.

11. Future Strategies

This project has provided proof-of-principle scientific data to underpin inclusion of vitamin D and/or 25-hydroxyvitamin D at the EU upper allowable level in the diet of beef, pork and hen feedstuffs, which will lead to foods with enhanced vitamin D content. These are important in terms of an overall foods-based strategy for addressing inadequacy of vitamin D intake in the Irish population. Continued and further dissemination of the findings to the relevant stakeholders may be needed to ensure the decision makers are aware of the potential. There is also a need for
future strategies to build on these findings in a number of ways. For example, there may be potential to make ‘nutritional claims’ on eggs and some red meats from hens/animals who have received such vitamin D-enhanced feedstuffs. In order to make such claims, analytical data on the vitamin D content of the biofortified meat and eggs will be needed. With the well-reported variability in performance of analytical laboratories in such analysis [Roseland et al. J Agric Food Chem. 2016;64:3167-75], a national centre with certified ability to perform this type of food analysis to the required specifications is a key requirement to be in place for Irish industry (and also possibly beyond the meat and egg sector, see below). Further exploration of the biofortification of Irish meats, beyond beef and pork, also holds merit, and including use of new UV light technology as potentially even more effective means than feed fortification.

Additional research in the area of vitamin D biofortification of other foodstuffs is still required as the foods first approach to tackling vitamin D inadequacy relies on increasing the vitamin D content of a number of foods to cater for diversity of food choice and consumption within the population. Such research could be funded by DAFM and some aspects possibly by Enterprise Ireland where some products are further along the research continuum.