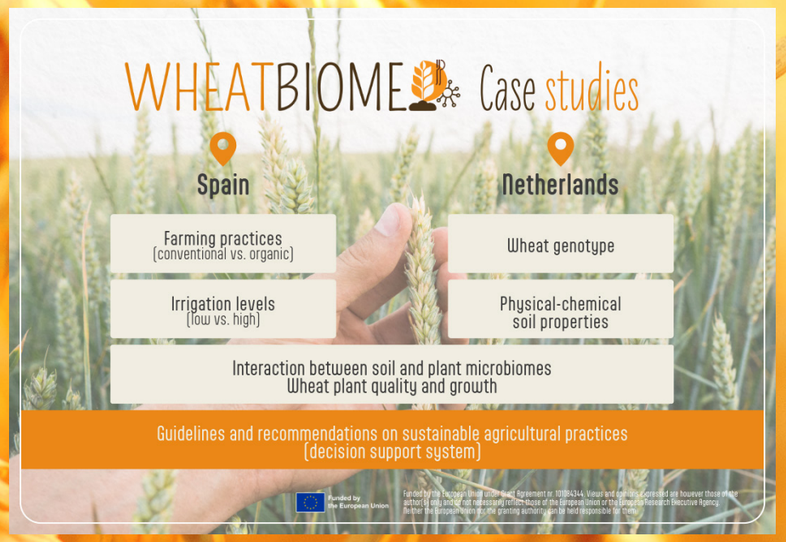
Harnessing the wheat microbiome: unlocking pathways to improved food quality and human health



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The food industry is facing unprecedented challenges to meet the exponential demand for food driven by demographic development. Consumption preferences are changing to consider not only food quality and security issues but also the environment and health-related properties. Wheat, a stable crop in European diets, confronts constant threats due to climate change and environmental stressors, imposing a global stagnation or decline of wheat yield in the near future.

The **WHEATBIOME** project seeks to advance our knowledge of microbiome-interaction function with a global perspective from **SOIL** to **PLATE** through a multidisciplinary and multi-actor approach. By investigating the impact of various factors on the wheat microbiome and exploring soil-plant microbiome interactions, food-human microbiome interactions and feed-animal-food interactions, the project aims to generate valuable insights for healthier food and feed and for sustainable farming and industrial practices while considering societal perceptions of microbiomes in food systems.

The WHEATBIOME project's mission is to unravel the intricate relationship between the microbiome and the development of healthier and sustainable wheat-based food and feed. This ambitious undertaking will be achieved through the collaborative efforts of 13 partners from academia, industry and governmental entities. By exploring the impact of both biotic and abiotic factors on the wheat microbiome, the project aims to shed light on the complex interplay between soil and plant microbiomes and how these interactions influence the quality of wheat-based food and feed, as well as the health of both humans and animals. Additionally, the project aims to create valuable knowledge to guide the implementation of sustainable farming practices by local farmers and by upcycling the industrial byproducts for feed production while addressing the needs of the food and feed system actors regarding the use of microorganisms in agriculture, food and animal feeding.

Understanding the role of microbiome in sustainable wheat-based food development

The WHEATBIOME project aims to elucidate the role of the microbiome in the sustainable production of wheat-based food and feed. Soil and plant microbiomes are crucial for plant evolution, adaptation and resistance to biotic and abiotic stress (e.g. soil characteristics, climate changes, agricultural practices). Environmental stress or human interventions can disrupt this balance, affecting plant health and grain nutritional quality. Traditional agricultural practices, such as pesticides, pose risks to the environment and soil, human and animal health.

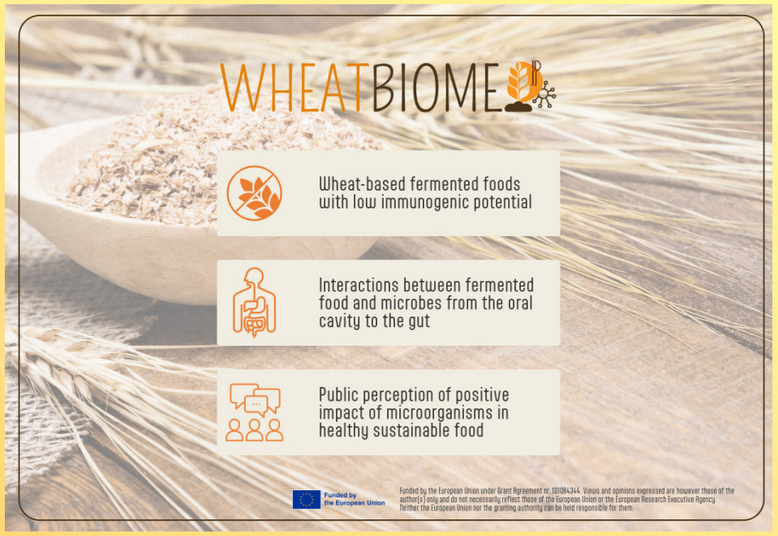
With an integrative multi-variable and multi-regional approach, the project will evaluate how soil characteristics, farming practices and climate conditions affect soil and wheat microbiomes and their interactions. Two case studies will be conducted: one in Spain (Mediterranean climate) and one in the Netherlands (Atlantic climate). The Spanish case study will examine the effects of conventional vs. organic farming practices and irrigation levels on wheat and soil microbiomes. The Dutch case study will investigate the impact of wheat genotype and physical-chemical properties of soil on microbiomes. The project will also assess how different microbial communities influence wheat plant quality and growth.

The generated knowledge will be used to develop a decision support system with guidelines and recommendations for sustainable agricultural practices, helping European farmers improve crop resilience, yield and nutritional quality in a sustainable manner.

Wheat-based fermented foods and wheat consumption-related immunologic diseases

Society is facing numerous challenges related to unhealthy diets, such as obesity-related diseases and rising food intolerances, which affect over 10 per cent of the global population. Cereals containing gluten are listed among the 14 food allergens in Europe. Wheat contains a significant number of gluten and non-gluten immunogenic proteins. There are three main forms of wheat immunogenicity manifestations: non-celiac gluten hypersensitivity, celiac disease and wheat allergy.

- **Non-celiac gluten hypersensitivity:** involves innate and adaptive immune responses without the autoimmune component of celiac disease.
- **Celiac disease:** the immune system damages the small intestine lining upon gluten exposure, triggering an inflammatory response against immunogenic gluten peptides.



- **Wheat allergy:** an IgE-mediated immune response to wheat proteins, leading to histamine release and inflammation.

The three conditions display distinct immunologic responses to wheat, each with unique pathophysiology, clinical manifestations and management strategies. Understanding these conditions is essential for accurate diagnosis, effective treatment and improving life quality for affected individuals. Likewise, a better understanding of these pathologies will contribute to advancing alternative nutritional strategies and food products for people suffering with immune reactions to wheat. Many commercially available gluten-free products use refined flours and starches, which can lead to higher fat content and lower intake of fibre and other essential nutrients. Natural strategies to reduce the levels of immunogenic proteins in wheat-based food can revolutionise the food system from FARM to FORK and improve the lives of millions suffering from wheat sensitivity. Plant-based fermented foods and beverages constitute approximately one-third of daily consumption and are valued for their high nutritional value and sustainable impact. The synergy between sustainability and highly nutritious foods is crucial for the long-term future, as sustainable practices ensure food safety with higher nutritional qualities.

Using microorganisms (probiotics) such as lactic acid bacteria has proven to be an effective method for enhancing food safety, nutritional content, sensory qualities and shelf-life. Moreover, the use of microbes to reduce gluten levels in food is an innovative approach that has been explored in food science. Traditional wheat-based fermented foods and beverages often use yeast like *Saccharomyces cerevisiae*, which have limited enzymatic activity for gluten breakdown and, therefore, a low impact on wheat-based food immunogenicity. Using a mixture of microorganisms with higher fermentation capacity coupled with prolonged fermentation times can reduce gluten levels, making wheat-based products more digestible and potentially safer for those with wheat sensitivity. Research on novel microbial strains could lead to new fermented plant-based products with functional and appealing properties.

Fermented foods can also positively influence gut microbiota, which may help alleviate some of the symptoms associated with wheat consumption-related immune reactions (e.g. nausea, diarrhoea, headache). Although wheat-based fermented foods can offer health benefits by reducing gluten content, they are not universally safe for all individuals with wheat immunologic diseases. WHEATBIOME will focus on novel microbial strains from wheat to create safer fermented foods and beverages. Evaluating the impact of sustainable farming practices and edaphoclimatic (soil and climate) conditions will be useful in producing fermented wheat-based food with higher nutritional quality and the lowest immunogenic potential.

WHEATBIOME aims to revolutionise wheat-based fermented food by exploring the role of autochthonous microbiota with probiotic potential in designing healthy and tasty fermented foods.

Generating knowledge on food-microbiome interactions

The interaction between fermented foods and the host microbiome is a dynamic relationship promoting overall well-being. Incorporating fermented foods into the diet can significantly enhance gut health, support the immune system, reduce inflammation and benefit mental health. Fermented foods, rich in live microorganisms, bioactive compounds and metabolites, can influence the composition and function of the gut microbiome. Probiotics from fermented foods can temporarily colonise the gut, outcompeting harmful bacteria and maintaining a balanced microbial ecosystem. This improves gut function, reinforces the intestinal barrier, favours the metabolisation of various bioactive compounds (like vitamins, short-chain fatty acids and antimicrobial peptides), modulates immune responses and reduces inflammation by enhancing the production of anti-inflammatory cytokines.

Additionally, microbes in fermented foods produce enzymes that break down complex carbohydrates, proteins and fats, making nutrients more accessible and digestible. Emerging research highlights the gut-brain axis and the connection between the gut microbiome and mental health. Probiotics from fermented foods can regulate the production of neurotransmitters like serotonin, dopamine and gamma-aminobutyric acid, influencing mood and cognitive function and potentially reducing symptoms of anxiety and depression.

While most studies and clinical assays focus on understanding the impact of a specific compound or microorganism on gut microbiota ecology and function, the impact of fermented food consumption on oral microbiota remains largely unexplored. The oral cavity is the first contact with food and hosts a diverse microbiome crucial for oral health, and that can be used as a biomarker of oral diseases. Fermented foods can benefit oral health by introducing beneficial microbes, producing antimicrobial compounds, modulating immune responses and enhancing salivary health, which can prevent dental caries and periodontal diseases and influence taste perception. Current intervention studies on fermented cereal-based products are mostly limited to sourdough bread, highlighting the need for further clinical research to explore the full potential of wheat-based fermented foods.

WHEATBIOME aims to explore the interactions between food and microbes from the oral cavity to the gut, elucidating the biochemical mechanisms by which the food matrix impacts the food-host microbial crosstalk to understand the role of microbiota in designing healthy and tasty food. Moreover, it will explore the effects of different wheat-based foods designed with various microbial populations on human microbiota, health and well-being.

Assessing societal perception of microbiomes in food systems

The WHEATBIOME project will evaluate societal attitudes towards microbiomes in food systems. Understanding public perceptions will allow the project to tailor its findings and recommendations to align with societal values and preferences. The concept of microbiomes in food is gaining attention in society, with public perception shaped by scientific research, media representation and cultural practices.

Advances in microbiome research highlight the crucial role of microorganisms in food production, safety and health. This scientific understanding is gradually reaching the public, increasing knowledge of the benefits of the microbiome. There is a growing market for functional foods that provide health benefits beyond basic nutrition. The increasing number of microbiome-enhanced products in supermarkets and health stores reflects consumer demand, with these products often marketed as microbiome-friendly, including terms like 'probiotic', 'gut health', and 'natural fermentation'.

Educational institutions and public health organisations are informing the public about the importance of microbiomes in food through workshops, documentaries and informational campaigns. In this context, WHEATBIOME aims to conduct webinars, workshops and dissemination activities involving all food system actors, from farmers to the food industry, academia and consumers. These activities will provide society with the tools to understand the impact of microbial communities on the food system.

WHEATBIOME

PROJECT SUMMARY

The WHEATBIOME project gathers 13 partners from academia, industry, food systems and governmental bodies aiming to explore how biotic/abiotic factors impact soil and wheat microbial communities. The project will contribute to the development of novel and healthier food and feed products while enhancing sustainable farming practices for resilient crops and societal perception about microbiomes within food systems.

PROJECT PARTNERS

WHEATBIOME consortium includes experts in the human microbiome (LAQV/REQUIMTE, PT), agro-edaphic microbiomes (UPORTO, PT), plant biochemistry (WUR, NL), microbial biotechnology (UVEG, ES), nutrition (UVIGO, ES), food technology (IBPRS, PL), food production (ISANATUR, ES), sustainability assessment (CTA, ES), animal health (SGGW, PL), food/feed legislation (UVMB, HU), clinical trials (NMS, PT), computer science (ART21, LT), communication/dissemination (CTA, ES), and education/training (EDAGRI, ES).

PROJECT LEAD PROFILE

LAQV/REQUIMTE is a research institute with a core mission to promote scientific and technological activities aligned with the United Nations sustainable development agenda and to provide smart and sustainable solutions to governments, industry and society. With a robust organisational structure, LAQV/REQUIMTE gathers top-notch technical resources coordinated by qualified staff, enhancing the institution's renowned scientific excellence.

PROJECT CONTACTS

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FUNDING

The WHEATBIOME project has received funding from the European Union's Horizon Europe work programme under grant agreement No. 101084344.