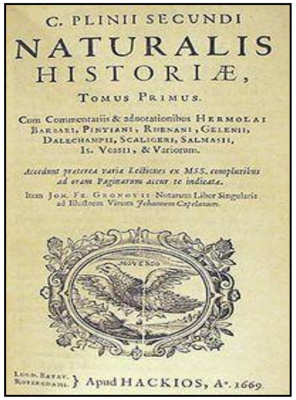
Récents développments de l'effet du levain sur les bénéfices nutritionnels

Marco Gobbetti

marco.gobbetti@uniba.it

Le Fonds de Dotation EKIP, Paris
28 Novembre 2016

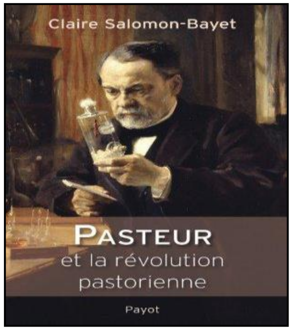
Historical excursus on the «leavening» of baked goods



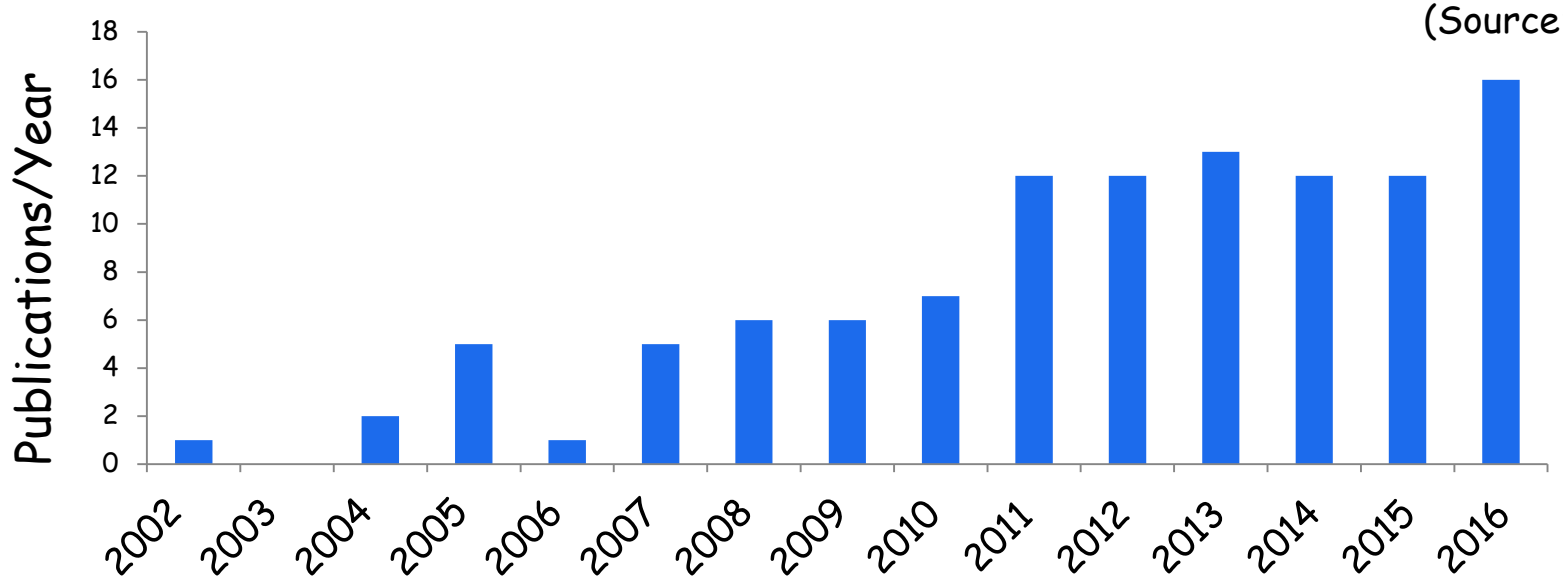
"*Tacuini Sanitatis* among the six elements needed for the well-being of people ... presence of sourdough (e.g., the bread must be completely fermented ..." (XI century, Codex 4182, Biblioteca Casanatense Rome)

"The leavened (sourdough) bread gives strength to the body" (Plinius the Elder, 23/24-79 A.D.)

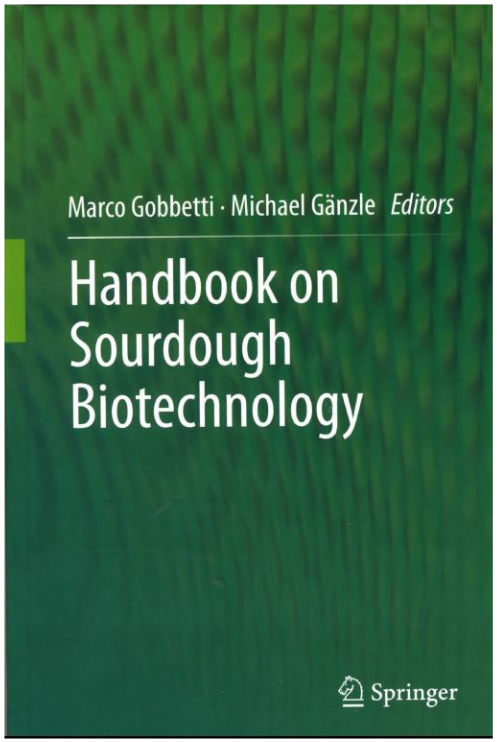
Pasteur et la révolution pastorienne (1822 - 1895) Salomon-Bayet, Claire (ed.), Payot, 1986



(Source: Web of Science)



Nutrition and sourdough



Food Microbiology 37 (2014) 30–40

Contents lists available at SciVerse ScienceDirect

Food Microbiology

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

How the sourdough may affect the functional features of leavened baked goods

Marco Gobbetti*, Carlo G. Rizzello, Raffaella Di Cagno, Maria De Angelis

Department of Soil, Plant and Food science, University of Bari, Italy

Critical Reviews in Food Science and Nutrition, 50:716–727 (2010)

ISSN: 1040-8398
DOI: 10.1080/10408398.2010.499770

Functional Microorganisms for Functional Food Quality

M. GOBBETTI, R. DI CAGNO, and M. DE ANGELIS

Dipartimento di Biologia e Chimica Agro–Forestale e Ambientale, University of Bari, Italy

International Journal of Food Microbiology xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

International Journal of Food Microbiology

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

Drivers for the establishment and composition of the sourdough lactic acid bacteria biota

Marco Gobbetti *, Fabio Minervini, Erica Pontonio, Raffaella Di Cagno, Maria De Angelis

Department of Soil, Plant and Food Sciences, University of Bari Aldo Moro, Bari, Italy

For instance … the Italian market

Fibers

Beta-glucans

…and minerals

How may sourdough lactic acid bacteria contribute to nutritional value?

Maltose

Glucose

Heterolactic fermentation

Glucose

Maltose

H^+

H^+

Glucose

Maltose

CO_2

5P-Xilulose

Acetate

Acetyl-P

3P-Glyceraldehyde

Ethanol

Piruvate

NADH+H

NAD

Acidification

Lactate

Homolactic fermentation

Glucose

NADH+H⁺

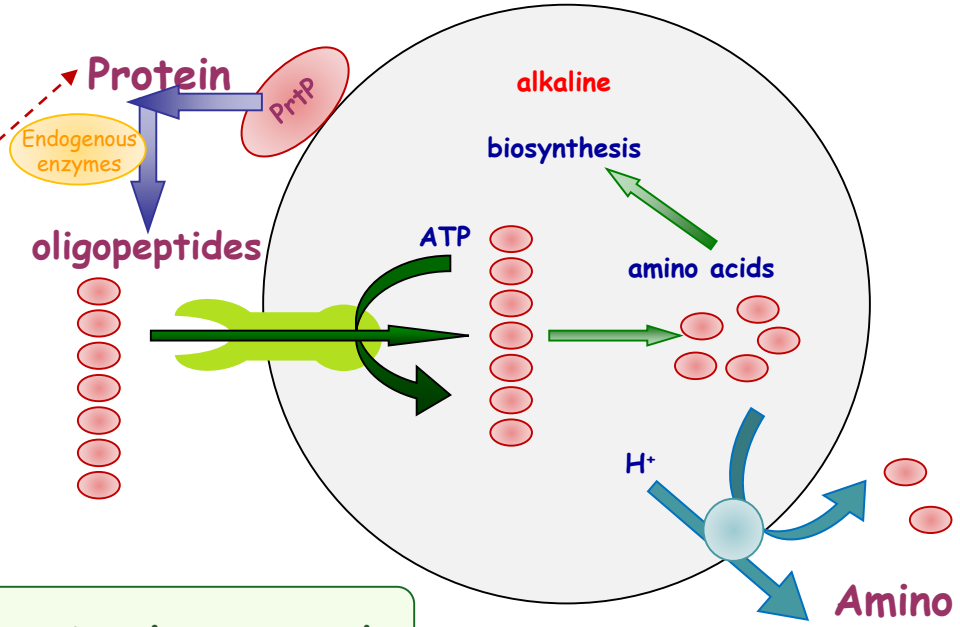
NAD

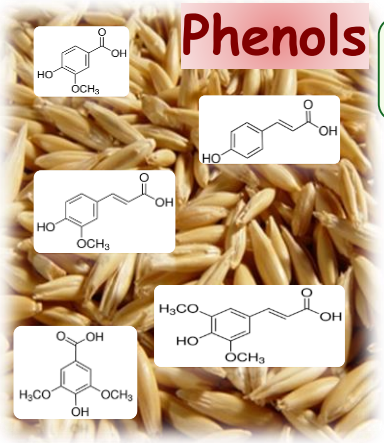
Piruvate

(2) Lactate

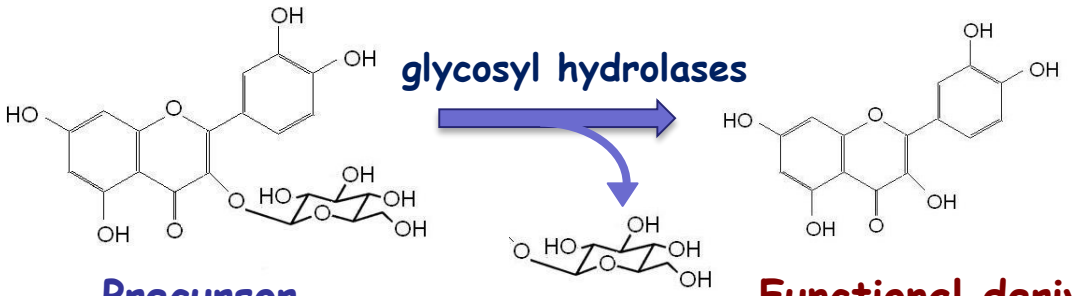
Acidification

How may sourdough lactic acid bacteria contribute to nutritional value?





Synthesis of functional compounds



Catabolism of amino acids

The sourdough fermentation may affect the nutritional/functional features of leavened baked goods through:

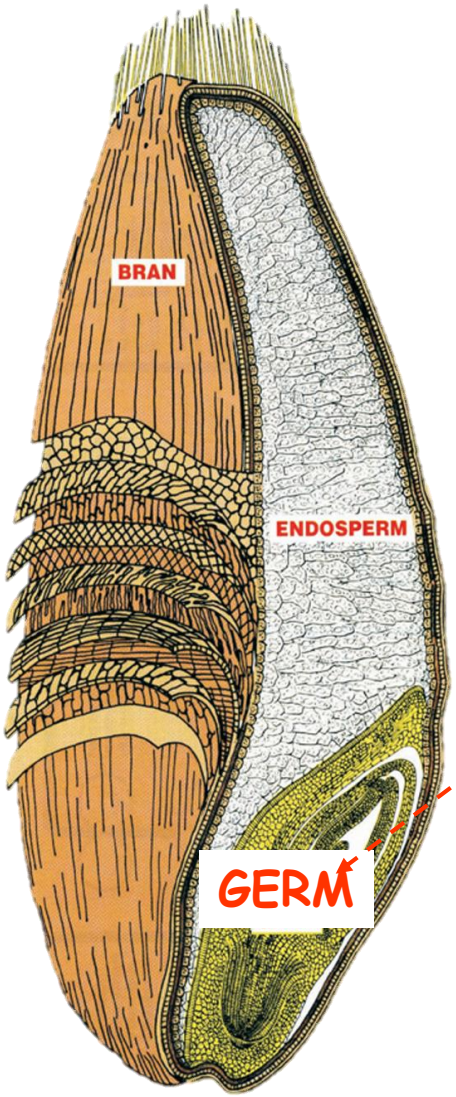
- Pre-treatment of raw materials (e.g., bran and wheat germ)
- Modification/increase of the bio-availability of dietary fibres, minerals and vitamins
- Decrease of glycaemic index/response
- Synthesis of bioactive peptides and amino acid derivatives
- Synthesis/liberation of antioxidant compounds
- Bio-preservation
- Decrease/elimination of the intolerance/sensitivity to gluten

Pre-treatment of bran

- Changes on the quality of dietary fibre and bio-availability of phytochemicals (Broekaert et al. 2011, *Crit Rev Food Sci Nutr* 51:178)

- Improved sensory and structure (e.g., loaf volume and crumb softness) characteristics (Katina et al. 2006, *LWT Food Sci Technol* 16:104; Katina et al. 2007, *Food Microbiol* 24:175)

Pre-treatment of wheat germ



- ✓ a-Tocopherol
- ✓ Vitamins B
- ✓ Dietary fibre
- ✓ Minerals
- ✓ Proteins
- ✓ Phytochemicals (flavonoids, sterols,…)
- ✓ Unsatured fatty acids

Antinutritional factors

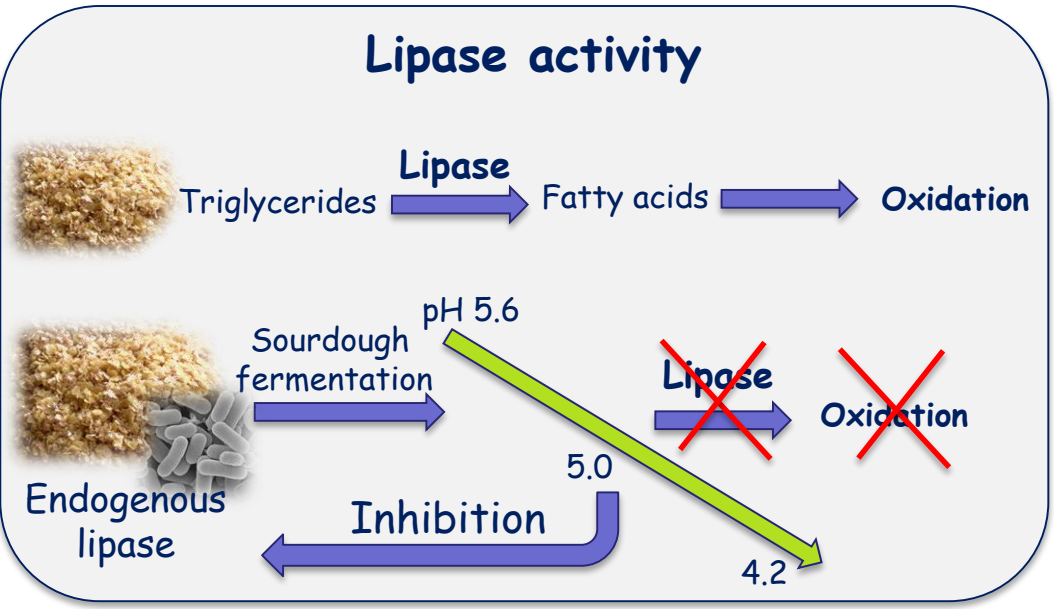
- ✓ Raffinose
- ✓ Phytic acid
- ✓ Wheat germ agglutinin

Pre-treatment of wheat germ

Sourdough fermentation

(selected, autochthonous lactic acid bacteria)

Lipase activity

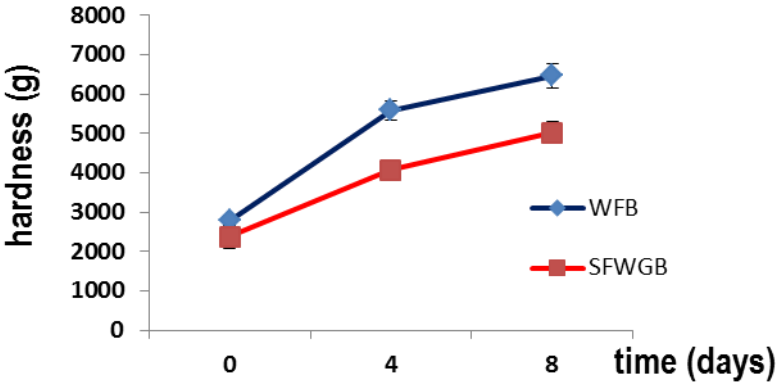


- Lipase activity **ca. 2.6-fold** lower than that found in raw wheat germ
- After 40 days of storage, a very low concentration of hexanal and other markers of lipid oxidation were found in fermented wheat germ (SPME analysis)

SFWG as ingredient for bread making

(4%, replacement of wheat flour)

- Specific volume + **16-18%**
- Improving of textural properties/ firmness delay:



Rizzello et al., 2010 *Eur Food Res Technol* 230:645
Rizzello et al., 2010 *Food Chem* 119:1079
Rizzello et al., 2011 *Food Chem* 127:952

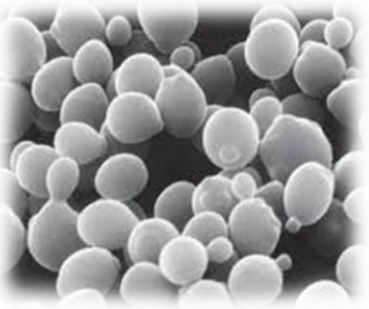
Modification/increase of the bio-availability of dietary fibres, minerals and vitamins

Grain endogenous phytase

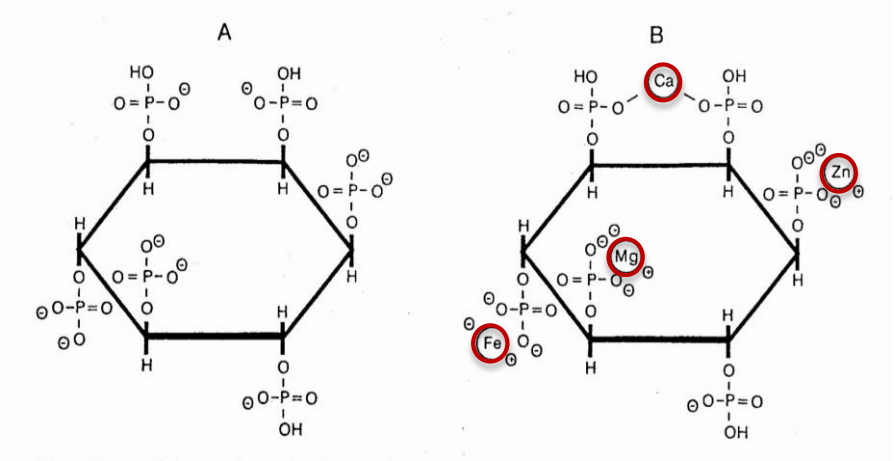
Sourdough fermentation

5.6 → 5.0 → 4.2

Activation



Microbial phytases
(lactic acid bacteria and yeasts)



Phytic acid

Phytic acid chelate

Phytase

EC 3.1.3.8
EC 3.1.3.26

- Inorganic phytate;
- Myo-inositol phosphate esters;
- Free minerals (e.g., Fe^{3+}, Zn^{2+}, Ca^{2+})
- Proteins, peptides, amino acids

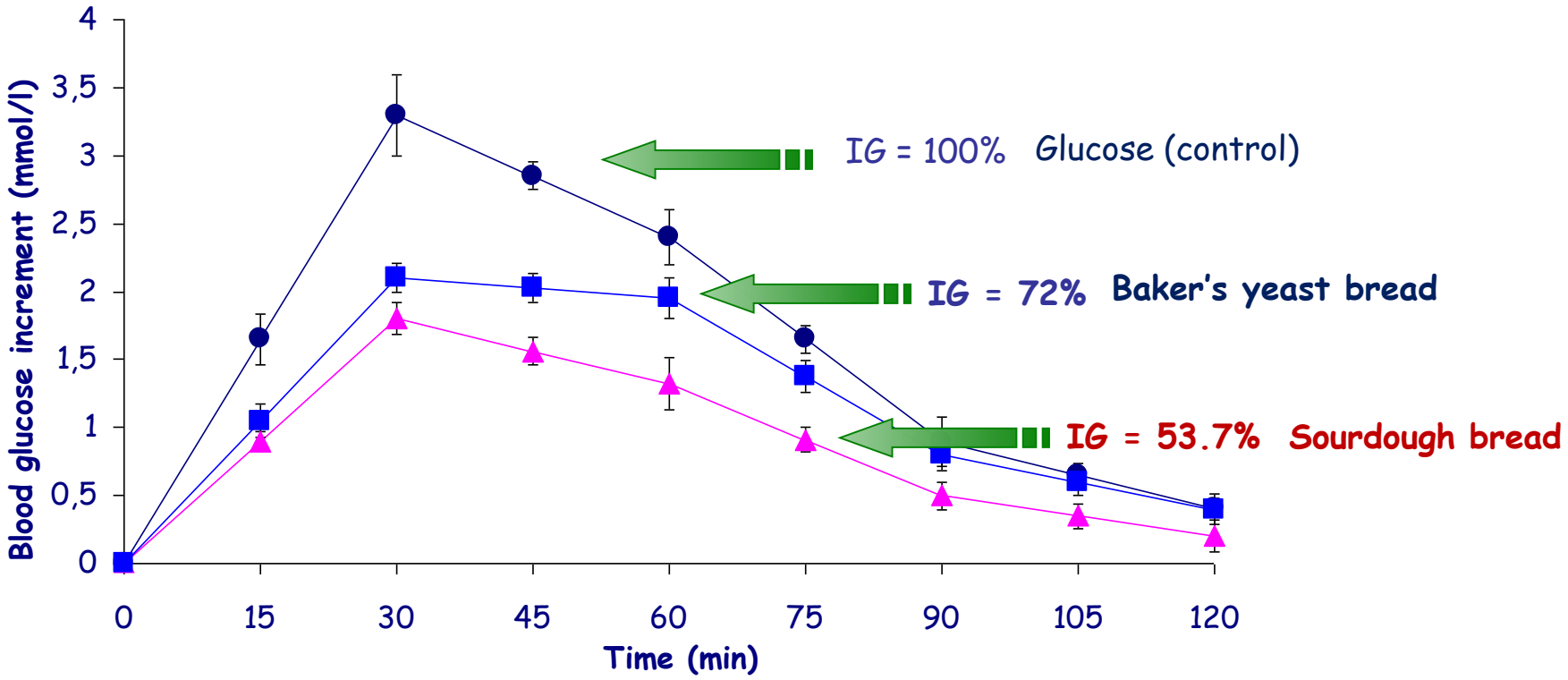
Gobbetti et al., 2014, *Food Microbiol*, 1-11

Decrease of glycaemic index/response

- Sourdough fermentation, possibly combined with the addition of soluble fibre, is an effective tool to decrease glycaemic index (GI) and insulin index (II) (Liljeberg et al. 1995; Juntunen et al. 2003; De Angelis et al., 2006; 2009; Fardet et al. 2006; Maioli et al. 2009; Najjar et al. 2009)

- Not all the sourdoughs impact on GI/II (Hardman Fredensborg et al. 2010)

Decrease of glycaemic index/response



De Angelis et al., 2007 *British J Nutr*, 98: 1196-1205

Hypotheses to explain the effect of sourdough fermentation

- Synthesis of organic acids, especially lactic acid (Liljeberg et al. 1995, *J Nutr* 125:1503; Liljeberg et al. 1998, *Eur J Clin Nutr* 52:368)
- Low pH (Burton and Lightowler 2006, *Br J Nutr* 96:877)
- Chemical changes (Östman 2003, PhD Thesis Lund University)
- Liberation of peptides and amino acids, and free phenolic compounds (Nilsson et al. 2007, *Am J Clin Nutr* 85:996; Katina et al. 2007, *Food Microbiol* 24:175)

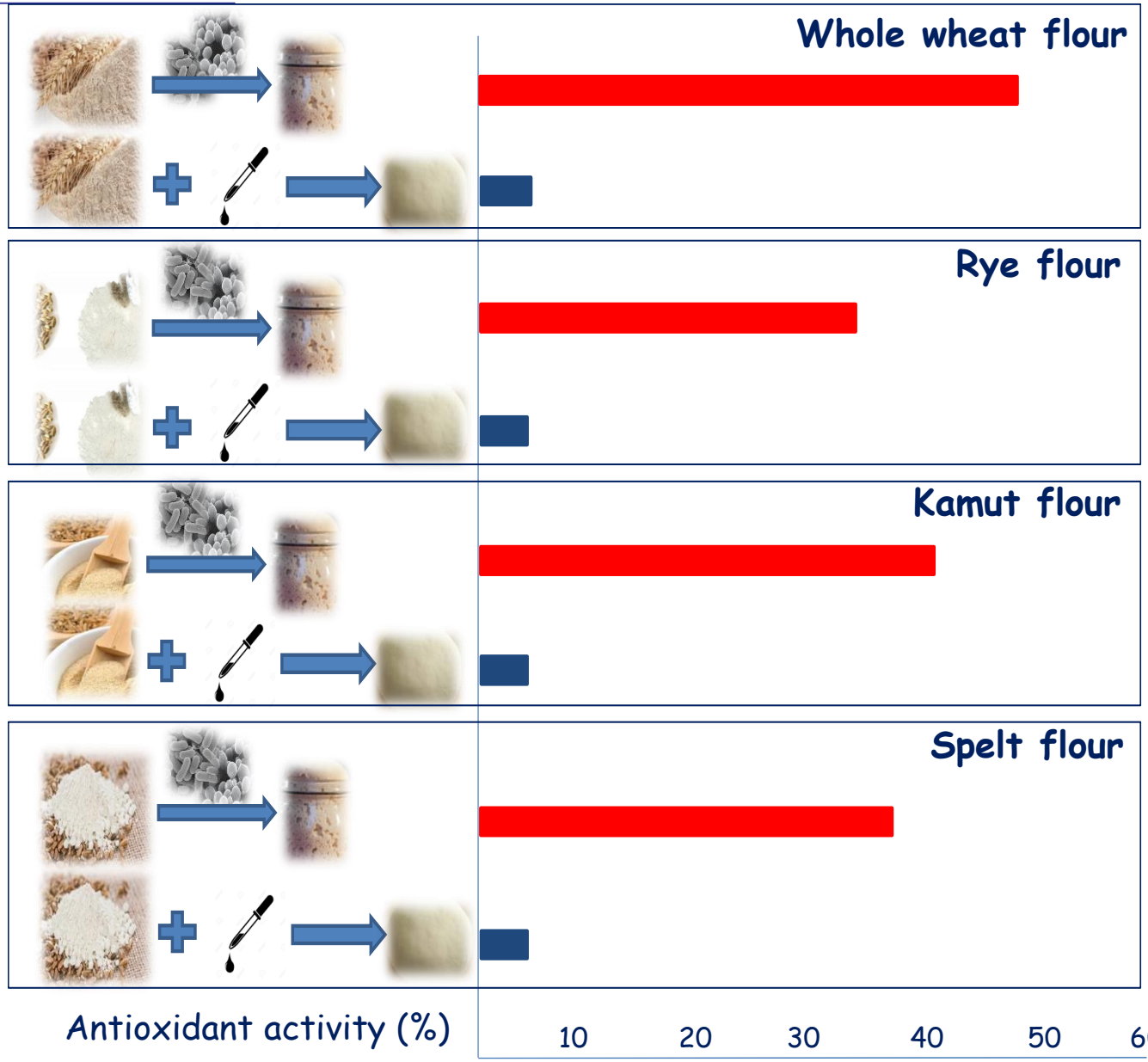
Bioactive peptides

Bioactive or biogenic peptides are defined as specific protein fragments that have a positive impact on the body function or condition, and may, ultimately, influence the human health

(Kits et al. 2003, *Curr Pharm Des* 9:1309)

Antioxidant activity

Coda et al., 2012, *Appl Environ Microbiol* 78, 1087-1096



Antioxidant peptides

Whole wheat

MAPAAVAAAEAGSK

DNIPIVIR

Rye

RLSLPAGPVTVAVSP

PAEMVAAALDR

Kamut

GVSNAAVVAGGH

DAQEFKR

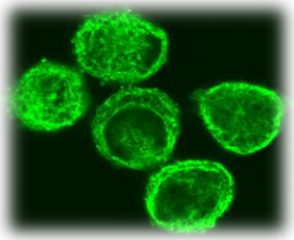
Spelt

GNQEKVLELVQR

HPVPPKKK

Coda et al., 2012, *Appl Environ Microbiol* 78:1087

Antioxidant peptides



Whole wheat flour

MAPAAVAAAAEAGSK
DNIPIPIVIR

Rye flour

RLSLPAGPVTVAVSP
PAEMVAAAALDR

Kamut flour

GVSNAAVVAGGH
DAQEFKR

Spelt flour

GNQEKVLELVQR
HPVPPKKK

CTRL (after oxidative stress)

Coda et al., 2012, *Appl Environ Microbiol* 78, 1087-1096

Lunasin

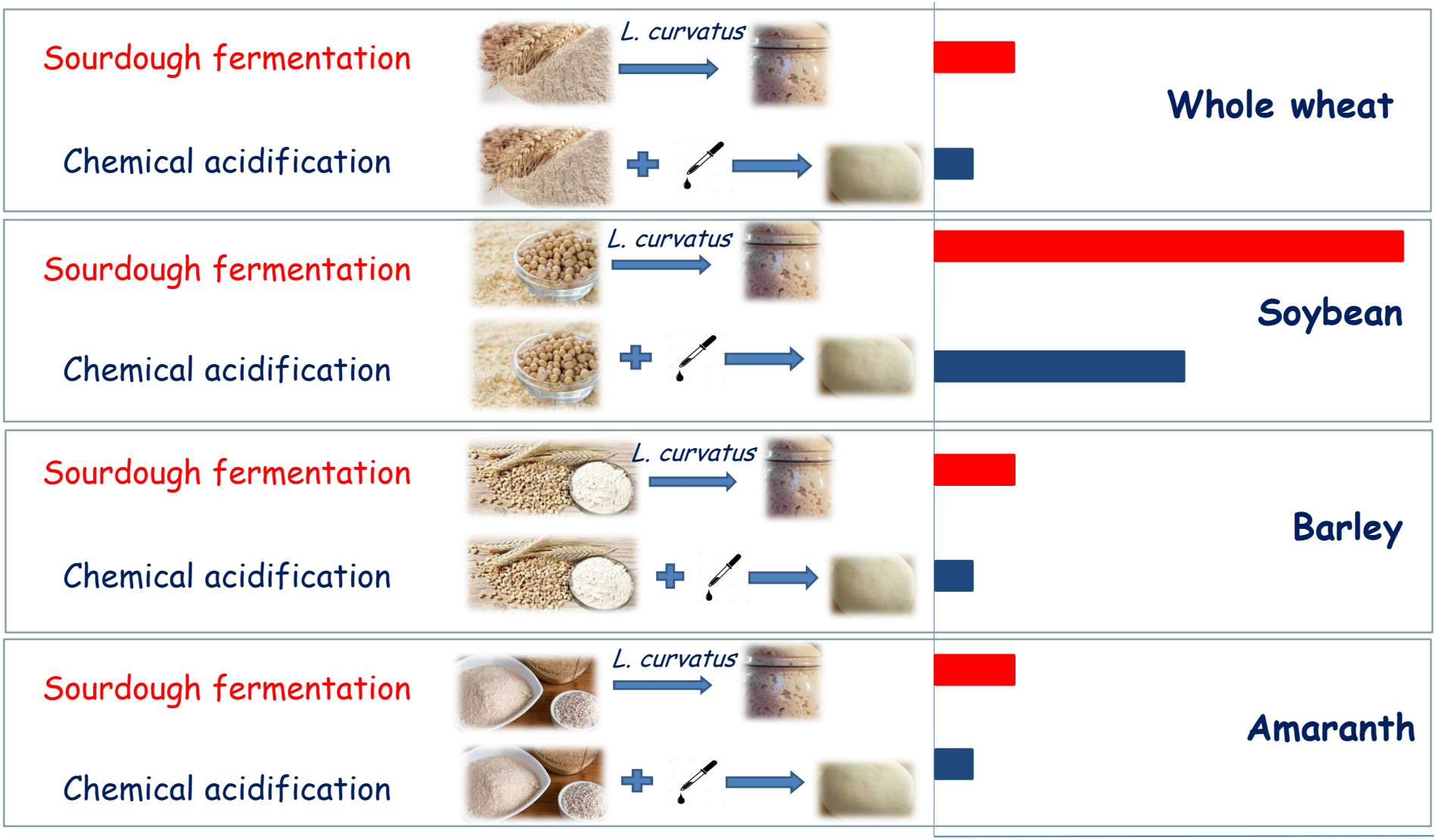
SKWQHQQDSCRKQGVNLTPCEKHIMEKIQGRGDDDDDDDDD

Immunoreactive epitope

- initially isolated from soy (small subunit of albumin Gm2S-1); further isolated from barley, wheat, amaranth, rye, Solanum nigrum)
- carcinogenesis suppressor (inhibitory effect against the core histone acetylation) (Galvez et al. 2011 Cancer Res 61:7473)
- antinflammatory activity (Dia et al. 2009, J Agric Food Chem 57:1260)
- resistant to gastrointestinal digestion: it can reach the blood plasma after oral ingestion (Park et al. 2007, J Agric Food Chem 55:10703)

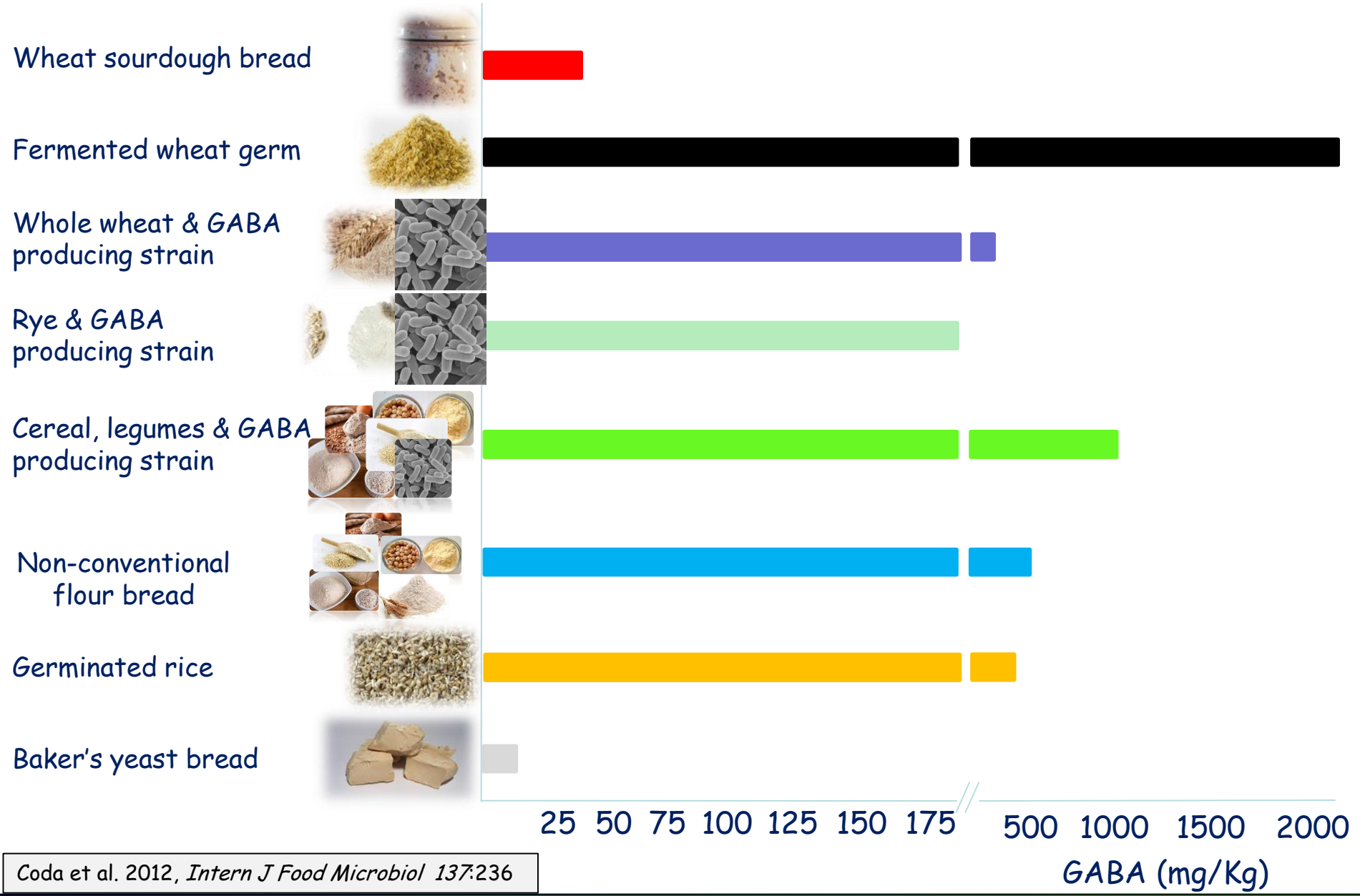
Rizzello et al. 2012, *Nutrition and Cancer* 64:111

Lunasin



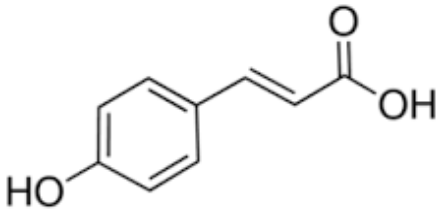
Rizzello et al. 2012, *Nutrition and Cancer* 64:111

γ-Amino butyric acid (GABA)

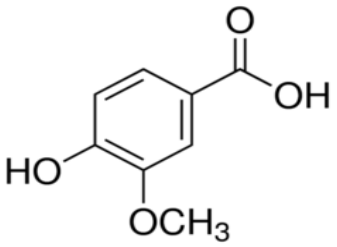


Coda et al. 2012, *Intern J Food Microbiol 137*:236

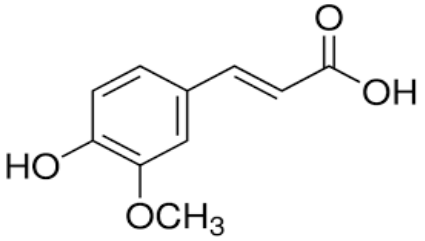
Synthesis/liberation of antioxidant compounds (phenols)



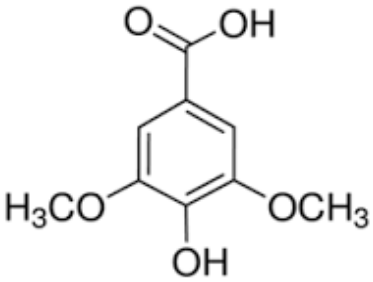
p-Coumaric acid



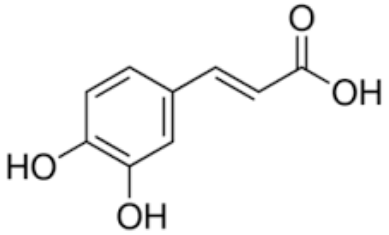
Vanillic acid



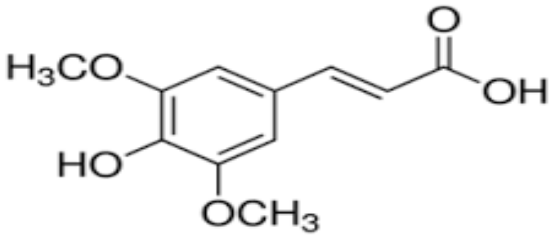
Ferulic acid



Syringic acid



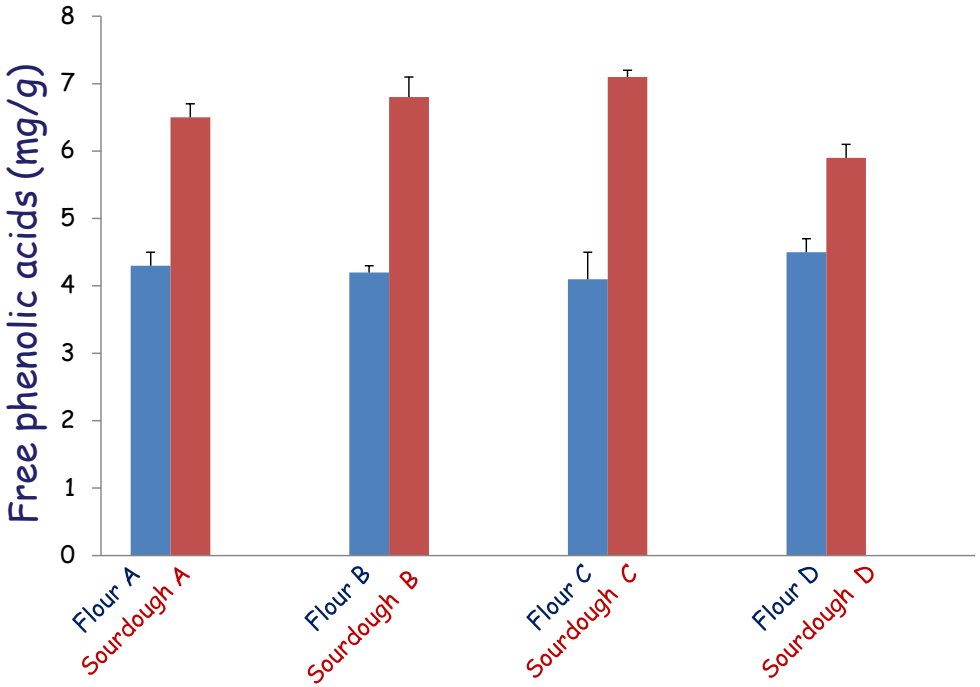
Caffeic acid

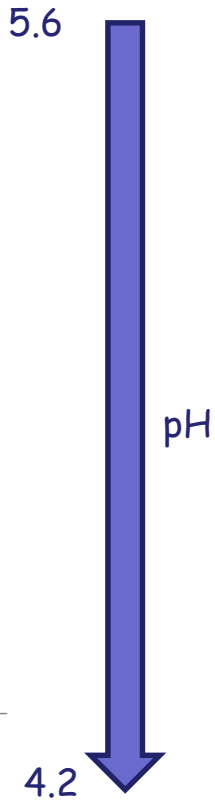


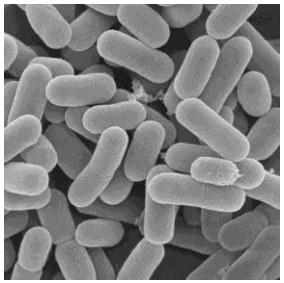
Sinapic acid

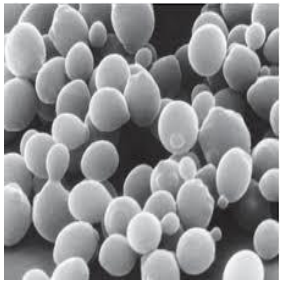
Hydrolysis of phenolic compounds

Sourdough fermentation









Microbial activity
(lactic acid bacteria and yeasts)

EC 3.2.1.21
β-Glucosidase

EC 3.1.1.73
Feruloyl-esterase

Sourdough fermentation

- Solubilization of phenolic compounds
- Increase of the concentration

Rizzello et al., 2014, *Appl. Environm. Microbiol.* 81: 3192-3204

Bio-preservation

VS

Additives

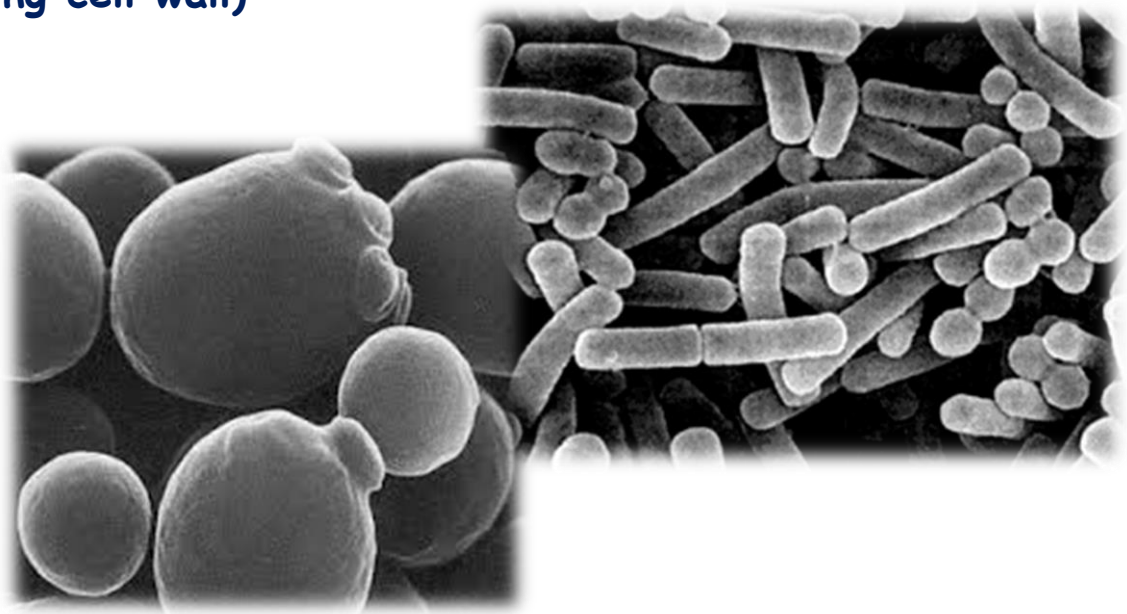
- ✓ Sorbic acid or potassium sorbate or calcium sorbate;
- ✓ Propionic acid or salts (e.g., sodium-, calcium-, and potassium-propionate);
- ✓ Ethanol;
- ✓ Acetic acid or salts (e.g., sodium-, calcium-, and potassium-acetate);
- ✓ Lactic acid or salts (e.g., sodium-, calcium-, and potassium-lactate)

Antifungal activity and baked goods

- ✓ Vegetable matrices (proteins and peptides)




- ✓ Selected lactic acid bacteria (organic acids/antifungal peptides) and yeasts (ethanol + ethyl-acetate/enzymes degrading cell wall)

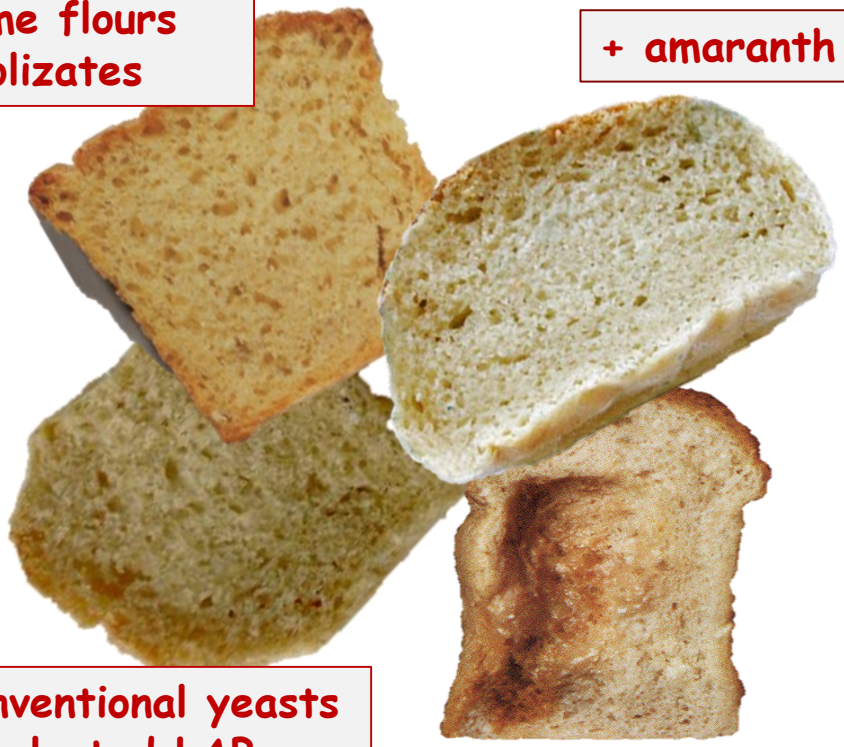
Fungal spoilage of experimental breads

Controls (baker's yeast, no exctracts, no propionate)

(10^2 conidia/ml)

+ legume flours hydrolizates

+ amaranth

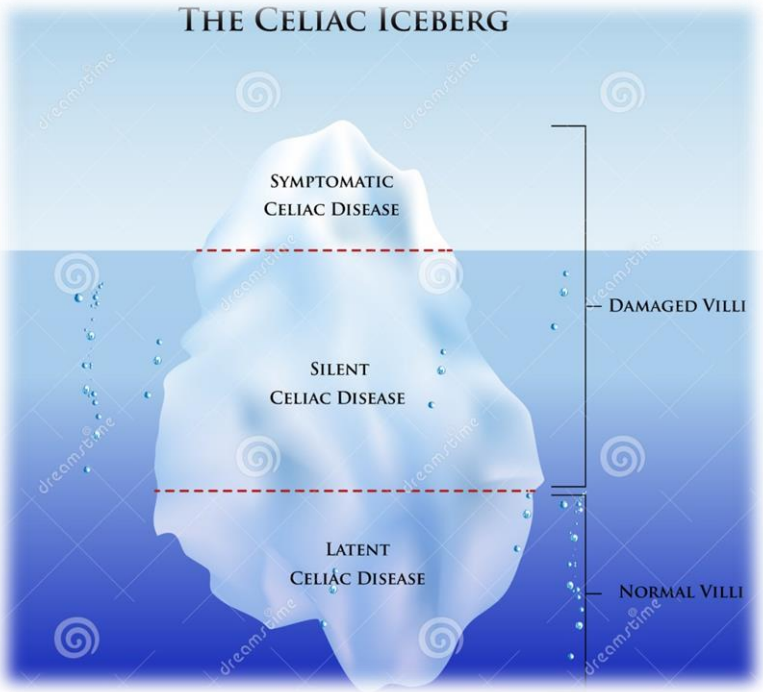


+ non conventional yeasts and selected LAB

+ calcium propionate

Delay of the fungal contamination of two weeks

Novel theraphies for celiac disease (Caputo et al., 2010. *Enzyme Res* 103:75)



- Wheat
- Barley
- Rye
- Spelt
- Kamut
- Triticale
- Oat*

Non-tolerated

- **Oral administration of bacterial endopeptidases** (*Flavobacterium meningosepticum*, *Sphingomonas capsulata*, *Myxococcus xanthus*, *Aspergillus niger*)

(Shan et al. 2004. *Biochem J* 383:311; Marti et al. 2005. *J Pharm Exp Therap* 312:19; Gass et al. 2005. *Biotechnol Bioeng* 92:674; Mitea et al. 2008. *Gut* 57:25)

- **Transamidation of gliadin**

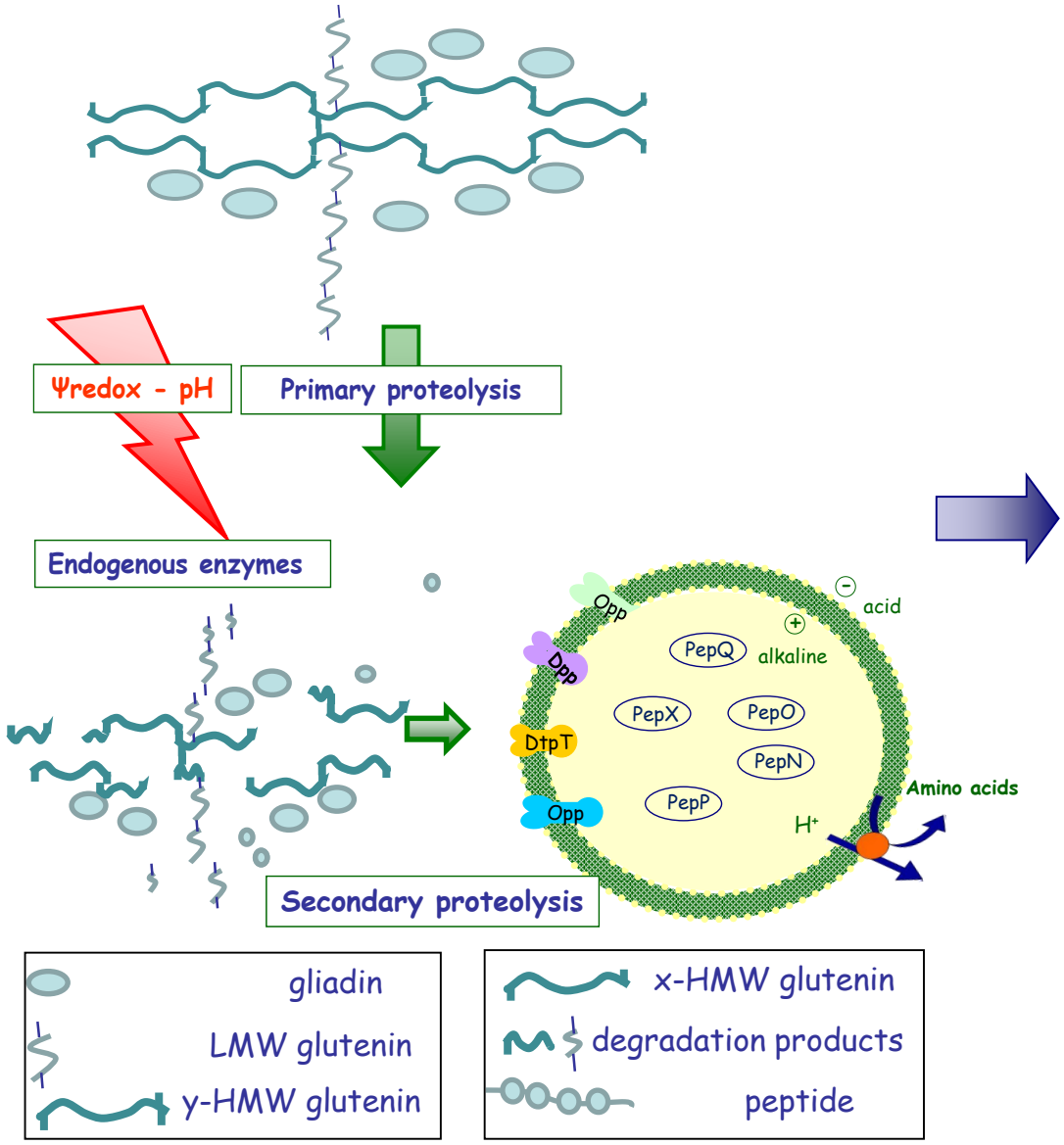
(Gianfrani et al. 2007. *Gastroenterology* 133:780)

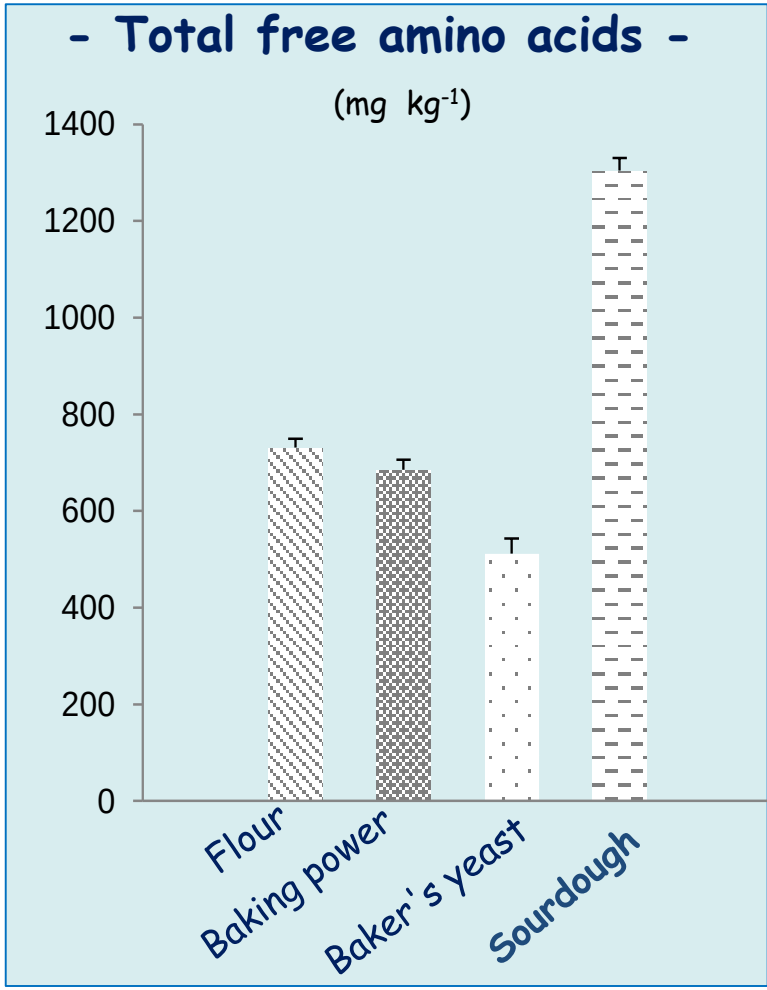
- **Transglutaminase inhibitors**

Esposito et al. 2007. *Cur Med Chem* 14:2572; Wodzinska et al. 2005. *Med Chem* 5:279; Dolyuchuk 1996. *Plast Reconst Surgery* 98:752; Hoffmann et al. 2009. *J Agric Food Chem* 57:10150).

Proteolysis during sourdough fermentation

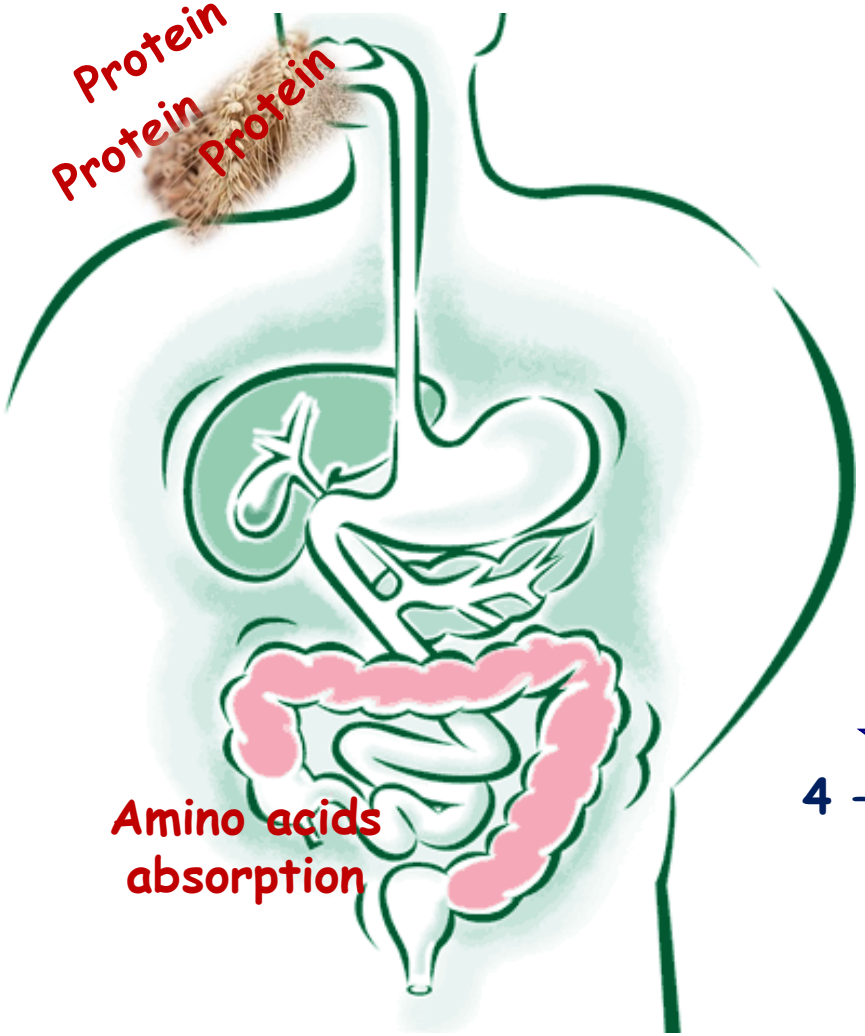
Ganzle *et al.* 2008, Trends Food Sci Technol 19:513





Gobbetti *et al.*, 1994 J. Food Sci. 59: 881-884

Human digestion



4 – 6 h

Sourdough fermentation

24 – 36 h

Altomare *et al.*, 1999. Dis. Colon Rectum, 42: 231–240;
Perri *et al.*, 2010. Dig. Liver Dis., doi:10.1016/j.dld.2010.01.001

APPLIED AND ENVIRONMENTAL MICROBIOLOGY, Feb. 2004, p. 1088–1096 Vol. 70, No. 2
0099-2240/04/$08.00+0 DOI: 10.1128/AEM.70.2.1088–1096.2004

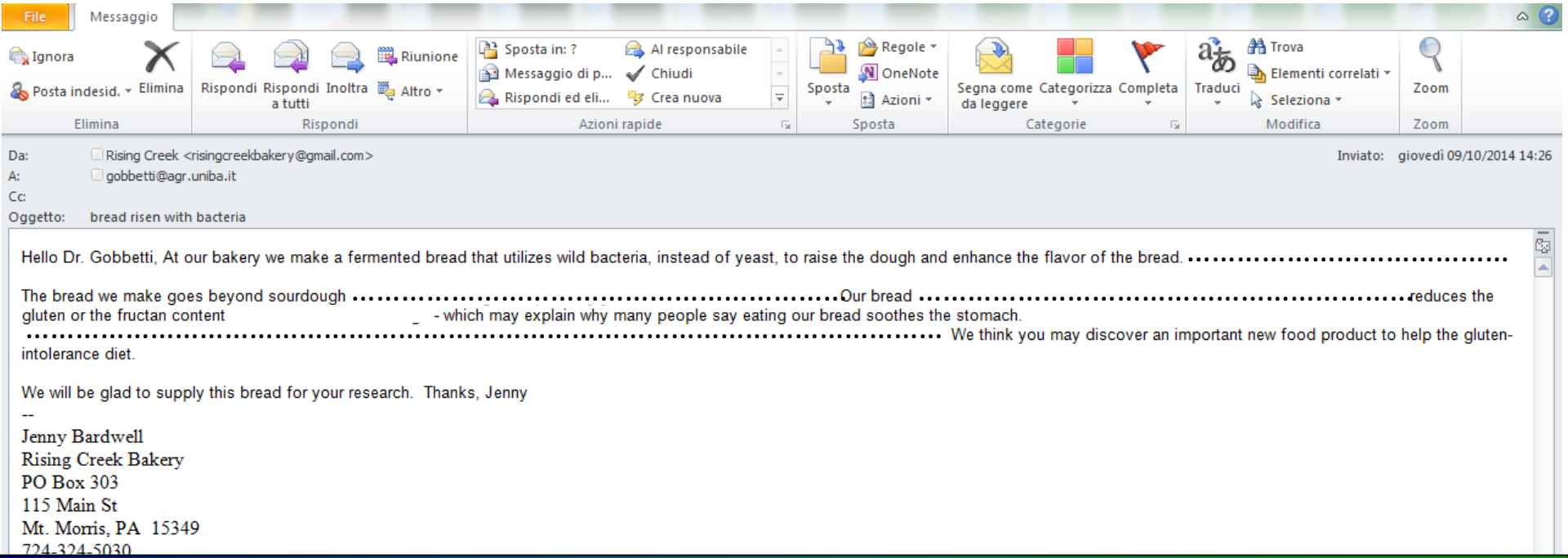
Sourdough Bread Made from Wheat and Nontoxic Flours and Started with Selected Lactobacilli Is Tolerated in Celiac Sprue Patients

Raffaella Di Cagno,[1]† Maria De Angelis,[2]† Salvatore Auricchio,[3] Luigi Greco,[3] Charmaine Clarke,[4] Massimo De Vincenzi,[5] Claudio Giovannini,[5] Massimo D'Archivio,[5] Francesca Landolfo,[3] Giampaolo Parrilli,[3] Fabio Minervini,[1] Elke Arendt,[4] and Marco Gobbetti[1]*

ACKNOWLEDGMENTS

This work was supported by the Italian Ministry of University and Scientific and Technological Research (Murst), Development of Research Networks no. 488/92, cluster C06 + 07, project 6-2.2.

We thank P. F. Fox for critical revision of the paper and Giuditta Alfonsi and Valeria Ancona for technical support. M.G. thanks his father for the practical suggestions which promoted the idea of this work.



File Messaggio

Ignora | Posta indesid. | Elimina — Elimina
Rispondi | Rispondi a tutti | Inoltra | Riunione | Altro — Rispondi
Sposta in: ? | Messaggio di p... | Rispondi ed eli... | Al responsabile | Chiudi | Crea nuova — Azioni rapide
Sposta | Regole | OneNote | Azioni — Sposta
Segna come da leggere | Categorizza | Completa — Categorie
Traduci | Trova | Elementi correlati | Seleziona — Modifica
Zoom — Zoom

Da: Rising Creek <risingcreekbakery@gmail.com>
A: gobbetti@agr.uniba.it
Cc:
Oggetto: bread risen with bacteria
Inviato: giovedì 09/10/2014 14:26

Hello Dr. Gobbetti, At our bakery we make a fermented bread that utilizes wild bacteria, instead of yeast, to raise the dough and enhance the flavor of the bread. .....

The bread we make goes beyond sourdough .....Our bread .....reduces the gluten or the fructan content - which may explain why many people say eating our bread soothes the stomach.
..... We think you may discover an important new food product to help the gluten-intolerance diet.

We will be glad to supply this bread for your research. Thanks, Jenny
--
Jenny Bardwell
Rising Creek Bakery
PO Box 303
115 Main St
Mt. Morris, PA 15349
724-324-5030

List of articles leading with gluten degradation

- **Di Cagno et al.**, 2002. Proteolysis by sourdough lactic acid bacteria: effects on wheat flour protein fractions and gliadin peptides involved in human cereal intolerance. *Applied and Environmental Microbiology*, 68:623–633.
- **Di Cagno et al.**, 2004. Sourdough bread made from wheat and nontoxic flours and started with selected lactobacilli is tolerated in celiac sprue patients. *Applied and Environmental Microbiology*, 70:1088–1096.
- **Di Cagno et al.**, 2005. Pasta made from durum wheat semolina fermented with selected lactobacilli as a tool for a potential decrease of the gluten intolerance. *Journal of Agricultural and Food Chemistry*: 53 (11):4393–4402.
- **De Angelis et al.**, 2006a. VSL#3 probiotic preparation has the capacity to hydrolyze gliadin polypeptides responsible for celiac sprue. *Biochimica et Biophysica Acta*, 1762:80–93.
- **De Angelis et al.**, 2006b. Fermentation by selected sourdough lactic acid bacteria to decrease the intolerance to rye and barley flours. *Journal of Cereal Science*, 43:301–314.
- **Gobbetti et al.**, 2007. Sourdough lactobacilli and celiac disease. *Food Microbiology*, 24(2):187-196.
- **Rizzello et al., 2007. Highly efficient gluten degradation by lactobacilli and fungal proteases during food processing: new perspectives for celiac disease. *Applied and Environmental Microbiology*, 73(14):4499-4507.**
- **Di Cagno et al.**, 2009. Different fecal microbiotas and volatile organic compounds in treated and untreated children with celiac disease. *Applied and Environmental Microbiology*, 75(12):3963–3971.
- **De Angelis et al.**, 2010. Mechanism of degradation of immunogenic gluten epitopes from *Triticum turgidum* L. var. *durum* by sourdough lactobacilli and fungal proteases. *Applied and Environmental Microbiology*, 76(2):508–518.
- **Di Cagno et al.**, 2010. Gluten-free sourdough wheat baked goods appear safe for young celiac patients: a pilot study. *Journal of Pediatric Gastroenterology & Nutrition*, 51(6):777–783.
- **Greco et al.**, 2011. Safety for patients with celiac disease of baked goods made of wheat flour hydrolyzed during food processing. *Clinical Gastroenterology and Hepatology*, 9(1):24-29.
- **Di Cagno et al.**, 2011. Duodenal and faecal microbiota of celiac children: molecular, phenotype and metabolome characterization. *BMC Microbiology*, 11,
- **Rizzello et al.**, 2014. Use of fungal proteases and selected sourdough lactic acid bacteria for making wheat bread with an intermediate content of gluten. *Food Microbiology*, 37;59-68.
- **Curiel et al.**, 2014. Manufacture and characterization of pasta made with wheat flour rendered gluten-free using fungal proteases and selected sourdough lactic acid bacteria. *Journal of Cereal Science*, 59;79-87.
- **Rizzello** et al. 2016. Characterization of the bread made with durum wheat semolina rendered gluten free by sourdough biotechnology in comparison with commercial gluten-free products. *Journal of Food Science*, doi:10.1111/1750-3841.13410.

Pool 1 (ca. log 9/ml)

Lb. brevis 14G
Lb. alimentarius 15M
Lb. hilgardii 51B
Lb. sanfranciscensis 7A

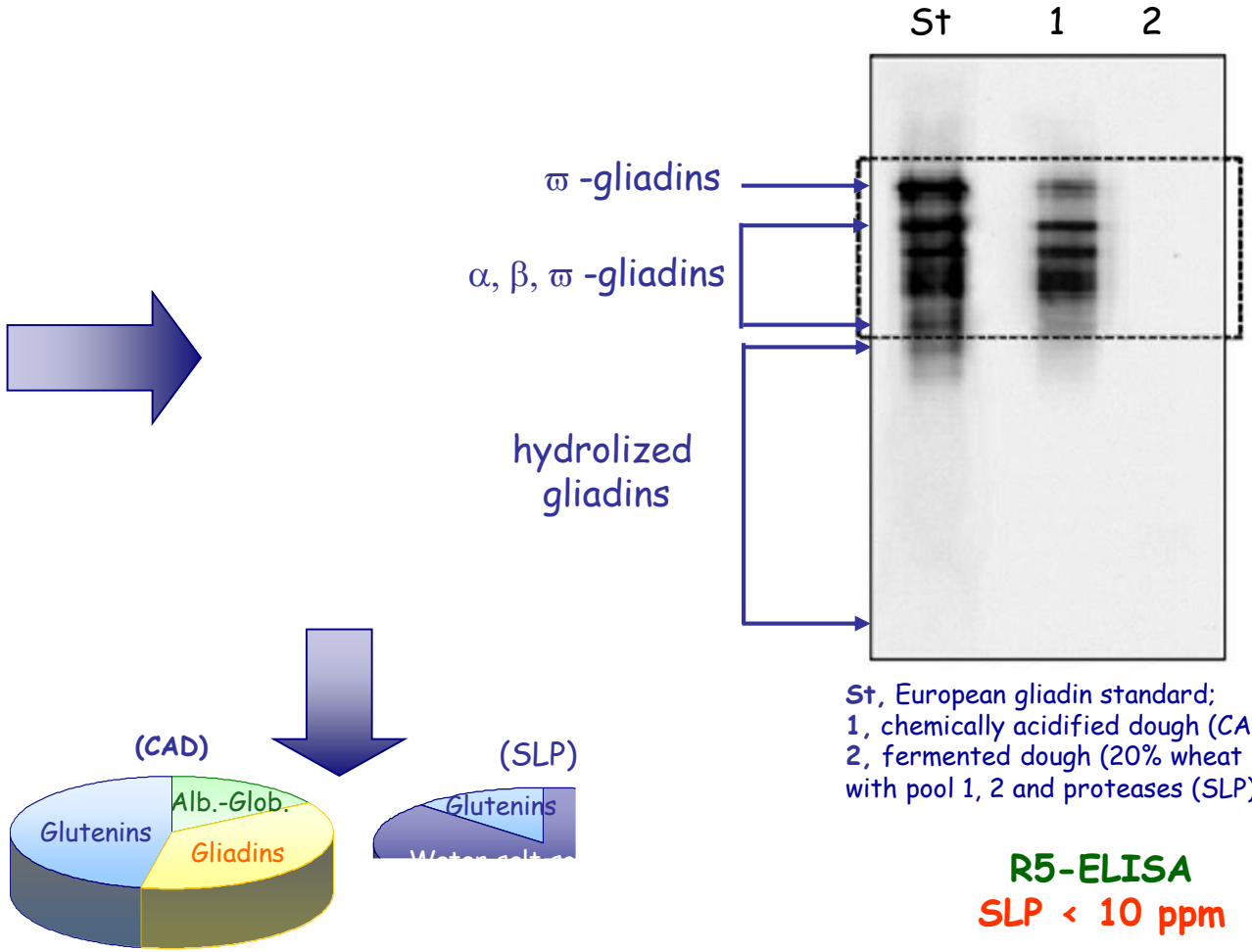
+

Pool 2 (ca. log 8/ml)

Lb. sanfranciscensis E14
Lb. sanfranciscensis E21
Lb. sanfranciscensis 174
Lb. sanfranciscensis 13
Lb. sanfranciscensis A1
Lb. sanfranciscensis 274

+

Fungal proteases (200 ppm)



St, European gliadin standard;
1, chemically acidified dough (CAD);
2, fermented dough (20% wheat flour) with pool 1, 2 and proteases (SLP)

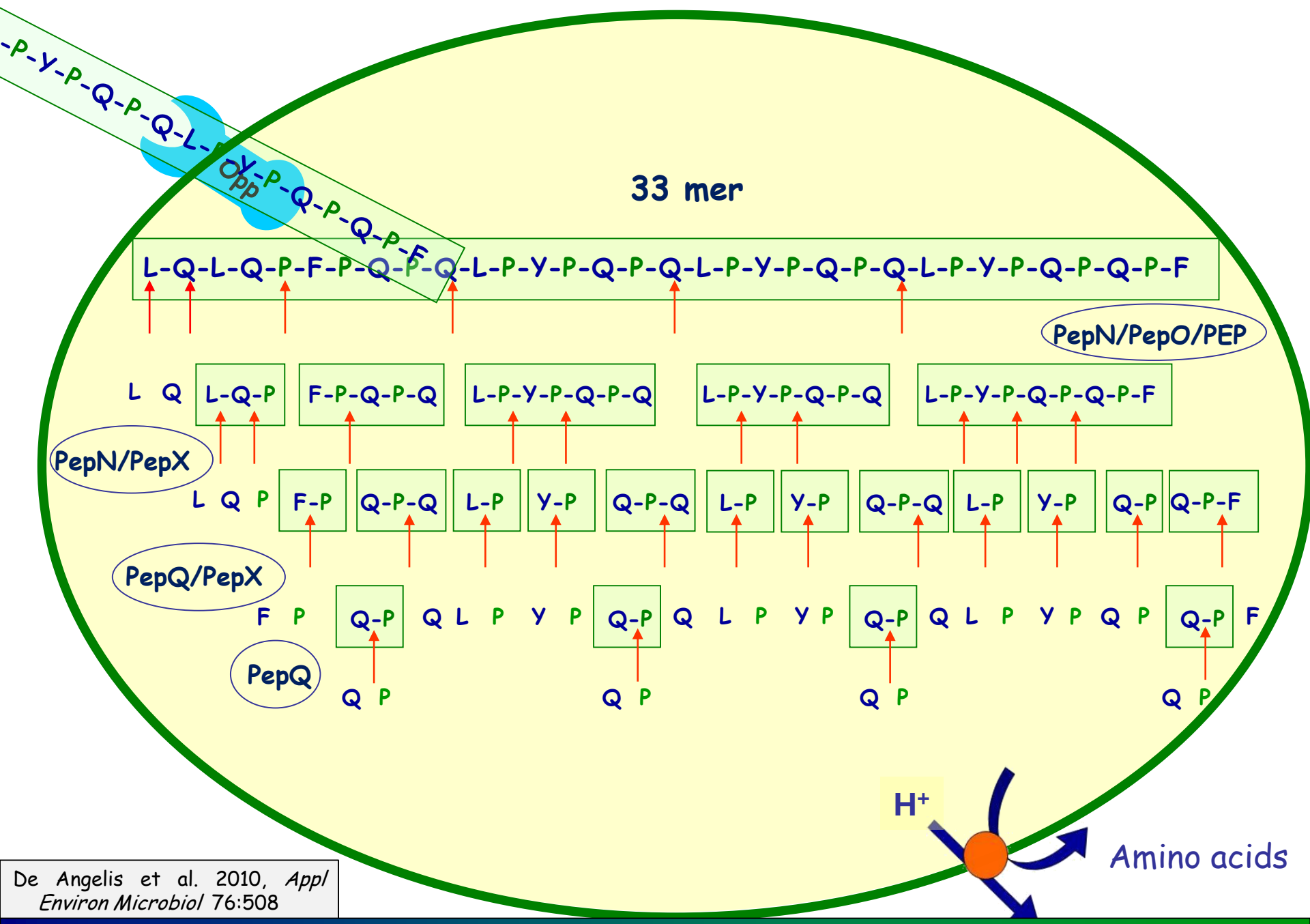
R5-ELISA
SLP < 10 ppm

Organic nitrogen concentration of spray-dried flour

APPLIED AND ENVIRONMENTAL MICROBIOLOGY, July 2007, p. 4499–4507 Vol. 73, No. 14
0099-2240/07/$08.00+0 doi:10.1128/AEM.00260-07

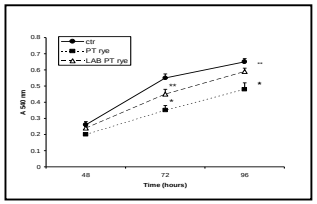
Highly Efficient Gluten Degradation by Lactobacilli and Fungal Proteases during Food Processing: New Perspectives for Celiac Disease[▽]

Carlo G. Rizzello,[1] Maria De Angelis,[1] Raffaella Di Cagno,[1] Alessandra Camarca,[2] Marco Silano,[3] Ilario Losito,[4] Massimo De Vincenzi,[3] Maria D. De Bari,[4] Francesco Palmisano,[4] Francesco Maurano,[2] Carmen Gianfrani,[2] and Marco Gobbetti[1]*



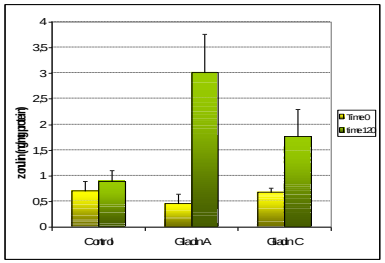
De Angelis et al. 2010, *Appl Environ Microbiol* 76:508

Viability of Caco-2/TC7 cells

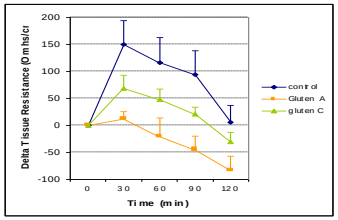


(De Angelis et al. 2006a)

Zonulin Release (IEC-6)

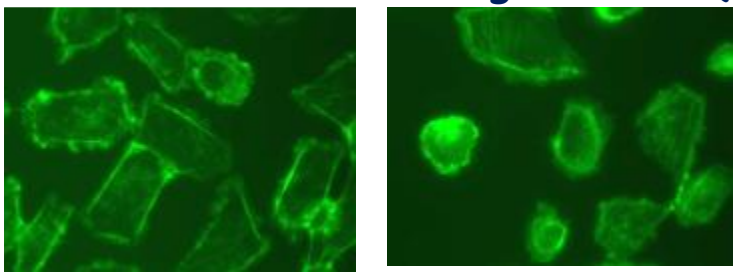


Tissue epithelial electrical resistance

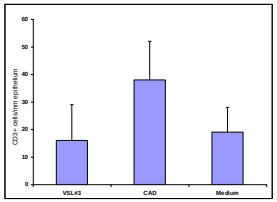


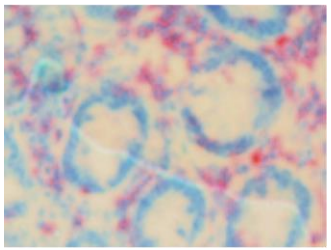
(De Angelis et al. 2006b)

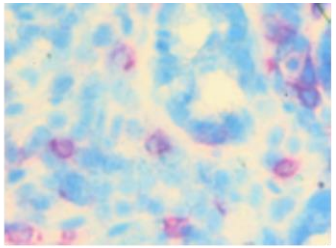
Intracellular F-actin reorganization (IEC-6)



CD3+ intraepithelial lymphocytes infiltration

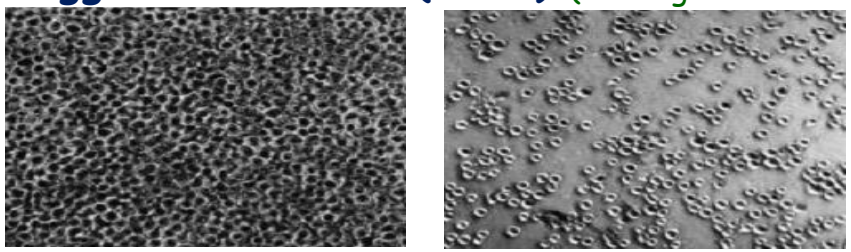






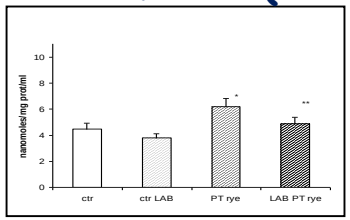
Agglutination test (K562)

(De Angelis et al. 2006b)

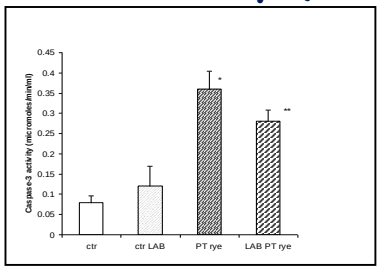


(Di Cagno et al., 2004; De Angelis et al. 2006a, 2006b)

Synthesis of NO (Caco-2)

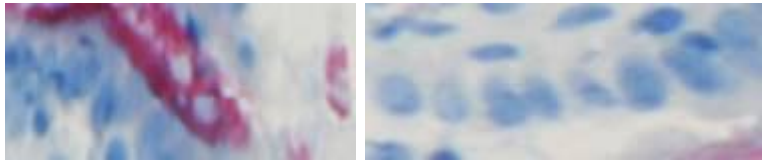


Caspase 3 activity (Caco-2)



(De Angelis et al. 2006a)

Fas expression (biopsies)



(De Angelis et al. 2006)

Clinical Challenge 2: Pediatrics and European Laboratory for the Study of Food Induced Diseases University of Naples, Federico II, Italy

Biscuits (200 g) corresponding to 100 g of processed wheat flour which contained 8 g of hydrolyzed gluten

Clinical challenge

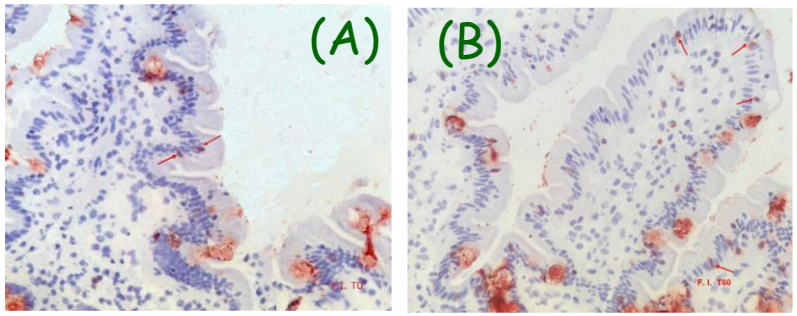
- Sixteen CD patients (age median 19, range 12-23 years),
- Daily consumption of ca. 200 g of biscuits,
- The challenge lasted 60 days

Greco et al. 2011, *Clin Gastroenterol Hepatol* 78:1087

	TIME	tTG	MARSH GRADE	CD3	γδ	CD25
F.I.	t_0	1.6	T0	39	5.6	6
	t_{60}	1.0	T0	38	8.6	5
I.C.	t_0	1.9	T0	3.7	0.9	11
	t_{60}	1.1	T0	11	3.8	9
R.R.	t_0	0.3	T1	53	11.5	3
	t_{60}	0.3	T1	56	17.8	4
I.I.	t_0	0.5	T0	31	8.4	21
	t_{60}	0.3	T0	36	12.8	21
C.C.	t_0	0.4	T0	32	21	3
	t_{60}	0.7	T0	47	18	7

tTG, anti-tissue transglutaminase antibodies; T0, normal duodenal mucosa; CD3, T1, architecturally normal duodenal mucosa with increased intraepithelial lymphocytes infiltration; and CD3, γδ CD25 are markers for intraepithelial lymphocytes in duodenal mucosa

Density of σδ⁺ intraepithelial lymphocytes in jejunal biopsy from patient 4 F.I. at the beginning (panel A) and after 60 day of challenge (panel B)



Water, wheat flour, fungal proteases, selected sourdough lactic acid bacteria

- Long-time
- Semi-liquid sourdough fermentation

1

Addition of gluten-free ingredients (rice, mais, starch, gums)

(short-time baker's yeast fermentation)

Wheat gluten-free baked goods

2

Spray dryer

Wheat gluten-free flour

(short-time baker's yeast fermentation)

(structuring agents)

Patent number(s) WO2014033765-A1, US2014065262-A1. Giuliani et al. 2014

PRODUCT REPORTED TO THE HEALTH MINISTRY.

GUARANTEED GLUTEN-FREE

Yes, you can

revolutionises the gluten-free world

Bontà di Pane

the first bread made of deglutenised wheat

FROM TRADITION TO INNOVATION

- The first gluten-free wheat bread
- Years of study of the natural rising process have permitted Giuliani to select patented enzymes and lactic cultures that eliminate gluten from wheat flour
- These patented enzymes and lactic cultures combined with the traditional bread-making method featuring a slow rising process permit creation of the first bread with deglutenised wheat flour

UNIQUE BREAD

- With all the properties of traditional bread
- Light and tasty
- All the flavor and fragrance of real bread
- All the nutritional properties of wheat, with complete fibre, vitamin, mineral and amino acid content
- Long-lasting
- Perfect for coeliacs and for anyone who is sensitive to gluten, has difficulty digesting it or stands to benefit from a gluten-free diet

OFFICIALLY REPORTED AND TESTED

- Reported to the Italian Health Ministry
- Guaranteed gluten-free with testing of every lot of deglutenised wheat flour and every lot of finished product
- Clinical tests have demonstrated perfect tolerance among coeliacs

Yes, you can

revolutionises the gluten-free world

Bontà di Pane

the first bread made of deglutenised wheat

PRODUCT REPORTED TO THE HEALTH MINISTRY.

GUARANTEED GLUTEN-FREE

"The advantages of the bread made with hydrolyzed gluten"

- ✓ Better flavour

"The advantages of the bread made with hydrolyzed gluten"

- ✓Extended shelf life

"The advantages of the bread made with hydrolyzed gluten"

Wheat gluten-free bread

Naturally gluten-free bread

✓ Better technology features

"The advantages of the bread made with hydrolyzed gluten"

✓ Better nutritional profile

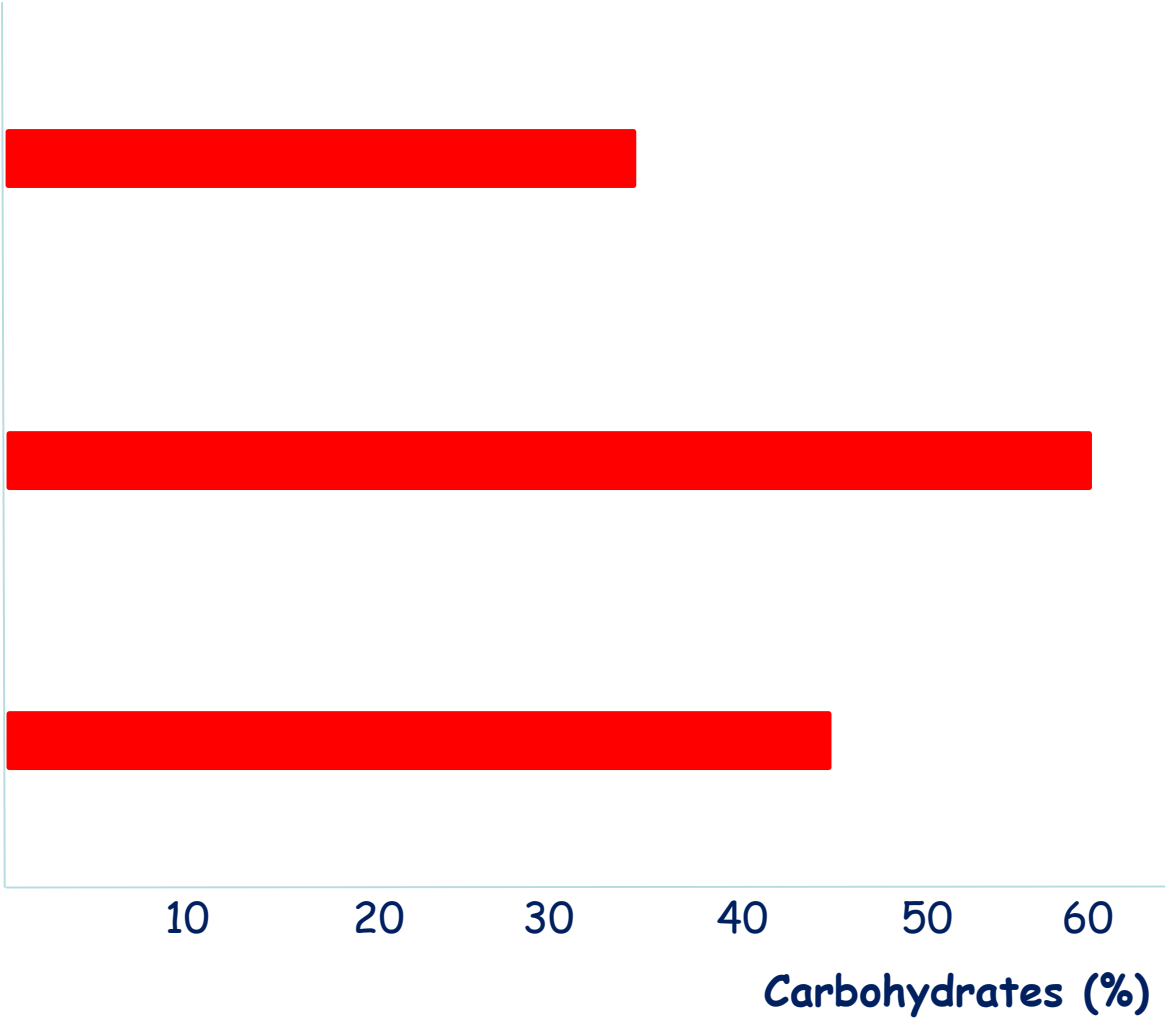
INFORMAZIONI NUTRIZIONALI - Valori medi per 100 g NUTRITIONAL INFORMATION - Values calculated on 100 g	
ENERGIA ENERGY	KJ/kcal 1477/353
GRASSI FATS	1,3 g
Di cui acidi grassi saturi Of which saturated	0,3 g
Di cui colesterolo Of which cholesterin	< 0,1 mg
CARBOIDRATI CARBOHYDRATES	77,5 g
Di cui zuccheri Of which sugar	0,3 g
FIBRE ALIMENTARI DIETARY FIBRES	1,8 g
PROTEINE PROTEINS	6,9 g
SALE SALT	0,02 g

Carbohydrates

Wheat gluten-free bread

Naturally gluten-free bread

Gluten containing bread



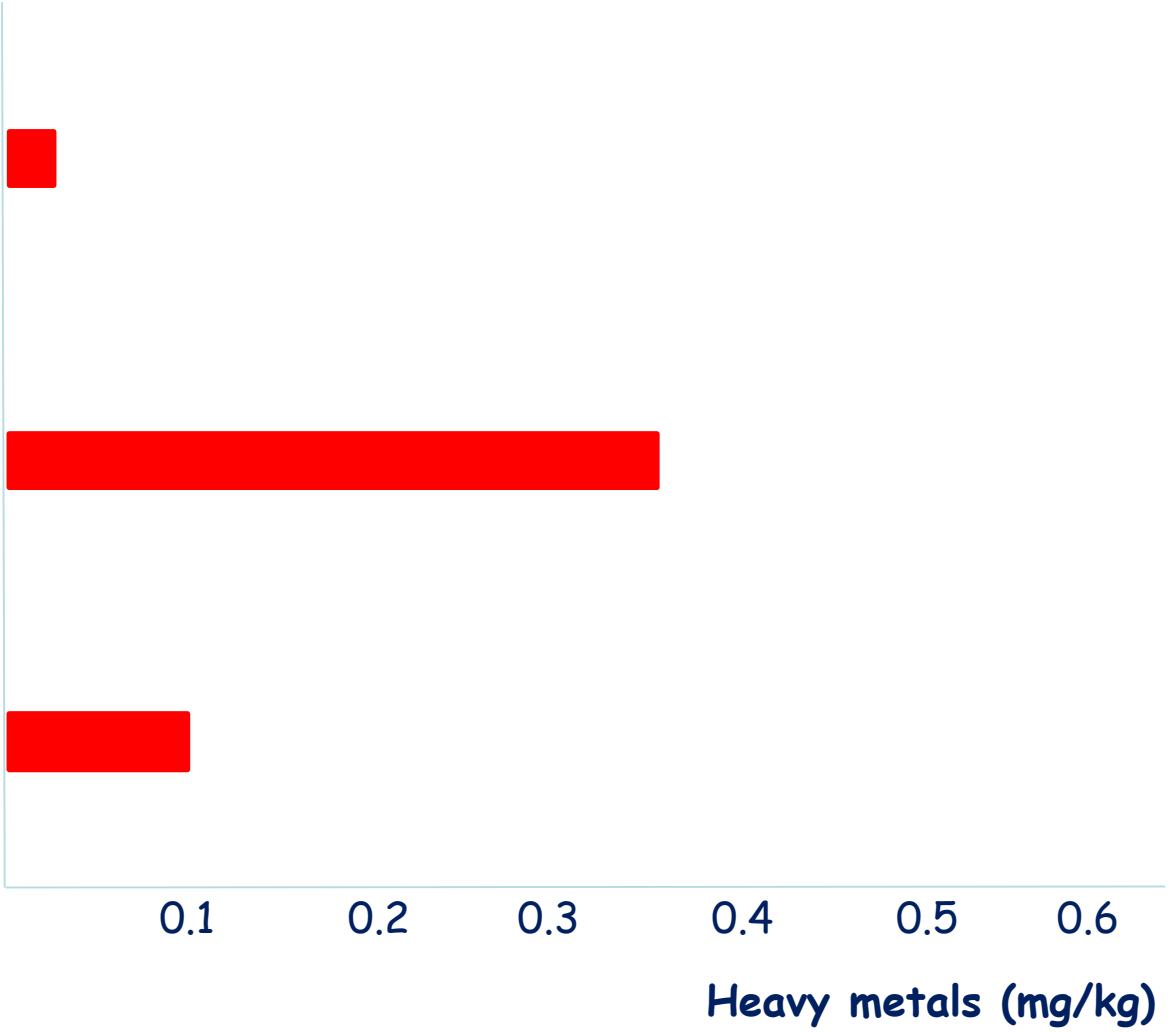
Rizzello et al., 2016. *J Food Sci*, doi: 10.1111/1750-3841.13410

Heavy metals

Wheat gluten-free bread

Naturally gluten-free bread

Gluten containing bread



Rizzello et al., 2016. *J Food Sci*, doi: 10.1111/1750-3841.13410

Mycotoxins

Content (µg/kg)	Wheat gluten-free bread	Gluten containing bread	Naturally gluten-free bread
			
Aflatoxins	n.d.	n.d.	n.d.
T2	n.d.	n.d.	n.d.
HT2	n.d.	n.d.	n.d.
Ochratoxin	n.d.	0.4±0.2	n.d.
Fumonisins	n.d.	n.d.	19.2±0.8
Zearalenone	n.d.	n.d.	45.0±1.1
Deoxynivalenol	n.d.	46.3±0.8	254.5±1.2

Rizzello et al., 2016. *J Food Sci*, doi: 10.1111/1750-3841.13410

NCGS and IBS

Non-celiac gluten sensitivity (NCGS)

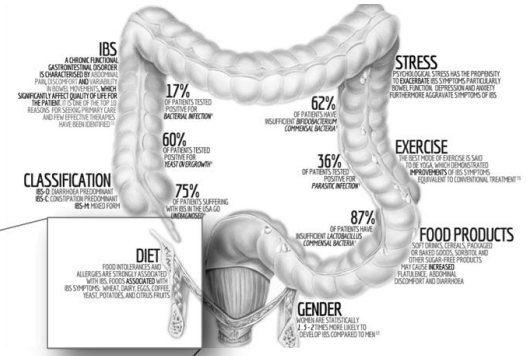
10% of the world's population

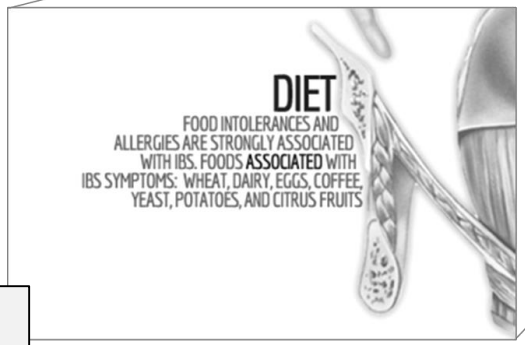
People with celiac disease

People who will develope celiac disease

People with non-celiac gluten sensitivity

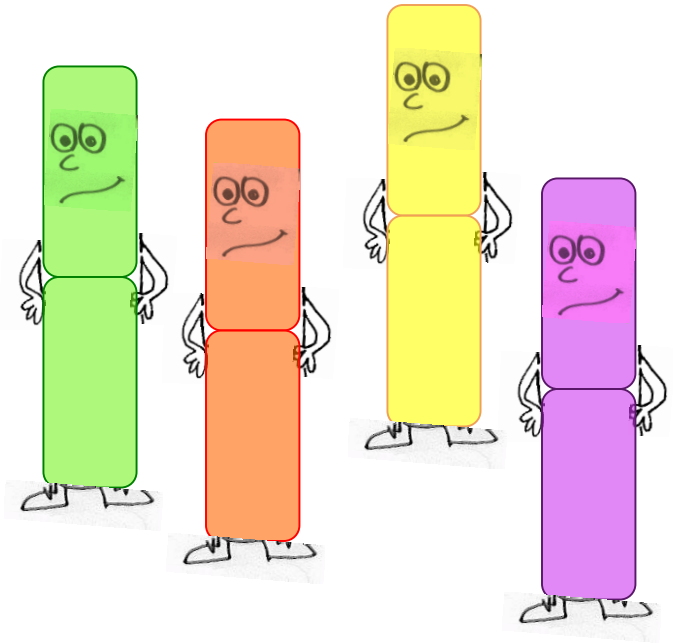
Irritable bowel syndrome (IBS)



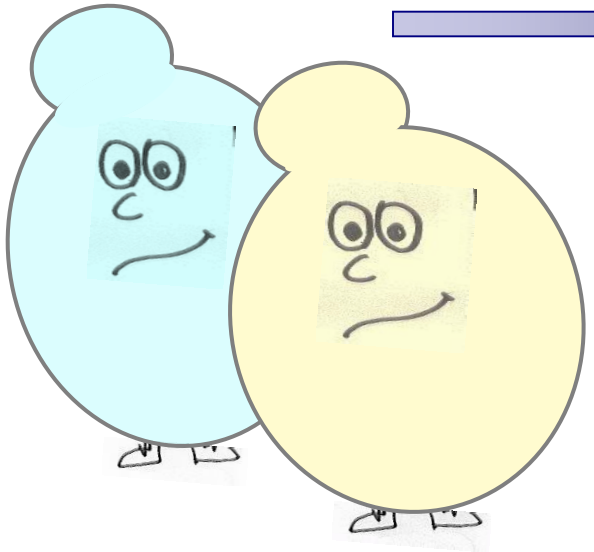


Chang. 2014, *World J Gastroenterol*. 20:2499-2514
Catassi et al. 2013, *Nutrients*. 5:3839-3853

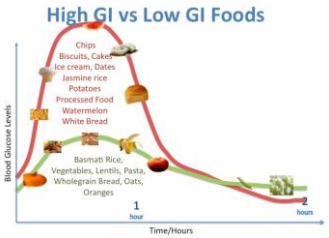
Interim prospects



Taking care of our «friends»



- ✓ Low glycemic index



- ✓ High content of fibres

- ✓ Enriched of high value of by-products (e.g., wheat germ)

- ✓ Naturally preserved

- ✓ Null-, low-, intermediate-gluten content