



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

Impact of microbial fermentation on food composition and nutritional attributes

part II

Dr. Rossana Coda



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the European Union



Fermented foods: bridging the past with the future

Fermented foods are strongly connected with people's traditions all over the world

Market of fermented foods is expanding to plant-based alternatives

Fermentation is process to obtain high-quality food products of increased nutritional value

Positive effects on gut microbiome (more studies needed)

Main challenges of plant-based ingredients

(Anti)nutritional factors

- Phytic acid
- Phenolic compounds (tannins, chlorogenic acid)
- Trypsin inhibitors
- Raffinose-oligosaccharides (RFOs)
- Vicine and convicine (faba)

Technological performance

- Flavor issues (beany, bitter)
- Poor structure forming capacity



Low consumer acceptance



Fermentation: adding value to plant-based foods

Enhances nutritional properties

- synthesis of bioactive compounds
- decrease ANF
- > starch and protein digestibility

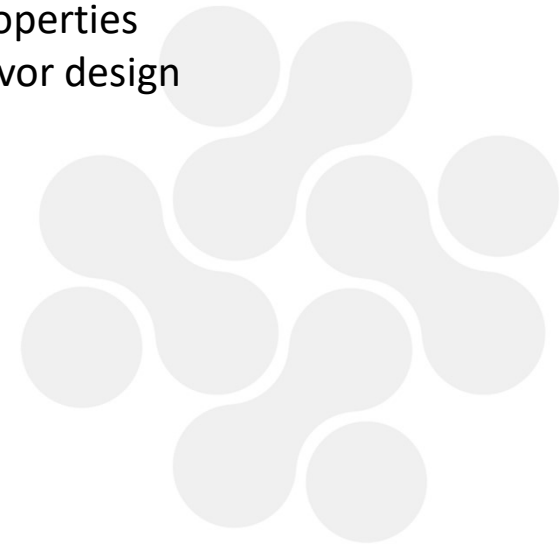
FERMENTATION

Improves technological quality

- synthesis of exopolysaccharides
- modification of rheological properties
- flavor design

Controls undesired microbes and standardization of the quality

Wholesome food with attractive properties

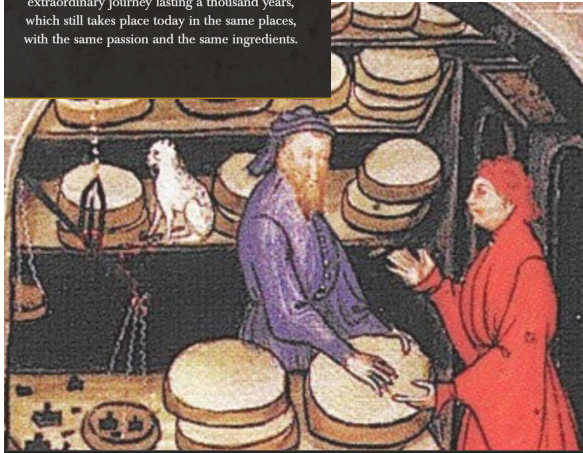


From tradition to innovation

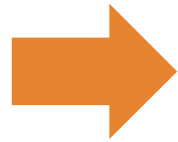
History

A journey lasting a thousand years

Parmigiano Reggiano embodies a unique and extraordinary journey lasting a thousand years, which still takes place today in the same places, with the same passion and the same ingredients.



<https://www.parmigianoreggiano.com/it/prodotto-storia>



<https://jessicainthekitchen.com/how-to-make-vegan-parmesan-cheese/>



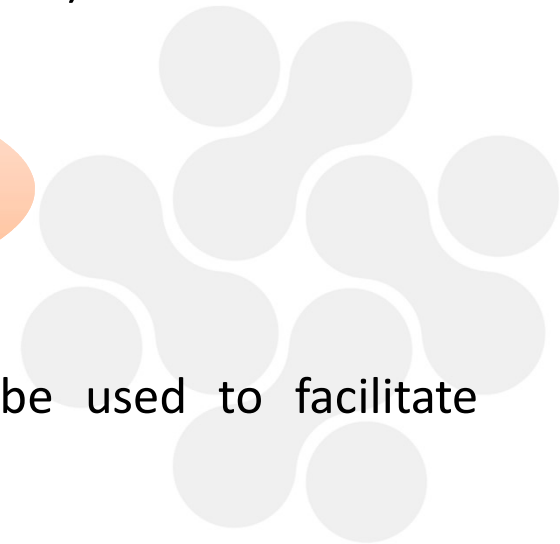
<https://nomaprojects.com/>

The role of microbes in fermented food properties

- Food fermentation starters can be selected based on their **metabolic traits**
- Metabolic traits rely on the **genomic information** (e.g. enzymes portfolio) and the **environmental pressure** (e.g. food ecosystem, process conditions)

Interactions between starters and raw material define the quality of fermentation

- Technological aids (fractionation, germination, enzymes) can be used to facilitate fermentation

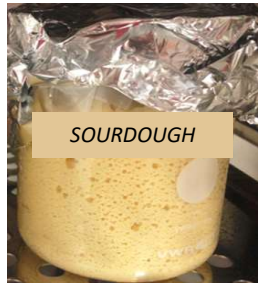


**Effects on chemical
composition and
nutritional properties of
plant-based food**



Sourdough fermentation of faba bean

Sourdough-type I fermentation of faba bean flour



Faba bean sourdough microbiota resembled kimchi

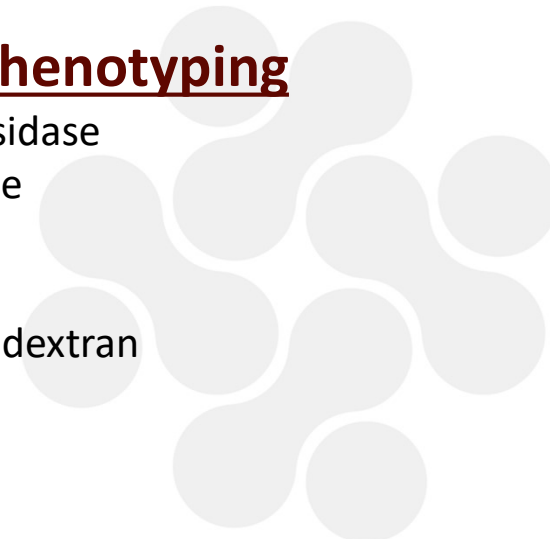
Pediococcus pentosaceus
Leuconostoc mesenteroides
Weissella koreensis



Traditional backslopping protocol enhanced nutritional attributes: increased total phenols and antioxidant activity, decreased ANFs

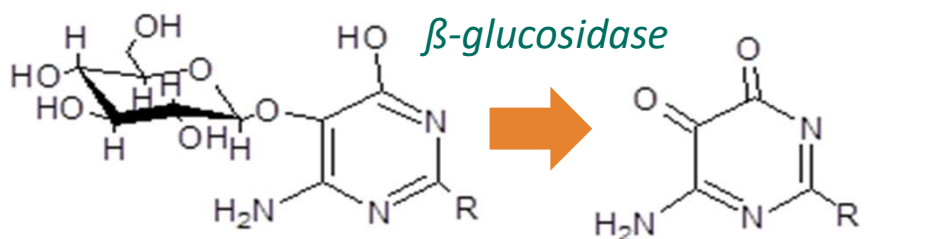
Strains phenotyping

Alfa-galactosidase
B-glucosidase
Peptidase
Phytase
Synthesis of dextran



Degradation of anti-nutrients in faba bean

Degradation of V and C (FAVISM)



Vicine: R=NH₂

Convicine: R=OH

Divicine: R=NH₂

Isouramil: R=OH

L. plantarum B24W

P. pentosaceus I02

- Fermentation with *L. plantarum* B24W decreased 90 and 95% of vicine and convicine.
- *Ex vivo* confirmation of low toxicity
- In mild acidification, vicine and convicine in breads were stable, but the toxic aglycones were not detected
- Fermentation conditions are important

OPEN

Degradation of vicine, convicine and their aglycones during fermentation of faba bean flour

Received: 07 March 2016
Accepted: 08 August 2016

Carlo Giuseppe Rizzello¹, Ilario Losito^{2,3}, Laura Facchini², Kati Katina⁴,
Francesco Palmisano^{2,3}, Marco Gobbetti¹ & Rossana Coda⁴

European Food Research and Technology (2019) 245:1507–1518
<https://doi.org/10.1007/s00217-019-03282-4>

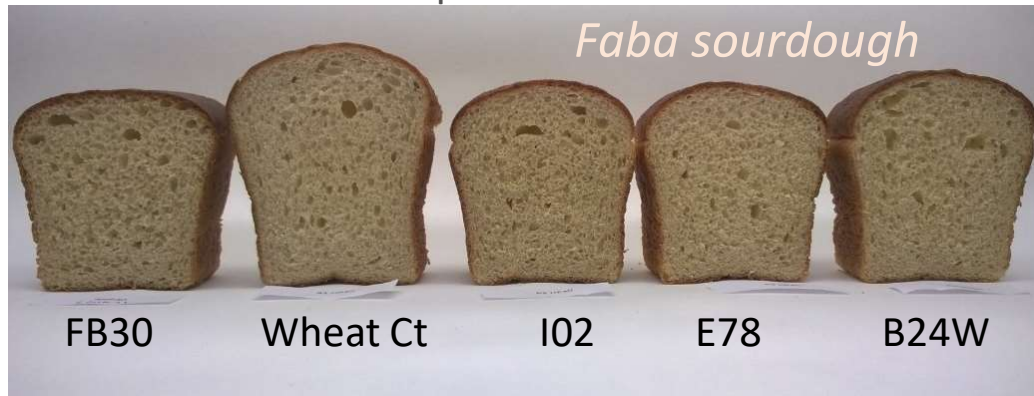
ORIGINAL PAPER

Possibilities of reducing amounts of vicine and convicine in faba bean suspensions and sourdoughs

Marjo Pulkkinen¹ · Rossana Coda^{1,2} · Anna-Maija Lampi¹ · Jutta Varis¹ · Kati Katina¹ · Vieno Piironen¹

Faba bean sourdough: wheat bread fortification

Faba bean flour 30% replacement



- *Pediococcus pentosaceus* I02
- *Lactiplantibacillus plantarum* B24W
- *Lactiplantibacillus plantarum* E78

Fermentation designed for mild acidification and proteolysis

- IVPD 64% in faba and wheat bread and 74% in faba bean fermented with I02
- GI: 100 vs 94% in faba and 81% in I02
- increase of nutritional indexes in composite bread
- Faba bean addition is challenging
- < volume and > hardness, better porosity and acceptable acidity
- absence of off-flavour



Contents lists available at [ScienceDirect](https://www.sciencedirect.com)

LWT - Food Science and Technology

journal homepage: www.elsevier.com/locate/lwt



Improvement of the protein quality of wheat bread through faba bean sourdough addition

Rossana Coda^a, Jutta Varis^a, Michela Verni^b, Carlo G. Rizzello^{b,*}, Kati Katina^a



Fortification of pasta with fermented faba bean

Compared to durum wheat pasta, pasta fortified with 30% faba bean fermented by *L. plantarum* B24W

- improved amino acids profile (EA index)
- higher protein digestibility (42 % 74%, **76%**)
- higher protein biological value (37, 61%, **64%**)

Fortification of cereal-based food with legumes is a strategy to increase their nutritional value

Innovative use of fermented ingredient

Durum wheat pasta



Faba bean pasta



Food &
Function

PAPER

[View Article Online](#)
[View Journal](#) | [View Issue](#)



Cite this: *Food Funct.*, 2017, **8**, 860

Influence of fermented faba bean flour on the nutritional, technological and sensory quality of fortified pasta†

Carlo G. Rizzello,^a Michela Verni,^a Hanna Koivula,^b Marco Montemurro,^a Laila Seppä,^{b,c} Marianna Kemell,^c Kati Katina,^b Rossana Coda^{a,b} and Marco Gobetti^a

Functional benefits: added value

L. brevis AM7 + *L. plantarum* C48



Formation of lunasin-like polypeptides:
9 bioactive peptides with *ex-vivo* anti cancer
and skin-barriers properties

Beans, chickpea, pea

Propionibacterium freudenreichii DSM
20271 + *L. brevis* ATCC 14869



Vitamin B12 content (ng/g, dw) **faba: 298,**
soy:407, lupine: 343 (daily requirement: 2.4 µg)

**Vitamin B12 is lacking in
plant based food!**

Rizzello et al. *Microb Cell Fact* (2015) 14:168
DOI 10.1186/s12934-015-0358-6



RESEARCH

Open Access



Italian legumes: effect of sourdough
fermentation on lunasin-like polypeptides

Carlo Giuseppe Rizzello¹, Blanca Hernández-Ledesma², Samuel Fernández-Tomé², José Antonio Curiel¹,
Daniela Pinto³, Barbara Marzani³, Rossana Coda⁴ and Marco Gobetti¹

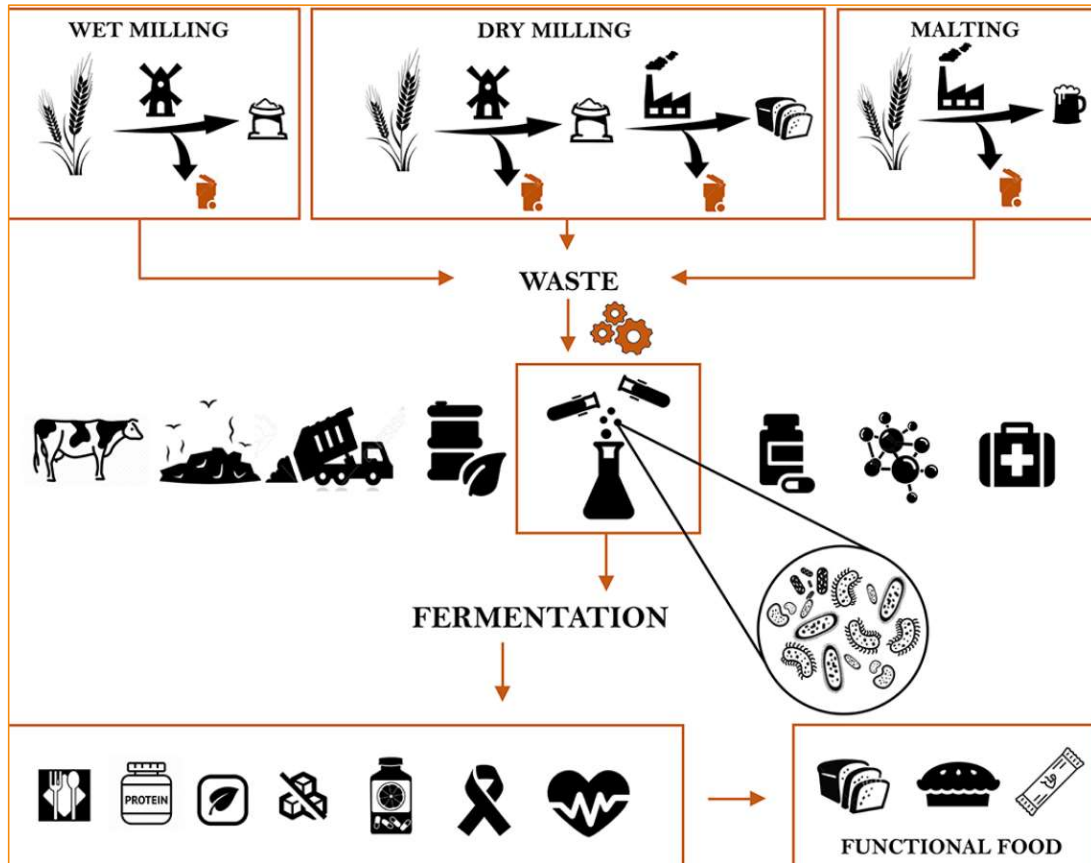


Fermentation of cereal, pseudo-cereal and legume materials with
Propionibacterium freudenreichii and *Levilactobacillus brevis* for vitamin
B12 fortification

Chong Xie^{a,b}, Rossana Coda^{a,b}, Bhawani Chamlagain^a, Minnamari Edelmann^a,
Pekka Varmanen^c, Vieno Piironen^c, Kati Katina^a

Fermentation technology for side-streams

CEREAL SIDE-STREAMS



Challenge: high fiber (lignin), poor structure, taste

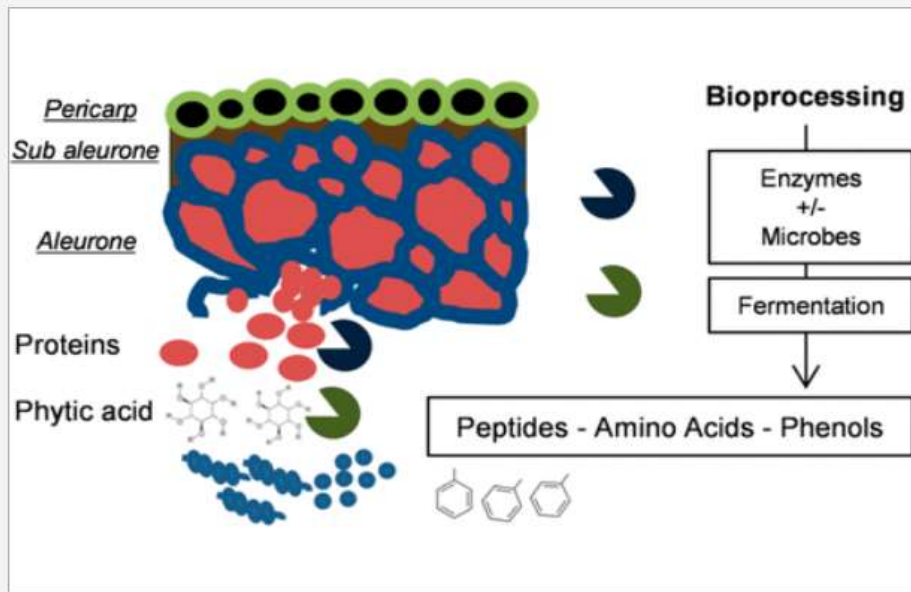
Functional ingredients via fermentation



Good nutritional quality
Sustainability

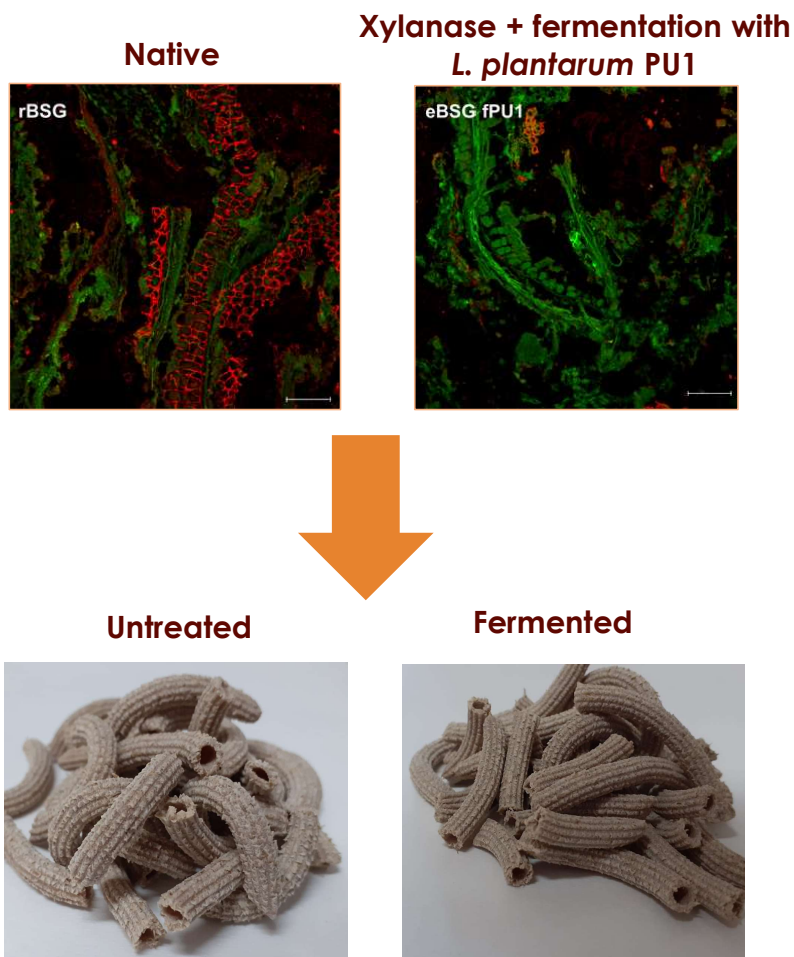
Enhancing bioaccessibility of nutrients: proteins from wheat bran

Fermentation with starters + cell wall degrading enzymes



- solubilized ca 50% of the entrapped proteins
- IVPD increased to 39% (vs 12% native)
- Increase of phytase activity and total phenols release
- Wheat breads with bioprocessed bran protein isolates were softer and delayed staling (Arte et al., 2019)

Enhancing bioaccessibility of nutrients: antioxidants from spent grains



- Release of phenolic compounds and bioactive peptides
- LAB metabolized phenolic acids and polymeric forms of proanthocyanidins into more active forms
- More homogeneous protein network in pasta
- Protective effects of digested pasta towards induced oxidative stress in Caco-2 cells cultures

Fermented sides-streams as “functional” food ingredients



Oilseed press-cake

Rapeseed protein concentrate



Wheat control RPC control 20% RPC CSB RPC DSB

- Improved free amino acid profile and decreased RFOs



Enhancing the utilization of rapeseed protein ingredients in bread making by tailored lactic acid fermentation

Yaqin Wang^a, Natalia Rosa-Sibakov^b, Minnamari Edelmann^a, Nesli Sozer^b, Kati Katina^a, Rossana Coda^{a,c,*}

Surplus bread



Wheat Ct. bread slurry 10% Fermented slurry

Antifungal peptides

800 mg/kg of GABA



Antifungal effect of bioprocessed surplus bread as ingredient for bread-making: Identification of active compounds and impact on shelf-life

L. Nionelli^{a,1}, Y. Wang^a, E. Pontonio^b, M. Immonen^a, C.G. Rizzello^b, H.N. Maina^a, K. Katina^a, R. Coda^{a,c,*}

Bran + surplus bread

Biosynthesis of γ -aminobutyric acid by lactic acid bacteria in surplus bread and its use in bread making

Michela Verni¹ | Anna Vekka² | Mikko Immonen² | Kati Katina² | Carlo Giuseppe Rizzello³ | Rossana Coda^{2,4}

**Effects on technological
quality: texture and flavor
improvement**



Fermentation: designing structure and flavor

Challenge

- Flavor is an important limiting factor of the acceptability and marketability of plant-based alternatives
- Flavor-active compounds are abundant in plant raw materials and might be challenging

Solutions

- Fermentation with LAB or LAB and yeasts is the most common approach in literature to improve quality of plant-proteins
- Exopolysaccharides synthesized *in situ* during fermentation



Exopolysaccharides synthesis in situ during fermentation

ADVANTAGES of EPS

Technological

- Higher specific volume, lower firmness and staling rate in bread
- Texture enhancers

Sensory properties

- Improved mouthfeel
- “Masking” off-taste

Nutritional quality

- Potential prebiotic effect



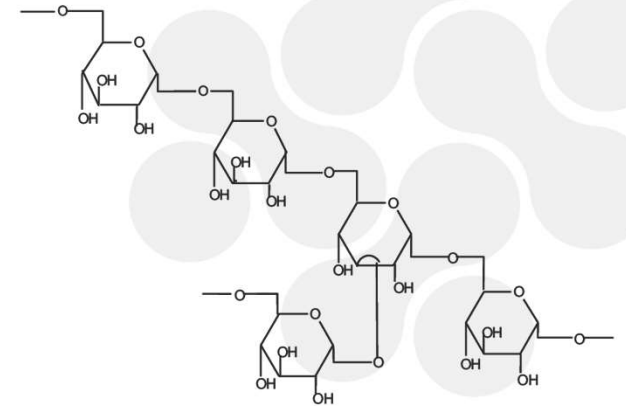
EPS have an important ecological and technological role in many fermented foods

Dextran benefits in plant-based food

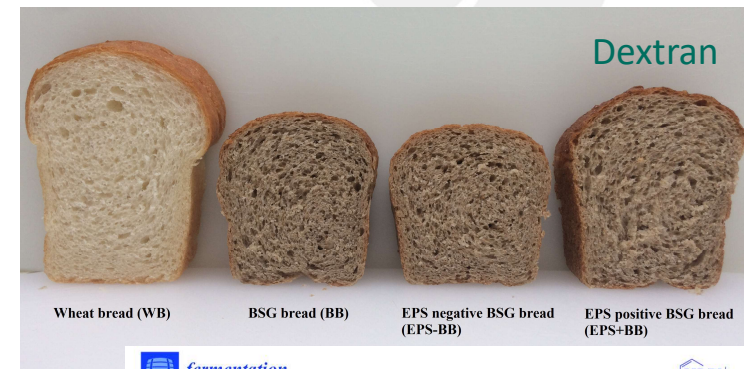
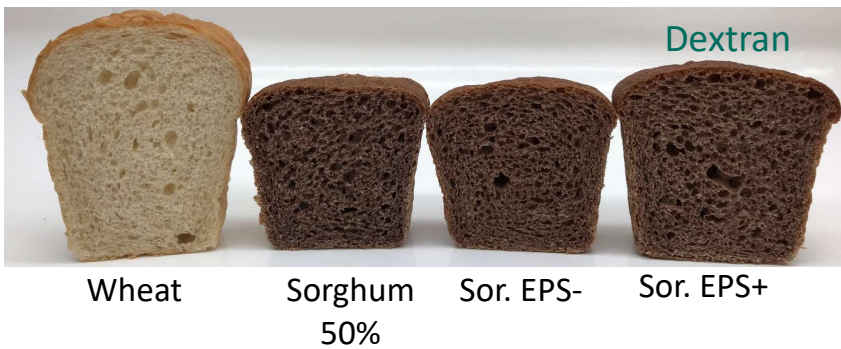
Hydrocolloid with water binding capacity which interact with the matrix structural components by modifying water distribution and stabilizing the solid/liquid interface

- Dextrans are synthesized from sucrose by dextransucrases produced by several species of LAB
- In presence of specific acceptor, also oligosaccharides can be formed

- Different strains have different ability to synthesize dextran
- Dextran properties depend on their molecular structure and interactions with the environment (e.g. linear dextran of high molecular weight is the best performer in baking)



Dextran benefits in plant-based food: composite bread



Article
Fermented Brewers' Spent Grain Containing Dextran and Oligosaccharides as Ingredient for Composite Wheat Bread and Its Impact on Gut Metabolome In Vitro

Prabin Koirala ^{1,*}, Alice Costantini ², Henry N. Maina ¹, Carlo Giuseppe Rizzello ³, Michela Verni ⁴,
Valentina De Beni ¹, Andrea Polo ², Kati Katina ¹, Raffaella Di Cagno ² and Rossana Coda ^{1,5}

- Improved volume and textural properties
- Alteration of taste/mouthfeel perception: low bitterness
- Increased nutritional potential (+fiber and +protein without negative repercussions)
- Prebiotic potential of dextran and oligosaccharides: higher FAA bioaccessibility and lower ammonia (*in vitro* digestion)

Tailoring structure and flavour with dextran: meat analogues

In situ synthesis of dextran by *W. confusa* in faba bean protein concentrate

- Avoid excessive acidity
- Mask bitterness

Modelling of fermentation parameters via central composite face design

Factors:

- Time (10-17-24h)
- Temperature 20°C 25°C 30°C
- Flour/water ratio (200, 300, 400)
- Inoculum 5-6-7 log cfu/g

Responses:

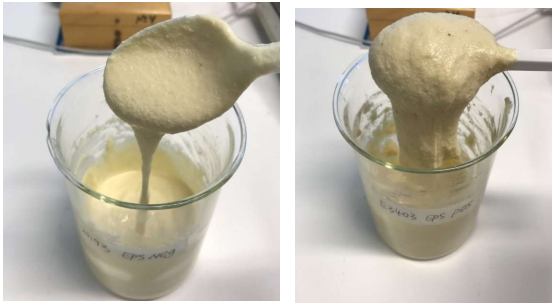
- Dextran
- Viscosity
- Acidity (pH, acids, TTA)



Optimal fermentation conditions

- Time: 11 h
- Temperature 23 °C
- Dough yield 380
- Inoculum ratio ca 7 cfu/g

DEXTRAN



Faba bean meat analogues: sensory study

Extrudates (faba bean protein concentrate + gluten)

Control
(no fermentation)

Fermented
(optimized dextran)



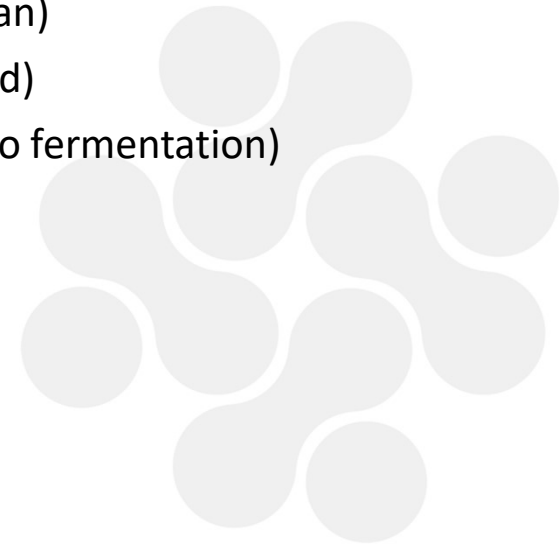
Extrudates:

- Control
- Fermented (no dextran)
- Fermented (optimized)
- Enzymatic dextran (no fermentation)

Descriptive sensory analysis

Dextran (optimized fermentation and enzymatic) improved the sensory properties of the extrudates

- decreased bitter and pea flavor, low sourness
- increased sweet and umami taste



EPS in fermented plant-based drinks and snacks

Fermentation can

- modify flavour attributes
- modify structure via synthesis of EPS (e.g. stronger gels, more efficient water binding)

Currently, dairy yogurt cultures and probiotics (*S. thermophilus*, *L. bulgaricus*, *Bifidobacterium*) have been quite successful

Fermentation process can be adapted to each plant matrix

e.g. lupine, quinoa, grains and legumes

Heps synthesised by
Lv. brevis AM7



EPS produced in oat bran and hemp protein concentrate



Manufacture and characterization of functional emmer beverages fermented by selected lactic acid bacteria

Rossana Coda, Carlo Giuseppe Rizzello*, Antonio Trani, Marco Gobetti
Dipartimento di Biologia e Chimica Agro-Forestale ed Ambientale, University of Bari, 70126 Bari, Italy

Different starters (L. plantarum, W. confusa and L. rhamnosus) conferred different properties to fermented emmer drinks

Fermentation: back to the future

Opportunities

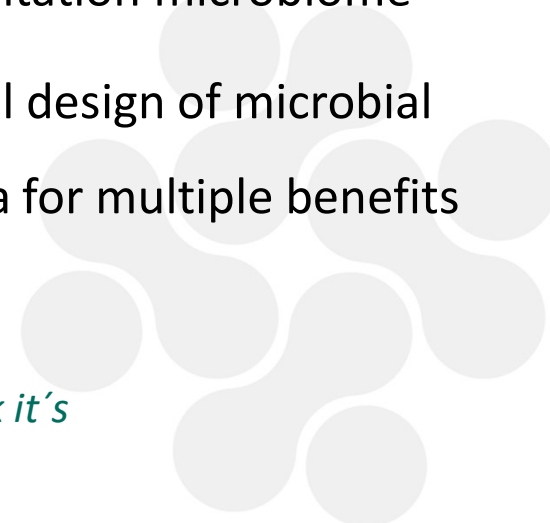
- Provide appealing plant-based alternatives
- Create new (plant-based) food
- Contribute to more sustainable diet



Our tools

- Increasing integrated knowledge of fermentation microbiome
- Rational design of microbial consortia for multiple benefits

*“I don’t think fermentation is undergoing a trend; I think it’s undergoing and understanding”
(D. Zilber, Noma, Copenhagen)*



ACKNOWLEDGEMENTS



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Grain Technology team

<https://www.helsinki.fi/en/researchgroups/grain-technology>

VTT Technical Research Center of Finland



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THANK YOU !

Credits

Hand holding kombucha scoby tea mushroom By exclusive-design (Freepik)

<https://www.littleecofootprints.com/2014/11/how-to-make-water-kefir-recipe.html>

[Image by topntp26](https://www.freepik.com/free-photo/mix-beans_1129797.htm#query=legumes&position=1&from_view=search&track=sph) on Freepik

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<https://www.daringgourmet.com/easy-hOMEMADE-greek-yogurt/>

