KU LEUVEN

Relevance of the air-water interfacial and foaming properties of wheat proteins for food systems

Arno G.B. Wouters

Laboratory of Food Chemistry and Biochemistry (LFCB)

Leuven Food Science and Nutrition Research Centre (LFoRCe)

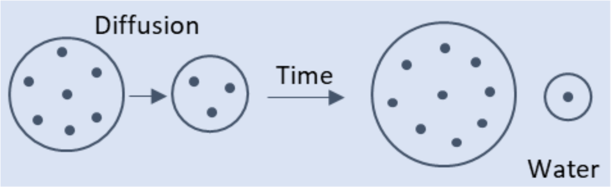
13 April 2023 – European Young Cereal Scientists & Technologists Workshop

- Introduction
- Air-water interfacial properties
- Foaming properties
- Relevance in food systems
- Outlook

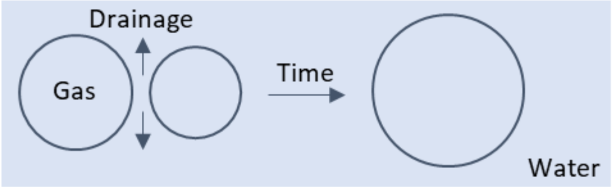
Introduction
(Food) foams

- Inherently unstable dispersion of gas in a liquid phase

Disproportionation

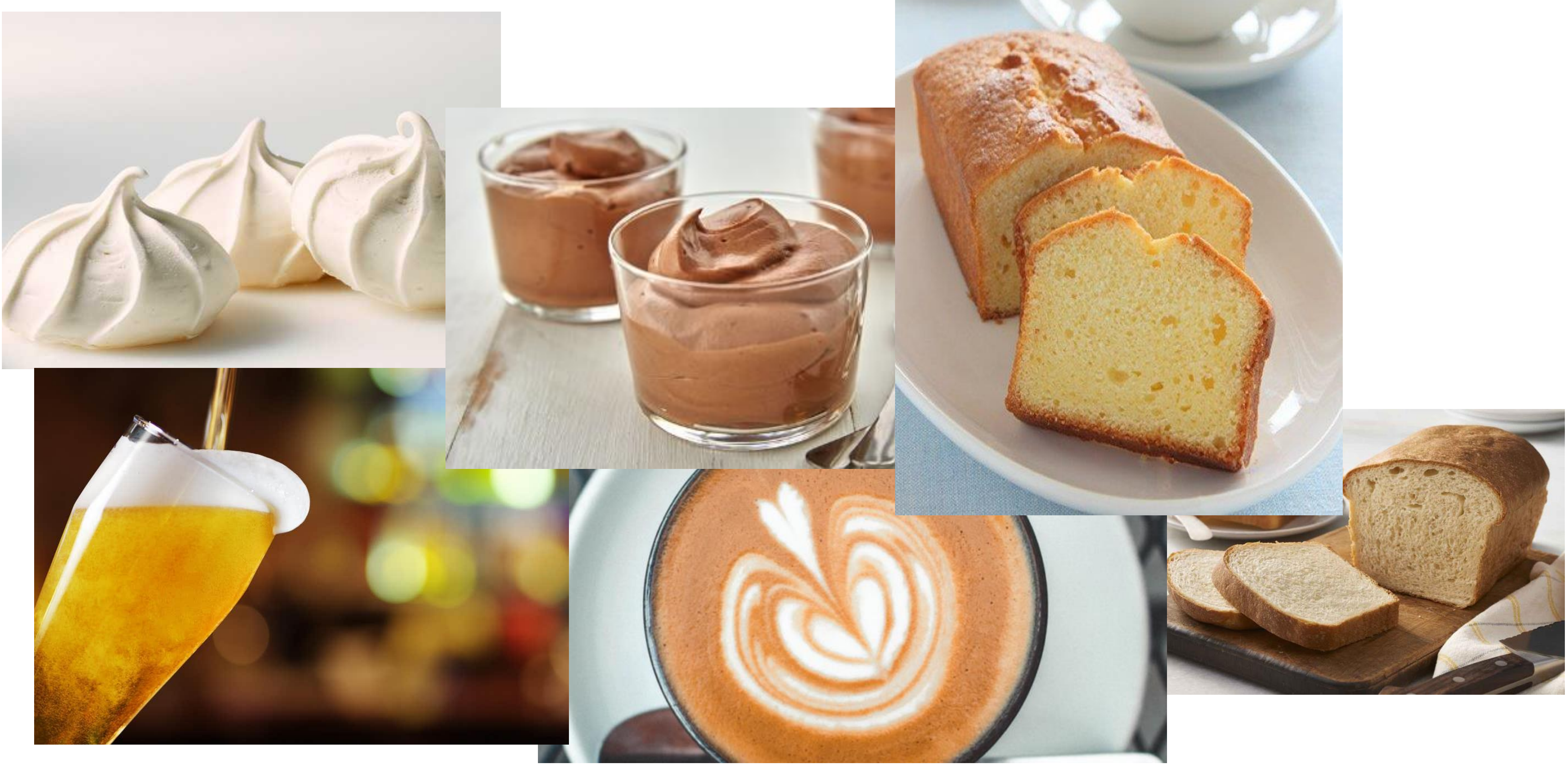


Coalescence



- Stabilization is required by food constituents
  - Proteins, low molecular mass surfactants (LMMS), non-starch polysaccharides (NSPs)
- Relevance in foods?

Foegeding & Davis (2011), Wilde et al (2004)



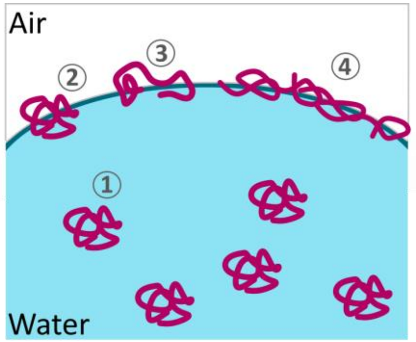
Foegeding & Davis (2011), Wilde et al (2004)

Introduction

Stabilization of food foams

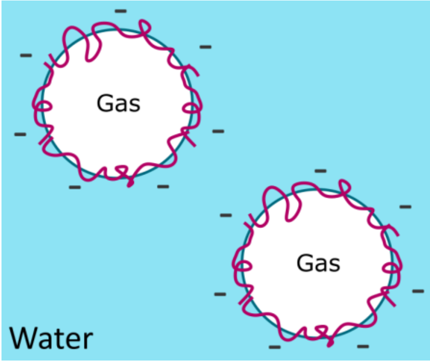
Proteins LMMS NSPs

Proteins

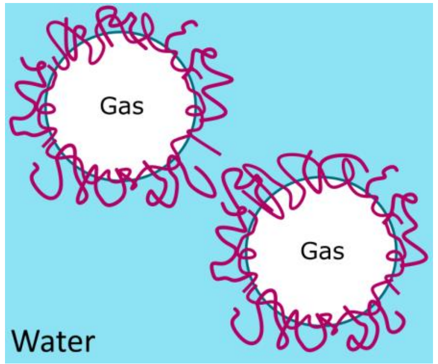


1 - Diffusion
2 - Adsorption
3 - Unfolding
4 - Protein-protein interaction
= Viscoelasticity

Electrostatic repulsion



Steric hindrance



LMM surfactants

Marangoni effect

Non-starch polysaccharides (NSP)

↑ bulk viscosity

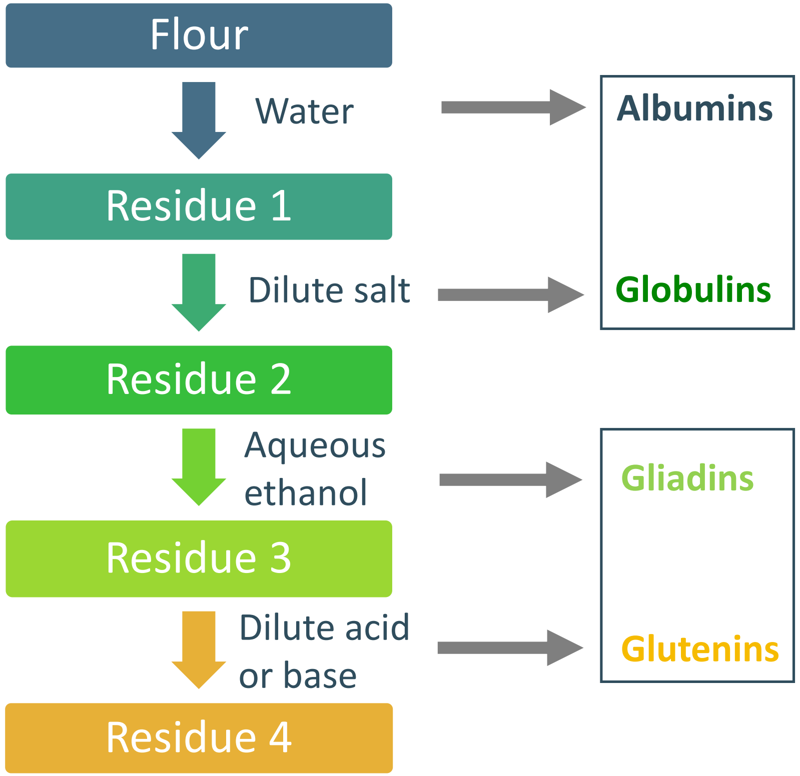
Protein-NSP complex

Damodaran (2005), Wilde et al (2004)

Introduction

Wheat proteins

Osborne Fractionation



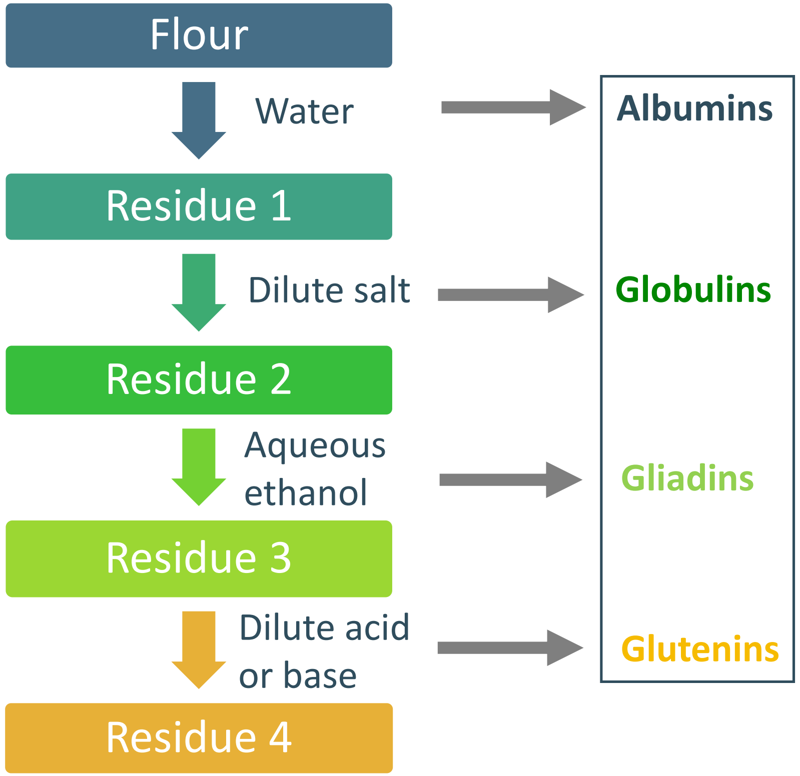
- ☑ **Soluble in aqueous systems**
- ☑ **Potential to stabilize air/water (A/W) interfaces or foams**

- ☑ **Major part of wheat proteins**
- ☑ **Most often focused on in cereal science, given their major functional contribution in food systems**

Osborne (1907)

Introduction
Wheat proteins

Osborne Fractionation



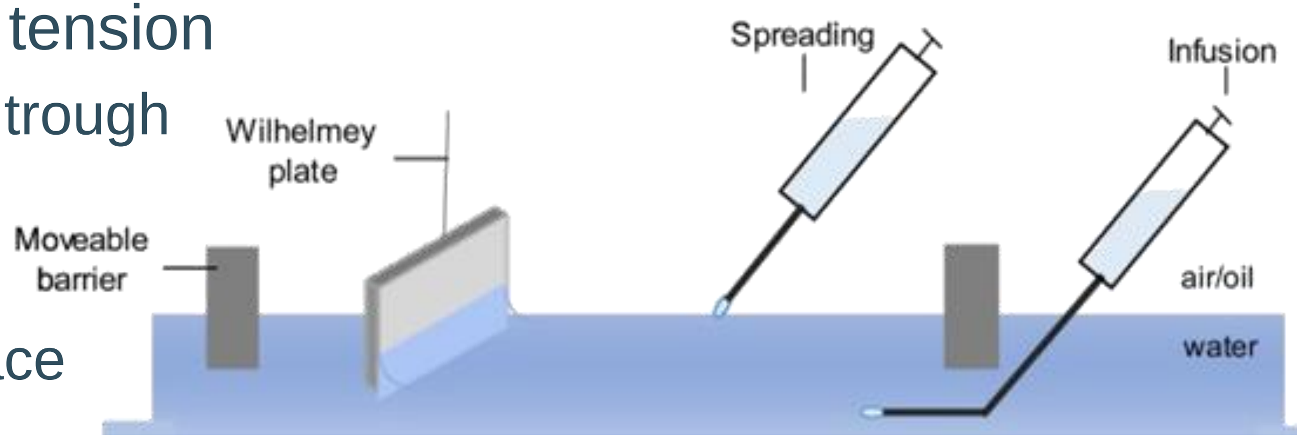
What is the potential of different wheat protein fractions for stabilizing A/W interfaces and foams?

What role can wheat proteins play in food foam stabilization?

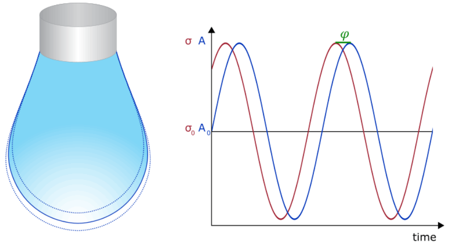
Osborne (1907)

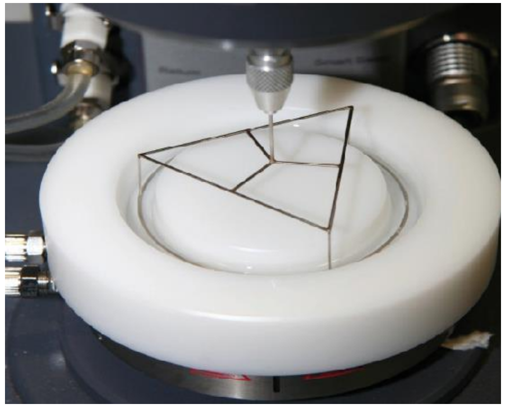
Air-water interfacial properties
Measurements

- Surface activity ~ decrease in surface tension
  - Wilhelmy plate method in a Langmuir trough
    - Spreading vs injection
  - Pendant drop tensiometry
  - Adsorption on solid hydrophobic surface (ellipsometry)



- Interfacial rheology ~ viscoelatic behavior at the A/W interface
  - Dilatational: e.g. oscillating pendant drop
  - Shear: e.g. double wall ring

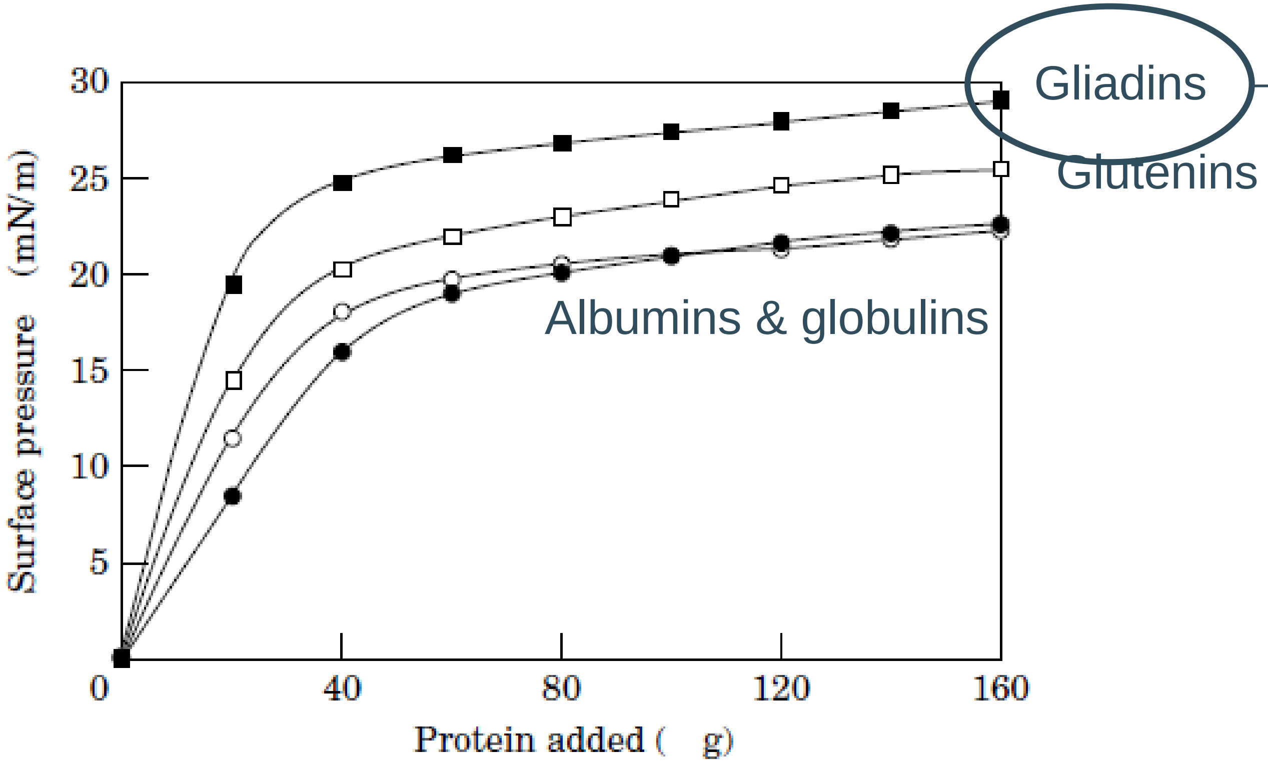




Hinderink et al (2022)

Air-water interfacial properties
Different Osborne fractions

- Surface activity of isolated albumin, globulin, gliadin & glutenin fractions
  - Injected into a 0.01M sodium acetate-acetic acid + 4% NaCl (pH 6) subphase

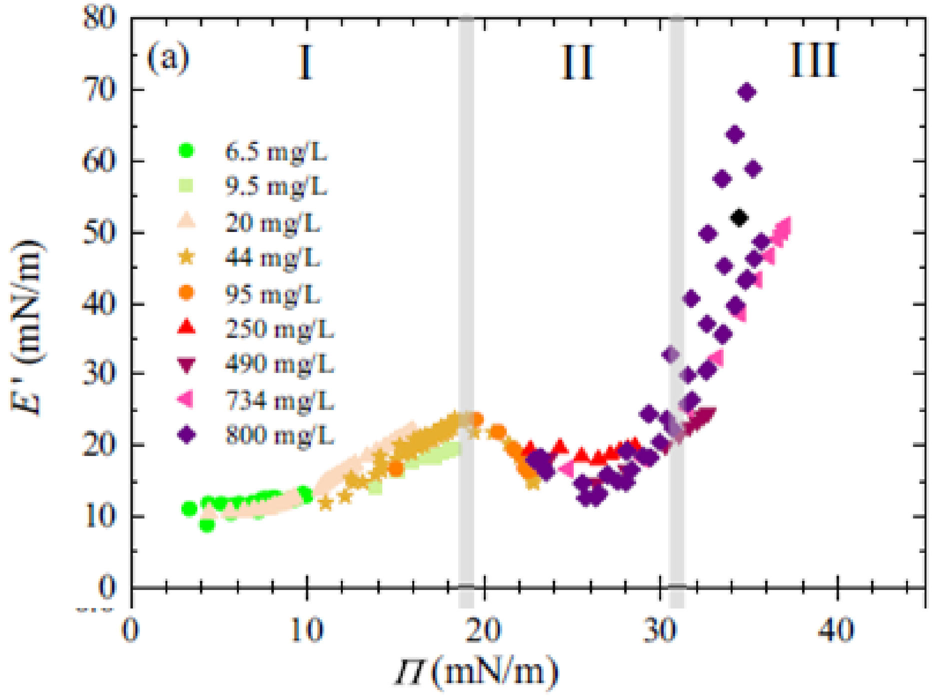


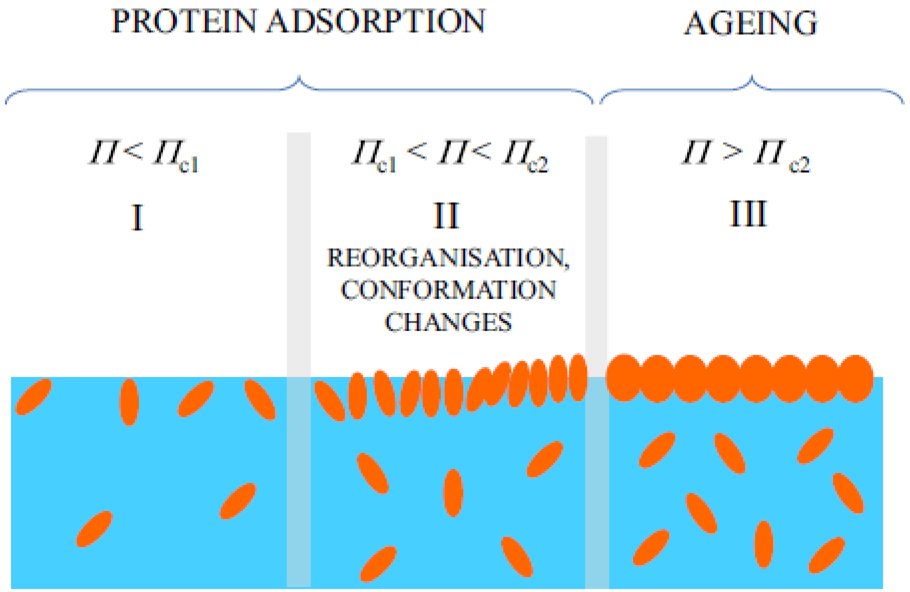
Focus of several additional fundamental studies

Keller et al (1997)

Air-water interfacial properties
Gliadins

- Interfacial rheology
  - Isolated gliadins dissolved in 50 mM acetic acid (pH 3)
  - Oscillating pendant drop tensiometry after spontaneous adsorption





Poirier et al (2018)

Foaming properties
Albumins and globulins

- Aqueous wheat flour extracts varying in (protein) composition

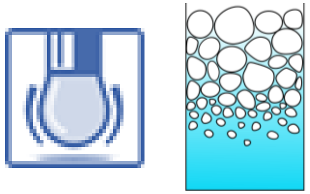
Wheat (cv. Apache) cultivation at
0 kg N/ha N
150 kg N/ha
300 kg N/ha

Milling

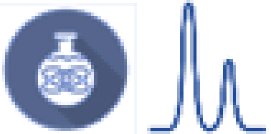
Wheat flour

Aqueous extraction

Wheat flour aqueous extract



In-depth chemical composition
- Protein, lipid, AX, ash, polymer glucose, fructan levels
- Protein apparent molecular weight distribution (SE-HPLC)
- Protein hydrophobicity distribution (RP-HPLC)

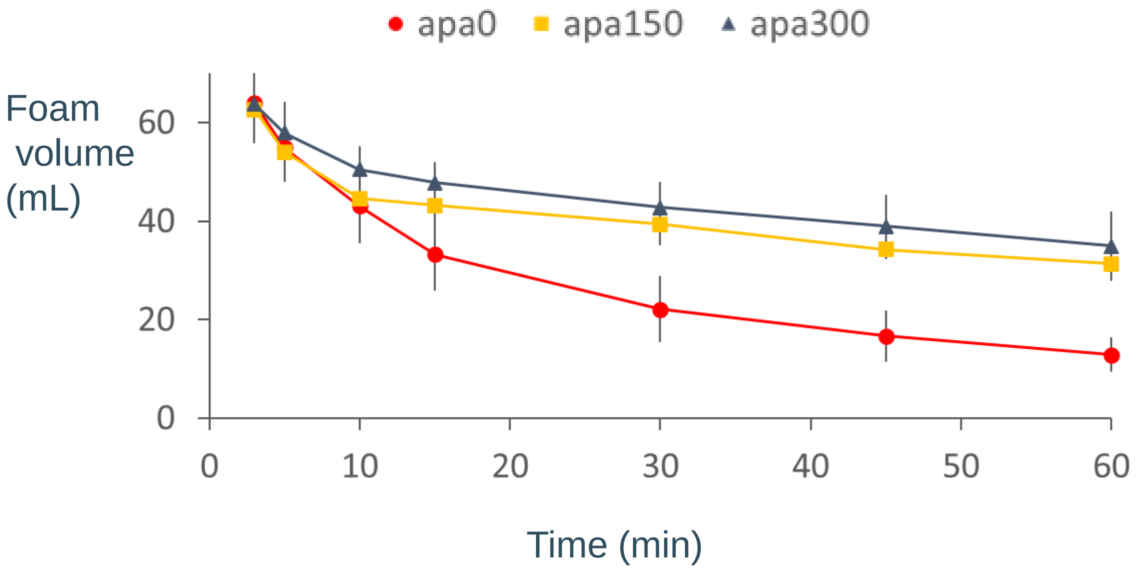


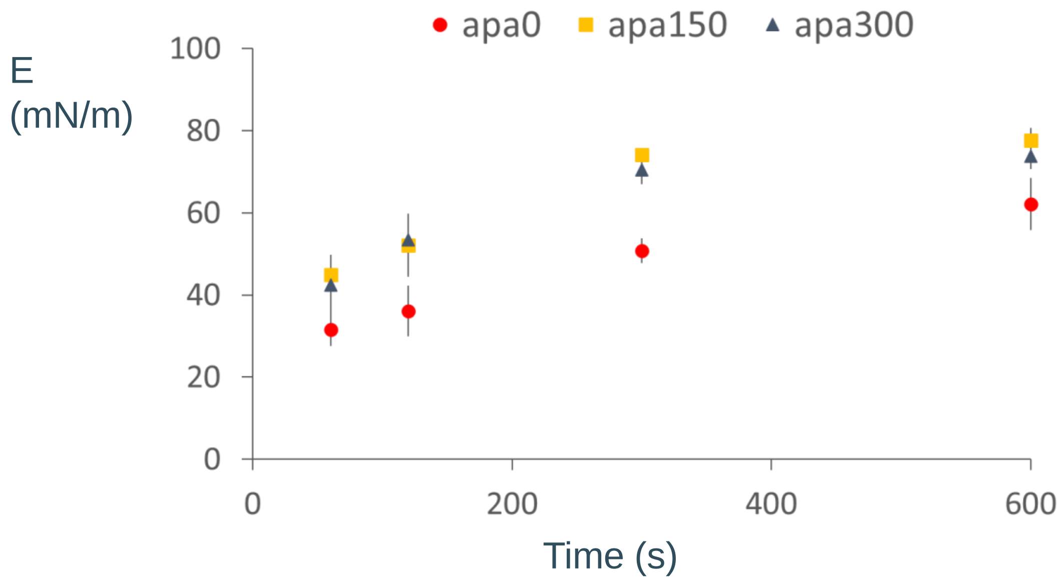
Janssen et al (2022)

Foaming properties

Albumins and globulins

- Aqueous wheat flour extracts varying in (protein) composition
  - Foaming and interfacial dilatational rheology (constant protein basis)





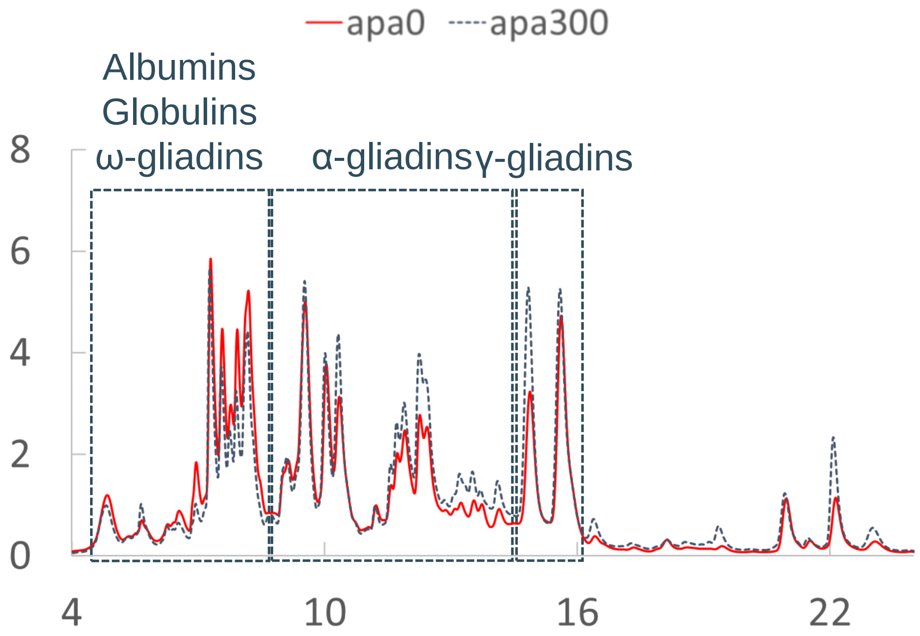
  - No major differences in overall composition that explained these observations

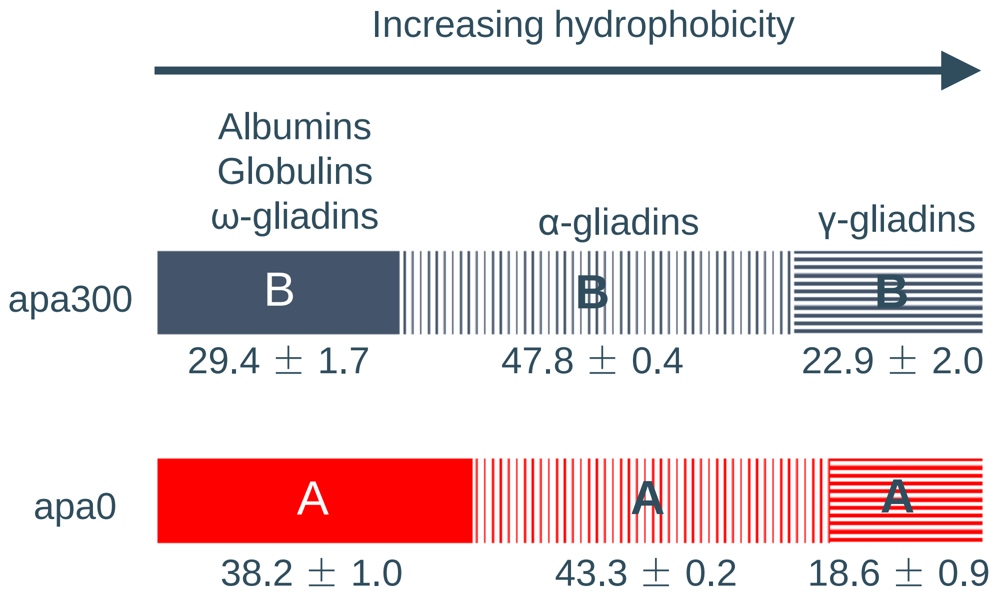
"apa" = cv. Apache; "apa300" = a sample cultivated under application of 300 kg N/ha

Foaming properties

Albumins and globulins

- Aqueous wheat flour extracts varying in (protein) composition
  - Protein composition: RP-HPLC



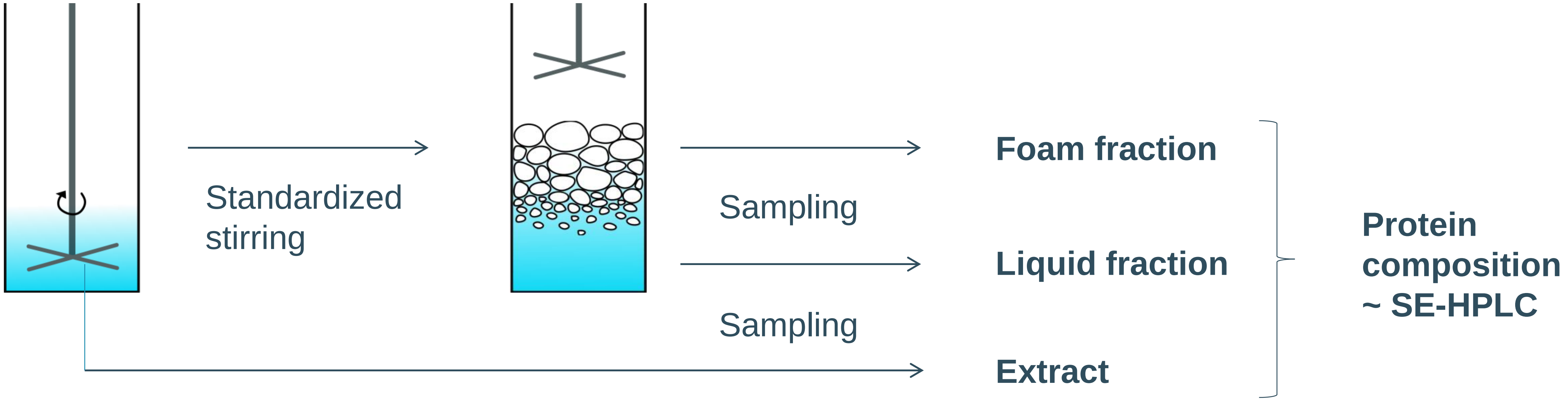


"apa" = cv. Apache; "apa300" = a sample cultivated under application of 300 kg N/ha

Foaming properties

Albumins and globulins?

- Aqueous wheat flour extracts varying in (protein) composition
  - Foam fractionation experiment: identification of surface-active species

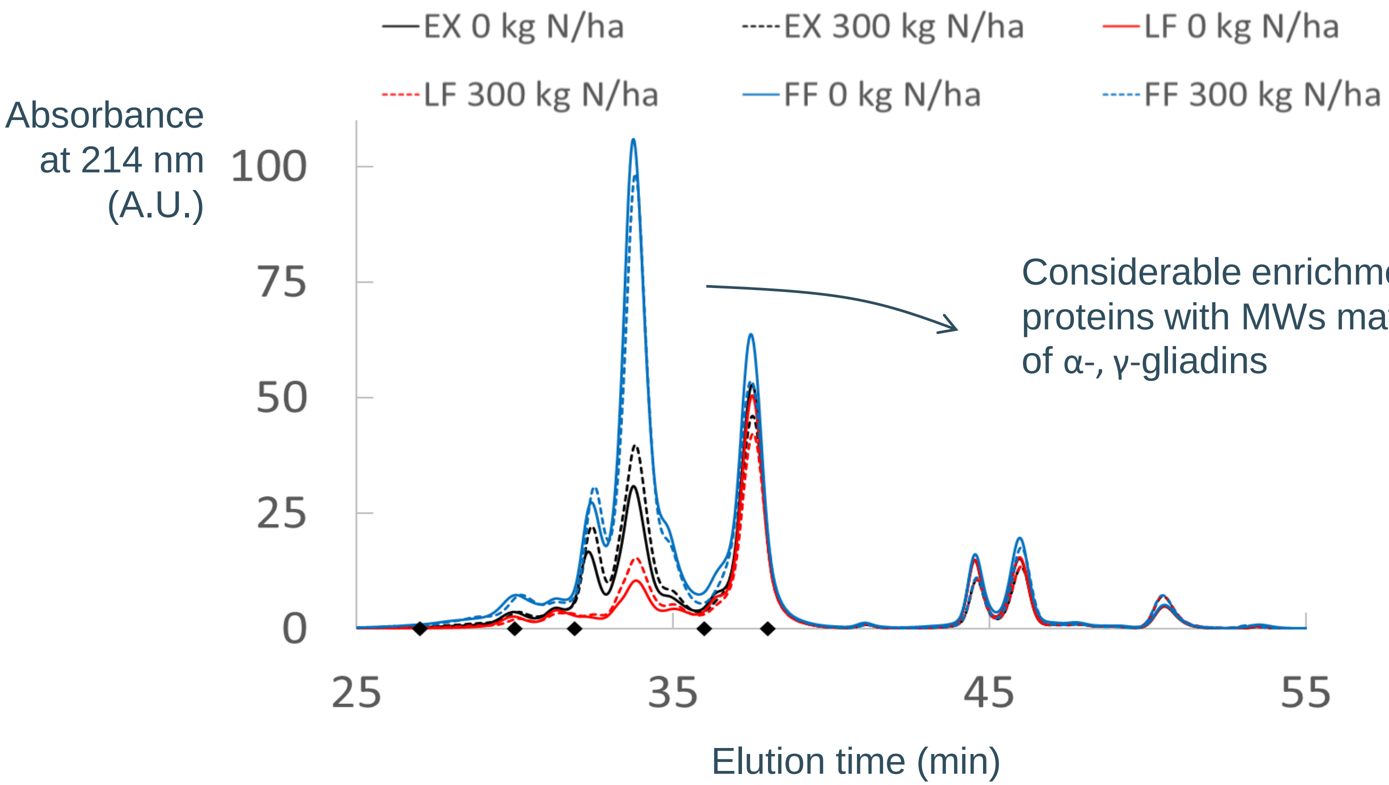


Janssen et al (2022)

Foaming properties

Albums and globulins? → ***and gliadins!***

- Aqueous wheat flour extracts varying in (protein) composition
  - Foam fractionation experiment: identification of surface-active species

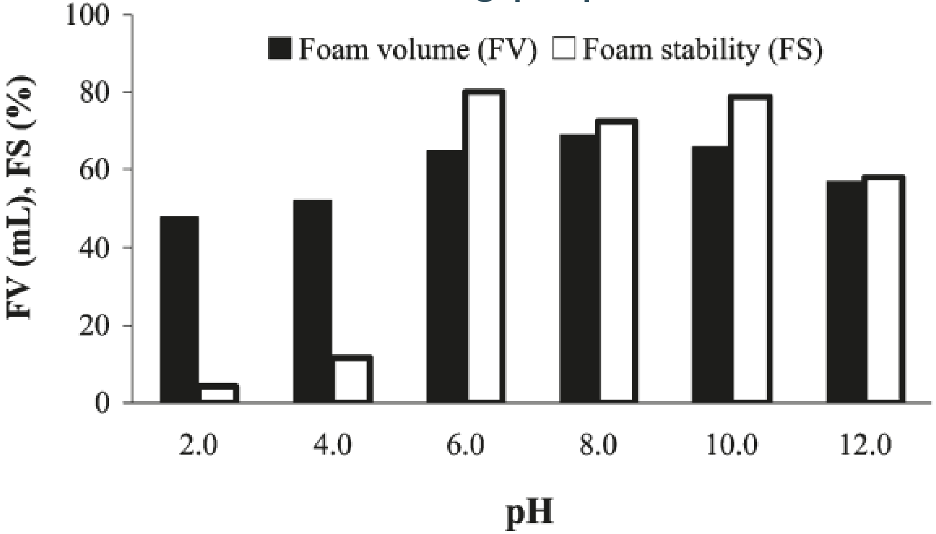


“apa” = cv. Apache; “apa300” = a sample cultivated under application of 300 kg N/ha

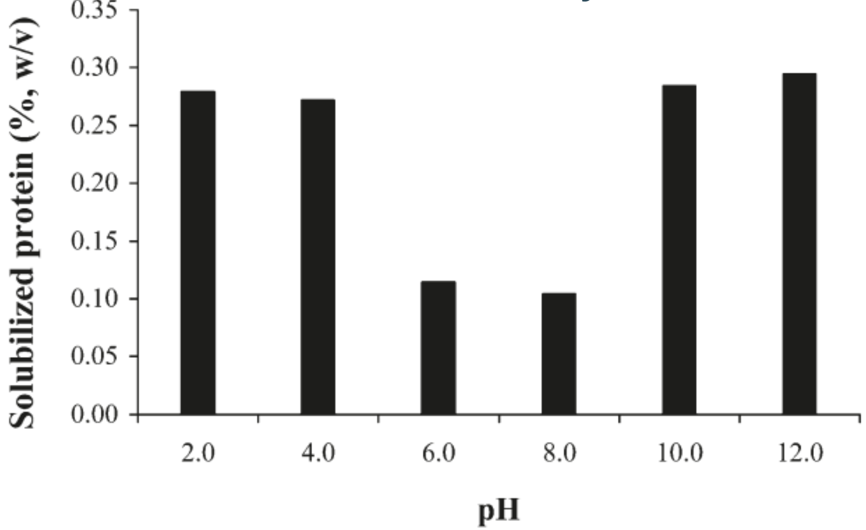
Foaming properties
Gliadins

- Isolated gliadins
  - pH-dependent foaming behavior of gliadins

Foaming properties



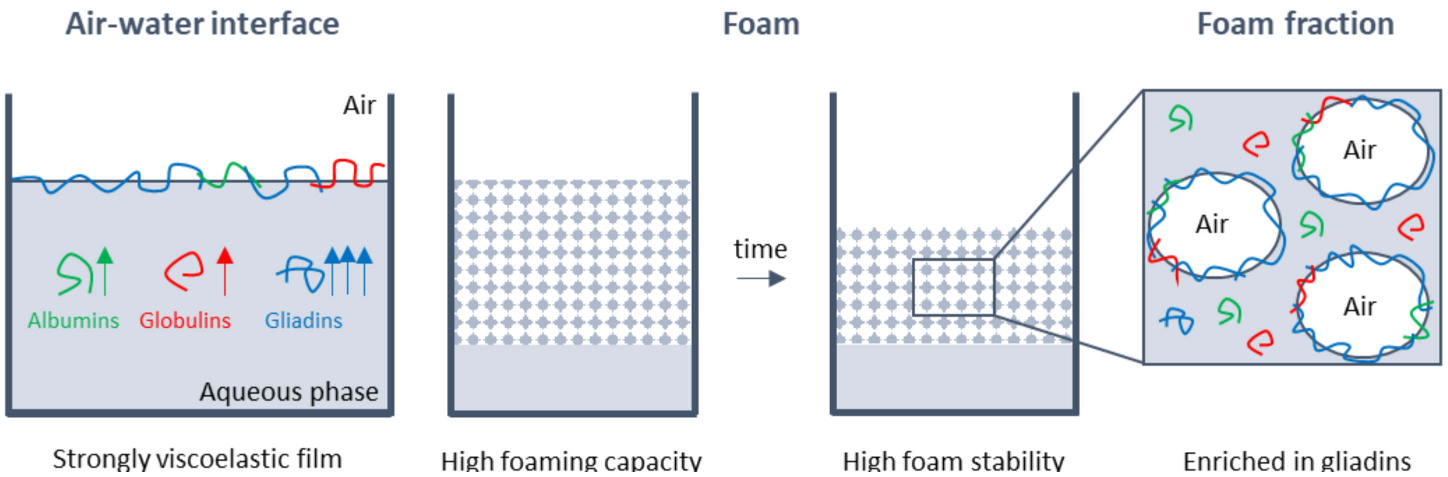
Protein solubility



Thewissen et al (2011)

A/W interfacial and foaming properties
Summary

- Gliadins have considerable solubility in aqueous systems
- Gliadins dominate the A/W interfacial and foaming properties of wheat proteins



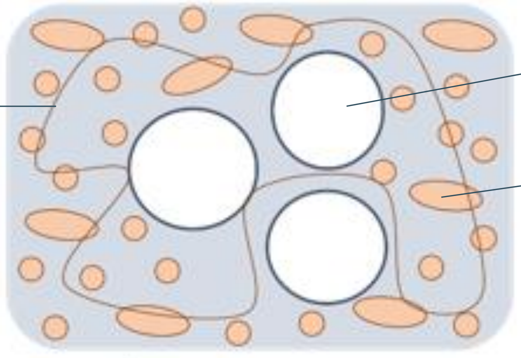
- Contribution to gas cell stabilization in actual food products?
- Still, a major fraction of wheat proteins is not functional in this context

Relevance in food systems

Gas cell stabilization in wheat based products

- Bread dough (or cake batter) can be considered foam-type structures

Gluten protein network

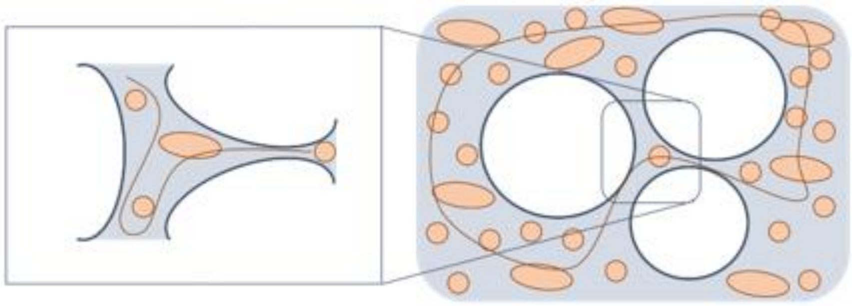


Gas cells

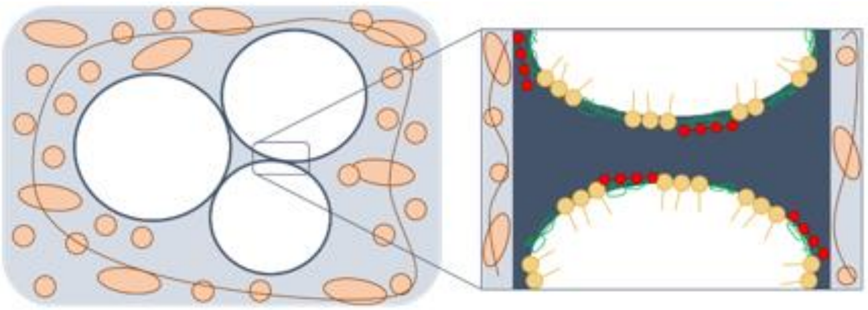
Starch granules

Mechanism 1: strain hardening by gluten proteins

Mechanism 2: Gas cell interface stabilization by surface-active constituents



Rupturing of gluten network because of pronounced extension during fermentation/baking

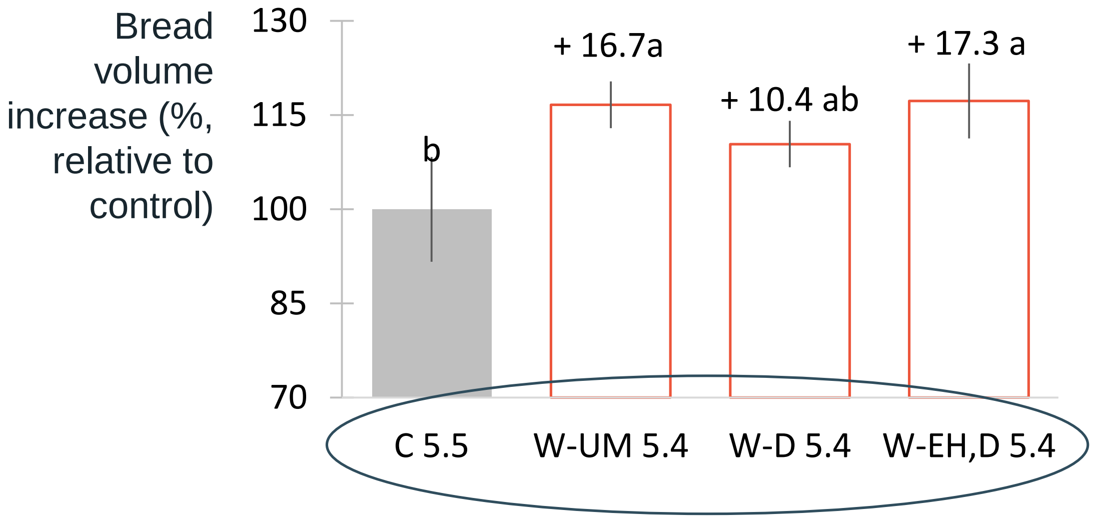


Janssen et al. (2021)

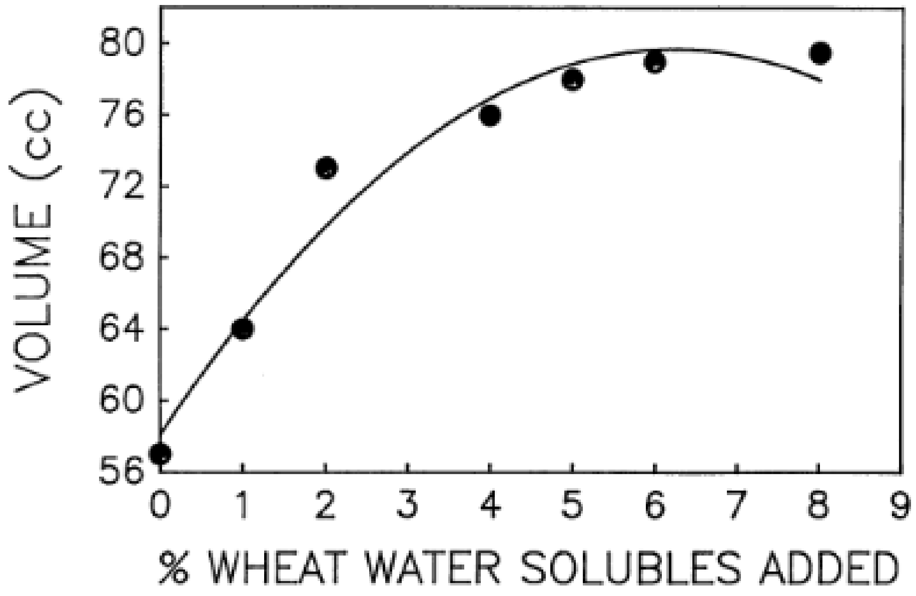
Relevance in food systems

Gas cell stabilization in wheat based products

- To what extent do wheat proteins play a direct role in gas cell stabilization in such systems?
- Some observations
  - Wheat water solubles increase bread loaf volume



Wheat aqueous extracts varying in composition

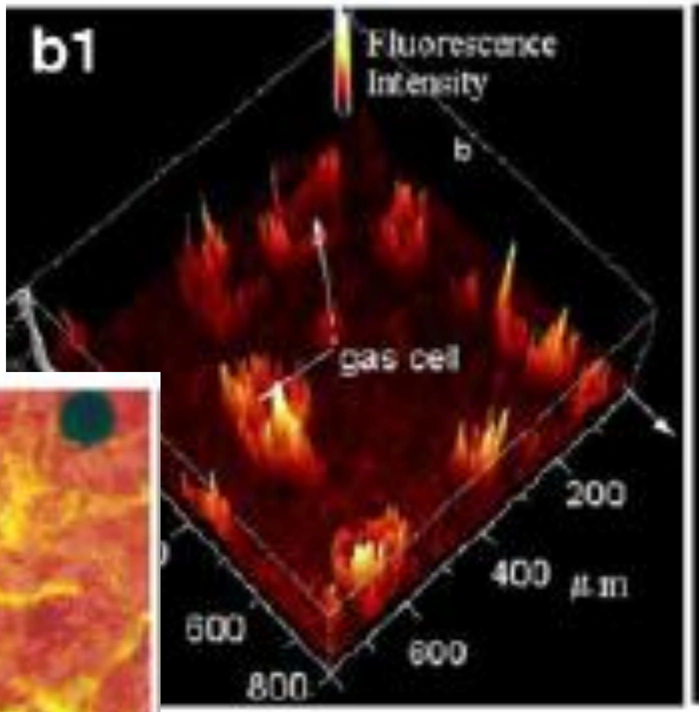


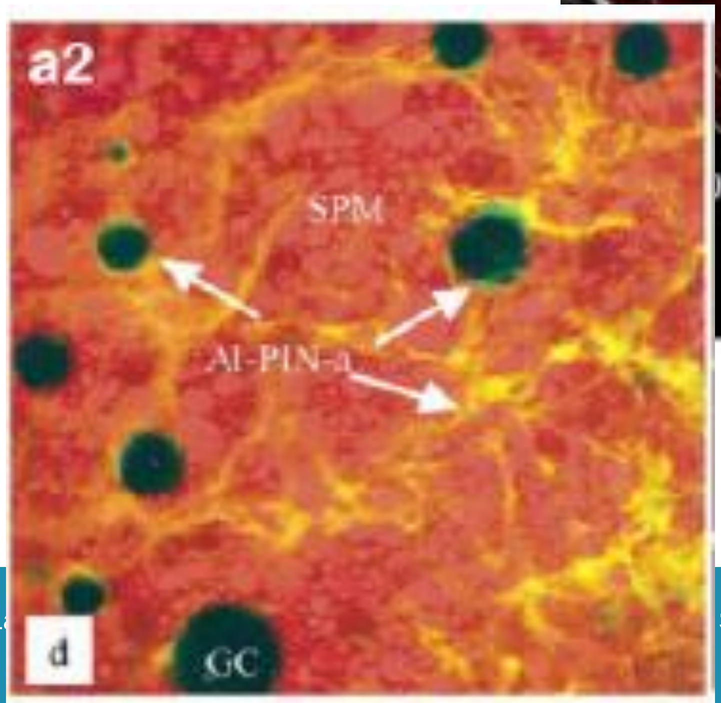
Delcour et al (1991); Monterde et al (tbd)

Relevance in food systems

Gas cell stabilization in wheat based products

- To what extent do wheat proteins play a direct role in gas cell stabilization in such systems?
- Some observations
  - Wheat water solubles increase bread loaf volume
  - PINs and gliadins at gas cell surfaces



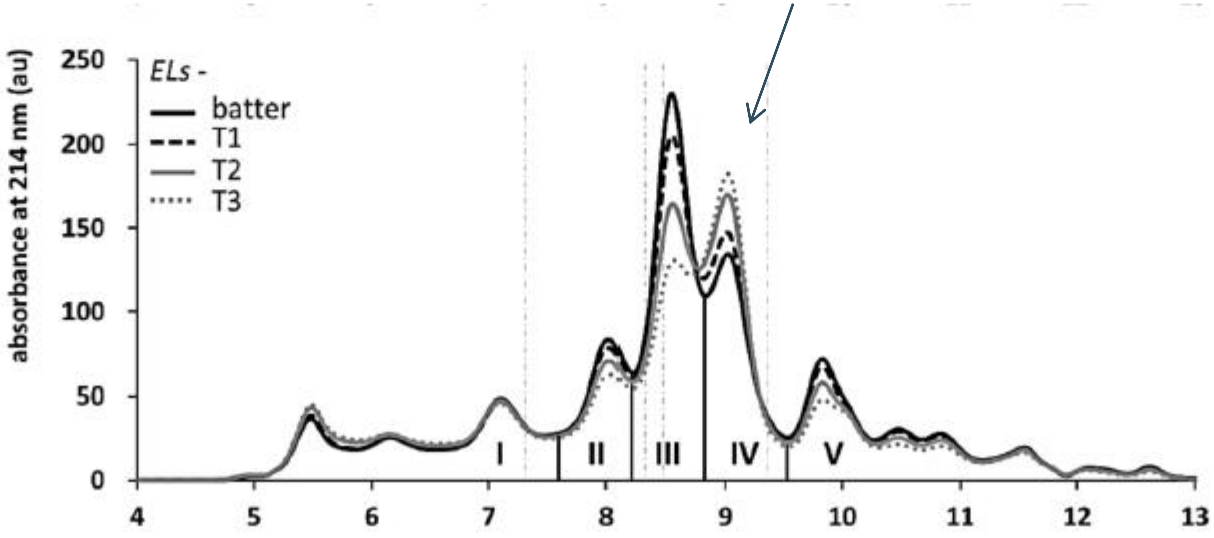


Dubreil et al. (2002); Li et al (2004); Janssen et al (2021)

Relevance in food systems
Gas cell stabilization in wheat based products

- To what extent do wheat proteins play a direct role in gas cell stabilization in such systems?
- Some observations
  - Wheat water solubles increase bread loaf volume
  - PINs and gliadins at gas cell surfaces
  - Protein enrichment in foams made from cake batter
  - Dough liquor as model system

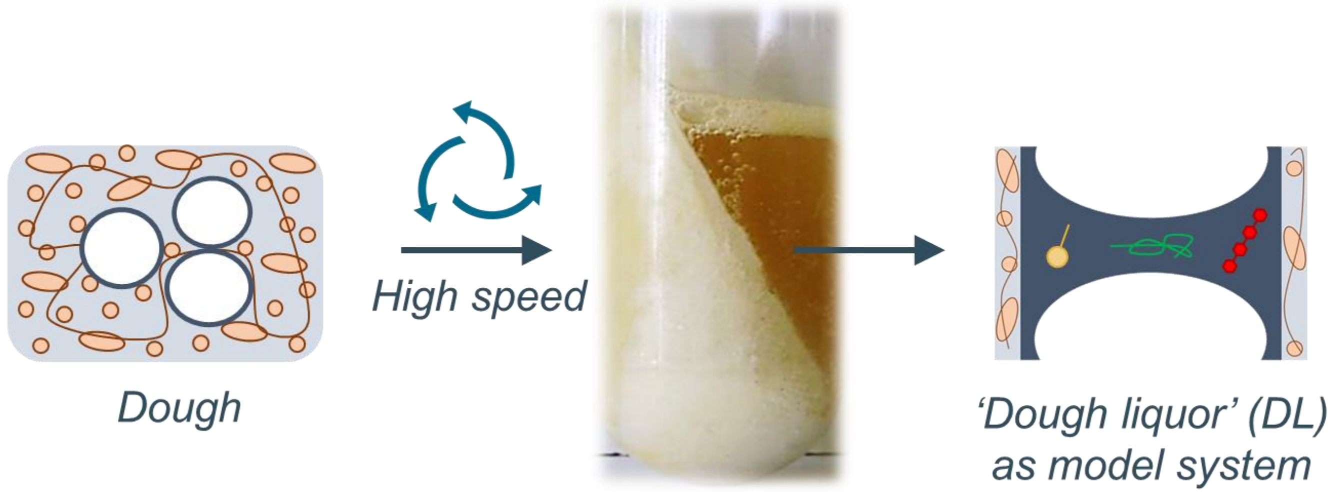
Over time, gliadins are enriched in foams

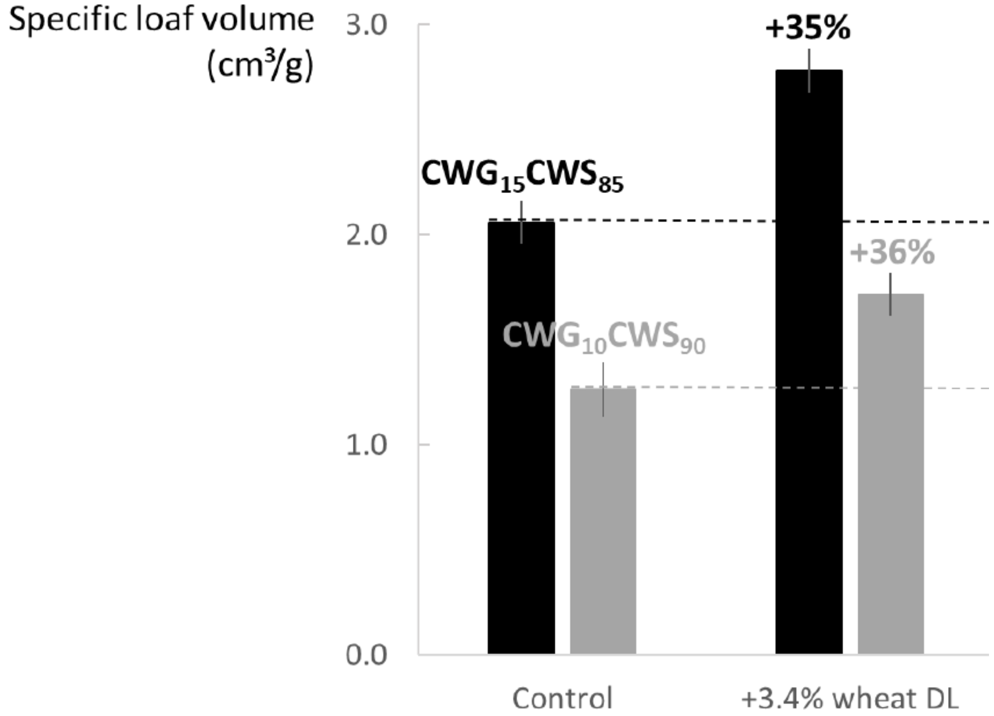


Relevance in food systems

Gas cell stabilization in wheat based products

- Dough liquor as model system
  - Ultracentrifugation → 'dough aqueous phase'
  - Impact on bread loaf volume
    → Which constituents cause this effect?



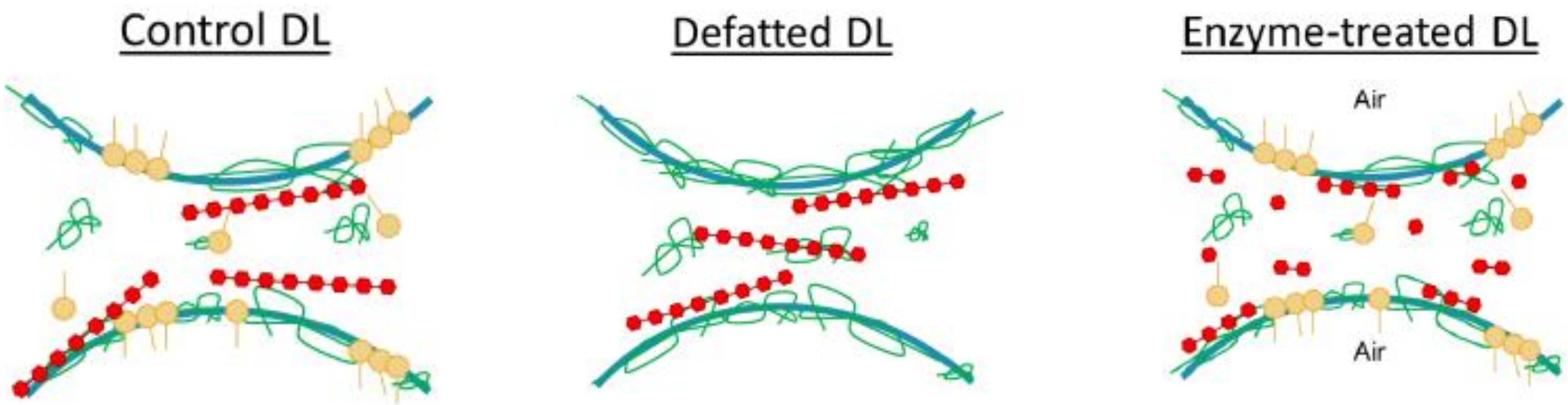


CWG/S = commercial wheat gluten/starch

Janssen et al (2021)

Relevance in food systems
Gas cell stabilization in wheat based products

- Dough liquor as model system
  - Foaming and air-water interfacial properties of (modified) dough liquors



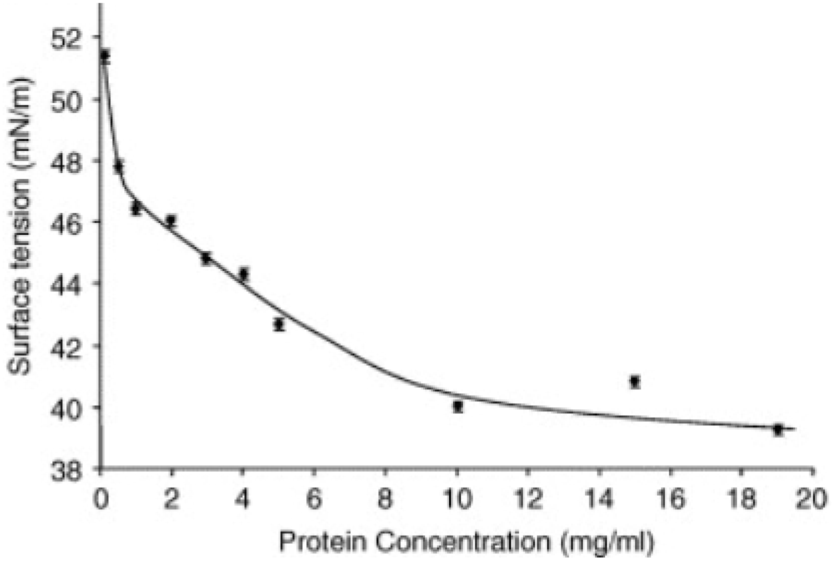
  - Complex interplay between constituents!
  - Correlation with bread gas cell stabilization in bread?

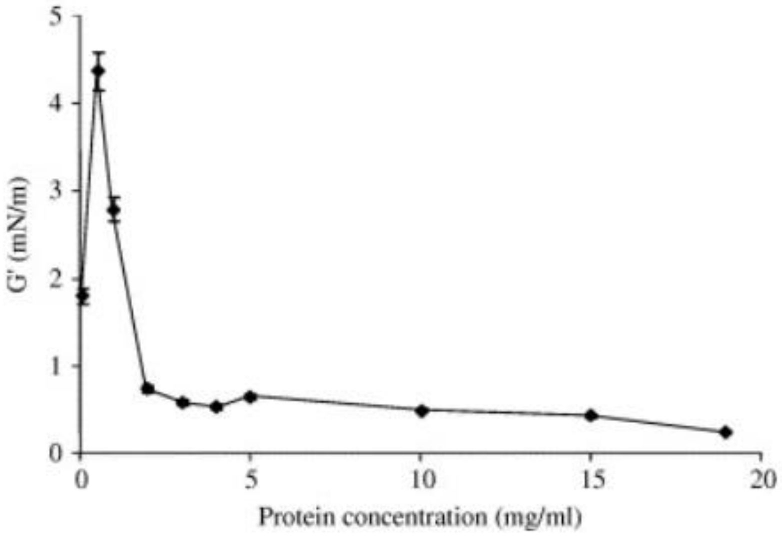
Janssen et al (2021)

Relevance in food systems

Gas cell stabilization in wheat based products

- Dough liquor as model system
  - Foaming and air-water interfacial properties of (modified) dough liquors
  - Effect of concentration?



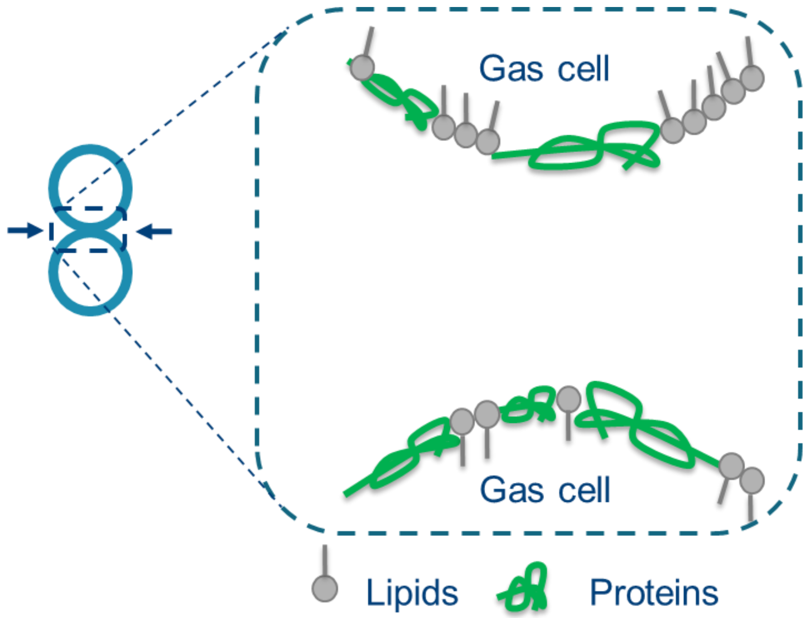


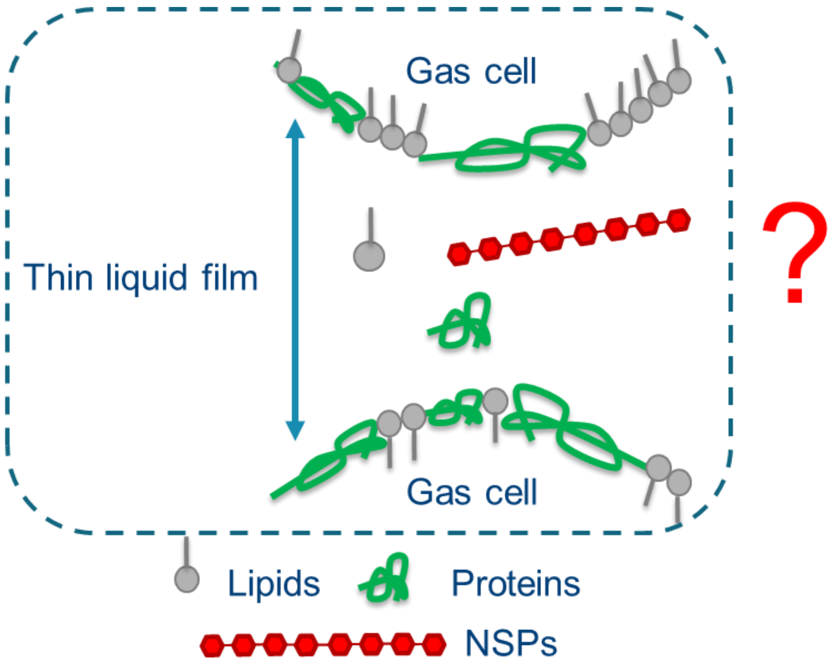
Salt et al (2006)

Relevance in food systems

Gas cell stabilization in wheat based products

- Dough liquor as model system
  - Thin liquid film stabilization



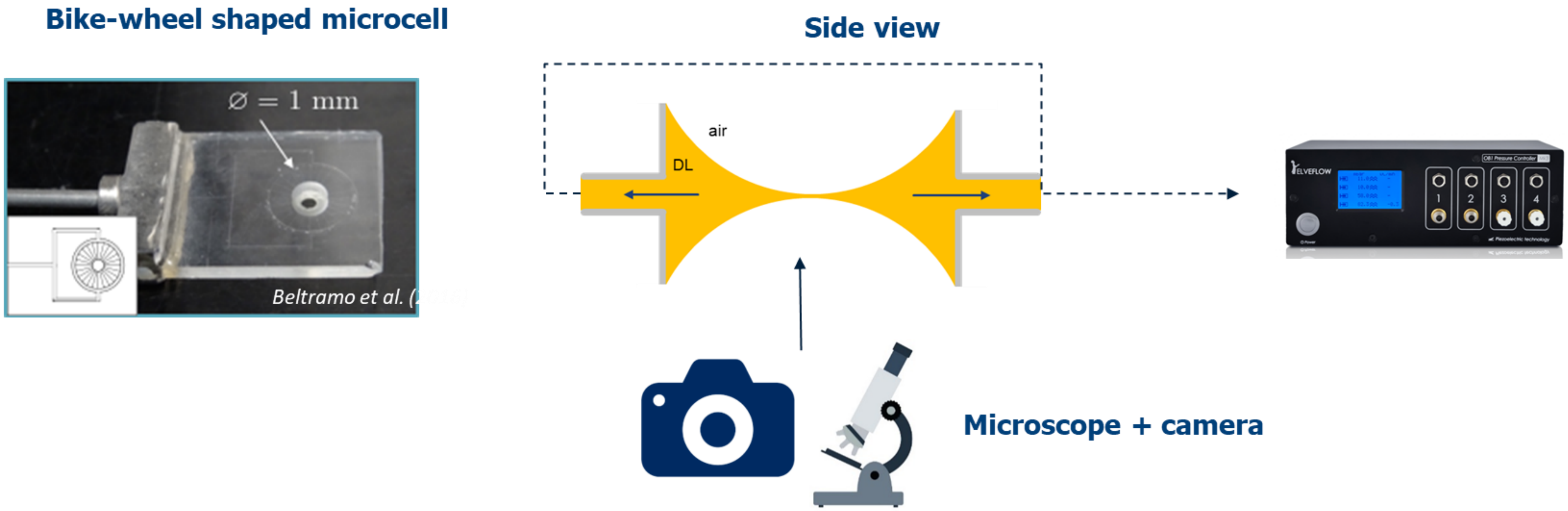


Janssen et al (2021)

Relevance in food systems

Gas cell stabilization in wheat based products

- Dough liquor as model system
  - Thin liquid film stabilization



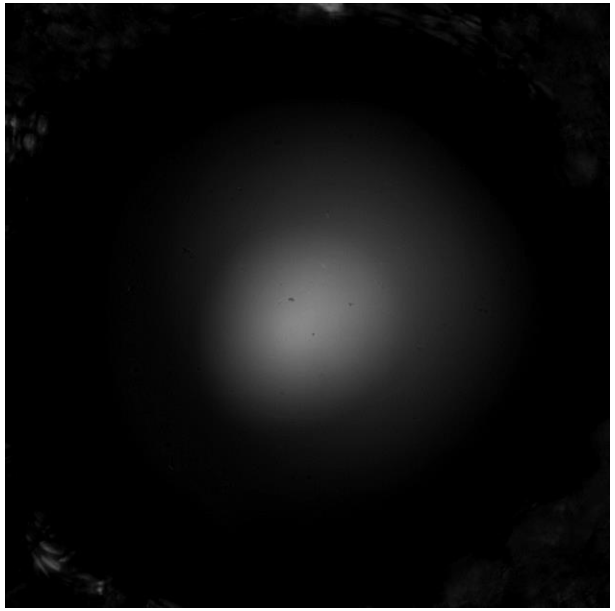
Janssen et al (2021)

Relevance in food systems

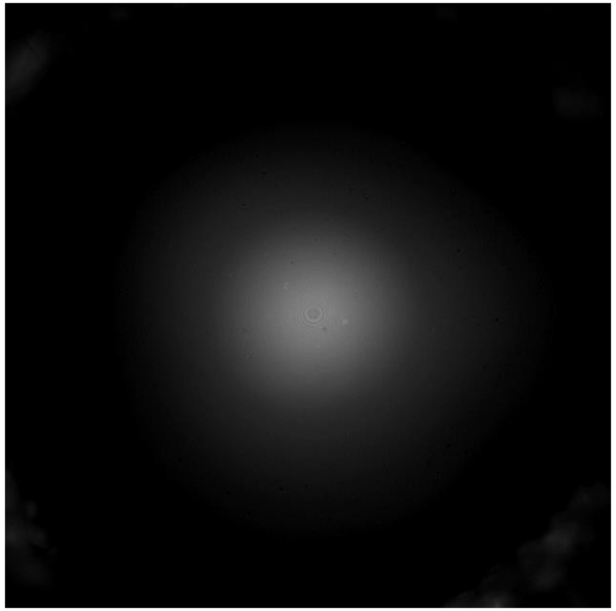
Gas cell stabilization in wheat based products

- Dough liquor as model system
  - Thin liquid film stabilization

Diluted wheat DL



Undiluted wheat DL



CWG/S = commercial wheat gluten/starch

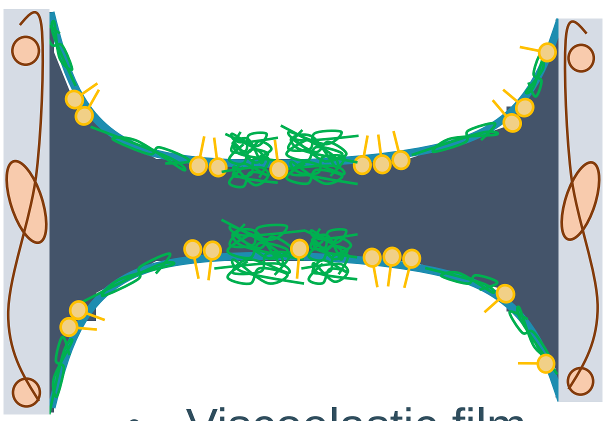
Janssen et al (2021)

Relevance in food systems

Gas cell stabilization in wheat based products

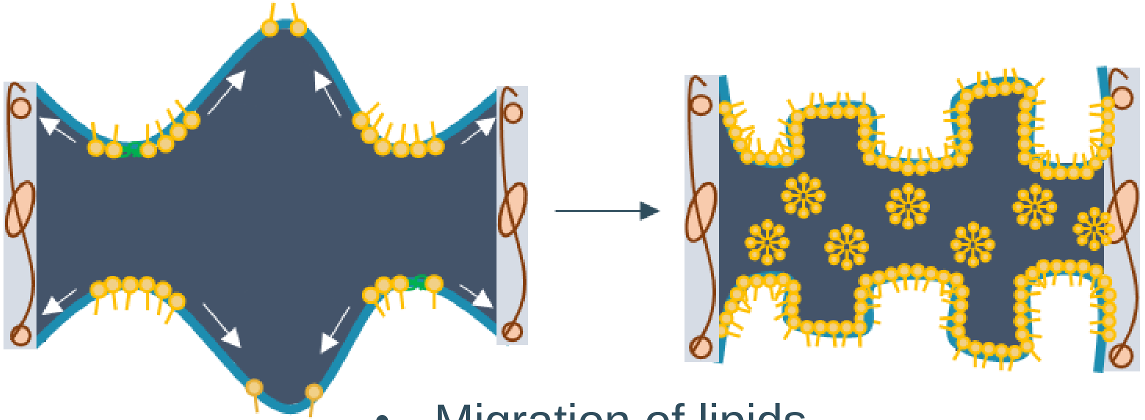
- Dough liquor as model system
  - Thin liquid film stabilization

Diluted wheat DL



- Viscoelastic film
- Planar interface
- No supra- or intermolecular interactions

Undiluted wheat DL



- Migration of lipids
- Dimpled interface
- Strong supra- and intermolecular interactions

Janssen et al (2021)

Conclusions and perspectives

- Wheat proteins have varying surface activities
- Gliadins are excellent foam stabilizers

- It is likely that direct gas cell stabilization in cereal based foods is at least to an extent relevant
- Protein (and other constituent) species responsible ?
- Interactions between different constituents ?
- Translation of model systems to actual food products is challenging

KU LEUVEN

Relevance of the air-water interfacial and foaming properties of wheat proteins for food systems

Arno G.B. Wouters

Laboratory of Food Chemistry and Biochemistry (LFCB)

Leuven Food Science and Nutrition Research Centre (LFoRCe)

13 April 2023 – European Young Cereal Scientists & Technologists Workshop