

Food fermentations for improved digestibility of plant foods – an essential ex situ digestion step in agricultural societies?

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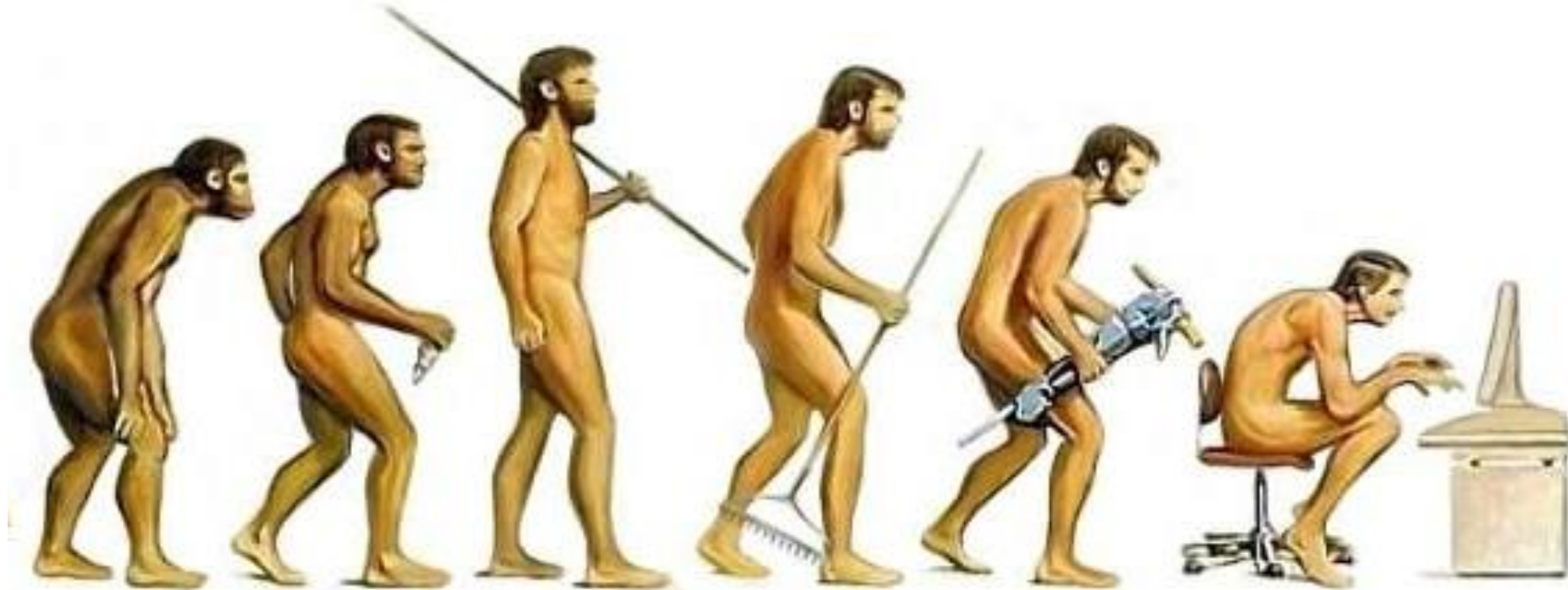
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Wuhan, Hubei



History of Sourdough



Hunter and Gatherer → Agriculture → Industrialisation → Knowledge economy

Key technologies

Arrow, Fling → Plow → Coal / Steel → IT, Biotechnology

Use of sourdough

- → Leavening → Acidification → Bread Quality

pictures from Google

Site of discovery of Natufian bread in contemporary Jordan (about 14,000 years old)



Who came first – bakers or farmers?

The demand for bread and / or beer likely was a driving factor in the domestication of wheat

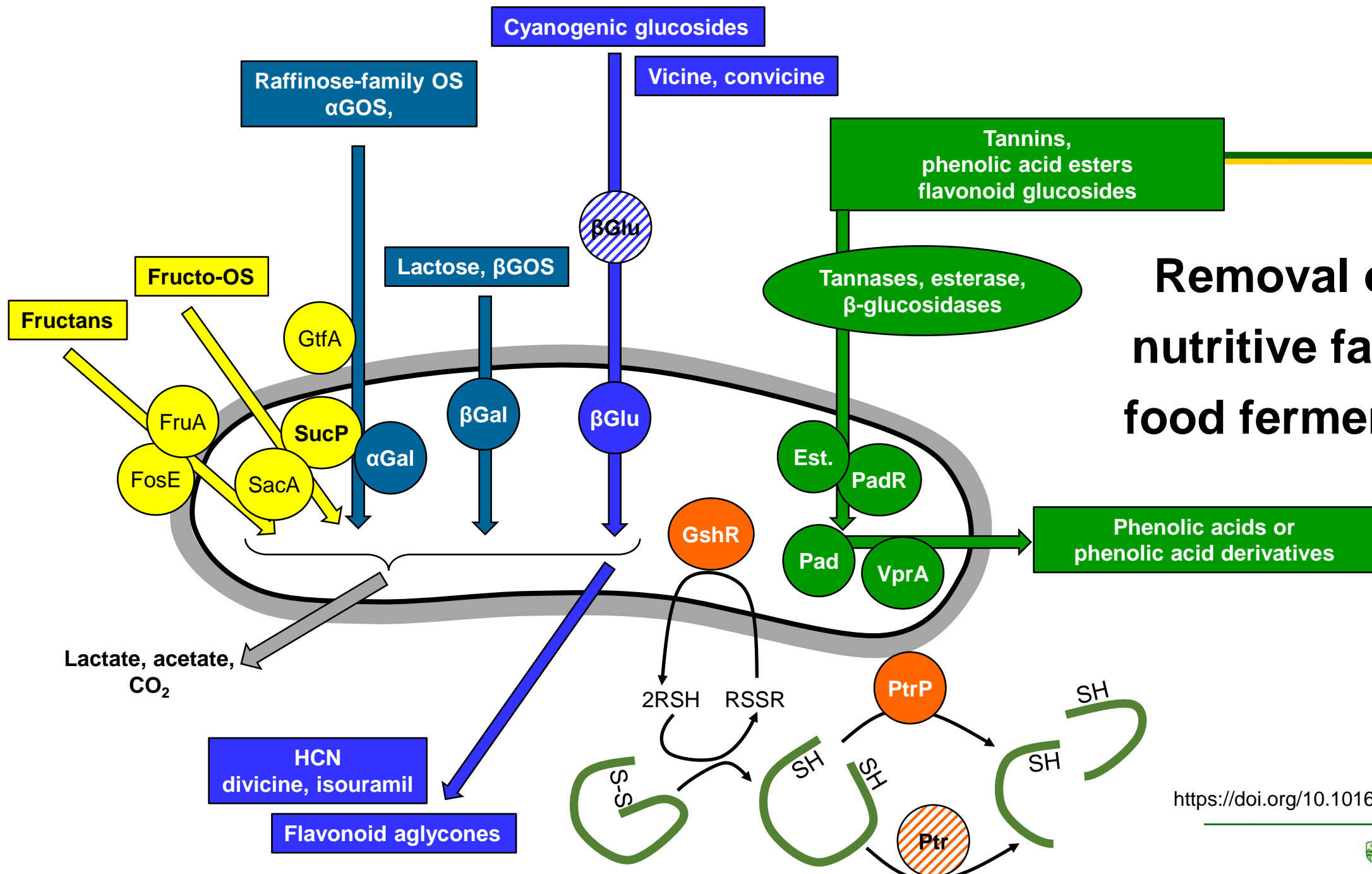
Grains, seeds and tubers are packed with nutrients but also with anti-nutritive factors or even toxins – without processing, they are not suitable for human nutrition.

www.pnas.org/cgi/doi/10.1073/pnas.1801071115; <https://www.nature.com/articles/d41586-021-01681-w>; <https://doi.org/10.1016/j.cofs.2020.04.002>

Fermentations in Bread Production

– a look into history -

- baking and the use of sourdough is about 14,000 old and likely predates crop agriculture
- until Louis Pasteur „invented“ Food Microbiology in 1857, sourdough was the major leavening agent (use of brewers yeast)



Removal of anti-nutritive factors in food fermentations

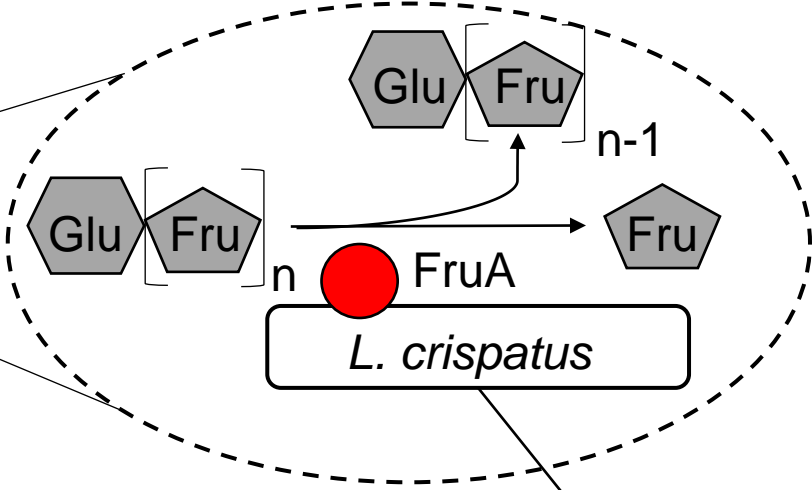
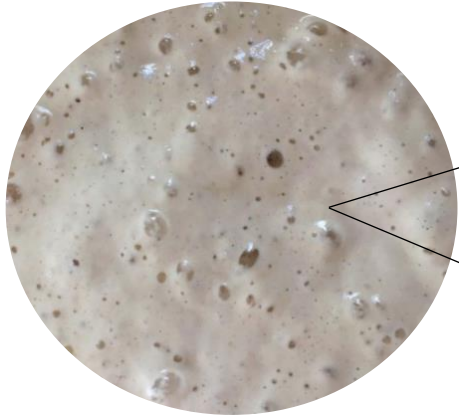
<https://doi.org/10.1016/j.cofs.2020.04.002>

What does that mean for wheat sourdough bread?

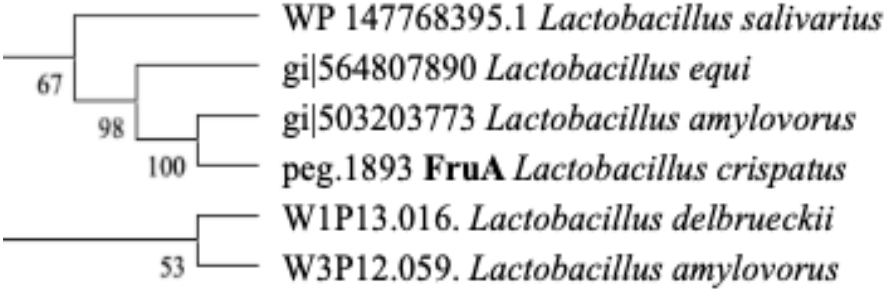
- Phytate
- FODMAPs
- Amylase/trypsin inhibitors
- Wheat germ agglutinin

Fructan degradation in wheat and rye sourdough baking

Sourdough with FruA expressing *L. crispatus*



Low-FODMAP bread



FruA: exclusive to host-adapted lactobacilli

Fructan and mannitol content of bread and sourdough bread

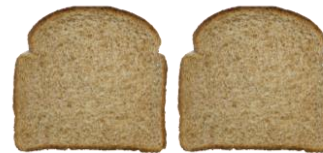
Strain	FruA addition	Contents in dry basis (mmol/kg)		
		Fructans	Fructose	Mannitol
Whole rye		242.8 ± 26.2	n.d.	n.d.
Whole wheat		120.4 ± 7.7	n.d.	n.d.
<i>L. crispatus</i>	N	10.9 ± 3.5	9.7 ± 1.3	0.7 ± 0.4
<i>Lm. reuteri</i>	N	40.9 ± 11.7	8.2 ± 7.6	8.9 ± 4.5
Straight dough	N	120.1 ± 20.9	20.9 ± 14.8	3.1 ± 1.3
	Y	n.d.	8.0 ± 1.6	3.5 ± 2.4

n.d., not detected.

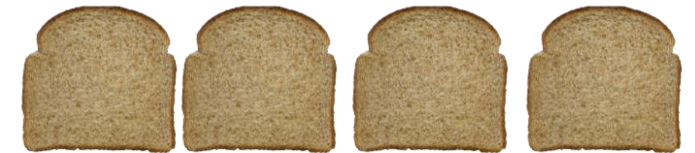
Low-FODMAP cutoff for grain products: < 0.3g per serving



Straight dough



Conventional sourdough



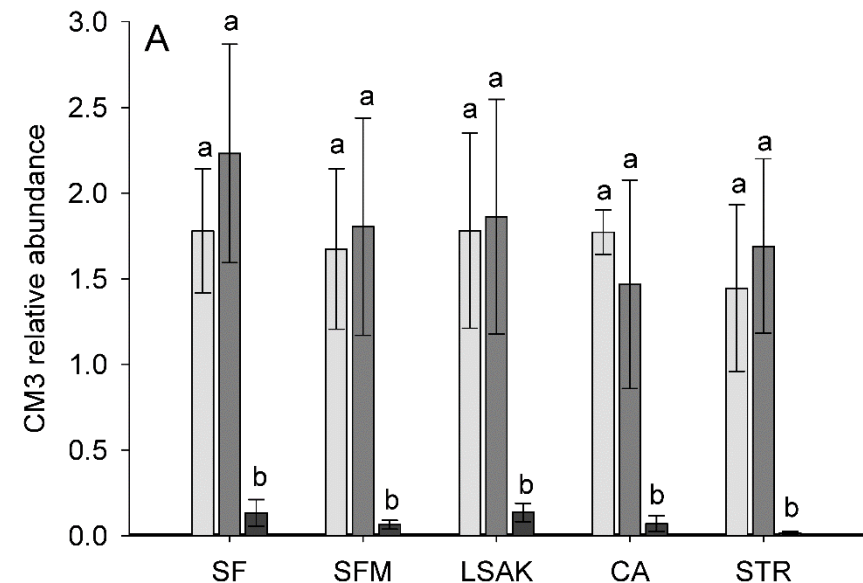
FruA-sourdough

ATI tetramer degradation throughout the bread-making process

Bread system	pH	log (CFU g ⁻¹)	After mixing	After proofing	After baking
Control, pH 5.0	-	-	1	1	0.60
Control, pH 4.0	-	-	1	0.63	0.61
<i>Fl. sanfranciscensis</i>	4.01±0.05	8.37±0.05	1	1	0.61
Wheat sourdough	3.69±0.04	9.57±0.19	1	0.64	0.57

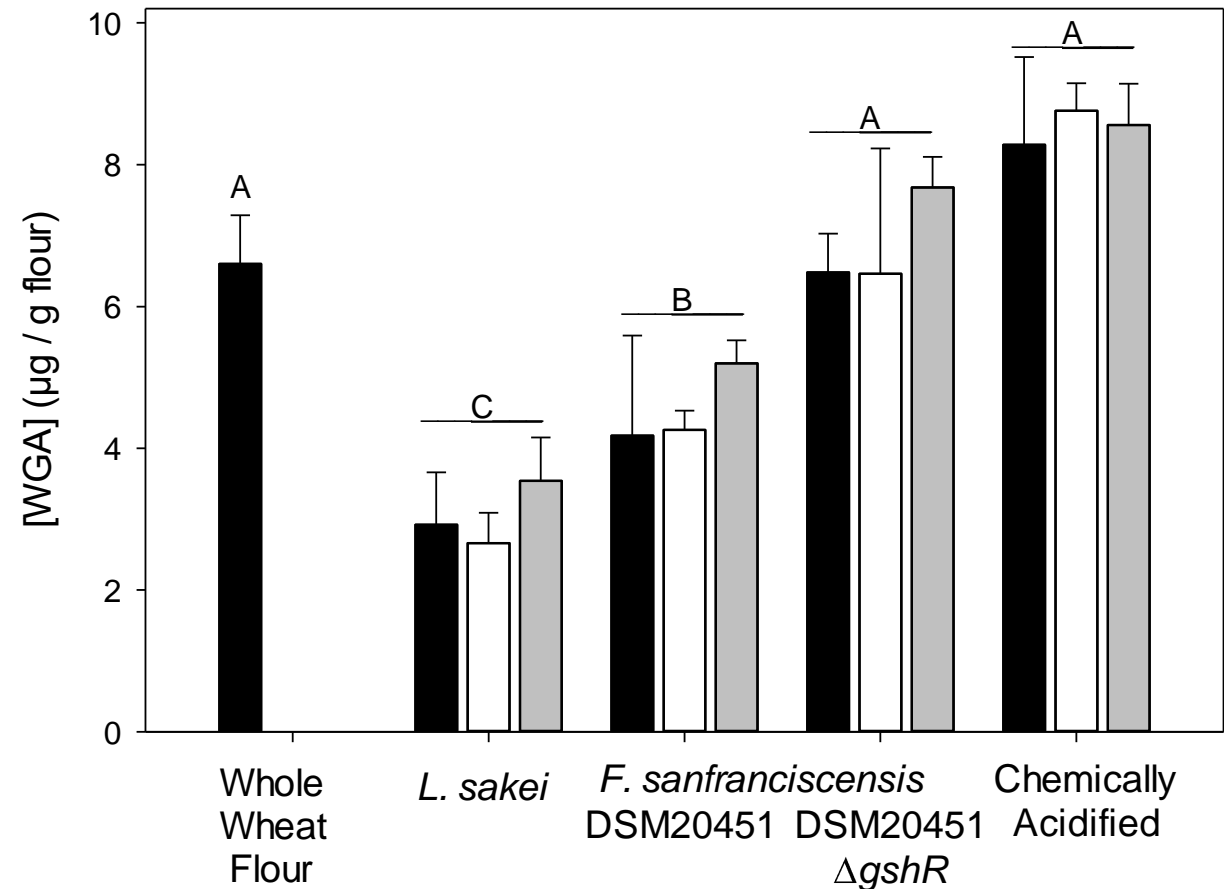
Qualitative assessment of tetramer to monomer ratio with fluorescence labeled ATI

Quantification of ATI with LC-MS/MS indicated no differences between sourdough bread and straight dough bread:



Wheat germ agglutinin degradation in sourdough

- WGA was quantified by ELISA in sourdoughs fermented with defined strains
- WGA could not be extracted from bread



- interim summary -

- ⇒ Sourdough baking partially or completely degrades phytate and fructans (FODMAPs)
- ⇒ Sourdough fermentation modifies immune-reactive proteins including ATI and WGA but it remains uncertain whether their content or bioactivity in bread is modified
- ⇒ The gluten content of sourdough bread is not different from straight dough bread

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- in the late 19th century, baker's yeast and brewer's yeast (with lactic acid bacteria) was increasingly used (growth on cereal substrates). Pure cultures of yeast were available after molasses was used for bakers yeast production (shift in the 1930ties / 1940ties)
- late 20th century: (almost) exclusive use of bakers yeast for wheat bread, continuing use of sourdough in rye applications

From Tradition to Innovation: Sourdough for „clean label“ formulations

1900: Flour, water, salt

Tradition

2010: Flour, water, sugar, salt, yeast, vital gluten, acetate, propionate, ascorbic acid, cystein, guar gum, sodium-stearoyllactylate, mono- and diglycerides, amylase, xylanase (...)

Innovation



Celiac Disease and Non-Celiac Wheat Sensitivity and Gluten Free Diets

Celiac disease (~ 1% of population):

- autoinflammatory disease in reaction to gluten protein leading to chronic inflammation of small intestine and nutrient malabsorption
- induced in sensitised persons by prolamins of *Triticum* cereals (gliadin from wheat, secalins from rye, hordeins from barley)
- most celiacs tolerate 10 mg gluten per day – one serving of wheat bread has ~ 1500 mg

Non-celiac wheat intolerance (~ 6 – 15% of population):

- poorly defined intestinal symptoms in response to wheat and / or FODMAPS (fermentable oligosaccharides, monosaccharides, and polyols)
- Contribution of ATI and WGA suggested but not known
- Overlap with irritable bowel syndrome and fructose malabsorption

An additional ~ 15% of U.S. customers do not react to wheat but still avoid wheat or gluten

Sourdough Baking and Celiac Disease or Non-Celiac Wheat Sensitivity: Correlation or Causality?

Celiac disease:

Sourdough does not improve tolerance!

Non-celiac wheat sensitivity:

What we know:

Consistent anecdotal reports imply that “ancient grains”, rye, and sourdough bread are often tolerated.

Conventional sourdough fermentation reduces content of FODMAPs

Sourdough fermentation modifies immune-active proteins but their role in NCWS is unknown.

What we don't know:

Appropriately powered randomized clinical trials to demonstrate improved tolerance of sourdough bread are lacking.

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- since ~ 5 years (U.S.) to 10 years (Europe): Sourdough applications in wheat baking are becoming mainstream again to improve the flavour, texture, and nutritional value of bread.

From Tradition to Innovation: Sourdough for „clean label“ formulations and improved bread quality

The length of the ingredient list is inversely proportional to the knowledge of the baker?

1900: Flour, water, salt

Tradition

2010: Flour, water, sugar, salt, yeast, vital gluten, acetate, propionate, ascorbic acid, cystein, guar gum, sodium-stearoyllactylate, mono- and diglycerides, amylase, xylanase (...)

Innovation

2021: Flour, water, salt

Knowledge

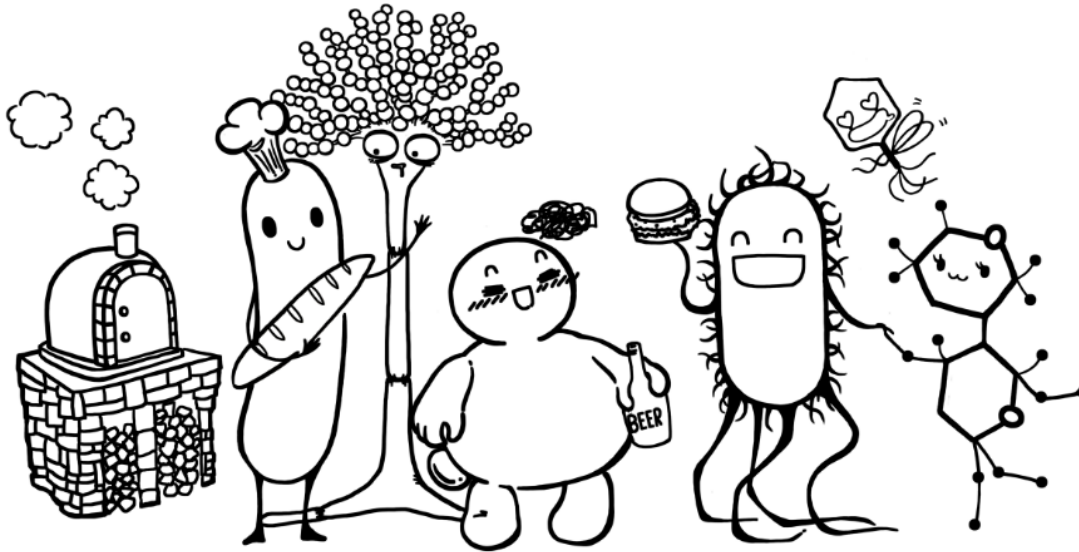


Summary

- ⇒ Sourdough baking modifies or degrades anti-nutritive compounds including phytate, FODMAPs, ATI and WGA.
- ⇒ Improved tolerance of sourdough bread in non-celiac wheat sensitivity is reported anecdotally but not documented in randomized clinical trials.
- ⇒ Until we know better, sourdough fermentation remains the best tool to improve tolerance of wheat
- ⇒ The shift to sourdough baking currently occurs at a big scale

Acknowledgements

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Food microbiology lab 2-50
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...You for your attention