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

15HDHL1- Innovative processing to preserve positive health effects in pelagic fish products

Final Report

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

SUMMARY

The aim of the project was to develop a comprehensive toolbox of optimised existing and novel technologies for developing healthy, high quality, safe and sustainable fish products from pelagic fish species. Pelagic fish products were processed using a range of novel nonthermal technologies, including high pressure processing, plasma technologies, superchilling with an aim to enhance the shelf life and improved health benefits whilst maintaining consumer acceptability. Variation in functional properties and quality and safety in pelagic fish (Atlantic herring, Baltic herring and Atlantic Mackerel) were investigated along with the effect of novel plasma technologies and packaging solutions on fish quality and safety. State-of-the art novel cold plasma technologies, high pressure processing and combination of conventional and novel technologies for pelagic fish products were developed. Smoking of fish in combination with high pressure processing was demonstrated to be effective to enhance shelf life. Plasma activated water using cold plasma technologies can be employed for washing of pelagic fish for enhance microbial safety and shelf life. Packaging strategies for fish products for improved shelf life and quality were developed. This project demonstrated the application of novel non-thermal technologies for improving the sustainability of fish and fish products. Huge potential exists for technological interventions to improve shelf life of pelagic fish with minimal impacts on nutritional quality.

KEYWORDS

Fish processing, non thermal technologies, shelf life

ACRONYM PROHEALTH

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Section 1 - Research Approach & Results

Start Date

01 March 2016

End Date

31 July 2019

Research Programme

Food Institutional Research Measure

TRL Scale

TRL 6: Technology demonstrated in relevant environment

NRPE Priority area

Food for Health

Total DAFM Award

€332,442.50

Total Project Expenditure

€310,695.04

Rationale for undertaking the Research

Increased awareness of the diet's importance for overall health, increase the demand for products with enhanced healthiness having good sensorial properties. Pelagic fish is rich in omega-3 lipids (EPA and DHA) with documented beneficial effect against coronary heart diseases, easily digestible proteins; vitamins (E and D). Therefore pelagic fish is a valuable food resource in a healthy diet. However, during processing; high temperatures, exposure to air, prooxidative components (like heme), may lead to loss or destruction of the valuable healthy components i.e. oxidation of omega-3 fatty acids and proteins. Fish nutrients are highly susceptible to oxidation resulting in loss of nutritional quality and formation of oxidation products with negative impact on consumer acceptance. As pelagic fish are rich in healthy fatty acids, minimizing oxidative deterioration of lipids during processing and storage is therefore key to deliver safe and healthy products. Therefore, optimal processing technologies to transfer healthy pelagic fish raw material into healthy and safe pre-prepared food products is needed in order to guarantee the consumer healthy pelagic fish products, quality and beneficial components should be preserved through the whole processing chain. The project was established to overcome processing challenges and knowledge gaps that hinder development of healthy pelagic fish food matrices.

Methodology

Pelagic fish products were processed using a range of novel non-thermal technologies, including high pressure processing, plasma technologies, supechilling with an aim to enhance the shelf life and improved health benefits whilst maintaining consumer acceptability. Variation in functional properties and quality and safety in pelagic fish (Atlantic herring, Baltic herring and Atlantic Mackerel) were investigated along with the effect of novel plasma technologies and packaging solutions on fish quality and safety. In order to develop comprehensive technology toolbox the following approaches were established.

- Identify main consumer preferences for pelagic fish products
- Optimize processing technologies (e.g. minimum process intensity, milder temperatures, high pressure, and novel packaging technologies) for production of pelagic fish food matrices that are healthy, safe with good sensory properties
- understand effect of processing methods on preserving quality and safety with special focus on health promoting nutrients
- understand effect of processing methods on the bioactivity and bioavailability of healthy components in model pelagic fish products High pressure processing (HPP), cold plasma treatment of mackerel to investigate the effect on key nutritional and quality parameters i.e. colour, lipid oxidation and biogenic amines was investigated. Several studies have been done on sous vide treated mackerel and herring – studying the effect of added antioxidants, temperature and time for heating and storage time. Smoking a traditional method for fish processing was studied in combination with high pressure processing. The effect of novel nonthermal techniques i.e. high pressure processing, cold/hot air plasma techniques on lipid profile, amino acid profiling was carried out. Various nutritional quality indices including saturation index, atherogenicity and thrombogenicity were studied.

Project Results

To identify optimal processing technologies for production of pelagic fish products that are healthy, safe, with good sensory properties and preserved bioactivity and bioavailability of healthy nutrients. The literature review report on chemical modifications of lipids and proteins by non-thermal food processing technologies has been reviewed and published in a peer-reviewed journal. Key outcomes include superchilling may double the shelf-life of the mackerel fillet compared to chilled storage. High pressure processing (HPP) of mackerel reduce the microbial load but also affects the sensory properties. High pressure combined with high temperature was not beneficial. HPP treatment can be used in combination with smoking. Cold plasma treatment of mackerel has was found to affect colour, lipid oxidation and biogenic amines. Smoking a traditional method for fish processing was studied in combination with high pressure processing and shelf life extension of mackerel was observed. A considerable improvement in colour characteristics was achieved when HPP was combined with smoking along with textural properties. The combination of HPP and smoking has been demonstrated to enhance the quality attributes of mackerel, contributing to the maintenance of its nutritional value, and is a promising treatment to extend the shelf life of mackerel.
The results show that sous vide treated pelagic fish has a good shelf life and that adding antioxidants is important for preserving the valuable lipids. The results showed that fresh raw materials give canned products with a higher sensory quality compared to the use of frozen raw material. Fish cakes with 50% mackerel had a good shelf life – but addition of herbs as antioxidants should be further studied with regard to microbial growth, the microbial flora of the herbs may give challenges for the stability of the products. HPP reduce the microbial load giving increased shelf life to the mince. Pressure up to 200 MPa gave fish cakes

that was acceptable with regard to texture while it was difficult to make fish cakes from mince treated at 300 MPa. The study of the mechanisms underlying the process induced changes in combination with production of model products is highly important and also innovative and can be used for optimization of other processes. Changes in quality characteristics in relation to protease activity and protein oxidation in chilled, superchilled and frozen mackerel fillets during storage were studied. The solubility of sarcoplasmic proteins was quite stable in mackerel samples for all storage experiments, whereas the solubility of myofibrillar proteins decreased in both superchilled and frozen samples. Various nutritional quality indices including saturation index, atherogenicity and thrombogenicity was studied. Plasma technology did not encourage observable undesirable reactions such as lipid oxidation. In addition, the stability of the fatty acid composition of mackerel was not affected by the treatment, along with their nutritional quality indices. However, cold atmospheric plasma could accelerate the formation of carbonyls which are related to protein oxidation. Amino acid profile of high pressure processed and plasma treated fish did not show significant changes.

Section 2 - Research Outputs

Summary of Benefits / Improvements of Project Findings

The ProHealth activities were directed to optimize existing and apply novel processing technologies for developing healthy, high quality, safe and sustainable fish products from pelagic fish species. The project has led to advanced understanding on the role and application of novel technologies on quality, consumer acceptance and later increased consumption of healthy food. This also addressed the European Council demand of "to provide the consumers with safer, high quality and health-promoting foods" and FoodWise2025 where food and health are two important focus areas.

Improved processing technologies for preserving the healthy components, quality and shelf-life of pelagic fish provide the industry to have better quality raw material for further processing enabling development of new, value-added products with good shelf life. The project outcome has expanding the knowledge and technology base on processing technologies for production of safe, high quality pelagic fish products with preserved beneficial components will enhance the competence of Irish SMEs operating along the fish processing chain. The technological toolbox and the know-how and expertise in enhancing the quality and nutritional value of pelagic fish products and help the processing industry to produce high quality and healthy fish products.

Key benefits and opportunities.

- State-of-the art novel cold plasma technologies, high pressure processing and combination of conventional and novel technologies for pelagic fish products were developed.
- Smoking of fish in combination with high pressure processing was demonstrated to be effective to enhance shelf life.
- Plasma activated water using cold plasma technologies can be employed for washing of pelagic fish for enhance microbial safety and shelf life.
- Packaging strategies for fish products for improved shelf life and quality were developed.
- Development of a comprehensive technology toolbox for a range of fish products.

Summary of Staff Outputs

Research Output	Male	Female	Total Number
PhD Students	0	1	1
Post Doctorates	0	2	2
Research Technicians/ Assistants	0	0	0
Other / Temporary	1	2	3

Summary of Academic Outputs

Research Outputs	Total Number	Details
Peer Reviewed Scientific Journals	14	1. Albertos, I., Martín-Diana, A. B., Cullen, P. J., Tiwari, B. K., Ojha, S. K., Bourke, P., Álvarez, C., & Rico, D. (2017). Effects of dielectric barrier discharge (DBD) generated plasma on microbial reduction and quality parameters of fresh mackerel (Scomber scombrus) fillets. Innovative Food Science & Emerging Technologies, 44, 11. 7-122. 2. Albertos, I., Martin-Diana, A. B., Cullen, P. J., Tiwari, B. K., Ojha, S. K., Bourke,P., & D. Rico. (2019) Shelf-life extension of herring (Clupea harengus) using in package

atmospheric plasma technology. Innovative Food Science & Emerging Technologies. 53, 85-91.

3. de Alba, M., Pérez-Andrés, J.M., Harrison, S.M., Brunton, N.P., Burgess, C.M., &Tiwari, B.K. (2019). High pressure processing on microbial inactivation, quality parameters and nutritional quality indices of mackerel fillets. Innovative Food Science and Emerging Technologies 55, 80–87.
4. Zhao, Y-M., de Alba, M., Sun, D-W., & Tiwari, B.K. (2019). Principles and recent applications of novel non-thermal processing technologies for the fish industry —a review. Critical Reviews in Food Science and Nutrition,59 (5), 728-742.
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6. Kulawik, P., Álvarez, C., Cullen, P. J., Aznar-Roca, R., Mullen, A. M., & Tiwari, B.(2018). The effect of non-thermal plasma on the lipid oxidation and microbiological quality of sushi. Innovative Food Science & Emerging Technologies, 45, 412-417.
7. Kulawik, P., & Tiwari, B. (2018). Recent advancements in the application of on-thermal plasma technology for the seafood industry. Critical reviews in food science and nutrition, 1-12.
8. Cropotova, J., Mozuraityte R., Standal I.B., Ojha, S. Rustad T. Tiwari, B.K. (2020). Influence of high-pressure processing on quality attributes of haddock and mackerel minces during frozen storage, and fishcakes prepared thereof, Innov. Food Sci. & Emerging Technol. 59, January 2020, 102236
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10. Pérez-Andrés, J.M.; Charoux, C.; Cullen, P.J. and Tiwari, B.K. 2018. Chemical modifications of lipids and proteins by nonthermal food processing technologies. J Agr. Food Chem. 66:5041-5054
11. Zhao, Y. M.; Ojha, S.; Burgess, C. M.; Sun, D. W.; Tiwari, B. K., Influence of various fish constituents on inactivation efficacy of plasma-activated water. International Journal of Food Science & Technology 2020, 55, (6), 2630-2641.
12. Zhao, Y. M.; Ojha, S.; Burgess, C. M.; Sun, D. W.; Tiwari, B. K., Inactivation efficacy and mechanisms of plasma activated water on bacteria in planktonic state. Journal of Applied Microbiology 2020.
13. Zhao, Y. M.; Ojha, S.; Burgess, C. M.; Sun, D. W.; Tiwari, B. K., Inactivation efficacy of plasma-activated water: influence of plasma treatment time, exposure time and bacterial species. International Journal of Food Science & Technology 2020.
14. Zhao, Y. M.; Patange, A.; Sun, D. W.; Tiwari, B., Plasma-activated water: Physicochemical properties, microbial inactivation mechanisms, factors influencing antimicrobial effectiveness, and applications in the food industry. Comprehensive Reviews in Food Science and Food Safety 2020.

Peer Reviewed Conference Papers	12	1. Yi-Ming Zhao, Shikha Ojha, Nicola Byrne, Brijesh Tiwari. Application of plasma activated water for surface decontamination of fish, in the 48th Conference of the West European Fish Technologists' Association, 2018, 15-18, October, Lisbon, Portugal. Oral presentation. 2. Yi-Ming Zhao, Shikha Ojha, Catherine M. Burgess, Da-Wen Sun and Brijesh Tiwari. Inactivation efficacy of four model bacteria in plasma activated water during cold storage, in the Microbial Society ECM Forum Summer Conference 2019, 20-21 June, Trinity College, Dublin. Poster presentation. 3. Yi-Ming Zhao, Shikha Ojha, Catherine M. Burgess, Brijesh Tiwari. Effect of food constituents and plasma activated water on the inactivation profile of microorganisms pertinent to fish processing, in the ASABE Annual International Meeting, 2019, 7-10, July, Boston, USA. Poster presentation. 4. Rustad, T.; Cropotova, J.; Mozuraityte, R.; Standal, I. B.; Tiwari, B.; Mytlewski,A.; Szlinder-Richert, J., Galli, F. 2017 Innovative processing to preserve positive health effects in pelagic fish. WEFTA Conf. Dublin, Ireland. NTNU; SINTEF; Teagasc, NMFRI, Univ Perugia 5. De Alba M., Burgess, C. Tiwari, B. K. Combined effect of high pressure processing and smoking on mackerel. WEFTA Conf. Dublin, Oct 2017 Teagasc 6. Cropotova, J.; Mozuraityte, R.; Standal, I. B.; Tiwari, Brijesh; Rustad, Turid. Changes in quality characteristics of haddock and mackerel minces, and fishcakes prepared thereof as affected by high-pressure processing. The 32nd EFFoST International Conference; 2018 Nantes, France, NTNU, SINTEF Teagasc 7. Cropotova, J.; Mozuraityte, R.; Standal, I. B.; Rustad, T.; Tiwari, B. Protein oxidation affecting quality parameters of haddock and mackerel minces subjected to high-pressure pre-treatment and frozen storage. IFT-EFFoST 2018 International Nonthermal Processing Workshop and Short course; Nantes, France NTNU, SINTEF Teagasc 8. Tiwari, B.K. Novel technologies for fish processing, 5th Fish Congress, Gdansk,Poland. Teagasc 9. Tiwari, B.K. Biochemical effects of ultrasound in food processing. 3ndinternational conference on ultrasonic-based applications: from analysis to synthesis. 11th-14th June 2018, Caparica, Portugal Teagasc 10. Tiwari, B.K. Novel technologies to ensure sustainability of food for the future, Teagasc Gateway event, 12 June 2018, Dublin, Ireland Teagasc 11. Yi-Ming Zhao, Shikha Ojha, Catherine M. Burgess, Da-Wen Sun and Brijesh Tiwari. Inactivation efficacy of four model bacteria in plasma activated water during cold storage. At the Microbial Society ECM Forum Summer Conference 2019, 20-21 June, Trinity College, Dublin. Poster presentation. 12. Yi-Ming Zhao, Shikha Ojha, Catherine M. Burgess, Brijesh Tiwari. Effect of food constituents and plasma activated water on the inactivation profile of microorganisms pertinent to fish processing. At the ASABE Annual International Meeting, 2019, 7-10, July, Boston, USA. Poster presentation.
PhD Theses	1	Dr Yiming Zhao, funded by CSC, China Thesis title: Plasma alone and in combination with other technologies to improve microbial safety and quality parameters of fish

Intellectual Property

N/A

Summary of other Project Outputs

Project Outputs	Details	Total No.
New Processes	Plasma technology for preservation of fish Application of high pressure processing in combination with smoking to preserve nutrients and quality of product.	2

Potential Impact related to Policy, Practice and Other Impacts

Impact	Details
Environmental Sustainability	Application of clean and chemical free techniques for preservation of fish products.
Socio-Economic	Promotion of pelagic fish for human consumption to improve nutritional profile
Industry	Knowledge base in ration to technologies for Irish seafood industries, working closely with Irish fish processors via EI Innovation Voucher, Industry funded project (100%) via PCF centre.

Dissemination Activities

Activity	Details
Workshops at which results were presented	Results were presented at ASABE, USA, IUFoST, India, WEFTA, Dublin, WEFTA, Portugal.
Seminars at which results were presented	National events (Technology Gateway, Teagasc), IFSTI conferences (2018, 2019)

Knowledge Transfer Activities

Identify knowledge outputs generated during this project.	Technological know and application for pelagic fish. Key scientific knowledge and understanding was disseminated via peer reviewed publications/seminars. Key knowledge outputs 1.Peer reviewed publications 2.Technical know how of processes -Plasma technologies for in-pack decontamination of fish -Plasma technologies for washing of fish as a replacement to chlorine/chemical disinfectants. -High pressure processing for fish
Identify any knowledge transfer activities executed within the project.	Currently some of the knowledge activities are at low TRL levels (<5) and additional funding via EI Innovation Partnership and direct industry projects are sought.
List any impacts resulting from the knowledge transferred during the project.	Industry trust on application of technologies Teagasc as a to-go hub for Irish seafood processors in terms of application of novel technologies for seafoods. Maximising the impact to employ technologies for other food sources e.g. knowledge gained and challenges in adoption of plasma technologies as a direct application in food yielded a new avenues for application of plasma in decontamination of meat chill room (EI - Meat Technology Ireland).

Section 3 - Leveraging, Future Strategies & Reference

Leveraging Metrics

Type of Funding Resource	Funding €	Summary
Additional Staff	€100,000.00	Additional funding for PhD student was secured via China Science Scholarship

Exchequer National Funding	€350,000.00	This project led to additional direct and indirectly to the following grants 1. EI Meat Technology Ireland (Aerial decontamination) 2. EI Partnership with HPP tolling (Euro 75,000) 3. SFI Industry fellowship with Industry (85 (SFI):15 (industry)) 4. EI Career FIT (result awaited) 5. PACK4SEA (project submission intended for FIRM, 2021)
Non Exchequer National Funding	€10,000.00	1. Keohane of Bantry (Industry income)
EU R&I programmes	€750,000.00	1. Submission of Green Deal H2020 project (EFFORT; Sea2Fork; DEMETRA) - results awaited.

Future Strategies

Future strategies includes the following

1. Innovation Partnership with Irish seafood processors
2. Seek additional EU Horizon Europe project funding

Project Publications

1. Albertos, I., Martín-Diana, A. B., Cullen, P. J., Tiwari, B. K., Ojha, S. K., Bourke, P., Álvarez, C., & Rico, D. (2017). Effects of dielectric barrier discharge (DBD) generated plasma on microbial reduction and quality parameters of fresh mackerel (Scomber scombrus) fillets. Innovative Food Science & Emerging Technologies, 44, 11. 7-122.
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