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

15F602 - Novel technological approaches for the development of low FODMAP food products.

Final Report

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SUMMARY

Irritable bowel syndrome (IBS) is a highly prevalent gastrointestinal disorder. IBS symptoms are associated with consuming certain food constituents: FODMAPs (fermentable oligo-, di-, monosaccharides and polyols). These are ubiquitous carbohydrates that are indigestible and poorly absorbed. and osmotically active, triggering thereby the symptoms. In several clinical studies, a diet low in FODMAPs (LFD) has successfully alleviated symptoms in most IBS patients. The key principle of the LFD is that high FODMAP foods should be replaced with nutritionally equivalent low FODMAP (LF) alternatives. Therefore, functional LF products are needed. However, especially in the European market, such products are scarce.

As part of the TALENTFood project, an accurate analytical method for quantifying FODMAPs was established that served as an analytical tool throughout the project's work. It could eventually serve as a standardized method in food testing laboratories. As a basis for further research and product development, the FODMAP contents of a wide range of cereal-product ingredients were screened, and the ingredients accordingly classified. Then, a LF product-development toolbox was established; different (bio)-technological FODMAP reduction strategies were investigated to identify the most effective approaches to lower FODMAP contents with a concomitant improvement of nutritional qualities. Using different approaches from the toolbox (including potent yeast- and LAB-strains, enzymes, and ingredient-based solutions), different low FODMAP prototypes of different categories (breads, pasta, biscuits, and crackers) were developed. These compared well to benchmark products with a known high consumer acceptance in nutritional, technological and sensory characteristics. Finally, the impact of the LF prototypes on the healthy microbiome was investigated during a simulated ex-vivo fermentation, providing evidence that the prototypes may be used in a LFD without compromising the microbiome diversity and composition. Ultimately, the TALENTFood project's outcome provides a profound understanding of (bio)-technological techniques for LF product development and their tolerability by IBS patients.

KEYWORDS

FODMAP-reduction; IBS; Enzymes

ACRONYM	TalentFood
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Section 1 - Research Approach & Results

Start Date

01 January 2017

End Date

31 December 2021

Research Programme

Food Institutional Research Measure

TRL Scale

TRL 7: System prototype demonstration in operational environment

NRPE Priority area

Food for Health

Total DAFM Award

€1,063,850.00

Total Project Expenditure

€949,430.15

Rationale for undertaking the Research

More than 25 % of the adult population in the US, Canada, and the UK suffer from functional bowel disorders, among those 5 % characterised as irritable bowel syndromes (IBS) according to recently updated Rome IV criteria. IBS-symptoms are often triggered by the ingestion of fermentable oligo-, di-, monosaccharides and polyols (FODMAPs). On reaching the small intestine and colon, FODMAPs increase the osmotic pressure in the lumen and provide substrates for bacterial fermentation, with consequent gas production, abdominal distension, pain, and discomfort. In >70 % of patients with IBS, a diet low in FODMAPs (LFD) effectively reduced symptoms. However, FODMAPs occur in a wide range of foods, including cereals and pulses. Hence, a shift toward a more sustainable, healthy diet with higher inclusion of whole-grain cereals and pulses, poses a severe challenge for susceptible individuals.

The current market situation shows a meagre picture regarding functional low FODMAP (LF) products in Ireland and globally. Currently, consumers in Europe mostly rely on web lists of categorisations based on product ingredients. Such products are mainly gluten-free (wheat-free), and thus assumed to be low in FODMAPs, yet the actual content is not analytically tested such as in Australian-certified products. Among the certified products the majority were actually gluten-free products. Those are naturally low in FODMAPs but inferior in sensory attributes. Furthermore, there is hardly any LF product at all available on the Irish market.

The TALENTFood project aimed to develop cereal-based LF foods using (bio)-technological FODMAP-reduction strategies and with a concomitant improvement of nutritional qualities.

Methodology

Systematic studies were designed to develop FODMAP reduction strategies in different cereal-based food categories. First, the FODMAP profile in a wide range of product ingredients was screened, using an advanced analytical technique (HPAEC-PAD). The analytical method was specifically established as an analytical tool for the work throughout this research project.

As a basis for the development of functional low FODMAP products, malting, fermentation with lactic acid bacteria (LAB), yeast and enzyme addition were investigated for their potential to degrade FODMAPs. Additionally, different fibre-enriched recipes, based on low FODMAP ingredients only, were formulated. The low FODMAP diet is often criticised to lack fibres, which are crucial for a healthy gut. Thereby, a low FODMAP product-development toolbox was established, including the most promising yeast- and LAB strains, enzymes, and ingredients. Using the established toolbox, prototypes of different whole wheat breads, fibre-enriched starch-and-gluten-based breads, pasta, biscuits, and crackers were developed. The impact of the LF prototypes on the healthy microbiome was investigated during a simulated ex-vivo fermentation to gain an understanding of the developed products' impact on the gut microbiome.

Project Results

A systematic analysis of the global market of products with a low FODMAP claim (~800 products globally), revealed that the market is dominated by gluten-free products, which are naturally low in FODMAPs but characterised by inferior sensory attributes. Less than 10 % of the products were manufactured using any targeted FODMAP-reduction techniques.

Furthermore, the lack of standardized adequate analytical methods for accurate quantification of all FODMAPs in different food matrices was evident, looking at the regulatory framework in different countries, as well as the scientific literature. Existing methods were partly based on a combination of different techniques, partly prone to errors, or not suitable for complex food matrices. Hence, an accurate and efficient analytical method for the quantification of all FODMAPs, using one single analytical approach (high-performance anion-exchange chromatography coupled with pulsed amperometric detection; HPAEC-PAD), was developed and served as an analytical tool throughout all studies of this research project.

The FODMAP contents of a broad range of cereal-product ingredients (incl. different cereals, pseudo-cereals, gluten-free flours, pulses, pulse protein ingredients, flours from sprouted seeds, and isolates and fractions from different grains were determined. This highlighted two main sources of FODMAPs originating from different ingredients: fructans from gluten-containing cereals (wheat, spelt, barley, rye) and α-galactooligosaccharides (GOS) from pulses (peas, lentils, chickpeas, etc.). Isolates and fractions from different raw materials (pulse protein ingredients, different starches, gluten) had varying GOS or fructan contents, depending on their production process. Gluten-free product ingredients (e.g., rice, millet, buckwheat) did not contain any of the FODMAPs commonly investigated. However, buckwheat accumulates other soluble indigestible carbohydrates (fagopyritols) that may act as FODMAPs.

Then, the impact of malting on the FODMAP profiles of different seeds was investigated and was shown to be an effective tool to lower FODMAP levels in pulses (by 80 − 90 %), while FODMAPs in malted cereals were enriched (up to 0.8 % newly synthesised fructans). In buckwheat, which contains the potential FODMAPs fagopyritols, the indigestible saccharides were degraded upon the malting process, similar to the effect observed in pulses.

Different yeast and lactic acid bacteria (LAB) isolates as well as purified enzymes (invertases, inulinases, α-galactosidases) were investigated for their FODMAP-degradation potential, which led to the selection of potent cultures and enzyme solutions. These could be successfully applied in different product formulations resulting in low FODMAP contents and high-quality characteristics comparable to conventional products. Furthermore, different fibre-enriched starch-and-gluten-based products were developed; this serves as a simple yet efficient additional approach, that does not require further FODMAP degradation.

Ultimately, the impact of the LF prototypes on the healthy microbiome was investigated during a simulated ex-vivo fermentation and provided evidence that the prototypes may be used in a low FODMAP diet without compromising the microbiome diversity and composition.

Overall, the systematic work of this project provides comprehensive and applicable knowledge essential for developing of low FODMAP products that are beneficial for IBS patients.

Section 2 - Research Outputs

Summary of Project Findings

The findings of the TALENTFood project gave the scientific community as well as industry, regulatory authorities and policymakers and ultimately also, consumers, an insight into the concept of the novel approaches and applications for the production of nutritious functional low FODMAP products, presenting in-depth knowledge and applicable solutions for accurate quantification of FODMAPs in ingredients and products, the purposeful selection of ingredients for targeted product formulations and different (bio-)technological approaches to obtain low FODMAP contents in different cereal-based products.

Summary of Staff Outputs

Research Output	Male	Female	Total Number
Post Doctorates	1	2	3
PhD Students	2	2	4

Summary of Academic Outputs

Research Outputs	Total Number	Details
Publications in Peer Reviewed Scientific Journals	13	1. Atzler, J. J., et al. (2020). Enzymatic degradation of FODMAPS via application of βfructofuranosidases and α-galactosidases- A fundamental study. Journal of Cereal Science, 95, 102993, doi: 10.1016/j.jcs.2020.102993. 2. Atzler, J. J.,et al. (2021a). Characteristics and properties of fibres suitable for a low FODMAP diet- an overview Trends in Food Science & Technology, 112, 823– 836, doi: 10.1016/j.tifs.2021.04.023. 3. Atzler, J. J., et al. (2021b). Investigation of different dietary-fibre-ingredients for the design of a fibre enriched bread formulation low in FODMAPs based on wheat starch and vital gluten. European Food Research and Technology, doi: 10.1007/s00217-021-03762-6. 4. Ispiryan, L., et al. (2019). Optimization and Validation of an HPAEC-PAD Method for the Quantification of FODMAPs in Cereals and Cereal-Based Products. Journal of agricultural and food chemistry, 67 (15), 4384–4392, doi: 10.1021/acs.jafc.9b00382. 5. Ispiryan, L., et al. (2021). Fundamental study on changes in the FODMAP profile of cereals, pseudo-cereals, and pulses during the malting process. Food chemistry, 343, 128549, 128549, doi: 10.1016/j.foodchem.2020.128549. 6. Ispiryan, L., et al. (2020).). Characterization of the FODMAP-profile in cereal product ingredients. Journal of Cereal Science, 92, 102916. Journal of Cereal Science, 92, 102916, doi: 10.1016/j.jcs.2020.102916. 7. Ispiryan,L. et al. (2021). Lachancea fermentati FST 5.1: an alternative to baker's yeast to produce low FODMAP whole

		wheat bread. Food Funct., 2021,12, 1126211277, doi: 10.1039/D1FO01983J. 8. Ispiryan, L. et al. (2021). FODMAP modulation as a dietary therapy for IBS: Scientific and market perspective. Comprehensive Reviews in Food Science and Food Safety. Compr Rev Food Sci Food Saf. 2022;1–26. doi: 10.1111/1541-4337.12903. 9. Joehnke, M. S., et al. (2021). Nutritional and anti-nutritional properties of lentil (Lens culinaris) protein isolates prepared by pilot-scale processing. Food Chemistry: X, 9, 100112, doi: 10.1016/j.fochx.2020.100112. (L. Ispiryan co-author) 10. O'Donnell, S. T., et al. (2019). The Progress of Multi-Omics Technologies: Determining Function in Lactic Acid Bacteria Using a Systems Level Approach. Frontiers in microbiology, 10, 3084, doi: 10.3389/fmicb.2019.03084. 11. O'Donnell, S. T., et al. (2021). Designing New Foods or Food Ingredients Targeting the Gut Microbiota to Reduce FODMAP-Induced Irritable Bowel Syndrome (IBS). Comprehensive gut microbiota, 182-196, doi: 1.1016/B978-0-12819265-8.00093-0. 12. Vogelsang-O'Dwyer, M., et al. (2020). Techno-Functional, Nutritional and Environmental Performance of Protein Isolates from Blue Lupin and White Lupin. Foods, 9 (2), doi: 10.3390/foods9020230. (L. Ispiryan co-author) 13. Zannini, E., & Arendt, E. K. (2018). Low FODMAPs and gluten-free foods for irritable bowel syndrome treatment: Lights and shadows. Food research international, 110, 33–41, doi: 10.1016/j.foodres.2017.04.001.
PhD Theses	4	1. PhD thesis Shane O'Donnell: Final, defended thesis submitted in June 2021; title of thesis: "Lactobacillus, omega-3 fatty acids and FODMAPs influence on the gut microbiome" 2. PhD thesis Lilit Ispiryan: Final, defended thesis submitted in October 2021; title of thesis: "FODMAPs in cereals, pseudo cereals and legumes: a systematic approach for the development of functional low FODMAP products" 3. PhD thesis Malgorzata Borowska: thesis in preparation; preliminary title: "Screening, characterisation and exploitation of yeast and lactic acid bacteria capable of FODMAPs utilisation" 4. PhD thesis Jonas Atzler: thesis in preparation; preliminary title: "Optimisation of food products low in FODMAPs – An investigation of dietary fibres in low FODMAP products and the reduction of FODMAPs via biotechnological processes"
Masters Theses	2	1. Master thesis Kristina Roos (Erasmus student from Germany): submitted in May 2018, title of thesis: "The

		Impact of Malting and Brewing on the FODMAP content in cereals” 2. Master thesis Jonas Atzler (Erasmus student from Germany, before he commenced his work as a PhD student on the project): submitted in October 2018, title of thesis: “Bio-degradation of FODMAPs via enzyme technology”
Other	3	Ready manuscrpits for submission to peer reviewed journals: 1. Manuscript will be soon submitted to Journal of Functional Foods by PhD student Jonas J. Atzler: Title: Characteristics of a low FODMAP pasta enriched with IBS suitable dietary fibres - a systematic approach 2. Manuscript will be soon submitted to Food and Function by PhD student Jonas J. Atzler: Title: Optimisation of a low FODMAP biscuit enriched with IBS suitable dietary fibre – a systematic approach 3. Manuscript will be soon submitted to Food and Function by PhD student Malgorzata Borowska: Title: Successful application of type II sourdough processing with homofermentative lactic acid bacteria resulting in low FODMAP whole wheat bread.

Intellectual Property

None to declare.

Summary of other Project Outputs

Project Outputs	Details	Total No.
New Technology	(Bio)-technological processes for the production of low FODMAP cereal-based products as alternatives to conventional high FODMAP products using the following approaches: • Product formulations based on low FODMAP isolate starch and gluten from high FODMAP ingredient wheat; formulations enriched with IBS beneficial fibers. • Use of malting as a tool to significantly reduce FODMAPs (GOS) in pulses (activity of seed endogenous enzymes). • Addition of purified enzymes to degrade FODMAPs in combination with yeast fermentation, to further reduce potential FODMAPs generated from degradation products.	4

	• Fermentation with potent yeast (i.e., L. fermentati FST 5.1) and/ or lactic acid bacteria (L. paracasei R3) to efficiently reduce FODMAP levels in fermented products.

Potential Impact related to Policy, Practice and Other Impacts

Impact	Details
Industry	The research outcome of the TALENTFood project provides in-depth and applicable knowledge for the production of functional low FODMAP products, with different strategies to reduce FODMAPs in product formulations and final products, enabling the safe and reliable production of functional food products to assist the low FODMAP diet. Furthermore, the analytical method established as part of the project could serve as a standardized technique in food testing laboratories.

Dissemination Activities

Activity	Details
Workshops at which results were presented	A first workshop was held in June 2018: Prof. Elke Arendt and Dr Emanuele Zannini organized and hosted the 7th International Sourdough Symposium in UCC (June 6th to June 8th). The second section of the symposium was fully dedicated to the application of low FODMAP and gluten-free sourdoughs for IBS and Coeliac Disease patients. The leading international researcher Dr Jane Muir from the Monash University (Australia), the head of research of Fazer Group from Helsinki as well as the PhD student Ms Lilit Ispiryan, presented their work which led to extensive, interesting discussions with the audience, composed of numerous international researchers and representatives from industry. All researchers from Prof Elke Arendt's group attended the conference. Mr Jonas Atzler (to that date master student) supported the companies Lesaffre, Böcker and Aryzta with the baking of sourdough products for sensory sessions at the conference. Prof Elke Arendt presented the keynote lecture of the first session with the title "Sourdough improving the nutritional properties in cereal products". Dr Emanuele Zannini held the keynote lecture on the last day with the title "Sourdough LAB as 'farm to fork' bio protection system".
Workshops at which results were presented	A final project workshop was held January 11th 2022 in APC, UCC. Lilit Ispiryan gave a comprehensive presentation on the overall project outcome with the title: "FODMAPs in cereals, pseudo cereals and legumes, a systematic approach for the development of functional low FODMAP products." followed by interesting and future-oriented discussions with the audience.

Workshops at which results were presented	Lilit Ispiryan was invited as a guest speaker at the Health Grain Forum Spring Workshop, which was held virtually in April 2021, where she talked about FODMAP reduction strategies in cereal-based products.
Seminars at which results were presented	• Lilit Ispiryan was invited as a keynote speaker to the 8th international Sourdough Symposium in Bolzano, Italy, in June 2022, where she presented the results of the TALENTFood project and talked about FODMAP reduction strategies in cereal-based products with a focus on the use of sourdough technology. • Lilit Ispiryan was invited as a guest Scientific Lecturer to the 73rd Convention of Milling Technology in Detmold, Germany, in September 2022, where she talked about FODMAPs in cereals, pseudo-cereals and pulses and a systematic approach to develop low FODMAP products. • Lilit Ispiryan was invited as a guest speaker for the Virtual Global IC- Symposium in October 2020, where she presented the analytical method established as part of the TALENTFood project to quantify FODMAPs. • Jonas J. Atzler attended the 7th Cereal and Europe Spring Meeting, Thessaloniki, Greece, in April 2022and gave an oral presentation on the development of a low FODMAP bread high in IBS-suitable fibres. • Malgorzata Borowska attended the Open Research Biosciences Meeting in Cork, in June 2022, where she talked about the application of the novel yeast strain Lachancea fermentati FST 5.1, as a promising strategy for producing a low FODMAP wholewheat bread. • Lilit Ispiryan presented a poster at the GastroDiet 2017 Conference at the Monash University, in Prato, Italy, in November 2017. • Shane O'Donnell presented a poster presentation at the 9th Probiotics, Prebiotics and New Foods Conference, in Rome in September 2017. • Elke Arendt gave an oral presentation at the 7th International Sourdough Symposium, UCC in June2018. • Emanuele Zannini gave an oral presentation at the 7th International Sourdough Symposium, UCC in June 2018. • Lilit Ispiryan gave an oral presentation at the 7th International Sourdough Symposium, UCC in June 2018. • Lilit Ispiryan gave an oral presentation at AACC Cereals & Grains 18 Conference, London, UK in October2018. • Malgorzata Borowska presented a poster at the 47th Annual Food Science and Technology Conference, UCC in December 2018. • Jonas Atzler presented a poster presentation at the 47th Annual Food Science and Technology Conference, UCC in December 2018. • Lilit Ispiryan was invited as a speaker at the IC-users meeting in Dublin in May 2018. • Lilit Ispiryan gave an oral presentation at the industry meeting with ABI at UCC in July 2018. • Jonas Atzler gave an oral presentation at the 5th International Symposium on Gluten-Free Cereal Products and Beverages, Leuven, Belgium in June 2019. • Lilit Ispiryan gave an oral presentation at the 5th International Symposium on Gluten-Free Cereal Products and Beverages, Leuven, Belgium in June 2019. • Malgorzata Borowska presented a poster at the 48th Annual Food Science and Technology Conference, UCC in December 2019.

	• Jonas Atzler gave an oral presentation at the Internal UCC FNS Conference in December 2019. • Lilit Ispiryan gave an oral presentation at the Internal UCC FNS Conference in December 2019. • Lilit Ispiryan gave an oral presentation at the Virtual Global IC- Symposium in October 2020. • Malgorzata Borowska gave an oral presentation at the 49th Annual Food Science and Technology Conference, UCC in December 2020. • Malgorzata Borowska presented a poster presentation at the virtual 13th international symposium on lactic acid bacteria in August 2021. • Malgorzata Borowska gave an oral presentation at the virtual 7th whole grain summit in October 2021. • Lilit Ispiryan gave a UCC Food science Module lecture I on FODMAPs in March 2021.
Media Events	Lilit Ispiryan received the scientific award from "Verband Deutscher Großbäckerein e.V" (Engl. Association of German Industrial Bakeries) for her doctoral thesis, which included 5 chapters of the work conducted as part of this project (4 experimental chapters of research papers as previously reported and published review article as previously reported). The award was announced at the 51st virtual scientific meeting from the Berlin-Brandenburg Society for Cereal Research, where Lilit also had a chance to talk about her project work and the outcome of her doctoral thesis. She is invited as a speaker for the 52nd meeting in Berlin next year, where she will give a presentation on the project. Furthermore, the award resulted in considerable media exposure with several online press articles (yumda.com; yumda.de; abzonline.de; baeko-magazin.de; webbaecker.de; verbaende.com; baeckerwelt.de; tk-report.de) published online, promoting the research outcome of this project.

Knowledge Transfer Activities

Identify knowledge outputs generated during this project.	• A systematic review of the current state of knowledge in scientific literature, was contrasted with the status quo of the global market of low FODMAP products. • An analytical method for FODMAP quantification was established. • A wide range of cereal-product ingredients was classified based on the analytical quantification of their FODMAP contents. • Different bio-technological approaches were identified as potent FODMAP reduction techniques: yeast and LAB strains with a high FODMAP degradation capacity (L.fermentati FST 5.1, Lacticaseibacillus paracasei R3, Pediococcus pentosaceus RYE106), malting technology as an approach to lower GOS in pulses and fagopyritols in buckwheat, the application of purified enzymes in combination with fermentation-based approached (i.e., invertases or inulinases in synergy with yeast-fermentation). • The application of functional low FODMAP ingredients (combination of different starches, protein ingredients and fibres) was developed as a simple

	and efficient approach that does not require further FODMAP degradation upon processing.
Identify any knowledge transfer activities executed within the project.	The project resulted in a huge output in published research papers and review articles in high-impact factor scientific journals (13 publications published, 3 more in progress), numerous oral presentations and poster presentations at 19 international conferences along the project. Several presentations and discussions on the project output were held at different virtual meetings, workshops, and seminars to communicate the research outcome to scientists and the industry. Two project workshops successfully demonstrated the great accomplishments of the project's research outcome, promoting and communicating the advanced analytical techniques, the novel FODMAP reduction strategies and low FODMAP product designs. Furthermore, the presentation of the TALENTFood project and different studies on online platforms (websites, research-gate, LinkedIn) further contributed to a successful and ongoing knowledge transfer of the project's outcome. The multiple awards that were given to PhD students for their research on the project (best presentation awards at conferences, best paper award in the School of Food and Nutritional Sciences (UCC), Science award of Industrial Bakeries) do not only demonstrate the great success of the project's research outcome but also resulted in considerable media exposure on different websites and with multiple press release articles.
List any impacts resulting from the knowledge transferred during the project.	The project outcome gave industry as well as academia an insight into the concept of the novel approaches and applications for the production of nutritious functional low FODMAP products, presenting in-depth knowledge and applicable solutions for accurate quantification of FODMAPs in ingredients and products, the purposeful selection of ingredients for targeted product formulations and different (bio-)technological approaches to obtain low FODMAP contents in different cereal-based products. The outcome of the project has a key role in promoting and initiating continued in-depth research in food science aiming for the production of low FODMAP food products, but also in biomedical sciences emphasizing the need to globally harmonize the low FODMAP concept, communicate the necessary criteria for scientists as well as industry (i.e., which carbohydrates are classified as FODMAPs, what are the tolerable levels, which analytical techniques are suitable for the determination of FODMAPs/ which interferences are possible and should be considered, what should gastroenterologists and dieticians communicate when advising on the low FODMAP diet, what should food manufacturers consider when designing low FODMAP products).

Section 3 – Research, Future Strategies & Reference

Leveraging Metrics

Type of Funding	Funding €	Summary Resource
EU R&I programmes	€1,281,588.00	SmartProtein: This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 862957.
EU R&I programmes	€621,670.00	MASTER project: This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 818368.
EU R&I programmes	€421,625.00	GiantLeaps project: Gap resolution in sAfety, NuTritional, alLergenicity and Environmental assessments to promote Alternative Protein utilization and the dietary Shift. Grant agreement No 101059632.
Non-Exchequer National Funding	€104,000.00	InFoTech project: Innovative food processing and new technological solutions for the design of novel healthy products for the prepared consumer foods sector. his project has received funding from the Department of Agriculture, Food and the Marine (FIRM). grant agreement no. 2019R495.
Non-Exchequer National Funding	€104,000.00	Solarbiome project: A novel food product harnessing the Mediterranean Diet to promote healthy ageing by maintaining the gut microbiome. This project has received funding from the Science Foundation Ireland.
Non-Exchequer National Funding	€22,500.00	The Teagasc Moorepark PhD student, Shane O Donnell, was awarded for a Fulbright award for his stay in the US where he worked on Task 2 of the project.

Future Strategies

As a future outlook, first and foremost, it is important that food scientists and biomedical scientists further cooperate in elaborating on carbohydrates which are included in the list of FODMAPs, identifying potential other FODMAPs and their sources and extending the list of routinely analysed FODMAPs, if necessary. Then, the scientific consensus should be acknowledged by scientists, industry and regulatory mechanisms to allow for a clear definition of the FODMAP concepts and a safe and reliable production of low FODMAP products. Future research in food science could focus on the combination of different tools, such as the use of functional ingredients to partially replace high FODMAP ingredients combined with enzyme and or fermentation approaches. The applicability of different models could be investigated in a larger variety of products and product formulations.

Project Publications

1. Atzler, J. J., Ispiryan, L., Gallagher, E., Sahin, A. W., Zannini, E., & Arendt, E. K. (2020). Enzymatic degradation of FODMAPS via application of β-fructofuranosidases and α-galactosidases- A fundamental study. Journal of Cereal Science, 95, 102993, doi: 10.1016/j.jcs.2020.102993.
2. Atzler, J. J., Sahin, A. W., Gallagher, E., Zannini, E., & Arendt, E. K. (2021a). Characteristics and properties of fibres suitable for a low FODMAP diet- an overview. Trends in Food Science & Technology, 112, 823–836, doi: 10.1016/j.tifs.2021.04.023.
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11. Atzler, J. J., Crofton, E.., Gallagher, E., Sahin, A. W., Zannini, E., & Arendt, E. K. (2022). Developing a low FODMAP pasta enriched with dietary fibre- Potentials and downfalls. Journal of functional foods. Manuscript ready for submission.
12. Atzler, J. J., Crofton, E., Gallagher, E., Sahin, A. W., Zannini, E., & Arendt, E. K. (2022). Optimisation of a low FODMAP biscuit enriched with IBS suitable dietary fibre – a systematic approach. Food and Function. Manuscript ready for submission.
13. Borowska, M., Ispiryan, L., Neylon, E., Sahin, A.W., Zannini, E., Arendt, E.K., Coffey, A. (2022). Successful application of type II sourdough processing with homofermentative lactic acid bacteria resulting in low FODMAP whole wheat bread. Food and Function. Manuscript ready for submission.