



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

Food Institutional Research Measure

Final Report

'PROSSLOW: Development of consumer accepted low salt and low lipid Irish traditional processed Meats.

DAFM Project Ref No: Ref 11/F/026

Start date: 01/10/2012

End date: 31/08/2017

Principle Coordinator: Dr. Maurice O'Sullivan (UCC)

Email: maurice.osullivan@ucc.ie

Collaborating Research Institutions and Researchers:

Prof..Joe Kerry (PI, UCC)

Dr. Susan Fellendorf (UCC), completed PhD student

Dr. Ruth Hamill (Teagasc, Ashtown)

Dr. Gonzalo Delgado-Pando (Teagasc, Ashtown)

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

Basic/Fundamental	→	Applied	→	Pre Commercial		
1	2	3	4	5 X	6	7

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: (max 4) *Sensory; Consumer-Driven; Nutritional; Optimisation*

1. Rationale for Undertaking the Research

This section should outline the rationale for carrying out the research and identify the need / problem to be addressed

Rationale: Salt has an essential function in meat products in terms of flavour, texture and shelf-life (Desmond, 2006). However, processed meat products comprise one of the major sources of sodium but reducing the salt content causes problems of microbial growth and affects technological properties such as water binding capacity and flavour perception. Salt use in preservation of traditional products was vital in the past, but modern ingredient, packaging and refrigeration technologies can reduce this primary role. Also, consumers demand healthy processed meats low in salt and also fat but demand a high sensory quality. We will meet this challenge by producing healthy low salt and fat processed meats with optimum sensory quality while maintaining functionality and shelf-life.

Background: In Ireland and the UK the daily sodium adult intake is approximately three times the recommended daily allowance and therefore public health and regulatory authorities are recommending reducing dietary intake of sodium to 2.4g (6 g salt) per day (Desmond, 2006). Also, the importance of this health issue was stressed by the European Commission through the EU Salt Reduction Initiative (EC, 2007) which proposed a reduction in the salt amounts of 16 % over 4 years. Also, high saturated fat levels present a greater risk of obesity, type 2 diabetes and cardiovascular disease (International Obesity Task Force, 2002; Jiménez-Colmenero, Carballo and Cofrades, 2001).

Relevance: This project addresses several of the specific DAFM Research Funding Programme's call: B.1.2.1 (ii)-Further development of science-based technologies to reduce the need for salt and fat in manufacturing while maintaining consumer acceptance; B.1.2.1 (iii)-Development of scientific knowledge of functional peptides with respect to meat; B.1.1.1 (iii) Development of new processes to produce safer, healthier and flavoursome traditional meat products.

Relevance to end user: TPMs low in salt and fat will be formulated while maintaining functionality food safety, shelf-life, consumer sensory quality and commercial viability. The FSAI has obtained good traction from the meat processing industry regarding salt reduction targets to date (See SRP-2011-2012). Where the project we propose differs from the SRP is that it principally uses consumer optimisation and state of the art methods to reduce the levels of salt, fat in TPMs in a clean label fashion by reducing these components or by utilising allergen friendly ingredients that can be used to replace additives. By project completion a roadmap will be available to the Irish meat industry with respect to achieving the above outlined objectives.

2. Research Approach

Specify the research methodologies employed, emphasising novel techniques and also outline any modifications from the original approved project proposal

PROSSLOW optimised traditional processed meats (TPMs), including cured and uncured meats, through the reduction and or replacement of salt and fat with respect to functionality, food safety, consumer sensory quality and commercial viability. The minimum concentrations of preservatives were identified while maintaining the above attributes in order to determine the very limits of such removal. Sensory consumer research was employed to optimise each of these approaches as well as using active coatings on packaging innovation, through the use of non-contact bioactive materials, to synergistically replace preservatives and maintain functionality, food safety and shelf-life of products where preservatives have been removed, reduced or replaced. The project showed clear quantitative goals for the sequential reduction of salt and fat in TPMs. The mean industry fat and salt levels in TPMs were initially identified in order to benchmark values as well as identified FSAI target levels. Our approach principally used consumer optimisation coupled with multivariate data analysis to reduce the levels of salt and fat, in TPMs in a clean label fashion as well as reducing these components by utilising traditional and new ingredient technologies that can be used to replace additives in parallel. By targeting the consumer, the sensory drivers, collected in a comprehensive, holistic and objective manner using state of the art sensory and multivariate data analytical technologies allows bespoke products to be created.

Non-replacer experiments

These first two studies determined the impact of different salt and fat levels on the physiochemical and sensory properties of white and black pudding sausages. For white pudding twenty-five formulations were produced, with a fat content of 20%, 15%, 10%, 5%, 2.5% w/w and sodium content of 1.0%, 0.8%, 0.6%, 0.4%, 0.2% w/w. For the black pudding study twenty-five black pudding formulations with fat contents of 2.5%, 5%, 10%, 15%, 20% (w/w) and sodium contents of 0.2%, 0.4%, 0.6%, 0.8%, 1.0% (w/w) were manufactured. Experimental work completed includes compositional analysis such as moisture, fat, protein, ash and salt content, also cooking loss, colour and texture profile of the final products have been determined. Sensory evaluation using untrained assessors (n = 25 - 30) for each sausage formulation was performed in duplicate for liking of appearance, flavour, texture, colour and overall acceptability in a hedonic assessment, followed by a separate sensory intensity assessment for grain quantity, fatness, spiciness, saltiness, juiciness, toughness and off-flavour. For white pudding, samples with 15% fat, 0.6% sodium achieved the recommended sodium target level of 0.6% by the FSAI, but no fat reduction while maintaining optimal sensory quality. However for the black pudding, samples with 0.6% sodium and 10% fat displayed a positive ($P < 0.05$) correlation to liking of flavour and overall acceptability.

Replacer experiments

For the replacer experiments twenty-two formulations of white pudding comprised of two different fat (10%, 5%) and sodium (0.6%, 0.4%) levels and containing 11 different ingredient replacers were produced. Also Twenty-two black puddings possessing different fat (10%, 5%) and sodium (0.6%, 0.4%) levels were used as base formulations for 11

different salt and fat replacers. Compositional, texture and sensory analysis, using sensory acceptance testing and sensory profiling, were conducted.

Adding replacers to low sodium and low fat white puddings showed a range of effects on sensory and physicochemical properties. In summary, two formulations containing 10% fat and 0.6% sodium and formulated with sodium citrate, as well as the combination of potassium chloride and glycine (KClG), were correlated to overall acceptance ($P < 0.05$) by assessors. These samples showed higher hardness values, scored lower ($P < 0.05$) for fatness perception and higher ($P < 0.05$) in spiciness perception. Furthermore, no off-flavours were observed ($P < 0.05$) for these samples by assessors. Hence, the recommended sodium target level of 0.6% by the Food Safety Authority of Ireland (FSAI, 2011) was achieved for white pudding products, in addition to a significant reduction in fat level from commercial levels, without causing negative sensory effects.

Black pudding samples with 5% fat and 0.6% sodium containing potassium chloride (KCl), potassium chloride and glycine mixture (KClG), and seaweed, respectively, and 10% fat and 0.4% sodium containing carrageen were rated ($P < 0.05$) higher for spiciness and saltiness. Samples with 10% fat and 0.4% sodium containing KClG were rated positive ($P < 0.05$) to fatness. Samples with 5% fat and 0.6% sodium containing pectin and a combination of potassium citrate, potassium phosphate and potassium chloride (KCPCI), as well as samples containing 10% fat and 0.4% sodium with waxy maize starch (WMS) were liked for flavour ($P < 0.05$) and overall acceptance ($P < 0.05$) by assessors. The Food Safety of Ireland (FSAI) recommends a sodium target level of 0.6%. and an even lower sodium level (0.4%) was achieved to produce a highly sensory accepted product.

The latter studies of this project investigated the impact of varying sodium levels (0.2% - 1.0%) and salt replacers in corned beef on physicochemical, sensory (affective and descriptive) and microbiological properties. Significant differences in colour, hardness and cooking loss were measured. Corned beef samples low in sodium (0.2%, 0.4%) showed reduced ($P < 0.05$) saltiness perception, but were positively correlated ($P > 0.05$) to liking of flavour and overall acceptability. Samples formulated with CaCl_2 , MgCl_2 and KCl scored higher ($P < 0.01$) in saltiness perceptions, but correlated negatively ($P > 0.05$) to liking of flavour and overall acceptability. However, a sodium reduction of 60% in corned beef was determined to be achievable as assessors liked ($P < 0.05$) the flavour of the sodium reduced corned beef containing 0.4% sodium and formulated with potassium lactate and glycine (KLG), even with the noticeable lower salty taste. Sodium reduction in corned beef (packaged under modified atmosphere) did not negatively impact on the microbiological shelf-life.

Packaging optimisation

Additionally packaging optimisation studies have been completed for corned beef. The following seven combinations were chosen: potassium chloride and sodium chloride 50/50% (CB_KCl); mixture of potassium lactate, potassium chloride and sodium chloride 10/40/50% (CB_KLCl); mixture of potassium citrate, potassium phosphate, potassium chloride and sodium chloride 20/20/20/40% (CB_KCPCI); mixture of potassium lactate, glycine and sodium chloride 20/20/60% (CB_KLG); mixture of calcium chloride, magnesium chloride, potassium chloride and sodium chloride 15/5/45/35% (CB_CaMgKCl1); mixture of calcium chloride, magnesium chloride, potassium chloride and sodium chloride

15/5/25/55% (CB_CaMgKCl₂) and a mixture of potassium chloride, glycine and sodium chloride 30/20/50% (CB_KClG). Two different packaging configurations were utilized: vacuum packaging (VP) and modified atmosphere packaging (MAP) (70% N₂: 30% CO₂).

For the shelf life analysis Total Viable Counts (TVC) were carried out for corned beef samples containing 1.0% sodium, 0.4% sodium and 0.4% sodium formulated with potassium lactate, glycine and sodium chloride (CB_KLG) (section 2.1). Three slices of corned beef sample (in duplicate) with thicknesses of 3 mm were packed for each shelf-life test run. Two different packaging configurations were utilized: vacuum packaging (VP) and modified atmosphere packaging (MAP) (70% N₂: 30% CO₂). On the day of commencing the shelf-life test, a 10 g sample was placed into a stomacher bag with sterile 90 ml Maximum Recovery Diluent (MRD) and homogenised in a paddle blender (STOMACHER 400, Colworth, UK) for 3 min. Appropriate sample dilutions were prepared as followed: 1 ml aliquot was transferred into sterile screw-capped tubes containing 9 ml MRD and then mixed (Vortex mixer SA 7, Stuart, Staffordshire, UK). Afterwards, 0.1 ml of each dilution were plated in duplicate onto Plate Count Agar (PCA). All plates were aerobically incubated at 37°C for 48 hr. The results were expressed as Colony Forming Unit per g sample (CFU/g). Following the guideline for cooked meat, including cured products, by the International Commission on Microbiological Specifications for Foods (ICMSF) (ICMSF, 2011), the acceptable limit in this study was defined as < 10⁵ CFU/g of sample.

The TVC-test was conducted for corned beef samples containing 1.0% sodium, 0.4% sodium and 0.4% sodium formulated with potassium lactate, glycine and sodium chloride (CB_KLG). The vacuum packaged corned beef samples containing 0.4% sodium possessed the shortest shelf-life from all examined samples, as a total viable count of ≥ 10⁵ CFU/ g per sample was recorded after 21 days of storage. After 56 days of storage, vacuum packaged corned beef samples formulated with 1.0% sodium, and accordingly CB_KLG, were also deemed to have expired. Hence, corned beef with the lowest sodium content, not surprisingly, had the shortest shelf-life. It is well known that salt acts as a food preservative by reducing the water activity of food, thereby inhibiting the growth of microorganisms. However, adding salt replacers like potassium lactate and glycine to corned beef with 0.4% sodium (CB_KLG) extended product shelf-life. This result corroborates the theory that glycine and lactate are able to decrease the water activity, and additionally, act as salt enhancer for various types of sausages (Gelabert et al., 2003; Gou et al., 1996; Kilcast & Angus, 2007).

The objective of final packaging study was to evaluate the shelf life of fresh sausages when packaged in an antimicrobial film manufactured using hydroxypropyl methylcellulose (HPMC) and commercially-sourced nanoparticle rosemary extract. The antimicrobial film and control HPMC film were both manufactured using distilled water. Nanoparticle rosemary extract (NP-ROSE) (0.5%) was sprayed on the test films. The control films had a mean thickness of 28µm and the antimicrobial film had a mean thickness of 45µm. Control (30%Fat, 2.5% salt) and a reduced salt (1% Velona, , 40% less Na than standard NaCl) and fat (20%) breakfast sausage were manufactured and packaged with the control and test films and vacuum packed, MAP and skin packaged. Microbial analysis was conducted periodically over a 20 day period. The antimicrobial activity of the rosemary film was evaluated for the two sausage samples. Samples were tested for the presence of the Gram-negative bacteria E-coli (media- compact dry E-coli

and Coliform) and *Pseudomonas fluorescens* (*P. fluorescens*) (media - Agar base to which a CFC supplement was added) and the presence of the Gram-positive bacteria *Staphylococcus aureus* (*S. aureus*) (media - Baird Parker agar) and Lactic acid bacteria (LAB) (media - MRS agar). Total Viable bacteria (media - MPCA) were conducted for each sample. Samples were inoculated with Gram-negative bacteria *E-coli* (NCIMB 11943) and stored with a control film (HPMC), an antimicrobial film (NP-ROSE) and with no film under vacuum pack only

The sausage samples were also inoculated with *E-coli* and stored at 4°C to examine the antimicrobial activity of the antimicrobial film further. Results from this work demonstrated that the 0.5% Rosemary film performed better than no film and control film treatments in retarding the growth of total bacteria (TVC). The Rosemary film showed protection against *E-coli* growth throughout vacuum package storage.

Bacon back rashers

Four different formulations of bacon back rashers were prepared with varying salt levels (2.88, 2.5, 2, and 1.5 %). Sensory acceptance and functionality were studied. A panel of 26 assessors was used for the sensory analysis, consisting of a hedonic test and a flash profiling for all samples in duplicate. Composition, cooking yield, colour, texture and microbial stability were also assessed. Differences in the salt levels were detected by the assessors (in terms of saltiness). The hedonic attributes were significantly negatively correlated only with the sample with the lowest salt quantity. Texture in cooked samples was significantly different; sample with 1.5 % salt had the highest hardness. Cooking yield was significantly lower for the high salt sample and the sample with 1.5 % salt had the highest. No significant differences were found in colour parameters. Samples with 1.5 % salt had the highest growth rate of bacteria affecting the shelf life of the product. However, bacteria levels of samples with salt levels at 2.55 % did not significantly differ. The Food Standards Agency salt recommendation in bacon (2.88 %) was reduced (to 2-2.55 %) without the addition of any replacer/flavouring and with no impairment of their sensory and functionality properties.

A combination of three different salt replacers and a reduction of sodium chloride were studied in back bacon rashers. A sample with 2.5 % salt was used as a control. Another five different formulations were manufactured where the salt content was reduced by half (1.25 %) and replacers were added: potassium chloride (1.25 %, sample R1), potassium chloride and potassium lactate (0.625 % each, sample R2), potassium chloride and calcium chloride (0.625 % each, sample R3), potassium lactate and calcium chloride (0.625 % each, sample R4) and a mixture of potassium chloride, potassium lactate and calcium chloride (0.5 %, 0.5 %, 0.25 % respectively, sample R5). Sensory acceptance and functionality were studied. Samples have been treated and stored in an appropriate manner for future analysis of microstructure. A panel of 24 assessors was used for the sensory analysis, consisting of a hedonic test and a flash profiling for all samples in duplicate. There was a positive and significant correlation for the liking of colour and redness and the control sample and sample R5; however sample R4 was significant but negatively correlated. Likeness of flavour and overall acceptability were highly correlated, control sample, R1 and R5 were the ones that correlated positively and significantly with these two hedonic parameters. The rest of the formulations had negative correlations, being only significant

for sample R3. Surprisingly there were no significant correlations for the rest of the measured parameters (including saltiness and tenderness). Cooking loss of the samples did differ. Samples with calcium chloride (R3 and R4) had the highest cooking loss. When checking the hardness of the samples by means of Texture Profile Analysis (TPA) we observed that the control sample did not significantly differ from the others, in accordance with the sensory panel. For instrumental colour we found significant differences in redness and cured colour ratio; control samples had higher redness and cured colour ratio than sample R1, R2 and R3. The bacteria count for all samples was below 6 log cfu/g after 30 days of storage, therefore, the addition of salt replacers to salt reduced bacon products did not negatively affect the microbiological counts. The use of potassium chloride seems a good strategy in order to decrease the salt content of back bacon rashers without impairing the organoleptic and physicochemical attributes. On the contrary, calcium chloride was not accepted by the sensory panel as a salt replacer in this type of products.

Cooked ham

Results from the retail experiment showed that mean salt levels in ham products (1.84 g/100 g) were above the agreed guidelines from FSA (1.63 g/100 g) for this type of product. Of the different types of cooked ham products, the premium ham had the highest salt value (2.02 g/100 g). We performed a study with four different salt concentrations in premium hams using only whole topside muscles. The salt concentrations were: 2 %, 1.6 %, 1.2 % and 0.8 %. We analysed the microbiological counts, physicochemical properties and sensory properties with an untrained panel (both for hedonic and flash profiling). Results from the sensory analysis showed that both control and 1.6 % samples were significantly positively correlated with liking of flavour, overall acceptability and intensity of juiciness and saltiness. The other two formulations were negatively correlated with these parameters but only significantly for the sample with the lowest salt content (0.8 %). The cook loss was higher for this sample and the expressible moisture was significantly lower. There were no significant differences in instrumental colour. Regarding the texture parameters, samples with the lowest salt contents (0.8, 1.6 %) had significantly higher hardness and chewiness than the other two formulations. After 26 days of storage all the samples were below 6 log cfu/g of total viable counts. Salt can be reduced in cooked ham products to the recommended levels without impairing the functionality and sensory properties of the products.

Another study was performed with formed ham and the use of two flavour enhancers: glycine and a yeast extract. A mixture design was employed where salt content ranged from 0.82-1.63 %, glycine from 0-0.7 % and yeast extract from 0-0.3 %. Twelve different formulations were manufactured and samples were analysed for functionality and sensory properties. Overall acceptability was highly correlated with flavour and both parameters showed a similar response; a combination of the three ingredients was the best approach for maximising these two sensory parameters. All the formulations scored above 5 in a 10 point hedonic scale. However, cooking loss was highly correlated with salt content without much influence from glycine or the yeast extract. Microbiological counts were above 6 log cfu/g after one month of storage for most of the samples indicating the need for a

replacer when working with salt levels below 1.63 %. A combination of glycine and yeast extract is a good combination of flavour enhancers for low salt products.

Streaky bacon rashers

A study of reduced salt streaky rashers was also undertaken. Salt levels were set between 2 and 2.88 %, drying time (60/90/120 °C) and cooking temperature (190/240 °C) were also taken into account. Cooking loss, texture, colour, microbiological counts and sensory analysis are being analysed.

3. Research Achievements/Results

Outline main results achieved

There are several research achievements of this project as outlined in the prolific research publication output. These publications have been widely disseminated through the peer review process in scientific journals with full papers, short papers, abstracts and presentations (oral and posters) in workshops and seminars. The principal outputs are outlined below.

Survey

1. Public health campaigns have successfully raised consumers' awareness to the negative health impacts of diets high in salt and fat.
2. The majority of respondents were well informed, nevertheless, less participants transferred this knowledge into their daily dietary habits
3. No conflict can be seen for the concept of traditional food products (white and black puddings) and innovation (salt and fat reduction), as long as the intrinsic sensory character was maintained
4. Respondents are looking for more information and a wider range of salt- and fat-reduced foods

Sensory Analysis

White Pudding

1 Sample (no replacers) with 15% fat, 0.6% sodium achieved the recommended sodium target level of 0.6% by the FSAI, but no fat reduction was achieved

2. White puddings (made with replacers) containing 10% fat and 0.6% sodium and formulated with sodium citrate and KClG were accepted ($P < 0.05$) and meet the recommended sodium target level of 0.6% set by the FSAI (2011) and additionally, a fat-reduction compared to the major commercial white puddings

Black Pudding

1. Samples with 0.6% sodium and 10% fat (without replacers) displayed a positive ($P < 0.05$) correlation to liking of flavour and overall acceptability. This level meets the sodium target level (0.6%) set FSAI, and shows additionally a fat reduction

2. Samples formulated with 5% fat and 0.6% sodium and containing pectin and KCPCI; and sample formulated with 10% fat and 0.4% sodium and containing WMS were liked ($P < 0.05$) in terms of flavour and overall acceptance. This sodium level (0.4%) is significantly lower than the recommended sodium level (0.6%) as set by the FSAI.

Corned Beef

Sample with KLG were rated lower in saltiness, liked ($P < 0.05$) in flavour and showed a positive directional correlation to overall acceptability

Sodium reduction of 60% achieved in corned beef

Sodium target level of 650 mg/100g set by Food Standards Agency (FSA, 2014), (applied within the UK).

Cured Meats (other)

The minimum salt levels for cured meat products with respect to functionality, food safety, shelf life and sensory quality have been addressed. In the case of back bacon rashers, levels up to 2.5 % of salt are acceptable with no addition of extra replacers and/or enhancers. This level is even below the proposed guidelines for these types of meat products (2.88 %). Regarding the studies with cooked ham, we observed that the guidelines of 1.63 % salt can be adopted without impairing the functionality, sensory quality and shelf life of these products.

Packaging

Vacuum packaged corned beef samples containing 0.4% sodium possessed the shortest shelf-life (21 days); corned beef samples formulated with 1.0% sodium and KLG (0.4% sodium) were expired after 56 days. All MAP packaged corned beef samples showed no microbial growth until day 82 of chilled storage. Results from bioactive packaging work demonstrated that the 0.5% Rosemary film performed better than no film and control film treatment by extending the shelf life of fresh sausages when packaged in an antimicrobial film. This film was manufactured using hydroxypropyl methylcellulose (HPMC) and commercially-sourced nanoparticle rosemary extract.

4. Impact of the Research

A summary of the tangible impact of the research project should be provided under the outcomes' and 'outputs' heading below. In addition, please provide a short narrative synopsis of the benefits / improvements the research has made to the area under investigation particularly as regards end users, e.g. industry, consumers, regulatory authorities, policymakers, the scientific community, etc

- It is possible to reduce salt and saturated fat contents in Irish traditional meat products, however, different products require different modifications
- Salt- and fat-reduction in black pudding is possible by stealth
- Even lower salt and fat contents in black pudding were obtained by using ingredient replacers
- To achieve sensory accepted salt- and fat-reduced white puddings the use of additives was necessary
- The use of additives was necessary to achieve sensory accepted salt-reduced corned beefs
- Bioactive films can be used to extend the shelf life of sausages

4(a) Summary of Research Outcomes

- (i) Collaborative links developed during this research

Number of companies in receipt of information:

- Kerry Foods,
- Rosderra,
- Granby Meats,
- FDII.
- Dawn farm foods

The HEALTHIER PROCESSED MEATS - Fact or Fiction, workshop was held on the 16th Feb 17 in Teagasc Ashtown. PROSSLOW data was presented by both UCC and Teagasc Ashtown partners and discussed with the audience. In attendance were: Hogan's Farm, UCD, Teagasc Dawn Farm Foods, Hilton Foods, O'Brien Fine Foods, Feldhues GmbH, Ribworld, Glenhaven Foods, Tesco Irl, FSAI, Dunbia, AllinAll Ingredients, Manor Farm

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

- Several new products have been developed in the course of this project including;
- Salt and fat reduced Black pudding without replacers
- Salt and fat reduced Black pudding with replacers
- Salt and fat reduced White pudding without replacer
- Salt and fat reduced White pudding with replacer
- Corned beef, salt reduced with and without salt replacers

- Rasher products with and without salt replacers
- All formulations are in the public domain and accessible by the food industry

(iii) Outcomes with economic potential

The principle outcomes with economic potential include the marketing of the above formulations to consumers in who are still interested in consuming traditional Irish processed meat products but are a little healthier than current products but which still have a high level of hedonic sensory quality.

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

PROSSLOW addressed a key goal of Horizon 2020 and the vision of the European Technology Platform Food for Life Programme in developing new innovative manufacturing technologies, addressing consumer expectations for high quality, novel or modified products to enhance the competitiveness of the European Food Sector.

PROSSLOW responds to the Strategic Research Agenda of the European Technology Platform-The growing demand for safer, healthier, higher quality food and for sustainable use and production. PROSSLOW supports the development of a sustainable European Knowledge Based Bio-Economy (KBBE) and offers a convergent and coordinated approach to address the challenges facing society. PROSSLOW also aligns with this challenge in enhancing the link with the KBBE further, this project will increase the number of researchers (post-graduates, post-doctorates) with knowledge and expertise in processed meat optimisation.

A socially inclusive and healthy Europe - PROSSLOW supports a defensive health policy in combating illness to a preventive approach promoting the health of every citizen. Healthier TPM (Traditional Processed Meats) products will assist in increasing the range of healthier processed foods in the marketplace. Additionally PROSSLOW supports Coordination with Theme 1 - 'Health', which is foreseen in the field of nutrition and prevention of diet-related diseases, in particular diabetes and obesity. Also PROSSLOW supports Coordination with Theme 5 - 'Science in Society' of the Specific Programme.

The innovation dimension: Research and innovation are part the Europe 2020 strategy. PROSSLOW utilises state-of-the-art sensory methodologies and multivariate analysis to optimise lower fat and salt TPMs while maintaining functionality, food safety, consumer and sensory quality. PROSSLOW is doubly innovative in that novel packaging applications will be developed and assessed as part of this project in order to counteract negative quality, shelf-life and safety issues that may arise as a consequence of altering product composition, namely the use of processing aids (salt etc), which have been traditionally used for preservation purposes in processed muscle-based food products.

4 (b) Summary of Research Outputs

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

Delgado-Pando, G., Allen, P., Fischer, E., O'Sullivan, M.G., Kerry, J.P. and Hamill, R.M. (2018). Salt content and minimum acceptable levels in whole-muscle cured meat products. *Meat Science*, 139, 179-186. <https://doi.org/10.1016/j.meatsci.2018.01.025>

Delgado-Pando, G., Allen, P., Kerry, J. P., O'Sullivan, M. G., & Hamill, R. M. (2018). Interaction of salt content and processing conditions drives the quality response in streaky rashers. *LWT*, 97, 632-639

Delgado-Pando, G., Allen, P., Kerry, J. P., O'Sullivan, M. G., & Hamill, R. M. (2019). Optimising acceptability of reduced-salt ham with flavourings using a mixture design. *Meat Science*, 156, 1-10.

Fellendorf, S., O'Sullivan, M.G. and Kerry J.P. (2015). Impact of varying salt and fat levels on the physicochemical properties and sensory quality of white pudding sausages. *Meat Science*, 103, 75-82.

Fellendorf, S., O'Sullivan, M.G. and Kerry J.P. (2017). Effect of different salt and fat levels on the physicochemical properties and sensory quality of black pudding. *Food Science & Nutrition* 5(2), 273-284.

Fellendorf, S., O'Sullivan, M.G. and Kerry J.P. (2016a). Effect of using replacers on the physicochemical properties and sensory quality of low salt and low fat white puddings. *European Food Research and Technology*, 242, 2105-2118.

Fellendorf, S., O'Sullivan, M.G. and Kerry J.P. (2016b). Impact of using replacers on the physicochemical properties and sensory quality of reduced salt and fat black pudding. *Meat Science* 113, 17-25.

Fellendorf, S., Kerry J.P., Hamill, R.H. and O'Sullivan, M.G (2018). Impact on the physicochemical and sensory properties of salt reduced corned beef formulated with and without the use of salt replacers. *LWT-Food Science and Technology*, 92, 584-592.

Fellendorf, S., Kerry J.P., and O'Sullivan, M.G (2018). Consumer Attitudes on Salt and Fat Reduced Foods in the Republic of Ireland. *Food and Nutrition Sciences*, 9, 880-898. doi: 10.4236/fns.2018.97066.

Fellendorf, S (2016). Development of consumer accepted low salt and low fat traditional Irish processed meats. March, 2016. PhD Thesis

O'Sullivan, M.G. (2017). CH11. Sensory Properties Affecting Meat and Poultry Quality. *A Handbook for Sensory and Consumer Driven New Product Development: Innovative Technologies for the Food and Beverage Industry*. Woodhead Publishing Ltd., United Kingdom, 225-257.

O'Sullivan, M.G. (2017). CH3. Sensory Affective (Hedonic) Testing. *A Handbook for Sensory and Consumer Driven New Product Development: Innovative Technologies for the Food and Beverage Industry*. Woodhead Publishing Ltd., United Kingdom, 39-57.

O'Sullivan, M.G. (2017). CH4. Rapid Sensory Profiling Methods. *A Handbook for Sensory and Consumer Driven New Product Development: Innovative Technologies for the Food and Beverage Industry*. Woodhead Publishing Ltd., United Kingdom, 59-82.

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

Short papers

Fellendorf, S., Kerry J.P. and O'Sullivan, M.G. (2017). Irish consumer attitudes on salt and fat processed meats. 63rd International Congress of Meat Science and Technology, Cork, Ireland.

Fellendorf, S., Hamill, R.M., Kerry J.P. and O'Sullivan, M.G. (2017). Sensory quality of salt reduced corned beefs formulated with salt replacers. 63rd International Congress of Meat Science and Technology, Cork, Ireland.

Gonzalo Delgado-Pando, Paul Allen, Joe Kerry, Maurice O'Sullivan and Ruth M. Hamill (2017). Use of potassium chloride as salt replacer in reduced-salt back bacon rashers: impact on shelf life. 63rd International Congress of Meat Science and Technology, Cork, Ireland.

Gonzalo Delgado-Pando, Paul Allen, Maurice O'Sullivan, Joe Kerry and Ruth M. Hamill (2017). Edible bioactive packaging applied to reduced-salt back bacon rashers: effect on shelf life. 63rd International Congress of Meat Science and Technology, Cork, Ireland.

Magazine article

O'Sullivan, M. G. and Kerry, J.P. (2016). Sensory optimisation and the reduction of salt fat and sugar in processed foods: New Food, December issue 2016.

Delgado-Pando, G., Kerry, J. P., O'Sullivan, M. G., & Hamill, R. M. (2016, Spring). Fat and salt in processed meat products- a challenge for industry. T Research 11: 30-31

Posters

Fellendorf, S., Kerry J.P. and O'Sullivan, M.G. (2018). Salt- and fat-reduced foods. A consumer survey on attitudes to reformulated traditional processed meats in Ireland. Eurosense 2018; A sense of taste, 2-5 September 2018, Verona, Italy.

Fellendorf, S., Kerry J.P. and O'Sullivan, M.G. (2017). Irish consumer attitudes on salt and fat processed meats. 63rd International Congress of Meat Science and Technology, Cork, Ireland.

Fellendorf, S., Hamill, R.M., Kerry J.P. and O'Sullivan, M.G. (2017). Sensory quality of salt reduced corned beefs formulated with salt replacers. 63rd International Congress of Meat Science and Technology, Cork, Ireland.

Gonzalo Delgado-Pando, Paul Allen, Maurice O'Sullivan, Joe Kerry and Ruth M. Hamill (2017). Edible bioactive packaging applied to reduced-salt back bacon rashers: effect on shelf life. 63rd International Congress of Meat Science and Technology, Cork, Ireland.

Gonzalo Delgado-Pando, Paul Allen, Joe Kerry, Maurice O'Sullivan and Ruth M. Hamill (2017). Use of potassium chloride as salt replacer in reduced-salt back bacon rashers: impact on shelf life. 63rd International Congress of Meat Science and Technology, Cork, Ireland.

Fellendorf, S., O'Sullivan, M.G. and Kerry J.P. (2015). Sensory optimisation methods for reducing salt and fat in processed meat. The 11th Pangborn Sensory Science Symposium, Gothenburg, Sweden.

Fellendorf, S., O'Sullivan, M.G. and Kerry J.P. (2015). Sensory acceptance testing and ranking descriptive analysis (RDA) for optimisation of reduced salt and fat black puddings developed using ingredient replacers. The 11th Pangborn Sensory Science Symposium, Gothenburg, Sweden.

O'Sullivan, M.G., Grønbeck, Marlene Schou and Byrne, Derek V (2015). Fast sensory and consumer driven product innovation in the food sector: still far from an industry standard? The 11th Pangborn Sensory Science Symposium, Gothenburg, Sweden.

Fellendorf, S., O'Sullivan, M.G. and Kerry J.P. (2014). The reduction of salt and fat levels in black pudding and the effects on physiochemical and sensory properties. 1st International PLEASURE Conference on SALT - SUGAR & LIPIDS Reduction in Foods, 18-19 June 2014 - La Rochelle - France.

Fellendorf, S., O'Sullivan, M.G. and Kerry J.P. (2014). Impact of varying salt and fat levels on the physiochemical properties and sensory quality of white pudding sausages. 1st International PLEASURE Conference on SALT - SUGAR & LIPIDS Reduction in Foods 18-19 June 2014 - La Rochelle - France.

(iii) National Report

Teagasc Gateways to Foods for Health 10th December 2015. In this event a showcase of the research conducted was presented to the different food and ingredient producers that attended.

(iv) Workshops/seminars at which results were presented

Delgado-Pando, G. (2017). Salt reduction in cured meat products. Healthier Processed Meats - Fact or Fiction? A workshop based on the outputs of "NutriMeat" and "PROSSLOW" projects. February 16th 2017, Teagasc, Ashtown.

O'Sullivan, M.G. (2018). Sensory Science in UCC. 61st European Sensory Network Meeting, 10-11 October, Ballsbridge, Dublin.

O'Sullivan, M.G. (2017). Development of low salt and low fat Irish traditional processed meats. Healthier Processed Meats - Fact or Fiction? A workshop based on the outputs of "NutriMeat" and "PROSSLOW" projects. February 16th 2017, Teagasc, Ashtown.

O'Sullivan, M.G. (2017). Innovative Sensory Methods for the Nutritional Optimisation of Foods. The Research and Innovation Conference and Exhibition, CityWest, Dublin, 14th February, 2017.

O'Sullivan, M.G. (2016). Sensory and consumer driven new product development: Innovative technologies for the food and beverage industry. 3rd National Food & Drink Business Conference and Exhibition, CityWest, Dublin, 14th September, 2016.

O'Sullivan, M.G. (2016). Sensory and consumer driven new product development: Innovative technologies for the food and beverage industry. Food and Drink NPD and Innovation Summit/ Food and Drink Quality and Safety Summit, Motorcycle museum, Birmingham, 30th November 2016.

O'Sullivan, M.G. (2016). Salt and fat reduction in processed meat. Reformulation for the Future. Food Product Improvement Seminar Friday, 20 May 2016, Ibec, Dublin

O'Sullivan, M.G. (2016). PROSSLOW data was presented to Dawn Farm Foods at a meeting held in UCC on 16th November 2016. All current data and findings were presented and discussed as well as support and opportunities for collaboration. In attendance were Dr. Maurice O'Sullivan, Prof. Joe Kerry (UCC), Mr. Connor Cahill and Mr. Michael Cullen (Dawn Farm Foods).

O'Sullivan, M.G. (2014). Update: Development of low salt and low fat Irish traditional processed meats. The coordinator of the FSAI salt reduction program (Karl McDonald), was briefed on the 4th July 2014 with regard to progress on the PROSSLOW project and is a member of the management committee for the project. The meeting proposed with the IBEC processed meat group is in process of arranging with collaboration with the FSAI.

O'Sullivan, M.G. (2015). Update; Development of low salt and low fat Irish traditional processed meats. The "IBEC Processed Meat Group", 28th January 2015. The IBEC HQ on Lower Baggott Street in Dublin. Current data and findings from the PROSSLOW project was presented in depth and discussion took place.

(v) Intellectual Property applications/licences/patents

(vi) Other

O'Sullivan, M.G. and Kerry, J.P. (2017). **Sensory Optimised Salt and Fat Reduction in Processed Meats: Technological Approaches for Creating Novel Product Formulations.** Food Science and Nutrition, Elsevier, scitech connect. <http://scitechconnect.elsevier.com/sensory-optimised-salt-fat-reduction-processed-meats/>

5. Scientists trained by Project

Total Number of PhD theses: 1

Please include authors, institutions and titles of theses and submission dates. If not submitted please give the anticipated submission date

Fellendorf, S (2016). Development of consumer accepted low salt and low fat traditional Irish processed meats. March, 2016. PhD Thesis

Total Number of Masters theses: 0

Please include authors, institutions and titles of theses and submission dates. If not submitted please give the anticipated submission date

6. Permanent Researchers

Institution Name	Number of Permanent staff contributing to project	Total Time contribution (person years)
UCC	2	6.87
Teagasc Ashtown	2	2.35
Total		

7. Researchers Funded by DAFM

Type of Researcher	Number	Total Time contribution (person years)
Post Doctorates/Contract Researchers	2	4.82
PhD students	1	0.82
Masters students	1	3.00
Temporary researchers	1	.58
Other		
Total	5	9.22

8. Involvement in Agri Food Graduate Development Programme

Name of Postgraduate / contract researcher	Names and Dates of modules attended
Susan Fellendorf	N/A

9. Project Expenditure

Total expenditure of the project: € 498787

Total Award by DAFM: €499721

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

Breakdown of Total Expenditure

Category	Name UCC	Name Teagasc	Name Institution 3	Name Institution 4	Total
Contract staff					
Temporary staff					
Post doctorates	159324	88,621			247,945
Post graduates	72,352				72,352
Consumables	28,195	13,681			41,876
Travel and subsistence	6,614	6,134.30			12,748
Sub total	266,485	110436			376,921
Durable equipment	940				940
Other	2000				2,000
Overheads	75,535	32,531.10			108,066
Total	344,792	140,552			485,344

10. Leveraging

Summarise any additional resources'/funding leveraged by this award from other sources e.g. Additional Staff, National/EU funding secured, EI Commercialisation Fund, etc.

11. Future Strategies

Outline development plans for the results of the research.

Results have been widely disseminated as domestic and international conferences as well as published in peer and non-peer reviewed sources. Data has also been presented in workshops as described above.

The information and data collected also forms a foundation for future research, expanding our knowledge of salt and fat interaction in processed meats. Additionally techniques like "flash profiling" are now being utilised by the food processing industry (Kerry Group-personal communication).