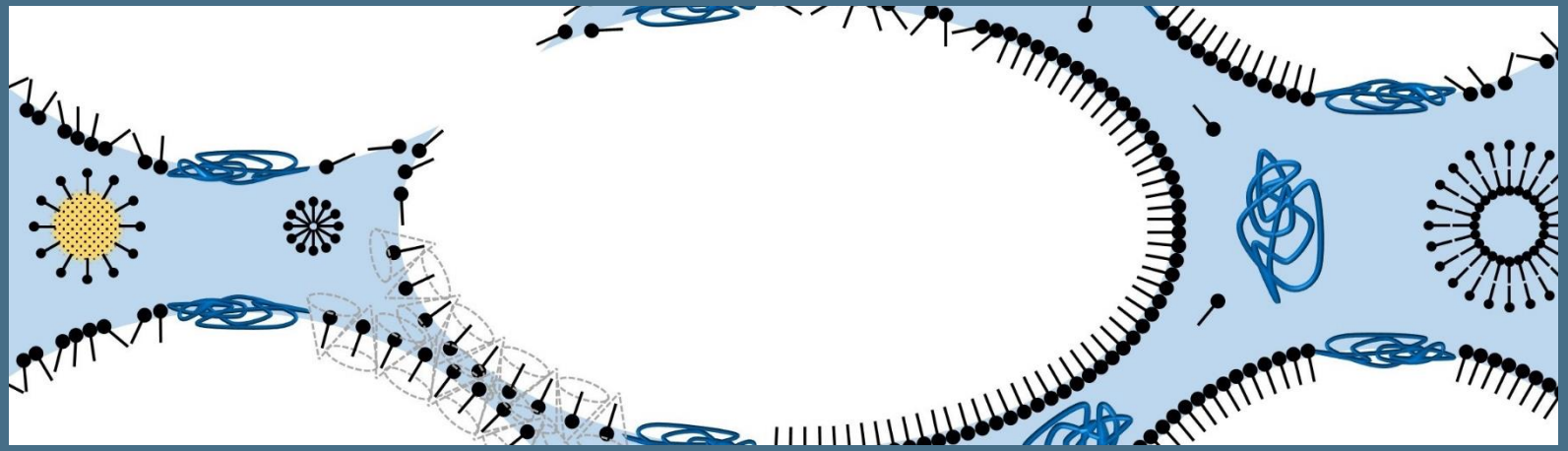


The role of wheat endogenous lipids and their enzymatically released hydrolysis products in bread making

Sara MELIS and Jan A. DELCOUR

ICBC 2021 | 30 March 2021 | Online event

KU LEUVEN

Laboratory of Food Chemistry and Biochemistry (LFCB)
Leuven Food Science and Nutrition Research Centre (LFoRCe)

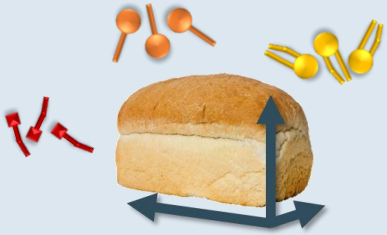
About me

KU LEUVEN **Master of Bioscience Engineering: Food Technology**

- Sep 2012 – Jun 2014
- The role of different egg yolk fractions during the production of pound cake

KU LEUVEN **Doctoral researcher** (Lab of Food Chemistry & Biochemistry)

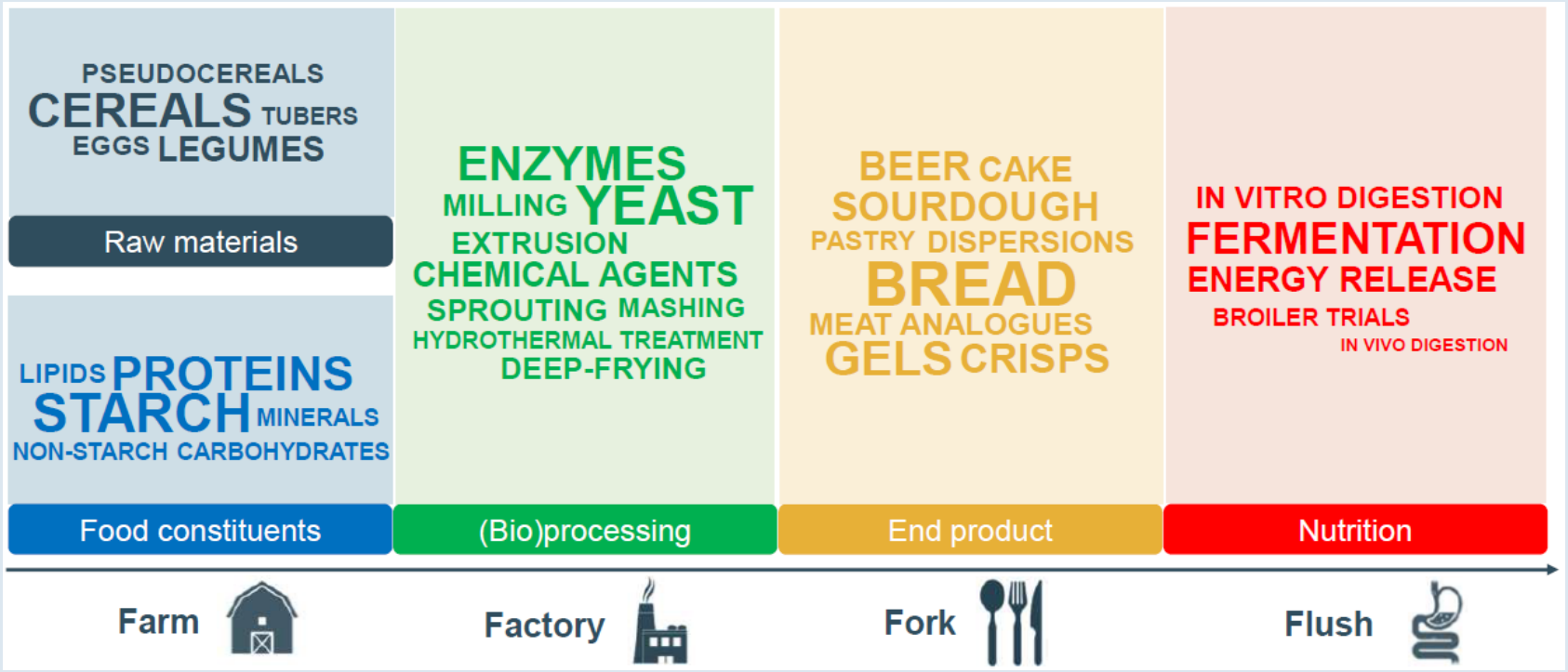
- Sep 2014 – Jun 2019
- The role of wheat endogenous lipids and their enzymatically released hydrolysis products in bread making

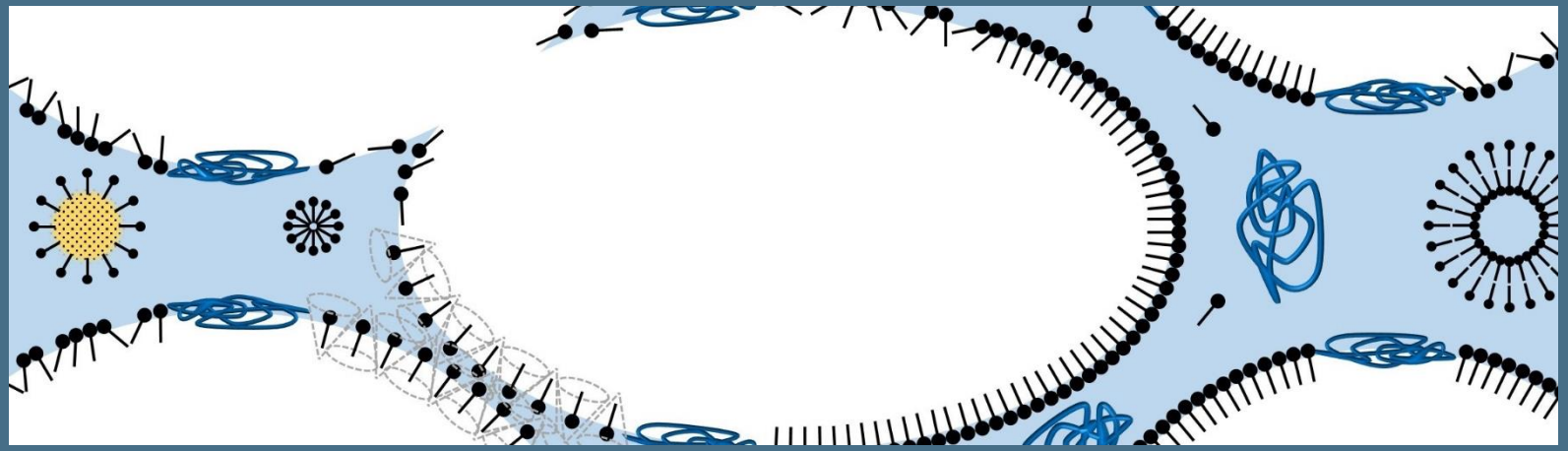


KU LEUVEN **Postdoctoral researcher** (Lab of Food Chemistry & Biochemistry)

- Jun 2019 – Aug 2019: Knowledge driven product development
- Sep 2019 – …: Coordination FIBRAXFUN project
  - "A knowledge base for exploiting novel wheats rich in arabinoxylan dietary fibre throughout the wheat value chain"

Lab of Food Chemistry & Biochemistry





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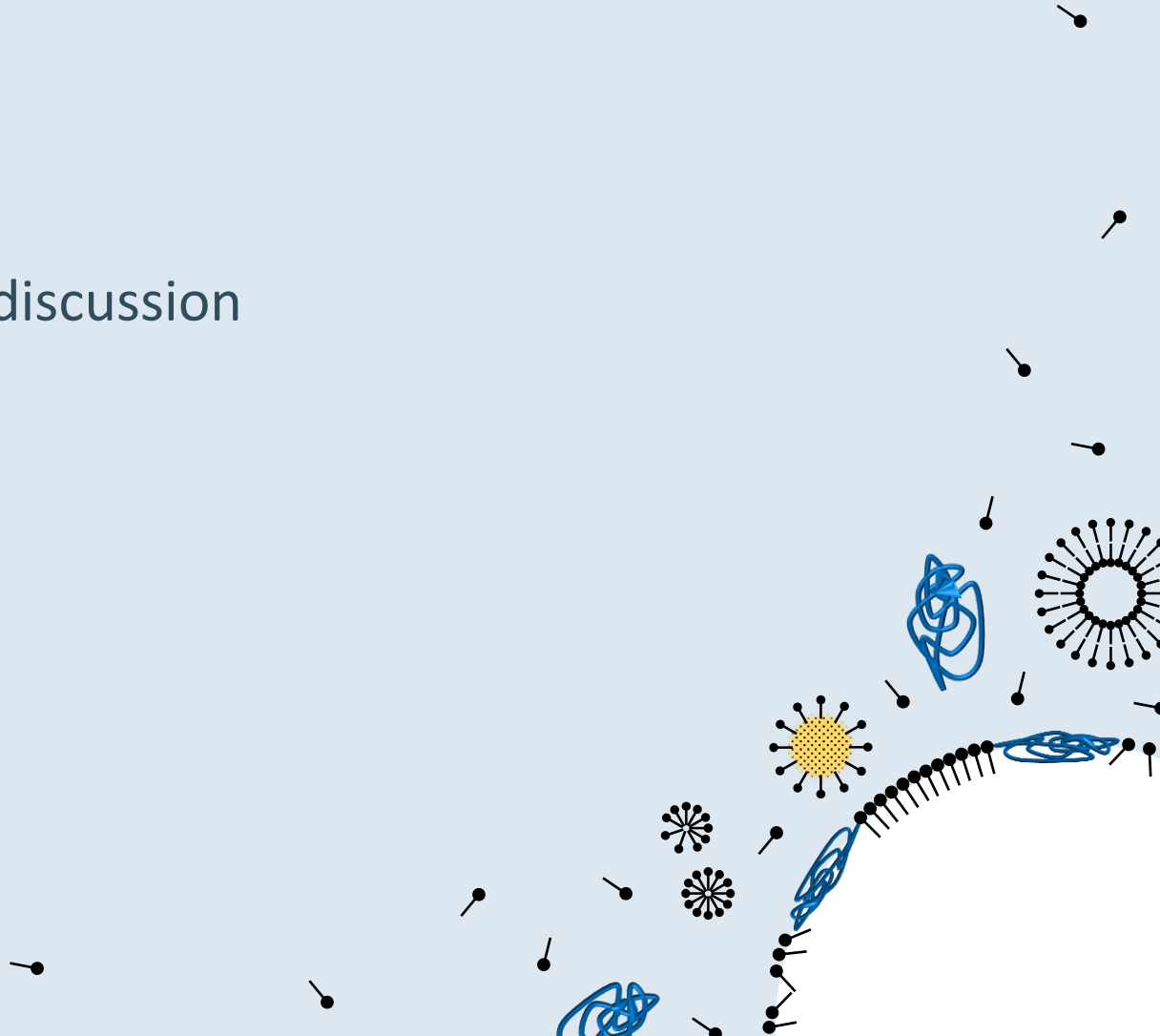
Overview

- Introduction
- Objective
- Results and discussion
- Conclusions



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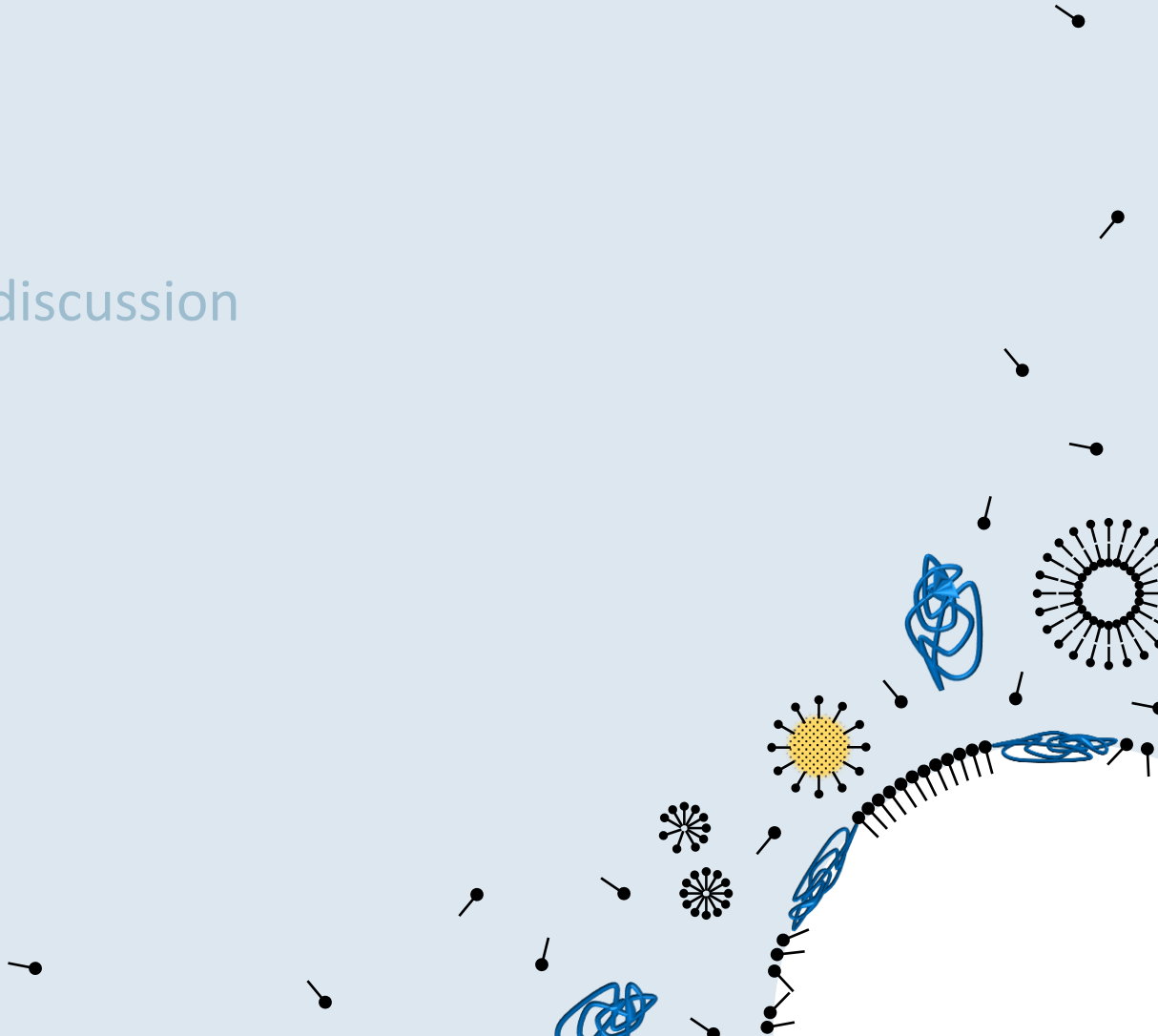
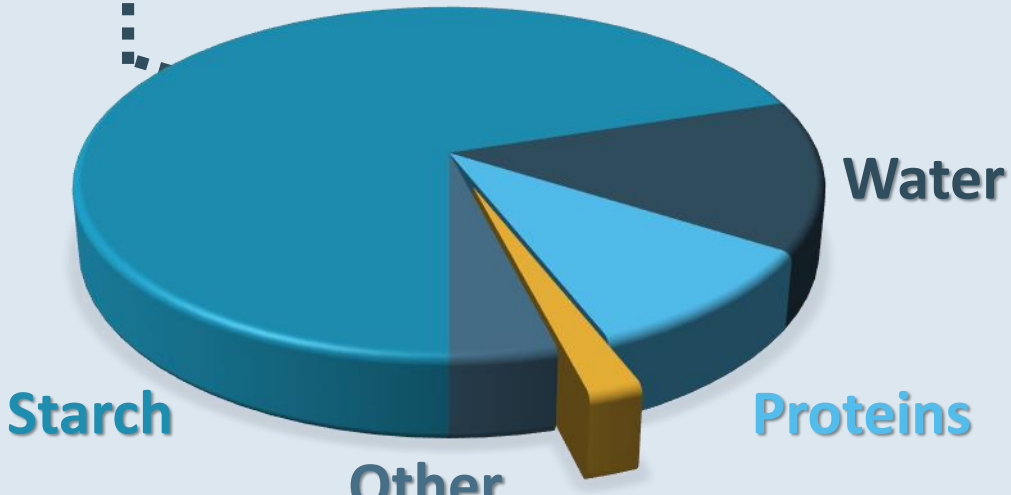


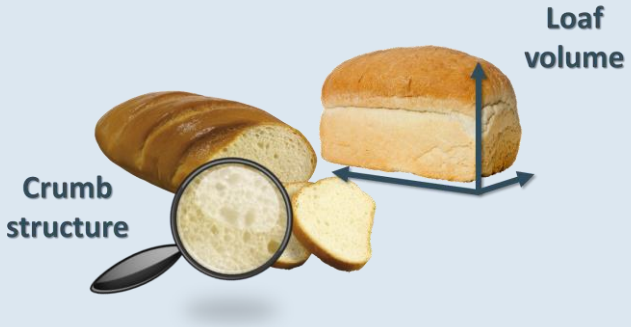
Introduction

Bread



2 – 3% Lipids

Important influence on bread quality!



(Cauvain and Young, 2007; Delcour and Hoseney, 2010; Goesaert et al., 2005)

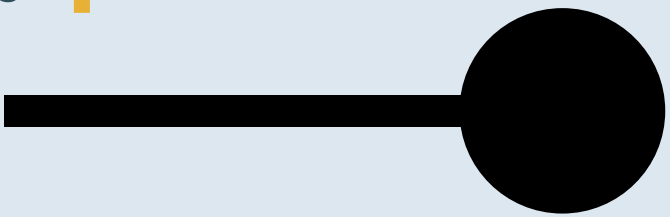
Introduction

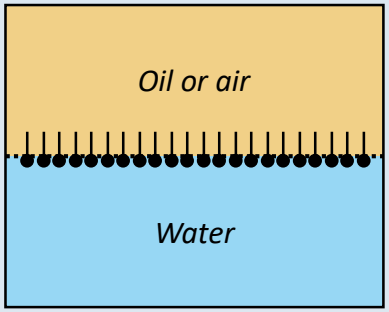
LIPIDS

Lipids are fatty acids and their derivatives, and substances related biosynthetically or functionally to these compounds

- Acylglycerols + **Free fatty acids (FFAs)** ⊢ **Nonpolar lipids**
- Galactolipids
- Phospholipids

⊢ **Polar lipids**





(Christie and Han, 2010; Chung et al., 2009; Morrison, 1978; Pareyt et al., 2011)

Introduction

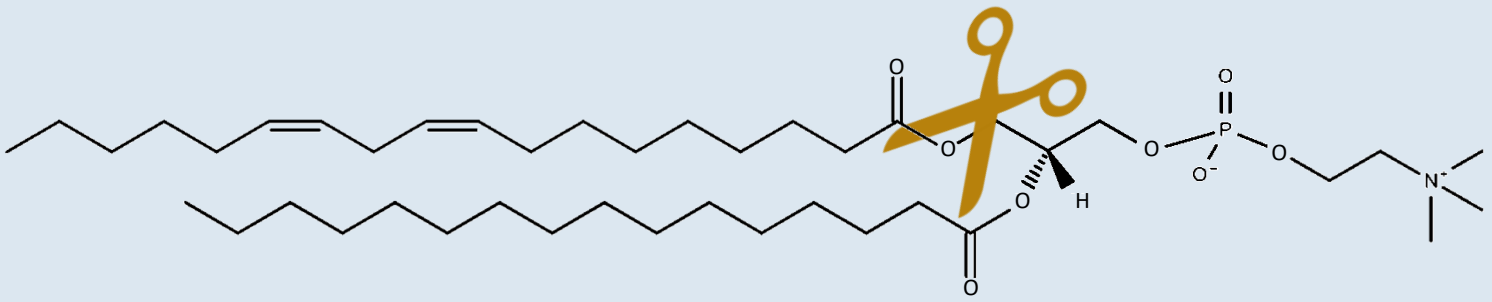
LIPIDS IN BREAD MAKING: IMPACT ON BREAD QUALITY

- Investigated in different ways
  - Flours varying in bread making quality
  - Fractionation-reconstitution experiments
  - Lipase technology

Introduction

LIPASES

Lipases are lipid degrading enzymes catalyzing the hydrolysis of (phosphodi)ester bonds of glycero(phospho)lipids

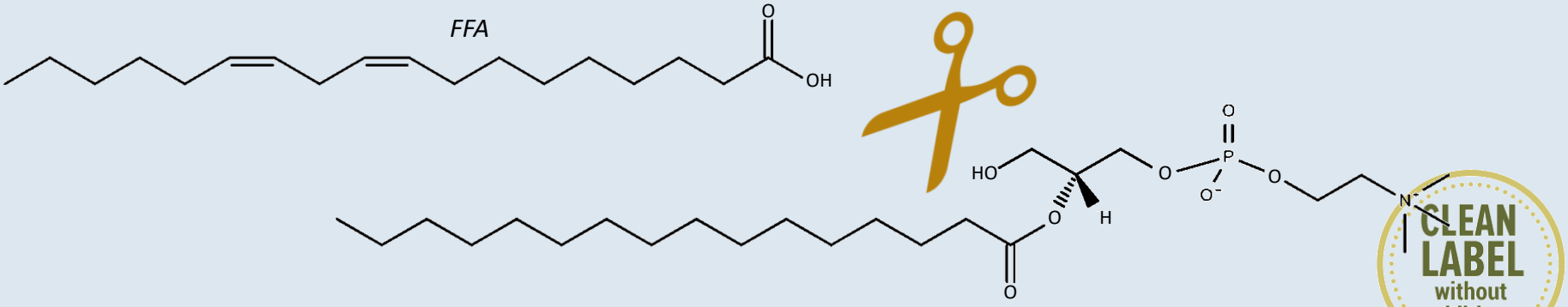


Phosphatidylcholine (PC)

Introduction

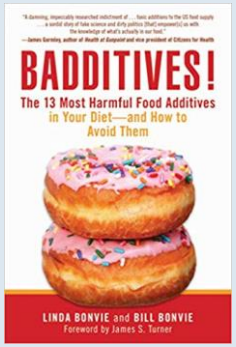
LIPASES

Lipases are lipid degrading enzymes catalyzing the hydrolysis of (phosphodi)ester bonds of glycero(phospho)lipids



Lysophosphatidylcholine (LPC)

- Excellent research tools
- Potential (clean label) alternatives for certain additives in bread making



Introduction

LIPIDS IN BREAD MAKING: IMPACT ON BREAD QUALITY

- Investigated in different ways
  - Flours varying in bread making quality
  - Fractionation-reconstitution experiments
  - Lipase technology
    - Delivered new insights
    - Limited/no information
      - Role of enzymatically released hydrolysis products
      - Interplay between wheat endogenous lipids and their enzymatically released hydrolysis products

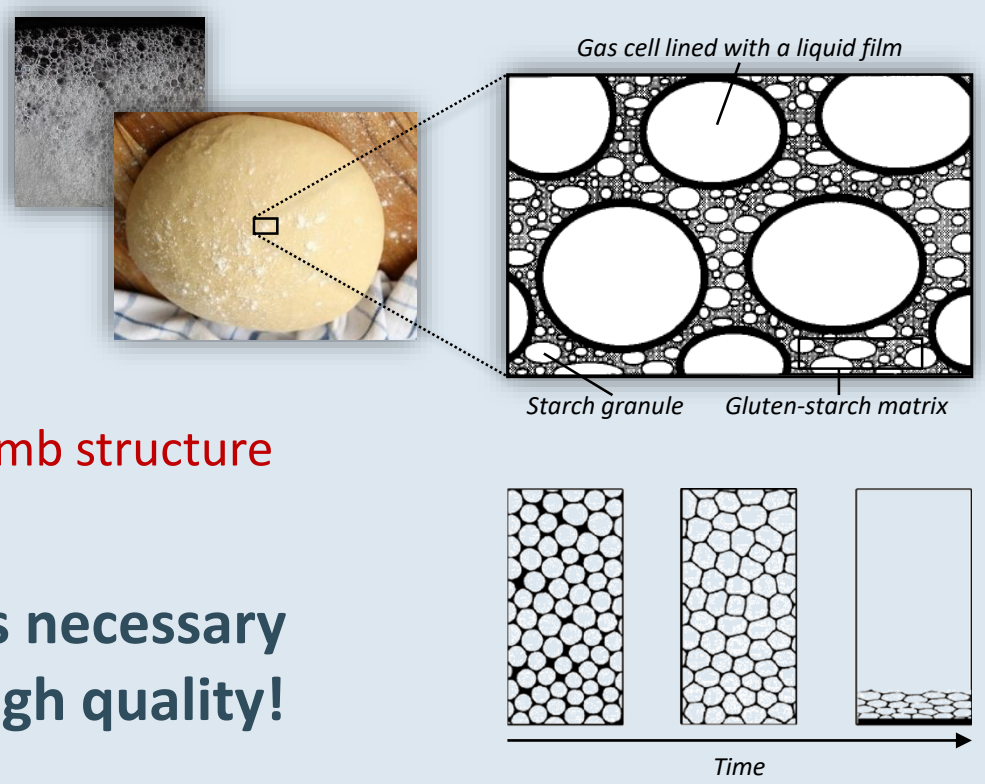
Introduction

Mechanisms whereby lipids impact bread quality

- Impact of lipids on loaf volume and crumb structure is related to the stability of gas cells in bread dough

- Bread dough = foam
  - Unstable
  - Gas is lost over time
    - 👎 Low loaf volume
    - 👎 Coarse, irregular crumb structure

  - **Stabilization of gas is necessary to obtain bread of high quality!**

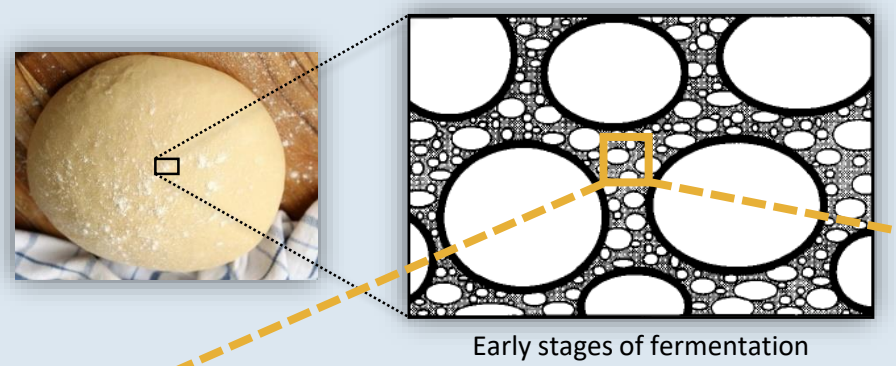


(Chung et al., Delcour and Hoseney, 2010; Gan et al., 1990; Gan et al., 1995; 2009; MacRitchie and Gras, 1973; Sroan and MacRitchie, 2009)

Introduction

Mechanisms whereby lipids impact bread quality

- Impact of lipids on gas cell stability in bread dough
  - **Indirect** → Strength of gluten-starch matrix
  - Direct

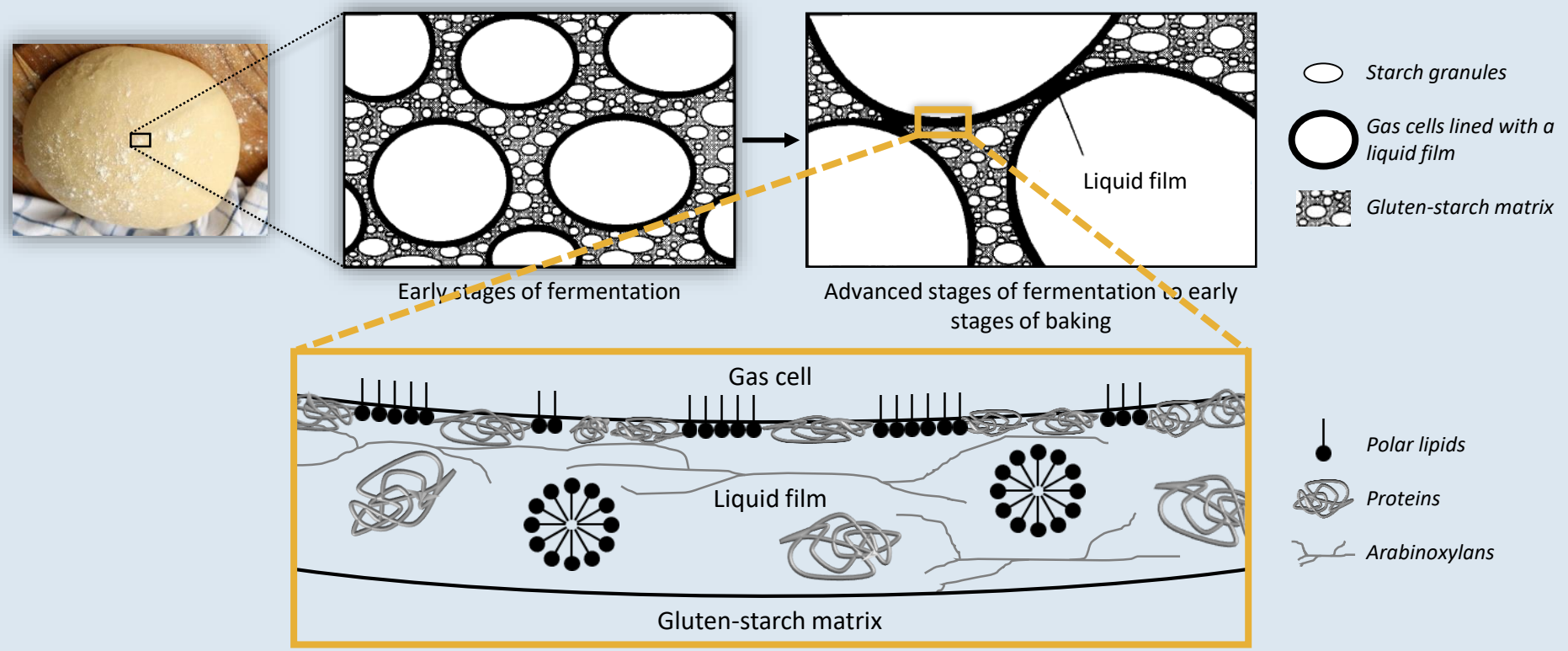


(Chung, 1986; Gan et al., 1990; Hess and Mahl, 1954; Hoseney et al., 1970; Pomeranz and Chung, 1978; Wehrli and Pomeranz, 1970)

Introduction

Mechanisms whereby lipids impact bread quality

- Impact of lipids on gas cell stability in bread dough
  - Indirect → Strength of gluten-starch matrix
  - **Direct** → Presence in liquid films

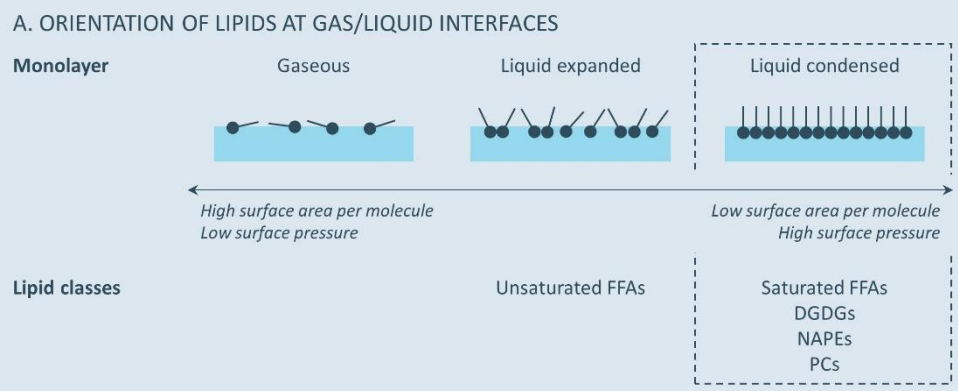


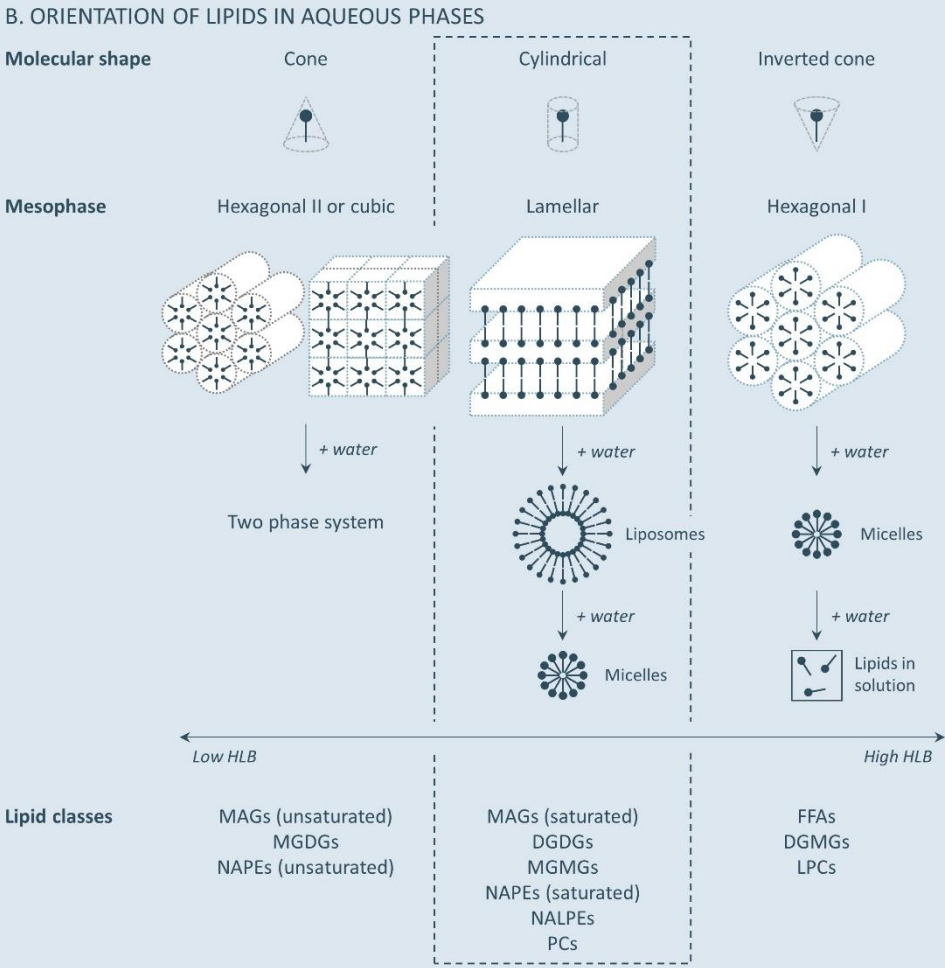
(Gan et al., 1990; Gan et al., 1995; Mills et al., 2003)

Introduction

Mechanisms whereby lipids impact bread quality

- Ability of lipids to directly stabilize gas cells depends on





(Eliasson and Larsson, 1993; Gunstone et al., 2007; Kaganer et al., 1999; Krog, 1981; MacRitchie, 1976b)

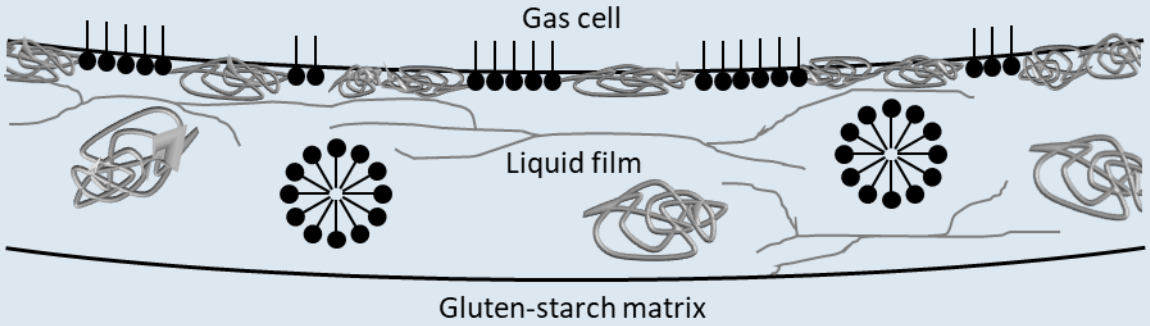
Introduction

Mechanisms whereby lipids impact bread quality

Leading hypothesis:

Impact of wheat endogenous lipids and their enzymatically released hydrolysis products is exclusively related to their **direct** action as surface-active components

- Flour lipids and lipases → no effect on dough bulk rheology
  (Gerits et al., 2015b; MacRitchie and Gras, 1973; Sroan et al., 2009; Sroan and MacRitchie, 2009)
- Effects of lipids on loaf volume and crumb structure
  ~ theoretical ability of lipids to (de)stabilize gas/liquid interfaces
  (MacRitchie, 1976a; MacRitchie, 1977; MacRitchie, 1981; MacRitchie and Gras, 1973)



Introduction

Mechanisms whereby lipids impact bread quality

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  (MacRitchie, 1976a; MacRitchie, 1977; MacRitchie, 1981; MacRitchie and Gras, 1973)

- Presence and action of lipids at gas cell interfaces in dough never experimentally proven!

Introduction
Conclusions

- Chung and coworkers (1978)
  - Reviewed the role of wheat flour lipids in bread making
  - Much information available
    - Fragmentary
    - Sometimes contradictory
  - Factors making sustained and consistent progress difficult
  - Little likelihood that a unified theory on the role of wheat lipids in the production of baked goods could be developed

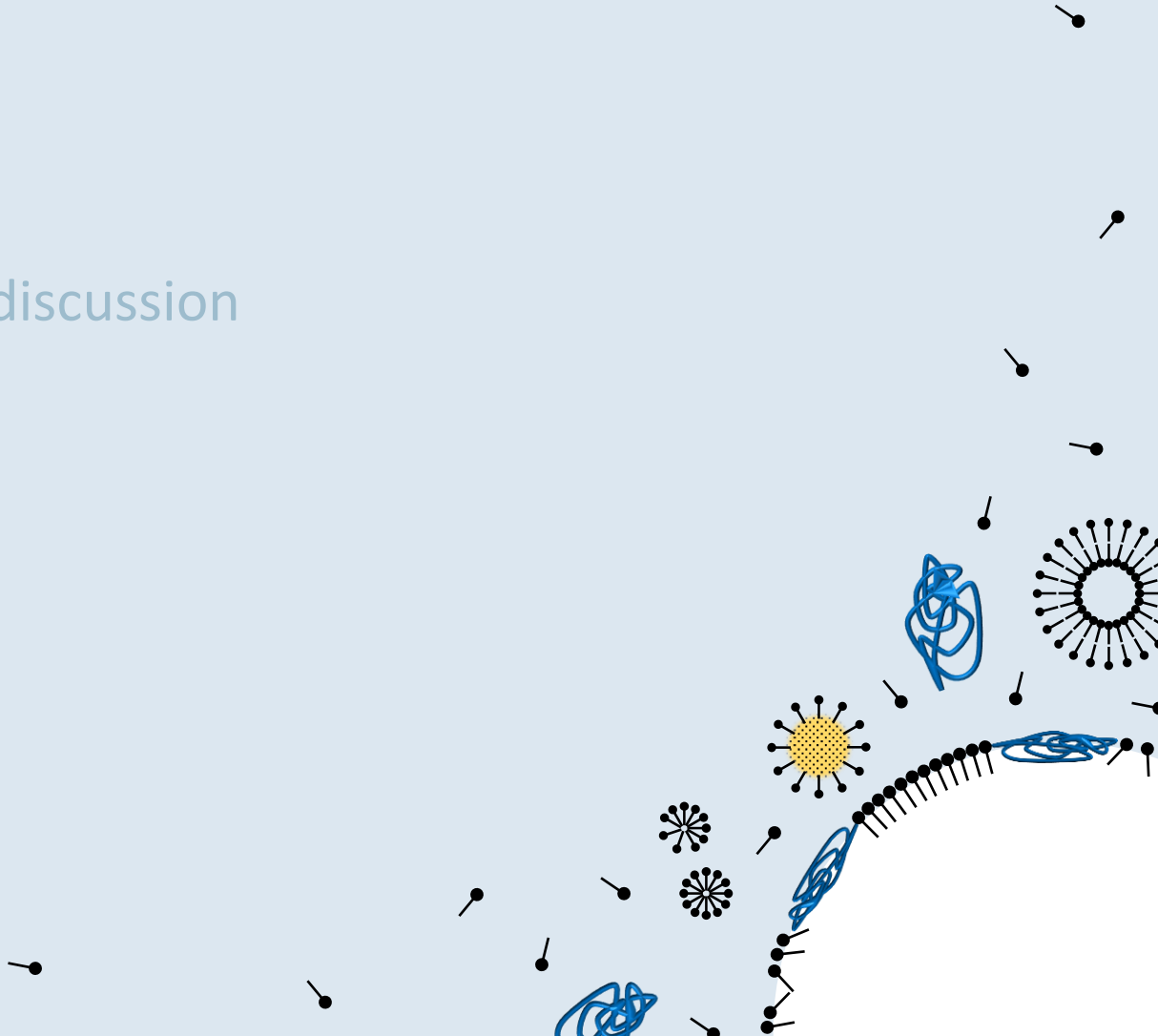
~

"Consequently, we will learn increasingly more about the role of lipids, but we will be frustrated by the complexity of the effects."

~

Overview

- Introduction
- Objective
- Results and discussion
- Conclusions



Objective

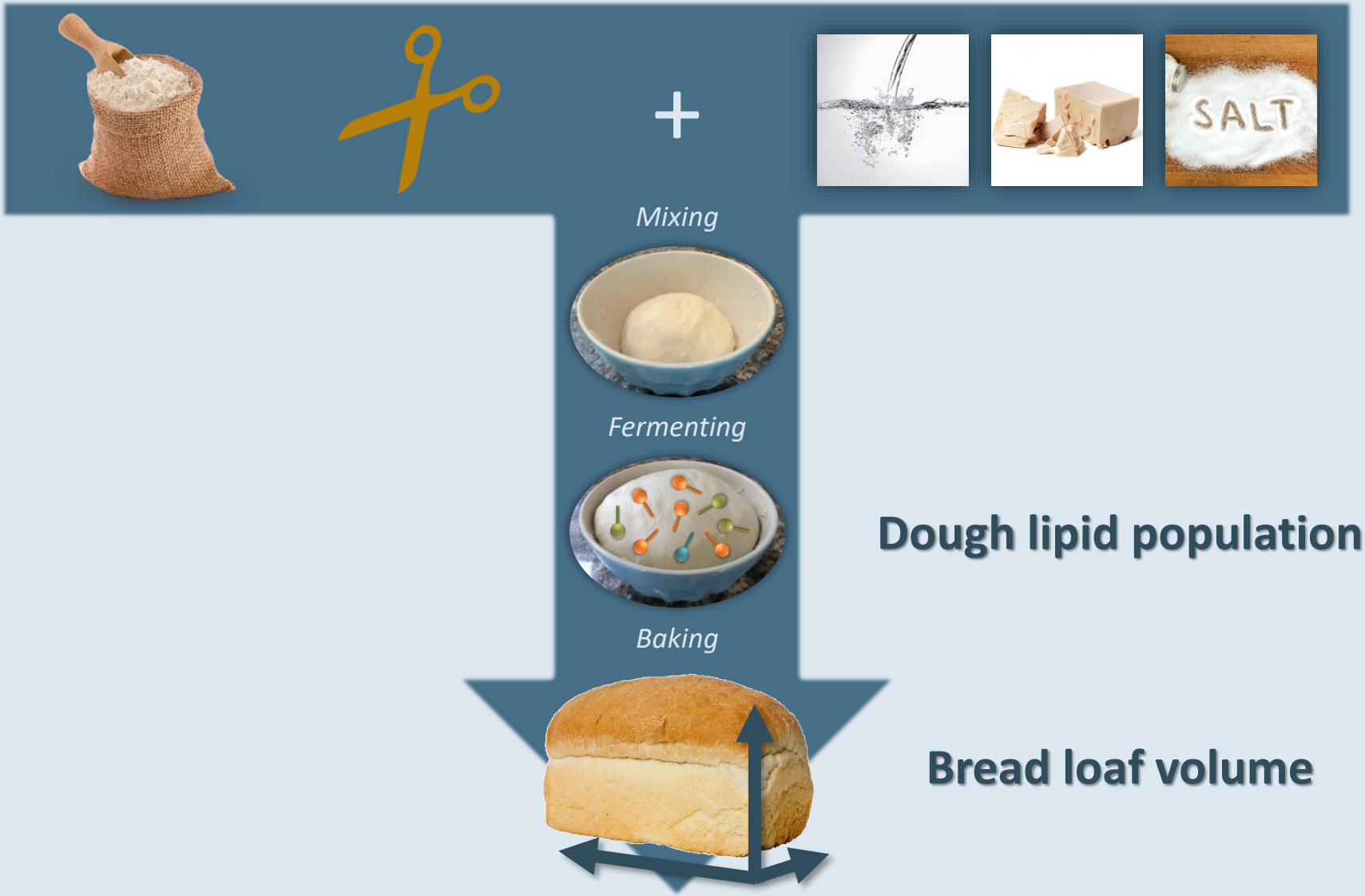
To unravel the role of wheat endogenous lipids and their enzymatically released hydrolysis products in bread making

Overview

- Introduction
- Objective
- Results and discussion
  - Impact of lipids on bread quality
  - Mechanisms whereby lipids impact bread quality
- Conclusions

Results and discussion

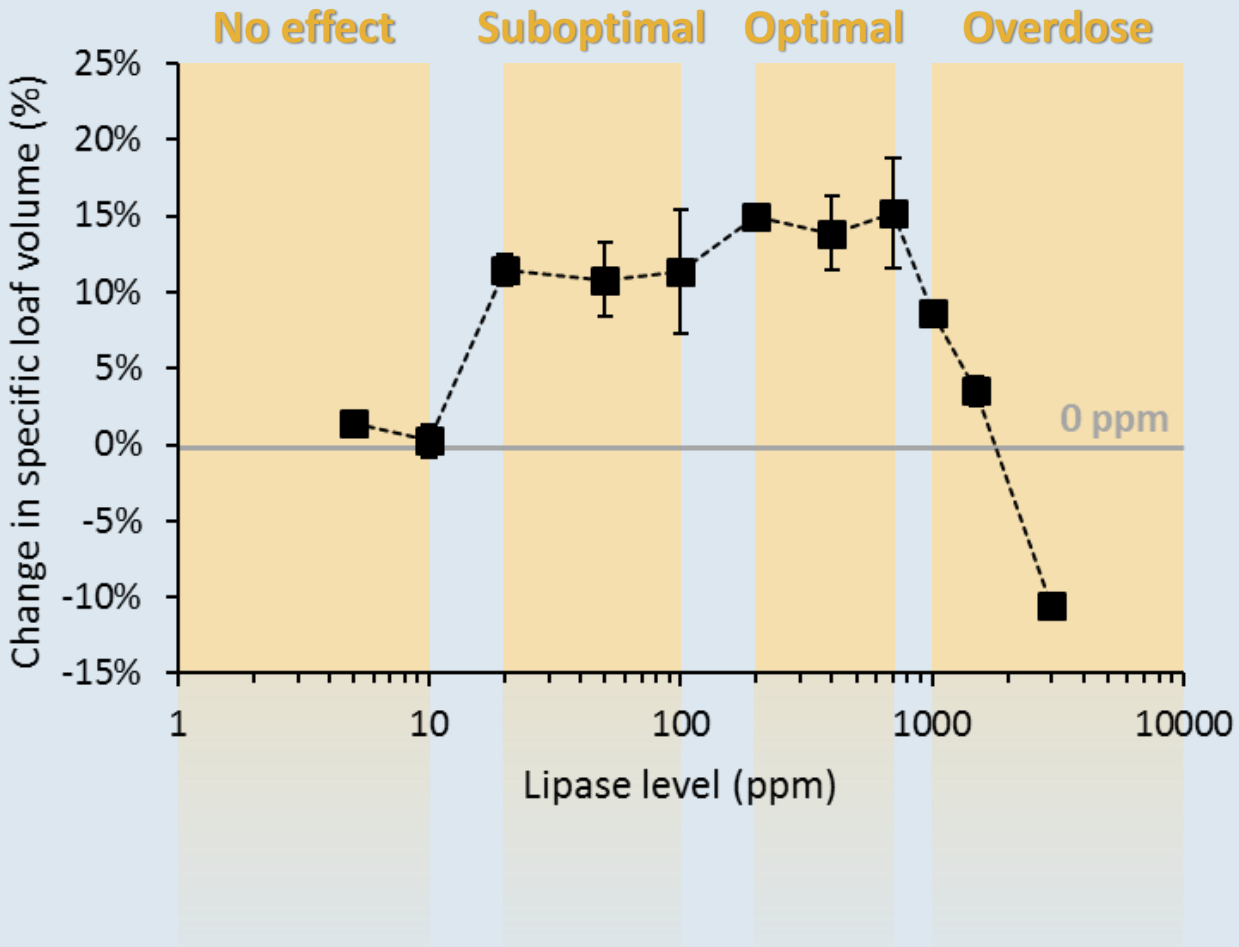
IMPACT OF LIPIDS ON BREAD QUALITY



Results and discussion

IMPACT OF LIPIDS ON BREAD QUALITY

- Change in specific loaf volume as a function of lipase level

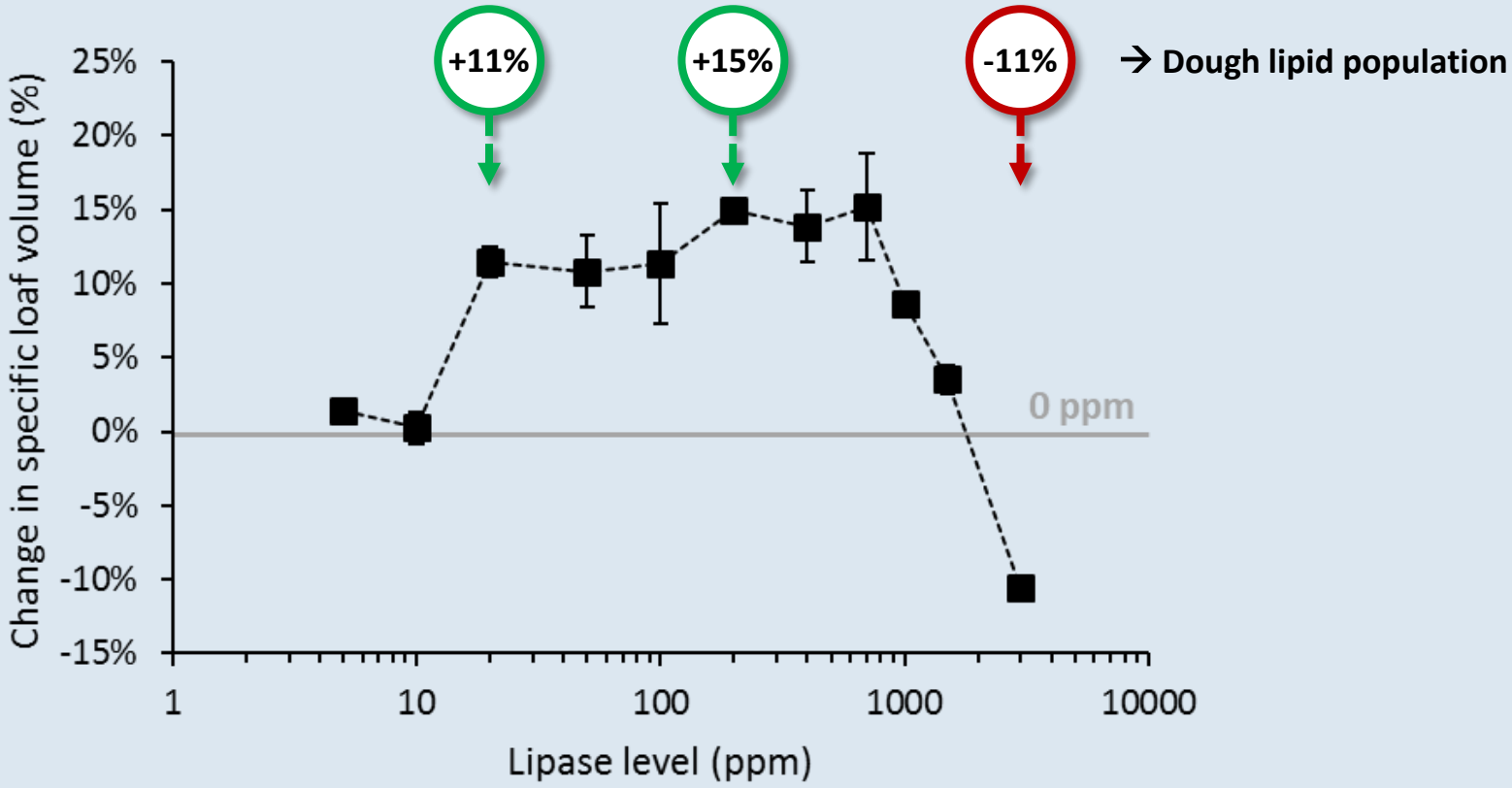


ppm, parts per million

Results and discussion

IMPACT OF LIPIDS ON BREAD QUALITY

- Change in specific loaf volume as a function of lipase level

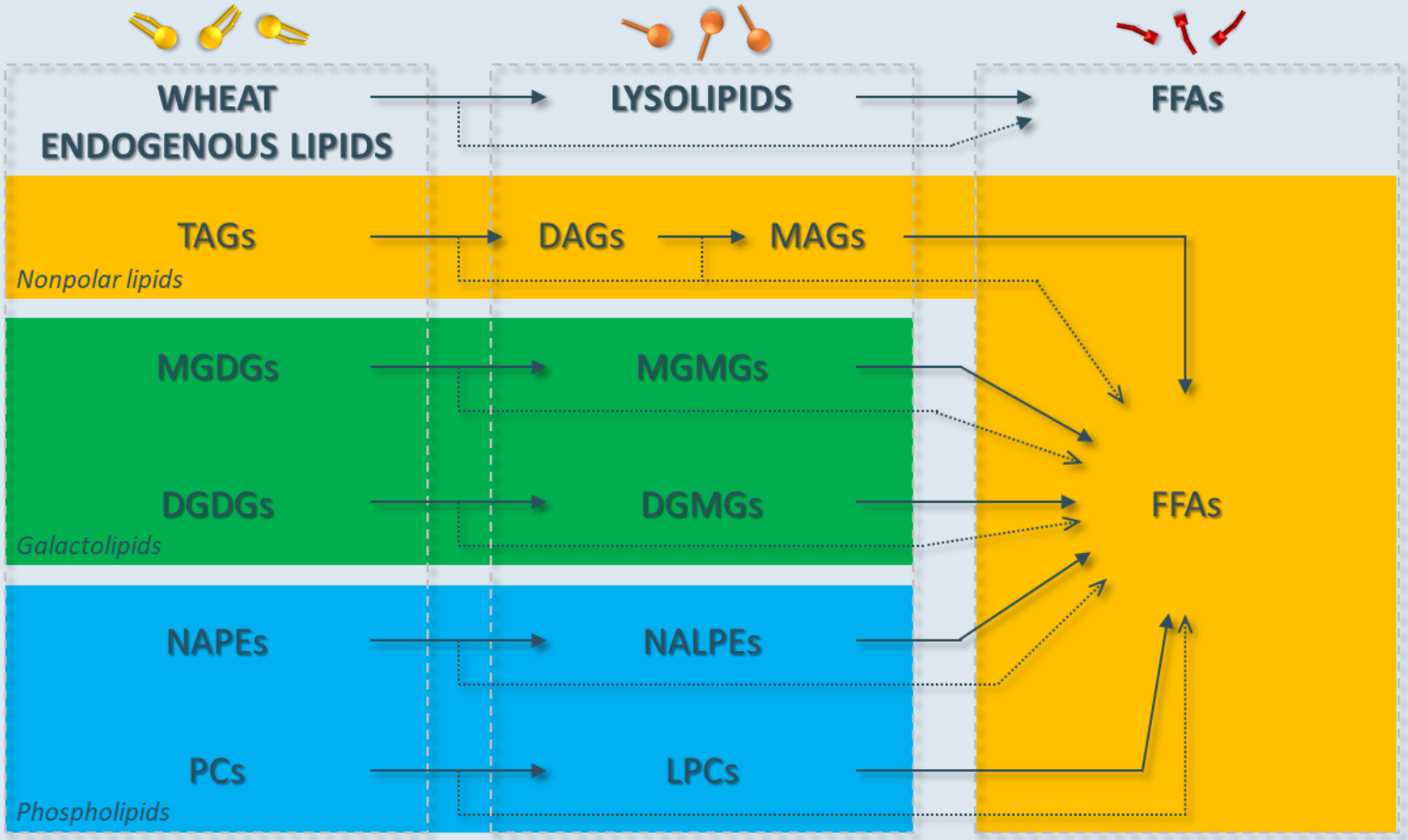


ppm, parts per million

Results and discussion

IMPACT OF LIPIDS ON BREAD QUALITY

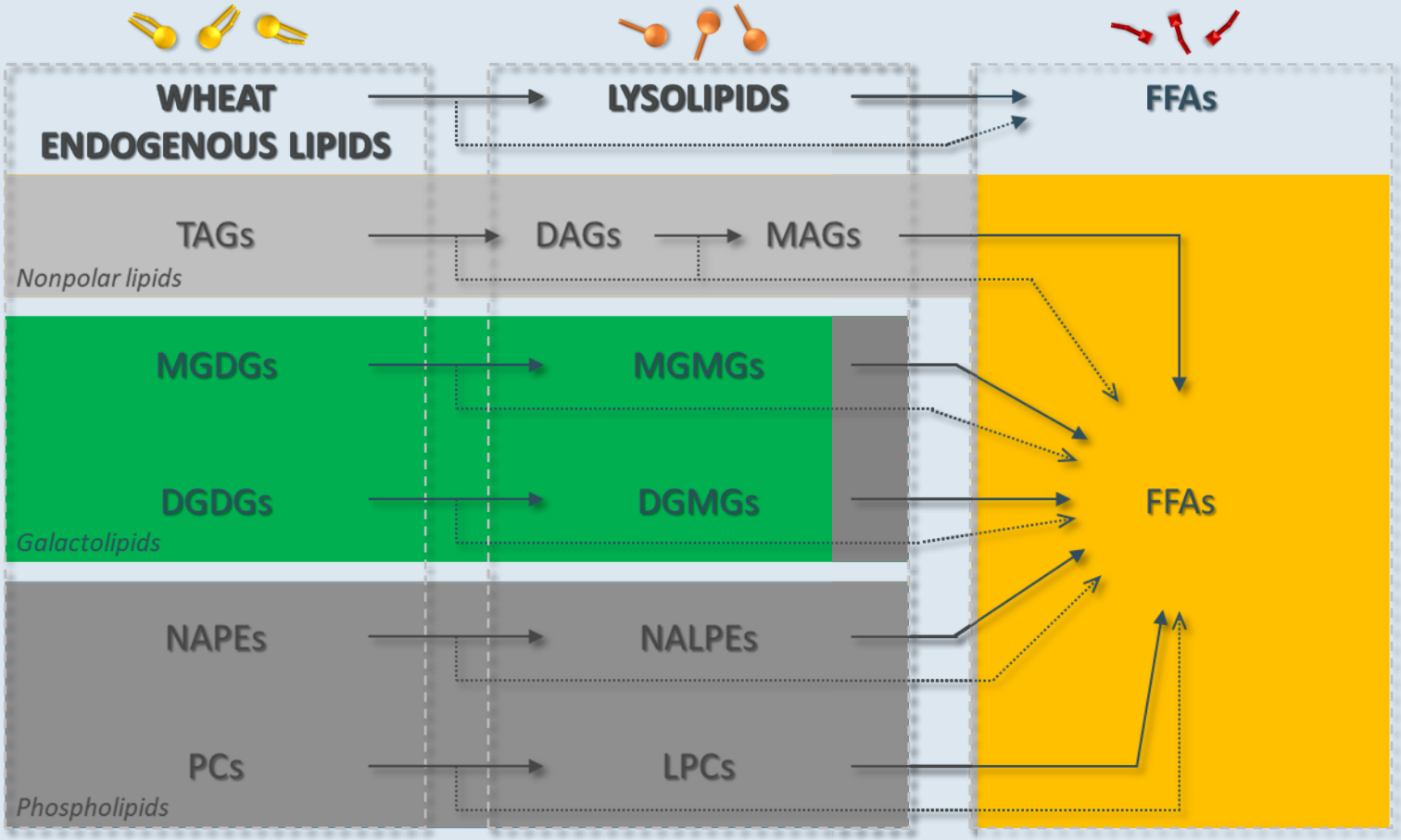
- Dough lipid population analysis (HPLC-ELSD)



Results and discussion

IMPACT OF LIPIDS ON BREAD QUALITY

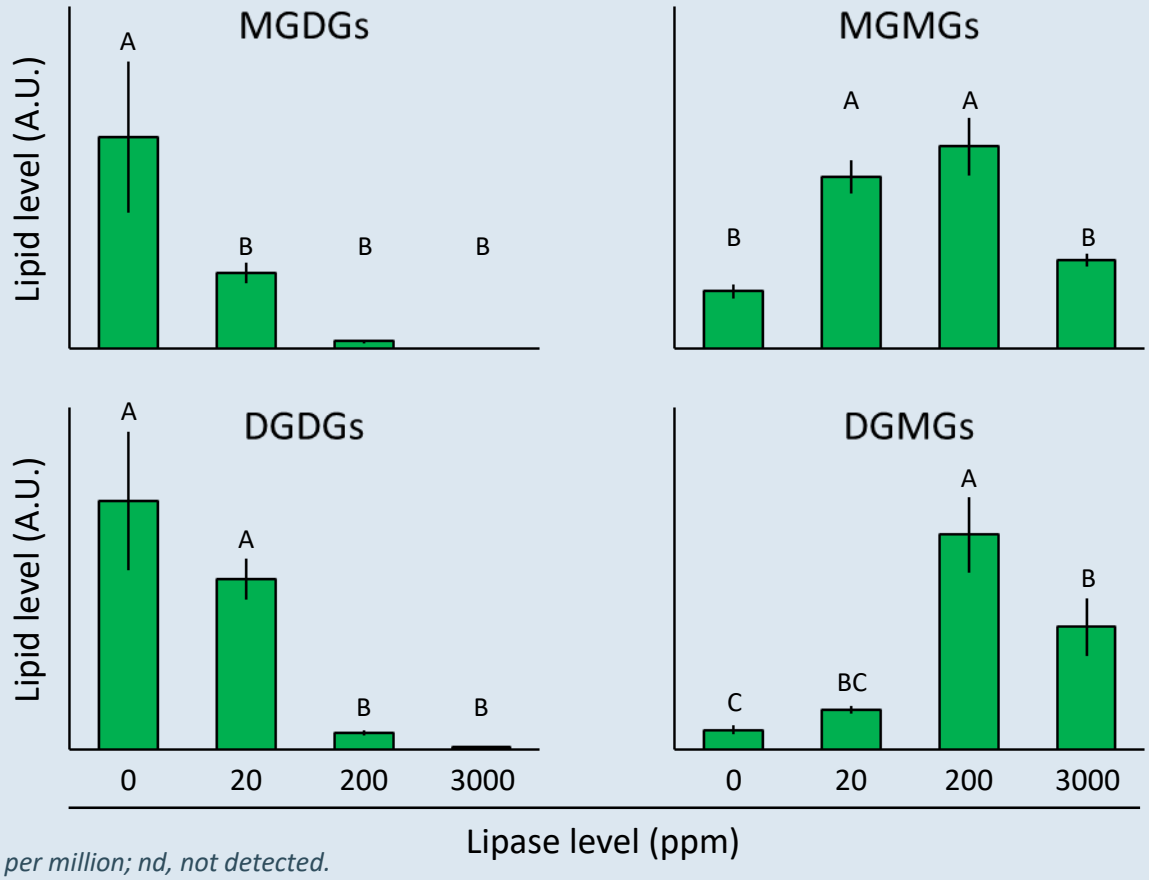
- Dough lipid population analysis (HPLC-ELSD)



Results and discussion

IMPACT OF LIPIDS ON BREAD QUALITY

- Lipid levels in dough prepared with and without different levels of lipase

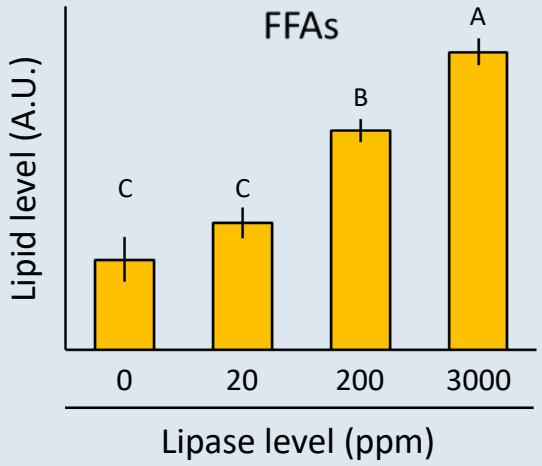


A.U., arbitrary units; ppm, parts per million; nd, not detected.
Bars with different capital letters are significantly different from each other ($p < 0.05$).

Results and discussion

IMPACT OF LIPIDS ON BREAD QUALITY

- Lipid levels in dough prepared with and without different levels of lipase



A.U., arbitrary units; ppm, parts per million.
Bars with different capital letters are significantly different from each other ($p < 0.05$).

Results and discussion

IMPACT OF LIPIDS ON BREAD QUALITY

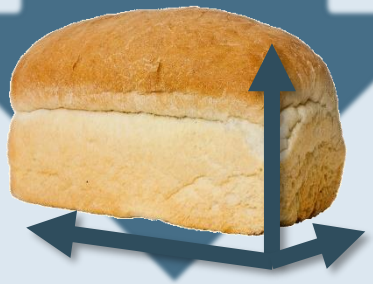
+

Mixing

Fermenting

Dough lipid population

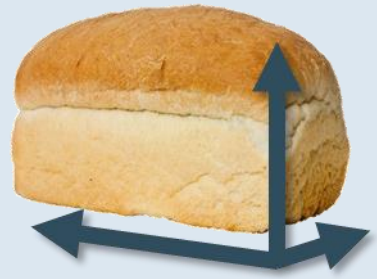
Baking

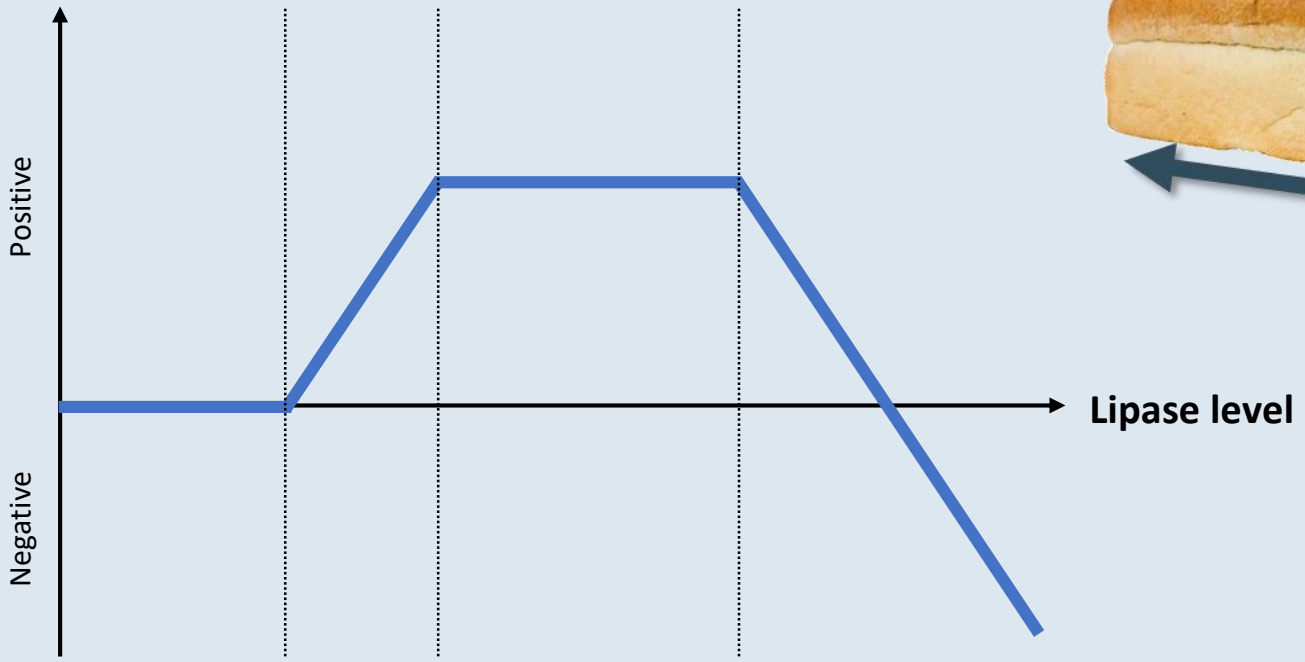


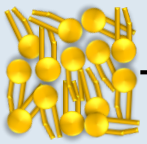
Bread loaf volume

Results and discussion

IMPACT OF LIPIDS ON BREAD QUALITY

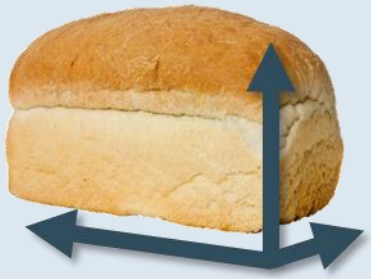






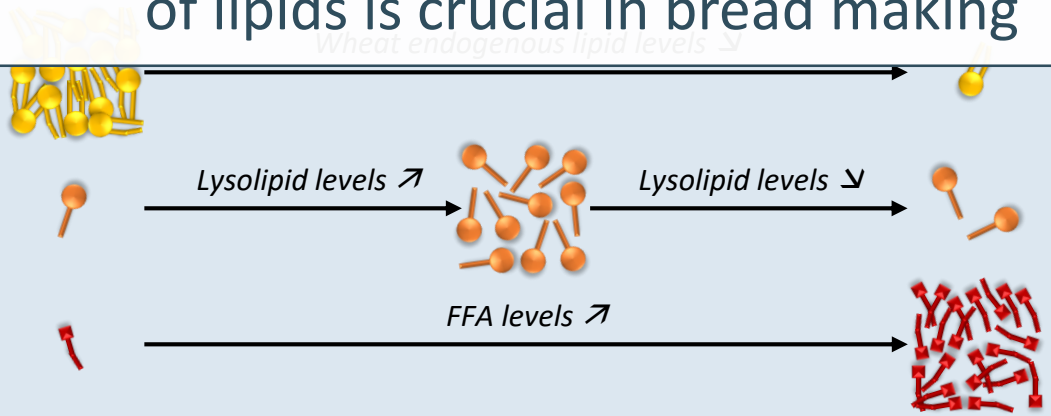
Results and discussion

IMPACT OF LIPIDS ON BREAD QUALITY



The positive effect of lipases in bread making is restricted by the unavoidable release of detrimental FFAs

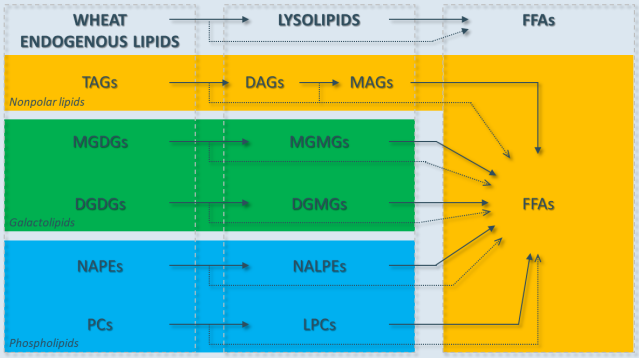
An appropriate balance between different types of lipids is crucial in bread making

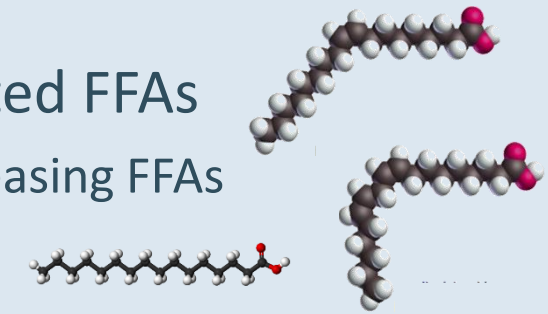


Results and discussion

Impact of lipids on bread quality

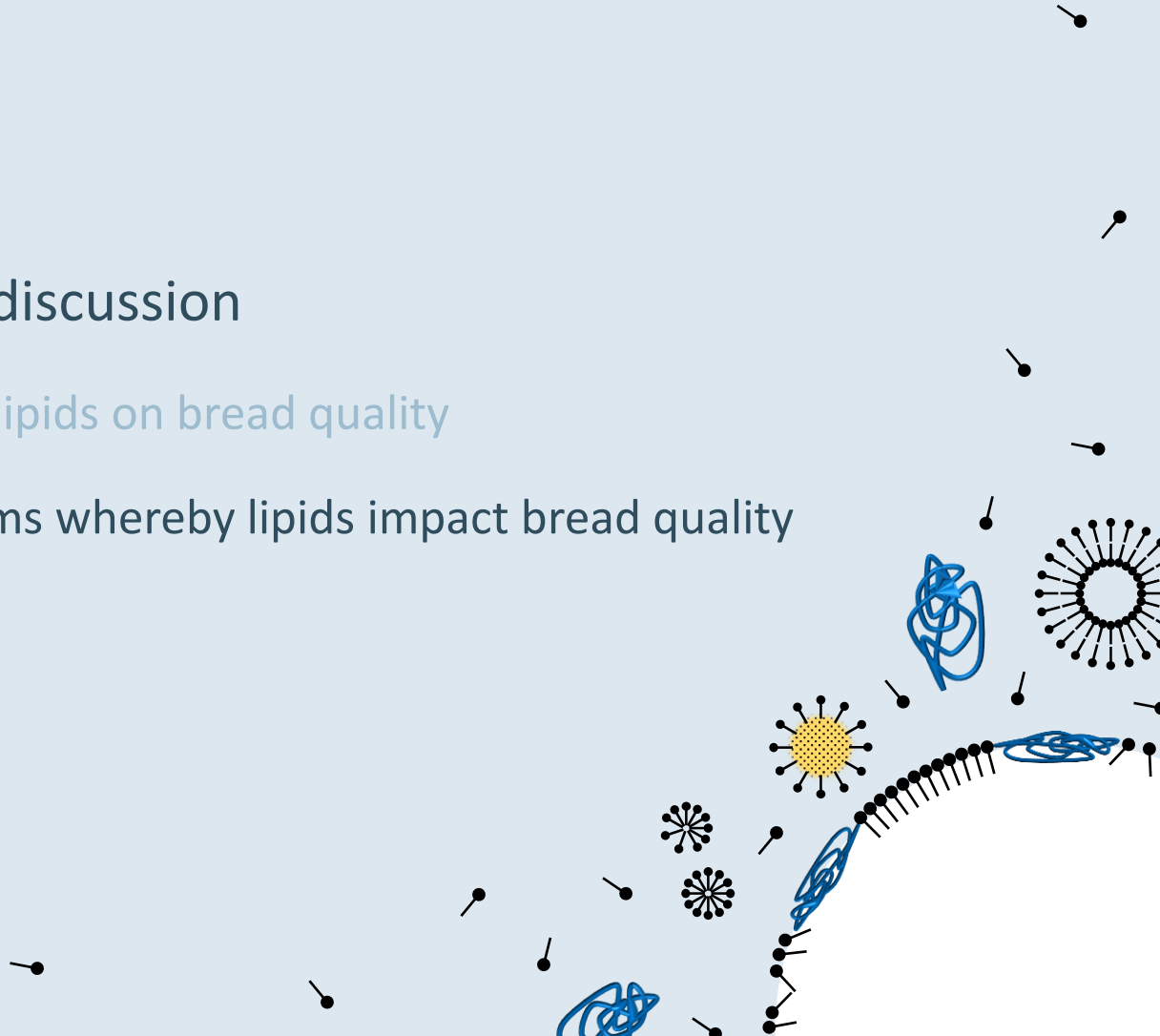
- **Perfect bread making lipases** preferably
  - ✂ MGDGs and NAPEs
    - ↗ highly beneficial MGMGs
    - ↘ detrimental NAPEs
  - ✂ DGDGs
    - DGDGs:DGMGs ≈ 1:1 (synergistic effects)
  - 🚫 TAGs and PCs
    - Limit release of detrimental FFAs
  - 🚫 Lysolipids
    - More beneficial than their precursors
  - ✂ Release saturated rather than unsaturated FFAs
    - Presumably delays detrimental effect of releasing FFAs





Overview

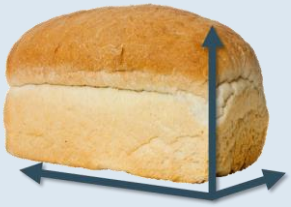
- Introduction
- Objective
- Results and discussion
  - Impact of lipids on bread quality
  - Mechanisms whereby lipids impact bread quality
- Conclusions

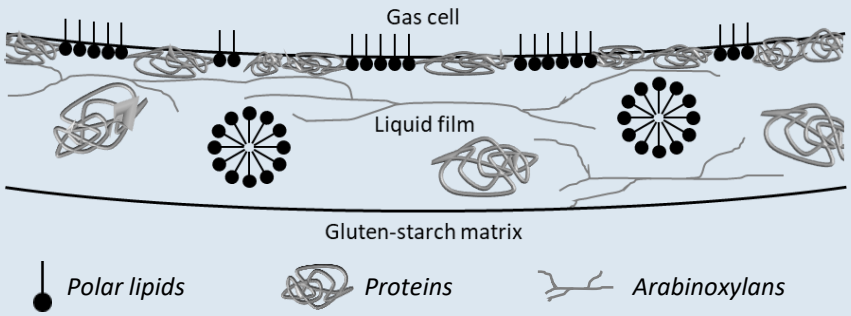


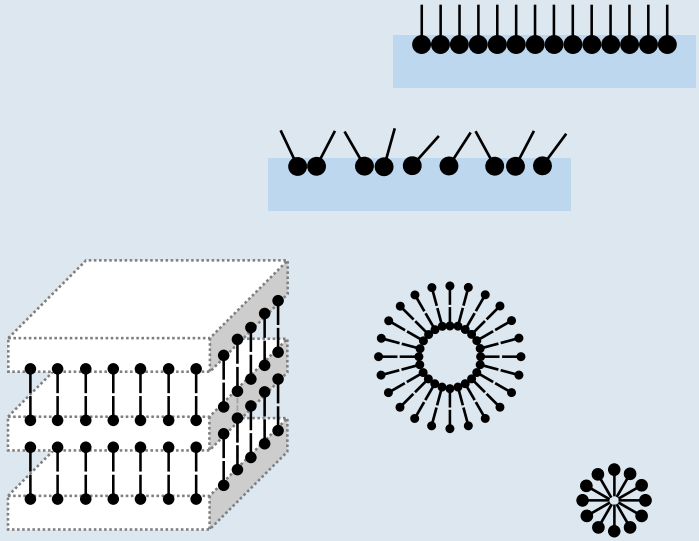
Results and discussion

Mechanisms whereby lipids impact bread quality

- A **mechanism** whereby wheat endogenous lipids and their enzymatically released hydrolysis products affect bread loaf volume was proposed
  - Entirely relies on the ability of lipids to **directly** stabilize gas cells in dough

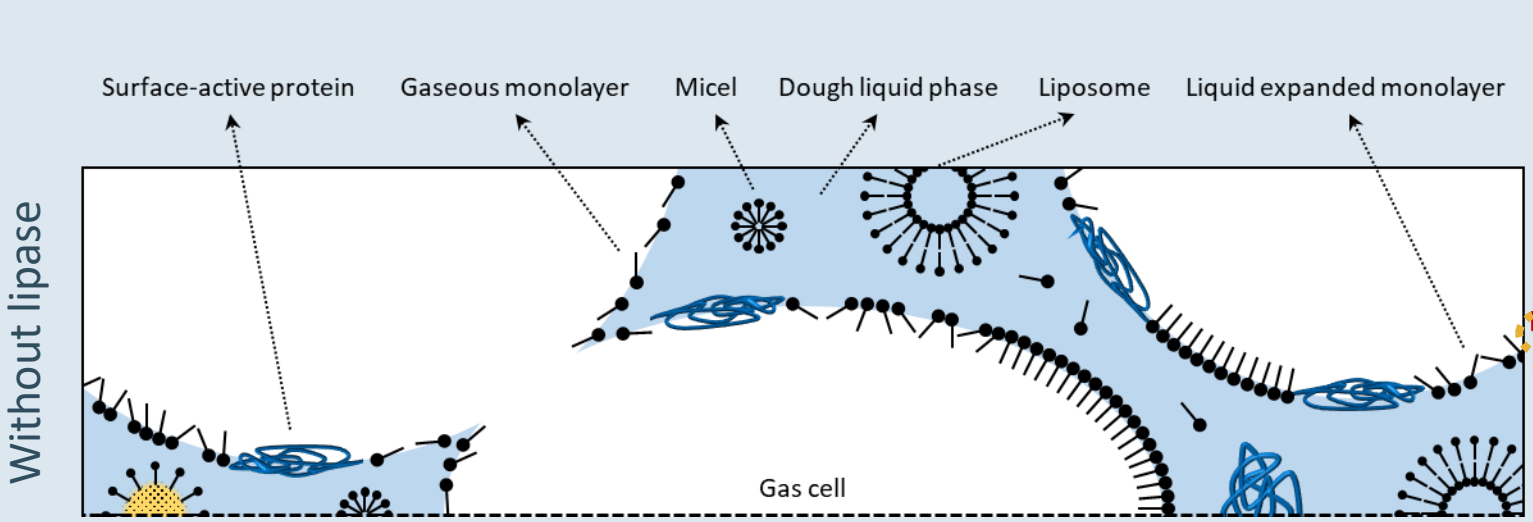


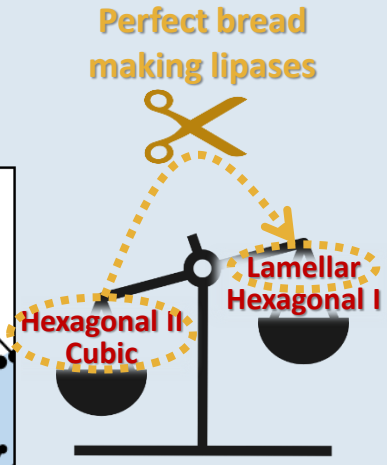


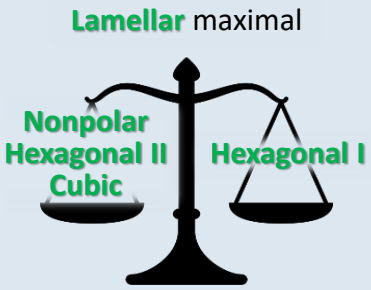


Results and discussion

Mechanisms whereby lipids impact bread quality



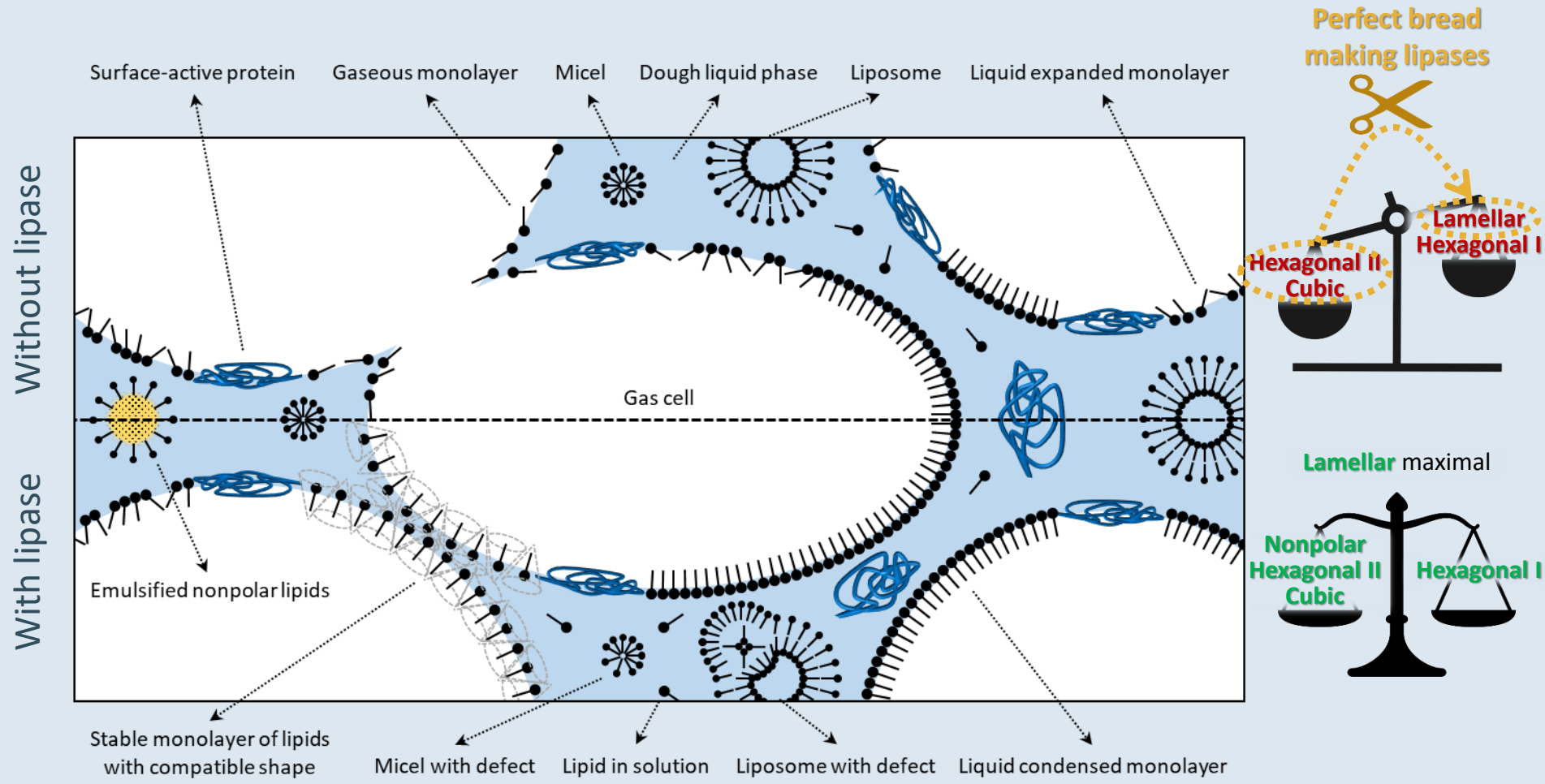




Lipases cause a change in the balance between different types of lipids

Results and discussion

Mechanisms whereby lipids impact bread quality



Results and discussion

Mechanisms whereby lipids impact bread quality

+

Mixing

Fermenting

Ultracentrifugation
(165 000 g, 60 min, 20°C)

Dough liquor composition and properties

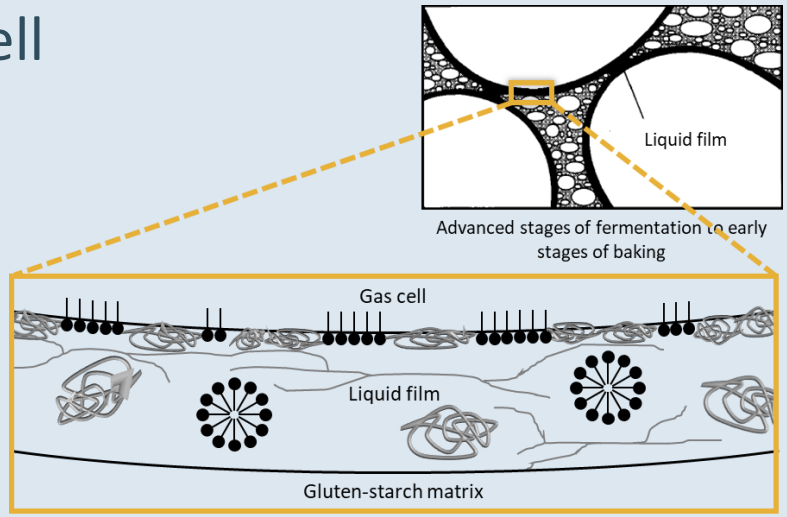
Results and discussion

Mechanisms whereby lipids impact bread quality

- **Dough liquor**

  ~ Fraction representative for liquid films surrounding gas cells in dough

  - Composition and properties
    → information about (components responsible for) **direct** gas cell stabilization in dough



(Baker et al., 1946; Gerits et al., 2015b; Primo-Martín et al., 2006; Salt et al., 2018; Salt et al., 2006).

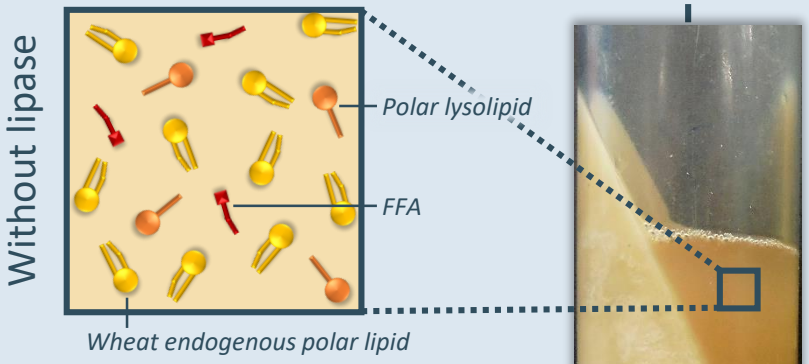
Results and discussion

Mechanisms whereby lipids impact bread quality

- **Dough liquor** ☞ **Direct** impact on gas cell stability

Lipid composition

Interfacial properties



Practically no polar lipids recovered!

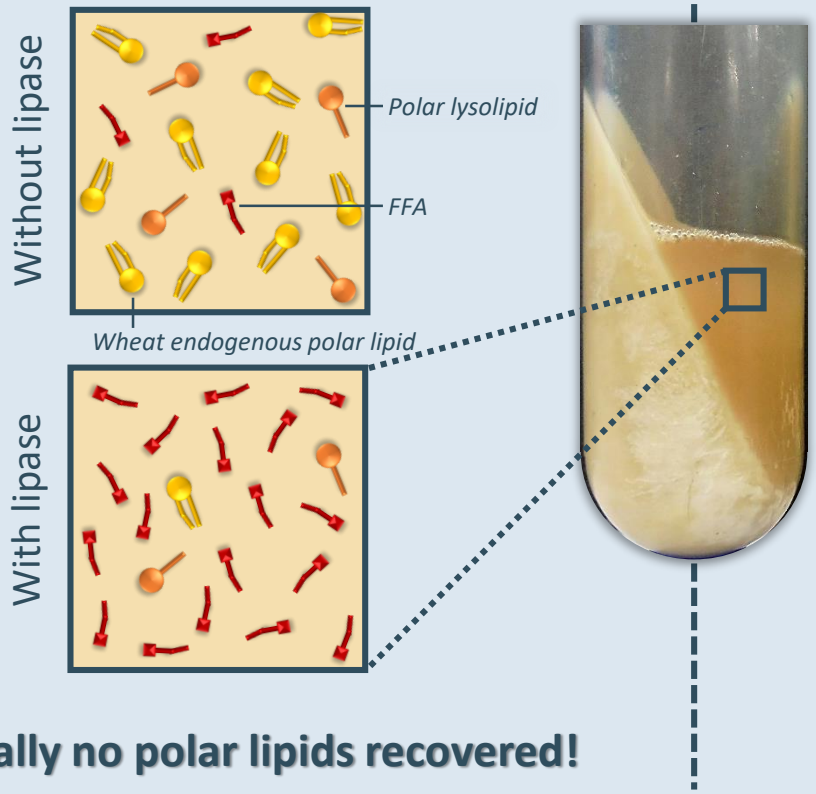
Results and discussion

Mechanisms whereby lipids impact bread quality

- **Dough liquor** ☞ **Direct** impact on gas cell stability

Lipid composition

Interfacial properties



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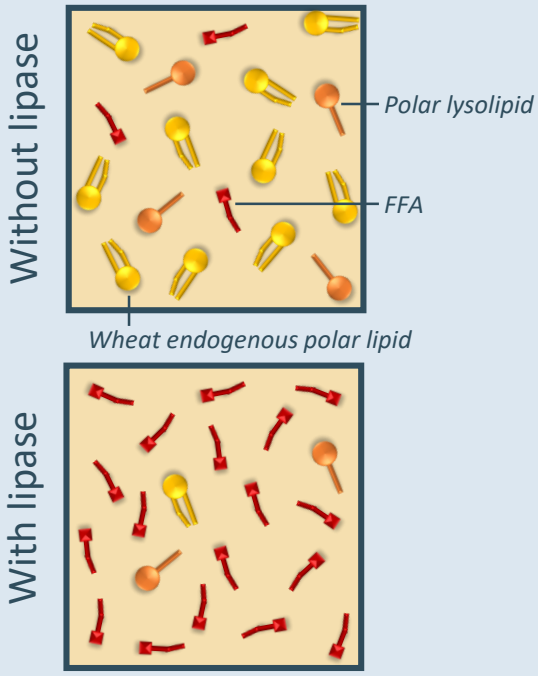
Results and discussion

Mechanisms whereby lipids impact bread quality

- **Dough liquor** ☞ **Direct** impact on gas cell stability

Lipid composition



Practically no polar lipids recovered!

Interfacial properties

- **Surface tension (γ)**
- **Surface dilatational modulus (E)**

Lipase impact on…

	Dough liquor		Bread
	γ	E	LV
	↘	≈	+ 30%
	↘↘	↗	+ 30%

No relation!

Results and discussion

Mechanisms whereby lipids impact bread quality

- **Dough liquor** ☞ **Direct** impact on gas cell stability

  - No relation between lipase-induced changes in…
    - Dough liquor composition and interfacial properties
    - Bread loaf volume

  →Lipase impact on loaf volume not due to altered dough liquor composition and/or interfacial properties

  - Unclear whether this is due to
    - Lipases having no positive impact on interfacial gas cell stability during bread making
    - Dough liquor not being an appropriate model system for gas cell interfaces in dough

Results and discussion

Mechanisms whereby lipids impact bread quality

+

Mixing

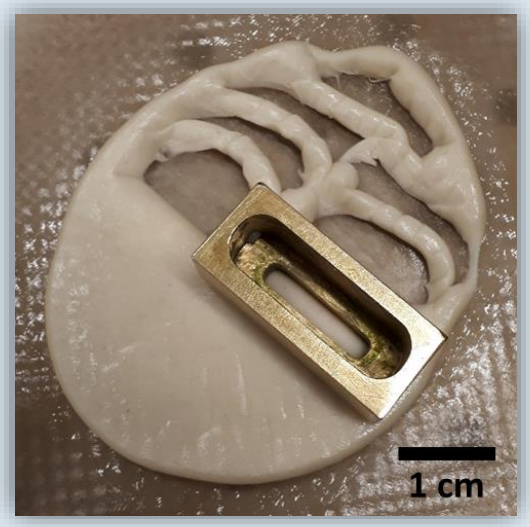
Preparing dough strands

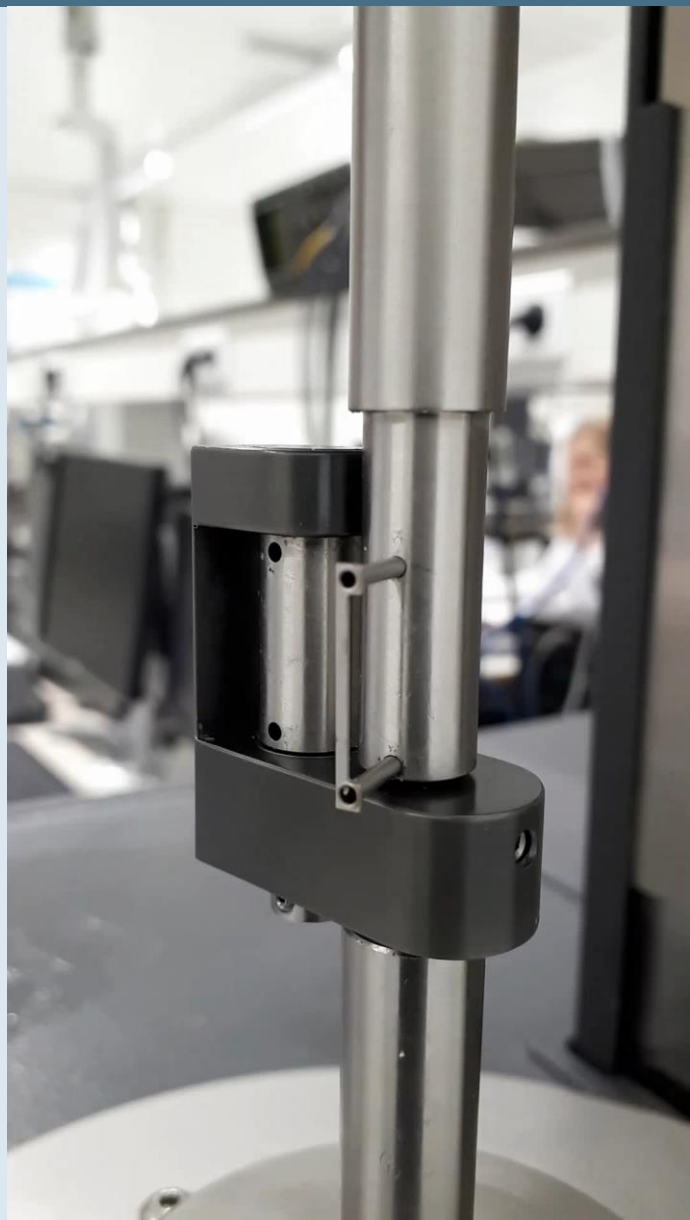
Dough uniaxial extension

Results and discussion

Mechanisms whereby lipids impact bread quality

- **Dough uniaxial extension**
  - ~ Dough flow behavior or rheology
  - Create dough strands

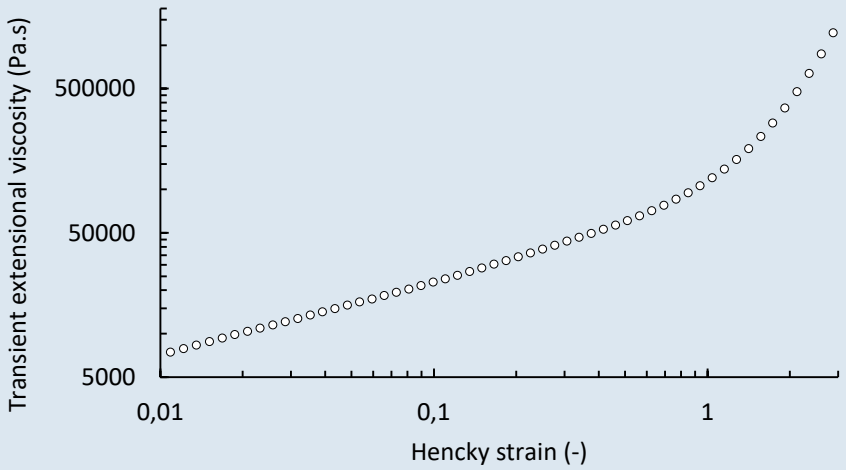


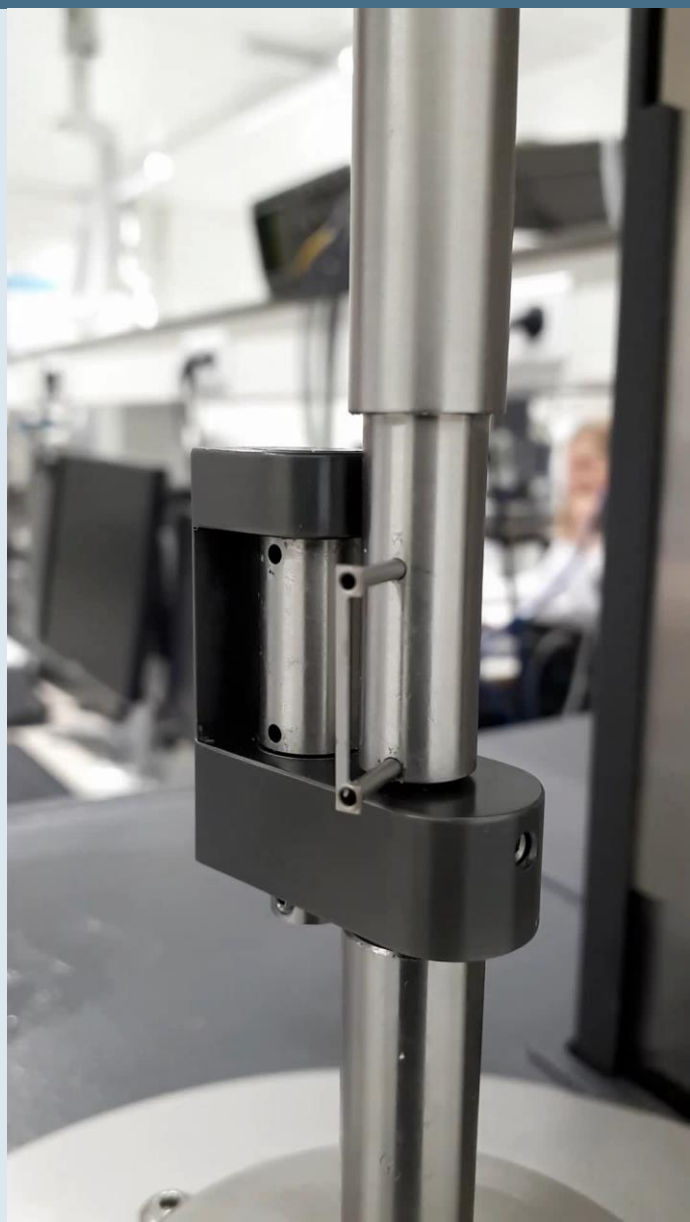


Results and discussion

Mechanisms whereby lipids impact bread quality

- **Dough uniaxial extension**
  - ~ Dough flow behavior or rheology
  - Create dough strands
  - Output

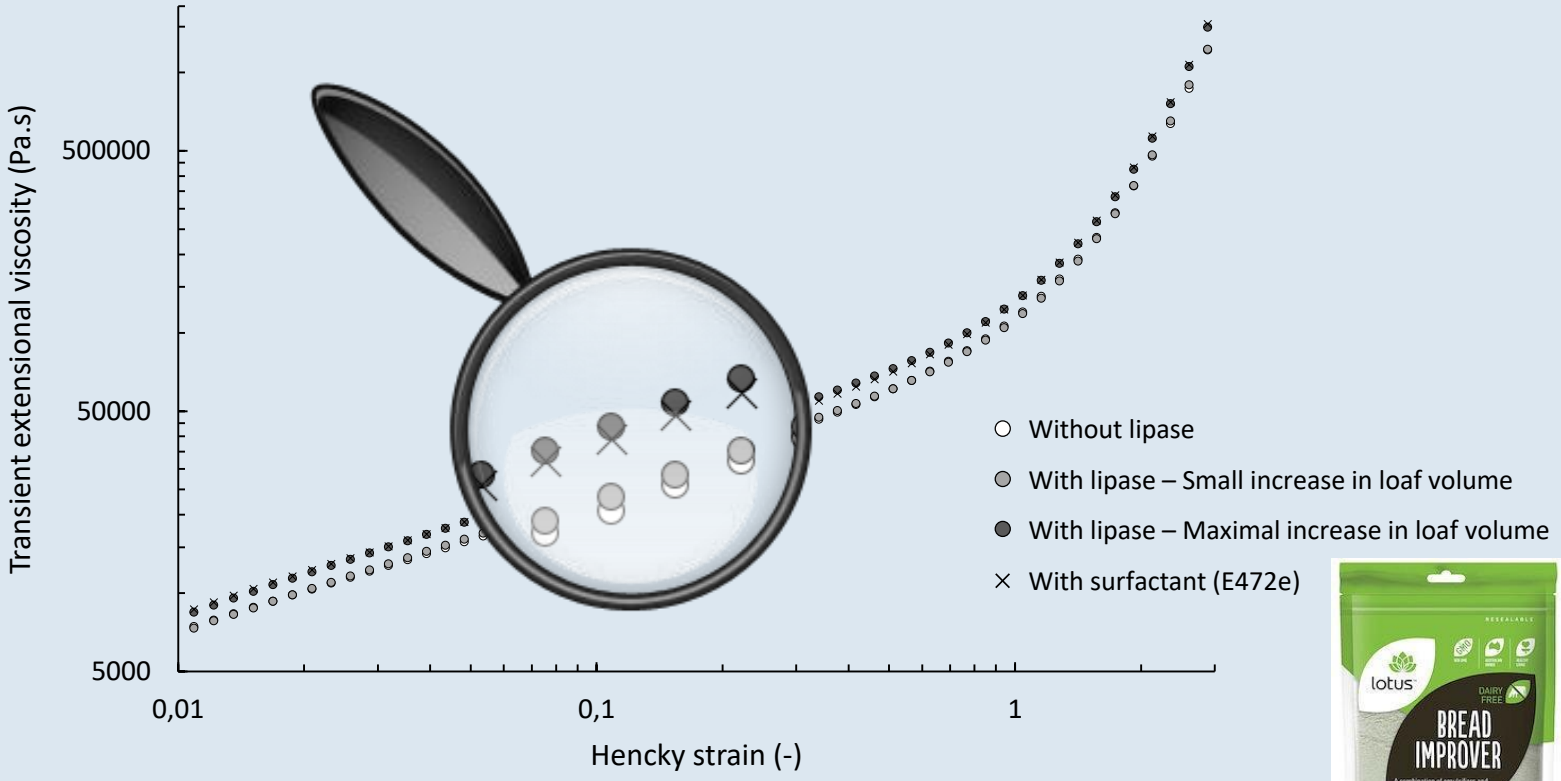




Results and discussion

Mechanisms whereby lipids impact bread quality

- **Dough uniaxial extension** ☞ **Indirect** impact on gas cell stability

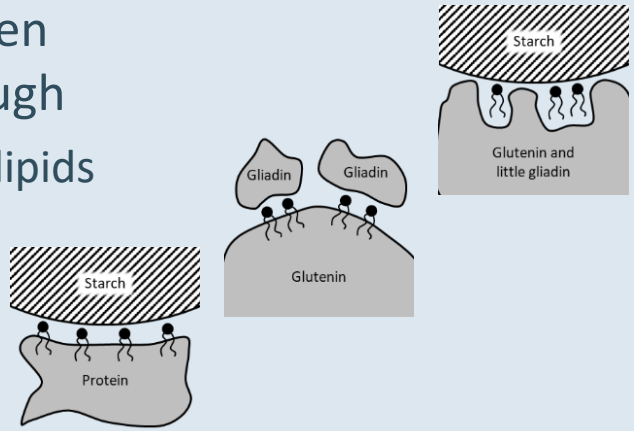


Results and discussion

Mechanisms whereby lipids impact bread quality

- **Dough uniaxial extension** ☞ **Indirect** impact on gas cell stability
  - Including lipase increased dough extensional viscosity
    - Enhanced lipid-mediated starch-gluten and gluten-gluten interactions in dough
      - Due to increased polarity of dough lipids

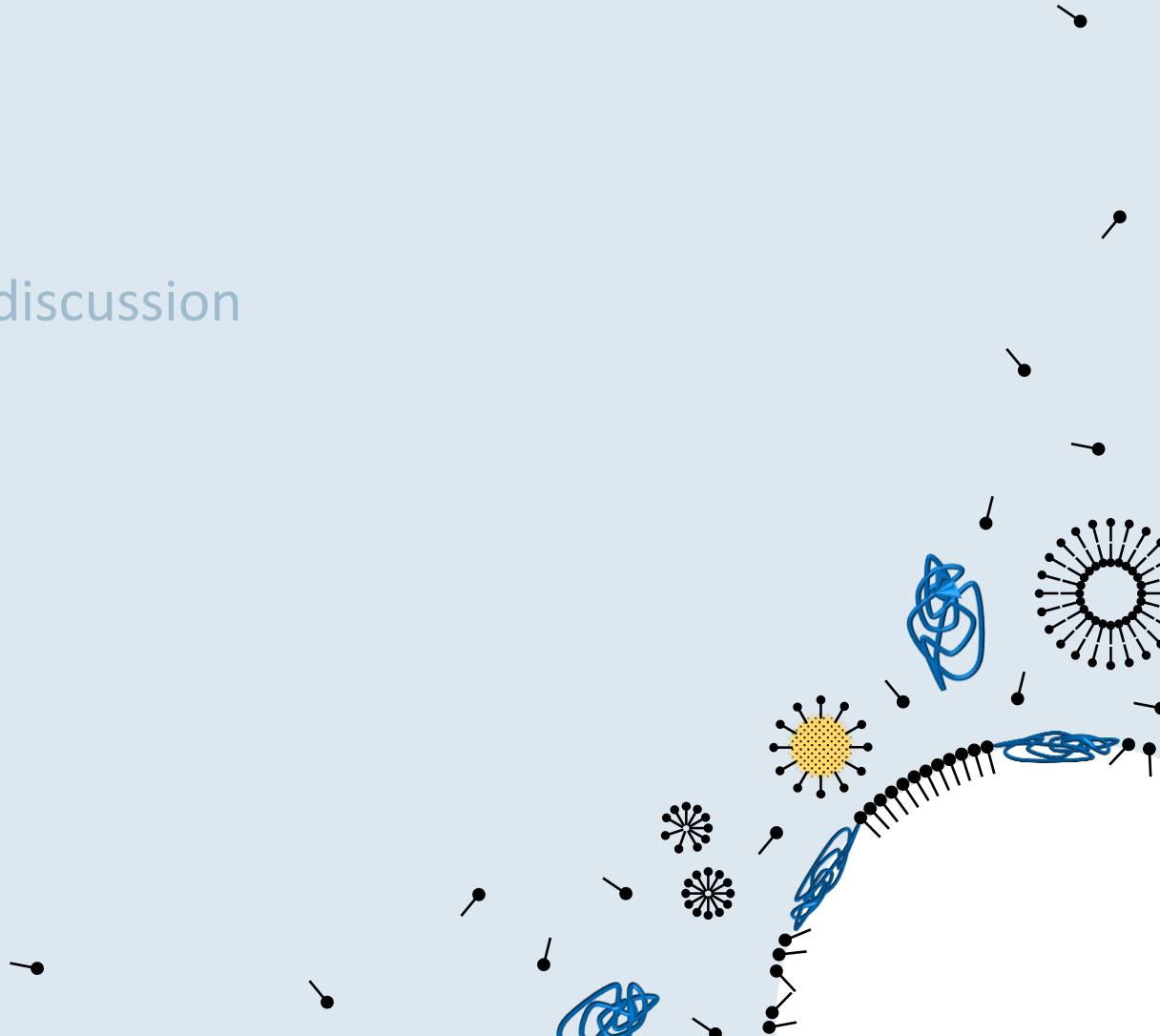
      ~ Lipids "bridge" starch and gluten
      - Improvement of
        - Dough strength
        - Dough gas holding capacity



→Lipids can contribute to the stability of gas cells in dough in an **indirect** way

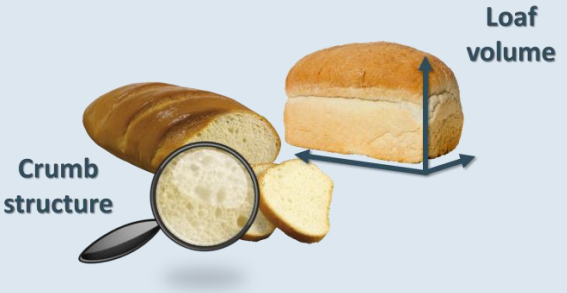
Overview

- Introduction
- Objective
- Results and discussion
- Conclusions



Conclusions

Wheat endogenous lipids and their enzymatically released hydrolysis products greatly impact bread loaf volume



- Lipids
  - Minor constituents in flour
  - Excellent targets for improving bread quality

- Perfect bread making lipases preferably
  - MGDGs and NAPEs
  - DGDGs
  - TAGs and PCs
  - Lysolipids
  - Release saturated rather than unsaturated FFAs

Conclusions

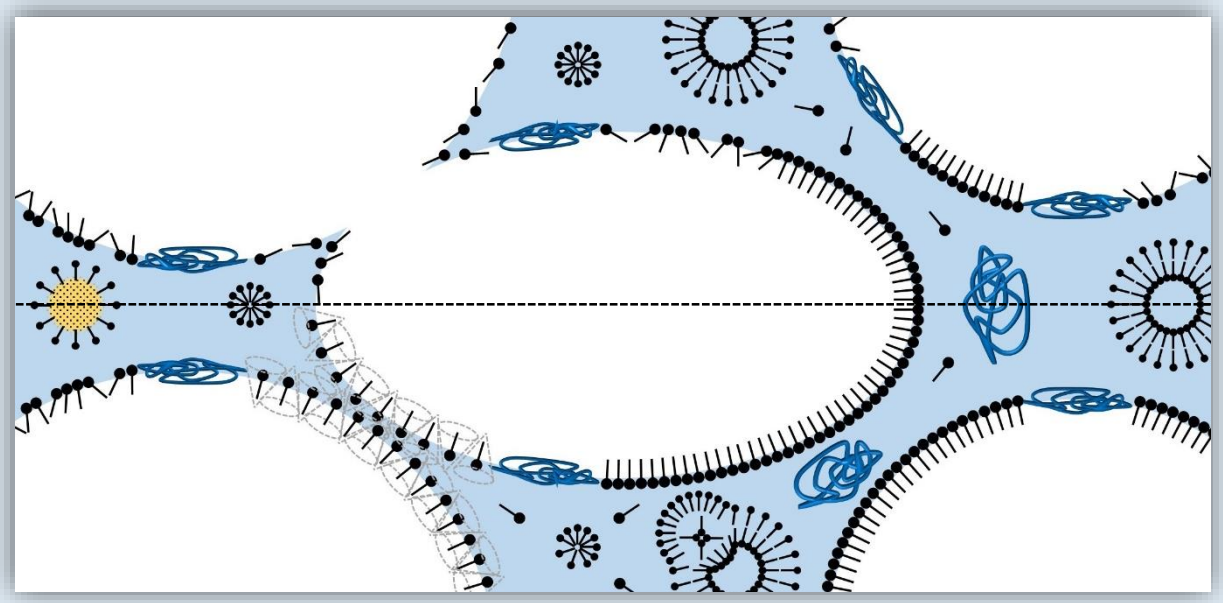
Wheat endogenous lipids and their enzymatically released hydrolysis products greatly impact bread loaf volume

- Appropriate balance between different types of lipids is crucial in bread making
  - Beneficial effects of enzymatically converting endogenous lipids into their corresponding lysolipids
  - Unavoidable release of detrimental FFAs

Findings aid in the development of new lipases and wheat varieties for bread making applications

Conclusions

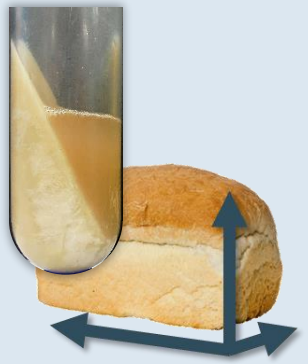
A mechanism whereby wheat endogenous lipids and their enzymatically released hydrolysis products affect bread loaf volume was proposed



- Completely relies on the ability of lipids to **directly** stabilize gas cells

Conclusions

A mechanism whereby wheat endogenous lipids and their enzymatically released hydrolysis products affect bread loaf volume was proposed

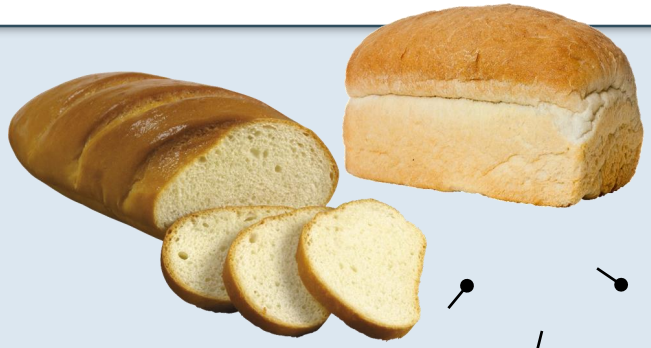


- Validity could not be proven
  - No relation between lipase-induced changes in…
    - Dough liquor composition and interfacial properties
    - Bread loaf volume
  - Lipases no positive impact on interfacial gas cell stability?
  - Dough liquor not an appropriate model system for gas cell interfaces?
- An **indirect** impact of lipids on the stability of gas cells in dough was demonstrated

Conclusions

Altogether, we suspect that the impact of wheat endogenous lipids and their enzymatically released hydrolysis products on bread loaf volume results from both their ***indirect*** *and* ***direct*** *effect on gas cell stability*

Findings contribute to the development of a unified theory on the role of wheat endogenous lipids (and their enzymatically released hydrolysis products) in bread making



The role of wheat endogenous lipids and their enzymatically released hydrolysis products in bread making

Sara MELIS and Jan A. DELCOUR

ICBC 2021 | 30 March 2021 | Online event

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