KU LEUVEN

Sprouting of wheat impacts its nutritional value and functionality in breakfast flake making

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- Objective and approach
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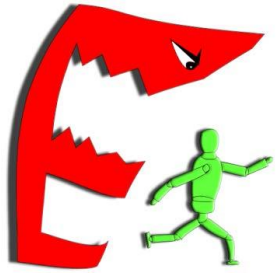
Challenges facing the food industry



Ingredients: Whole Grain Wheat, Corn Bran, Modified Wheat Starch, Guar Gum, Color Added, Cellulose Gum, Salt, Baking Soda, Corn Oil, Aspartame*.

Vitamins and Minerals: Calcium Carbonate, Zinc and Iron (mineral nutrients), Vitamin C (sodium ascorbate), A B Vitamin (niacinamide), Vitamin B_6 (pyridoxine hydrochloride), Vitamin B_2 (riboflavin), Vitamin B_1 (thiamin mononitrate), A B Vitamin (folic acid), Vitamin B_{12}.

Malnutrition and Fe deficiency

Consumption of energy-dense but micronutrient-poor foods

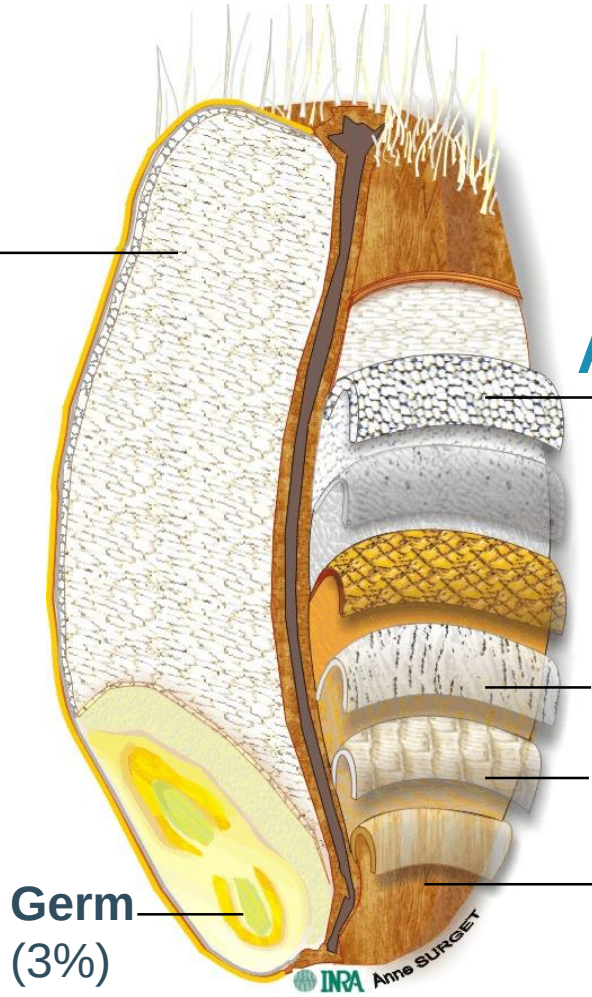
Lack of access to food

WHO (2011)

Getting most out of wheat

Starchy endosperm
(80-85%)

- *Starch*
- *Proteins*



Aleurone layer
(6-9%)

- *Soluble & insoluble dietary fiber*
- *Proteins*
- *Antioxidants (phenolic acids)*
- *Vitamin E*
- *B vitamins*
- *Choline, betaine*
- *Minerals*
- *Phytic acid*

- *Lipids*
- *Antioxidants*
- *Vitamin E*
- *B vitamins*
- *Minerals*

Germ
(3%)

Inner and outer pericarp
(4-5%)

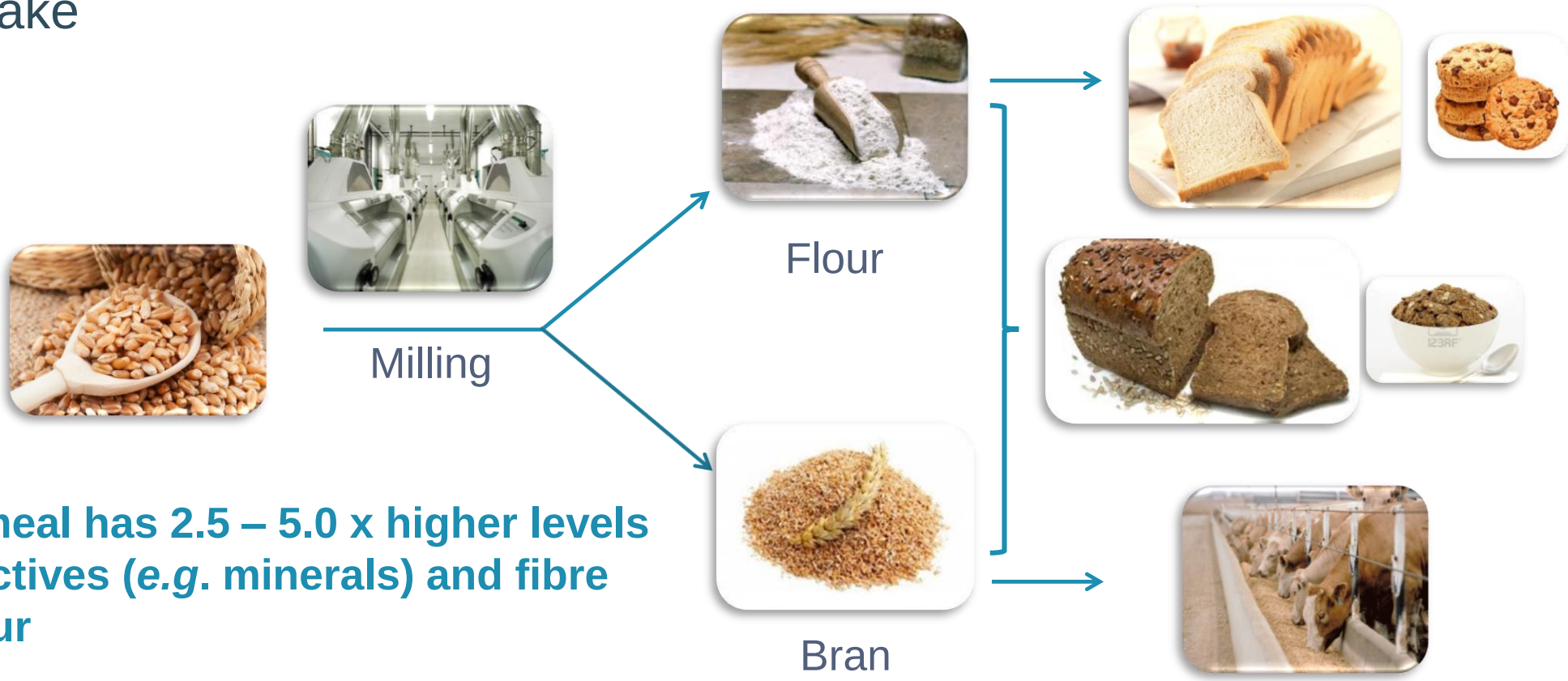
- *Insoluble dietary fiber*
- *Antioxidants (phenolic acids)*

Bran

Courtesy of Healthgrain Forum

Wheat derived products

- In Western countries, wheat accounts for more than 25% of the human caloric intake

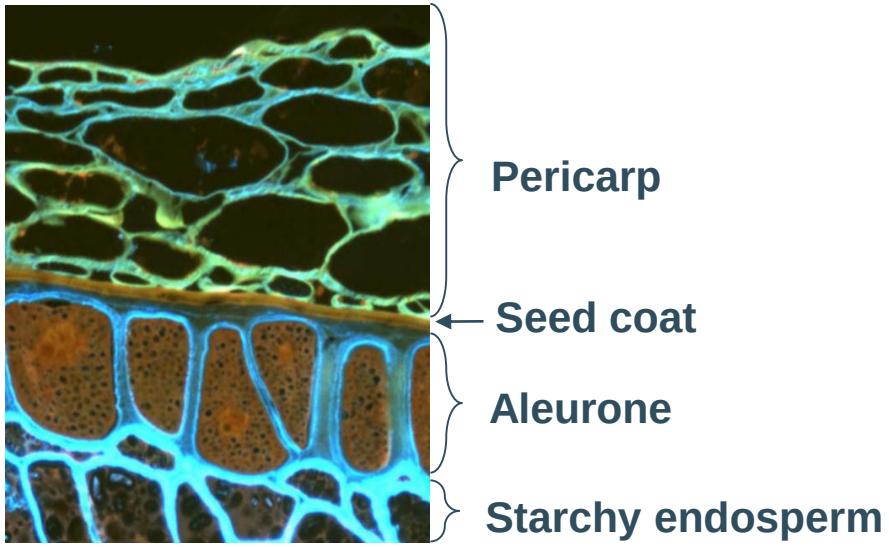


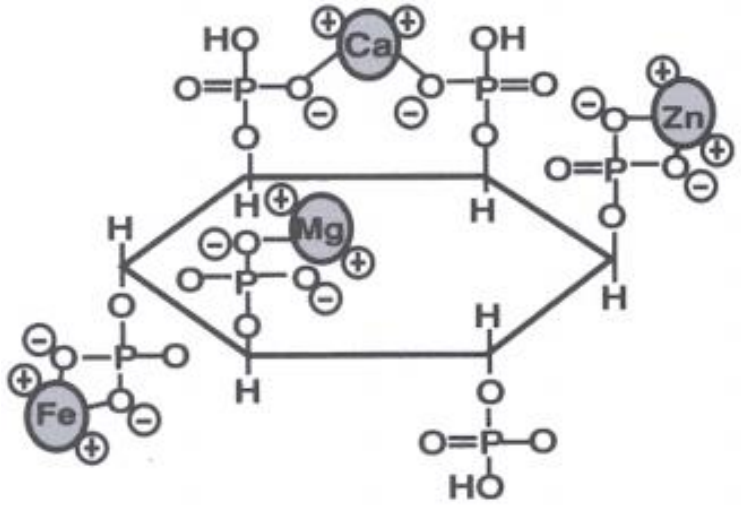
Whole meal has 2.5 – 5.0 x higher levels of bio-actives (*e.g.* minerals) and fibre than flour

Cakmak *et al.* (2008)

Low mineral bio-accessibility

- However,
  - Bio-accessibility of Fe and Zn amounts to only **3 to 5%** (Lemmens et al., 2018)



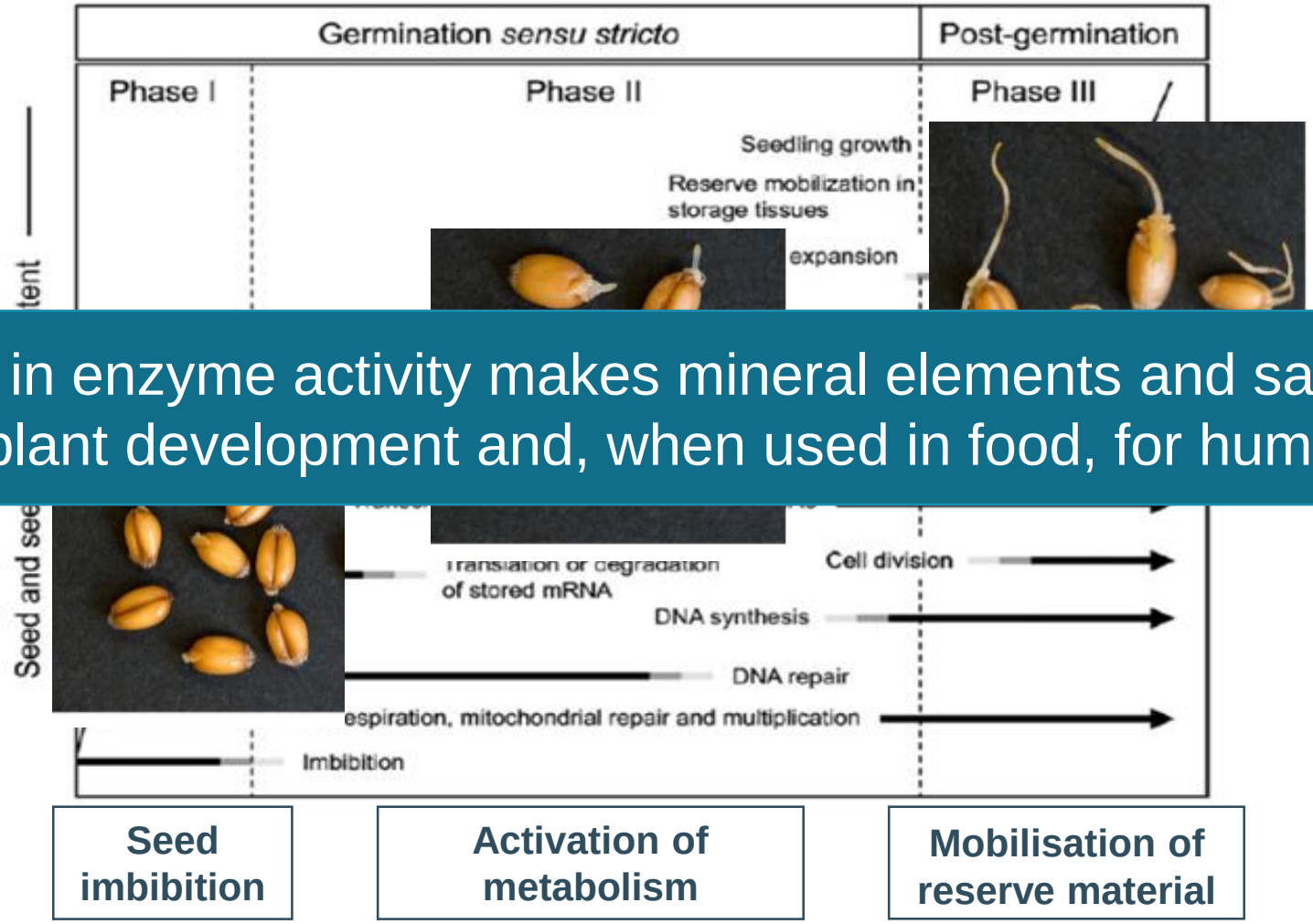


- Innovative wheat processing technologies are needed to substantially increase Fe and Zn bio-accessibility

Added sugars

- Sugars (“empty calories”) are included in the recipe of cereal derived-products, since cereals contain only **1%** of intrinsic sugars

Physiology of seed sprouting process



The increase in enzyme activity makes mineral elements and saccharides available for plant development and, when used in food, for human uptake

Nonogaki *et al.* (2010)

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Objective and approach

To produce breakfast flakes with high levels of bio-accessible minerals and presence of (sweet) intrinsic saccharides by

- (i) using regular and sprouted wheat grains (or blends thereof) as ingredients and
- (ii) rationally modifying the breakfast flake process to allow *in situ* enzyme action

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Producing breakfast flakes, standard process

Mixing of ingredients

Recipe (400 g dm)
- 89.5% whole meal
- 7.5% sucrose
- 2.5% glucose
- 0.5% salt

→ Resting
30 min, room temperature

2 min mixing
Removal/refilling
30 sec mixing
Moisture content *ca.* 28%

Extrusion

Laboratory single screw extruder

Mixing in bowl (0-60 min)
Extrusion (*ca*. 3 min, 70-100 °C, 7 bar)
Moisture content *ca.* 25%

↓

Flaking

Roller mill

Flaking at room temperature
Moisture content *ca.* 25%

← Air-dried overnight
Conditioned in climate chamber (30 °C, 80% RH)
Moisture content 12-15%

Drum roasting

3 min at 248 °C
Moisture content < 6%

Standard process flow chart

Control wheat

Milling

Flake production

Control wheat

Sprouting at standard * condition (15 °C, 48 h)

Joe White micro-malting system

Sprouted wheat

Drying

Milling

Flake production

* Similar to industrial malting conditions

Standard process flow chart

Control wheat

Sprouting at standard condition (15 °C, 48 h)

Joe White micro-malting system

Sprouted wheat

Blend 25-75%

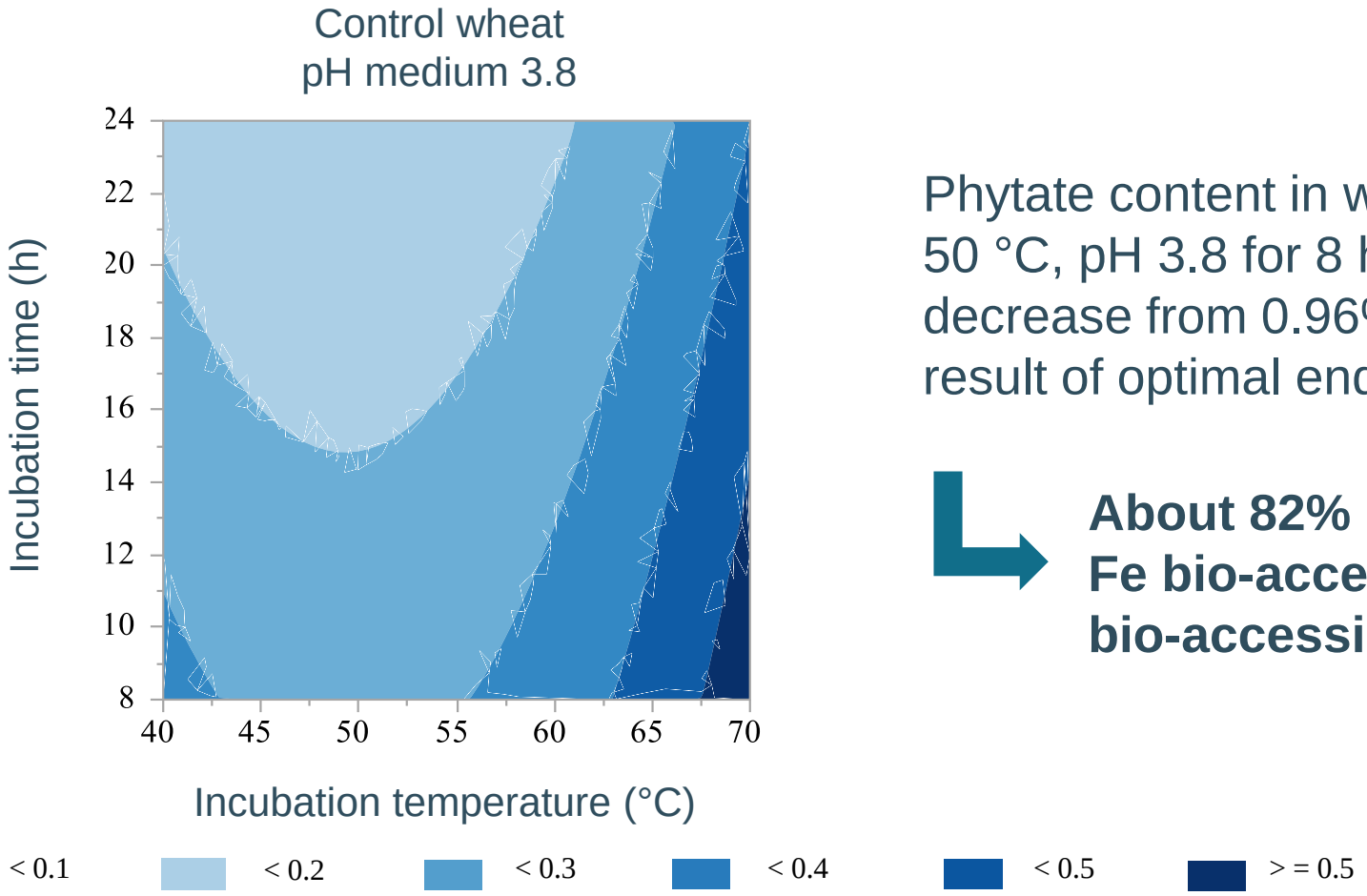
Control wheat

Drying

Milling

Flake production

Rationale modified production process



Phytate content in wheat hydrothermally processed at 50 °C, pH 3.8 for 8 h is predicted and verified to decrease from 0.96% initial dm to 0.17% initial dm as a result of optimal endogenous phytase action

About 82% breakdown led to an increase in Fe bio-accessibility from 3 to 37% and in Zn bio-accessibility from 5 to 27%

Lemmens *et al.* (2018)

Producing breakfast flakes, modified process

Mixing of ingredients

Recipe (400 g dm)
- 89.5% whole meal
- 7.5% sucrose
- 2.5% glucose
- 0.5% salt

Incubating
1 h at 50 °C

2 min mixing
Removal/refilling
30 sec mixing
Moisture content *ca.* 28%

Hydrating with 100 mM sodium acetate buffer (pH 3.8)

Air-dried overnight
Conditioned in climate chamber (30 °C, 80% RH)
Moisture content 12-15%

Drum roasting

3 min at 248 °C
Moisture content < 6%

Extrusion

Laboratory single screw extruder

Mixing in bowl (0-60 min)
Extrusion (*ca*. 3 min, 70-100°C, 7 bar)
Moisture content *ca.* 25%

Flaking

Roller mill

Flaking at room temperature
Moisture content *ca.* 25%

Modified process flow chart

Control wheat

Milling

Flake production

Allowing (synthesised) enzymes to be active by tailoring the breakfast flake making process

Control wheat

Sprouting at standard * condition (15 °C, 48 h)

Joe White micro-malting system

Sprouted wheat

Drying

Milling

Flake production

Modified process flow chart

Control wheat

Sprouting at standard condition (15 °C, 48 h)

Joe White micro-malting system

Sprouted wheat

Drying

Milling

Flake production

Blend 25-75%

Control wheat

Allowing synthesised enzymes to be active by tailoring the breakfast flake making process

Textural properties of flakes

	Bulk density (g/l)
Control wheat, standard process	399 ± 22[b]
Control wheat, modified process	324 ± 17[b]
Sprouted wheat, standard process	198 ± 21[a]
Sprouted wheat, modified process	335 ± 39[b]
Blend, standard process	340 ± 1[b]
Blend, modified process	366 ± 11[b]

Bulk density decreased when using sprouted wheat due to amylase action during extrusion

Partial hydrolysis of the starchy food matrix probably allows more expansion after extrusion

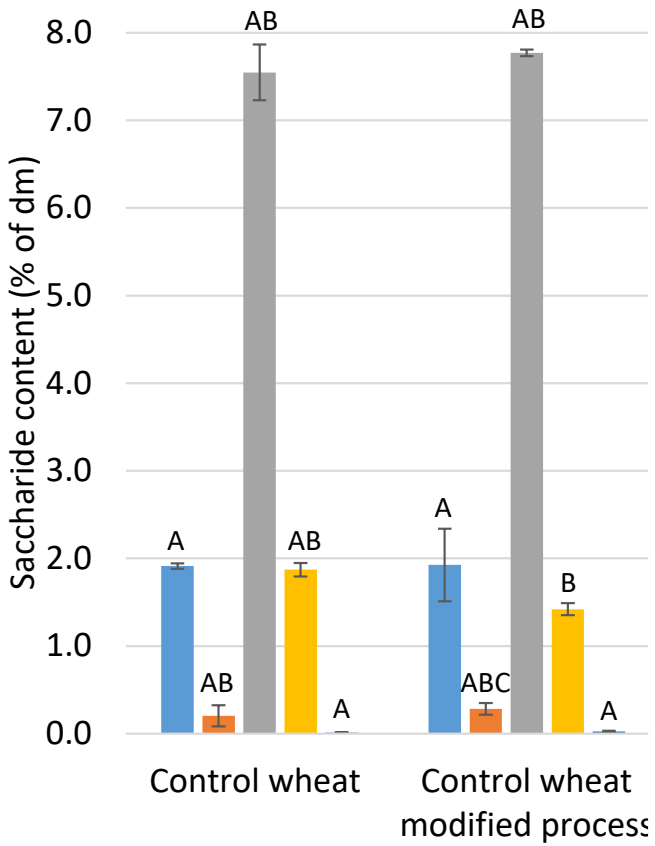
Textural properties of flakes

	Bulk density (g/l)	Hardness (N)	Hardness after 30 s soaking (N)
Control wheat, standard process	399 ± 22^{b}	441 ± 32^{bcA}	322 ± 22^{aB}
Control wheat, modified process	324 ± 17^{b}	438 ± 18^{bcA}	311 ± 17^{aB}
Sprouted wheat, standard process	198 ± 21^{a}	439 ± 50^{cA}	332 ± 21^{aA}
Sprouted wheat, modified process	335 ± 39^{b}	451 ± 13^{bcA}	338 ± 39^{aB}
Blend, standard process	340 ± 1^{b}	499 ± 3^{bcA}	397 ± 1^{aB}
Blend, modified process	366 ± 11^{b}	547 ± 5^{bA}	403 ± 11^{aB}

Soaking process in milk corresponded to a loss of 20-27% of initial hardness of the flakes

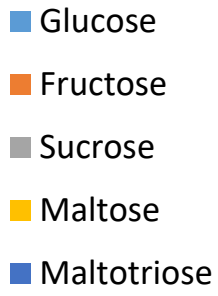
The hardness values before and after 30 s of soaking differ significantly ($P < 0.05$) when not sharing the same upper case letter.

Soluble saccharide content of flakes

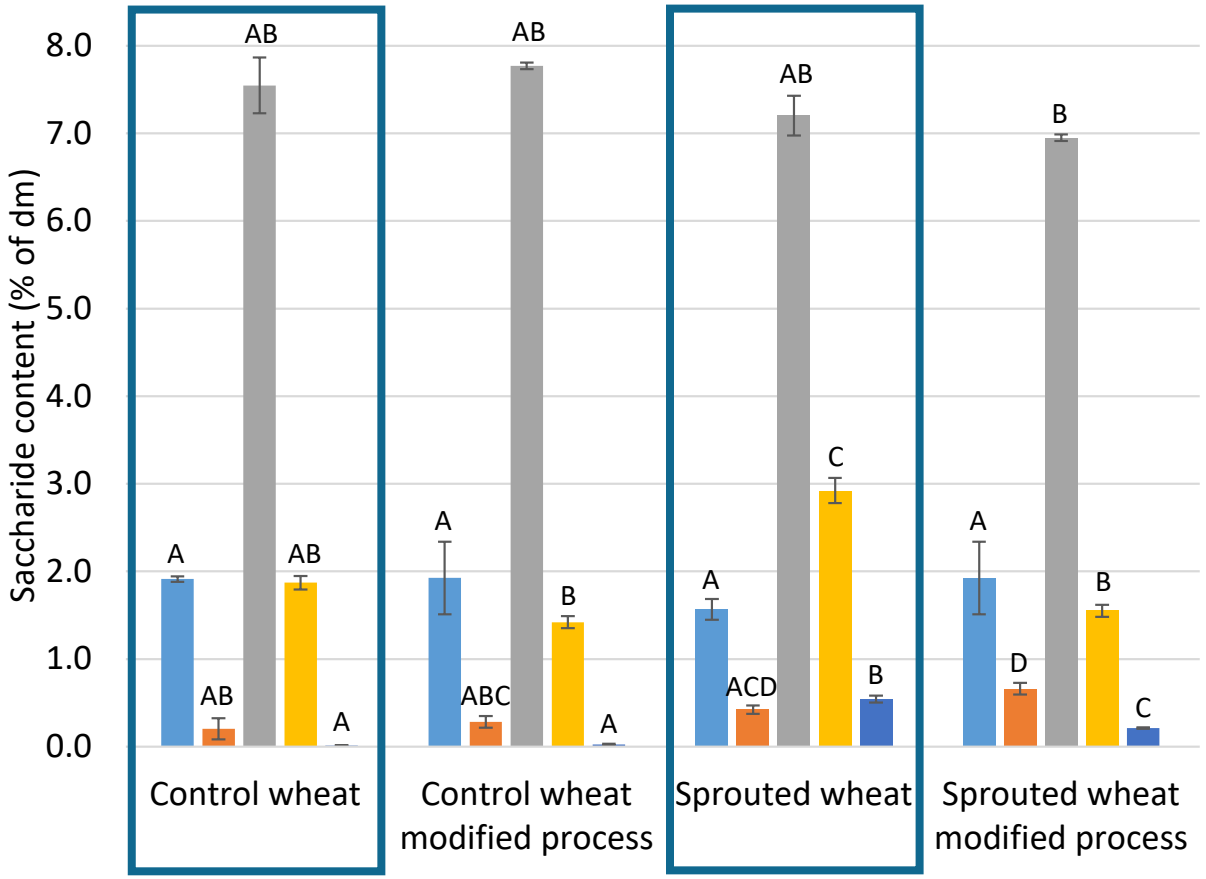


Total: 11.5% of dm
Relative sweetness: 10.1

Total: 11.4% of dm
Relative sweetness: 10.2



Soluble saccharide content of flakes



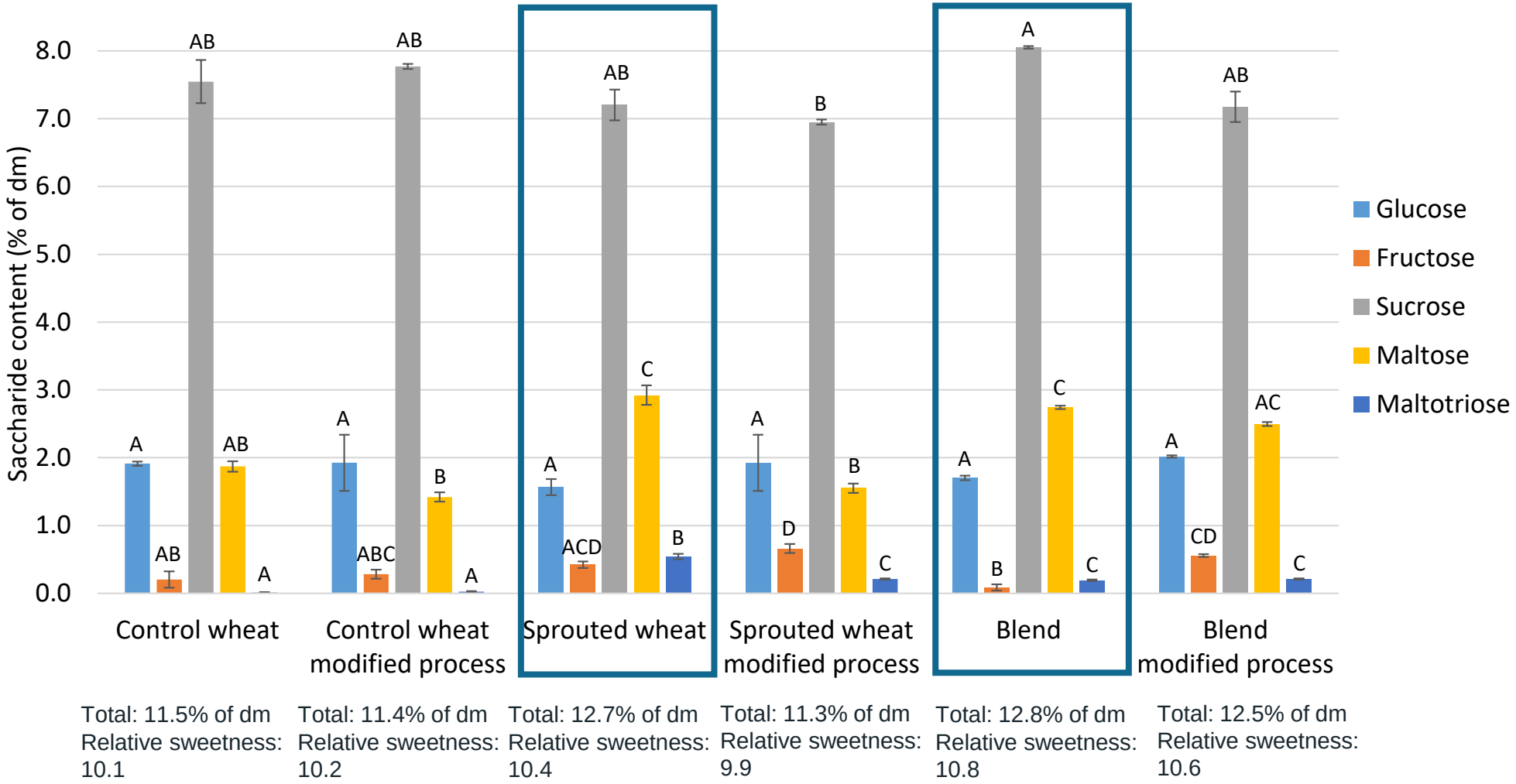
Total: 11.5% of dm
Relative sweetness: 10.1

Total: 11.4% of dm
Relative sweetness: 10.2

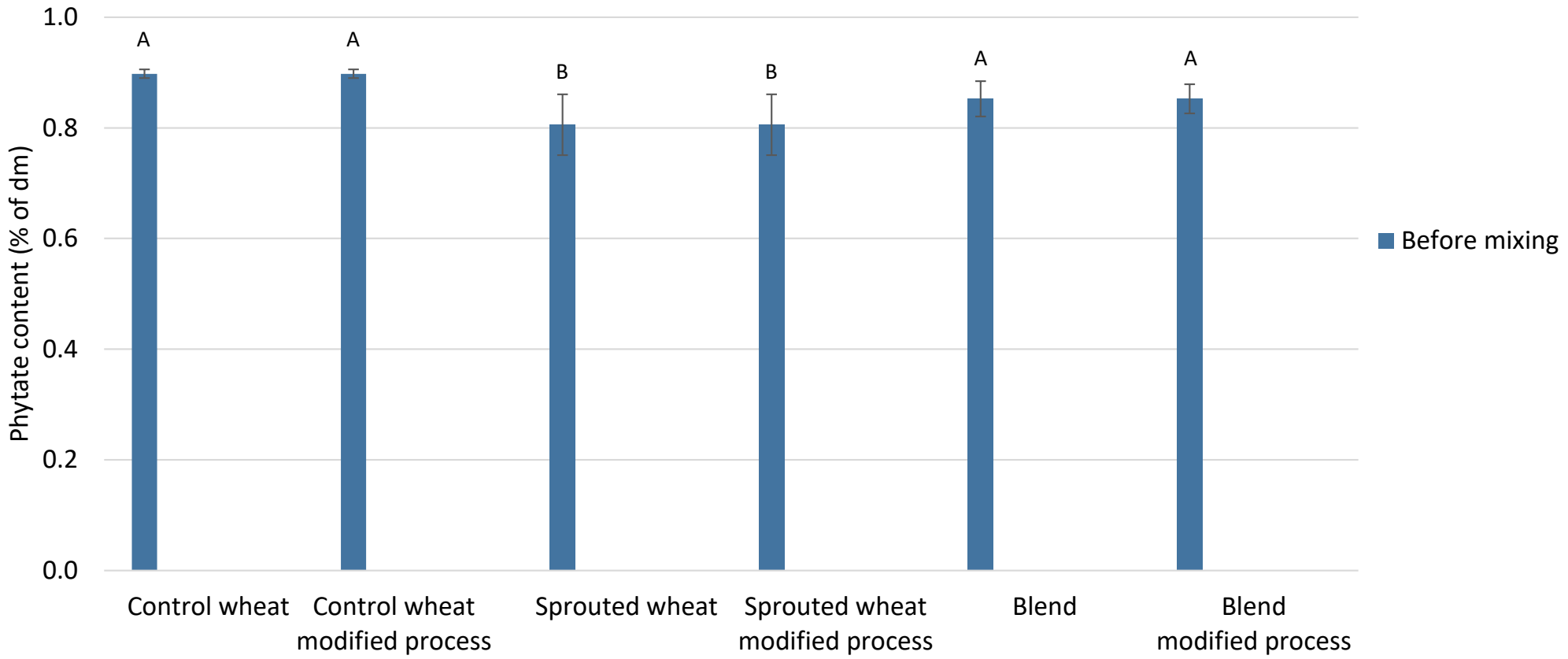
Total: 12.7% of dm
Relative sweetness: 10.4

Total: 11.3% of dm
Relative sweetness: 9.9

Soluble saccharide content of flakes



Phytate hydrolysis during flake production



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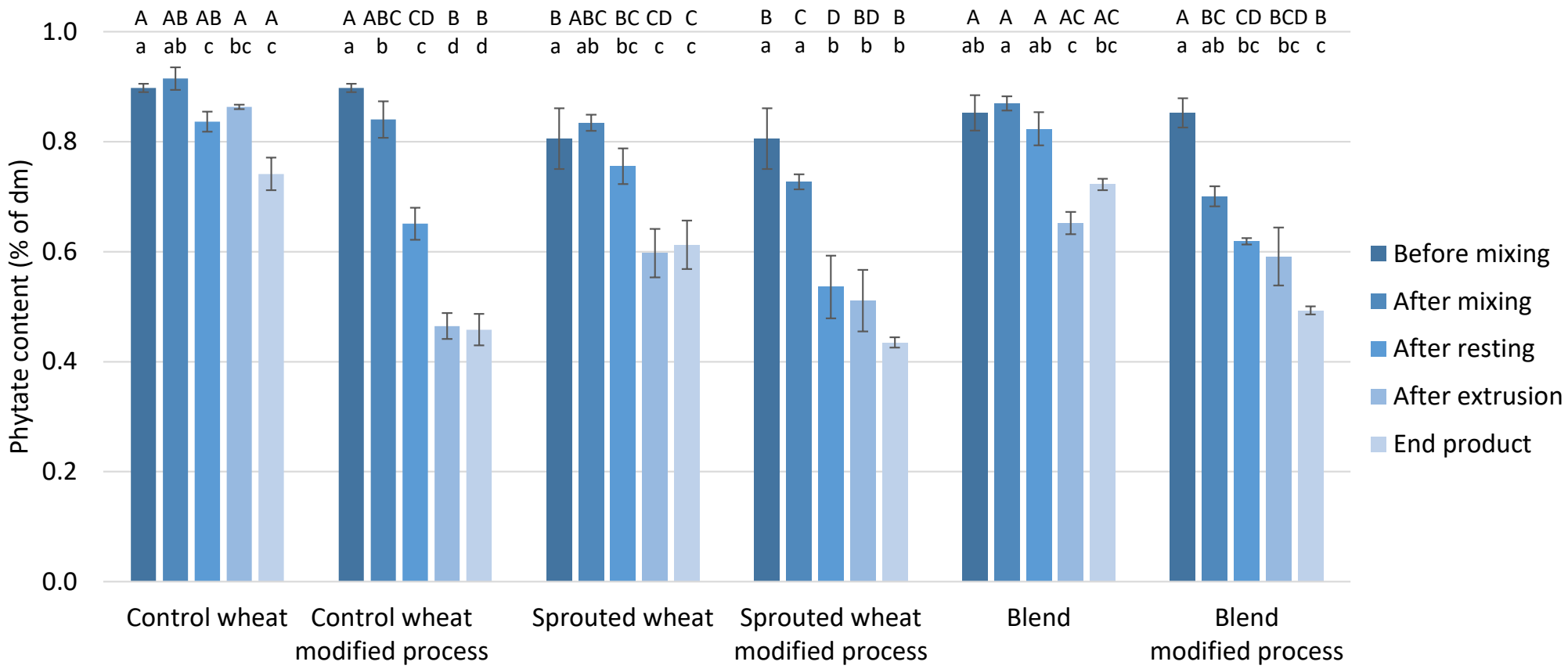
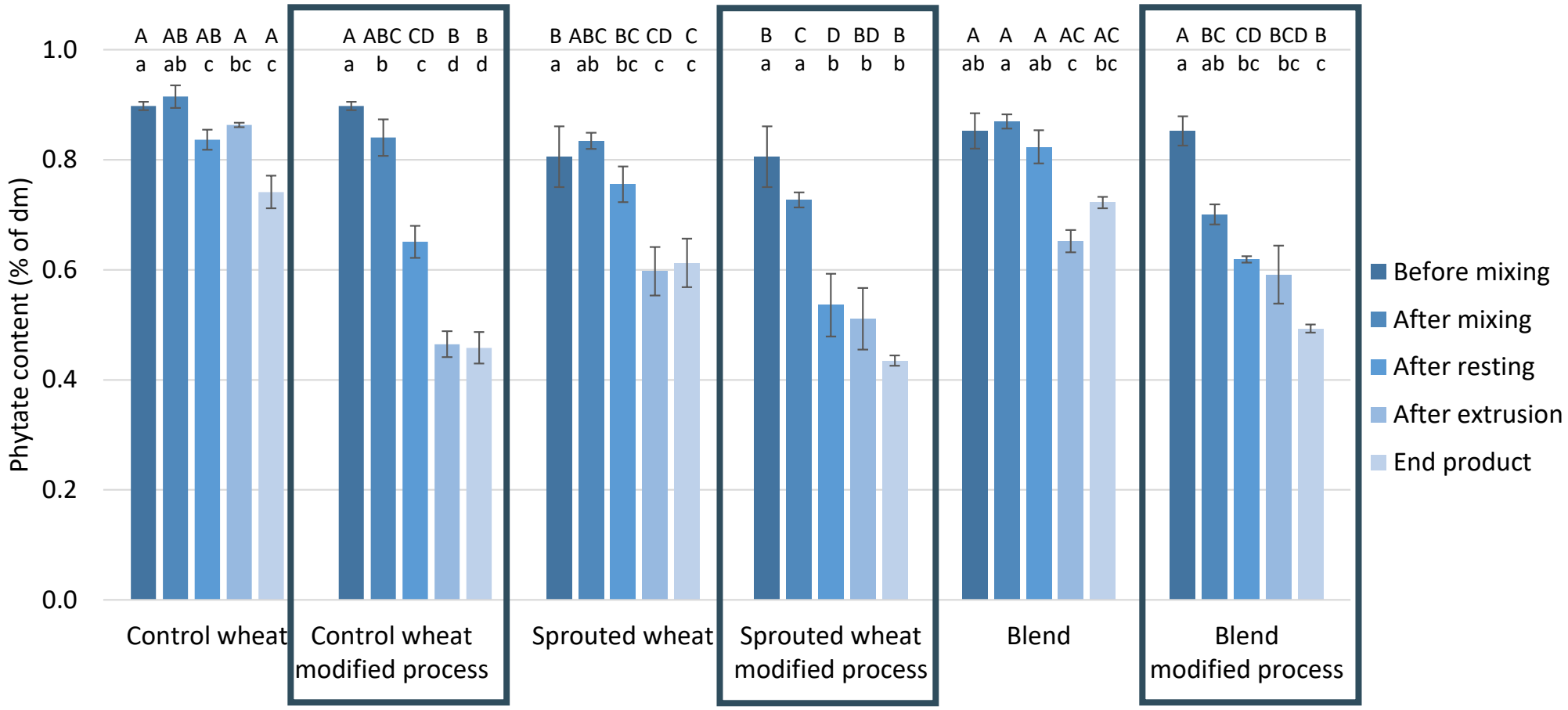


Phytate hydrolysis during flake production



No large differences in phytate content using control or sprouted wheat as ingredient

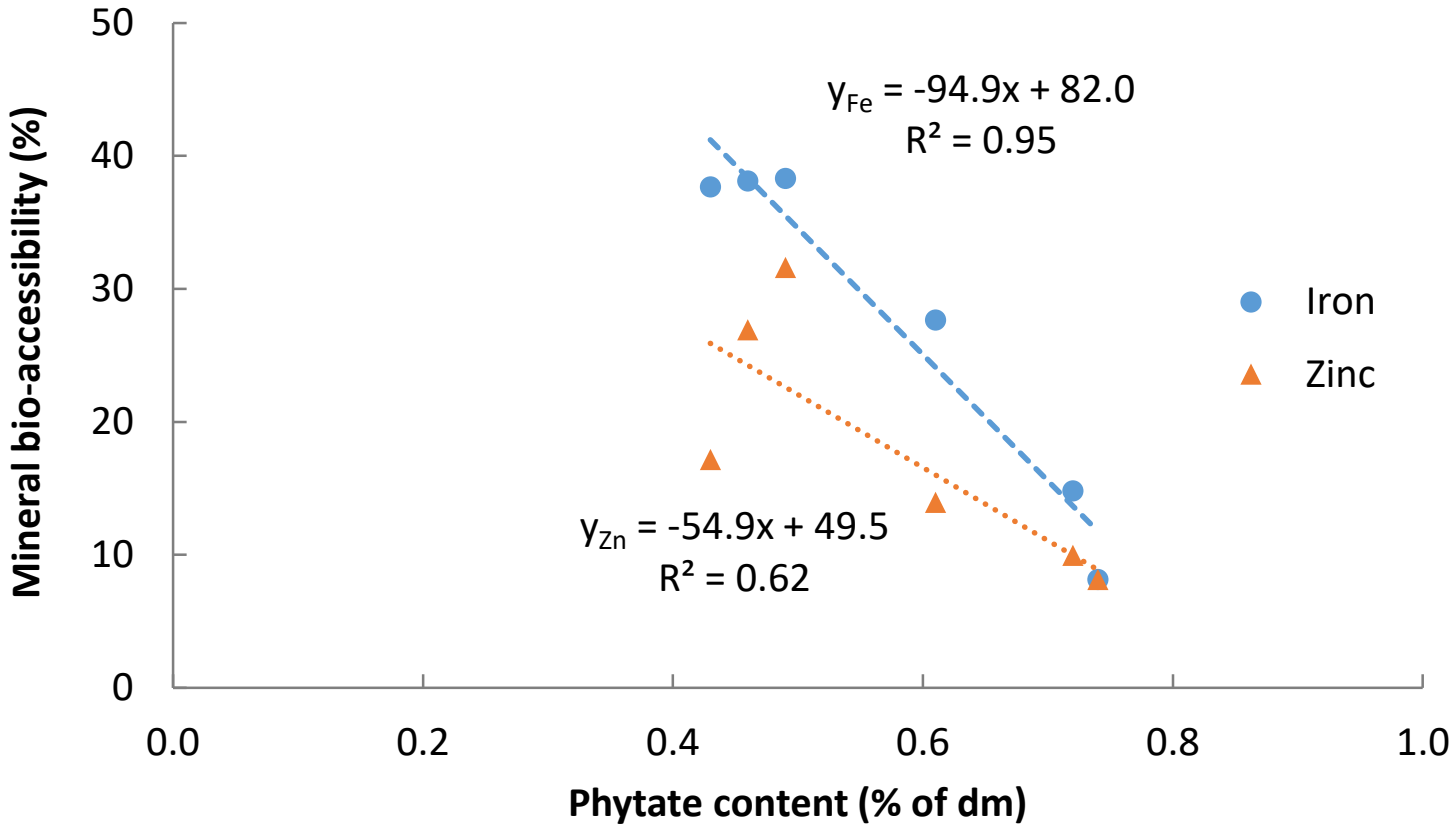
Fe and Zn bio-accessibility

	Fe bio-accessibility (%)
Control wheat, standard process	8.1 ± 0.8^{a}
Control wheat, modified process	38.1 ± 3.5^{b}
Sprouted wheat, standard process	27.7 ± 2.3^{c}
Sprouted wheat, modified process	37.7 ± 5.4^{b}
Blend, standard process	14.8 ± 2.6^{a}
Blend, modified process	38.3 ± 0.8^{b}

Fe and Zn bio-accessibility

	Fe bio-accessibility (%)	Zn bio-accessibility (%)
Control wheat, standard process	8.1 ± 0.8^{a}	8.1 ± 4.5^{a}
Control wheat, modified process	38.1 ± 3.5^{b}	26.9 ± 1.0^{bc}
Sprouted wheat, standard process	27.7 ± 2.3^{c}	13.9 ± 1.6^{a}
Sprouted wheat, modified process	37.7 ± 5.4^{b}	17.1 ± 0.5^{ac}
Blend, standard process	14.8 ± 2.6^{a}	10.0 ± 1.6^{a}
Blend, modified process	38.3 ± 0.8^{b}	31.6 ± 5.9^{b}

Fe and Zn bio-accessibility



Linear relationships suggest that lower phytate contents render Fe an Zn more accessible in human gastro-intestinal tract

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Conclusion

1. Using sprouted wheat grains in breakfast flake recipe resulted in:
   I. acceptable hardness before and after soaking for 30 s in semi-skimmed milk
   II. flakes with higher intrinsic saccharide (maltose and maltotriose) content due to α-amylase action

2. Modifying the breakfast flake production process by incubating the ingredient mix at 50 °C and pH 3.8 for 1 h, allowed optimal phytase action and led to a 45-60% phytate breakdown in the flakes
   I. resulting in a 4- to 5-fold increase in Fe bio-accessibility, and
   II. a 2- to 4-fold increase in Zn bio-accessibility

3. Blends with limited amounts of sprouted grains can be used as enzyme source to act on regular wheat during breakfast flake making

Lemmens *et al. (*2021); LWT Food Science and Technology 143

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