An Roinn Talmhaíochta,
Bia agus Mara
Department of Agriculture,
Food and the Marine

Food Institutional Research Measure (FIRM)

Final Report

'Delivering processed meats with health benefits'
NutriMeat

DAFM Project Reference No: 11/F/035

Start date: 01/12/2012

End Date: 31/07/2018

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Collaborating Research Institutions and Researchers: University College Dublin (Prof. Frank Monahan, Assoc. Prof. Nigel Brunton, Prof Jim Lyng, Dr JC Jacquier, Dr Sabine Harrison); Teagasc (Prof. Aidan Moloney, Dr Ruth Hamill); University College Cork (Prof. Joe Kerry, Dr Michael O'Grady)

Basic/Fundamental ⟶ Applied ⟶ Pre Commercial

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

Priority Area (s)	**H Food for Health**

Key words: Consumer, Processed Meats, Nutrient, Claim

1. Rationale for Undertaking the Research

The overall aim of the project was to reduce "unhealthy" constituents while simultaneously increasing the level of desirable bioactive constituents in processed meat products thereby increase their "healthiness" and counteracting some of the negative associations that have emerged between processed meat products and consumer health. Meat is not generally thought of as a functional food despite its potential for delivery of functional ingredients in the diet of humans. Furthermore, all processed meats tend to get branded unfavourably despite the fact that they can be formulated to be healthy (e.g. low fat, low salt, minimal additives) and there are untapped opportunities to increase the level of ingredients with health promoting properties in processed meats. The research adopted a tripartite approach of (i) evaluating consumer attitudes to processed meats containing health promoting bioactives, (ii) technically evaluating the potential to "match" healthy processed meat formulations with selected European Food Safety Authority (EFSA)-approved bioactives and (iii) conferring with industry partners on the feasibility of different product formulations.

2. Research Approach

The project focused on the development of processed meat with a healthy nutritional profile on the basis of having reduced fat and salt, having a healthy fatty acid profile, and containing bioactive constituents. We focused on two types of product:

(i) reformed products (e.g. deli meats)
(ii) comminuted sausage-type products (e.g. breakfast sausage)

In both product types bioactives, which already have EFSA-approved health claims associated with them, were included. Among the ingredients considered were:

Ingredient	Health claim	Levels required
Olive polyphenols	Protection of LDL particles from oxidative damage	5mg of hydroxytyrosol and its derivatives (e.g. oleuropein complex and tyrosol) should be consumed daily
Plant sterols/stanols	Reduction of blood cholesterol concentrations	Food should provide at least 0.8g/d or plant sterols/stanols in one or more servings
Vitamin E	Protection of DNA, protein and lipids from oxidative damage	Must meet the requirements for 'a source of vitamin E' i.e. at least a significant amount as defined by Directive 90/496 i.e. the RDA is 12mg. A significant amount is generally considered to be 15% of the RDA supplied by 100mg or 100ml of product

□-linolenic acid	Reduction of blood cholesterol	At least 15% of the proposed labelling reference intake of 2g ALA per day

Although not EFSA-approved, commercial micro-DHA and macroalgae extracts prepared from Ascophyllum nodosum were also investigated as potential functional food ingredients.

From a food processing perspective bioactive ingredients were chosen on the basis of "best fit" with the product type, for example □-linolenic acid inclusion was more suited to sausage-type products, which typically contain higher levels of fat than deli meats.

3. Research Achievements/Results

The project set out to reduce "unhealthy" constituents while simultaneously increasing the level of desirable bioactive constituents in processed meat products thereby increasing their healthiness.

- Using a focus group approach, consumer attitudes to processed meats containing health promoting bioactives were evaluated. Strategies that consumers felt as important for improving the health profiles of processed meat were dominated by using better quality meat and less salt, fat, preservatives and other chemicals. Regarding healthier meat formulations, they expressed divergent attitudes and concerns under four themes: (i) controversies around processed meat as the carrier of healthy ingredients; (ii) debates as to whether functional meat is 'actual' or 'pseudo' healthier; (iii) perceived value of functional meat to different consumers; (iv) trust and self-control in relation to healthy ingredients. In general, a large proportion of participants felt more uncertain than positive about the idea of functional meat.
- An online survey of 500 consumers explored consumer acceptability of healthy processed meats. Results showed that processed meats were not equally perceived as unhealthy. Consumers were in general more uncertain than positive about enriching processed meat with healthy ingredients. Purchase intention towards processed meat based functional foods was primarily driven by their attitudes, i.e. those who held stronger beliefs and less scepticism about the product concept were more likely to buy the product. Health perception and eating frequency of processed meat were also associated with an increased likelihood to purchase, i.e. frequent eaters of processed meat and those who thought processed as 'not bad' or 'healthy' were more likely to buy the product.
- In terms of the strategies that consumers support to make processed meat healthier, results have shown that the reduction of additives and preservatives, and the reduction of salt content were ranked first, followed by the increase of lean meat content and fat reduction. The use of natural forms of preservatives and flavourings and the addition of healthy ingredients were considered relatively less important. Consumers who were positive about salt and/or fat reduction were also positive about healthy ingredient enrichment.

- The project has developed low fat/low salt processed meat product formulations containing bioactive ingredients (most with which EFSA-approved nutrient and health claims could be associated) to enhance their healthiness. Among the bioactives investigated to date are vitamin E, plant sterols, □-linolenic acid (ALA), calcium, iron, hydroxytyrosol and microalgal oil and macroalgal extracts.
- Two review articles, 11 peer reviewed scientific papers, 3 PhD theses and 1 MSc thesis were delivered from the research project.

4. Impact of the Research

4(a) Summary of Research Outcomes

(i) Collaborative links developed during this research

Excellent collaborative links were formed in the course of the project. In particular the project partners engaged with two companies, Dawn Farms and Manor Farm. The companies provided insights and feedback on healthy processed meat formulations and, in the case of Dawn Farms, use of their pilot facility for product manufacture. Both companies provided meat samples free of charge for the project. Forty three delegates from 10 companies attended a project workshop 'Healthier Processed Meats – Fact or Fiction'.

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

Processed meat products on which a health claim could potentially be made were developed as described here. (a) A turkey product containing plant sterols on which *High Protein, Low Fat* nutrient claims could be made and the following health claim could potentially be made: *Plant sterols have been shown to lower/reduce blood cholesterol. High cholesterol is a risk factor in the development of CHD*. (b) a chicken sausage with added omega-3 and vitamin E on which *High Protein, High in Omega-3, High in Vitamin E* nutrient claims could be made and the following health claims could potentially be made: *"Alpha Linolenic Acid (ALA) contributes to the maintenance of normal blood cholesterol levels. The beneficial effect is obtained with a daily intake of 2g"* and *"Vitamin E contributes to the protection of cells from oxidative stress"*. Less developed were product formulations containing calcium, iron, and hydroxytyrosol (all of which have potential nutrient and health claims associated with them) and microalgal oil and macroalgal extracts.

(iii) Outcomes with economic potential

The project demonstrated that meat products could be developed with acceptable sensory quality attributes and the potential for nutrient and health claims. Products such as these have the potential to support the meat sector in adapting to changes in consumer perspectives on meat and meat products and in developing new product offerings. The

engagement of meat companies with the project is indicative of the economic potential of the products.

(iv) Outcomes with national/ policy/social/environmental potential

The project was selected for presentation at a UCD Institute of Food and Health Policy Seminar entitled "How can Public Policies change Food Systems to Promote Public Health?", indicating the relevance of the project outcomes. In addition, over the course of the project, consumer views of, preferences for, acceptance of and evaluations of reformulated processed meats were sought and reported on; these have the potential to inform policy.

4 (b) Summary of Research Outputs

(i) Peer-reviewed publications, International Journal/Book chapters.

1. Grasso S, Brunton NP, Lyng JG, Lalor F and Monahan FJ (2014). Healthy processed meat products – regulatory, reformulation and consumer challenges. Trends in Food Science and Technology, 39, 4-17.
2. Bolger Z, Brunton NP, Lyng JG and Monahan FJ (2016). Comminuted meat products - consumption, composition and approaches to healthier formulations. Food Reviews International, 33, 143-166.
3. Grasso S, Brunton NP, Monahan FJ and Harrison SM (2016). Development of a method for the analysis of sterols in sterol-enriched deli-style turkey with GC-FID. Food Analytical Methods. 9 (3), 724-728.
4. Grasso S, Brunton NP, Lyng JG, Harrison SM and Monahan FJ (2016). Quality of deli-style turkey enriched with plant sterols. Food Science and Technology International. 22, 743-751.
5. Grasso S, Monahan FJ, Hutchings SC and Brunton NP (2017). The effect of health claim information disclosure on the sensory characteristics of plant sterol-enriched turkey as assessed using the Check-All-That-Apply (CATA) methodology. Food Quality and Preference, 57, 69-78.
6. Bolger Z, Brunton NP, Lyng JG and Monahan FJ (2016). Quality attributes and retention of vitamin E in reduced salt chicken sausages fortified with vitamin E. Journal of Food Science and Technology, 53, 3948-3959.
7. Shan LC, Regan A, Monahan FJ, Li C, Murrin C, Lalor F, Wall P, McConnon A. Consumer views on 'healthier' processed meat (2016). British Food Journal, 118(7): 1712-1730.
8. Shan, LC, Regan, Á., Monahan, F.J., Li, C., Lalor, F. Murrin, C., Wall, P.G., McConnon, Á. (2017).
   Consumer preferences towards healthier reformulation of a range of processed meat products: A qualitative exploratory study", British Food Journal, Vol. 119, Issue: 9, pp.2013-2026, https://doi.org/10.1108/BFJ-11-2016-0557

9. Shan, L.C., Henchion, M., De Brún, A., Murrin, C., Wall, P.G., Monahan, F.J. (2017). Factors that predict consumer acceptance of enriched processed meats. Meat Science, 133,185-193. https://doi.org/10.1016/j.meatsci.2017.07.006
10. Shan, LC, De Brún, A., Henchion, M., Li, C., Murrin, C., Wall, P.G., Monahan, F.J. (2017). Consumer evaluations of processed meat products reformulated to be healthier – A conjoint analysis study. Meat Science 131, 82–89. https://doi.org/10.1016/j.meatsci.2017.04.239
11. Grasso, S., Harrison, S.M., Monahan, F.J., Brayden, D. and Brunton, N.P. (2017). The effect of plant sterol-enriched turkey meat on cholesterol bioaccessibility during in vitro digestion and Caco-2 cell uptake. International Journal of Food Sciences and Nutrition, 69, 176-182. https://doi.org/10.1080/09637486.2017.1348493
12. Bolger, Z., Brunton, N.P. and Frank J. Monahan, F.J. (2017). Effect of mode of addition of flaxseed oil on the quality characteristics of chicken sausage containing vitamin E and omega 3 fatty acids at levels to support a health claim. Food and Function,8, 3563–3575; DOI: 10.1039/c7fo00929a
13. Bolger, Z., Brunton, NP and Monahan, FJ. 2018. Impact of inclusion of flaxseed oil (preemulsified or encapsulated) on the physical characteristics of chicken sausages. Journal of Food Engineering 230, 39- 48. https://doi.org/10.1016/j.jfoodeng.2018.02.026

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

1. Grasso S, Brunton NP, Lyng JG and Monahan FJ (2014). Sterol-enriched turkey meat: quality and oxidative stability. In Proceedings of the 43rd Annual Food Research Conference, University College Dublin, 10-11 December, p21
2. Grasso S, Monahan FJ and Brunton NP. Consumers' acceptability of a functional plant sterolenriched deli-style turkey product. In Proceedings of the 62nd International Congress of Meat Science and Technology, 14-19th August 2016, Bangkok, Thailand.
3. Grasso S, Monahan FJ, Hutchings S and Brunton NP. The effect of health claim information disclosure on the consumer evaluation of plant sterol-enriched turkey. In Proceedings of the 18th World Congress of Food Science and Technology, 21-25th August 2016, Dublin, Ireland.
4. Grasso S, Monahan FJ, Hutchings S and Brunton NP. The effect of health claim information disclosure on the sensory characteristics of plant sterol-enriched turkey as assessed using the Check-All-That-Apply (CATA) methodology. In Proceedings of the 7th European Conference on Sensory and Consumer Research, 11-14th September 2016, Dijon, France.

5. Bolger Z, Brunton NP, Lyng JG and Monahan FJ. (2014). Retention of vitamin E and quality parameters in reduced salt chicken sausages containing added vitamin E. In Proceedings of the
   43rd Annual Food Research Conference, University College Dublin, 10-11 December, p28
6. Bolger Z, Brunton NP, Lyng JG and Monahan FJ. Quality characteristics of chicken sausages fortified with vitamin E and alpha-linolenic acid, using different flaxseed oil incorporation methods. In proceedings of the 18th World Congress on Food Science and Technology, Royal Dublin Society, Dublin, 21st-25th August 2016.
7. Shan LC, Wall P, Lalor F, McConnon A, Li C and Monahan FJ (2014). Irish consumers' views on 'healthier processed meat'. In Proceedings of the 43rd Annual Food Research Conference, University College Dublin, 10-11 December, p42.
8. Shan LC (2016). Consumer perspectives on 'healthier' processed meat. Oral presentation at: Food Product Improvement Seminar for the Food and Drink Industry at IBEC; May 20, 2016; Dublin, Ireland.
9. Shan LC, Regan A, Lalor F, Henchion M, Li C, Murrin C, McConnon A, Wall P, Monahan F (2016). Consumers' views on "healthier" processed meats: insights from qualitative and quantitative studies. Oral presentation at: 18th World Congress of Food Science and Technology (IUFoST); August 21-25, 2016; Dublin, Ireland.
10. Shan LC, Regan A, Lalor F, Henchion M, Murrin C, Li C, Wall P, McConnon A, Monahan F (2016). Consumer reaction to healthier reformulation of processed meat. Poster presented at the 7th European Conference on Sensory and Consumer Research (Eurosense); September 11-14, 2016; Dijon, France.
11. Shortle E, O'Grady MN, Edwards M and Kerry JP (2015). Influence of edible Irish seaweeds on the sensory properties of cooked minced beef. In Proceedings of the Nutramara Conference (Harnessing Marine Bioresources for Innovations in the Food Industry), Royal Dublin Society (RDS) Dublin, 29 – 30 June, p71.
12. Shortle E, O'Grady MN, Edwards M and Kerry JP (2015). Effect of edible Irish seaweeds on the quality and shelf-life of beef patties stored in modified atmosphere packs. In Proceedings of the 29th European Federation of Food Science and Technology (EFFoST) International Conference (Food Science Research and Innovation: Delivering Sustainable Solutions to the Global Economy and Society), Athens, Greece, 10 – 12 November, p1086.
13. Shortle E, O'Grady MN, Edwards M and Kerry JP (2015). Profiling the anti-oxidative potential of brown seaweed (*Ascophyllum nodosum*) extracts using *in vitro* and muscle-based test systems.
    In Proceedings of the 29th European Federation of Food Science and Technology (EFFoST) International Conference (Food Science Research and Innovation: Delivering Sustainable Solutions to the Global Economy and Society), Athens, Greece, 10 – 12 November, p914.

(iii) National Report

n/a

(iv) Workshops/seminars at which results were presented

1. F Monahan/Z Bolger/ N Brunton / J Lyng / V Carton et al. New meat (chicken) products for health – workshop. UCD Carton Group Workshop, 20/12/2113
2. Bolger Z and Monahan FJ (2014). Consumer perception, fat profile and mineral composition of chicken meat compared to other meat species. Report delivered to Manor Farm, 1 December 2014. 13 pages.
3. UCD, presentation workshop and product sampling on the NutriMeat project. Presentations by Simona Grasso, Zara Bolger and Christine Shan 31/03/2015.
4. Shan LC (2017). Consumer attitudes towards and acceptance of 'healthier' processed meats. Oral presentation at: 'Healthier Processed Meats – Fact or Fiction' Workshop, February 16, 2017; Teagasc, Dublin, Ireland.
5. Grasso, S. (2017) Development of re-formed meat products with health benefits. Oral presentation at: 'Healthier Processed Meats – Fact or Fiction' Workshop, February 16, 2017; Teagasc, Dublin, Ireland.
6. Bolger, Z (2017). Development of comminuted meat products with health benefits. Oral presentation at: 'Healthier Processed Meats – Fact or Fiction' Workshop, February 16, 2017; Teagasc, Dublin, Ireland.
7. O'Grady, M. (2017). Development of processed beef and pork meat products containing health promoting marine derived ingredients. Oral presentation at: 'Healthier Processed Meats – Fact or Fiction' Workshop, February 16, 2017; Teagasc, Dublin, Ireland.
8. Monahan, FJ, Lalor, F and Shan C. 2018. Consumers and Reformulation of Healthier Processed Meats. To be presented at the UCD Institute of Food and Health Policy Seminar entitled "How can Public Policies change Food Systems to Promote Public Health?" (November 15, 2018)

(v) Intellectual Property applications/licences/patents No IP has arisen from the project.

(vi) Other

Interactions with industry:

1. Tuesday 31 March 2015: UCD, presentation workshop and product sampling on the NutriMeat project. Presentations by Simona Grasso, Zara Bolger and Christine Shan (see Appendix 1)
2. Friday 17th April 2015: Dawn Farms Food. Meeting with Aisling Dullaghan, Pat Mahon, Shane Cooke. Presentations by Simona Grasso and Zara Bolger, quick

overview of project to date, discussion on next steps, schedule trial dates, agreement on future support.

3. Tuesday 26th May 2015: Dawn Farms Food-Pat Mahon, pilot trial using chunks of turkey, rather than mince, to produce sterol enriched turkey.
4. Tuesday 13th October 2015: Dawn Farms Food- Pat Mahon and Aisling Dullaghan, kitchen trial using different mince size (3.2 mm and 8 mm) to produce sterol enriched turkey.
5. Monday 19th October 2015: Dawn Farms Food- Pat Mahon, pilot trial using 3.2 mm mince to produce sterol enriched turkey.
6. Tuesday 27th October 2015: Dawn Farms Food- Shane Cooke, to collect control turkey, slice and pack.
7. Friday 13th January 2017: industry circulated via a mail-shot regarding upcoming workshop to disseminate the results of the project - Healthier Processed Meats - Fact or Fiction? (Scheduled 16 February 2017)
8. Thursday 16th February 2017: 'Healthier Processed Meats – Fact or Fiction' was held on February 16, 2017. See appendix 1 for workshop programme). There were 43 delegates at the workshop with representatives from 10 companies (O'Brien Fine Foods, Dawn Farm Foods, Hilton Foods, Feldhues GmbH, Ribworld, Glenhaven Foods, Tesco Irl, Dunbia, AllinAll Ingredients, Manor Farm) as well as representatives from the FSAI, UCD, UCC and Teagasc.
9. Monahan, FJ, Lalor, F and Shan C. 2018. Consumers and Reformulation of Healthier Processed Meats. To be presented at the UCD Institute of Food and Health Policy Seminar entitled "How can Public Policies change Food Systems to Promote Public Health?" (November 15, 2018)

5. Scientists trained by Project

Total Number of PhD theses: 3

1. Shan LC (2017). Consumer Attitudes towards and Acceptance of Healthier Reformulated Processed Meat (January 2017).
2. Grasso S (2017). Development and Characterisation of a Processed Meat Product with Health Benefits: deli style turkey enriched with plant Sterols (April 2017)
3. Bolger (2017). Delivering Processed Meat Products with Health Benefits (September 2017)

Total Number of Masters theses: 1

Shortle E (2016). Development of healthier beef and pork products using dried macroalgae/extracts and microalgal oil as functional ingredients.

In addition, four contract scientists were hired for various durations, and received training, over the course of the project.

6. Permanent Researchers

Institution Name	Number of Permanent staff contributing to project	Total Time contribution (person years)
UCD	5	2.48
UCC	2	2.33
Teagasc	2	0.01
Total	**9**	**4.82**

7. Researchers Funded by DAFM

Type of Researcher	Number	Total Time contribution (person years)
Post Doctorates/Contract Researchers	4	1.29
PhD students	3	11.29
Masters students	1	3.00
Temporary researchers		
Other		
Total	**8**	**15.57**

8. Involvement in Agri Food Graduate Development Programme

Name of Postgraduate / contract researcher	Names and Dates of modules attended
-	-

9. Project Expenditure

Total expenditure of the project: €572,512.61

Total Award by DAFM: €598,950.00

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

Meat samples provided as benefit in kind from Dawn Farms and Manor Farms

Breakdown of Total Expenditure

Category	Name Institution 1 UCD	Name Institution 2 UCC	Name Institution 3 Teagasc	Name Institution 4	Total
Contract staff	25863.23				25863.23
Temporary staff					
Post doctorates		6732.96			6732.96
Post graduates	239968.01	61026.64			300994.65
Consumables	33804.50	35014.15	13785.26		82603.91
Travel and subsistence	9961.25	4527.41	80.97		14570.49
Sub total	309597.85	107301.16	13866.23		430765.24
Durable equipment	2599.40	1000.00			3599.40
Other	8918.40				8918.40
Overheads	92879.36	32190.35	4159.87		129229.57
Total	413995.01	140491.51	18026.10		572512.61

10. Leveraging

As a result of the project we were able to leverage the assistance of China Scholarship Council-funded PhD student, Xinyi Hong, who worked with us on the project and has co-authored a number of papers (on her findings from the project) with us since:

Xinyi Hong, Chenguang Li, Liming Wang, Mansi Wang, Simona Grasso and Frank J. Monahan (2023). Consumer Preferences for Processed Meat Reformulation Strategies: A Prototype for Sensory Evaluation Combined with a Choice-Based Conjoint Experiment. Agriculture, 13, 234. https://doi.org/10.3390/agriculture13020234

Xinyi Hong, Chenguang Li, Liming Wang, Zhifeng Gao, Mansi Wang, Haikuan Zhang, and Frank J. Monahan (2022). The Effects of Nutrition and Health Claim Information on Consumers' Sensory Preferences and Willingness to Pay. Foods, 11, 3460. https://doi.org/10.3390/foods11213460.

Department of Agriculture, Food and the Marine grant number Project 11/F/03 is acknowledged on both papers.

Note: Since the final report was submitted we have also published a further paper from the project (from the work of PhD students Z Bolger and S Grasso – both funded by the project:
Zara Bolger, Simona Grasso, Nigel Brunton, Aidan P. Moloney, Ruth Hamill, Frank J. Monahan. 2022. In vitro bioaccessibility of alpha-linolenic acid in chicken sausages as affected by flaxseed oil incorporation method. 167, 113808.
https://doi.org/10.1016/j.lwt.2022.113808

11. Future Strategies

The results of the research have been extensively publicised through industry engagement, a workshop, publications in the popular press, conference presentations and peer reviewed publications as outlined in section 4b.