
Cereal Based Products For The Future

Prof Elke Arendt

School of Food and Nutritional Sciences
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School of Food and Nutritional Science

1920er

Dairy Science Institute



1978

Food Science and Technology
Building
Food Processing Hall
Department of Agriculture



1994

Food Science and Technology
Research Complex
Department of Education

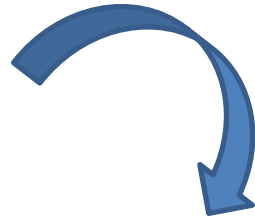


Malting and Brewing facilities



CEREAL AND BREWING SCIENCE AT THE UCC

- Prof. Elke K. Arendt
 - 4 Post Docs
 - 12 PhD students
 - 4 MSc students
 - 3 Researcher

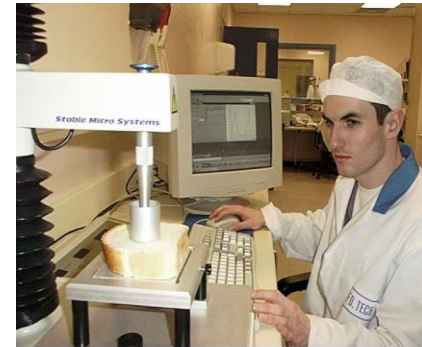


CEREAL RESEARCH

- ✓ Gluten free cereal products
- ✓ Antimicrobial agents
- ✓ Reduction of calories in cereal products
- ✓ Sourdough starters and microbial metabolites
- ✓ Improving the nutritional quality of products
- ✓ Utilization of brewing by-products
- ✓ Rheology & ultrastructure
- ✓ Proteomics

BEVERAGE RESEARCH

- ✓ Starter culture development for malting and brewing
- ✓ Functional beverages
- ✓ Malting and brewing with alternative cereals



Coeliac Disease – Gluten free bread



Coeliac Disease

What is coeliac disease?

- ✚ Autoimmune disease
- ✚ Intolerance to gluten
- ✚ Changes to the lining of the upper part of intestine
- ✚ Malabsorption

Symptoms:

Infancy (0-2 years)

Diarrhoea, Abdominal distension, Failure to thrive, Anorexia and Psychomotor impairment

Childhood

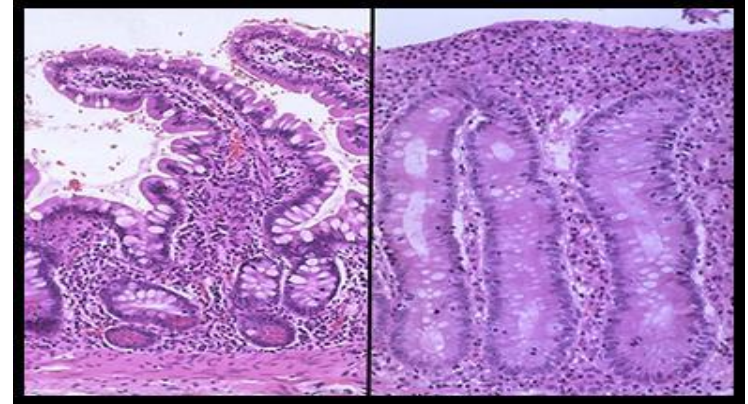
Diarrhoea or constipation
Anaemia
Loss of appetite

Adulthood

Diarrhoea or constipation
Anaemia
Aphthous ulcers, sore tongue and mouth

Disease mechanism

- ✚ Epithelial cells renewed every 4 days
- ✚ Enzyme production for digestion
- ✚ Gluten triggers immunological response in small intestine
→ destroys absorptive epithelial cells



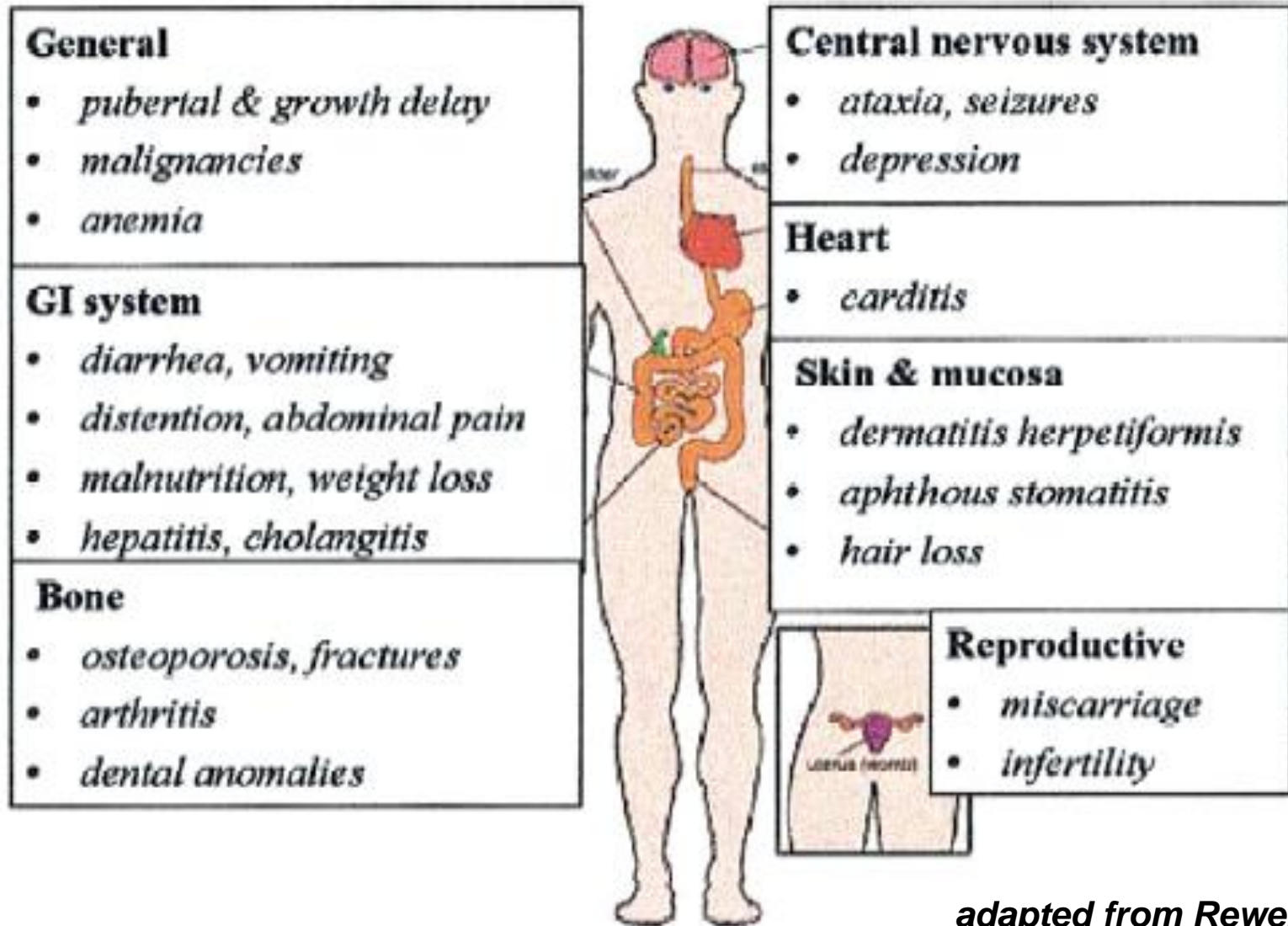
Left - Normal intestinal mucosa

Right - Mucosa involved by celiac sprue

Possible causes

- ✚ Genetic predisposition
- ✚ Environmental factors
- ✚ Immunological based inflammation

CD is a multi-organ autoimmune disease caused by gluten intolerance



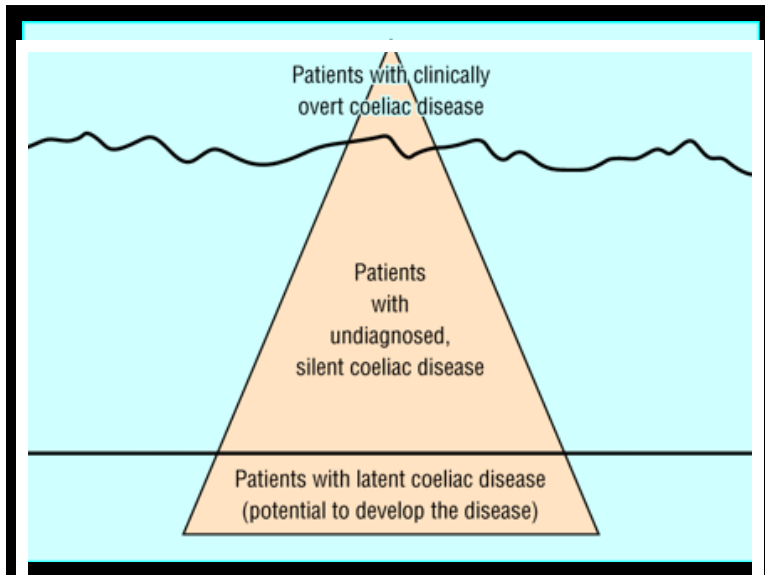
adapted from Rewers 2005

Epidemiology of coeliac disease

- ✚ 1 to 2 % of the world population suffers from coeliac disease.
- ✚ Most common food intolerance

Prevalence of coeliac disease based on clinical diagnosis or screening data (from Fasano and Catassi, 2001)

Geographic area	Prevalence on clinical diagnosis	Prevalence on screening data
Denmark	1:10,000	1:500
Finland	1:1000	1:130
Germany	1:2300	1:500
Italy	1:1000	1:184
Netherlands	1:4500	1:198
Norway	1:675	1:250
Sweden	1:330	1:190
United Kingdom	1:300	1:112
United States	1:10,000	1:111
Worldwide average	1:3345	1:266



Iceberg model depicting prevalence of coeliac disease from Feighery (1999)

Treatment - Gluten free diet



Cereals Allowed:

GF Cereals and Pseudocereals



Dryzoidae
rice



Panicoideae
zea mays
Maize



Sorghum bicolor
Sorghum



Eragrostis tef
Teff



Eleusin coracana
Finger millet



Pennisetum
glaucum
Perl Millet



Setaria Italica
Italian Millet



Fagopyrum
esculentum
Buckwheat



Amaranthus
cruentus
Amaranth



Chenopodium
quinoa
Quinoa

Pseudocereals

Consumers benefitting from a gluten free diet

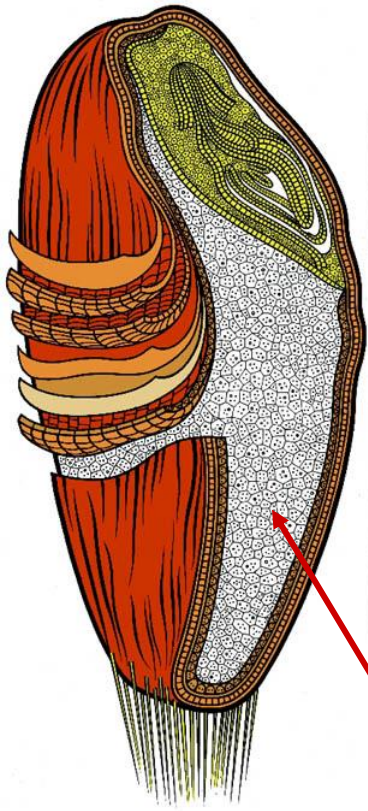
- **Coeliac Disease patients (1 to 2 % of the population)**
- **Gluten sensitivity**
- **Wheat protein allergies**
- **Autism**
- **Irritable Bowel Syndrome and Crones Disease**
- **Skin-disorders**
- **Life style choice**
- **Special diets**
- **Relations from above patients**

**9 out of 10 consumers buying GF-foods
are not Coeliac patients**

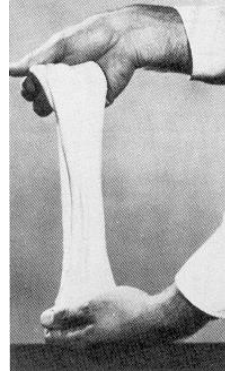
What is Gluten ?



Gluten



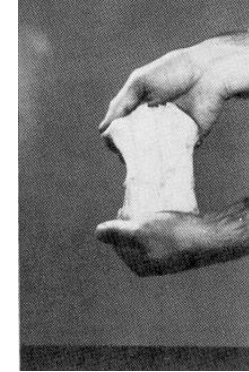
Gluten



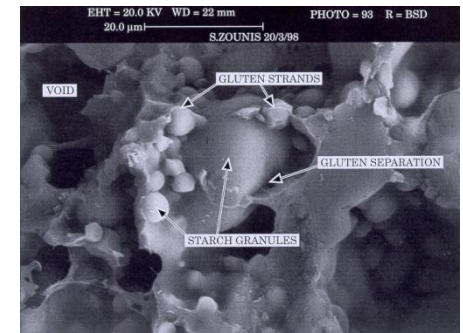
Gliadin



Glutenin



Endosperm



Function

- Water-binding - helps starch gelatinisation during baking
- Visco-elastic properties - gas retention during fermentation
- Gluten associated proteases - bread flavour

wheat flour + water



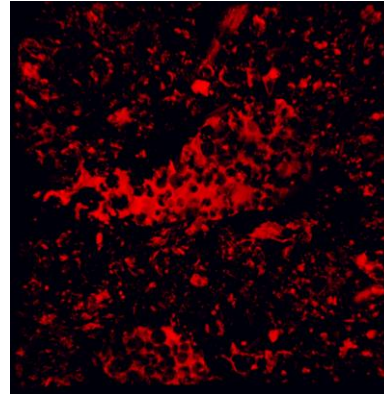
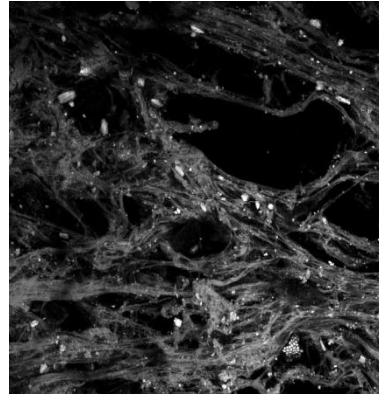
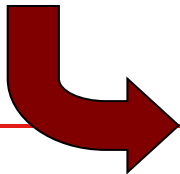
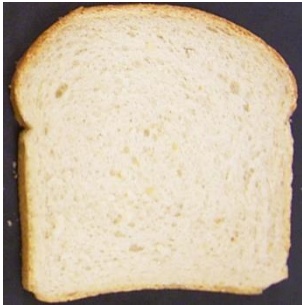
mixing



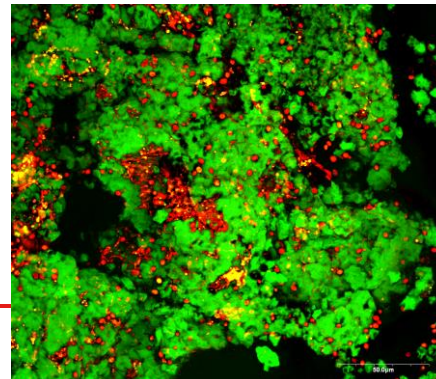
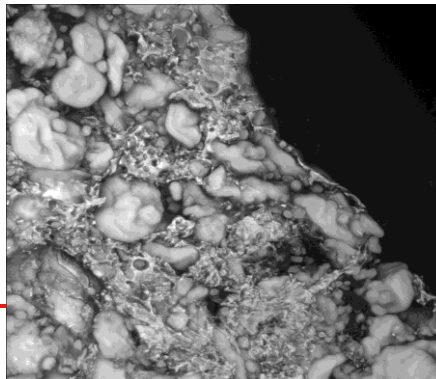
proofing



baking



CLSM of dough/batter



CLSM of bread crumbs

Bread-making

Wheat vs. Gluten-free

GF flour + water



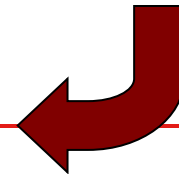
mixing



proofing



baking



Advances in the development of gluten free bread



Gluten free Market

- Free-from market: 300% growth since 2000
- US market for GF products: 1,6 billion \$ (2010) – predicted to be 2,6 billion \$ (2012)
- Growth rate of 25% per year
- Only 1 out of 10 consumers buying GF-products are Coeliac patients

Marketing study UCC






100 bread products from 15 countries

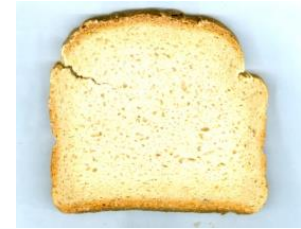
Nutritional Information
Volume
Texture
Sensory evaluation
Price



Brown Bread	Country	Kcal/100g	Carbohydrates		Fibre	Protein	Fat	Saturates
			[g/100 g]	Sugars	[g/100g]	[g/100g]	[g/100g]	[g/100g]
Meingast Krustenbrötchen	Austria	261	54.4	3.7	2.3	2.4	3.7	0.4
Minderleinsmuehle rolls	Austria	279	43.8	n.a.	n.a.	4.3	9.6	n.a.
Minderleinsmuehle sunflower bread	Austria	311	43.3	n.a.	n.a.	6.4	12.5	n.a.
Tattarileipä Buckwheat bread	Finland	253	52.8	2.5	2.5	2.2	3.6	0.5
Tumma leipä Dark bread	Finland	260	56.5	5.5	2.6	2.4	2.6	0.4
Hapan mausteleipä sourdough bread	Finland	262	54.2	3.1	2.7	2.6	3.8	0.5
Pirjon Pakari Buckwheatbread	Finland	201	41.9	3.9	4.1	5.2	1.1	0.0
Schnitzer spezial Landbrot	Germany	192	36.6	2.0	4.4	6.5	2.2	0.3
Schnitzer spezial Buchweizenbrot	Germany	214	30.1	2.8	5.8	9.4	6.2	0.8
3 Pauly Schwarzbrot mit Teff	Germany	223	38.2	2.0	3.6	5.2	5.2	0.6
3 Pauly Vollkorn Schnittbrot	Germany	196	38.0	1.0	5.0	6.0	2.0	0.3
Schaer Landbrot	Germany	224	44.7	3.5	5.2	3.4	3.5	0.5
Schaer Ciabatta rustica	Germany	255	39.6	3.7	8.9	5.8	8.1	1.0
Schaer Rustico	Germany	229	40.8	3.0	5.7	3.2	2.5	0.4
ener Bio Buchweizenbrot	Germany	214	30.1	2.8	5.8	9.4	6.2	0.8
Hammermuehle Bio Landbrot	Germany	223	49.0	n.a.	n.a.	4.4	1.2	n.a.
Kelkin Sliced Brown Bread	Ireland	223	47.8	2.6	1.3	2.0	3.8	1.1
ENER G Gluten-Free Flax Loaf	Ireland	264	41.0	2.9	3.4	2.1	4.3	1.2
Genius Gluten Free Brown Bread	Ireland	277	42.2	5.1	9.5	6.7	13.3	2.2
Marks & Spencer 4 soft brown baps	Ireland	250	31.6	0.4	9.3	5.1	11.7	1.3
NUTRIFREE PanFette Integrale	Italy	283	60.0	2.4	5.6	2.3	3.8	0.8

Nutritional Composition of GF Breads

	Gluten free white bread		Wheat bread
Calories	196 kcal 	311 kcal	219 kcal
Fat	1.7 % 	15.6 %	1.4 %
Protein	1.1 % 	6.6 %	8.7 %
Carbohydrates	35.0 % 	62.7 %	43.0 %
Fibre	0.1 % 	8.3 %	2.8 %



A Bite of GF Bread-Marketing Study



- Dry, crumbly mouth feel and off-flavor
- Lack of Nutrients, **high in fat**
- Rapid staling (mostly starch based)
- Expensive

Evaluation of
over 100 gluten free cereal products
from 15 different countries

Characterisation of GF- cereals

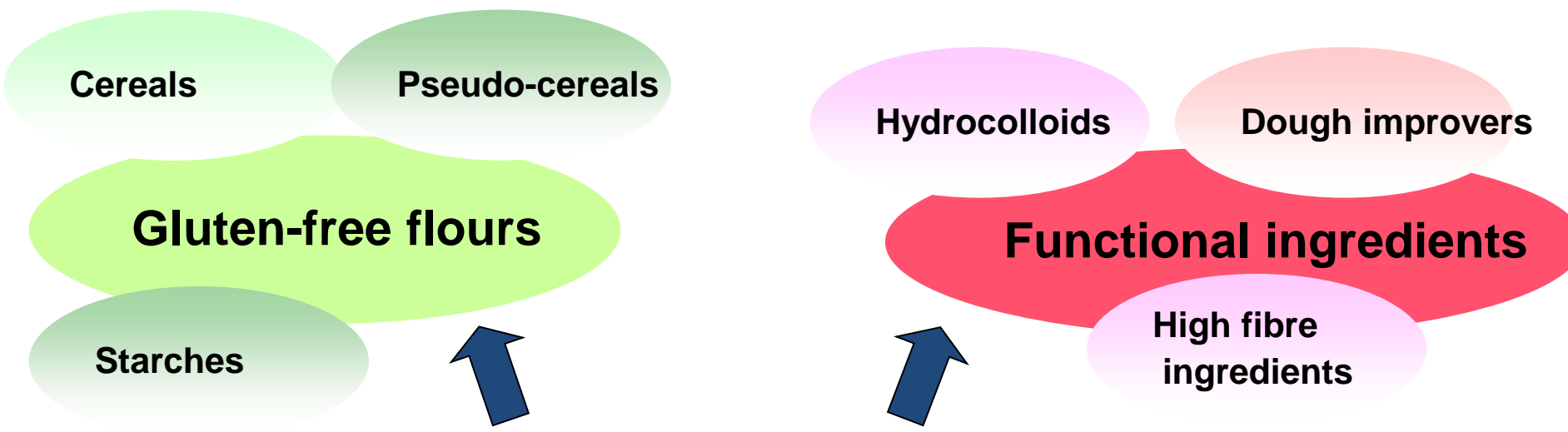




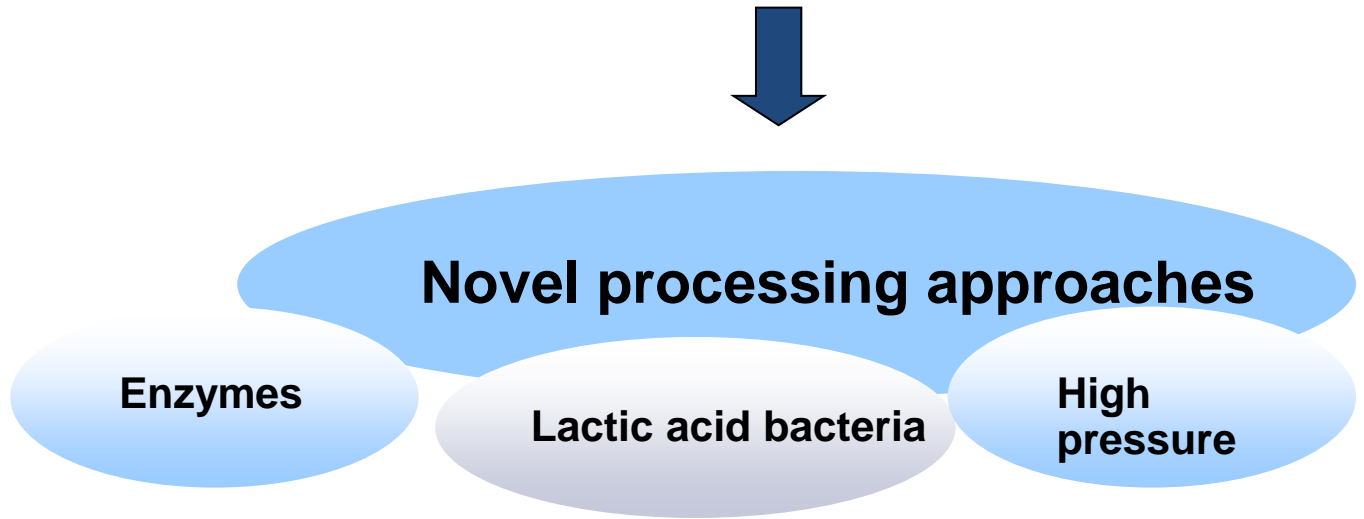
Objective

**To produce a gluten-free products,
which is of comparable quality to wheat
products**

**To produce a GF-products which takes
the safety and nutritional requirements
of Coeliac patients into account**



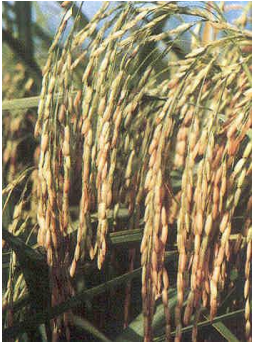
New Generation Gluten-free bread development



Gluten free cereals - Characterisation



Gluten free cereals



Oryzoidae
Rice



Panicoideae
zea mays
Maize



Sorghum bicolor
Sorghum



Eragrostis tef
Teff



Eleusin coracana
Finger millet



Pennisetum glaucum
Proso Millet



Avena sativa L.
Oats



Fagopyrum esculentum
Buckwheat



Amaranthus cruentus
Amaranth

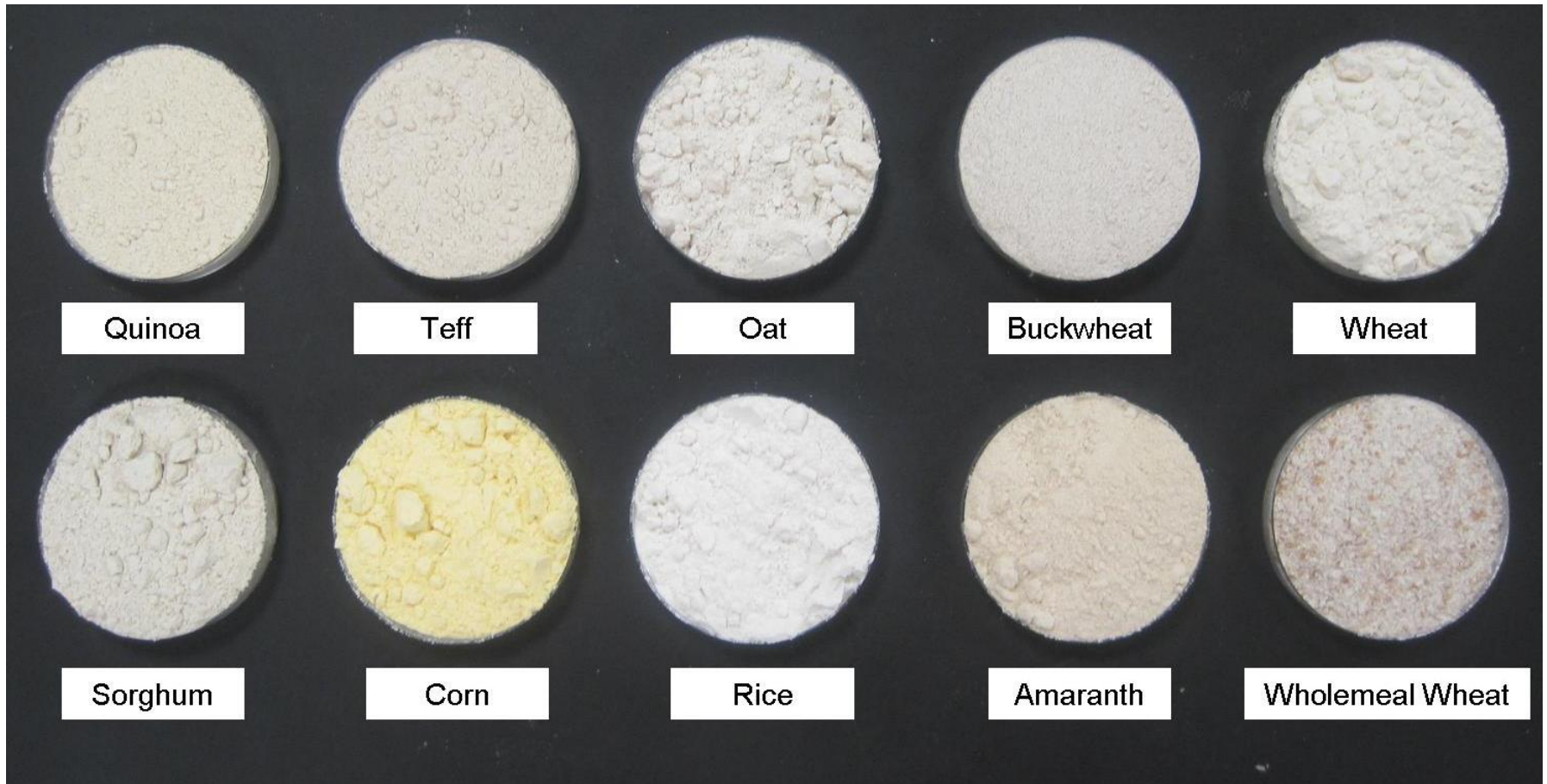


Chenopodium quinoa
Quinoa



Pseudocereals

Gluten free flours -Evaluation



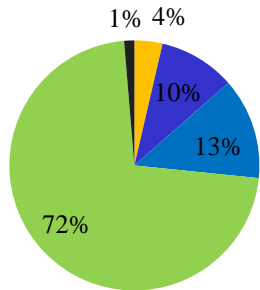
Potential nutritional deficiencies

On diagnosis	On GF diet	On long-term GF diet
<p>Protein/calorie</p> <p>Fibre</p> <p>Fe, Zn, Cu, Mn</p> <p>Vit D, Vit K</p> <p>Ca, Mg</p> <p>Folate, B₁₂</p> <p>Thiamin</p> <p>Niacin</p> <p>Pyridoxine</p> <p>Riboflavin</p> <p>Se, Carnitine</p>	<p>Fibre</p> <p>Fe, Zn</p> <p>Vit D</p> <p>Ca, Mg</p> <p>Folate, B₁₂</p> <p>Niacin</p> <p>Riboflavin</p>	<p>Fibre</p> <p>Folate, B₁₂</p> <p>Niacin</p> <p>Pyridoxine</p>

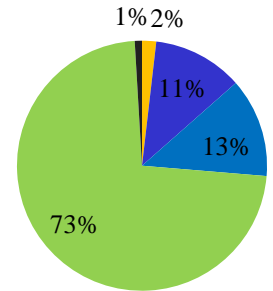
based on data provided by Kennedy et al.

Compositional analysis

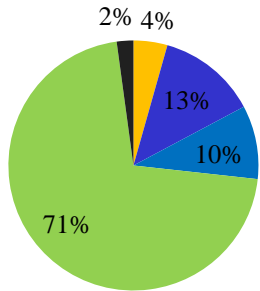
Whole wheat



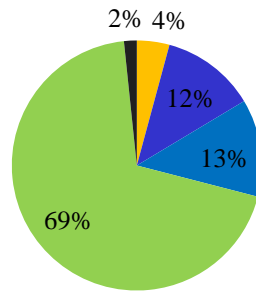
Wheat



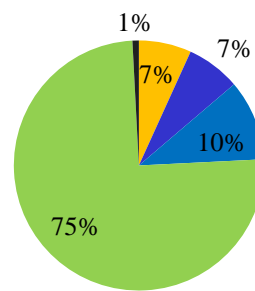
Teff



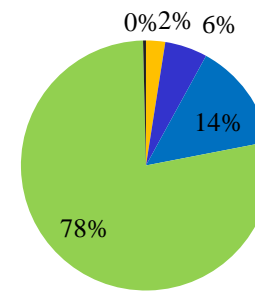
Buckwheat



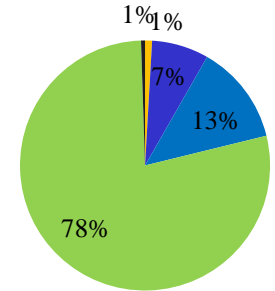
Oat



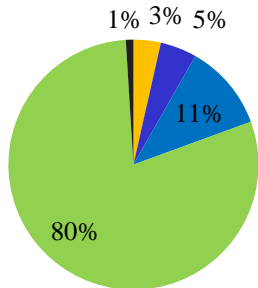
Maize



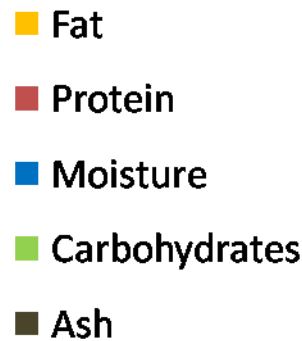
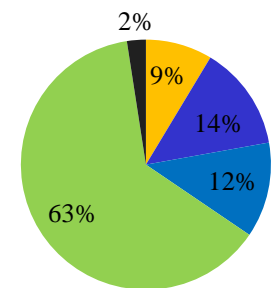
Rice



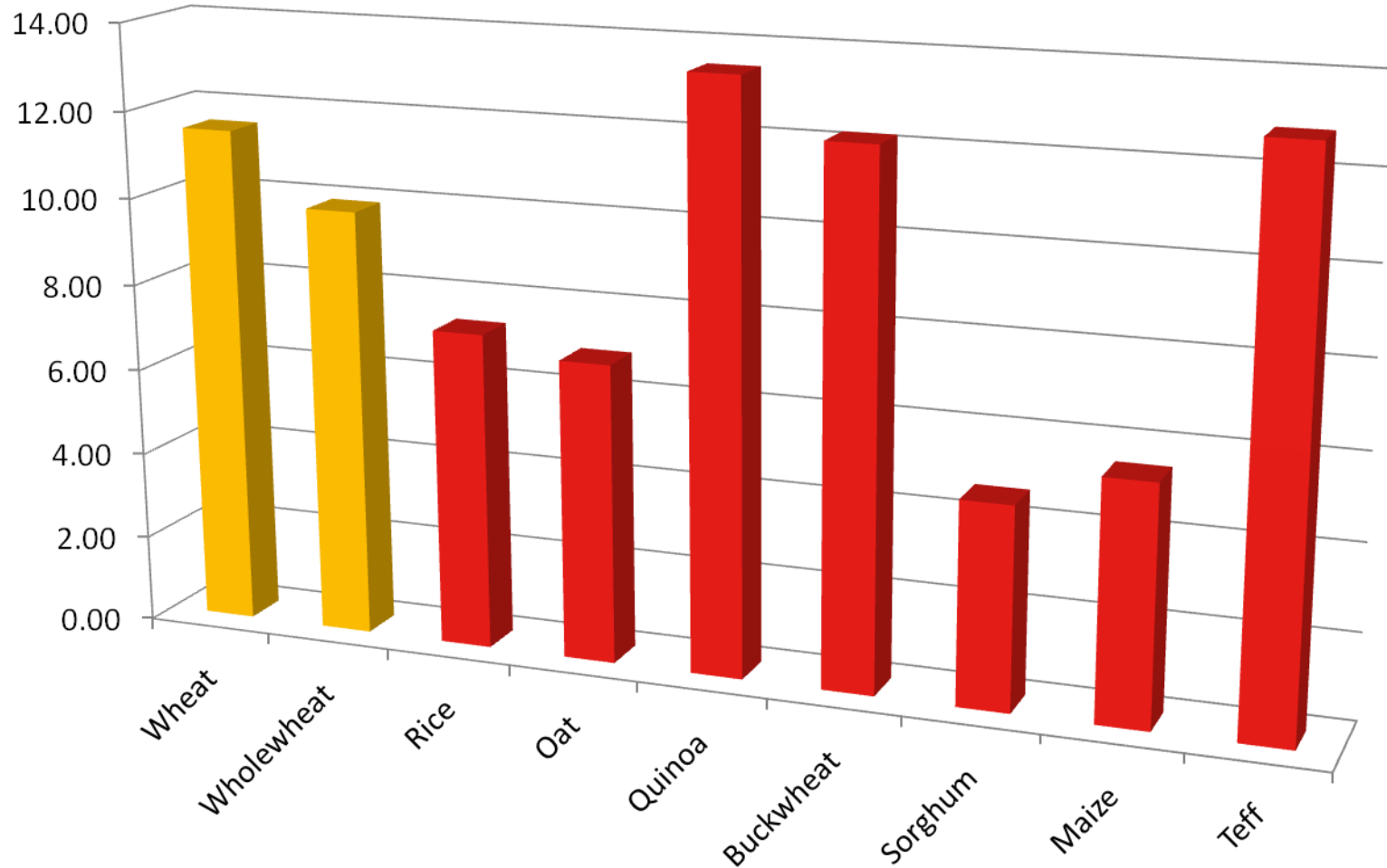
Sorghum



Quinoa

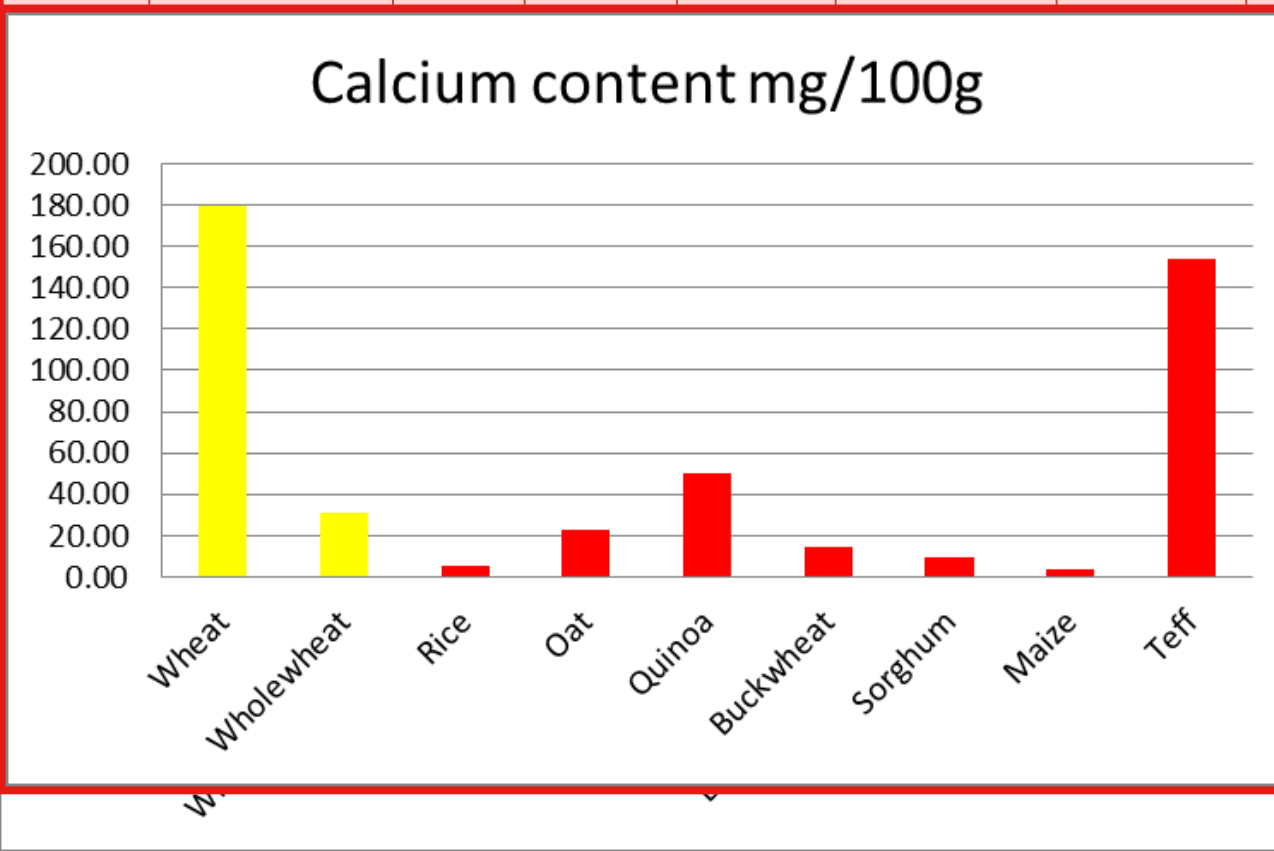


Protein content g/100g



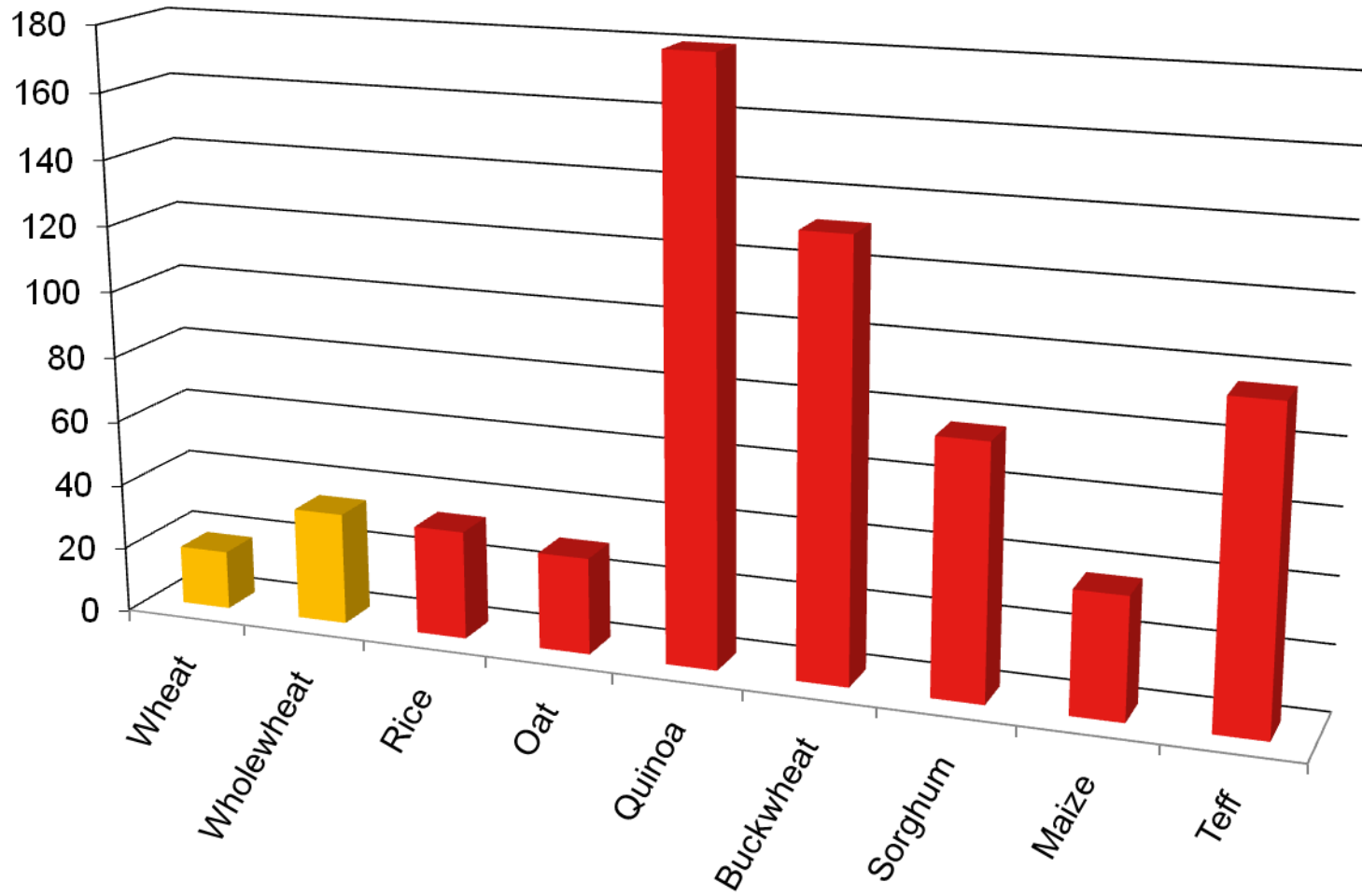
Mineral characterisation

	Wheat	Wholewheat	Rice	Oat	Quinoa	Buckwheat	Sorghum	Maize	Teff
Ash[§]	0.92	1.32	0.51	0.82	2.43	1.65	0.97	0.37	2.15
Calcium*	179.80	30.80	5.10	22.50	49.80	14.80	9.80	3.30	154.30
Iron*								0.91	8.53
Sodium*								0.50	6.00
Potassium*								48.70	382.80
Copper*								0.09	0.93
Manganese*								0.15	3.45
Zinc*								0.66	4.15
Chloride*								8.40	48.10
Phosphorus*								1.40	361.70

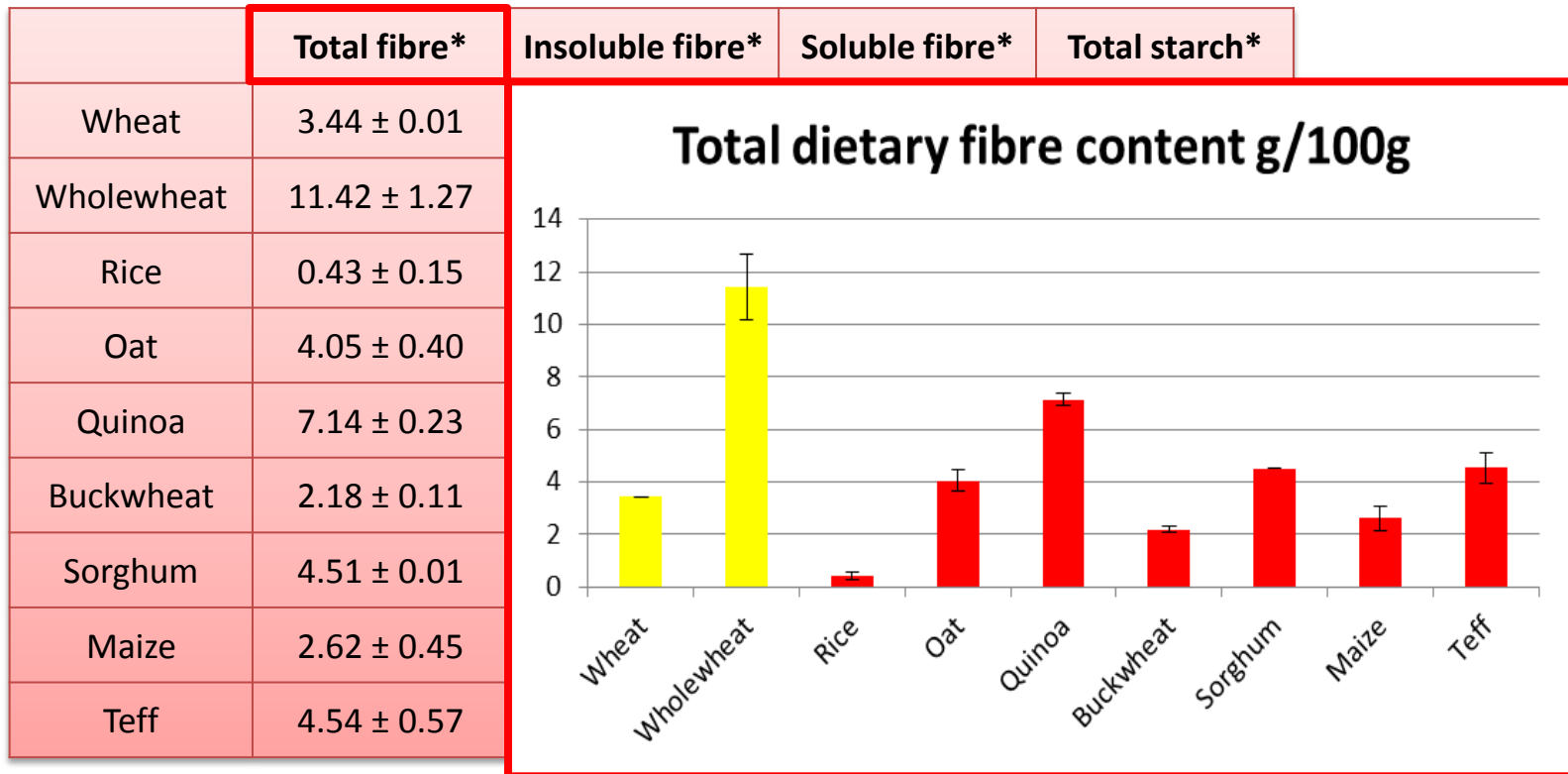


§ g/100g
* mg/100g

Folate levels $\mu\text{g}/100\text{g}$

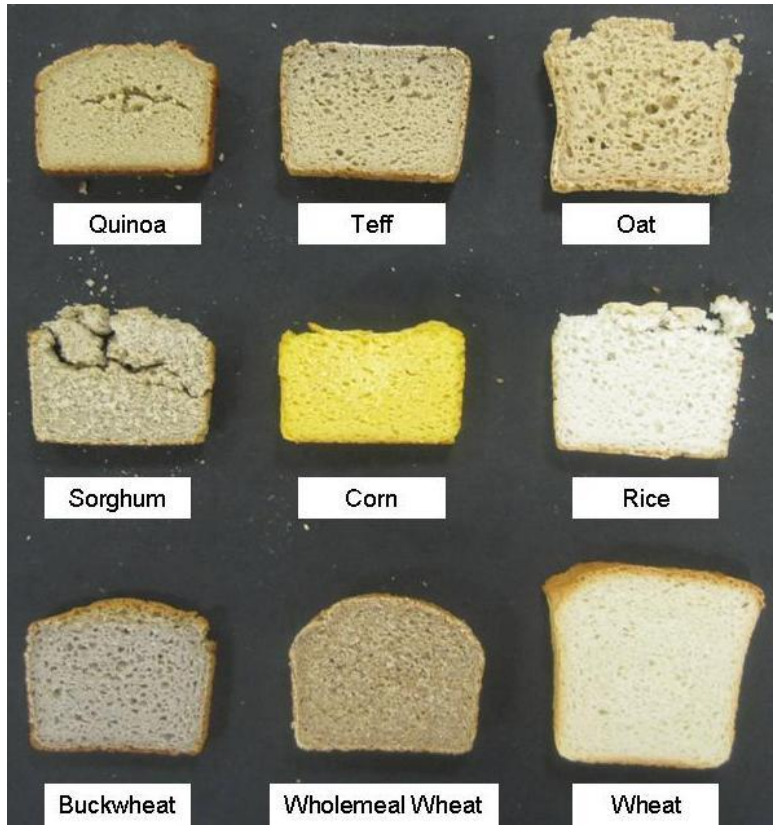
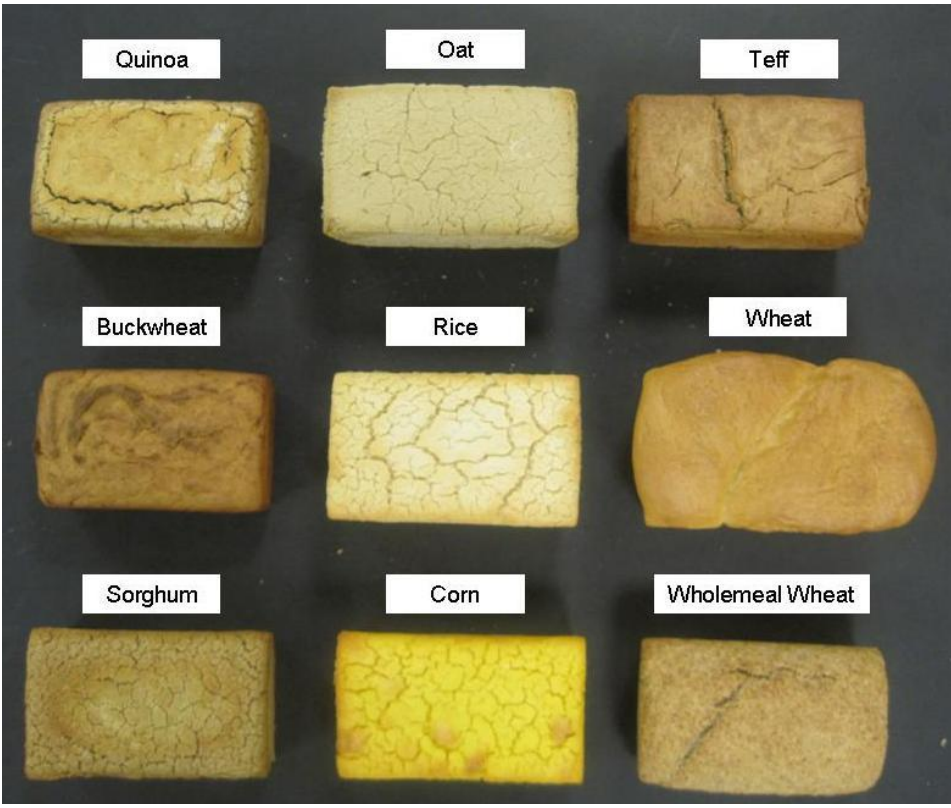


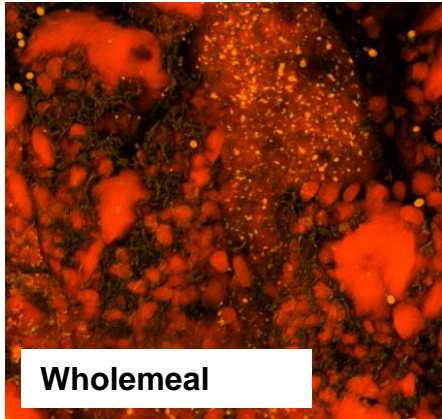
Dietary fibre content



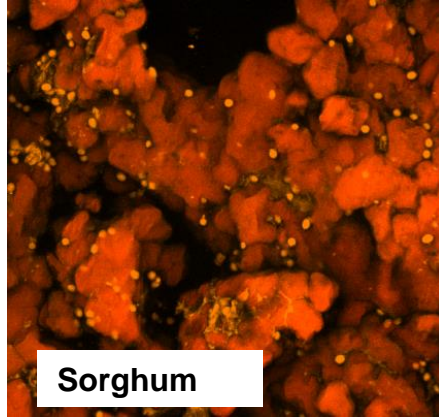
* g/100g

Resulting loaves

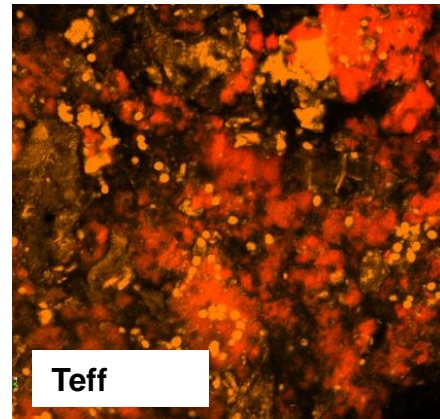




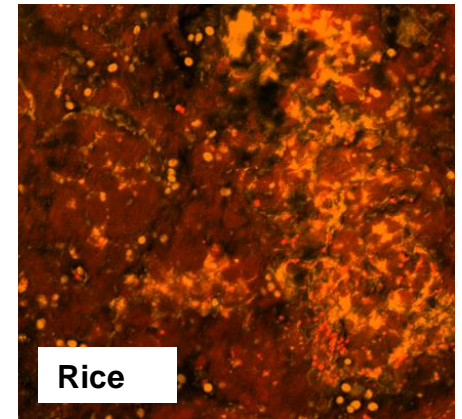
Wholemeal



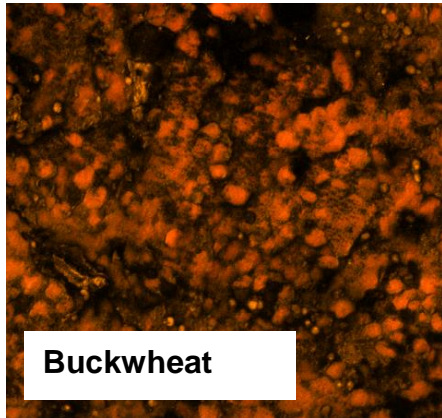
Sorghum



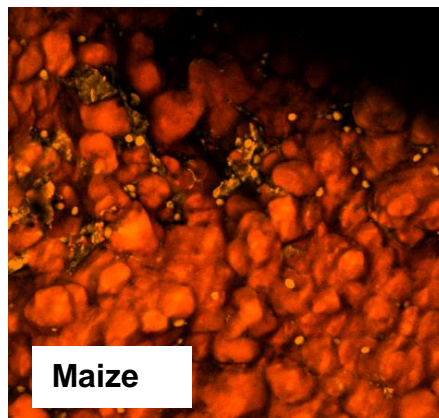
Teff



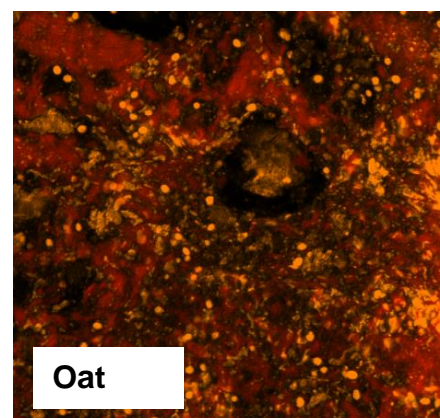
Rice



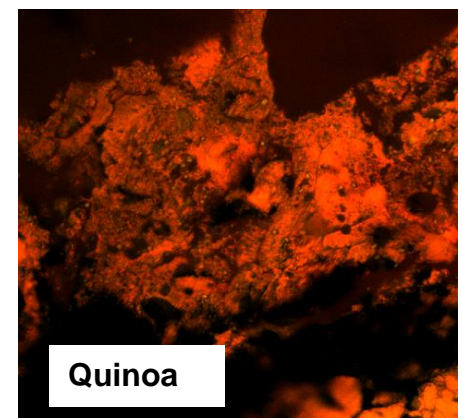
Buckwheat



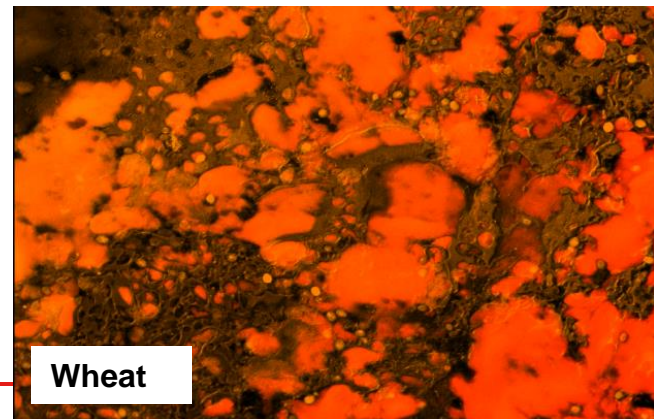
Maize



Oat



Quinoa

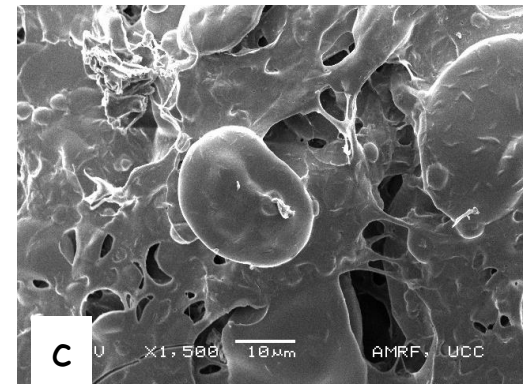
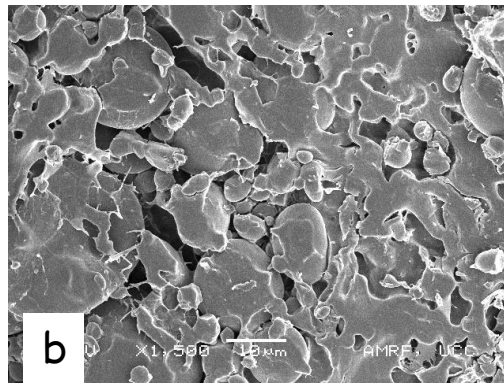
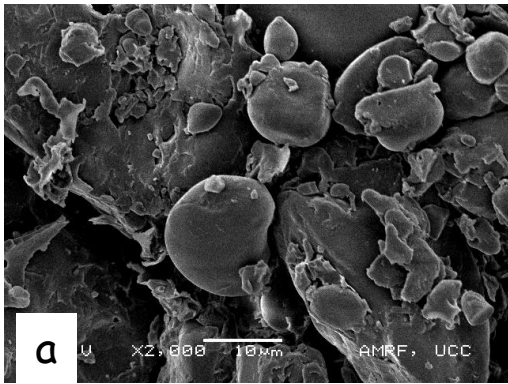


Wheat

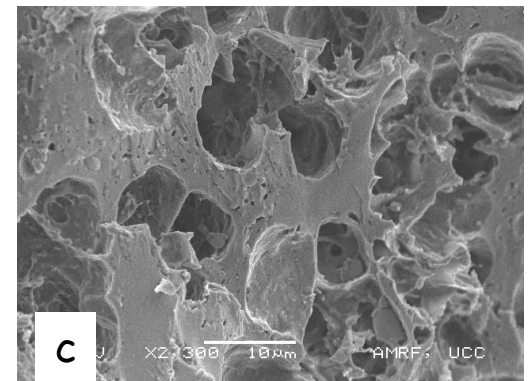
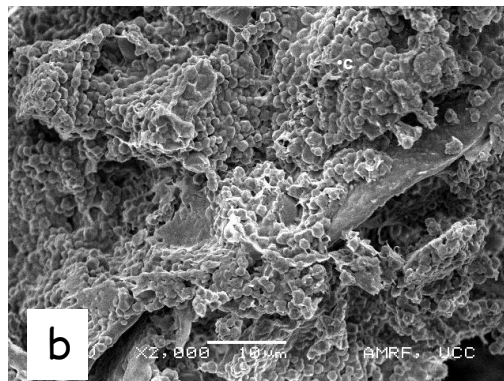
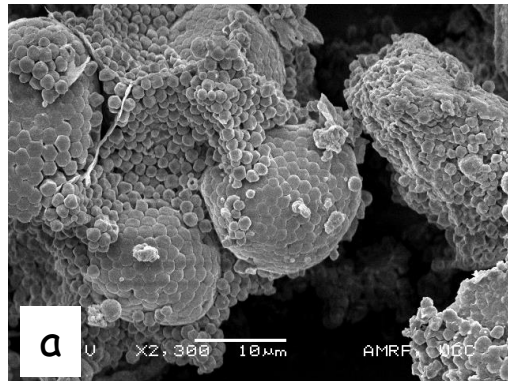
Laser scanning microscopy

40 x magnification

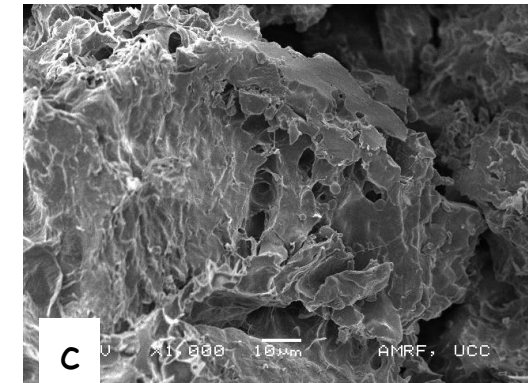
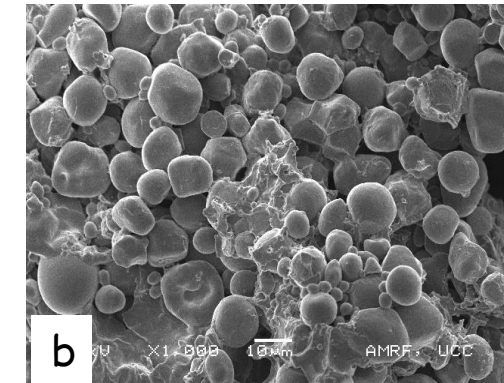
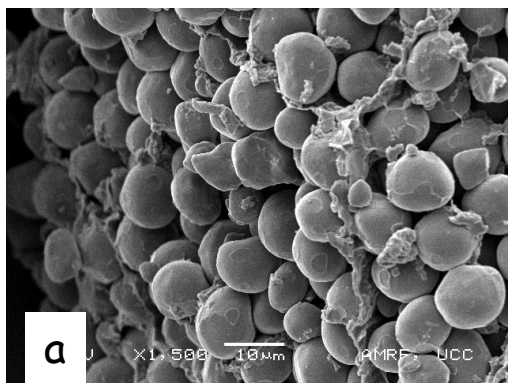




SEM micrographs (1500/2000x) of wheat flour (a); dough (b), and bread (c).



SEM micrographs (2200/2300x) of quinoa flour (a), dough (b) and bread (c)



SEM micrographs (1500/1000x) of maize flour (a), dough (b), and bread (c)



Gluten Free Bread - The New Generation



Objective

**To produce a gluten-free products,
which is of comparable quality to wheat
products**

**To produce a GF-products which takes
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of Coeliac patients into account**

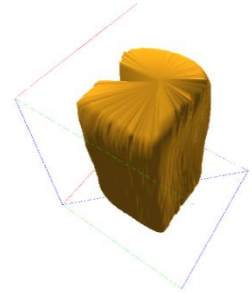
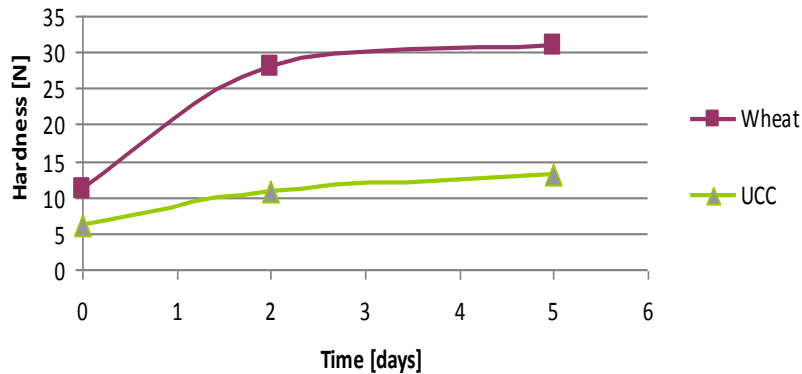
New Generation of Gluten free bread



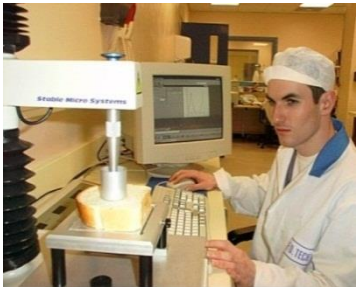
New Generation of Gluten free bread



Comparison of wheat and NG GF bread



NG- Gluten free bread:
specific volume **3,5 ml/g**
comparable to wheat
and higher than most GF
on the market



NG-Gluten-free bread is softer and has a lower staling rate than wheat bread – stays fresh for longer



Sensory evaluation






Comparison of new generation GF- bread with GF- Market leaders from different EU-countries (Panel 70 non celiacs and 35 celiacs)

65 % of both panels preferred UCC GF Bread

Comparison of Wheat bread and New Generation GF-bread (Panel of 70 non celiacs)

Panel could not distinguish between UCC GF and Wheat bread

Compositional analysis

Nutritional Information Typical values per 100g of dry product			 BFree Be Wheat & Gluten Free ☒	Range based on market study
Energy	219 kcal	296 kcal	204 kcal	196 - 311 Kcal
Protein	8.7g	8.4g	6.6 g	1.1 - 8.4 g
Carbohydrates Of which sugar	43g 2.42g	41.1g 3.0g	34.2 g 1.13 g	35.0 - 62.7
Fat Of which saturates	1.4g 0.4g	13.0g 0.9g	2.8 g	1,7 -15,6
Fibre	2.8g	9.7g	8.0 g	0,1 - 8.3
Sodium	0.45g	0.63g	0.62 g	



New Generation Gluten -free bread

Summary



- ✚ Lower in calories
- ✚ High in Fibre (highest in fibre, 9.5 %)
- ✚ Wheat free (no wheat starch used in the product)
- ✚ Lactose free
- ✚ Protein of high biological value (6.6 %)
- ✚ Low in fat (<3%)
- ✚ Flavour and texture comparable to wheat bread
- ✚ Preferred over the GF-bread market leaders
- ✚ Long shelf-life (stays fresh for longer)
- ✚ Visually appealing (specific volume 3.5 g/ml)
- ✚ Range of products such as baguettes, roles etc.

BFree
Be Wheat & Gluten Free ☒

It is possible to produce a Gluten free bread comparable to wheat bread

BFree
Be Wheat & Gluten Free ☒



Gluten free malt and beer



Strategies for making gluten-free beer

↪ Maximize the elimination of the relevant protein and protein degradation products from traditional raw materials



↪ Seek alternative cereals and cereal-like materials from which to produce the beer

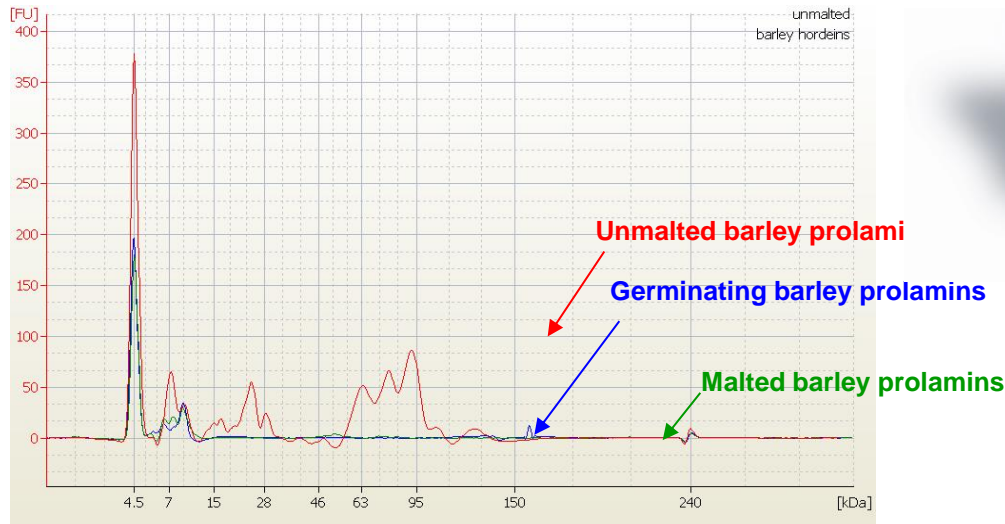
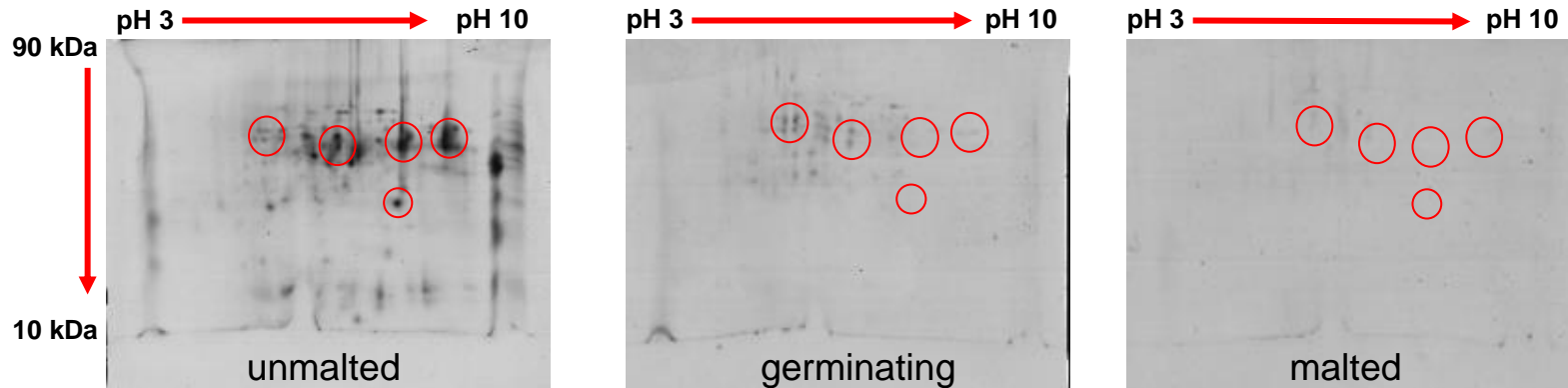


↪ Develop replacement beers derived from non-protein - containing materials, for example fermented sugars.



Understanding protein changes during malting & brewing

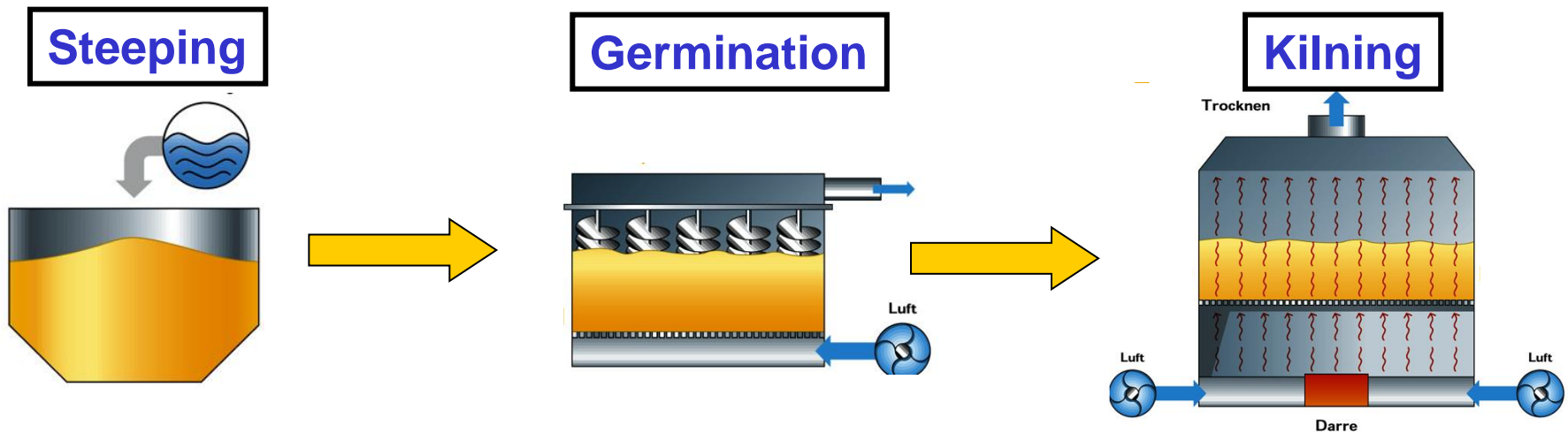
Example: Hordein changes during malting



➤ Hordeins: nearly complete breakdown during malting

Malting Process

Limited germination of cereals or pseudocereals under controlled conditions



initiate metabolic processes by soaking the kernels with water

degradation & assembly of macromolecules (enzymatic systems are activated or will be *de novo* synthesised)

gentle drying of the grain to stop germination and make the malt storable as well as formation of desired substances

Malting and brewing with

Non traditional Cereals



Oryzoidae
Rice



Panicoideae
zea mays
Maize



Sorghum bicolor
Sorghum



Eragrostis tef
Teff



Eleusin coracana
Finger millet



Pennisetum glaucum
Proso Millet



Avena sativa L.
Oats



Fagopyrum esculentum
Buckwheat



Amaranthus cruentus
Amaranth



Chenopodium quinoa
Quinoa

Malt Applications

Beverage Industry

Usage of malt in the beverage industry

Beer

Spirits

Production of alternative drinks –

Bionade, Karamalz

Coffee substitutes and hot drinks

Malt vinegar



Food Industry

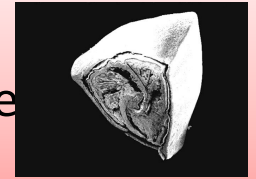
- Breakfast cereals
- Cereal bars
- Baking – enzyme additive and flavouring ingredient
- Pre-digested foods for special dietary needs
- Fermented gruels, porridges (Africa)



Malting of nontraditional cereals

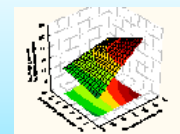
Characterisation of raw-material

Composition analysis, bioactive compounds, ultra-structure
Proteomics – buckwheat, sorghum, oats, proso millet



Optimisation of malting conditions

RSM based designs: Optimisation steeping, germination, kilning



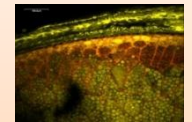
Understanding processing changes

Ultra-structure: Laser scanning microscopy, electron-microscopy,

Proteins: Capillary electrophoresis, Size Exclusion-HPLC, 2D gel electrophoresis

Starch: RVA, Fundamental rheology, DSC

Bio-active compounds: poly-phenols, anti-oxidants, vitamins, minerals, mineral bio-availability, dietary fibre



Good quality gluten free malt

Ingredient for: beer, cereal products and functional drinks



Malting regimes

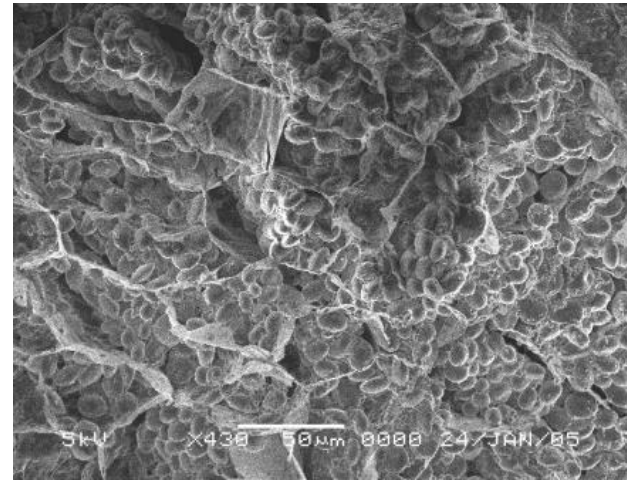
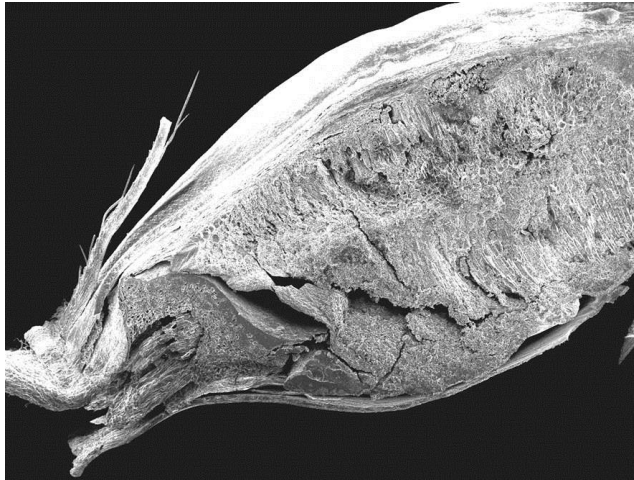
Optimisation of the malting regimes

Rawmaterial	Barley	Sorghum	Buckwheat	Oats
Steeping	36 h 13-18 °C	24 h 20-25 °C	10 h 10 °C	16 h 16 °C
Germination	5-7 d 13-18 °C	5 d 20-25 °C	4 d 15 °C	6 d 16 °C
Drying		24 h 50 °C	5 h, 40 °C 3h, 50 °C 3h, 60 °C	22 h 49-85 °C

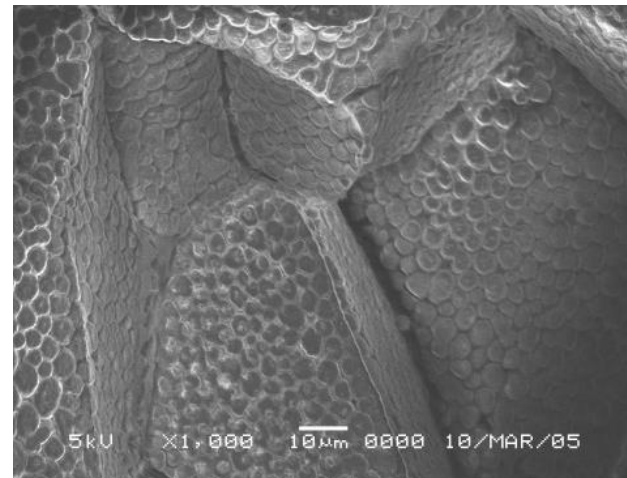
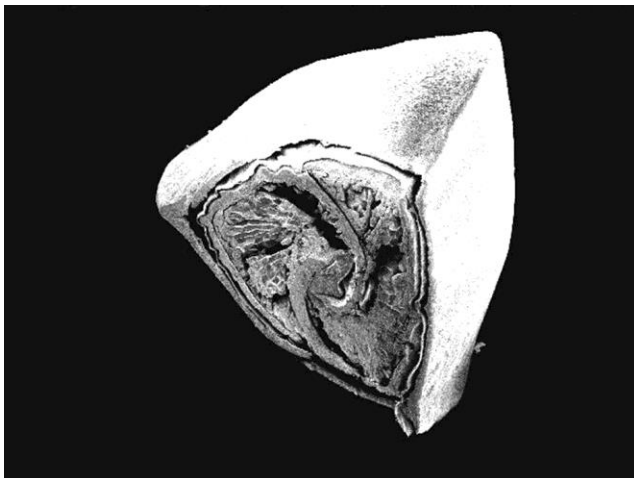
Ultra-structure (SEM)

Analyse of raw material

Barley



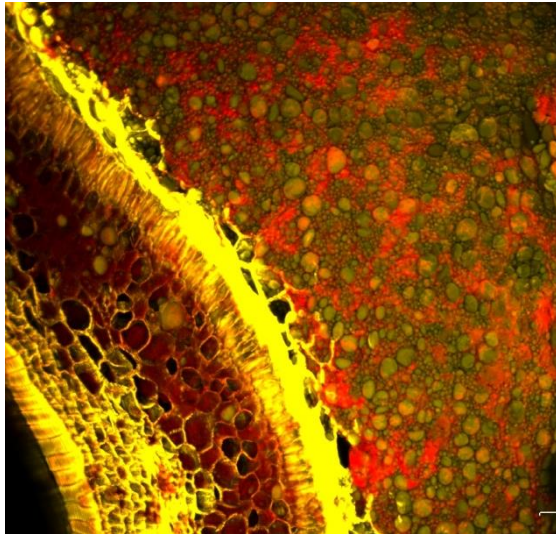
buckwheat



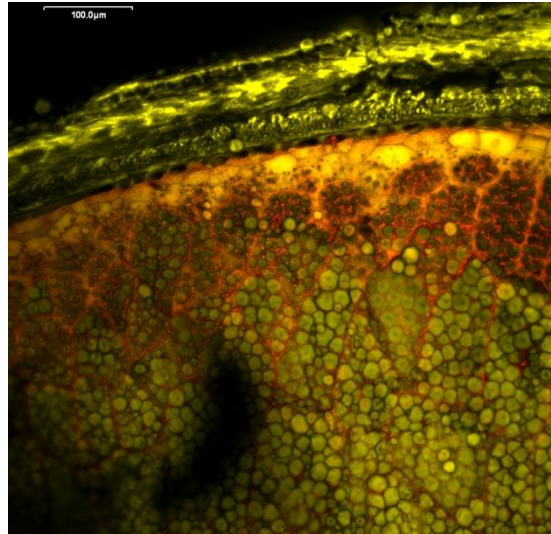
Ultra-Structure Laser-Scanning-Microscopie (CLSM)

Analyse der Grains

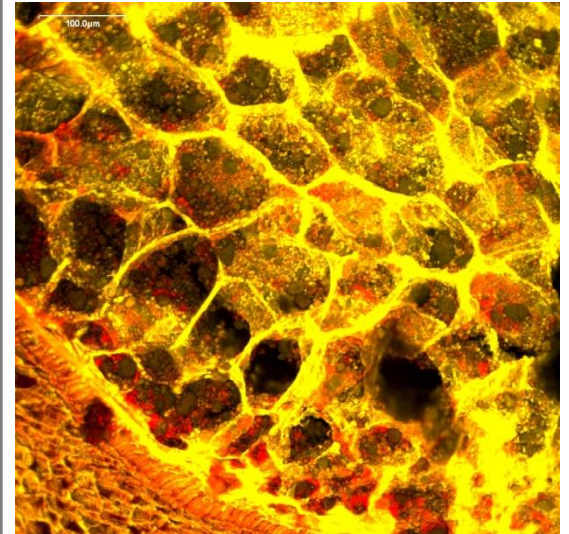
wheat



sorghum



oats



Brewing with alternative cereals



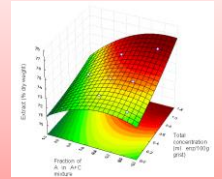
Brewing Process



Brewing with Alternative cereals

Mashing

RSM-mash parameters, enzyme optimisation, proteomics, bio-active compounds



Lautering

Optimization of husk, evaluation of alternatives

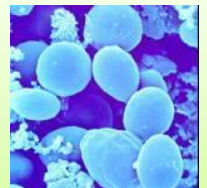
Wort boiling

Optimization of hop addition, Optimization of the wort boiling



Fermentation

Optimization of yeast type
Removal of (Off-)flavor, fermentation time and temperature



Gluten free beer

Flavor profile, sensory evaluation, protein characteristics, foam shelf-life



Processability of Buckwheat during brewing

Mashing



Increased Viscosity Enzymes

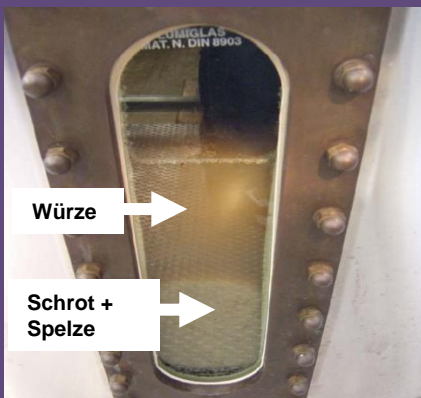
β -Amylaseactivity Amyloglucosidase

α -Amylaseactivity heast stable bacterial α -Amylasen

Extrakt Enzymes, intensives mashing

FAN intensives mashing

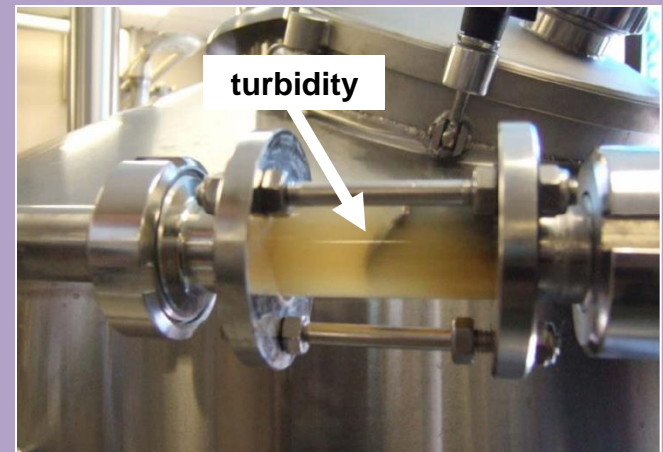
Lautering



Use of rice husk

And

Enzymen



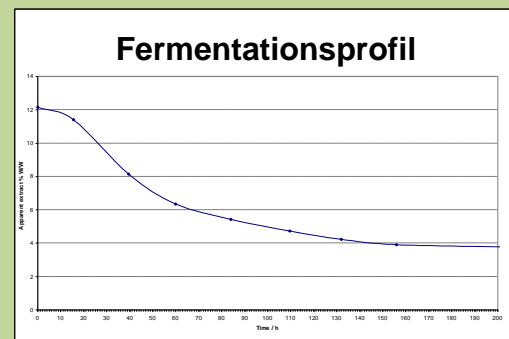
Quality of gluten free beer – Example buckwheat

Fermentation



Fermentation at 21 °C

Use of top fermenting yeast
(wheat beer yeast)



	Buckwheat beer	German wheat beer
Ethylacetat [mg/l]	32	29
2-Methylpropanol [%]	53	40
3-Methylbutanol	55	61
3-Methylbutylacetat	4	3,6
2-Methylbutylacetate	0,4	0,25

Buckwheat beer has a similar flavour than wheat beer

Conclusion – Brewing with Gluten free cereals

- It is possible to produce GF malt
- Malting conditions are different to barley based malt
- GF malt is not comparable to barley based malt
- It is possible to produce good quality GF beer from GF cereals
- Enzyme addition is essential for the production of GF Beer
- Production process has to be adapted to the cereal



Glass of oats malt beer

Acknowledgements



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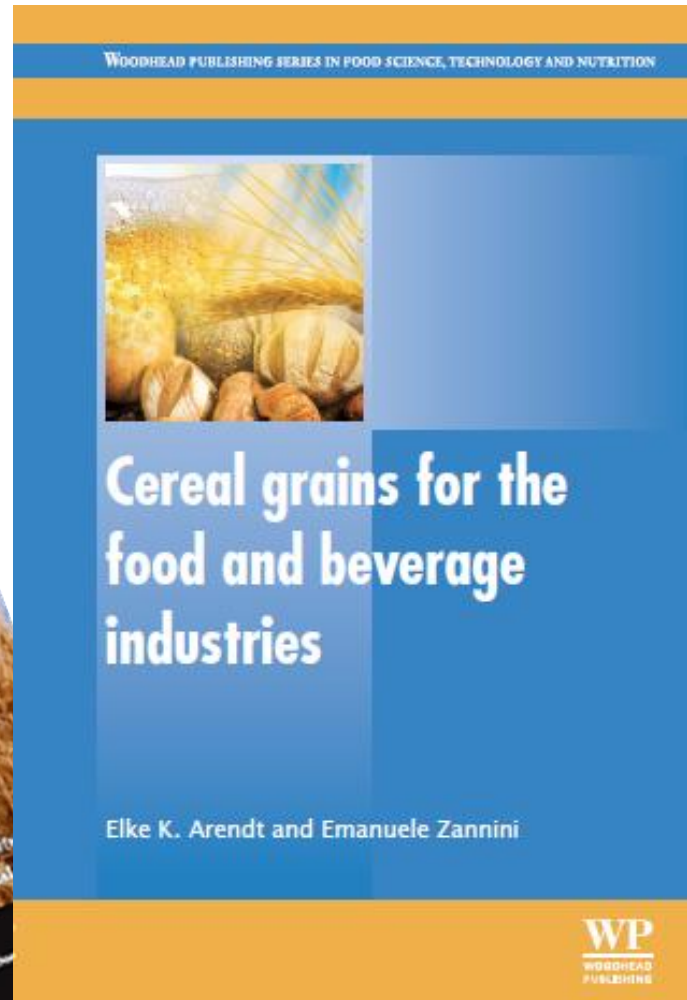
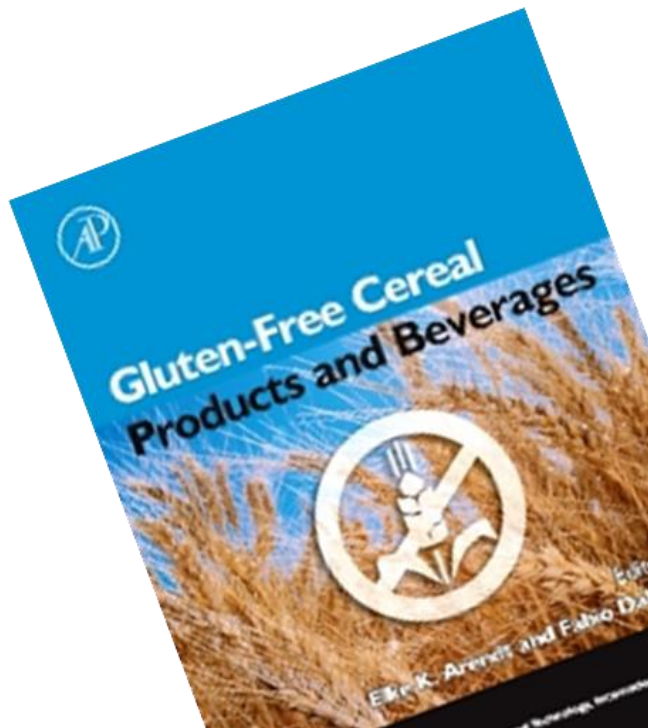
Dr Anika Wolter

Dr Deobrah Water

Claudia Axel

Stefan Hartmann

Further Reading



**School of Food and Nutritional Sciences,
University College Cork, Ireland**



UCC
Coláiste na hOllscoile Corcaigh, Éire
University College Cork, Ireland

**Thank you very much
for your attention!**

