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

Fermented foods for health- what are the evidences?

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Confédération suisse
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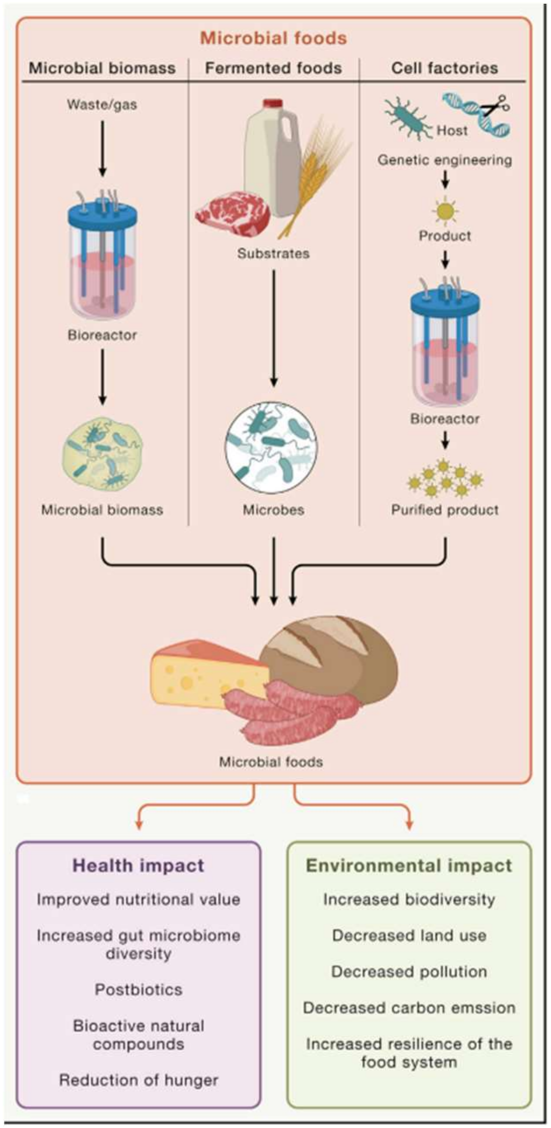
Confederaziun svizra

Microbioal foods

All types of microbial foods have the potential to positively impact human and planetary health.



Fermented foods— traditionally produced from grains, seeds, nuts, legumes, fruit, vegetables, roots, milk, meat, and fish through the controlled transformation by microorganisms.

Microbial biomass --- produced from a defined sugar source such as glucose but also possibly from different waste streams or atmospheric gases, followed by the harvesting of microbial biomass and its processing into palatable and safe foods.

Cell factories --- defined microorganisms that are selected and (genetically) optimized to produce certain compounds. These compounds are usually purified and used for various applications—such as enzymes for baking.

Jahn et al. (2023) Cell

Fermented foods and beverages

"Foods made through desired microbial growth and enzymatic conversions of food components"

Marco et al., 2021, The International Scientific Association for Probiotics and Prebiotics (ISAPP) consensus statement on fermented foods

Fermented foods

~8000 BC
~1/3 of the world’s food consumption

>3500 fermended food products

Milk, cereals, legumes, vegetables, the, meat and fish

(Xiang et al., 2019. *Food Science and Human Wellness*)

Fermented foods

Food stability	Food saftey	Sensory characteristics	Perceived health-benefits

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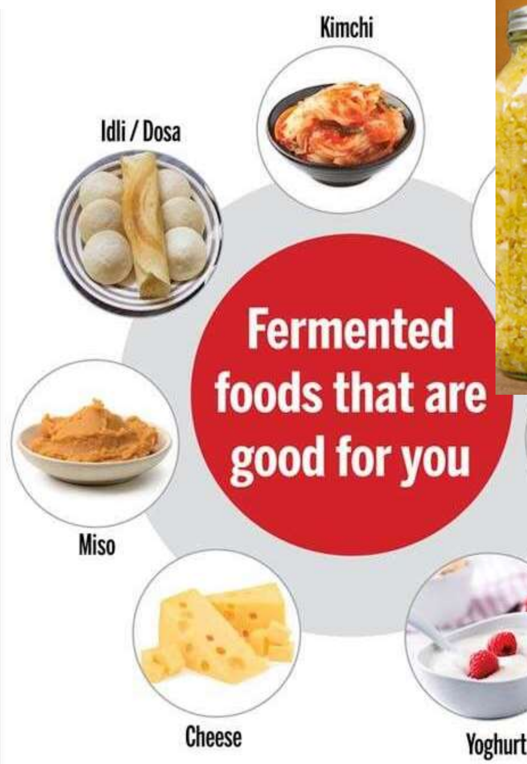
Perceived health-benefits of fermented foods



Recommendations & claims?

- Despite the many ***potential*** benefits of fermented foods, their recommended consumption has not been widely translated to global inclusion in food guides.
- One exception in Asia is the Indian food guide, which stresses the consumption of fermented foods for the public and specifically, for **pregnant women** ("***eat more whole grains, sprouted grams and fermented foods***"
- Only one claim for beneficial microbes has been approved in the European Union (EU) (yoghurt improves lactose tolerance)

Description and microbial content of common fermented foods

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Name	Description	Region of Origin	Source of Microorganisms	Microorganisms Identified in Final Product *
Kefir	Fermented milk beverage	Caucasus	Starter culture	*Lactobacillus kefiri, Lactobacillus paracasei, Lactobacillus parabuchneri, Lactobacillus casei, Lactobacillus lactis, Lactococcus lactis, Acetobacter lovaniensis, Kluyveromyces Lactis, Saccharomyces cerevisiae*
Kombucha	Fermented tea beverage	China	Starter culture	*Komagataeibacter xylinus, Saccharomyces cerevisiae, Zygosaccharomyces bailii. Brettanomyces bruxellensis, Acetobacter pasteurianus, Acetobacter aceti, Saccharomyces cerevisiae, Zygosaccharomyces bailii, Brettanomyces bruxellensis, Acetobacter xylinum, Zygosaccharomyces* spp.*, Acetobacter, Gluconacetobacter*
Sauerkraut	Fermented cabbage	China	Spontaneous	*Lactobacillus sakei, L. plantarum, Candidatus accumulibacter phosphatis, Thermatoga* spp.*, Pseudomonas rhizosphaerae, L. hokkaidonensis, L. rhamnosus, Leuconostoc carnosum, Clostridium saccharobutyrilicum, Rahnella aquatillis, Citrobacter freundii, Enterobacter cloacae, Bifidobacterium dentium, Enterococcus faecalis, Lactobacillus casei, Lactobacillus delbrueckii, Staphylococcus epidermidis, Lactobacillus curvatus, Lactobacillus brevis, Weissella confusa, Lactococcus lactis, Enterobacteriaceae, Leuconostoc* spp.*, Yarrowia brassicae*
Tempeh	Fermented boiled and dehulled soybeans	Indonesia	Starter culture (*Rhizopus oligoporus*)	*Enterococcus faecium, Rhizopus oryzae, Rhizopus oligoporus, Mucor indicus, Mucor circinelloides, Geotrichum candidum, Aureobasidium pullulans, Alternaria alternata, Cladosporium oxysporum, Trichosporon beigelii, Clavispora lusitaniae, Candida maltosa, Candida intermedia, Yarrowia lipolytica, Lodderomyces elongisporus, Rhodotorula mucilaginosa, Candida sake, Hansenula fabiani, Candida tropicalis, Candida parapsilosis, Pichia membranefaciens, Rhodotorula rubra, Candida rugosa, Candida curvata, Hansenula anomola*
Natto	Fermented soybean	Japan	Starter culture (*Bacillus subtilis* natto)	Data not available
Miso	Fermented soybean paste	Japan	Starter culture (*Aspergillus oryzae*)	*Bacillus subtilis, Bacillus amyloliquefaciens, Staphylococcus gallinarum, Staphylococcus kloosii, Lactococcus* sp. GM005
Kimchi	Fermented vegetable dish	Korea	Spontaneous, Addedcommercially	*Leuconostoc gasicomitatum, Leuconostoc gelidum, Leuconostoc mesenteroides, Weissella koreensis, Weissella confuse, Lactobacillus sakei, Lactobacillus plantarum, Lactobacillus curvatus, Trichosporon domesticum, Trichosporon loubieri, Saccharomyces unisporus, Pichia kluyveri*
Sourdough bread	Bread made from longer ferment	Middle East and Europe	Spontaneous or backslopping	Data not available

Dimidi et al. (2019)

Perceived health-benefits of fermented foods

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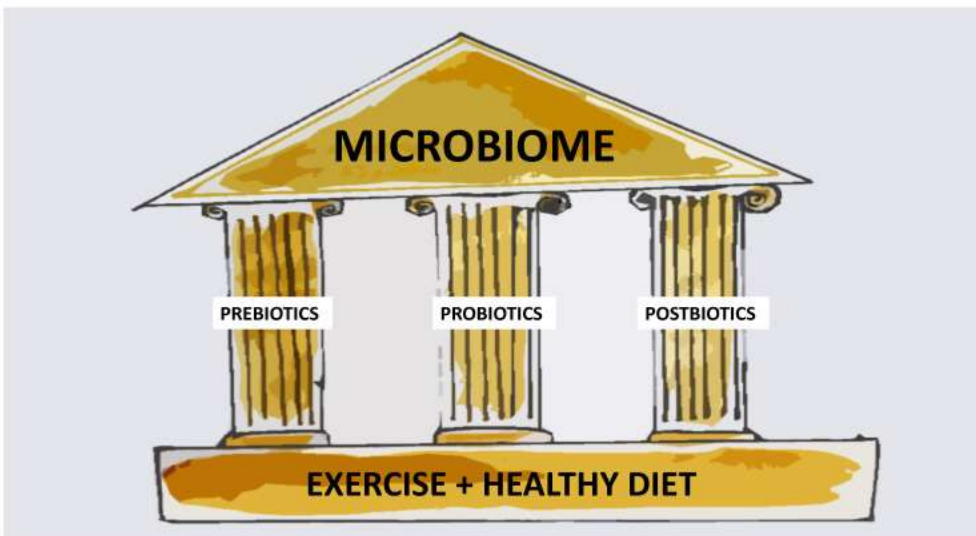
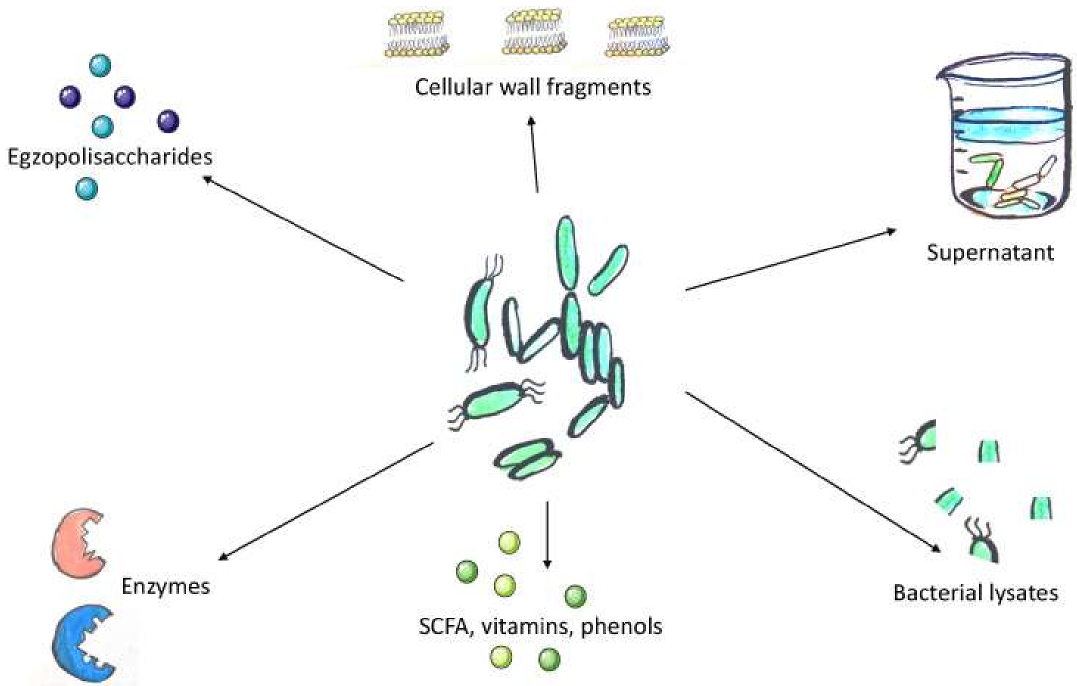
- Little is known
- Observational studies, few intervention trials
- Yoghurt



Żółkiewicz et al. (2020) Nutrients

Postbiotics



Żółkiewicz et al. (2020) Nutrients

Postbiotics- Preparation of inanimate microorganisms and/or their components that confers a health benefit on the host.

Effective postbiotics must contain ***inactivated microbial cells*** or ***cell components***, with or without ***metabolites***, that contribute to observed ***health benefits***

Salminen et al. (2021) Nat Rev Gastroenterol Hepatol.

Products of gut microbial fermentation of **carbohydrates**, **protein** and **dietary polyphenols**

Mediators of health effects?

Krautkrame et al. (2021) Nature Reviews

Metabolite	Pathway	Genera or species
Acetate	Pyruvate decarboxylation to acetyl-CoA	*Akkermansia muciniphila*, *Bacteroides* spp., *Bifidobacterium* spp., *Prevotella* spp., *Ruminococcus* spp.[21,26–28]
	Wood–Ljungdahl pathway	*Blautia hydrogenotropphica*, *Clostridium* spp., *Streptococcus* spp.[21,26–28]
Propionate	Acrylate pathway	*Coprococcus catus*, *Eubacterium hallii*, *Megasphaera elsdenii*, *Veillonella* spp.[21,26–28]
	Succinate pathway	*Bacteroides* spp., *Dialister* spp., *Phascolarctobacterium succinatutens*, *Veillonella* spp.[21,26–28]
	Propanediol pathway	*Roseburia inulinivorans*, *Ruminococcus obeum*, *Salmonella enterica*[21,26–28]
Butyrate	Classical pathway via butyrate kinase	*Coprococcus comes*, *Coprococcus eutactus*[21,26–28]
	Alternate pathway using exogenous acetate	*Anaerostipes* spp., *C. catus*, *E. hallii*, *Eubacterium rectale*, *Faecalibacteerium prausnitzii*, *Roseburia* spp.[21,27,28,35]
Short-chain fatty acids and branched-chain fatty acids	Amino acid fermentation through various dissimilatory proteolytic reactions	*Acidaminococcus* spp., *Acidaminobacter* spp., *Campylobacter* spp., Clostridia spp., *Eubacterium* spp., *Fusobacterium* spp., *Peptostreptococcus* spp.[21,26–28,44]
'Kynurenines' (kynurenine and its derivatives)	Various bacterial enzymes homologous to mammalian enzymes of the kynurenine pathway	*Lactobacillus* spp., *Pseudomonas aeruginosa*[89], *Pseudomonas fluorescens*[85] Putative: *Pseudomonas* spp., *Xanthomonas* spp., *Burkholderia* spp., *Stenotrophomonas* spp., *Shewanella* spp., *Bacillus* spp., members of Rhodobacteraceae, Micrococcaceae and Halomonadaceae families[85]
Indole	Hydrolytic β-elimination of tryptophan to indole (tryptophanase)	*Achromobacter liquefaciens*, *Bacteroides ovatus*, *Bacteroides thetaiotamicron*, *Escherichia coli*, *Paracolobactrum coliforme*, *Proteus vulgaris*[11,89]
Indole derivatives	Multiple	*Bacteroides* spp., *Clostridium* spp. (*Clostridium sporogenes*, *Clostridium cadaveris*, *Clostridium bartlettii*), *E. coli*, *Lactobacillus* spp., *E. halli*, *Parabacteroides distasonis*, *Peptostreptococcus* spp. (*Peptostreptococcus anaerobius*)[4,11,88,167]
Tryptamine	Decarboxylation of tryptophan	*C. sporogenes*, *Ruminococcus gnavus*[168]
Serotonin	Induction of host synthesis[a]	Indigenous spore-forming bacteria, dominated by *Clostridium* spp.[59] and *Turicibacter* spp.[103]
Histamine	Decarboxylation of histidine (histidine decarboxylase (HDC))	*E. coli*, *Morganella morganii*, *Lactobacillus vaginalis*[105] Putative: *Fusobacterium* spp.[101]
Imidazole propionate (ImP)	Non-oxidative deamination of histidine to urocanate followed by reduction of urocanate to ImP by urocanate reductase (UrdA)	*Aerococcus urinae*, *Adlercreutziae equolifaciens*, *Anaerococcus prevotii*, *Brevibacillus laterosporus*, *Eggerthella lenta*, *Lactobacillus paraplantarum*, *Shewanella oneidensis*, *Streptococcus mutans*[106]
Dopamine	Decarboxylation of levodopa (L-DOPA) via tyrosine decarboxylase (TyrDC)	*Enterococcus* spp. (*Enterococcus faecalis*, *Enterococcus faecium*, 77 human isolates of *Enterococcus* spp.), *Lactobacillus brevis*, *Helicobacter pylori*[107,108]
p-Cresol	From tyrosine or phenylalanine via two pathways: direct cleavage of the Cα–Cβ bond in tyrosine to yield *p*-cresol by tyrosine lyase; and a series of reactions involving transamination, deamination and decarboxylation of tyrosine or phenylalanine via formation of the cresol precursor phenylacetic acid[4,110]	Assay proven: *Blautia hydrogenotrophica*, *Clostridioides difficile*, *Olsenella uli*, *Romboutsia lituseburensis*[109] Predicted: *Acidaminococcus fermentans*, *Anaerococcus vaginalis*, *Anaerostipes* spp., *Bacteroides* spp., *Bifidobacterium infantis*, *Blautia* spp., *Citrobacter koseri*, *Clostridium* spp., *Eubacterium siraeum*, *Fusobacterium* spp., *Klebsiella pneumoniae*, *Lactobacillus* spp., *M. elsdenii*, *Roseburia* spp., *Ruminococcus* spp., *Veillonella parvula*[109]
Phenylacetylglutamine (PAGln) and phenylacetylglycine (PAGly)	Synthesized during host hepatic phase II metabolism via conjugation of either glutamine or glycine to phenylacetic acid, an intermediate in microbial fermentation of phenylalanine[4,117]	Conjugation of phenylacetic acid to glutamine or glycine occurs in the host liver; see *p*-cresol (above) for information about its precursor, phenylacetic acid

Health-benefits of fermented foods - yoghurt

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Table 2 **Summary of studies**

Area studied	Total no. of studies	Study types	No. of positive-quality studies	No. of neutral-quality studies	No. of negative-quality studies	Fermented products studied	Comparators	No. of studies with favorable outcome	No. of studies with no significant effect	No. of studies with unfavorable outcome
Gastrointestinal health and disease	26	RCT=16 RCOT=8 CS=1 …	19	6	1	Yogurt, fermented milk, fermented milk drinks, pasteurized yogurt, probiotic yogurt, kefir	Dahi, ultra-heated yogurt, nonfermented dairy product, milk, pasteurized yogurt, acidified …	20	6	0
								16	11	1
								19	3	0
Cancer	17	RCT=1 CC=5 CH=11	1	16	0	Yogurt, fermented milk	No yogurt	9	5	3
Diabetes	9	RCT=1 RCOT=2 CS=1 CH=5	2	5	1	Yogurt, probiotic in fermented milk	Sweetened yogurt, skim milk, orange juice, no supplementation, nonfermented milk	7	1	0
Bone health	7	RCT=1 CS=3 CH=3	1	6	0	Yogurt, laban	No yogurt	5	2	0

Abbreviations: CC, case-control (study); CH, cohort (study); CS, cross-sectional (study); NRCT, nonrandomized controlled trial; RCOT, randomized crossover trial; RCT, randomized controlled trial.

CONCLUSIONS
Consistent associations exist between **fermented milk consumption** and **reduced risk of breast** and **colorectal cancer, T2D, improved weight maintenance, and improved cardiovascular, bone**, and **GI health**.

Associations between yoghurt and reduced risk of:

- Breast and coloncancer
- Type 2 diabetes
- Improved weight management
- Improved inflammatory markers, cardiovascular, bone, and GI health

Savaiano, 2020, *Nutrition Reviews*
SaeidiFard, 2019, *Clinical Nutrition ESPEN*
Baruah, 2022, *Journal of Applied Microbiology*

Savaiano and Robert W. Hutkins (2020) Nutrition Reviews

Effects of Kefir on gasatrointestinal health (intervention studies)

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Study	Study Design	Study Population	Intervention	Control	Duration	Gut Microbiota	Other Findings
Ino et al., 2015 [58]	Non-randomised, cross-over controlled intervention	Constipation, *n* = 11	6 g/day lyophilized kefir. 3 g/day lactose in last 40 day of treatment period	6 g/day powdered milk (baby-formula)	3 months	Not reported	Only three of the 11 participants experienced "more frequent BM without laxative use". Summary descriptive statistics not shown.
Maki et al., 2018 [59]	Non-randomised, cross-over intervention study	Constipation (hospitalised), *n* = 42	6 g/day of lyophilized kefir	6 g/day powdered milk	12 weeks each period	Not reported	No difference in laxative use between kefir and control groups (7.5 times/3 months *vs* 8.1 times/3 months; $p = 0.35$). No difference in number of people who did not require laxatives. No difference in stool consistency/volume.
Turan et al., 2014 [60]	Non-randomised, uncontrolled intervention study	Functional constipation, *n* = 20	500 mL/day kefir	-	4 weeks	Not reported	Increased stool frequency at follow-up compared to baseline (median 2 BM/week *vs* 5 BM/week; $p < 0.001$). Fewer people with hard stools at follow-up compared to baseline (12/20 *vs* 6/20; $p = 0.014$). Improvement in bowel satisfaction scores ($p = 0.001$). Reduction in gut transit time in participants with slow gut transit time at baseline ($p = 0.013$). No change in straining or laxative use. No major adverse events.
Bekar et al., 2011 [61]	Double-blind RCT	Dyspepsia and *H. pylori* infection, *n* = 85	500 mL/day kefir	250 mL/day milk	2 weeks	Not reported	Higher *H. pylori* eradication rate in kefir *vs* control (78% *vs* 50%; $p = 0.026$). Lower occurrence of diarrhoea (relative risk RR = 0.48; $p = 0.001$), headache (RR=0.17; $p = 0.008$), nausea (RR = 0.47; $p = 0.029$), and abdominal pain (RR = 0.38; $p < 0.001$).
Hertzler et al., 2003 [57]	Cross-over RCT	Lactose malabsorption, *n* = 15	1) 508 mL/day plain kefir 2) 519 g/day raspberry flavoured kefir (equivalent to 20 g lactose)	3) 407 mL/day low fat cow's milk 4) 378 g/day plain yoghurt (equivalent to 20 g lactose)	Acute 5-day study, each treatment followed by an 8 h breath H_2 test	Not reported	Higher breath H_2 AUC in milk compared with plain kefir ($p = 0.001$), plain yogurt ($p = 0.001$), or flavoured yogurt ($p = 0.005$). Higher breath hydrogen AUC in flavoured kefir compared to plain yogurt ($p = 0.043$) or plain kefir ($p = 0.008$). No difference in breath hydrogen AUC between flavoured kefir and milk ($p = 0.425$) or flavoured yogurt ($p = 0.331$). No difference in flatulence severity and frequency, diarrhoea and abdominal pain.

Dimidi et al. (2019) Nutrients

Effects of sauerkraut, soy products and kimchi in gastrointestinal health and disease (interventions)

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Study	Fermented Food	Study Design	Study Population	Intervention	Control	Duration	Gut Microbiota	Other Findings
Fujisawa et al., 2006 [104]	Natto/miso	Uncontrolled open-label study	Healthy, $n = 8$	200 mL miso soup containing 50 g Natto per day	-	2 weeks	Following natto-containing soup: Higher *Bifidobacteria* and Bacilli, Lower Enterobacteriaceae, Higher acetic acid and propionic acid (all $p < 0.05$)	-
Kil et al, 2004 [105]	Kimchi	Non-randomised trial	*H. pylori* infection, $n = 6$	300 g of kimchi	60 g of kimchi	4 weeks	Increased *Lactobacillus* (p = 0.0003) and *Leuconostoc* ($p = 0.0004$)	*H. pylori* not eradicated in any participants ($p = 0.944$). Lower stool pH ($p = 0.0001$), β-glucuronidase ($p = 0.0065$) and β-glucosidase ($p = 0.0001$) activity
Mitsui et al., 2006 [106]	Natto	Controlled trial	Infrequent bowel movements, n = unknown	50 g/day Natto (*Bacillus subtilis* K-2, 3.8×10^9 CFU)	50 g/day boiled soybeans	2 weeks	Following Natto compared to control: Increased ratio of stool *Bifidobacteria*:total bacteria	Following Natto compared to control: Higher number of bowel movements. Higher number of days with bowel movements Higher stool quantity
Nielsen et al., 2018 [18]	Sauerkraut	Randomised, double-blind controlled trial	Irritable bowel syndrome, $n = 58$	75 g/day unpasteurised sauerkraut containing LAB	75 g/day pasteurised sauerkraut	6 weeks	No significant effects of either unpasteurised or pasteurised sauerkraut on microbiota composition	Lower IBS-SSS score following both unpasteurised ($p = 0.003$) and pasteurised ($p = 0.04$) sauerkraut No difference in change in IBS-SSS between groups

LAB, lactic acid bacteria; IBS-SSS Irritable Bowel Syndrome Severity Scoring System.

Dimidi et al. (2019) Nutrients

Effects of sourdough bread in gastrointestinal health and disease

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Study	Study Design	Study Population	Intervention	Control	Duration	Other Findings
Korem et al., 2017 [170]	Randomised crossover trial	Healthy, $n = 20$	145 g sourdough wholegrain wheat bread	110 g white wheat bread	1 week	Significant interpersonal variability in glycaemic responses Baseline microbiome could predict type of bread that results in lower glycaemic response in each participant
Polese et al., 2018 [171]	Double-blind, cross-over RCT	Healthy, $n = 17$	2 sourdough croissants	2 brewer's yeast croissants	Single study day	11% decrease in gastric volume AUC 3 h post-consumption ($p = 0.02$) 30% lower hydrogen production during the 4 h post-consumption ($p = 0.03$) Milder abdominal discomfort ($p = 0.002$), bloating ($p = 0.001$) and nausea ($p = 0.004$)
Raninen et al., 2017 [172]	Randomised cross-over trial	Minor gastrointestinal symptoms, $n = 8$	6–10 slices/day of sourdough wholegrain rye bread	6–10 slices/day of wheat bread enriched with bioprocessed (fermented) rye bran	4 weeks	Significant difference in exhaled breath volatile organic compound profile between groups in fasting state ($p = 0.026$). No difference was shown at 30, 60 and 120 min after a standardised meal
Laatikainen et al., 2016 [11]	Randomised, double-blinded, cross-over trial	Irritable bowel syndrome, $n = 87$	7–8 slices/day low FODMAP sourdough rye bread	7–8 slices/day traditional sourdough rye bread	4 weeks	Lower breath H_2 in low FODMAP rye bread group compared to traditional rye bread (median AUC 53 ppm *vs* 73; $p = 0.01$) Milder flatulence ($p = 0.04$), abdominal cramps ($p = 0.01$), rumbling ($p = 0.001$) and total symptoms ($p = 0.02$) No difference in IBS-SSS ($p = 0.40$). Lower weight in low FODMAP rye bread compared to traditional rye bread (mean difference −0.5 kg, 95% CI −0.9–0.0; $p = 0.03$)
Laatikainen et al., 2017 [164]	Double-blinded RCT	Irritable bowel syndrome with subjective wheat intolerance, $n = 26$	6 slices/day sourdough wheat bread (fermentation time > 12 h)	6 slices/day yeast-fermented wheat bread (fermentation time approx. 2 h)	7 days	No difference in gastrointestinal symptoms or markers of low-grade inflammation. Worse symptoms of tiredness ($p = 0.01$), joint symptoms ($p = 0.03$) and "decreased alertness" ($p = 0.003$)
Di Cagno et al., 2010 [173]	Non-randomised, uncontrolled study	Coeliac disease, $n = 8$	200 g/day baked products with sourdough wheat flour (10 g hydrolysed gluten)	None	60 days	All patients had normal IgG and IgA-AGA and IgA-tTG antibodies values at the end of the intervention period
Mandile et al., 2017 [174]	RCT	Coeliac disease, $n = 20$	Sourdough wheat bread (fermented with lactobacilli and yeast)	Traditional wheat bread	3 days	No increase in INF-γ secretion Mobilisation of INF-γ secreting cells in the blood following traditional wheat bread

IBS-SSS Irritable Bowel Syndrome Severity Scoring System; RCT, randomized controlled trial.

Dimidi et al. (2019) Nutrients

Fermented foods and gastrointestinal health

In summary:

- Very limited evidence on the effectiveness of most fermented foods in gastrointestinal health
- Majority of studies being of low quality
- Kefir most studied
  - Lactose malabsorption
  - H Pylori eradication

Metabolic effects of fermeted vs non-fermented rye crisp bread

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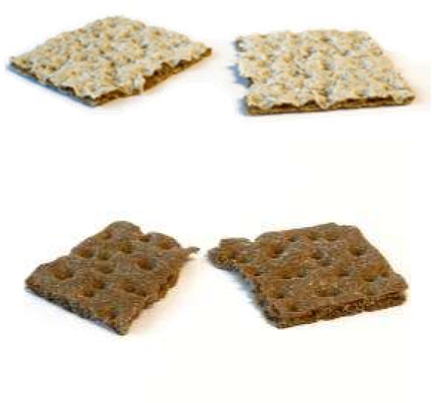

PLOS | ONE

RESEARCH ARTICLE

Effects of Unfermented and Fermented Whole Grain Rye Crisp Breads Served as Part of a Standardized Breakfast, on Appetite and Postprandial Glucose and Insulin Responses: A Randomized Cross-over Trial

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AIMS:

- Difference between fermented and unfermented bread?
  - Appetite
  - GLycemia

Unfermented whole grain rye crisp bread

Fermented whole grain rye crisp bread

Refined wheat crisp bread

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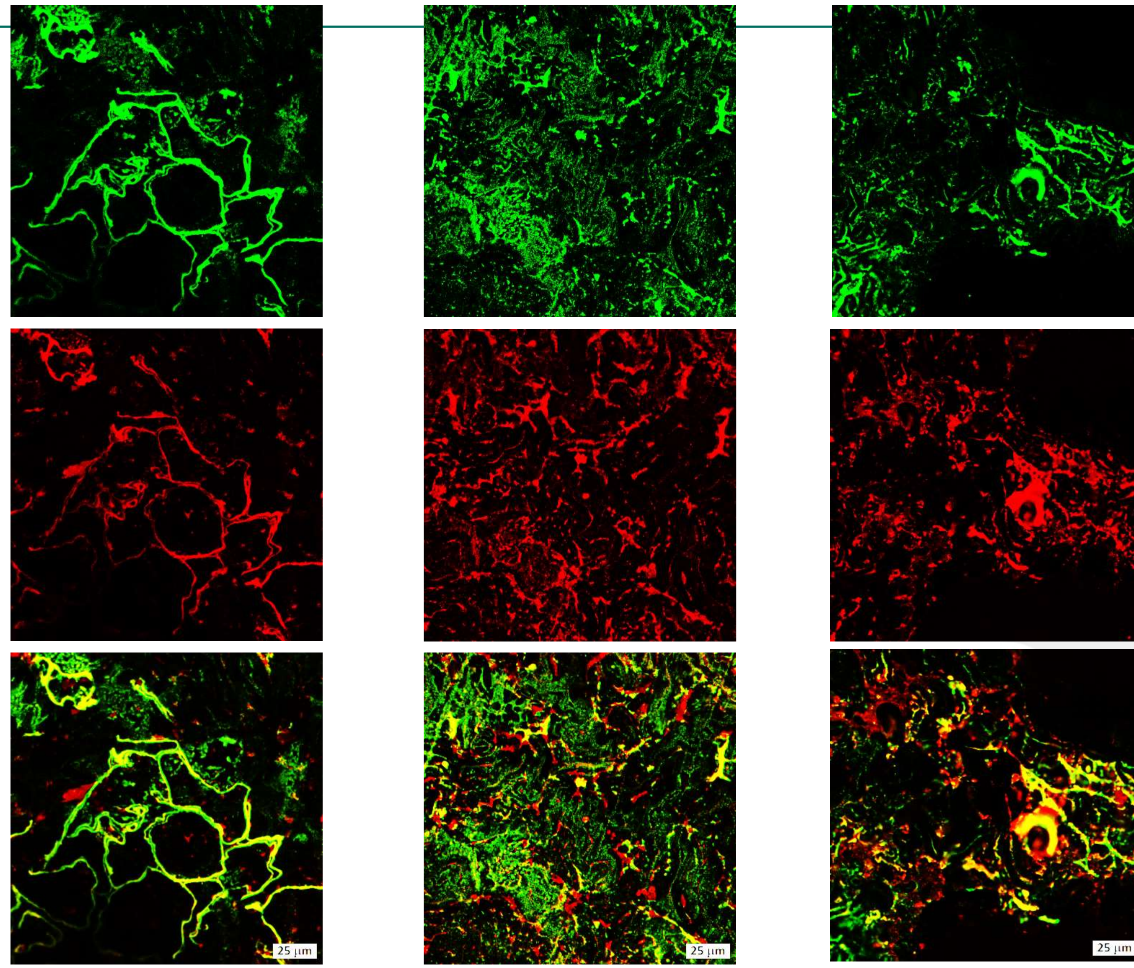
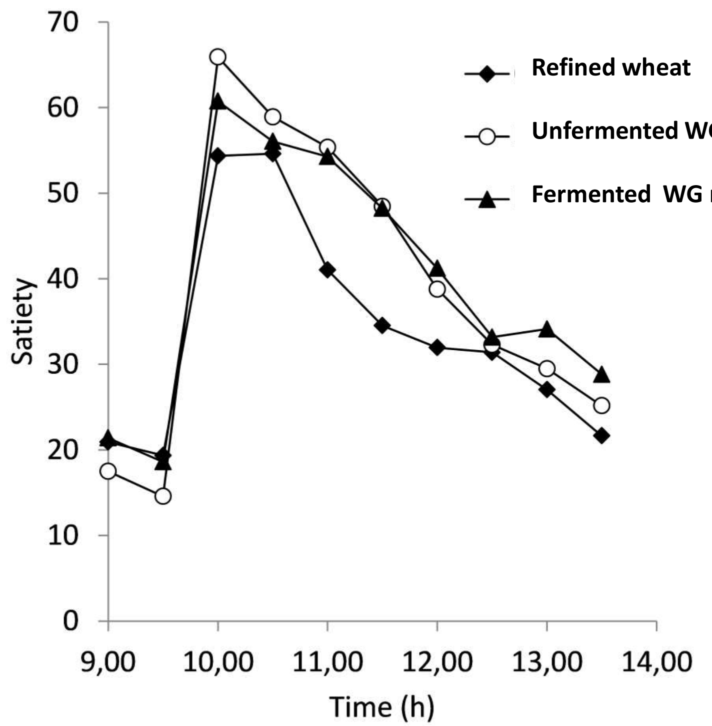
1-3,1-4-β-D-glucans

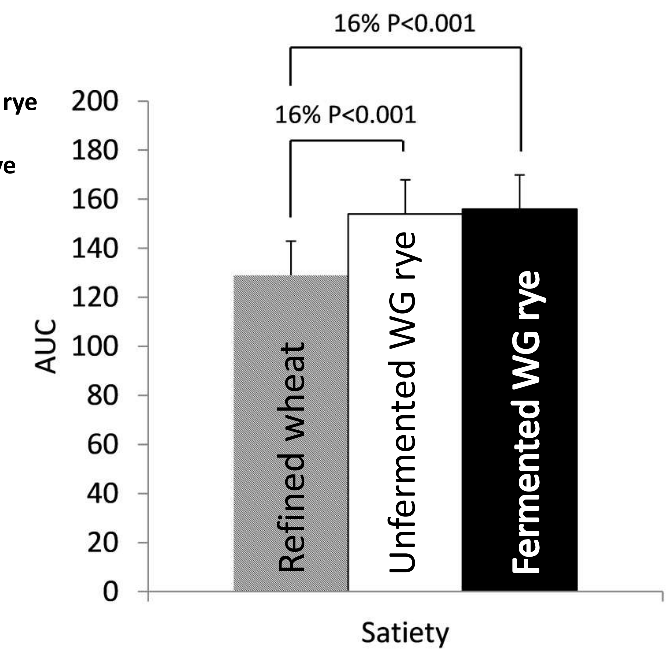
Arabinoxylans LM11 antibody



José Luis Vázquez Gutiérrez and Maud Langton

Results- Satiety

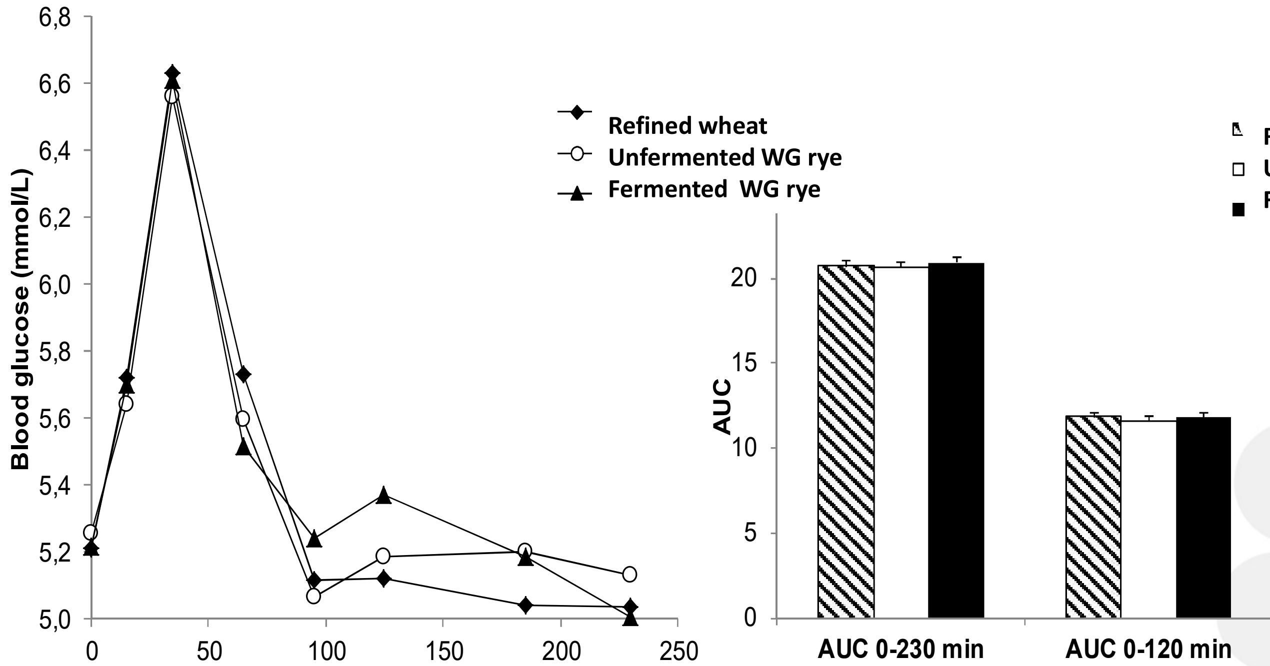




Differences between White- Husman & White- Delikatess (P<0.001)

D. Johansson, I Lee, U Risérus, M Langton, R Landberg (2015) PloS One

Results- Glucose



No significant difference in glucose profiles

D. Johansson, I Lee, U Risérus, M Langton, R Landberg (2015) PloS One

Lower insulin secretion after rye- The ”rye factor”-effect

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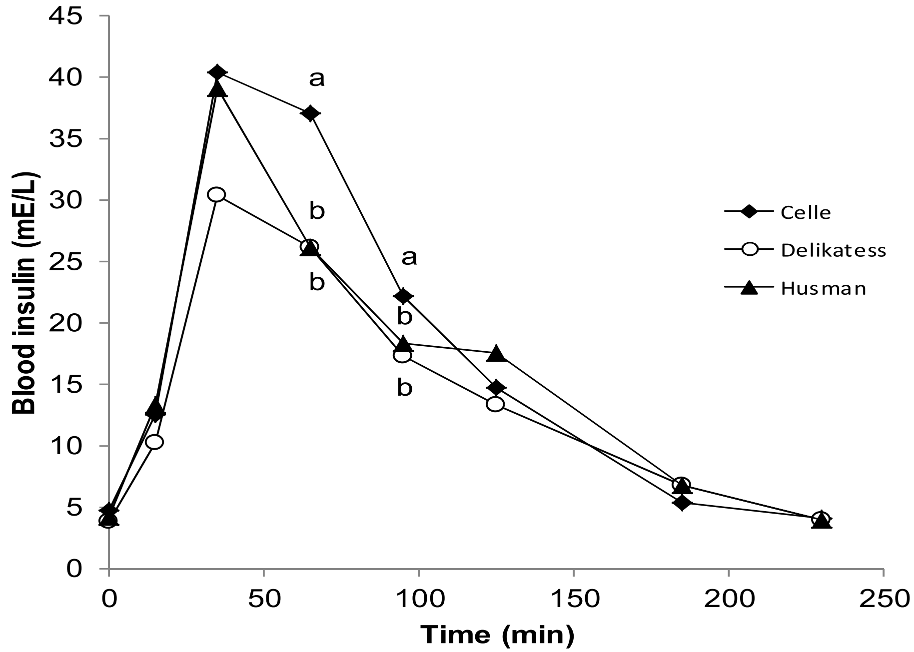
Plasma insulin



Significant differences at certain time points (treatment x time P<0.05)

Johansson et al. (2015) PloS One

Follow-up study ”Crisp II”

AIMs:

- Confirm effects of uRCB on appetite and postprandial insulin responses
- Evaluate the role **of <u>sourdough fermented</u>** rye crisp bread on appetite and metabolic effects

British Journal of Nutrition (2017), **118**, 686–697 doi:10.1017/S000711451700263X

Impact of sourdough fermentation on appetite and postprandial metabolic responses – a randomised cross-over trial with whole grain rye crispbread

Galia Zamaratskaia[1]*† Daniel P. Johansson[1]†, Matheus Antunes Junqueira[1], Linda Deissler[1]‡, Maud Langton[1], Per M. Hellström[2] and Rikard Landberg[1,3]§

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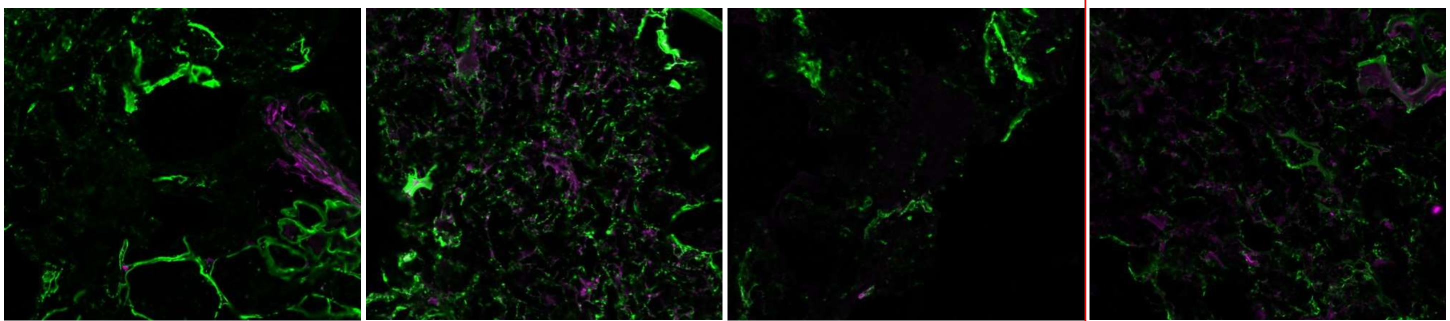
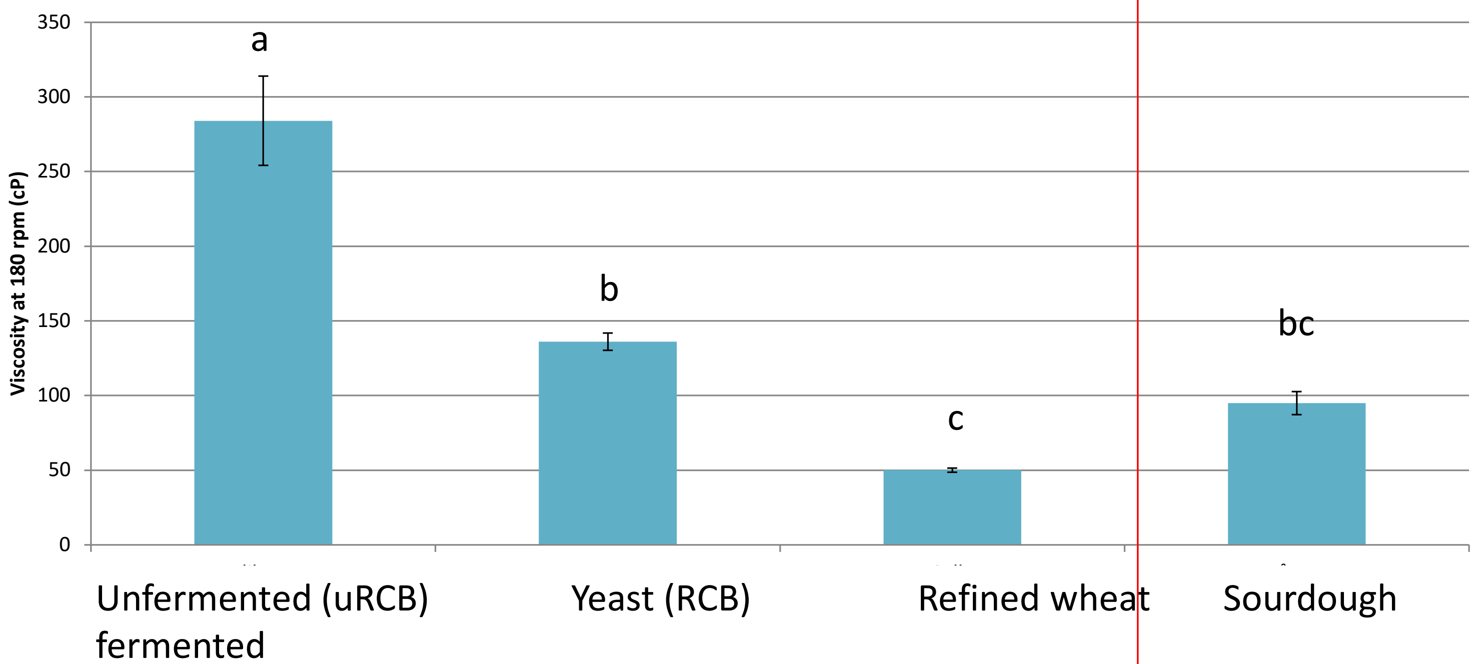
(Submitted 4 January 2017 – Final revision received 10 August 2017 – Accepted 8 September 2017)

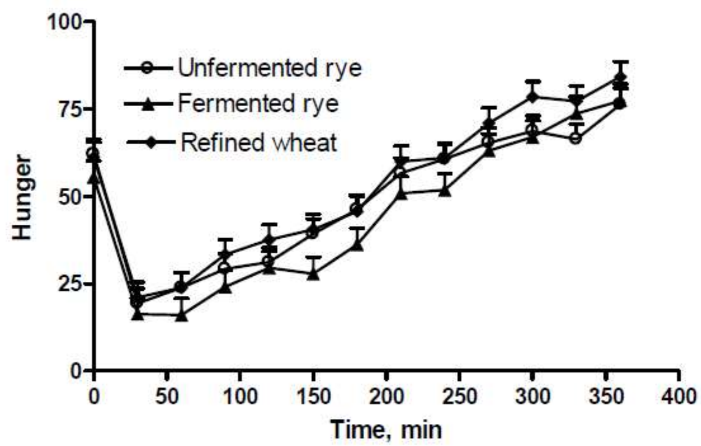
Zamaratskaia et al (2017)

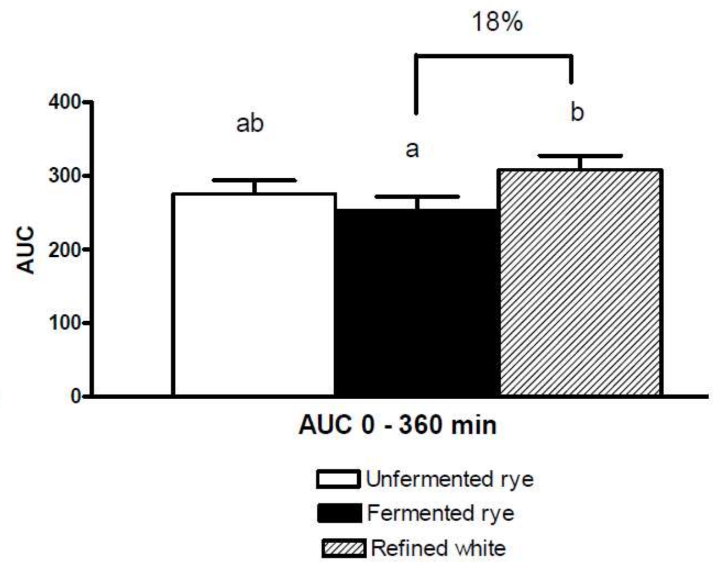
β-glucan in green and arabinoxylan in magenta



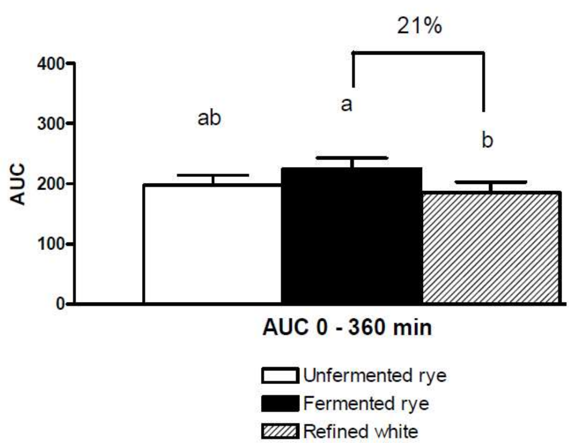


Effects on appetite





Fullness

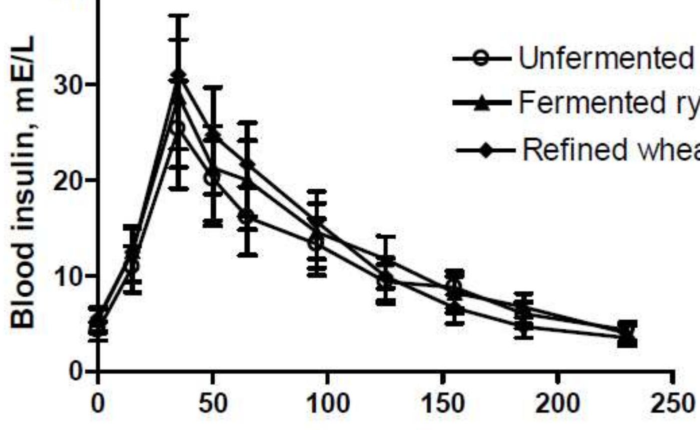


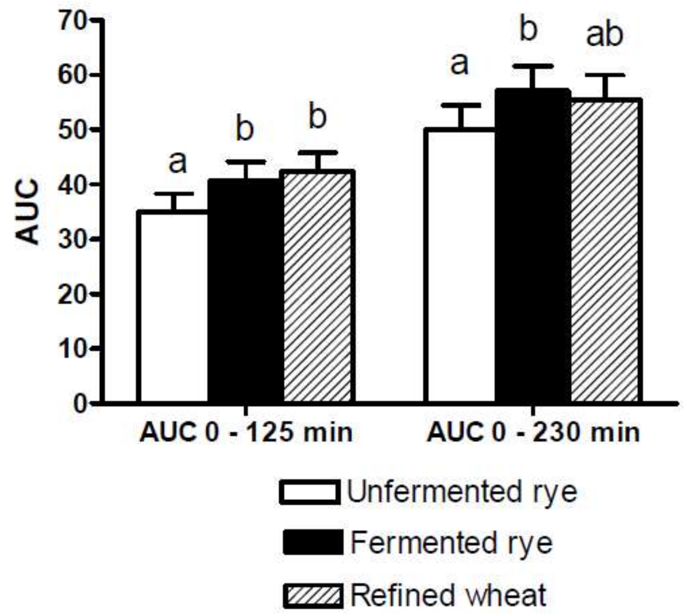
- Unfermented rye differed slightly vs control (boarderline significant)
- Sourdough fermented rye about 20% different vs control

Zamaratskaia et al (2017)

Effects on insulin

HealthFerm





Lower postprandial insulin responses at some time points (significant interaction)

Zamaratskaia et al (2017)

Effects of rye and sourdough content- A cross-over breakfast study

- 6 armed cross-over design
  - 5 sourdough rye breads
  - 1 refined wheat bread

Appetite records every 30 minutes

7:30
Breakfast

11:30
Lunch

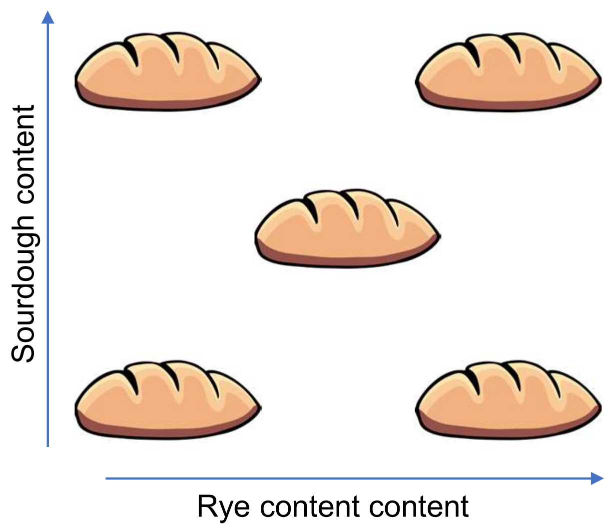
Nöhr-Iversen et al. (2018) Nutrients

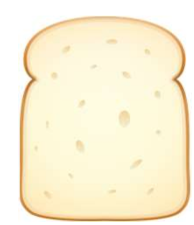
Cross-over breakfast study

- 23 healthy volunteers
  - 8 males / 15 females
- 23-63 years old

Nöhr-Iversen et al. (2018) Nutrients

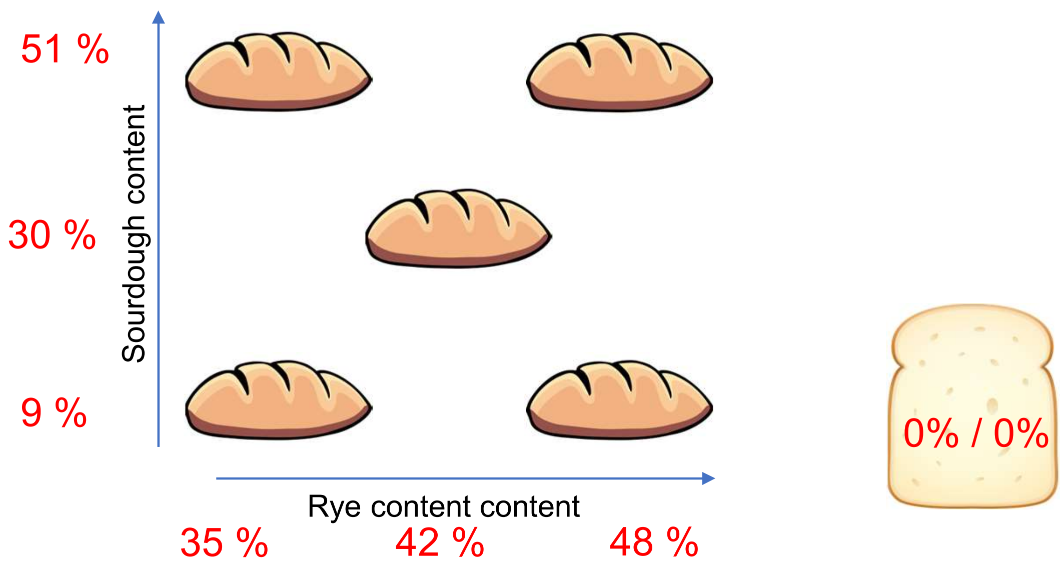
Sourdough rye bread





Nöhr-Iversen et al. (2018) Nutrients

Sourdough rye bread



Nöhr-Iversen et al. (2018) Nutrients

Table: Rye bread recipes and design

Bread sourdough/rye	R. sourdough[a]	Rye flour	Rye total[b]	Wheat flour	Total water[c]	% Sourdough of total dough	% Rye flour of total flour
1. MS/MR	1250	500	1000	900	1570	30	42
2. HS/LR	2125	0	850	1050	1540	51	35
3. HS/HR	2125	300	1150	750	1540	51	48
4. LS/LR	375	700	850	1050	1600	9	35
5. LS/HR	375	1000	1150	750	1750	9	48

[a] Sourdough consisting of 40:60 whole grain rye flour:water.
[b] Sum of whole grain rye flour added and included in sourdough.
[c] Sum of water added and included in sourdough

Nöhr-Iversen et al. (2018) Nutrients

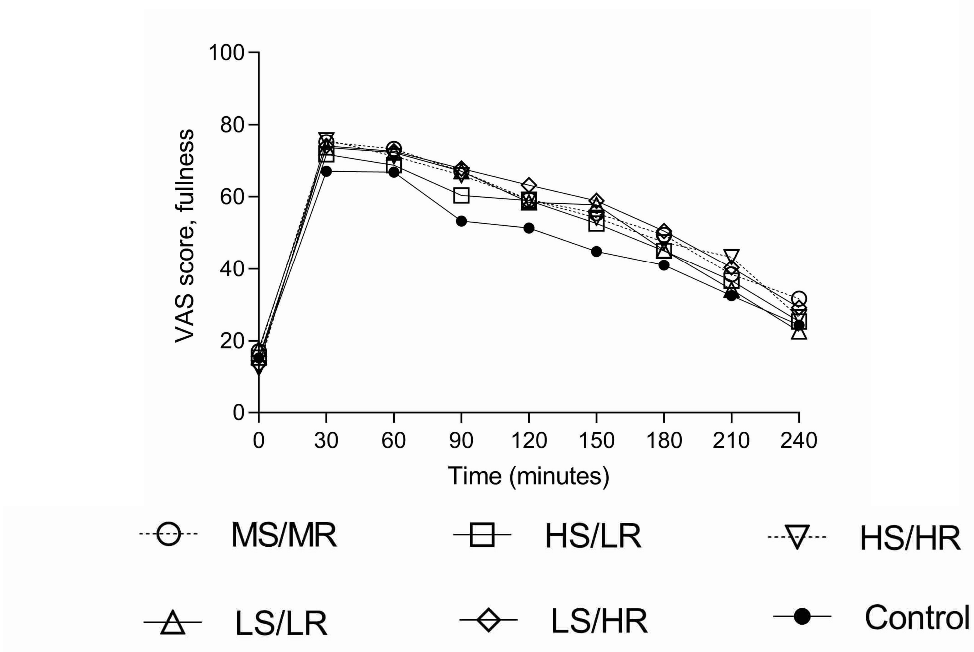
Table: Composition of rye breads (100 g- a serving in the study)

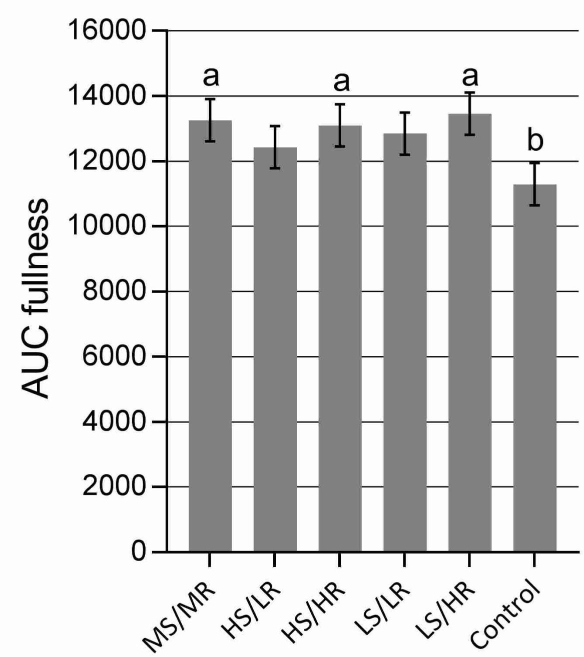
HealthFerm

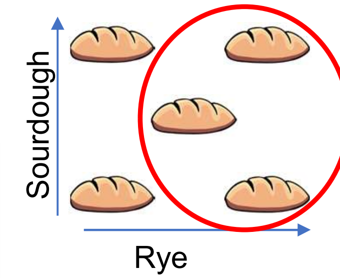
	MS/MR	HS/LR	HS/HR	LS/LR	LS/HR	Reference
Protein (g)	7.1	7.2	6.9	7.3	6.3	7.5
Fat (g)	2.2	2.2	2.2	2.2	1.9	3.9
Starch (g)	41.2	41.9	39.9	40.4	39.8	41.9
Total fiber[a] (g)	7.0	6.0	7.2	6.8	8.3	3.6
Soluble fiber (g)	2.3	2.0	2.5	2.1	2.7	1.6
Insoluble fiber (g)	4.7	4.0	4.7	4.7	5.5	3.0
Ash (g)	1.7	1.6	1.7	1.7	1.5	1.4
Water (g)	35.0	35.7	36.1	35.8	35.7	38.0
Energy (kJ)[b]	959	963	934	946	920	992
pH	4.4	4.2	4.2	5.2	5.3	5.0
Acid equivalents[c]	10.3	11.5	12.5	6.3	6.6	4.3
Lactic acid (g)	0.81	0.81	0.89	0.4	0.36	0.27
Acetic acid (g)	0.13	0.14	0.16	0.07	0.04	0.04

Nöhr-Iversen et al. (2018) Nutrients

Fullness

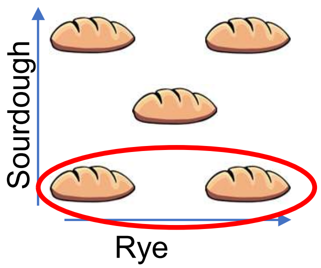


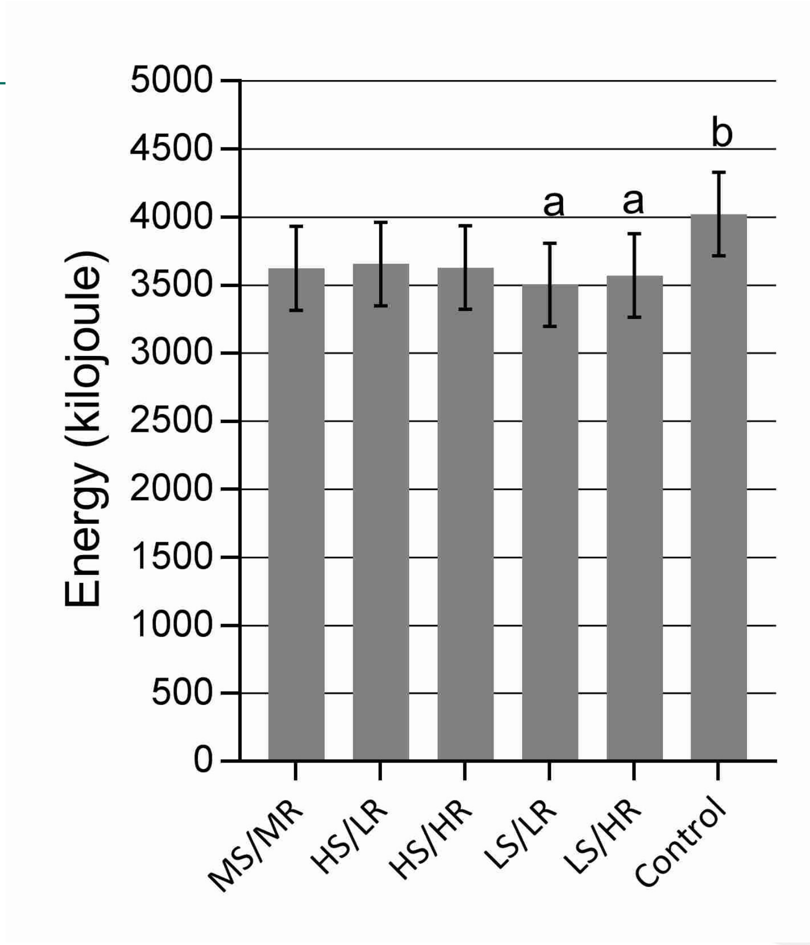




Nöhr-Iversen et al. (2018) Nutrients

Ad libitum lunch





Nöhr-Iversen et al. (2018) Nutrients

Conclusion

HealthFerm

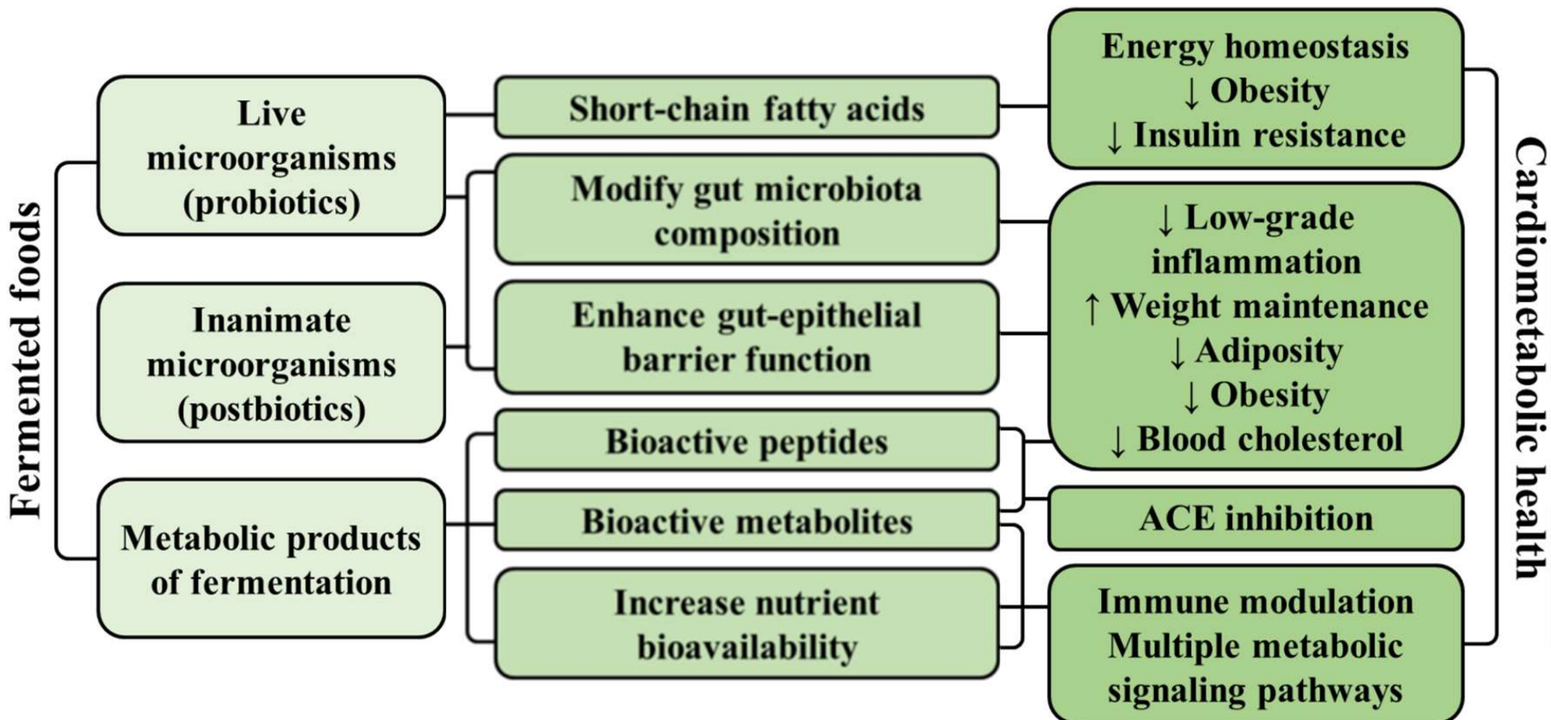
- **No difference between the sourdough rye breads**

- No indication of an effect of increasing sourdough content
  - Despite large difference, 9-51%

- Some indication of an effect of increasing rye content
  - Relatively small difference, 35-48%

Nöhr-Iversen et al. (2018) Nutrients

Fermented foods and cardiometabolic health – proposed mechanisms



Li, 2022, *Frontiers in Nutrition*

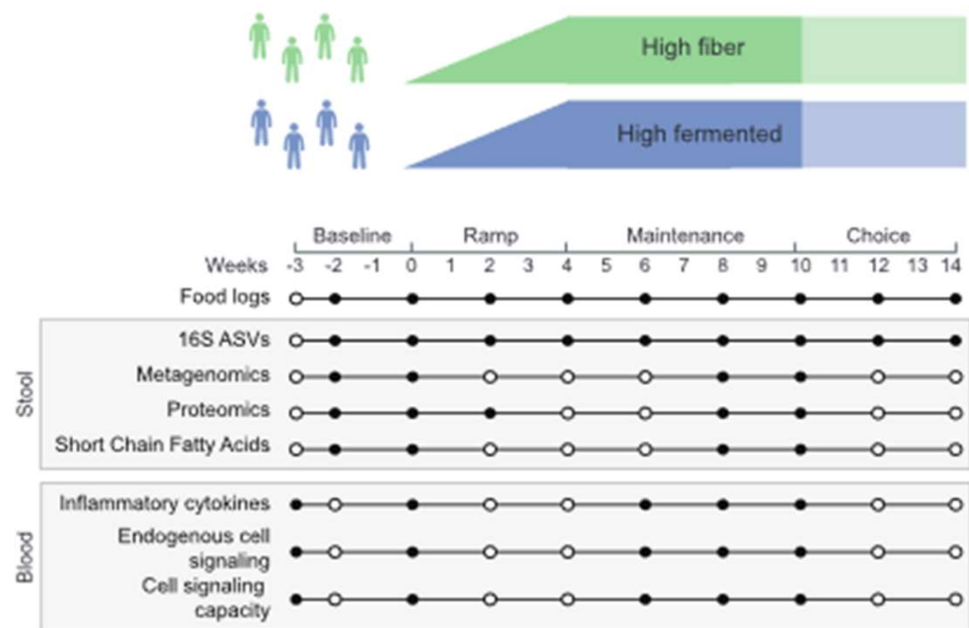
Health benefits of fermented and high fiber foods – clinical trial

HealthFerm

- Parallel study
- Healthy adults, n=18
- Dietary fiber - 20 g/day
- Fermented food - 6 servings/day

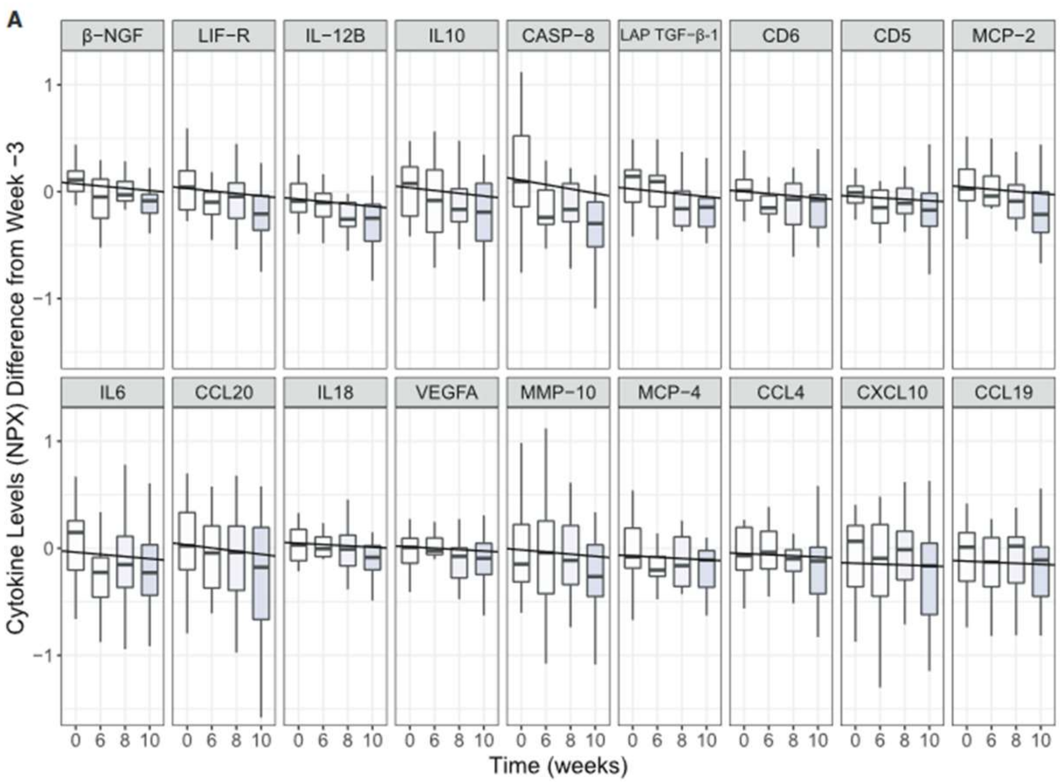
Primary aim: Change in Cytokine Response Score

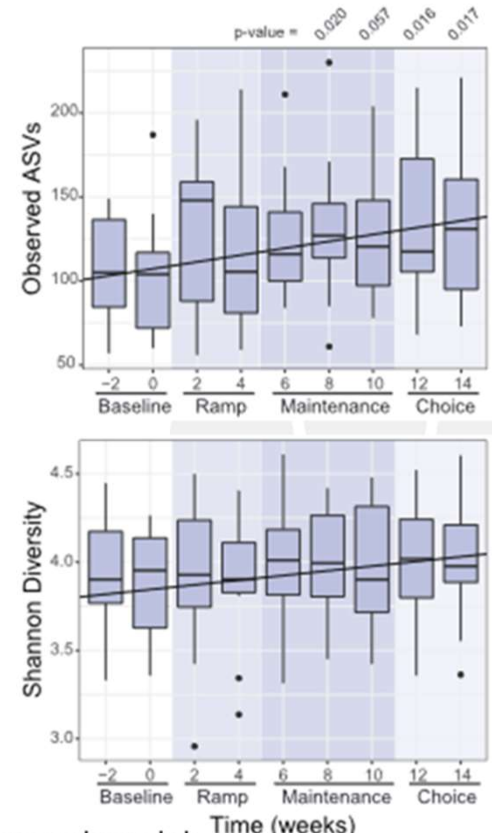
Secondary aims: Effect on microbiota, SCFAs, inflammatory markers, lipid profile



Wastyk et al 2021, *Cell,* Sonnenburg lab

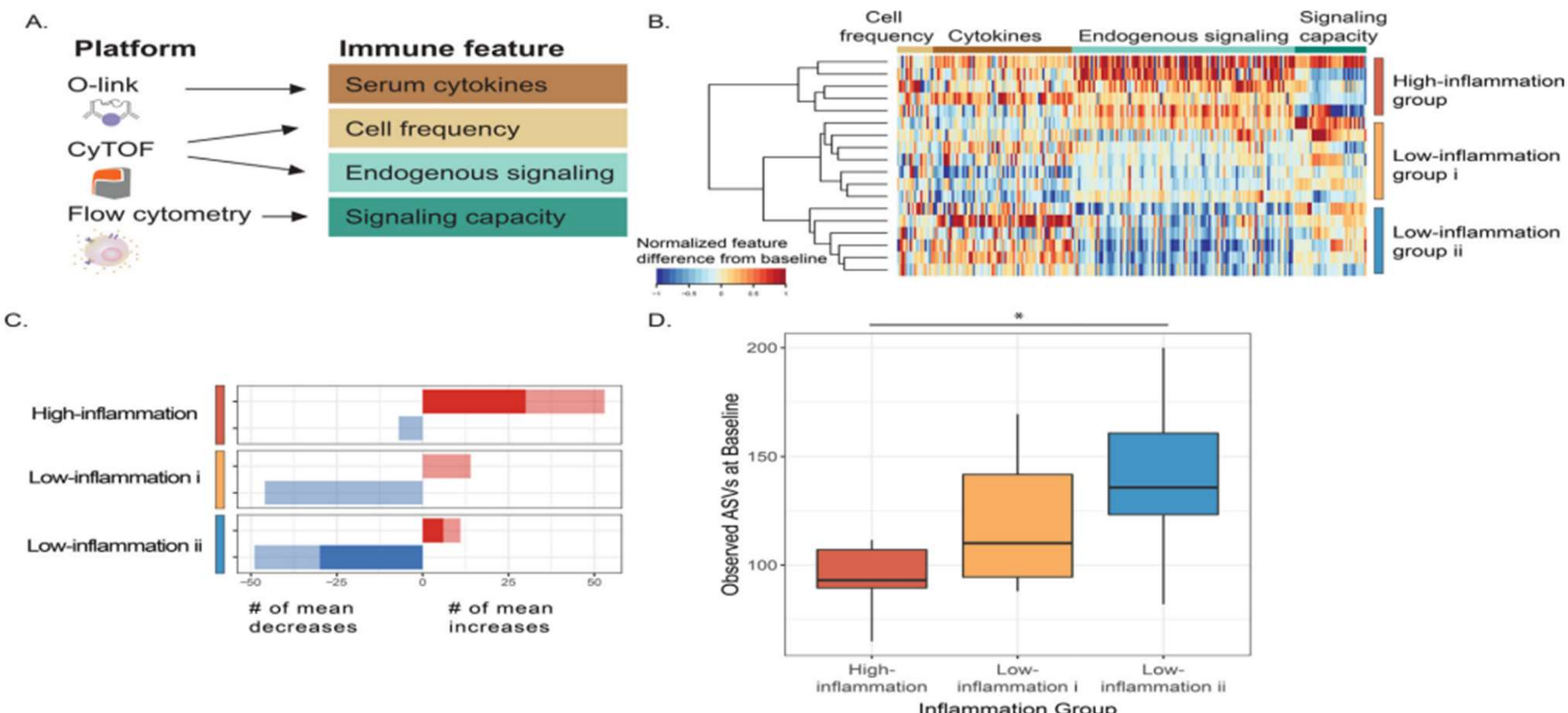
Health benefits of fermented and high fiber foods – clinical trial



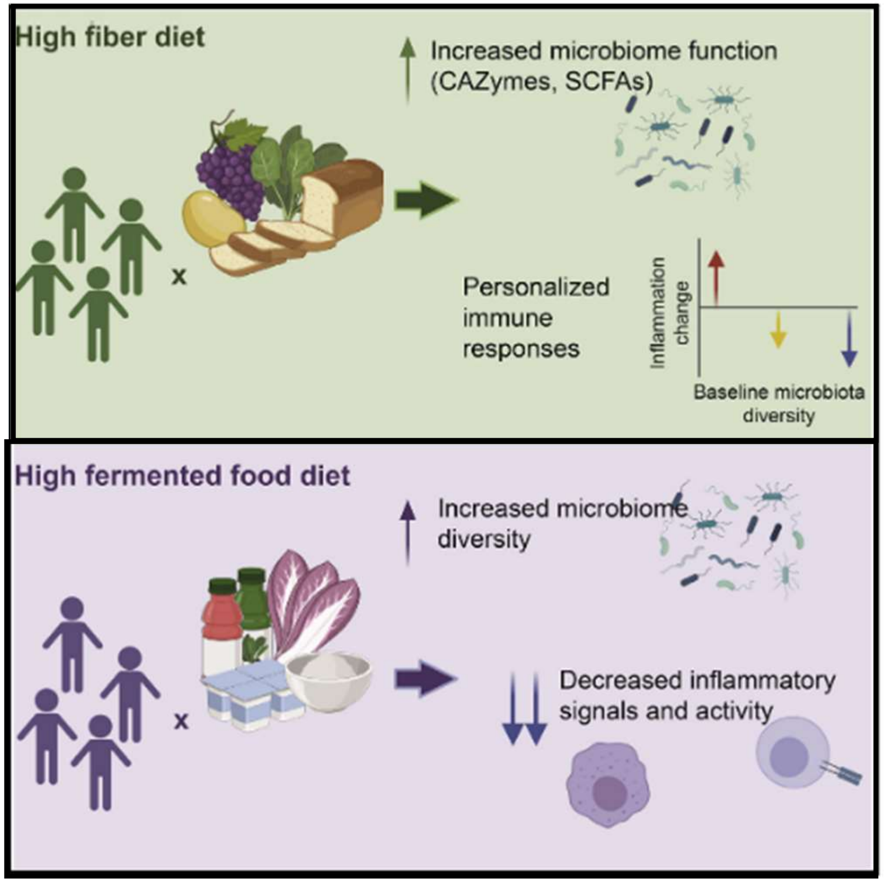


Wastyk et al 2021, *Cell,* Sonnenburg lab

Inflammation response groups



Wastyk et al 2021, *Cell,* Sonnenburg lab



Wastyk et al 2021, *Cell,* Sonnenburg lab

HealthFerm

Plant-based fermented foods

for healthier and more sustainable diets

HealthFerm is a Horizon Europe research project investigating innovative pulse and cereal-based food fermentations together with the health effects and consumer perception of novel fermented foods.

4-year project

23 partners

Funded by the European Union

Fermented Plant-based Portfolio Diet 4 Metabolic Health (FermDiHealth)

HealthFerm

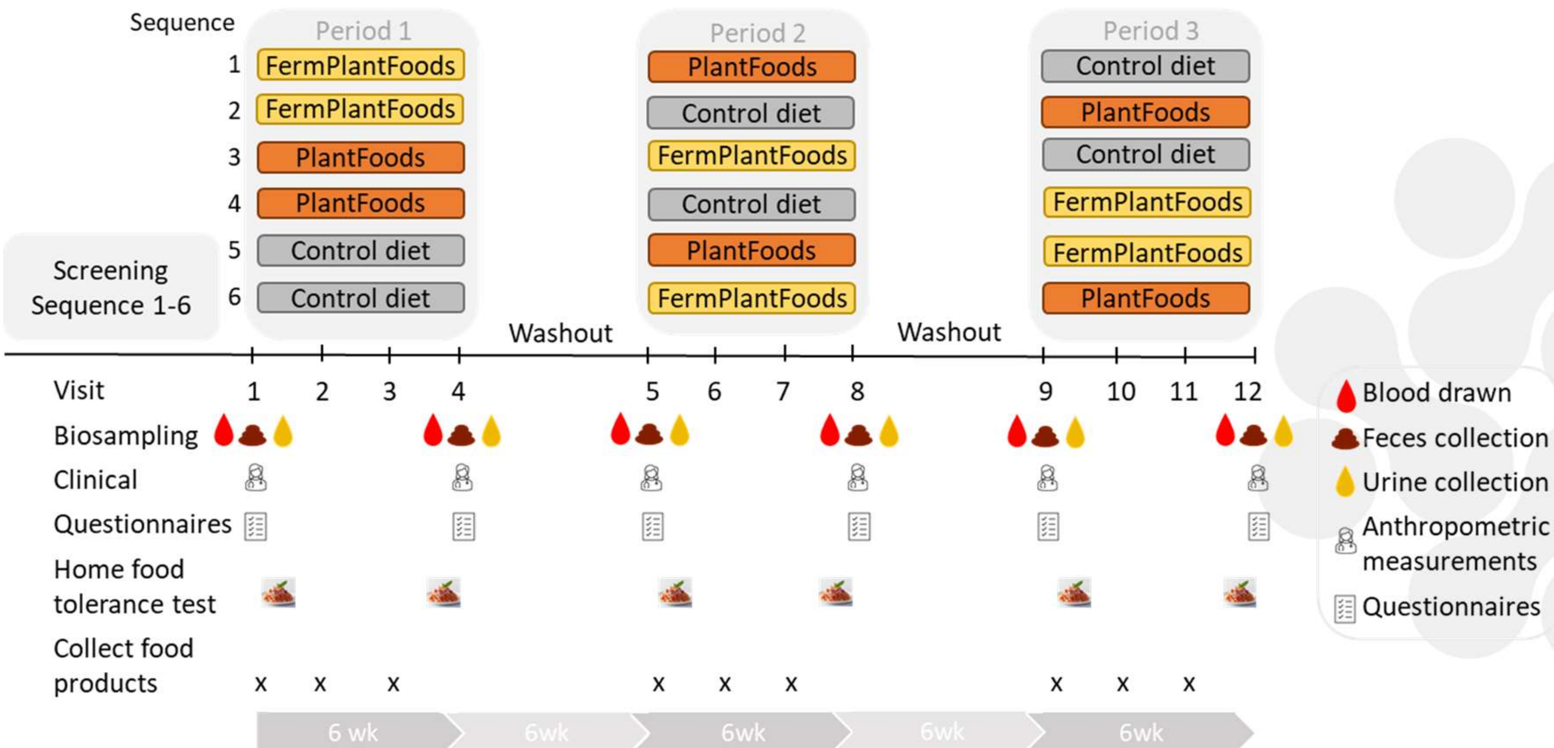
- Randomized controlled crossover study
- Subjects with metabolic syndrome, n=100

Primary aim: Difference in the inflammatory biomarker(s)

Secondary aims: Lipid profile, glucose and insulin, blood pressure, inflammatory markers, glycaemic variability, microbiota, metabolome, (stratification – Enterotypes)

FermPlantFoods	PlantFoods	Control diet
Fermented foods: - Yogurt like product - Meat alternative - Vegetables - Kombucha - Bread	Non-fermented counterpart	Average Swedish diet

Fermented Plant-based Portfolio Diet 4 Metabolic Health (FermDiHealth)



Food4GutMarKIT

HealthFerm

Literature review

Step 1

Identification of gut microbiota associated with reduction of cardiovascular risk factors

→ *F.prausnitzii, Oscillospiraceae, Faecalibacterium*

Step 2

Identified foods shown to increase these bacteria in human intervention trials

→ Rich in fibers and whole grains + fermented foods

⇩

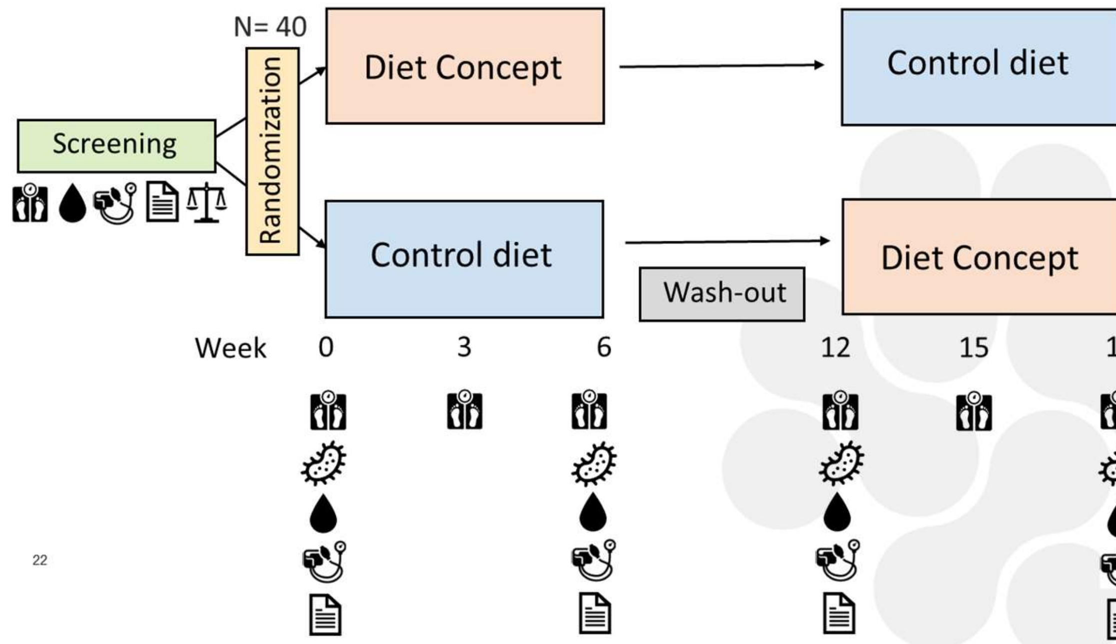
Diet concept

- Rich in fibers and whole grains + fermented foods (4 servings/day)
- Nordic Nutrition Recommendations

Palmnäs et al *in preparation*

Food4GutMarKIT – clinical trial

- Randomized controlled cross-over study
- BMI<25, BMI>25
- Completers n=30



Primary aim: Effect on gut microbiota previously shown associated with reduction of cardiovascular risk factors

Secondary aims: Effects on lipids, blood pressure, fasting glucose, CRP and the metabolome.

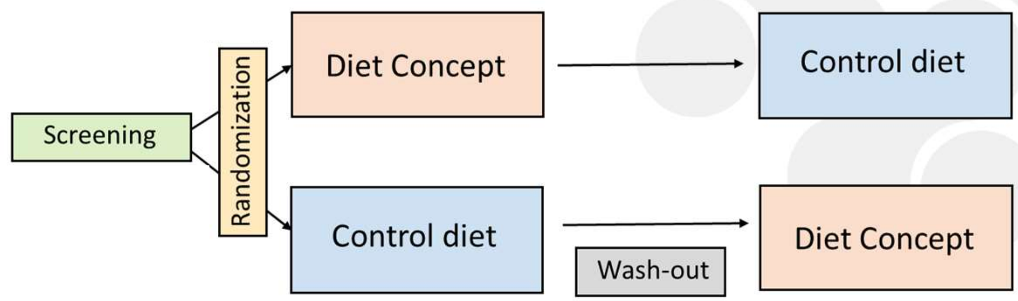
22

GutMarkIT – clinical trial

Stay tuned!

Expected findings

- The intervention diet will alter specific microbes previously shown inversely associated with risk factors for cardiovascular disease
- Affected microbes will be linked with reduction of cardiovascular risk factors
- The effect on microbiota will be mirrored in the metabolome
- Differ between individuals with BMI <25 and BMI >25



Take home messages

HealthFerm

- Fermented foods is s diverse group! Many different MOs and metabolites formed
- Several mechanisms at play at the same time
- Studies on non-dairy fermented foods and health are lacking
- RCTs on plant based fermented foods and helath are on the way

External collaborators

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2023-06-15

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