Bubble structure formation in bread and cakes

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Bread and cake structure

• Bubbles are a key aspect of the product structure.
• Important for:
  – Product volume (~75-80% air)
  – Softness
  – Whiteness (diffuse scattering)
• Recipe, ingredient and process variations can be used to achieve a wide range of structures for different product styles.
Bread structure

- Expanded foam structure
- Bubble nuclei created in mixer
- Expanded by gas production in proof and baking
- Converted to set sponge structure during baking
Factors affecting structure formation

- Bubble nuclei
  - Mixing

- Gas production
  - Proof

- Gas retention
  - Proof and baking
Gas volume measurement

- Calculated from dough density
- Buoyancy method
- Dynamic measurement for doughs proved in warm oil.
Gas volume production

- Differences in initial gas entrainment in mixer

![Graph showing gas volume production with different yeast concentrations and mixer pressures.](image)
Effect of mixer headspace pressure

- Lower final pressure gives less gas entrained in dough.
- This results in finer bread structure.
Measurement of bubbles in dough

- Samples frozen in liquid nitrogen
- Microscopy
  - Imaging of cross-sections
- X-ray micro CT
  - Non-destructive 3D imaging
Effect of mixer pressure

0.5 bar

1.5 bar

Bubbles in freshly mixed dough
Bubble size distribution - effect of pressure

- Similar range of sizes
- More bubbles for higher final mixer pressure.

Mixed dough

Number of bubbles / mm$^3$/log$_{10}$(bin width)

Bubble diameter (mm)
Measurement of bubbles in bread

C-Cell bread imaging system
– Image analysis of bread slices

X-ray micro CT

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Bubble size distribution - effect of pressure

- Many bubbles lost during processing
- More bubble nuclei \Rightarrow\text{coarser bread}

Mixed dough

Bread

(N.B. different y scale)
Mechanisms of bubble loss

• Damage
  – e.g. during moulding

• Ostwald ripening
  – Large bubbles grow preferentially

• Coalescence
  – Bubbles merge due to rupture of walls between them
Why do more bubble nuclei give coarser structure?

More bubble nuclei:
- Thinner walls
- Greater likelihood of coalescence
- Stable expansion
- Coarser eventual structure

Fewer bubble nuclei:
- Thicker walls
- Uniform structure

Hypothesis

Same gas volume

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Bubble structure during proof and baking

- X-ray CT scanning
- Oven placed inside scanner
Structure development during bread production

- Gas retention important
- Determined by flour quality and dough development

Breadmaking flour  Non-breadmaking flour
Effect of lipid ingredients

Control  DATEM  Lipase

Spiral mix

Tweedy
Effect of lipid ingredients

- Effects of Datem and lipase apparent during baking.
- They help stabilise bubbles at this stage.

Spiral mix

Tweedy

Control  DATEM  Lipase
Dough moulding
Dough moulding: sheeting
Dough moulding: curling

- Elongated bubbles
- Air trapped between layers of dough sheet
- Rows of bubbles within dough sheet
Single piece moulding effects

start of proof  |  end of proof  |  bread
Single piece moulding effects

Start of proof  End of proof  Bread
Four-piece moulding
Cell elongation in a 4-piece loaf

- C-Cell measurements
- Varies with slice position
Radical bread process

Campden BRI patented process
• Combine ingredients to an underdeveloped dough
• Dough lamination
• Cutting and orientation of dough pieces in pan
• Proof, baking and cooling

Benefits
• Finer structure
• Increased softness
• Increased volume

CBP control
C-Cell contrast:
0.7895 ± 0.005
153 ± 24 g
4.21 ± 0.07 ml/g

Radical process
0.832 ± 0.008
116 ± 18 g
4.36 ± 0.08 ml/g
Cake structure during baking
High ratio yellow cake

- Oven temperature = 180°C
- Baking time = 47 minutes
Temperature

Measured with thermocouples 20mm from the imaged plane

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<thead>
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<th>Temperature /°C</th>
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Start
• Cold, dense batter
0-20 minutes
• Convection
25-35 minutes
• Temperature gradient
• Low density zone moves upwards
40-45 minutes
• Contraction
45 minutes
• End of baking

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Pressure in a high ratio cake

- Foam to sponge conversion occurs as the temperature reaches ~95°C, which is the starch gelatinisation temperature in this system.
Sponge • 190°C • 20 minutes
Muffins

- 180°C
- 24 minutes
Model for formation of tunnel holes

Muffin

• Bubbles are large enough to span a steep viscosity gradient.
• High viscosity at one end of the bubble prevents migration.
• Low viscosity at the other end facilitates growth,
• This results in tunnel holes.
• Hypothesis: Tunnel holes form if the rate of bubble growth is similar to the speed of a setting front.
Fruit cakes

- Control
- Increased water
- Increased water, no tartaric acid

Fruit sinking
Conclusions

• Methods such as X-ray tomography enable us to study the mechanisms of structure formation in bread and cakes.

• Bread:
  – The number of bubble nuclei formed in mixing is critical;
  – Gas retention during proof and baking depends on flour quality and dough development;
  – Ingredients such as Datem and Lipase have their effect during baking.

• Cakes:
  – The structure depends on the balance between the rates of bubble growth and setting. Tunnel holes occur when the rates are similar.