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

13F458 - Shelf-life extension ingredient and processing technologies applied to Fish

Final Report

This project was funded under the Department of Agriculture, Food and the Marine Competitive Funding Programme.

SUMMARY

The overall objective of the project was to develop methods to rapidly assess the freshness of salmon and cod and a tool to predict shelf-life as well as investigating chemical and physical interventions that may extend the shelf-life of the fish.

The project developed/delivered the following:

1. Quality Index Method (QIM) and a Quality Descriptive Analysis (QDA) for assessing the freshness of cod and salmon using sensory analysis parameters for raw and cooked fish, respectively.
2. A summary report on the effectiveness of the PRECICE® K-Freshness Assay Kit.
3. An Excel based mathematical model that predicts bacterial (TVC (mesophiles and psychrophiles), Enterobacteriaceae, Pseudomonads, H2S producing bacteria (HSPB), Brochrothrix thermosphacta, lactic acid bacteria (LAB) and Photobacterium phosphoreum) growth and hence shelf-life based on the QIM score.
4. Data on the effect of clean label ingredients (5% (v/v) lactic acid, citric acid and ascorbic acid and 0.5% and 1% (v/v) cavacol, thymol, eugenol and citral), applied as both a spray and dip, in combination with different packaging conditions (aerobic, skin (anaerobic) and modified atmospheric conditions) on the shelf-life of salmon and cod.
5. Data which shows that crust-freezing under sub-zero temperatures has the greatest potential as a means of preservation and shelf-life extension (the microbiological shelf-life of salmon was extended by between 8 to 12 days).
6. Studies which demonstrate the potential of high intensity light pulses (HILP) for the effective decontamination of polyethylene cutting board and stainless-steel surfaces. Moreover, in period 4, Clostridium sporogenes (a surrogate for Clostridium botulinum) inoculation studies found that at 2°C storage there was no risk to the consumer but in a temperature abuse scenario (20°C), C. sporogenes grew well in high barrier film skin packs suggesting consumers are exposed to a potential botulism risk if the skin packaged fish is temperature abused.

KEYWORDS

Fish; food safety; shelf-life.

ACRONYM	SEA-FISH
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COLLABORATORS, INSTITUTION	Dr Paul White, Dr James Lyng and Dr Nigel Brunton, University College Dublin.
PUBLICATION DATE	April 2020.

Section 1 - Research Approach & Results

Start Date

01 March 2014

End Date

31 May 2018

Research Programme

Food Institutional Research Measure

TRL Scale

TRL 2: Technology Concept Formulated

NRPE Priority area

Sustainable Food Production and Processing

Total DAFM Award

€583,100.00

Total Project Expenditure

€548,374.00

Rationale for undertaking the Research

This project was undertaken to; [1] help achieve the target of 43% increase in the value of the seafood sector as set out in Food Harvest 2020, and [2] to provide R&D food safety and shelf-life support for the development of a sector worth over €700m to the Irish economy (including exports worth €379) per annum. After discussion with our stakeholders the specific areas of interest included; the application of clean label ingredients with and without novel processing technologies to optimize shelf-life (thereby facilitating access to more distant export markets), the development of rapid methods for assessing fish freshness, shelf-life predictor tools as well as information on the application of light technologies (UV, HILP, blue light) for the control of microbial contaminants in critical areas within fish processing plants and on food contact equipment surfaces.

Methodology

This project used the most up-to-date international and peer reviewed laboratory methods in microbiology, sensory analysis, etc. to design and undertake food safety and shelf-life studies. All studies were designed in full consultation with key stakeholders and dissemination activities were undertaken to reach a broad audience which included the seafood industry, academia and regulatory personnel. This included the provision of information leaflets, participation in relevant national and international conferences and a dedicated workshop in addition to publishing scientific papers in the peer reviewed journals.

Project Results

The main results, conclusions and/or deliverables included; [1] data on the relationship between the microbiology, sensory attributes and chemistry (the breakdown of ATP to IMP, inosine and hypoxanthine) in salmon and cod during storage; [2] a Quality Index Model (QIM) for sensory evaluation of cod and salmon to assess freshness and [3] an Excel based model that related QIM score to the microbial characteristics of the fish

and which may be used to predict remaining shelf-life; [4] A report for the Irish fish processing industry on the application of clean label ingredients in extending the shelf-life of skin packaged fresh cod and salmon which reported that; (a) dip or spray treatment of cod or salmon with the 'clean label' ingredients did not retard bacterial growth or extend shelf-life.; (b) vacuum packaging extended shelf-life by up to 5 days but may present a risk of botulism poisoning if the product is subject to temperature abuse, and (c) sub-zero (-2 °C) storage did not extend shell-life; [5] A report on the effectiveness and potential application of physical decontamination technologies, alone and in combination with clean label ingredients for fish shelf-life extension that reported that; (a) high-power ultrasound (US) was a suitable technology to decontaminate salmon at low temperatures; (b) the application of crust-freezing on skin-packed salmon increased its microbiological shelf-life; (c) ultraviolet light (UV-C) and pulsed light (HILP) proved to be effective in reducing the microbial population in raw salmon and cod; (d) oregano oil and ascorbic acid dipping treatments in combination with crust-freezing extended the shelf-life of skin-packed salmon fillets, and (e) HILP technology was more effective than UV-C light for food-contact surface decontamination; [6] A report on the potential application of a range of different clean label ingredients in fish preservation and the effect of the most effective shelf-life extension technologies (ingredient/ingredient plus physical processing interventions) on the nutritional and sensory attributes of skin-packed fresh fish and salmon, which reported that; (a) ascorbic acid (1.25%) and citric acid (0.63%) proved to be the most suitable organic acids from a sensory perspective for salmon and cod respectively; (b) none of the essential oils tested in cod were organoleptically acceptable under the tested concentrations (effective in vitro), ranging from 0.1 to 0.2%; (c) oregano oil (0.2%) was the most suitable essential oil from a sensory perspective for salmon, and (d) oregano oil and ascorbic acid dipping treatments in combination with crust-freezing extended the shelf-life of salmon by 3 to 7 days respectively.

Section 2 - Research Outputs

Summary of Project Findings

The technologies developed and data/knowledge generated in this project provide the Irish fish processing sector with; [1] a Quality Index Method (QIM) and a Quality Descriptive Analysis (QDA) for assessing the freshness of cod and salmon using sensory analysis parameters for raw and cooked fish, respectively; [2] an Excel based mathematical model that predicts bacterial (TVC (mesophiles and psychrophiles), Enterobacteriaceae, Pseudomonads, H_2S producing bacteria (HSPB), Brochrothrix thermosphacta, lactic acid bacteria (LAB) and Photobacterium phosphoreum) growth and hence shelf-life based on the QIM score; [3] a high intensity light pulses (HILP) method for the effective decontamination of polyethylene cutting board and stainless steel surfaces thus preventing cross-contamination; [4] a crust freezing technology that may extend the shelf-life of salmon fillets by up to 12 days and [5] data on the potential application of a range of clean label ingredients to extend the shelf-life of cod and salmon fillets. Moreover, the food safety studies, especially the data generated on the C. botulinum risk associated with the application of high barrier vacuum (skin-pack) films will be of interest to both the industry and regulatory functions in Ireland.

Summary of Staff Outputs

Research Output	Male	Female	Total Number
PhD Students	2	1	3

Summary of Academic Outputs Research

Outputs	Total No.	Details
Publications in Peer Reviewed Scientific Journals	7	1. Pedrós-Garrido, S., Condón-Abanto, S., Beltrán, J. A., Lyng, J. G., Brunton, N. P., Bolton, D., Whyte, P. (2017). Assessment of high intensity ultrasound for Surface decontamination of salmon (S. salar), mackerel (S. scombrus), cod (Gadus morhua) and hake (M. merluccius) fillets, and its impact on fish quality. Innovative Food Science and Emerging Technologies, 41, 64-70. 2. Pedros-Garrido, S., Condon-Abanto, S., Clemente, I., Beltran, J.A., Lyng, J.G., Bolton, D., Brunton, N., Whyte, P. (2018). Efficacy of ultraviolet light (UV-C) and pulsed light (PL) for the microbiological decontamination of raw salmon (Salmo salar) and food contact surface materials. Innovative Food Science and Emerging Technologies, 50, 124-131. 3. Pedrós-Garrido, S., Clemente, I., Calanche, J. B., Condón-Abanto, S., Beltrán, J. A., Lyng, J. G., Brunton, N., Bolton, D., Whyte, P. (2020) Antimicrobial activity of natural compounds against Listeria spp. and their effects on sensory attributes in salmon (Salmo salar) and cod (Gadus morhua). Food Control, 107, 106768. 4. Conor Smyth, Paul Whyte, Colin Fogarty and Declan Bolton (2018). The effect of organic acid, trisodium phosphate and essential oil component immersion treatments on the microbiology of cod (Gadus morhua) during chilled storage. FOODs, 7, 200; doi:10.3390/foods7120200 (published online). 5. Colin Fogarty, Paul Whyte, Nigel Brunton, James Lyng, Conor Smyth, John Fagan and Declan Bolton (2019). The microbiology of farmed Atlantic salmon (Salmo salar) stored on ice for 10 days. Food Microbiology, 77, 38-42. 6. Colin Fogarty, Conor Smyth, Paul Whyte, Nigel Brunton and Declan Bolton (2019). Sensory and ATP derivative-based indicators for assessing the freshness of Atlantic salmon (Salmo salar) and cod (Gadus morhua). Irish Journal of Agriculture and Food Research, 58 (1), 71-80. 7. Colin Fogarty, Catherine Burgess, Paul Cotter, Raul Cabrera-Rubio, Paul Whyte, Conor Smyth and Declan Bolton (2018). Raul CabreraRubio. Characterization of the microbial community present in the gut of Atlantic salmon (Salmo salar) farmed in Irish waters. Journal of Applied Microbiology, 127 (3), 648-657.
PhD Theses	3	1. Shelf-life extension ingredient and processing technologies applied to cod (Ph.D., Conor Smyth, UCD, 8th April 2019). 2. Shelf-life extension ingredient and processing technologies applied to Atlantic salmon (salmo salar) (Ph.D. Colin Fogarty, UCD, 11th April 2019).

		3. Investigation of ingredient and process technologies for the extension of shelf-life in fresh fish. (Ph.D., Selene Pedros-Garrido, UCD May 2018.
Peer Reviewed Conference Papers	20	1. Selene Pedrós, J. Meade, J. Lyng, D. Bolton, J. Fagan, N. Brunton & Paul Whyte (2014). A study of decontamination of the natural microflora on salmon. Poster presentation at the XIX National Food Microbiology Congress, Zaragoza, Spain, 24th to 26th September 2014. 2. Selene Pedrós, J. Meade, J. Lyng, D. Bolton, J. Fagan, N. Brunton & Paul Whyte (2014). Surface decontamination of salmon natural flora. Oral communication at the 43rd Annual Food Research Conference, IFSTI, Dublin, 2014. 3. S. Pedrós, S. Condón-Abanto, J.G. Lyng, D. Bolton, J. Fagan, N. Brunton, P. Whyte (2015). A novel technique to decontaminate fresh fish using high-power ultrasonication. Poster presentation at the All Island State Veterinarians Conference (AISVC), Limerick, 2015. 4. S. Pedrós, J. Meade, J. G. Lyng, N. Brunton, D. Bolton, C. Arroyo Casabona, J. Fagan, P. Whyte (2015). The potential for UV-C light in the surface decontamination of salmon (Salmo salar). Poster presentation at the Institute of Food Technology (IFT) Conference, Chicago, Illinois, 2015. 5. S. Pedrós-Garrido, J.A. Beltrán, J.G. Lyng, D. Bolton, N. Brunton, P. Whyte (2015). Effect of crust-freezing on the shelf-life of salmon (Salmo salar) stored at low temperatures under different packaging technologies. Oral communication at the Trans-Atlantic Fisheries Technology (TAFT) Conference, Nantes, France, 2015. 6. Selene Pedrós, C. Arroyo, J.G. Lyng, N. Brunton, D. Bolton, J. Fagan & P. Whyte (2016). Effect of High intensity Light Pulses (HILP) on the surface microflora of salmon (Salmo salar) and cod (Gadus morhua). Poster presentation, at International Union of Food Science and Technology Conference (IUFoST), Dublin, 21st to 25th August 2016. 7. Selene Pedrós-Garrido, S. Condón-Abanto, J.A. Beltrán, J.G. Lyng, N. Brunton, D. Bolton, P. Whyte (2016). Effect of high-power ultrasound on the decontamination of salmon (S. salar) and mackerel (S. scombrus) natural flora. Oral communication, at West European Fish Technologists Association Conference (WEFTA), Split (Croatia), 12th to 14th October 2016. 8. Selene Pedrós-Garrido, J.A Beltrán, James Lyng, Nigel Brunton, Paul Whyte (2017). Assessment of light technologies effect on the quality of Atlantic salmon from aquaculture. Poster presentation at the “XVI Congreso nacional de acuicultura, Paraninfo Universidad de Zaragoza, 3rd-5th October 2017. Conference book p. 296-297. 9. S. Pedrós Garrido, J.A. Beltrán, J.B. Calanche, J.G. Lyng, N. Brunton, D. Bolton, P. Whyte (2017). Preliminary study of the application of a chitosan edible coating on defrosted cod (Gadus morhua) fillets and its effect on microbiological quality. Poster presentation at the 47th

WEFTA Conference, Aviva Stadium, Dublin, 9th to 12th October 2017, Conference Book, page 122.

10. S. Pedrós-Garrido, J.A. Beltrán, J.G. Lyng, D. Bolton, N. Brunton, P. Whyte (2017). Effect of High Intensity Light Pulses (HILP) on the surface microflora of salmon (Salmo salar) and cod (Gadus morhua). Poster presentation at 31st EFFoST International Conference, Sitges (Spain), 13-16th November 2017. Poster abstracts book [P2.107].
11. S. Pedrós-Garrido, J.A. Beltrán, J.G. Lyng, D. Bolton, N. Brunton, P. Whyte (2017). Comparison of the effect of crust-freezing before and after skin-packaging on the shelf-life of salmon (Salmo salar) stored at low temperatures. Poster presentation at 31st EFFoST International Conference, Sitges (Spain), 13-16th November 2017. Poster abstracts book [P1.158].
12. Selene Pedrós-Garrido, S. Condón-Abanto, S., Beltrán, James Lyng, Nigel Brunton, Declan Bolton, Paul Whyte (2016). Effect of high power ultrasound on the decontamination of salmon (s. Salar) and mackerel (s. Scombrus) natural flora. Poster presentation at the 46th West European Fish Technologists Association (WEFTA) Conference, Split, Croatia, 12th to 14th October 2016.
13. Selene Pedros-Garrido, Jose A. Beltran, Juan B. Calanche, James lyng, Nigel Bruton, Declan Bolton, John Fagan and Paul Whyte (2017). Preliminary study of the application of a chitosan edible coating on defrosted cod fillets and its effect on microbiological quality. Poster presentation at the 47th West European Fish Technologists Association Conference, Aviva Stadium, Dublin, 9th to 12th October 2017, Conference Book, page 122.
14. Conor Smyth, Nigel Brunton, James Lyng, Paul Whyte and Declan Bolton (2016). Studies on the shelf-life of cod (Gadus morhua) using clean label ingredients. Poster presentation, at the IUFoST International Conference, RDS Dublin, 21st to 25th August 2016, Abstract Book, page 1075.
15. Conor Smyth, Nigel P. Brunton, James L. Lyng, Paul Whyte and Declan J. Bolton (2016). Assessing the quality of raw cod (gadus morhua) using microbiological, sensory and chemical indicators. Poster presentation at the 46th West European Fish Technologists Association (WEFTA) Conference, Split, Croatia, 12th to 14th October 2016.
16. Conor Smyth, Paul Whyte, James Lyng, Nigel Brunton, John Fagan, Colin Fogarty and Declan Bolton. (2017). Effect of the combination of clean label ingredients and packaging conditions on the shelf-life and microbiology of meat. Poster presentation at the 63rd International Congress of Meat Science and Technology, Rochestown Park Hotel, Cork, 13th to 18th August 2017. Abstract Book, page 912.
17. Colin Fogarty, Conor Smyth, Paul Whyte, James Lyng, Nigel Brunton, John Fagan and Declan Bolton (2017). Using natural ingredients and packaging technologies to enhance the shelf-life of cod and salmon. Oral presentation at the 47th West European Fish Technologists

Association Conference, Aviva Stadium, Dublin, 9th to 12th October 2017, Conference Book, page 59.

18. Colin Fogarty, Conor Smyth, Paul Whyte, James Lyng, Nigel Brunton, John Fagan and Declan Bolton (2017). Using natural ingredients and packaging technologies to enhance the shelf-life of cod and salmon. Oral presentation at the 47th West European Fish Technologists Association Conference, Aviva Stadium, Dublin, 9th to 12th October 2017, Conference Book, page 59.
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20. Colin Fogarty, Conor Smyth, Paul Whyte, James Lyng, Nigel Brunton, John Fagan and Declan Bolton (2017). Using natural ingredients and packaging technologies to enhance the shelf-life of cod and salmon. Oral presentation at the 47th West European Fish Technologists Association Conference, Aviva Stadium, Dublin, 9th to 12th October 2017, Conference Book, page 59.

Intellectual Property

Not applicable

Potential Impact related to Policy, Practice and Other Impacts

Impact	Details
Industry	The first project deliverable was a Quality Index Method (QIM) and a Quality Descriptive Analysis (QDA) for assessing the freshness of cod and salmon using sensory analysis parameters for raw and cooked fish. This could be used by fish processors to assess and control the freshness of fish arriving at the processing plant. The impacts would include improved food safety, reduced wastage and the delivery of a better product to the consumer. The QIM and QDA should be used with the Excel based mathematical model that predicts bacterial growth to allow fish processors and retailers to more accurately predict shelf-life. The impacts would also be enhanced fish safety and quality with reduced waste. The high intensity light pulses (HILP) method for the effective decontamination of polyethylene cutting board and stainless-steel surfaces should be used as part of the fish processing plant sanitary practices and the impact would be cleaner surfaces, reduced cross-contamination of the fish resulting in a better quality product with longer shelf-life. A crust freezing technology was also delivered that would increase the shelf-life of skin packed salmon fillets by up to 12 days. Fish is increasingly being sold as a processed product with added ingredients such as garlic or batters. The clean label ingredient data generated in this project could be used to extend the shelf life of these types of cod and salmon products. As the food industry moves to using skin (vacuum) packaging films with higher oxygen barrier properties the studies on the

	potential growth and toxin production by C. botulinum in high barrier film (skin-pack) pouches subject to temperature abuse should be used to inform and facilitate the development of food safety policy on their usage, which would protect public health and the reputation of the seafood sector.
Other	The studies on the potential growth and toxin production by C. botulinum in high barrier film (skin-pack) pouches subject to temperature abuse should inform regulatory policy on their usage.

Dissemination Activities

Activity	Details
Other	The dissemination activities included; an introductory leaflet, a final leaflet, industry workshop as well as peer reviewed published papers and oral/poster presentations at national and international conferences.
Seminars at which results were presented	National & international conferences (as above); 1. Selene Pedrós, J. Meade, J. Lyng, D. Bolton, J. Fagan, N. Brunton & Paul Whyte (2014). A study of decontamination of the natural microflora on salmon. Poster presentation at the XIX National Food Microbiology Congress, Zaragoza, Spain, 24th to 26th September 2014. 2. Selene Pedrós, J. Meade, J. Lyng, D. Bolton, J. Fagan, N. Brunton & Paul Whyte (2014). Surface decontamination of salmon natural flora. Oral communication at the 43rd Annual Food Research Conference, IFSTI, Dublin, 2014. 3. S. Pedrós, S. Condón-Abanto, J.G. Lyng, D. Bolton, J. Fagan, N. Brunton, P. Whyte (2015). A novel technique to decontaminate fresh fish using high-power ultrasonication. Poster presentation at the All-Island State Veterinarians Conference (AISVC), Limerick, 2015. 4. S. Pedrós, J. Meade, J. G. Lyng, N. Brunton, D. Bolton, C. Arroyo Casabona, J. Fagan, P. Whyte (2015). The potential for UV-C light in the surface decontamination of salmon (Salmo salar). Poster presentation at the Institute of Food Technology (IFT) Conference, Chicago, Illinois, 2015. 5. S. Pedrós-Garrido, J.A. Beltrán, J.G. Lyng, D. Bolton, N. Brunton, P. Whyte (2015). Effect of crust-freezing on the shelf-life of salmon (Salmo salar) stored at low temperatures under different packaging technologies. Oral communication at the Trans-Atlantic Fisheries Technology (TAFT) Conference, Nantes, France, 2015. 6. Selene Pedrós, C. Arroyo, J.G. Lyng, N. Brunton, D. Bolton, J. Fagan & P. Whyte (2016). Effect of High intensity Light Pulses (HILP) on the surface microflora of salmon (Salmo salar) and cod (Gadus morhua). Poster presentation, at International Union of Food Science and Technology Conference (IUFoST), Dublin, 21st to 25th August 2016. 7. Selene Pedrós-Garrido, S. Condón-Abanto, J.A. Beltrán, J.G. Lyng, N. Brunton, D. Bolton, P. Whyte (2016). Effect of high-power ultrasound on the decontamination of salmon (S. salar) and mackerel (S. scombrus) natural flora. Oral communication, at West European Fish Technologists

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Workshops at which results were presented	A Project industry workshop, titled ‘Adding Value and New Market Opportunities for the Seafood Sector’ took place in the Training and Conference Centre, Teagasc Food Research Centre (Ashtown) on Thursday 26th July 2018. There were presentations given by the research partners on all the tasks undertaken in the project with particular focus on the commercial relevance of the R&D. Attendees included; Ruth Dalton (Musgraves), Yiming Zhao (Teagasc), Des Walsh (Teagasc), Declan Bolton (Teagasc), Aoife McDermott (Teagasc), Colin Fogarty (Teagasc), Conor Smyth (Teagasc), James Lyng (UCD), Paul Whyte (UCD), Nigel Brunton (UCD), Federico Lian (UCD), Santiago Condón (UCD), Selene Pedros-Garrido (UCD), John Fagan (BIM), Myles Mulligan (BIM), Juan Blancs (Glenmar Shellfish), Brendha Truccollo (Teagasc), Damian Connolly (Bantry Bay Seafoods), Yvonne Stedman (Bantry Bay Seafoods), Jennifer Gray (Teagasc), Siobhan McSharry (Teagasc), Shaun Smith (FSAI), Aileen O’Sullivan (SFPA), Kaye Burgess (Teagasc), Leonard Koolman (Teagasc), Elena Ingulia (Teagasc), Amelie Rouger (Teagasc), Daryl Gunning (Keohane Seafoods), Elizabeth O’Leary (Keohane Seafoods), Lauren Russell (Teagasc), Katie Healy (BIM), Paul Tonge (Brennan Group), Frank Brannigan (Brennan Group), Bláithín Maunsell (SFPA), Albert O'Sullivan-Greene (Shellfish Ireland), Ken Ecock (Oceanpath), Julien Cazabat (UCD), Albert O’Sullivan-Green (Shellfish De La Mer) & Katie Healy (BIM).

Knowledge Transfer Activities

Identify knowledge outputs generated during this project.	Knowledge outputs: • Knowledge/data on the shelf-life of cod & salmon under a range of packaging and storage conditions shelf-life • Knowledge/data on the effect of physical and chemical interventions on fish • Knowledge/data on food safety aspects of the application of high barrier films in skin-packed fish.
Identify any knowledge transfer activities executed within the project.	Knowledge transfer activities: 1. Participation in national/international conferences (detailed elsewhere in this report) 2. Project workshop 3. Peer reviewed papers (8) 4. Theses (3)
List any impacts resulting from the knowledge transferred during the project.	The seafood processing sector has been provided with tools for assessing fish freshness and shelf-life of cod and salmon. Data/knowledge on how best to prevent cross-contamination during processing and to optimise shelf-life were also provided. If applied these could provide for enhanced food safety, shelf-life and reduced wastage supporting the sustainable development of this sector. See 'Industry impact' above.

Section 3 – Leveraging, Future Strategies & Reference

Leveraging Metrics

None

Future Strategies

We will continue to work with the seafood sector, BIM and other relevant stakeholders to support the development of this sector, subject to funding being available the following key issues were identified for future collaborative research; the Excel based model that predicts the shelf-life of cod and salmon should be extended to include other fish species; in-plant trials (validation) on the application of crust-freezing on skin-packed salmon to increase its microbiological shelflife and further investigation of the C. botulinum risks associated with vacuum packaging as this technology may be used to extend shelf-life by up to 5 days.

Project Publications

1. Pedrós-Garrido, S., Condón-Abanto, S., Beltrán, J. A., Lyng, J. G., Brunton, N. P., Bolton, D., Whyte, P. (2017). Assessmentof high intensity ultrasound for Surface decontamination of salmon (S. salar), mackerel (S. scombrus), cod (Gadus morhua) and hake (M. merluccius) fillets, and its impact on fish quality. Innovative Food Science and Emerging Technologies, 41, 64-70.

2. Pedros-Garrido, S., Condon-Abanto, S., Clemente, I., Beltran, J.A., Lyng, J.G., Bolton, D., Brunton, N., Whyte, P. (2018). Efficacy of ultraviolet light (UV-C) and pulsed light (PL) for the microbiological decontamination of raw salmon (Salmo salar) and food contact surface materials. Innovative Food Science and Emerging Technologies, 50, 124-131.https://doi.org/10.1016/j.ifset.2018.10.001.
3. Pedrós-Garrido, S., Condón-Abanto, S., Beltrán, J. A., Lyng, J.G., Bolton, D., Brunton, N., Whyte, P. Effect of applying crust-freezing after skin-packaging on the natural microflora of Atlantic salmon (Salmo salar) during storage at low temperatures. Submitted to: Food Research International, May 2019.
4. Pedrós-Garrido, S., Clemente, I., Calanche, J. B., Condón-Abanto, S., Beltrán, J. A., Lyng, J. G., Brunton, N., Bolton, D.,Whyte, P. Antimicrobial activity of natural compounds against Listeria spp. and their effects on sensory attributes in salmon (Salmo salar) and cod (Gadus morhua). Submitted to: Food Control, May 2019 (under review).
5. Conor Smyth, Paul Whyte, Colin Fogarty and Declan Bolton (2018). The effect of organic acid, trisodium phosphate and essential oil component immersion treatments on the microbiology of cod (Gadus morhua) during chilled storage. FOODs, 7, 200; doi:10.3390/foods7120200 (published online).
6. Colin Fogarty, Paul Whyte, Nigel Brunton, James Lyng, Conor Smyth, John Fagan and Declan Bolton (2019). The microbiology of farmed Atlantic salmon (Salmo salar) stored on ice for 10 days. Food Microbiology, 77, 38-42.
7. Colin Fogarty, Conor Smyth, Paul Whyte, Nigel Brunton and Declan Bolton (2019). Sensory and ATP derivative basedindicators for assessing the freshness of Atlantic salmon (Salmo salar) and cod (Gadus morhua). (Irish Journal of Agriculture and Food Research – accepted for publication).
8. Colin Fogarty, Catherine Burgess, Paul Cotter, Raul Cabrera-Rubio, Paul Whyte, Conor Smyth and Declan Bolton (2018). Raul Cabrera-Rubio. Characterization of the microbial community present in the gut of Atlantic salmon (Salmo salar) farmed in Irish waters. Journal of Applied Microbiology, 127 (3), 648-657.
9. Selene Pedrós-Garrido, S. Condón-Abanto, S., Beltrán, James Lyng, Nigel Brunton, Declan Bolton, Paul Whyte (2016). Effect of high-power ultrasound on the decontamination of salmon (s. Salar) and mackerel (s. Scombrus) natural flora. Poster presentation at the 46th West European Fish Technologists Association (WEFTA) Conference, Split, Croatia, 12th to 14th October 2016.
10. Selene Pedros-Garrido, Jose A. Beltran, Juan B. Calanche, James lyng, Nigel Bruton, Declan Bolton, John Fagan and Paul Whyte (2017). Preliminary study of the application of a chitosan edible coating on defrosted cod fillets and its effect on microbiological quality. Poster presentation at the 47th West European Fish Technologists Association Conference, Aviva Stadium, Dublin, 9th to 12th October 2017, Conference Book, page 122.
11. Conor Smyth, Nigel Brunton, James Lyng, Paul Whyte and Declan Bolton (2016). Studies on the shelf-life of cod (Gadusmorhua) using clean label ingredients. Poster presentation, at the IUFoST International Conference, RDS Dublin, 21st to 25th August 2016, Abstract Book, page 1075.
12. Conor Smyth, Nigel P. Brunton, James L. Lyng, Paul Whyte and Declan J. Bolton (2016). Assessing the quality of raw cod (gadus morhua) using microbiological, sensory and chemical indicators. Poster presentation at the 46th West European Fish Technologists Association (WEFTA) Conference, Split, Croatia, 12th to 14th October 2016.
13. Conor Smyth, Paul Whyte, James Lyng, Nigel Brunton, John Fagan, Colin Fogarty and Declan Bolton. (2017). Effect of the combination of clean label ingredients and packaging conditions on the shelf-life and microbiology of meat. Poster presentation at the 63rd International Congress of Meat Science and Technology, Rochestown Park Hotel, Cork, 13th to 18th August 2017. Abstract Book, page 912.
14. Colin Fogarty, Conor Smyth, Paul Whyte, James Lyng, Nigel Brunton, John Fagan and Declan Bolton (2017). Using natural ingredients and packaging technologies to enhance the shelf-life of cod and salmon. Oral presentation at the 47th West European Fish Technologists Association Conference, Aviva Stadium, Dublin, 9th to 12th October 2017, Conference Book, page 59.

15. Colin Fogarty, Conor Smyth, Paul Whyte, James Lyng, Nigel Brunton, John Fagan and Declan Bolton (2017). Using natural ingredients and packaging technologies to enhance the shelf-life of cod and salmon. Oral presentation at the 47th West European Fish Technologists Association Conference, Aviva Stadium, Dublin, 9th to 12th October 2017, Conference Book, page 59.
16. Conor Smyth, Paul Whyte, James Lyng, Nigel Brunton, John Fagan, Colin Fogarty and Declan Bolton. (2017). Effect of the combination of clean label ingredients and packaging conditions on the shelf-life and microbiology of meat. Poster presentation at the 63rd International Congress of Meat Science and Technology, Rochestown Park Hotel, Cork, 13th to 18th August 2017. Abstract Book, page 912.
17. Colin Fogarty, Conor Smyth, Paul Whyte, James Lyng, Nigel Brunton, John Fagan and Declan Bolton (2017). Using natural ingredients and packaging technologies to enhance the shelf-life of cod and salmon. Oral presentation at the 47th West European Fish Technologists Association Conference, Aviva Stadium, Dublin, 9th to 12th October 2017, Conference Book, page 59.