HealthFerm

Innovative pulse and cereal-based food fermentations for human health and sustainable diets

HealthFerm.eu

Leveraging Fermentation Technology for Health and the HealthFerm project

Prof. Christophe M. Courtin, KU Leuven

Bolzano, October 29, 2024

Microbes 4 Sustainable Foods
empowering tomorrow's food

Co-funded by the European Union

Schweizerische Eidgenossenschaft
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KU LEUVEN

Short introduction

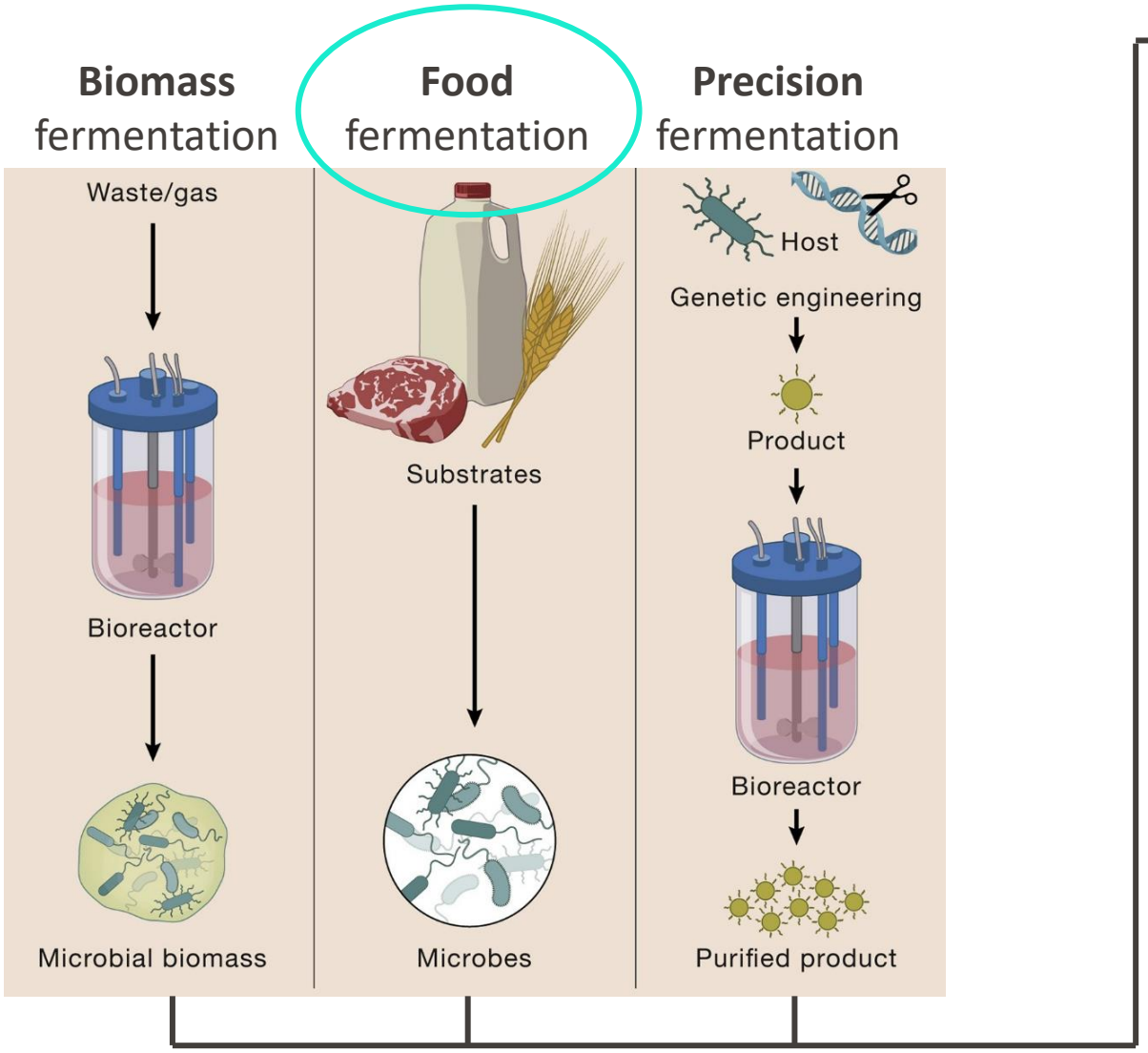
- Myself
  - Full professor of Food Biochemistry
  - Vice-dean of Faculty of Bioscience Engineering @ KU Leuven
  - Coordinator of the Horizon Europe HealthFerm project (2022-2026)

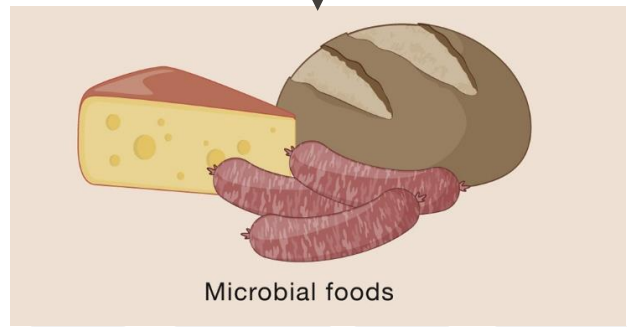
- Topic of today
  - Potential of food fermentation technology in our transition to more plant-based food consumption
  - High on the agenda throughout Europe and in industry

Overview

- **Different types** of fermentation and fermented foods
- **Why** food fermentations?
- **What** does fermentation do to foods?
- **Research needs** in the field of food fermentation
- The **HealthFerm** project

Microbial Foods

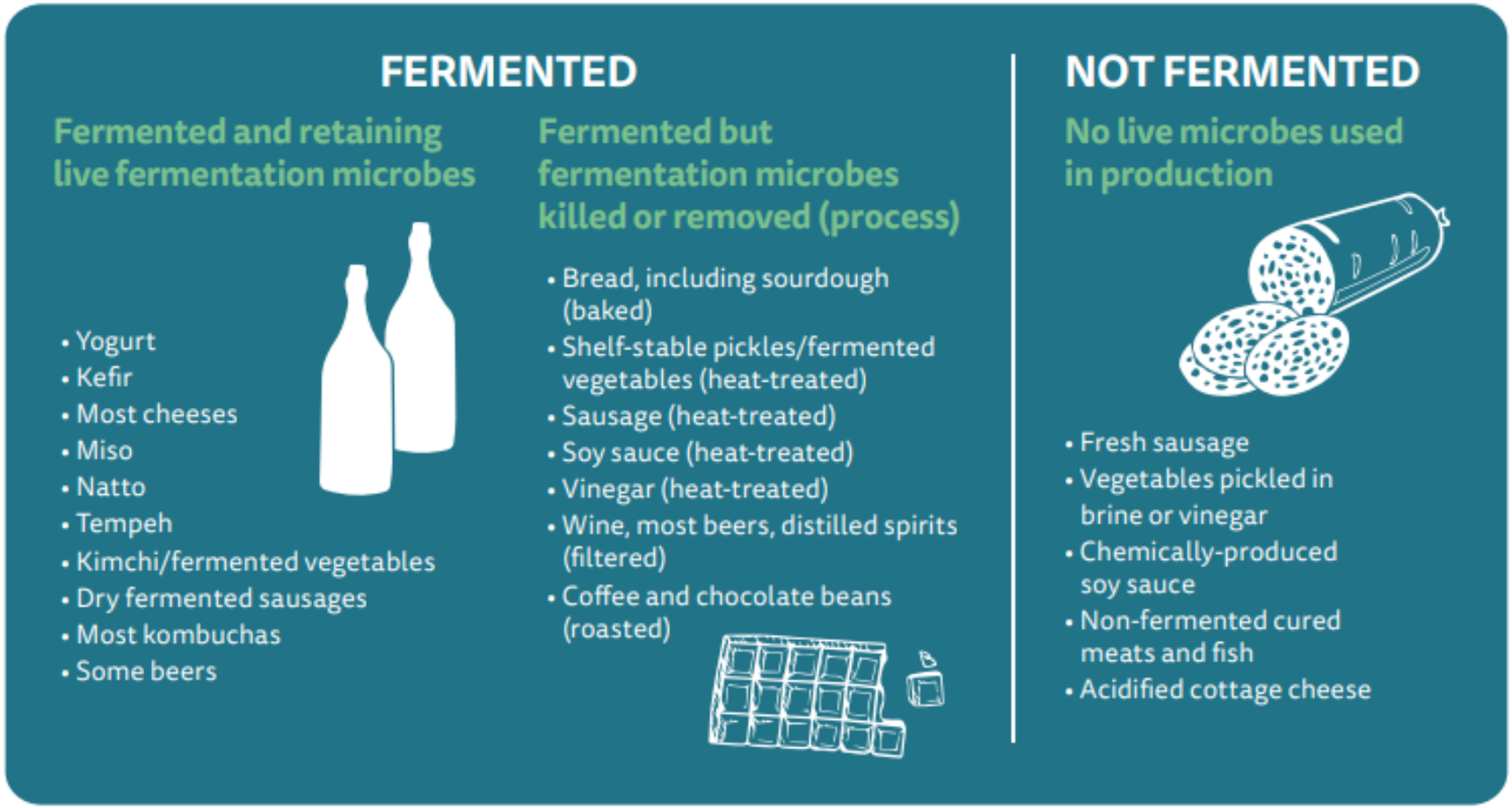




Jahn et al. Cell 186 (3) (2023)

Fermented Foods

- Fermented foods and beverages are “foods made through desired microbial growth and enzymatic conversions of food components”.



ISAPP (2020)

Marco et al. Nat Rev Gastroenterol Hepatol 18, 196–208 (2021)

Food Fermentation

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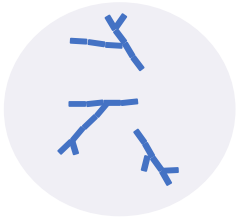
Bacteria

(Lactobacillus, Streptococcus, Propionibacteria,…)

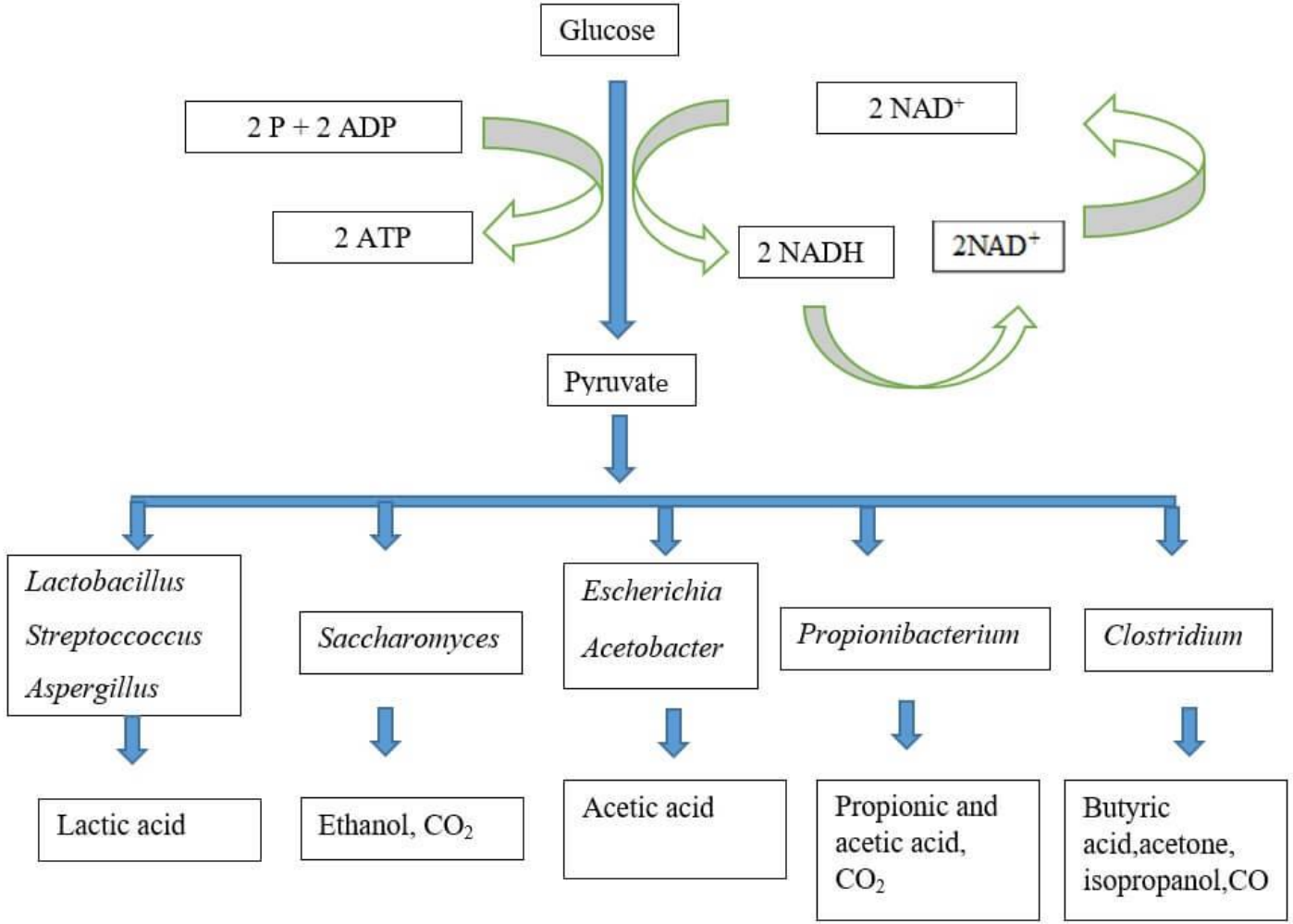


Fungi

(Aspergillus, Penicillium, Rhizopus,…)

Yeasts

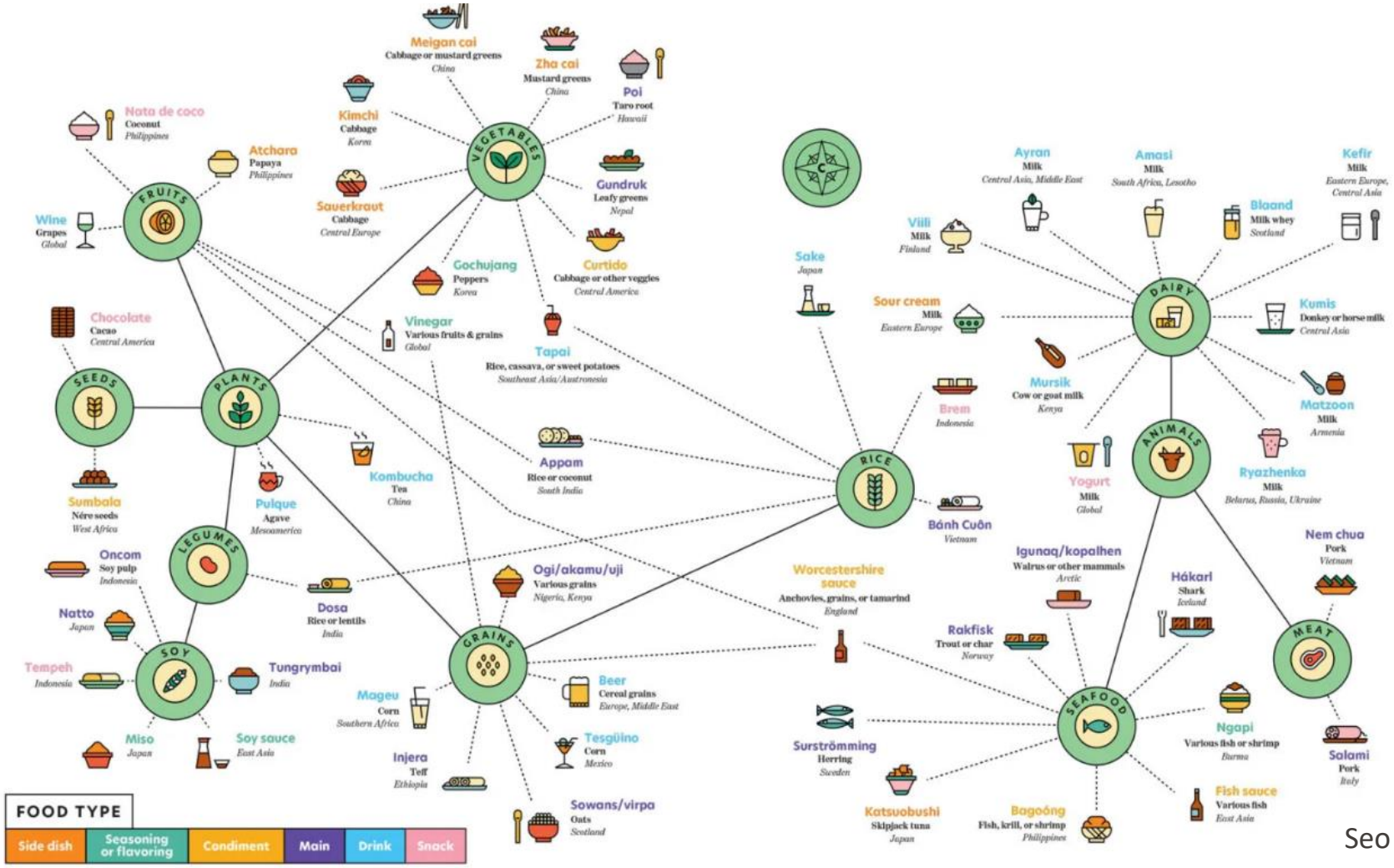
(Saccharomyces, Kluyveromyces,…)



Flowchart: Generalized pathways for the production of some fermentation end products from glucose by various organisms.

Fermented Foods

- There are roughly 5,000 varieties of fermented foods and beverages prepared and consumed worldwide, contributing 5% to 40% to the human diet.

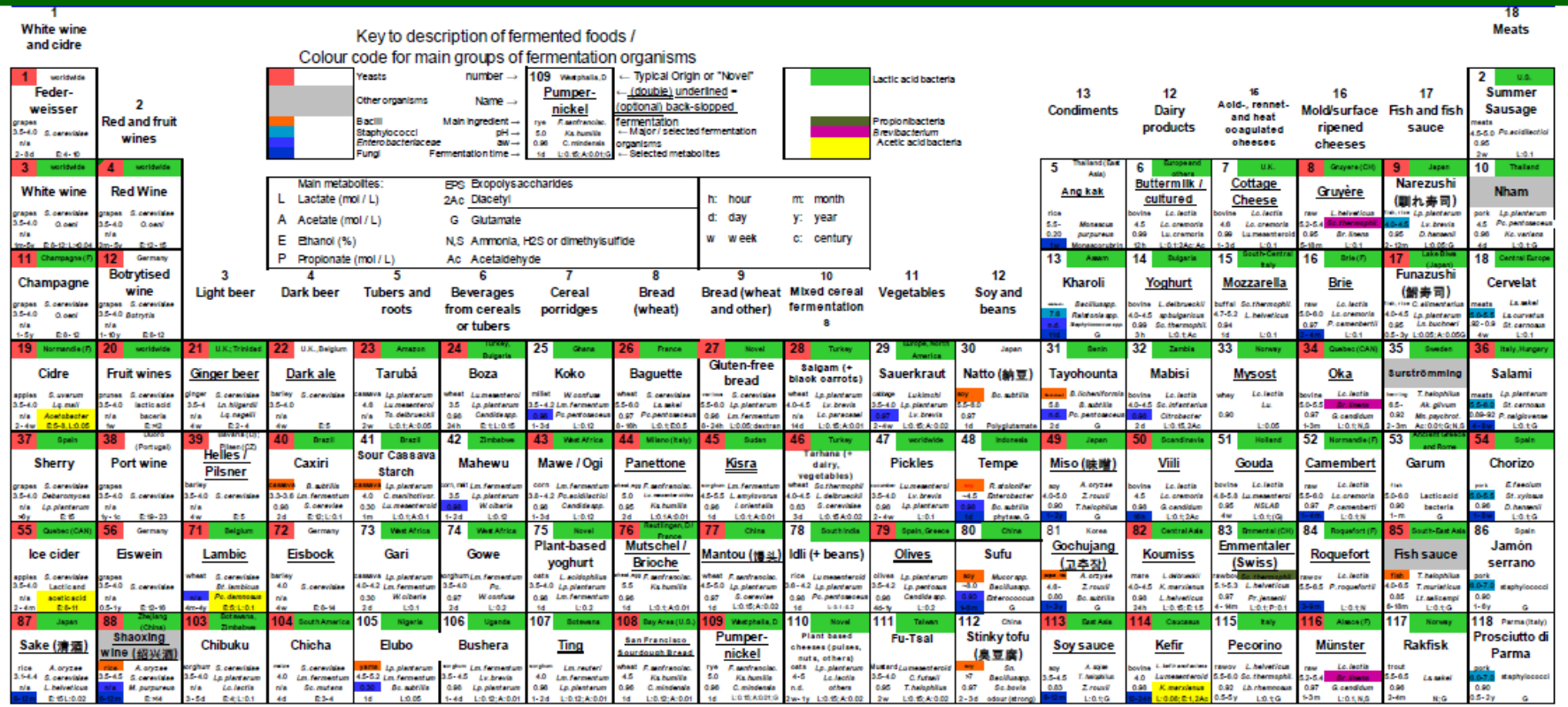


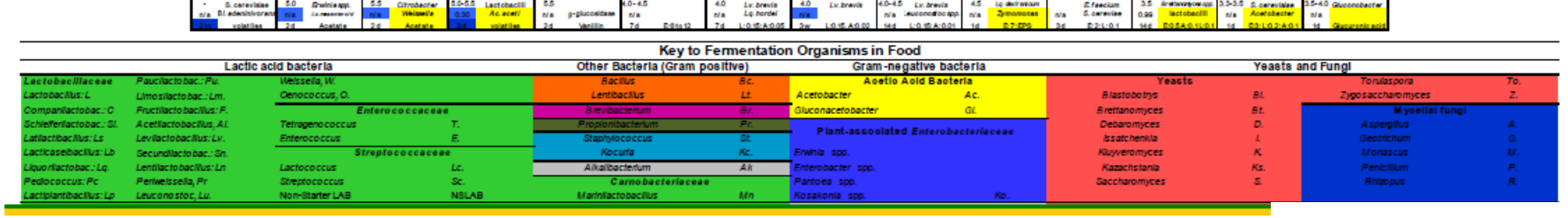
Seo et al. Popular Science (2020)

Periodic Table of Fermented Foods

Michael Gänzle

Department of Agricultural, Food and Nutritional Science, University of Alberta, Edmonton, AB, Canada





Acknowledgements: Dr. Lynn McMullen and Dr. Ying Hu are acknowledged for helpful suggestions

Lactic acid bacteria

Propionibacteria
Brevibacterium

Acetic acid bacteria

Yeasts

Other organisms

Bacilli
Staphylococci
Enterobacteriaceae
Fungi

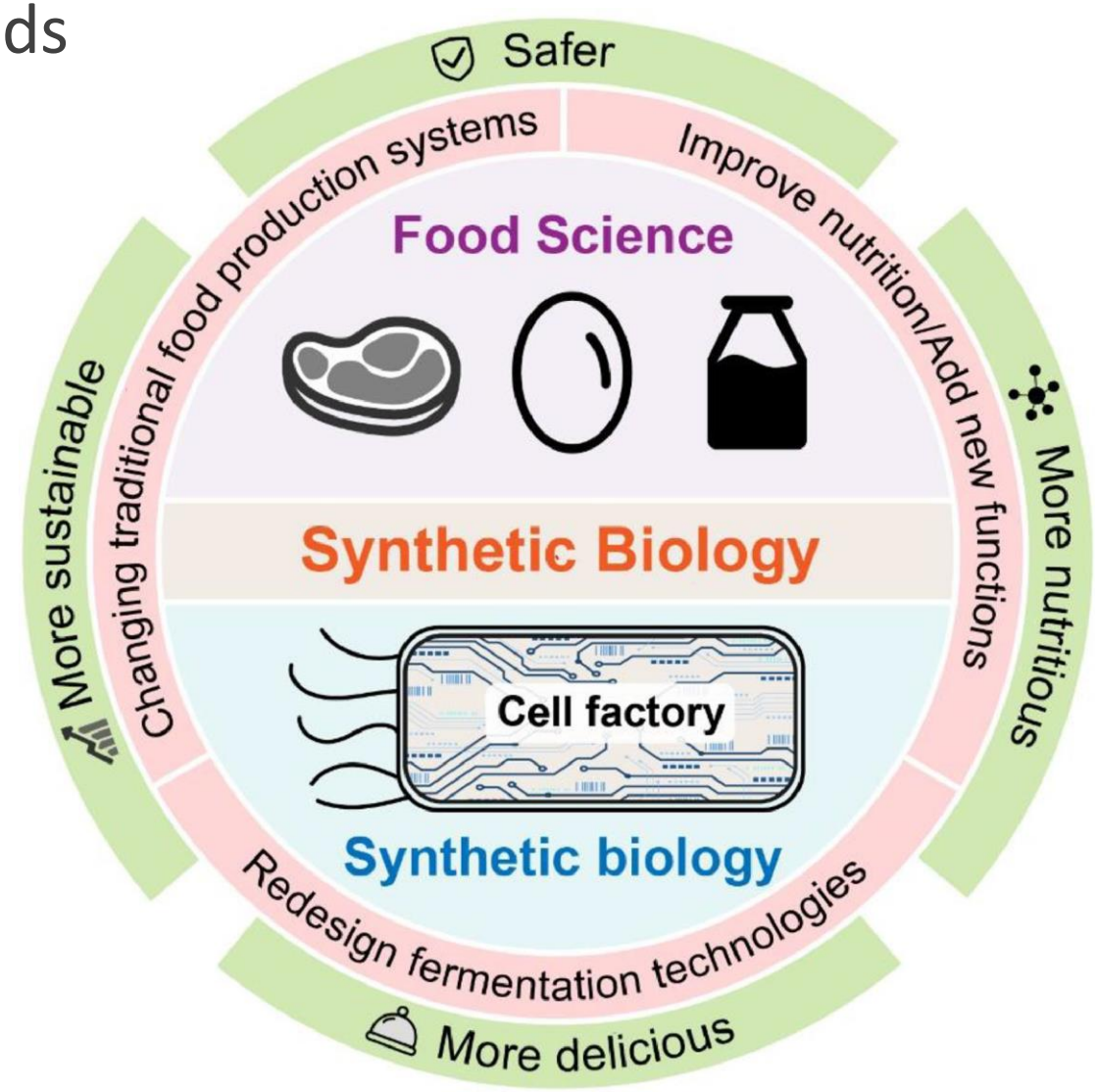
Gänzle, M. Appl Micr Bio 106, 2815–2826 (2022)

Overview

- **Different types** of fermentation and fermented foods
- **Why** food fermentations?
- **What** does fermentation do to foods?
- **Future research** in the field of food fermentation
- The **HealthFerm** project

Why Food Fermentation?

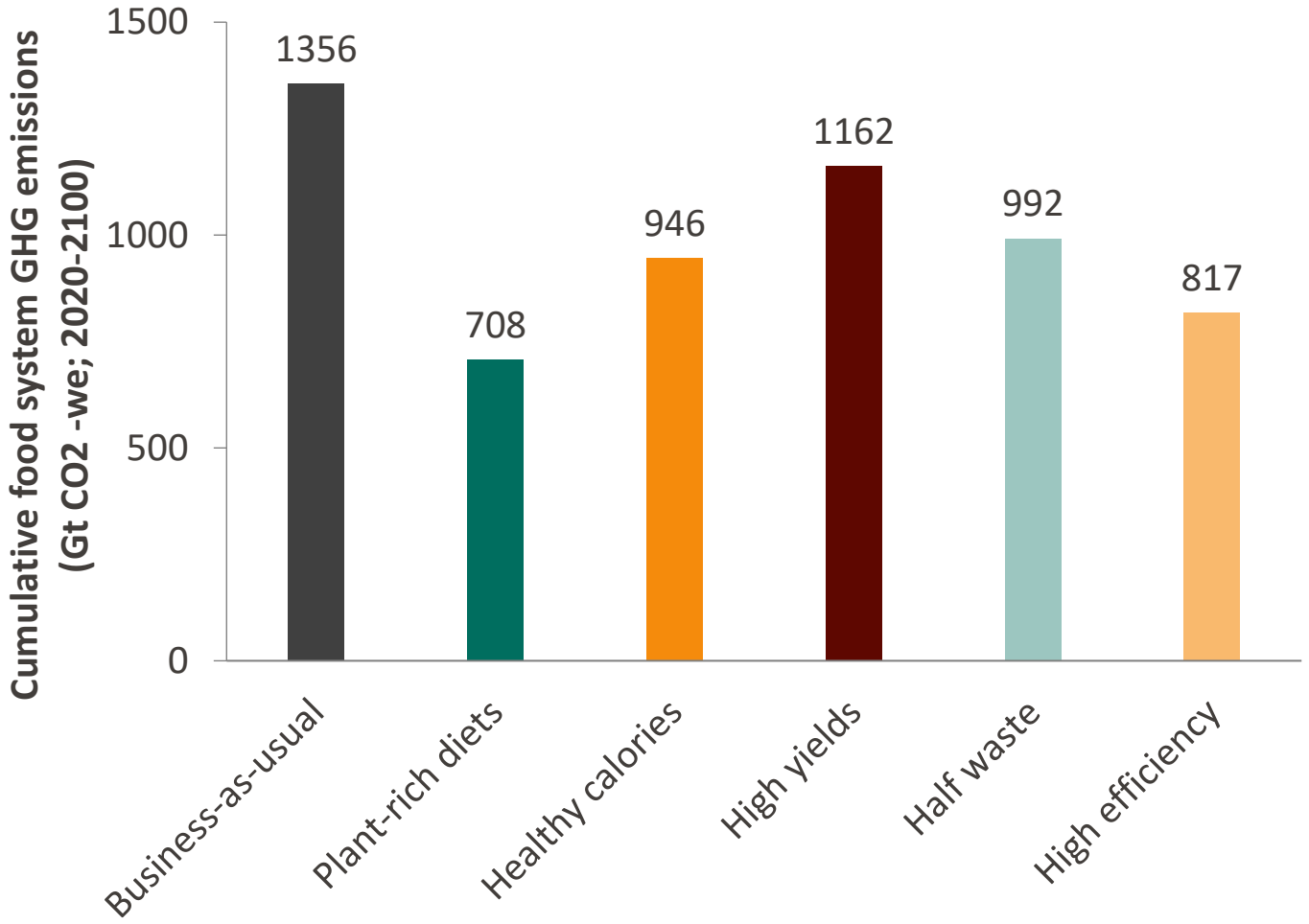
- More sustainable foods
- More delicious foods
- Safer foods
- Healthier foods



Lv et al. Future Foods 3, 100025 (2021)

Towards plant-based fermented foods

- Impact of different food system changes on greenhouse gas emissions



A transition towards a plant-rich diet could result in a **48% reduction** of food emissions!

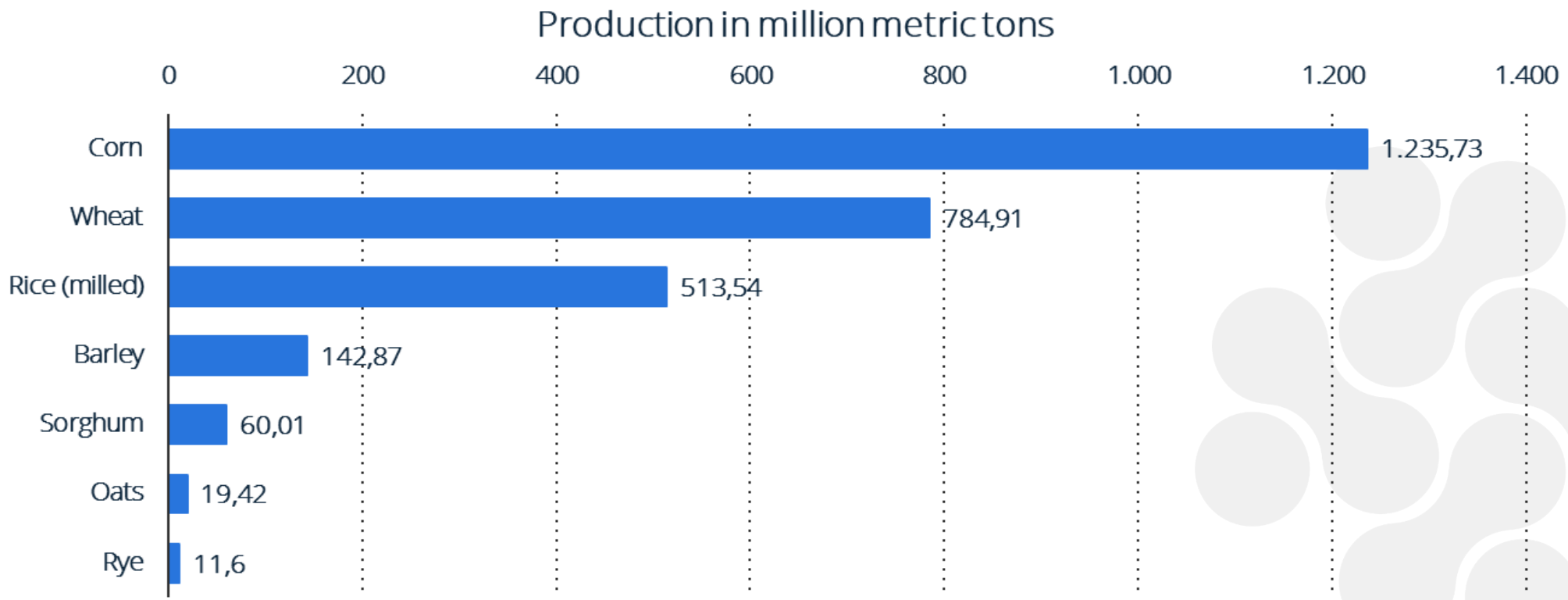
Clark et al., Science 370, 705–708 (2020)

Cereal grains

HealthFerm

Worldwide production of grain in 2023/24, by type (in million metric tons)*

Grain production worldwide 2023/24, by type



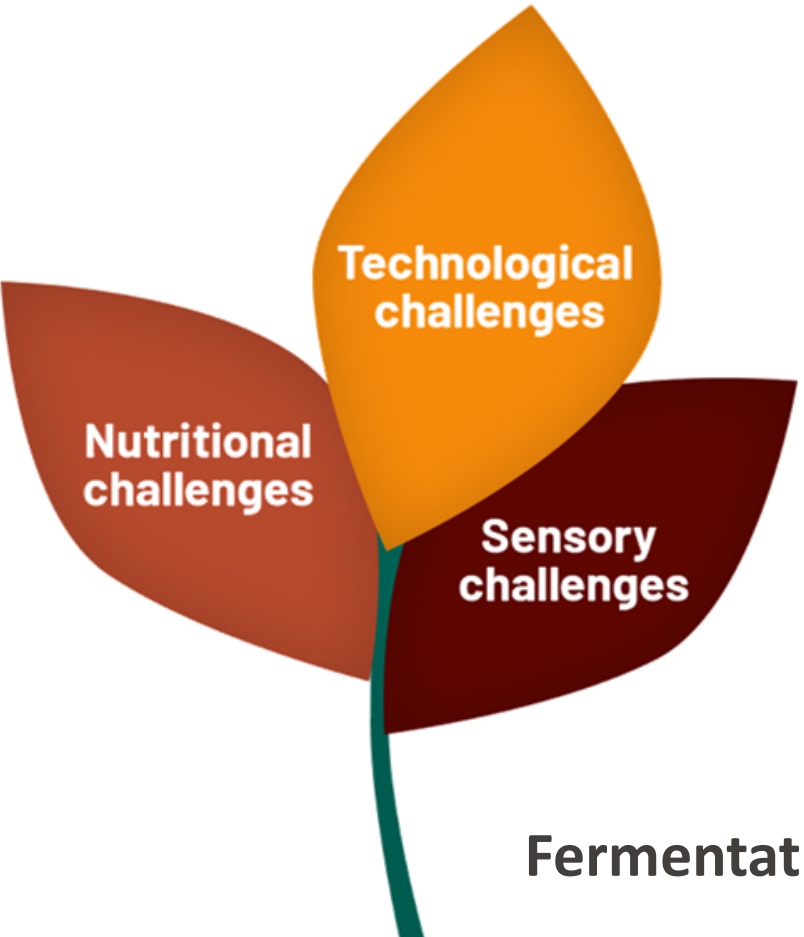
1 kg of cereal grain / person / day !!

Note(s): Worldwide; 2023/2024*
Further information regarding this statistic can be found on page 8.
Source(s): FAO; US Department of Agriculture; ID 263977

statista

Towards plant-based fermented foods

- Challenges related to plant-based foods



- Low solubility of plant proteins
- Poor techno-functionality of plant-based ingredients

- Off-flavours
- Food structure and texture

- Low mineral bioavailability
- Low levels of vitamin B12
- Anti-nutritional factors
- Low protein digestibility

Fermentation technology has the **potential** to overcome these challenges

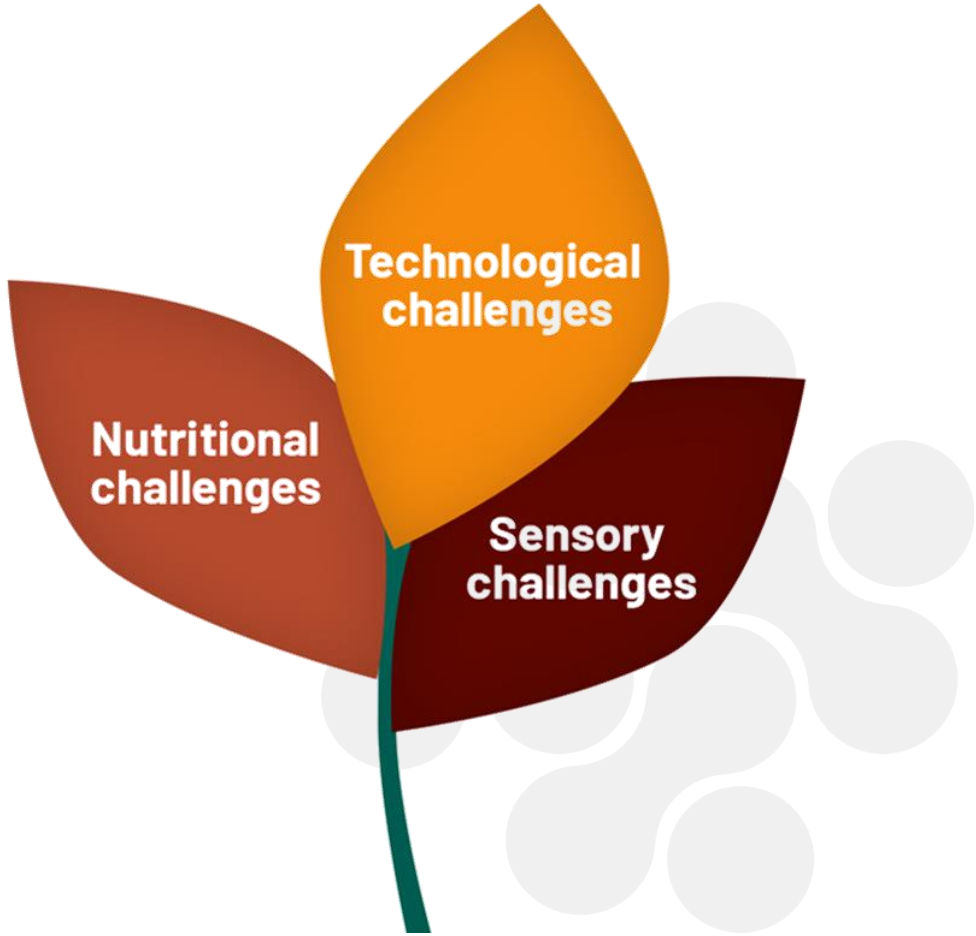
Towards plant-based foods

- Opportunities for plant-based foods

  - Dietary fibre-rich raw materials and foods to help close the dietary fibre gap in our diets
  - From recalcitrant to fermentable dietary fibre

  - Opportunities for side stream valorisation (pre-digestion)

  - Dietary fibres as texturisers, hydrocolloids



Health aspects of fermentation

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Except for yoghurt and cultured dairy products, **few human clinical studies have been performed to verify the benefits of (plant-based) fermented foods**

Food & Function

ROYAL SOCIETY OF CHEMISTRY

REVIEW

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Cite this: *Food Funct.*, 2022, **13**, 4804

Underlying evidence for the health benefits of fermented foods in humans

F. Rul,[a] C. Béra-Maillet,[a] M. C. Champomier-Vergès,[a] K. E. El-Mecherfi,[b] B. Foligné,[c] M. C. Michalski,[d] D. Milenkovic[e,f] and I. Savary-Auzeloux[*e]

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RESEARCH ARTICLE
Host-Microbe Biology

Check for updates

Consumption of Fermented Foods Is Associated with Systematic Differences in the Gut Microbiome and Metabolome

Bryn C. Taylor,[a] Franck Lejzerowicz,[b] Marion Poirel,[f] Justin P. Shaffer,[b] Lingjing Jiang,[c] Alexander Aksenov,[d] Nicole Litwin,[i] Gregory Humphrey,[b] Cameron Martino,[e] Sandrine Miller-Montgomery,[h,i] Pieter C. Dorrestein,[b,d,i] Patrick Veiga,[g] Se Jin Song,[i] Daniel McDonald,[b] Muriel Derrien,[g] Rob Knight[b,h,i,j]

Randomized Controlled Trial | Cell. 2021 Aug 5;184(16):4137-4153.e14.
doi: 10.1016/j.cell.2021.06.019. Epub 2021 Jul 12.

Gut-microbiota-targeted diets modulate human immune status

Hannah C Wastyk [1], Gabriela K Fragiadakis [2], Dalia Perelman [3], Dylan Dahan [2], Bryan D Merrill [2], Feiqiao B Yu [4], Madeline Topf [2], Carlos G Gonzalez [5], William Van Treuren [2], Shuo Han [2], Jennifer L Robinson [3], Joshua E Elias [4], Erica D Sonnenburg [6], Christopher D Gardner [7], Justin L Sonnenburg [8]

Affiliations + expand

PMID: 34256014 PMCID: PMC9020749 DOI: 10.1016/j.cell.2021.06.019

Free PMC article

Available online at www.sciencedirect.com
ScienceDirect

Current Opinion in Biotechnology

ELSEVIER

Health benefits of fermented foods: microbiota and beyond

Maria L Marco[1], Dustin Heeney[1], Sylvie Binda[2], Christopher J Cifelli[3], Paul D Cotter[4], Benoit Foligné[5], Michael Gänzle[6], Remco Kort[7], Gonca Pasin[8], Anne Pihlanto[9], Eddy J Smid[10] and Robert Hutkins[11]

CrossMark

frontiers | Frontiers in Nutrition

TYPE Review
PUBLISHED 20 September 2022
DOI 10.3389/fnut.2022.976020

Review | Nutrients. 2019 Aug 5;11(8):1806. doi: 10.3390/nu11081806.

Fermented Foods: Definitions and Characteristics, Impact on the Gut Microbiota and Effects on Gastrointestinal Health and Disease

Eirini Dimidi [1], Selina Rose Cox [1], Megan Rossi [1], Kevin Whelan [2]

Affiliations + expand

PMID: 31387262 PMCID: PMC6723656 DOI: 10.3390/nu11081806

Free PMC article

Review | Crit Rev Food Sci Nutr. 2019;59(3):506-527. doi: 10.1080/10408398.2017.1383355. Epub 2017 Oct 20.

Health benefits of fermented foods

Nevin Şanlier [1], Büşra Başar Gökcen [2], Aybüke Ceyhun Sezgin [3]

Affiliations + expand

PMID: 28945458 DOI: 10.1080/10408398.2017.1383355

Abstract

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*CORRESPONDENCE
Katherine J. Li

Fermented foods and cardiometabolic health: Definitions, current evidence, and future perspectives

Katherine J. Li[1,2*], Kathryn J. Burton-Pimentel[2], Guy Vergères[2], Edith J. M. Feskens[1] and Elske M. Brouwer-Brolsma[1]

[1]Division of Human Nutrition and Health, Wageningen University & Research, Wageningen, Netherlands, [2]Agroscope, Bern, Switzerland

Overview

- **Different types** of fermentation and fermented foods
- **Why** food fermentations?
- **What** does fermentation do to foods?
- **Research needs** in the field of food fermentation
- The **HealthFerm** project

What does fermentation do to foods?

- Transformation of food constituents

- Affecting food texture

- Synthesis of bioactive compounds

- Provides (live) micro-organisms in food

Marco et al. Curr Opin Biot 44, 49-102 (2017)

Transformation of food constituents

- Long fermentation times + metabolic activity of microorganisms + enzymatic activity of the raw material leads to partial hydrolysis or structural changes in major and minor constituents
  - Starch
  - Fibres
  - Proteins
  - Phytate
  - …
- This can
  - Reduce or improve the technofunctional properties of these constituents
  - Affect digestibility and bio-availability of constituents

Transformation of food constituents

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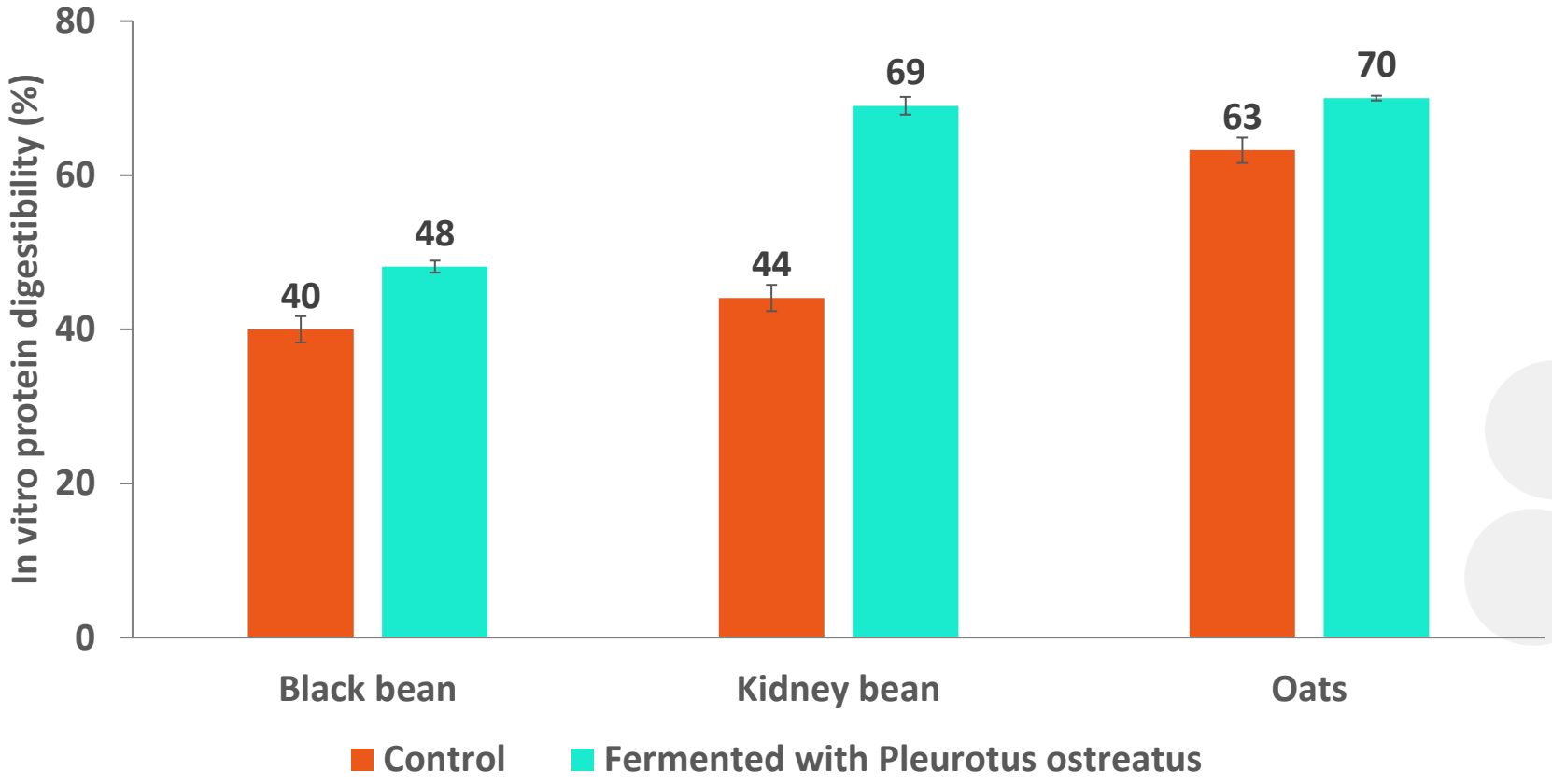
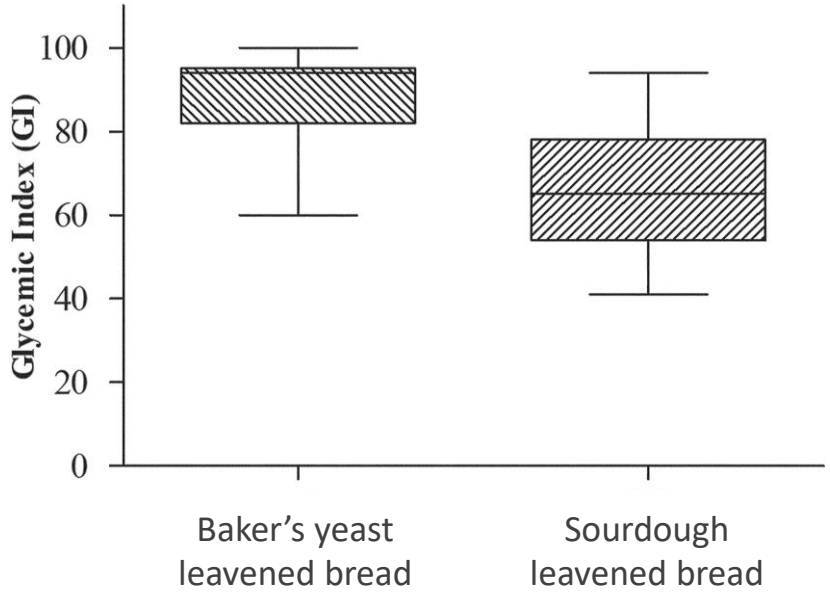
- Examples: increased protein digestibility



Espinosa-Páez et al., Molecules 22, 2275 (2017)
Sá et al., Crit. Rev. Food Sci 60:20, 3367-3386 (2020)

Transformation of food constituents

- Example: postprandial glycemic response



Blood Glucose response (N = 20*)	Healthy individuals N = 14, n = 263	Individuals with metabolic disease N = 6, n = 78

CONFLICTING EVIDENCE

- 50% of studies showing NO significant differences
- Different cereals, milling types, recipes and fermentation conditions used

Thirty years of knowledge on sourdough fermentation: A systematic review

Kashika Arora [a,1], Hana Ameur [a,1], Andrea Polo [a], Raffaella Di Cagno [a], Carlo Giuseppe Rizzello [b], Marco Gobbetti [a,*]

[a] Faculty of Science and Technology, Libera Università di Bolzano, Piazza Università, 5, 39100, Bolzano, Italy
[b] Department of Soil, Plant and Food Sciences, University of Bari Aldo Moro, Via G. Amendola, 165/a, 70126, Bari, Italy

Arora et al., Trends Food Sci Technol., 108, 71-83 (2021)

Review

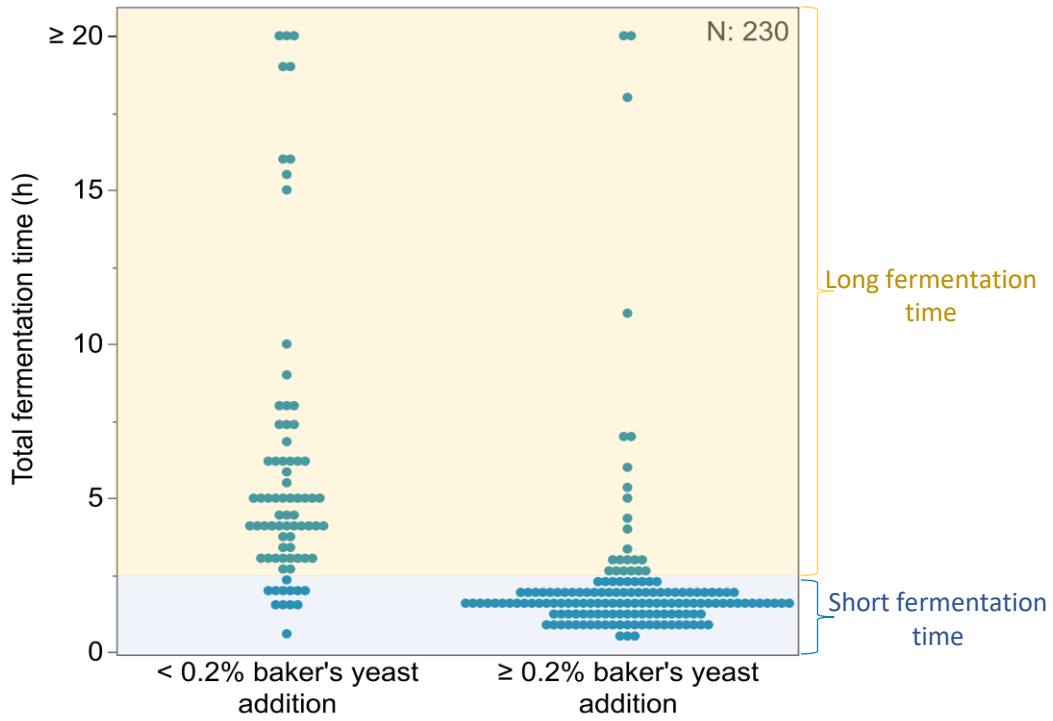
Nutritional benefits of sourdoughs: A systematic review

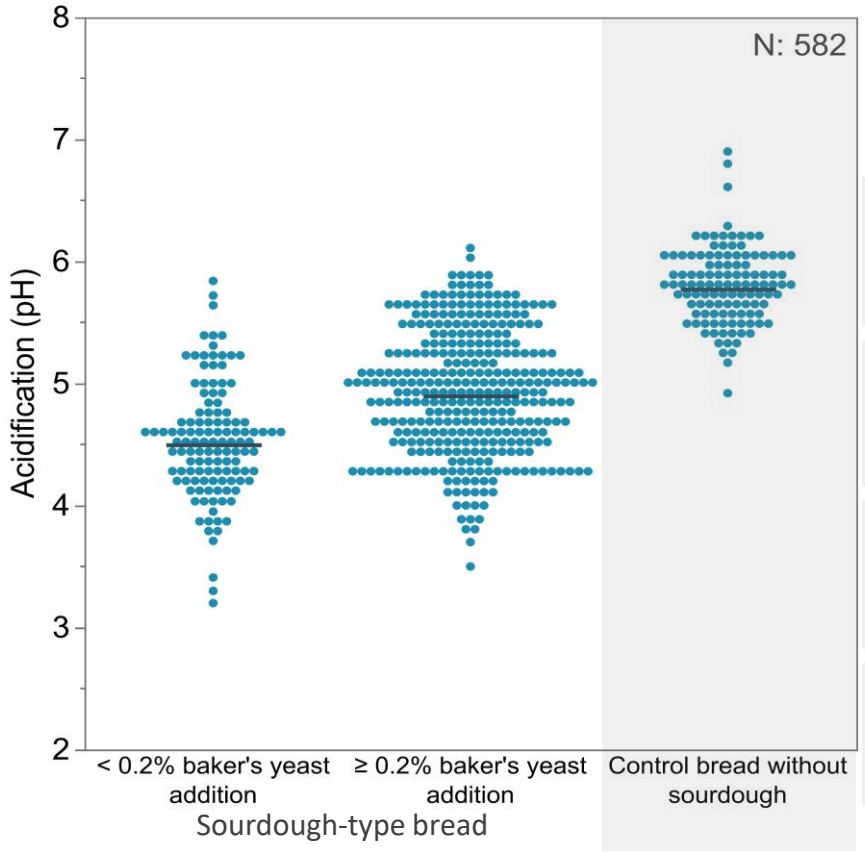
Léa Ribet [1,†], Robin Dessalles [2,†], Corinne Lesens [1], Nele Brusselaers [3,4,5], Mickaël Durand-Dubief [6,*]

Ribet et al. Adv. Nutr., 14, 1, 22-29 (2023)

Transformation of food constituents

- Decreased postprandial glycemic response?
  - Variety in fermentation conditions and product quality of sourdough-type bread!

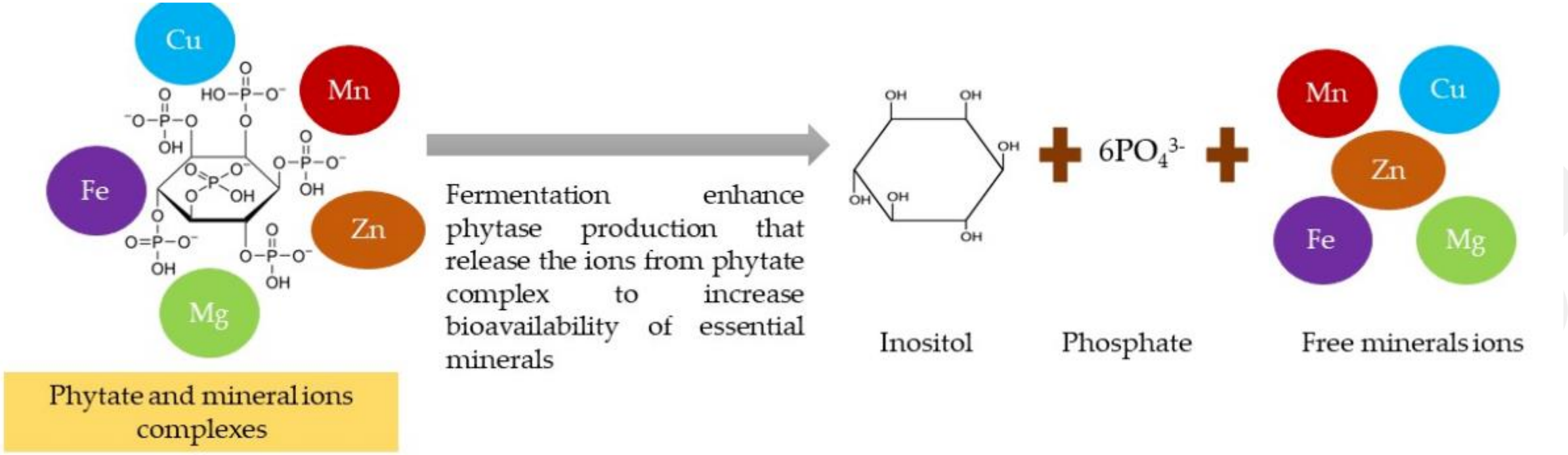




De Bondt et al. (2024)

Transformation of food constituents

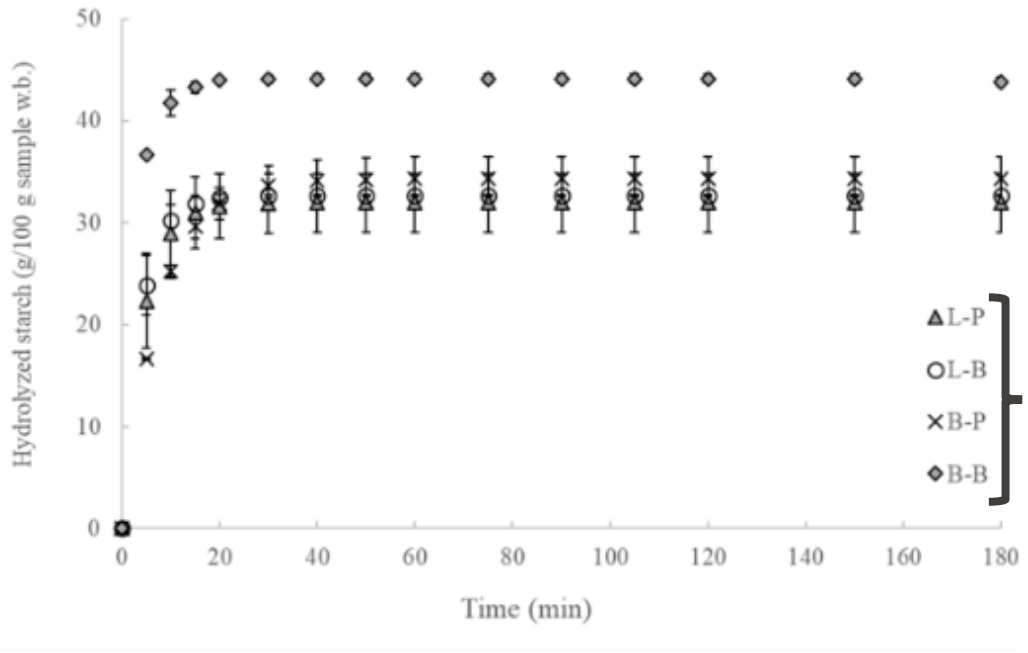
- Degradation of phytate could affect mineral bioavailability



Samtiya et al., Fermentation 7, 63 (2021)

Affect food texture

- Changes in constituent properties and pH will affect food texture
- This can affect mastication and digestion



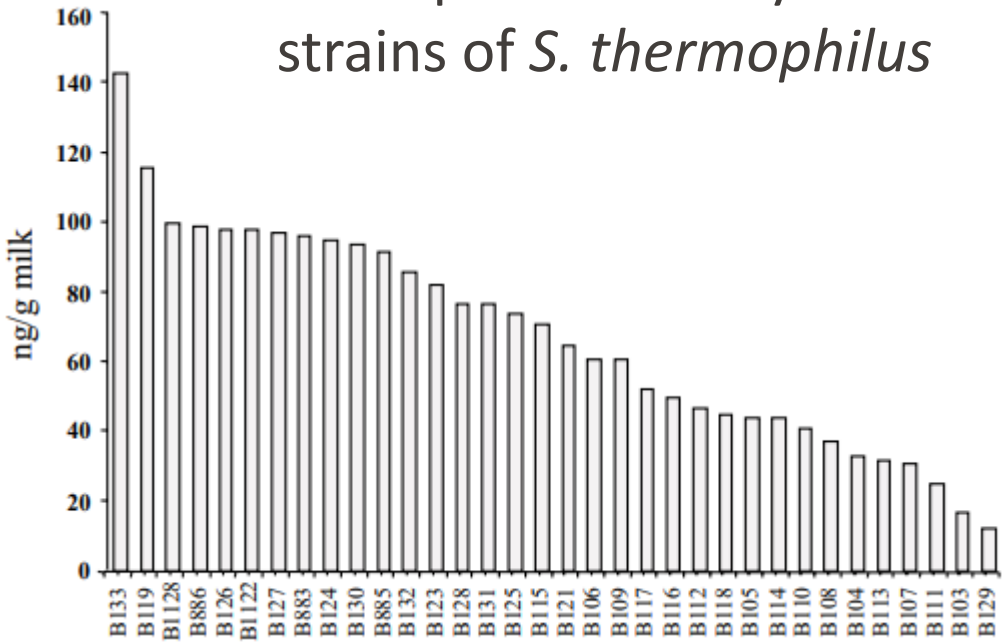
Different bread structure and disintegration

Aleixandre et al. Nutrients 11, 2105 (2019)

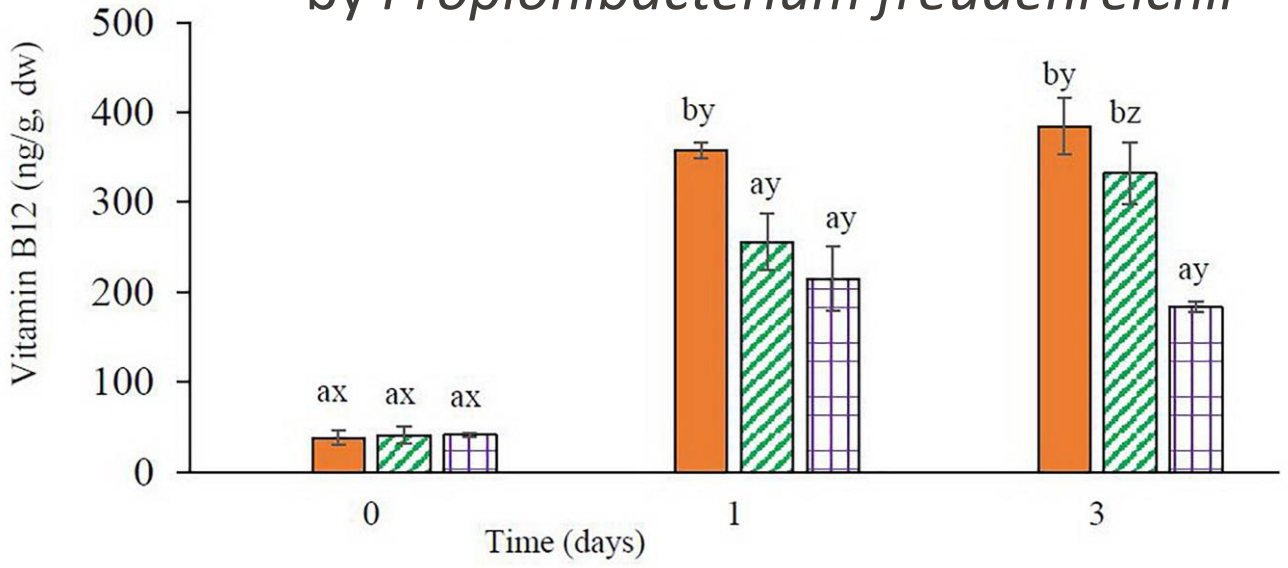
Synthesis of new bioactive compounds

- Production of acids (lactic acid, acetic acid, propionic acid…)!
- Vitamin production,…

Folic acid production by different strains of *S. thermophilus*



Vitamin B12 production in wheat bran by *Propionibacterium freudenreichii*



Wouters et al. Int Dairy Journal 12, 91–109 (2002)
Xie et al. Front. Microbiol. 10:1541 (2019)

Provide (live) micro-organisms

- Estimating dietary intake of live microbes in 9338 foods (NHANES data)

Low <10^4 CFU/g
Processed/heated foods
8998 (**96%**)

Medium 10^4-10^7 CFU/g
Fresh fruits and vegetables
284 (**3%**)

High >10^7 CFU/g
Unheated fermented foods
106 (**1%**)

- ~100 g/day of microbe-containing foods is consumed → $10^{8\text{-}9}$ microbes/day
- >90% are from fermented foods

Marco et al., J. Nutr., 152(7), 1729–1736 (2022)

Provide (live) micro-organisms

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- Consumption of foods with higher microbial concentrations associated with lower
  - Systolic blood pressure
  - C-reactive protein
  - Plasma glucose
  - Plasma insulin
  - Triglyceride
  - Waist circumference
  - BMI levels

Nutritional Epidemiology

Positive Health Outcomes Associated with Live Microbe Intake from Foods, Including Fermented Foods, Assessed using the NHANES Database

Colin Hill [1,†], Daniel J. Tancredi [2,†], Christopher J. Cifelli [3], Joanne L. Slavin [4], Jaime Gahche [5], Maria L. Marco [6], Robert Hutkins [7], Victor L. Fulgoni III [8], Daniel Merenstein [9], Mary Ellen Sanders [10,*]

Hill et al., J. Nutr., 153(4), 1143-1149 (2023)

Overview

- **Different types** of fermentation and fermented foods
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Research needs in the field of food fermentation?

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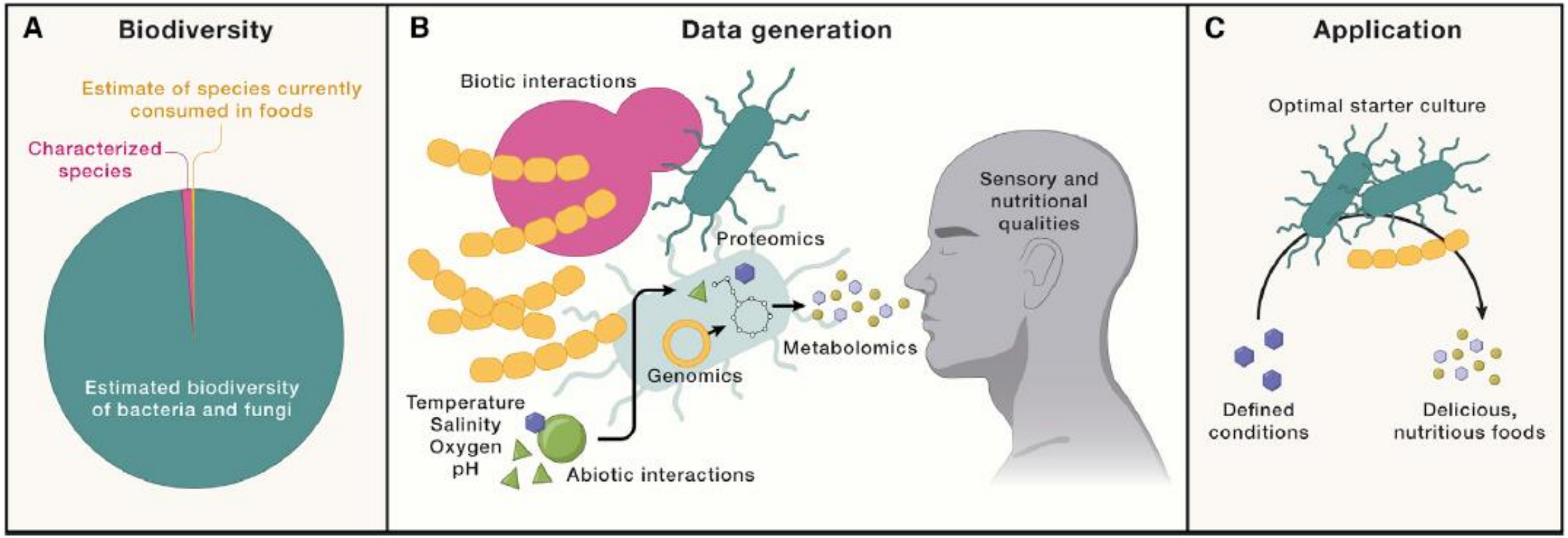
Microbial Biodiversity should be exploited for food fermentations



Jahn et al. Cell 186 (3) (2023)

Research needs in the field of food fermentation?

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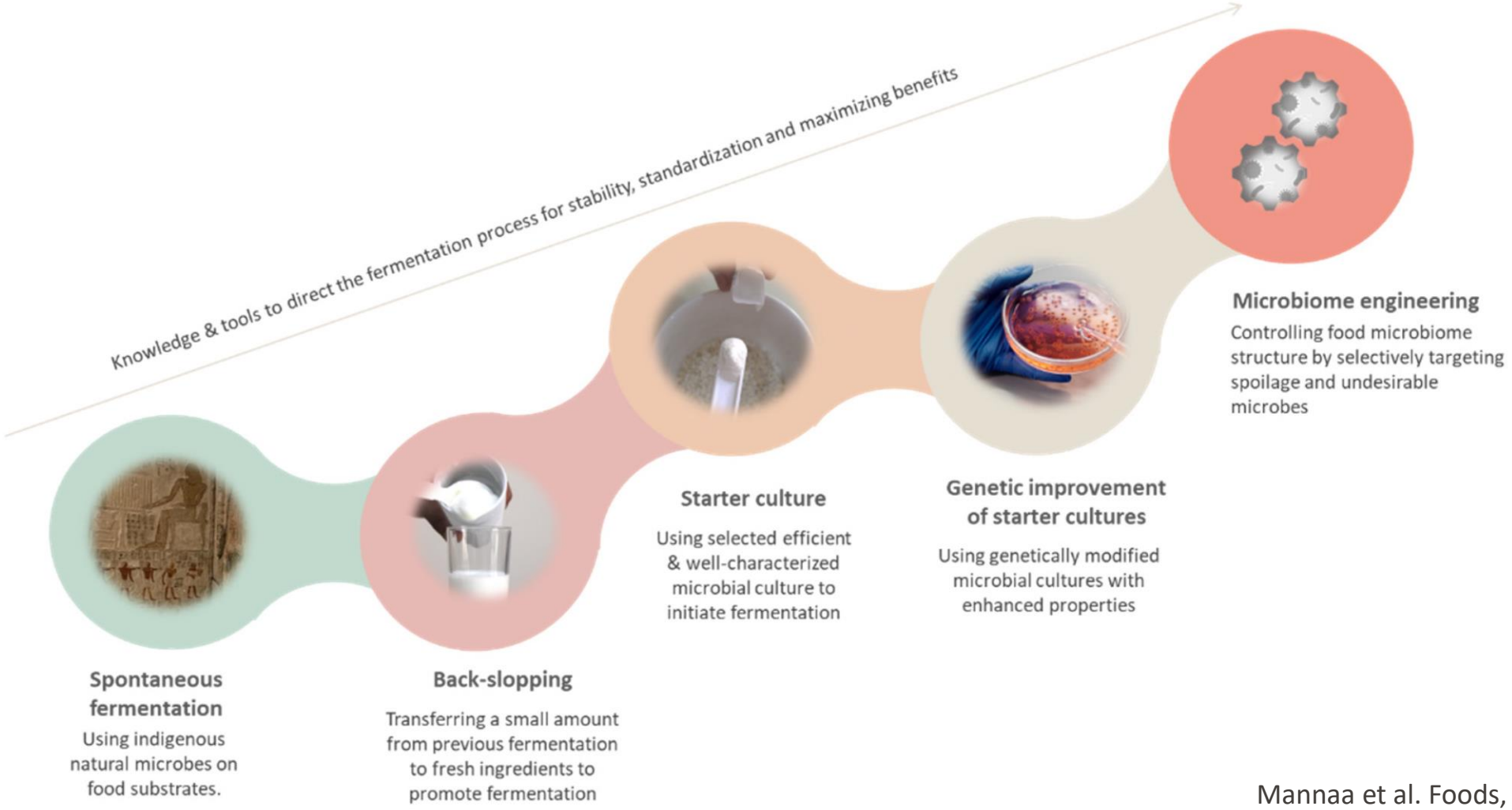
Engineering microbial communities for food production



Mannaa et al. Foods, 10, 2861 (2021)

Research needs in the field of food fermentation?

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A better understanding of the **health benefits** of fermented foods is needed

- Harvesting information from existing population-based diet and health databases
- New well-designed Randomized Controlled Trials with thoroughly characterised products

Even if no explicit health benefits are proven for plant-based fermented foods, planetary health will profit from the transition from (fermented) animal- to plant-based food consumption. If fermentation can support this: perfect!!

Marco et al. Nat Rev Gastroenterol Hepatol 18, 196–208 (2021)

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Innovative pulse and cereal-based food fermentations for human health and sustainable diets

The HealthFerm Project

HORIZON-CL6-2021-FARM2FORK-01-14, RIA

Co-funded by the European Union

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

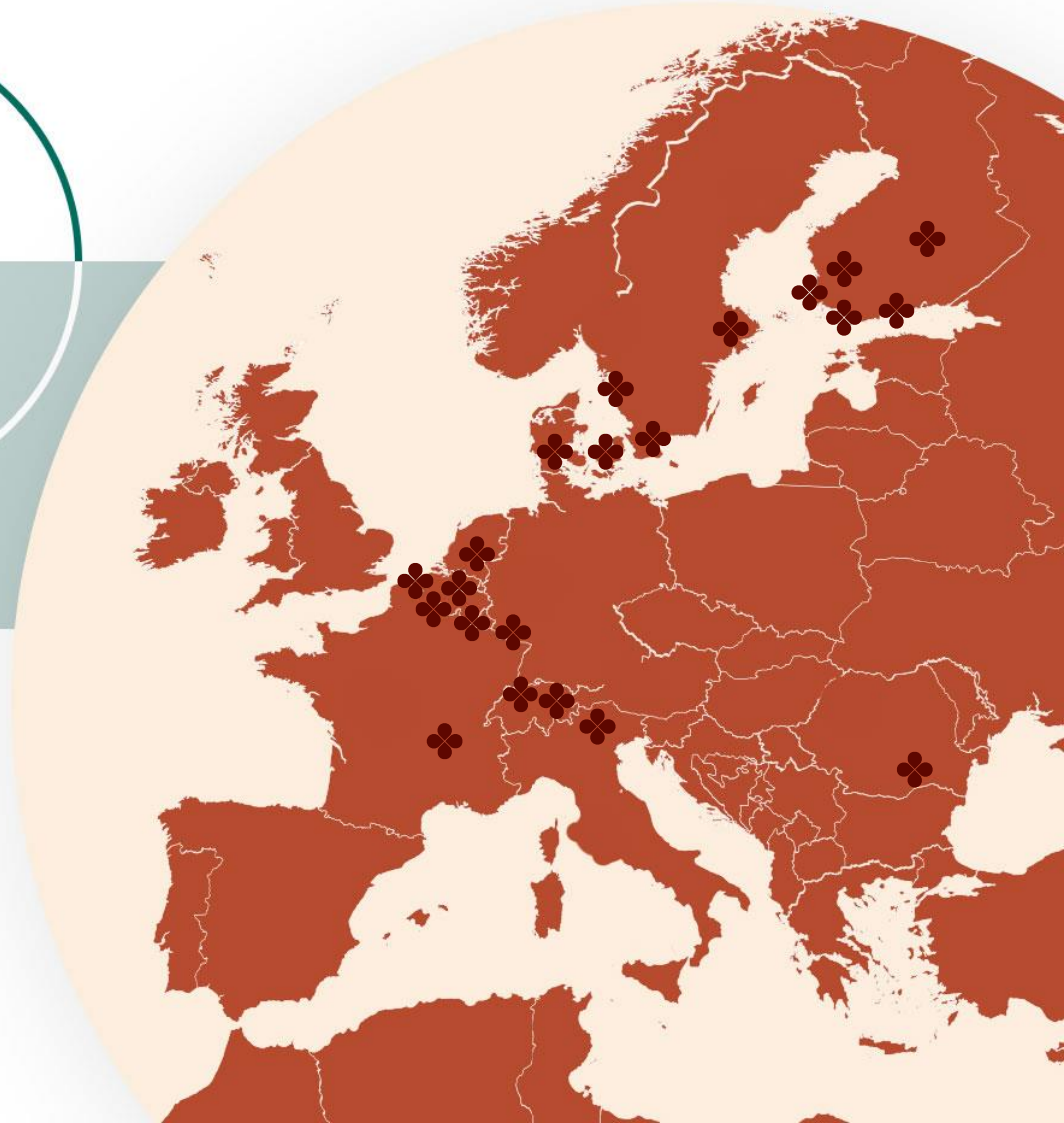
The HealthFerm project

HealthFerm

23 PARTNERS
11 COUNTRIES

13.1 MIO €
BUDGET

48 MONTH
DURATION



Coordinator: KU LEUVEN

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The HealthFerm project

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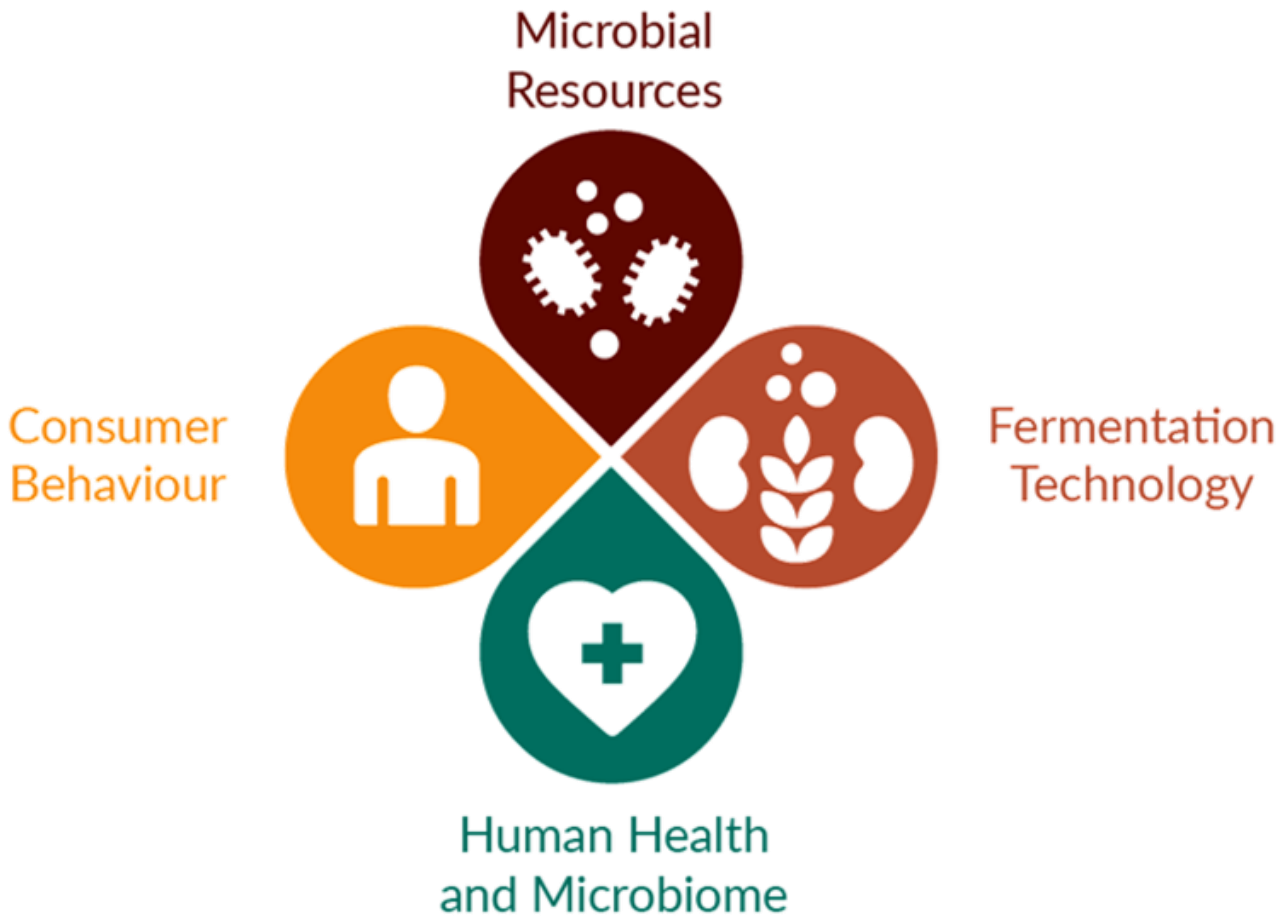

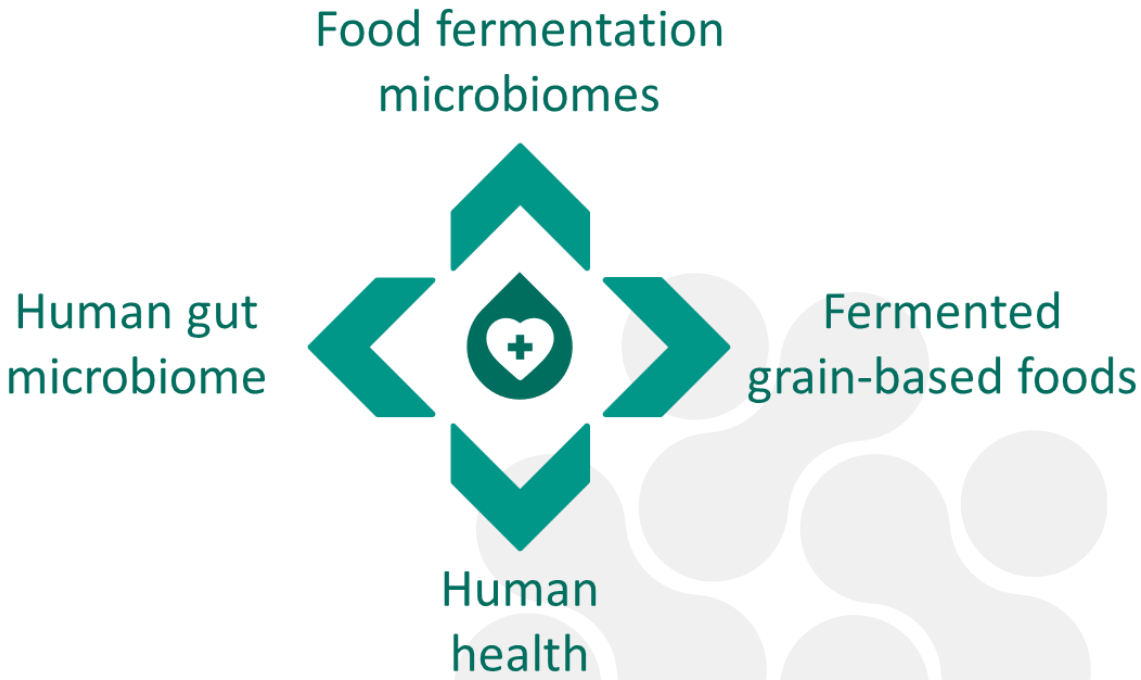

HealthFerm aims to enable an **evidence-based** transition in society and industry from traditional to **sustainable plant-based fermented** foods and diets that deliver **health benefits** to consumers **by design**

Project overview

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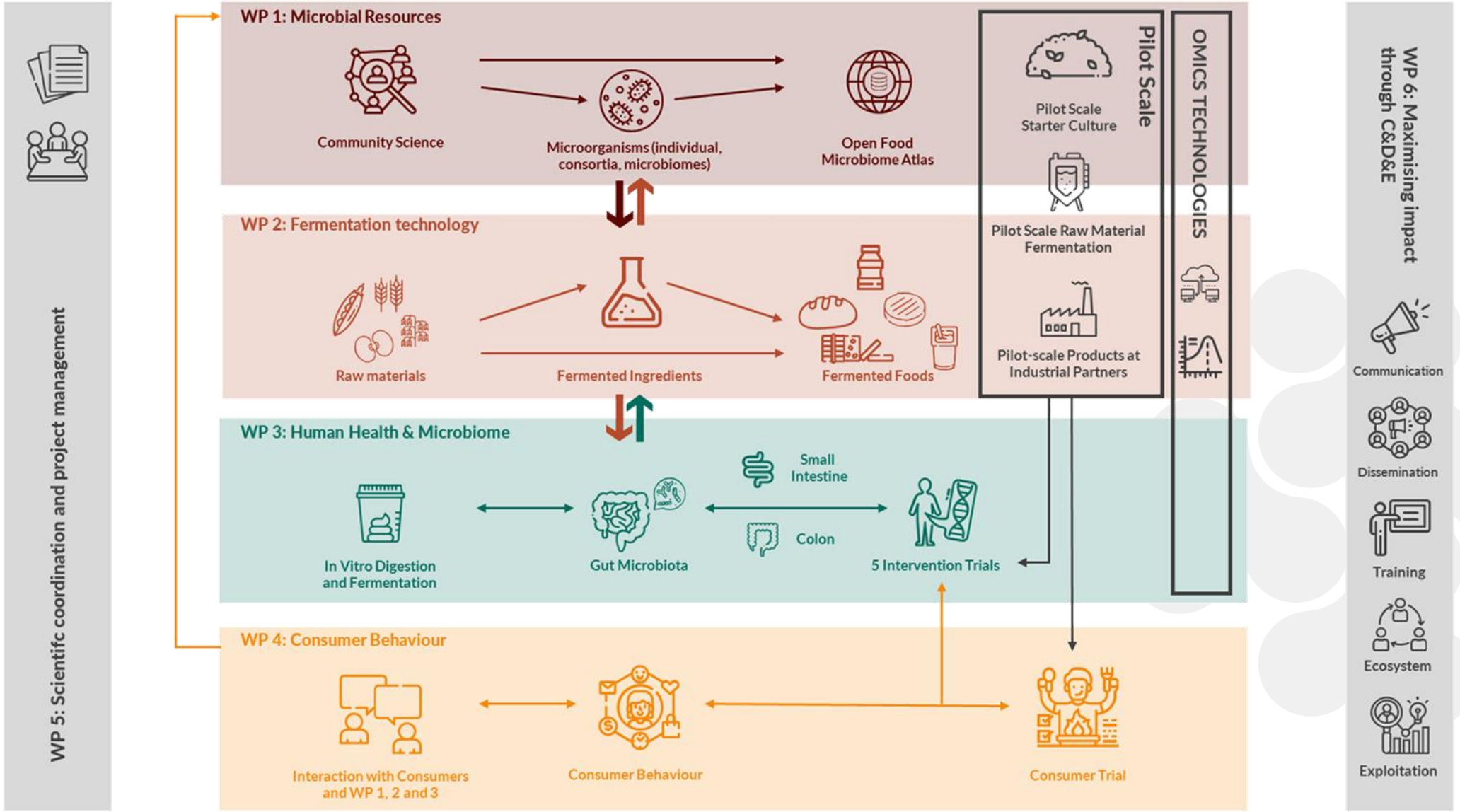

Major choices we made

- **Community science project** for food fermentations
- **Plant-based raw materials:** cereals & pulses
- **Liquid & (semi-)solid foods**
- **Human intervention studies** to investigate the health impact and related mechanisms of fermented food consumption
- Omics technologies for **food and human microbiomes**
- **Integration of social sciences** in all aspects of the project
- **Education and ecosystem** building
- **Interlinked WPs but also stand alone** with their own research questions

The HealthFerm network

External Ethics Advisor

Stakeholder board

HealthFerm

Expert Panel

Fermented Food Ecosystem

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Thank you for listening!

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Confédération suisse
Confederazione Svizzera
Confederaziun svizra