Business from technology

Process induced structural features of solid cereal foams- in relation to oral processing

PhD thesis
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Ariful's dissertation: Process induced structural features of solid cereal foams

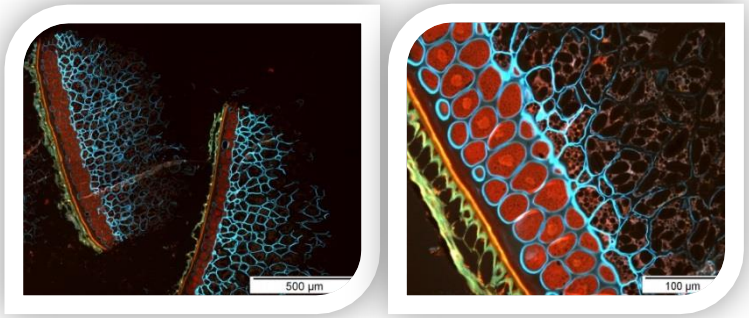
- Work started in 2014
- Research at VTT Espoo
- Studies at the University of Helsinki, Department of Food and Environmental Sciences.
- Supervisors:
  - Docent Nesli Sozer (Senior Scientist at VTT)
  - Assist. Prof. Kati Katina (UH)
  - Academy Prof. Kaisa Poutanen (VTT)
- Funded by: Academy of Finland, VTT & Raisio Plc. Research Foundation

Objective: Understand the main structural and mechanical features of healthy solid foams. Elucidate mechanism of structural disintegration of healthy solid foams in mouth and stomach phase.

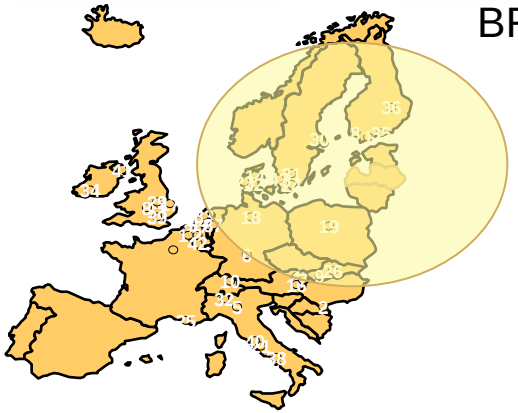
Overview of the PhD thesis & publications

- Influence of particle size reduction on structural & mechanical properties of extruded rye bran
  - **Published at Food and Bioprocess Technology, 2014** ACADEMY OF FINLAND VTT
- Effects of rye bran particle size reduction on *in vitro* starch digestibility and structural & textural properties of high-fibre extrudates
  - **Submitted to Food and Bioprocess Technology, 2015)** ACADEMY OF FINLAND RAISIO
- Structural and mechanical properties of brittle cereal foams affecting disintegration in mouth during *in vivo* mastication
  - **On-going study…….** VTT RAISIO
- Disintegration of high fibre solid cereal foams in mouth (*in vivo*) & in stomach (*in vitro*) & their positive impact on physiological responses
  - **Funding: 2016-2017 (to be applied)**

Why RYE?



BRAN



RYE BRAN
40-45% **dietary fibre**
15-20% **protein**
13-20% **starch**
4-5% **fat**

- **90%** of world rye production is in Europe
- **30%** is consumed as food
- Traditional use as whole grain breads, often produced by sour dough fermentation
- Health effects of rye bread increasingly demonstrated
- Development of new types of rye products & ingredients for the modern consumer is important

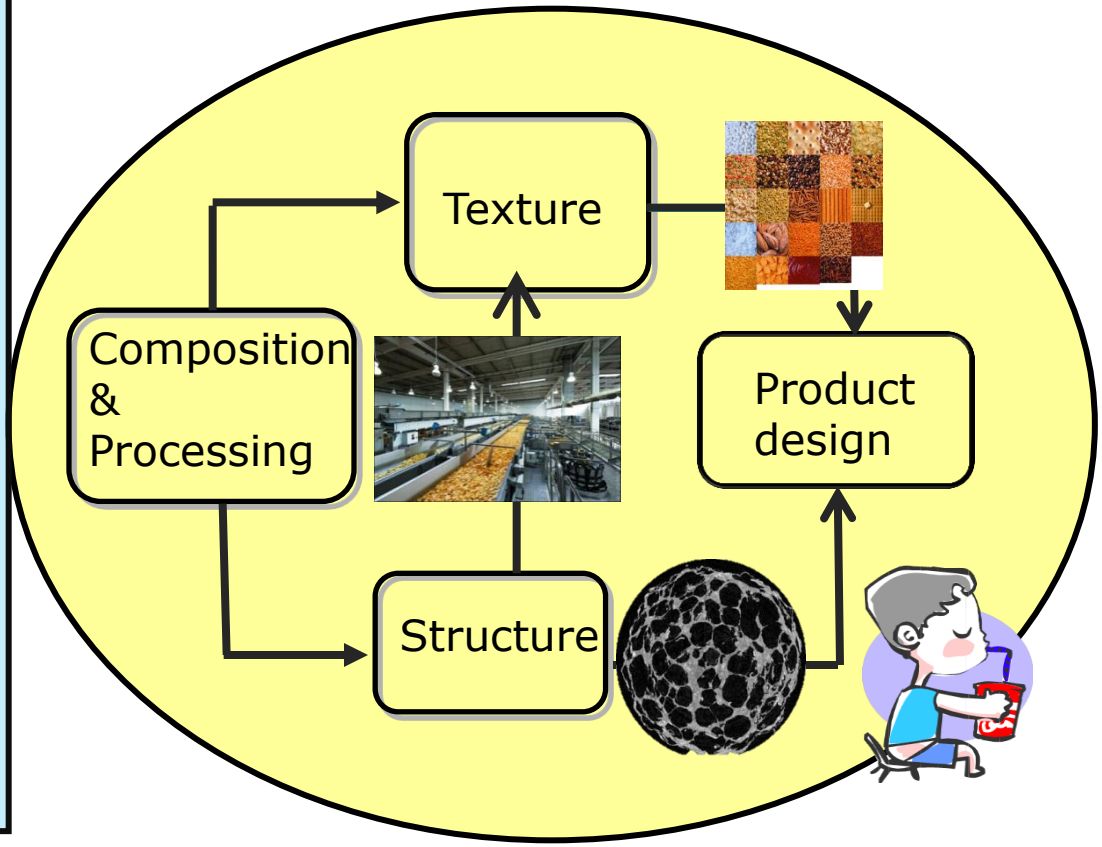
Beneficial physiological effects in humans

Background

- Extrusion processing can be used for production of a wide range of solid cereal foams e.g., puffed snacks, flakes etc.
- Addition of DF into extruded product improve the nutritional quality
- Bran addition →product quality (e.g., expansion, hardness & crispiness) attributes reduced
- Addition of DF into extruded product improve the nutritional quality
- Breakdown in mouth by mastication inversely related to food hardness and thus affects hydrolysis rate
- Prediction of the disintegration pattern of solid cereal foams → Mathematical modelling

Importance of structure and texture formation in food design

- Increased **demand for high quality healthy food** products.
- **Technological and physical challenges** in high fibre food matrices.
- **Adverse affect on sensory** texture and flavor/taste.
- **Important to understand the physical basis of texture** in order to be able **to design palatable and healthy** foods.



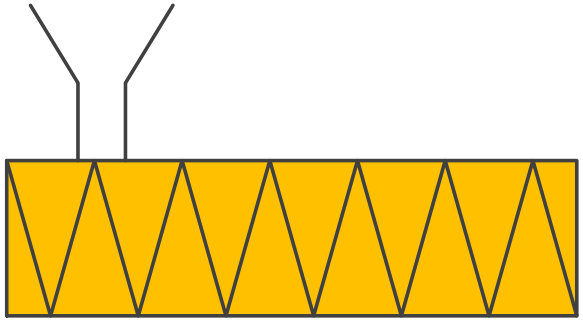
Objectives

- Understand the main structural and mechanical features of healthy solid foams e.g., puffs and flakes

- Assessing the effect of structural and mechanical properties of high fibre extruded puffs & flakes on disintegration in mouth (*in vitro*) and in bolus formation

- Elucidate mechanism of structural disintegration of healthy puffs and flakes (*in vivo* mouth and *in vitro* stomach phase) in comparison to regular wheat based foams

Flow chart of 4-year work



Extrusion

Open cereal matrices

Microstructure

Macrostructure

WAI & WSI

Texture

Starch HI

Open & closed cereal matrices

In vivo mastication

Particle size

Bolus

In vitro stomach

Viscosity

Hierarchical model

Psychophysical model

Experimental design paper 1 & 2/4

Publication 1:

100 % rye bran

3-particle sizes of rye bran:

- Coarse (440 µm)
- Medium (143 µm)
- Fine (28 µm)

- Screw speed: 300/500rpm
- Feed Moisture: 17/ 19 %
- Barrel T profile: low (110°C) / high (130°C)
- Hydration regimen: In-barrel/ Preconditioning

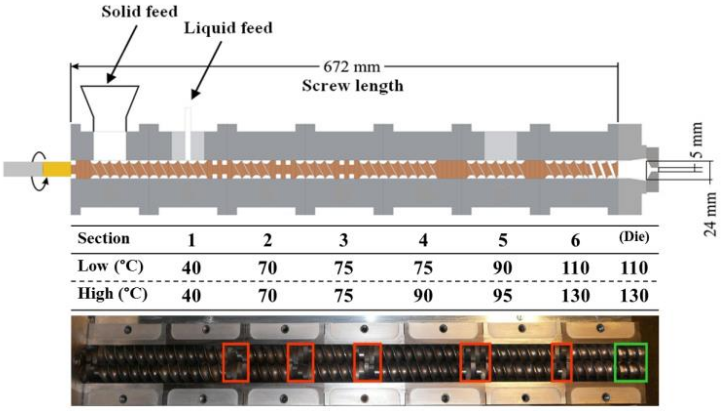
Raw material:

RYE BRAN

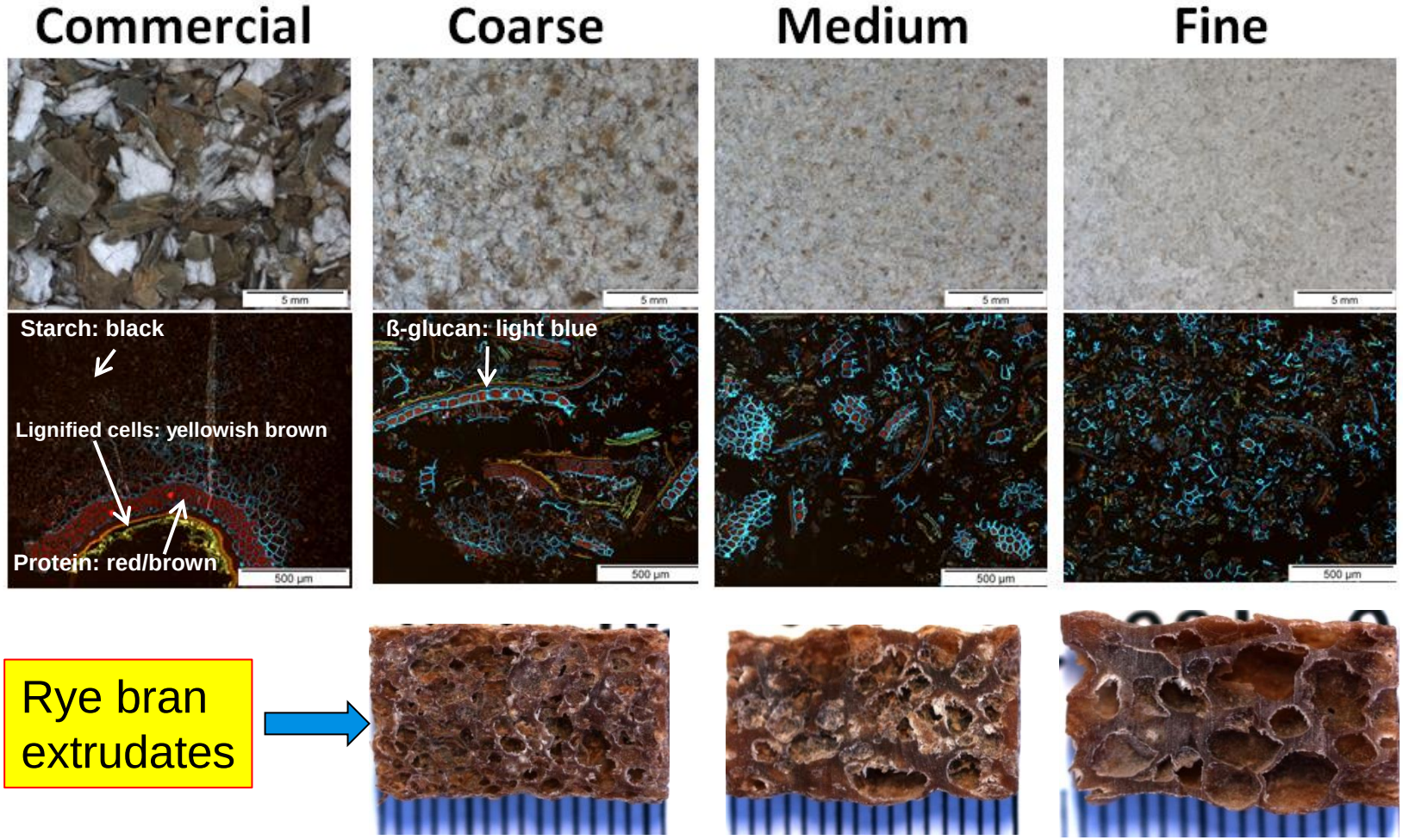
Publication 2:

Rye endosperm fllour + 15/30% rye bran

- 2-particle size (Coarse vs. Fine)
- Screw speed: 500 rpm
- Feed moisture: 17%
- Barrel T profile: low (110°C)
- Hydration regimen: In-barrel/ Preconditioning

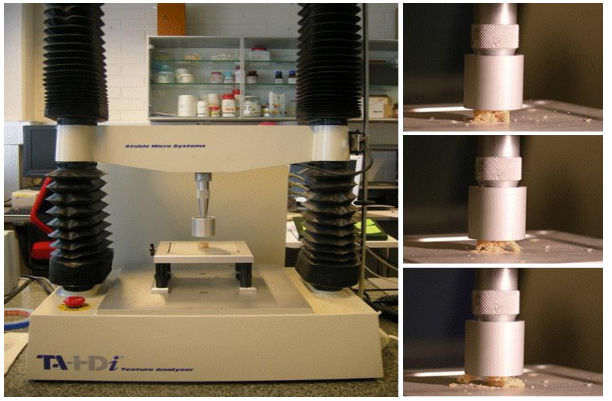


Partile size reduction and effect on rye bran quality and on extrudates



Structural & textural parameters

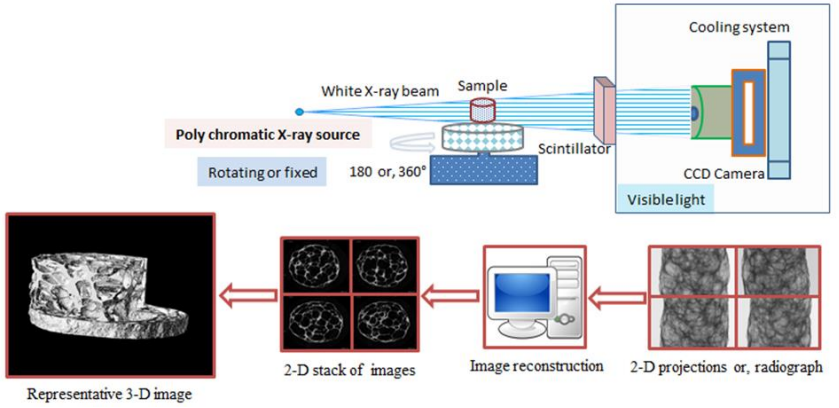
- Macro-structural vs. Textural parameters
  - Expansion
  - Piece density
  - Crispiness



- Microstructure
  - Effect of particle size and extrusion on microstructure (LM)
  - X-ray microtomography (XMT)

- Texture Analysis: Uni-axial compression test for puffs & crammer shear compression for flakes

- Micro-structural vs. Textural parameters
  - Porosity, air cell diameter
  - Cell wall thickness, crispiness

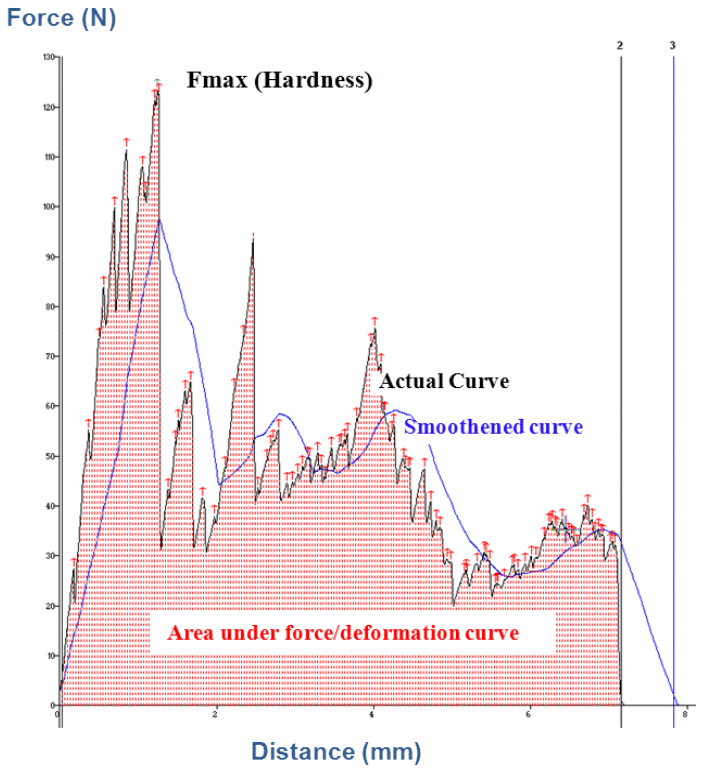


Crispiness index

Mechanical properties of the extrudates were analysed using a texture analyzer (TAXT2i) and the Texture Exponent software (v5.1.2.0) (both from Stable Micro Systems, UK).

- A 36 mm Al cylindrical compression plate was used to compress the samples to 70% of their original diameter (test speed of 1 mm/s).

- $Crispiness\ index\ (CI) = \frac{Curve\ length\ (N)}{A * Fmean}$

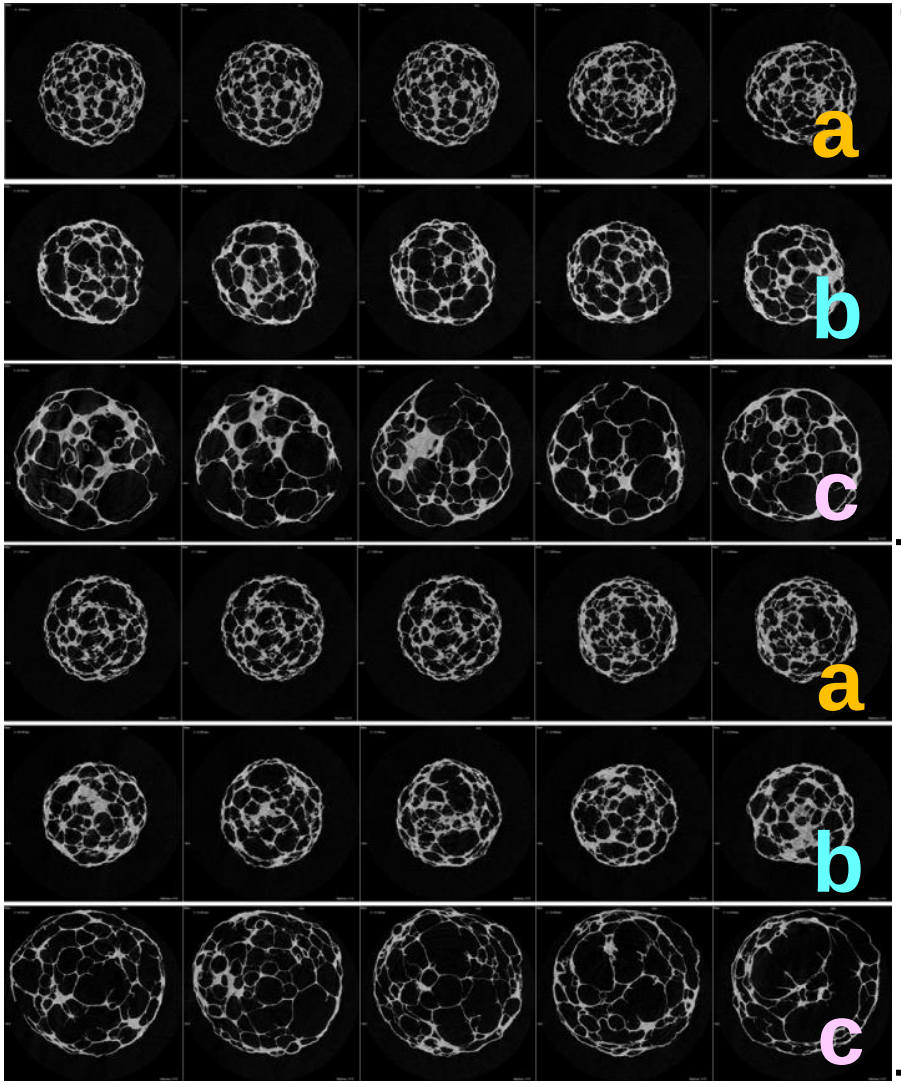


A = Area under the f-d curve

Fmean = Average force of the # peaks from the F-d curve

$$Curve\ length = \sum |\Delta Force|$$

Particle size reduction gives lower thickness to radius ratio; less thick and more expanded cells



In barrel

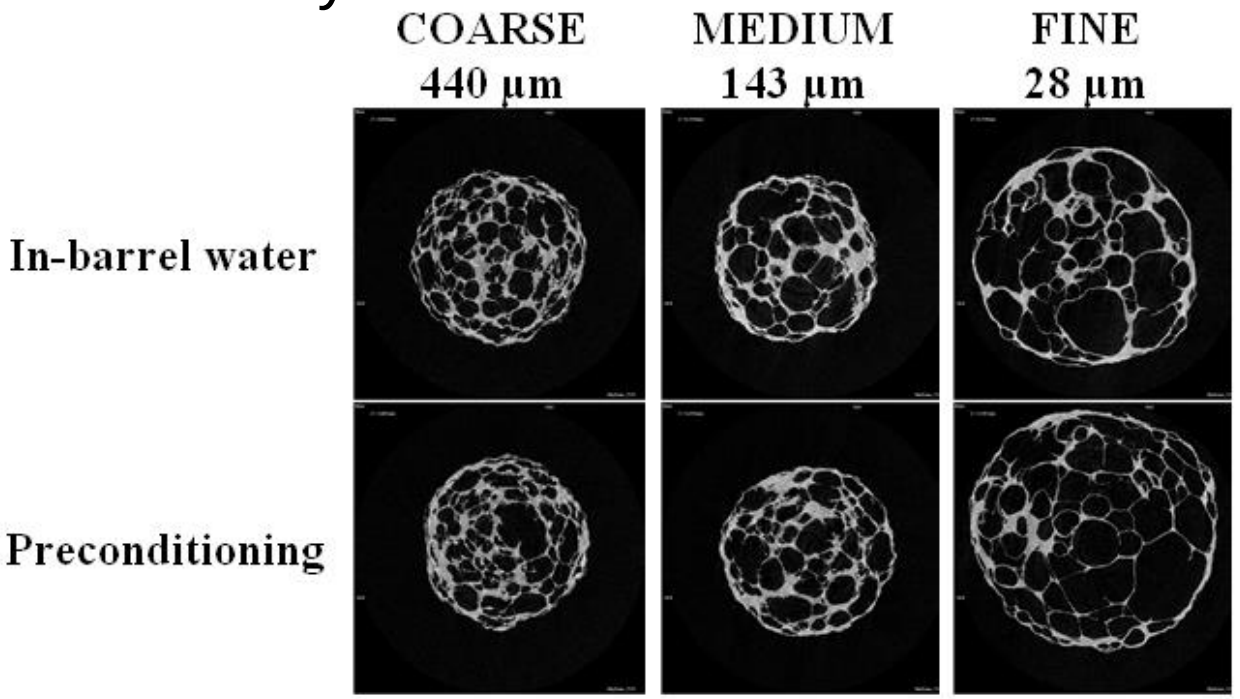
Representative XMT images of
a) Coarse
b) Medium
c) Fine particle-sized
extruded rye bran samples

Pre-conditioned

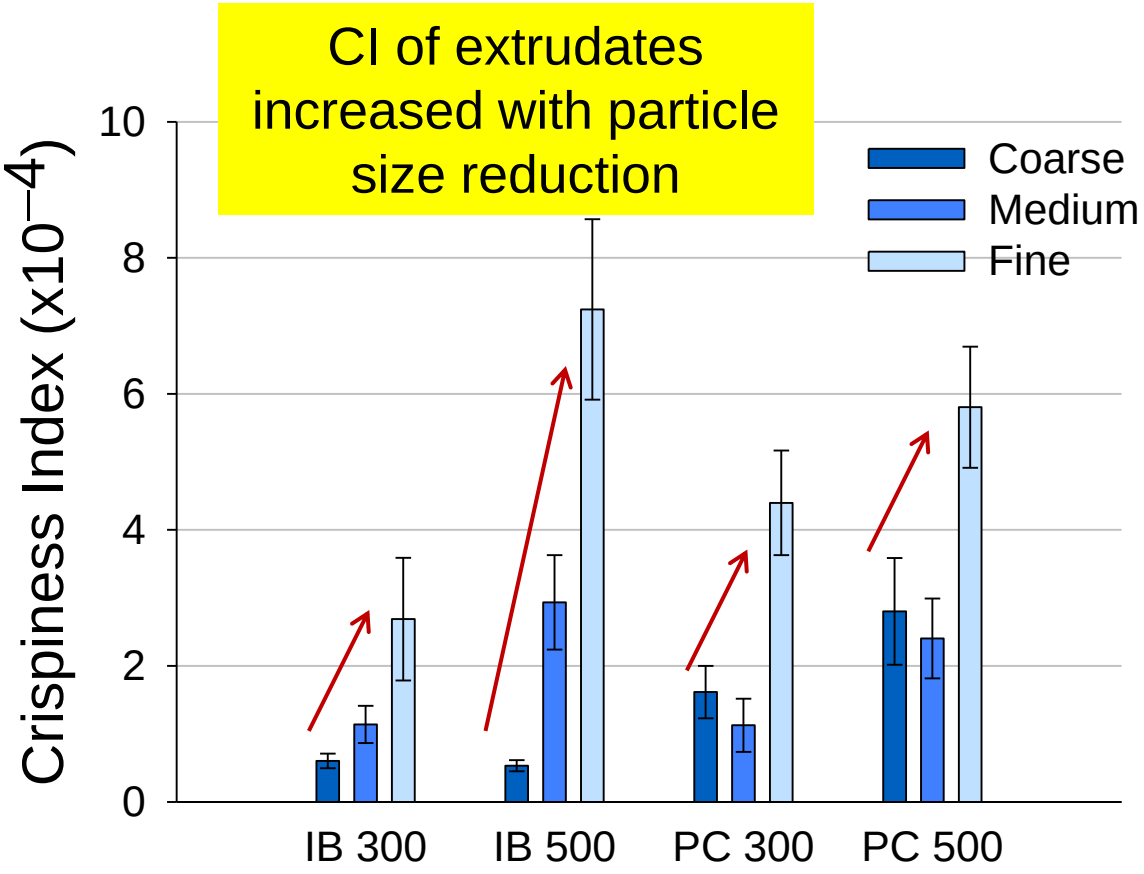
Macro-structural vs. Textural parameters

- High screw speed and small particle size
  - ➢good expansion
  - ➢low density

- High expansion and low density
  - ➢More crispy
  - ➢less hard textrure



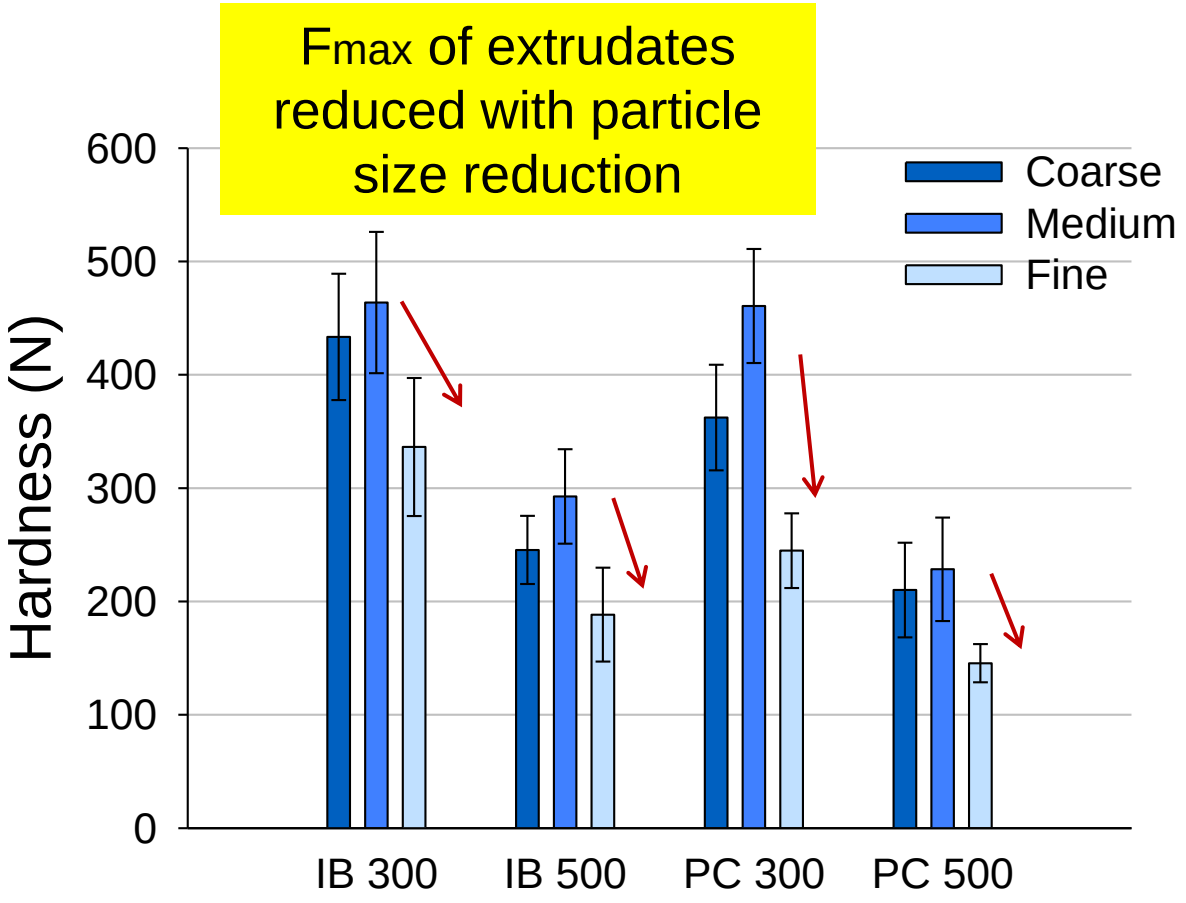
Particle size reduction to 28 µm gave extrudates with crispy texture. Pre-conditioning had an adverse affect on crispiness



- Fine particle increased the crispiness for both in-barrel and preconditioned extrudates
- In-barrel water feed in combination with high screw gave crispiest puffs

IB= In-barrel water feed; PC= Preconditioning; Screw speed = 300 & 500 rpm

In general particle size reduction reduced Fmax. Pre-conditioning before extrusion reduced hardness (Fmax) values



- Higher screw speed reduced the hardness
- Preconditioning reduced the hardness for all particle size

IB= In-barrel water feed; PC= Preconditioning; Screw speed = 300 & 500 rpm

Fibre modification

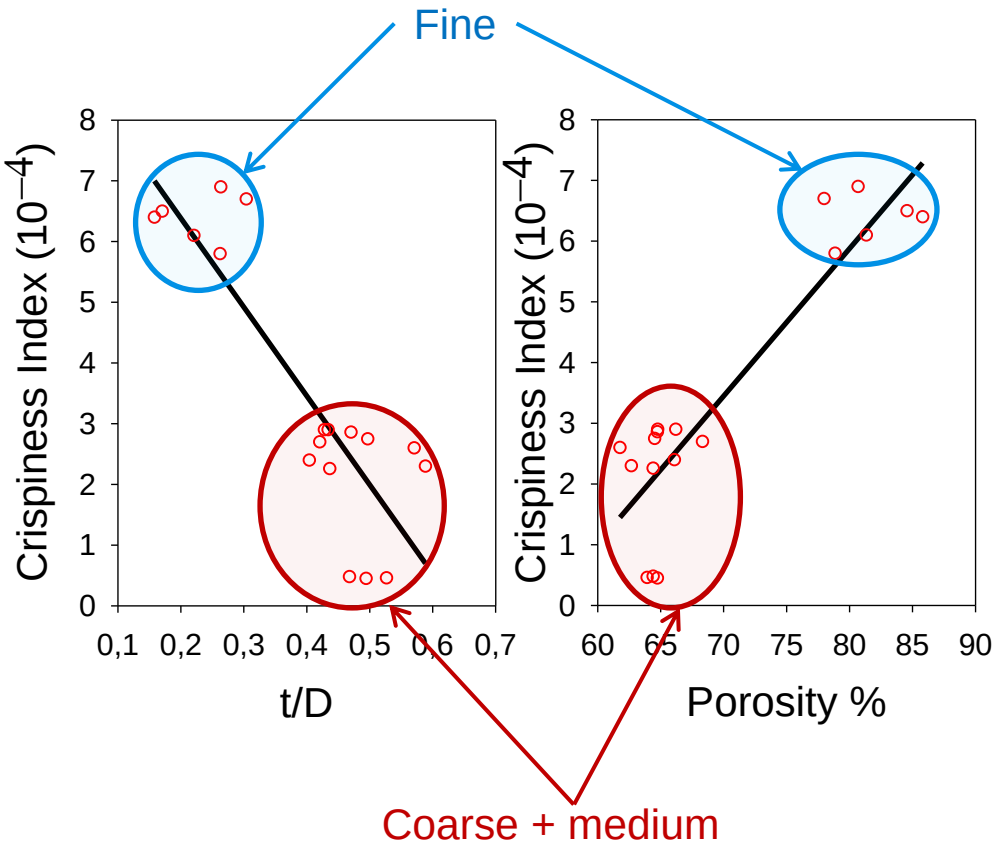
- Coarse rye bran
  - No significant effect
- Medium and fine rye bran:
  - Increase in IDF and TDF
  - SDF increased only in few samples

	Coarse	Medium	Fine
IDF	→	↑	↑
SDF	→	→↑	→
TDF	→	↑	↑

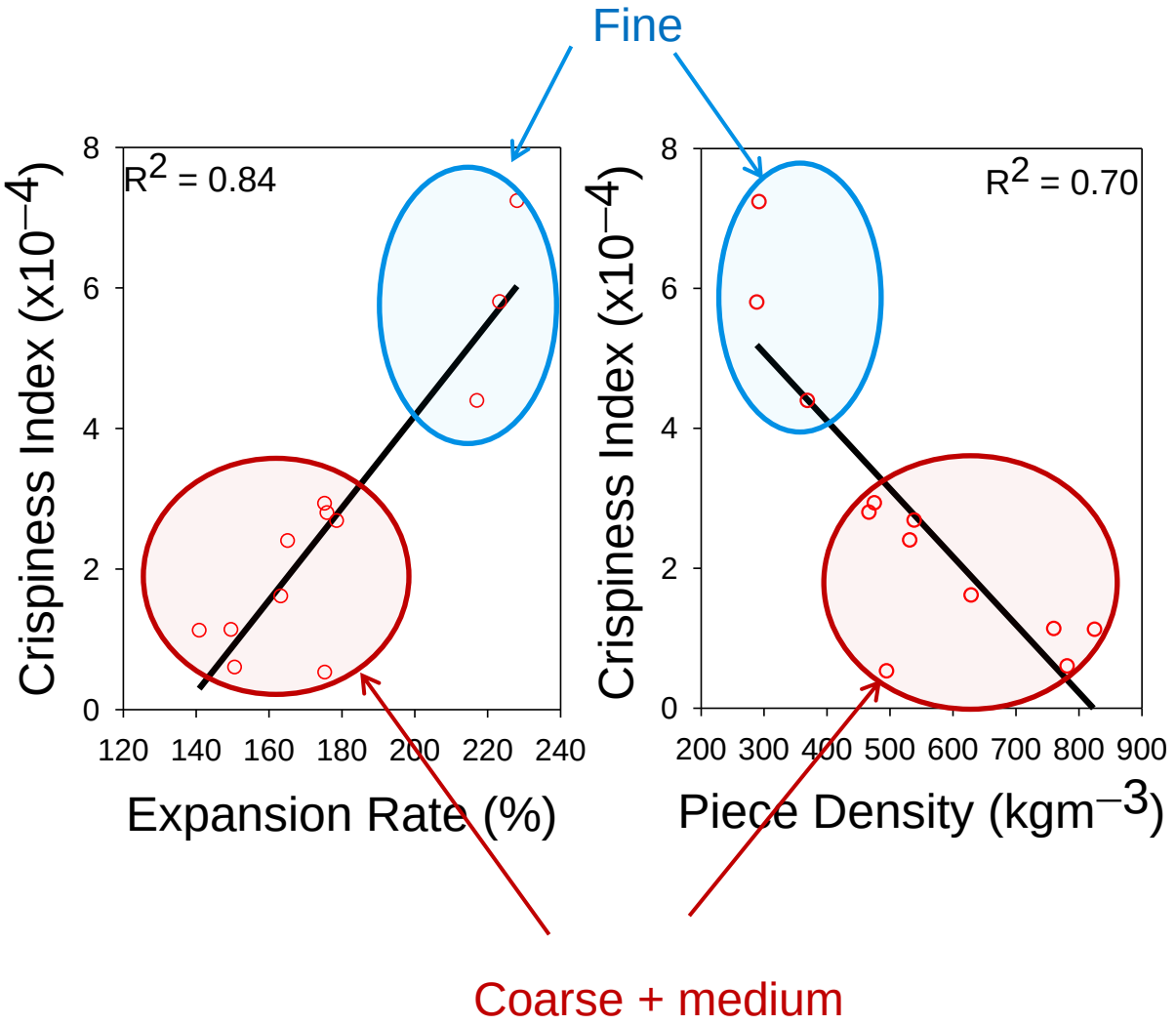
- Extrusion had only limited effect on DF composition
- The effect was more pronounced with medium and fine rye bran

Micro-structural vs. Textural parameters

- Particle size reduction to 28 µm
  - Porosity ↑
  - Air cell diameter ↑
  - t/D ratio ↓
    - ➢ more expanded air cells in relation to cell wall thickness
- Energy required to fracture big air cells with thin cell walls is lower than that required for small air cells with thick cell walls
- Less hard, more crispy extrudates

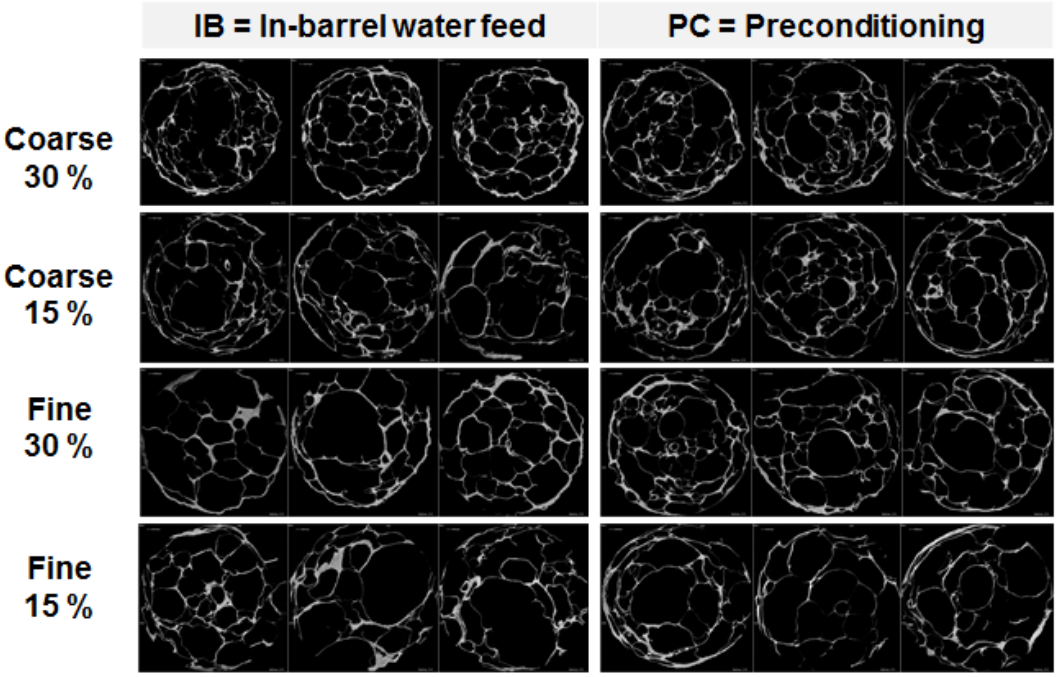


Crispiness increases with increased expansion and decreased piece density for fine particle sized rye bran extrudates

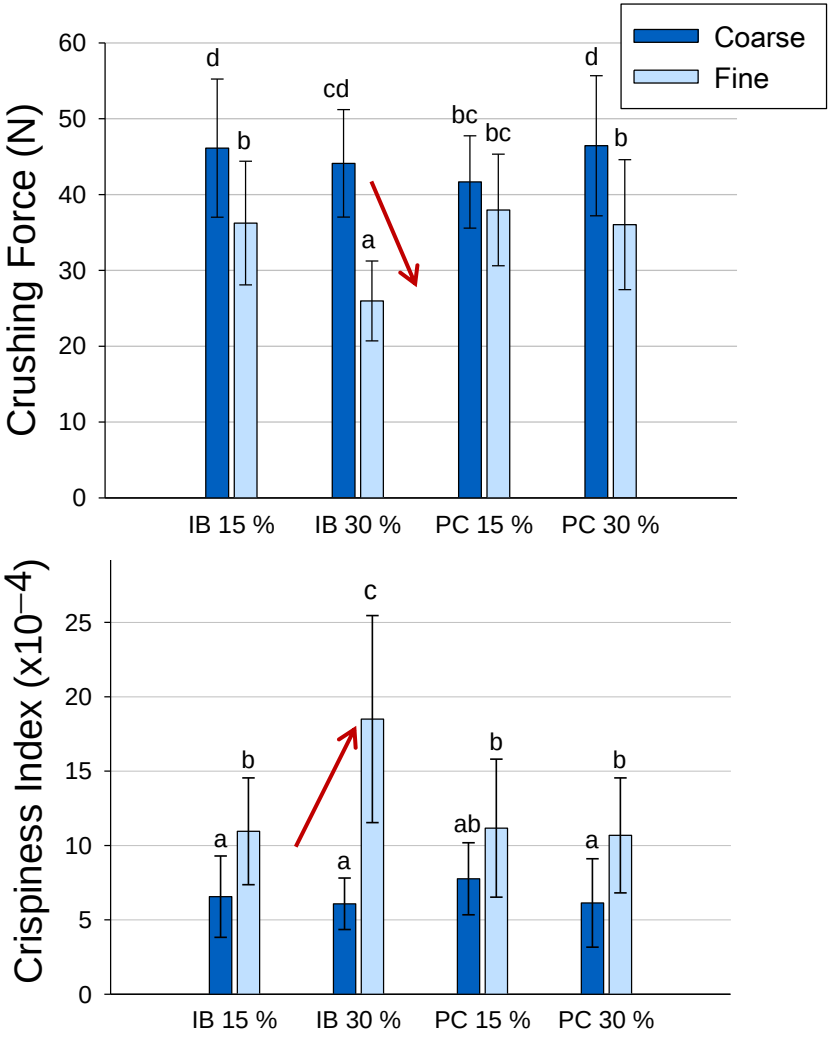


- Higher expansion tends to give crispy puffs
- Higer density reduced crispiness

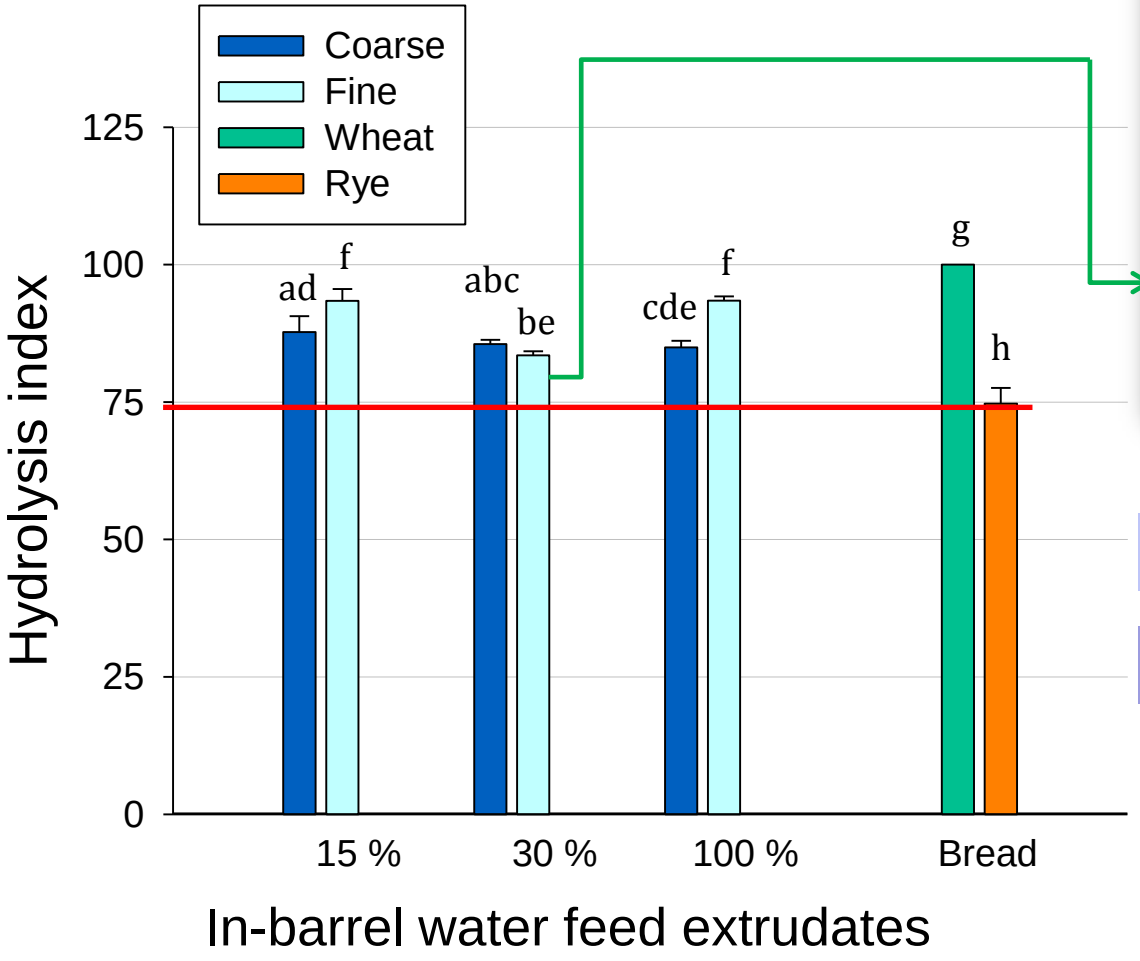
2nd paper: Effects of rye bran particle size reduction on *in vitro* starch digestibility and structural and textural properties of starch-based high-fibre extrudates (submitted)



Fine IB 30:
High cell wall thickness
&
Large cell wall area



Effect of particle size on in vitro starch digestibility



t (mm)	C_wA
0.14 ± 0.01 a	1.55 ± 0.15 ab
0.16 ± 0.01 ab	1.02 ± 0.11 ab
0.14 ± 0.01 a	1.36 ± 0.44 ab
0.14 ± 0.00 ab	1.12 ± 0.12 ab
0.17 ± 0.01 bc	1.73 ± 0.40 ab
0.19 ± 0.01 c	**2.06 ± 0.29 b**
0.15 ± 0.01 ab	0.86 ± 0.63 a
0.16 ± 0.00 abc	1.41 ± 0.54 ab

15% bran addition → **Fibre: 8.2%**

30% bran addition → **Fibre: 12.6%**

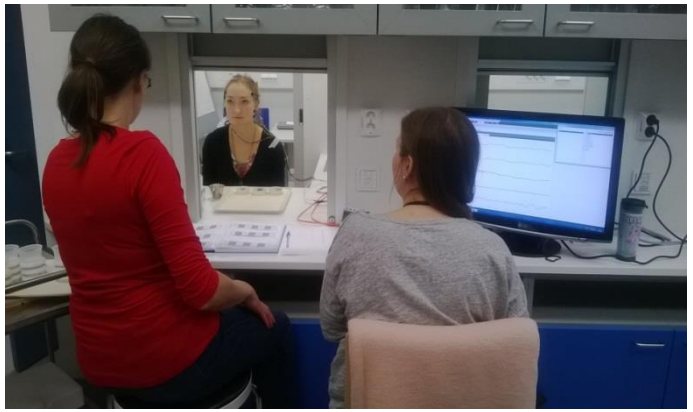
Experimental design 3/4

Publication 3:

100% Rye flour & Rye flour + 10% rye bran

- Screw speed : 250 (F) & 345 (P)
- Feed moisture 4.5 (P) & 12 (F) In-barrel
- Barrel T profile: low (80-95-110-120°C)

- Interidividual variance due to chewing pattern
- Effect of fibre: **7 vs. 9%**
- Structure/texture effect on masticaation: puffs vs. flakes



EMG: **EMG activity time -> Chewing time -> Number of bites -> Duty cycle ->Total work-> Work/bite**

3rd paper outline

100% Rye flour & 90% Rye bran

Extruded puffs and flakes

Fibre: 7 & 9%

Mastication & EMG

15 female volunteer

Bolus

Starch digestibility

Image analysis

Microscopy

Saliva impregnation

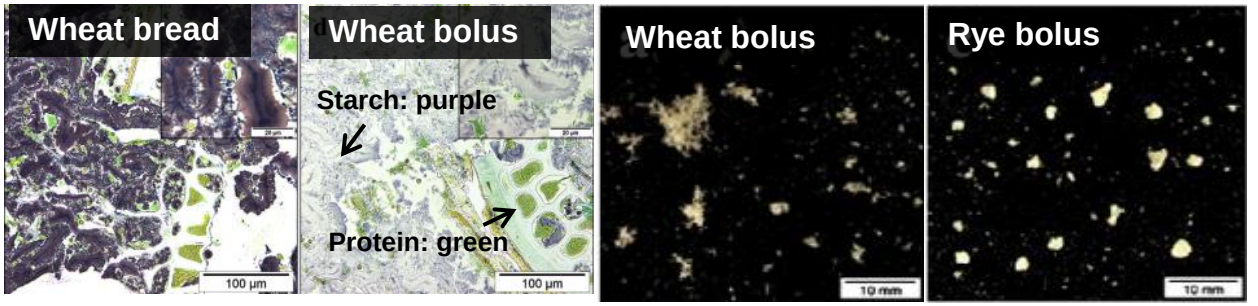
X-ray Microtomography

Starch HI

Viscosity

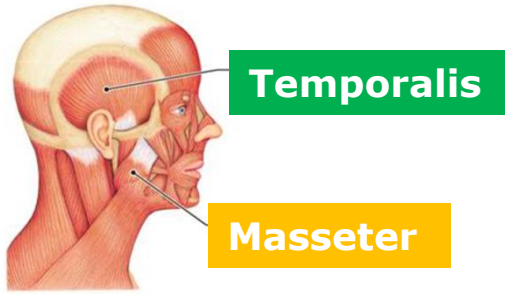
Microscopy

Texture



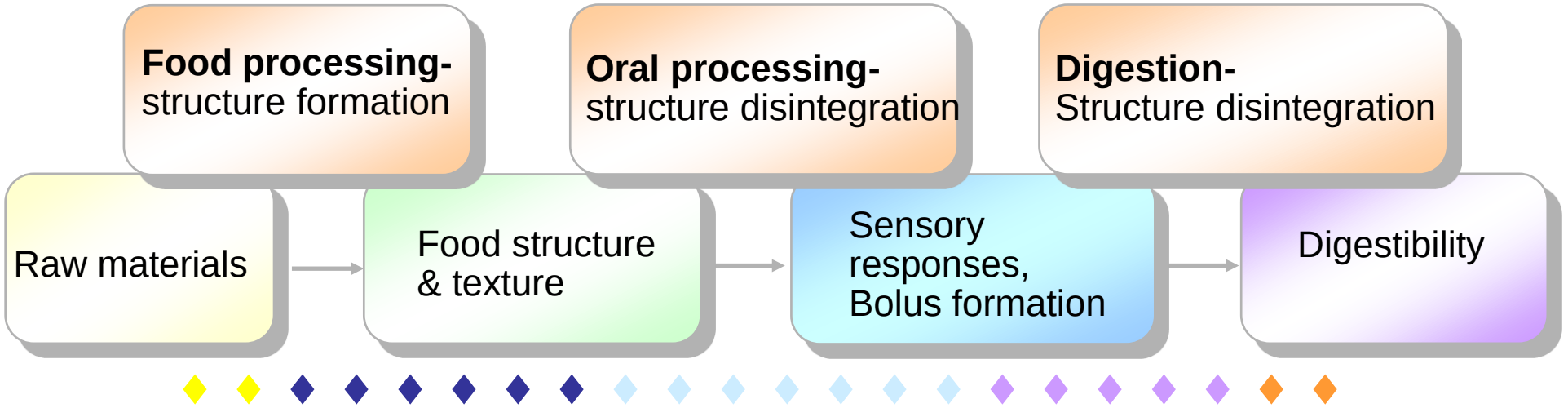
Microscopy & particle area distribution of masticated bread sample

Mastication trial/Electromyography



- 15 participants
- Bipolar electrodes on the **masseter** and **temporal** muscles on both sides of the face
- 3 portions
    - control bread: (2x2x2) cm cube
    - Puffs: (2x3.5) cm ribbon
    - Flakes: 1 table spoon
- Masticated until subjective swallowing point and the bolus was then expectorated
- EMG activity measured continuously
- Onset, duration and amplitude of each bite event were extracted from EMG time series

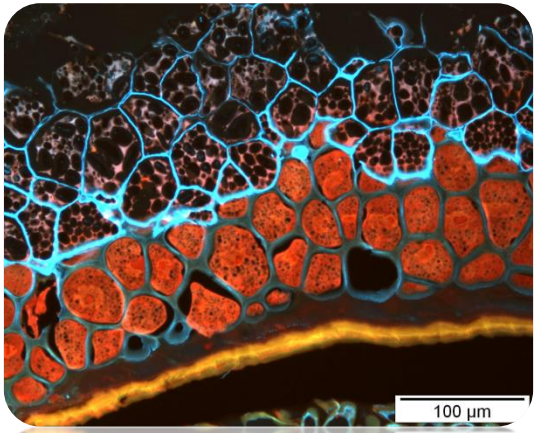
Conclusions



HIGH FIBRE (RYE) FOODS ARE HAVE GOOD POTENTIAL TO ASSIST IN REDUCTION OF RISK OF CHRONIC DISEASES.

UNDERSTANDING THEIR STRUCTURE FORMATION AND ORAL DISINTEGRATION - THE CONNECTION BETWEEN FOOD PROCESSING AND EATING – HELPS TO DEVELOP BETTER FOODS.

THANK YOU!



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