X-ray computerised tomography investigation of bread dough: Changes in the structure and cell volume distribution during proving

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Aim

To investigate the change in dough cellular structure during proving.

Introduction

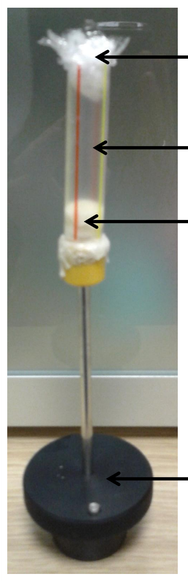
Air cells are a key ingredient in bread, making up to 80% of the volume. They play an important role in its texture and other quality attributes. The cellular structure of bread is largely formed during proving. During proving, carbon dioxide from yeast metabolism diffuses into the gas cells entrained during mixing, making them expand, rupture and interact with each other, and overall resulting in an increase in dough volume.

Due to the fragile and opaque nature of bread dough, only a handful of studies have been conducted on monitoring the dynamic cellular changes. This study investigates the change in dough cellular structure during proving using fast x-ray computerised tomography. Analysis of changes in cell shape, cell volume distribution, voidage distribution and dough volume were conducted.

Method

Dough was made in a kitchen planetary mixer

Ingredient	Quantity (±0.01g)
Wheat flour, 15% protein	200
Salt	3.6
Water, 38°C	133
Quick yeast	2
Sugar	6



Nikon XTek 225/320 kV CT housed in a customised bay

Dough sample rotated over 360º for 100s, collecting 400 projections per scan, with a voxel size of 10.2µm.

The experiment took place over 145 minutes with a new scan being acquired every 5 minutes.

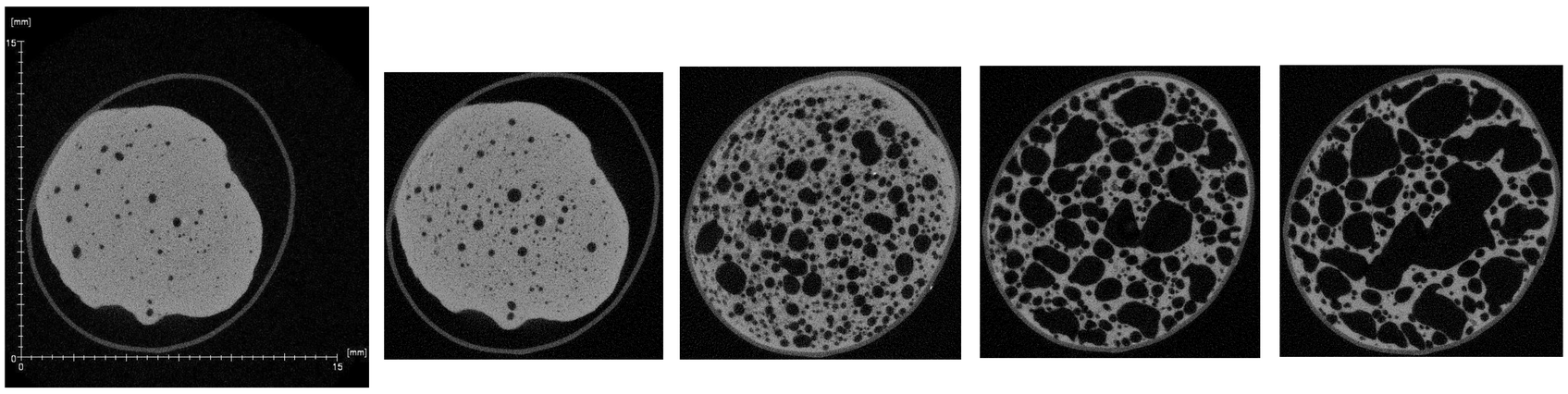
Data sets were reconstructed using a Nikon Metris CT Pro 3D (Metris XT 2.2, version 2.2.4365.28608).

Reconstructed data sets were processed and analysed in Avizo Fire 7.1 (Visualization Sciences Group, Bordeaux, France).

Further analysis of cell volume, voidage and Feret shape distribution were conducted to find relationships between the parameters.

Results and discussion

0 minutes | 20 minutes | 70 minutes | 110 minutes | 145 minutes



Cell Feret shape: 1.6
Mean cell volume: $1.21 \times 10^6 \mu m^3$
Cell number density: 19900 cells/cm^3

Cell Feret shape: 1.8
Mean cell volume: $2.87 \times 10^7 \mu m^3$
Cell number density: 13900 cells/cm^3

Cell Feret shape: 1.9
Mean cell volume: $1.89 \times 10^8 \mu m^3$
Cell number density: 3480 cells/cm^3

Increase in Feret shape and mean cell volume, decrease in cell number density

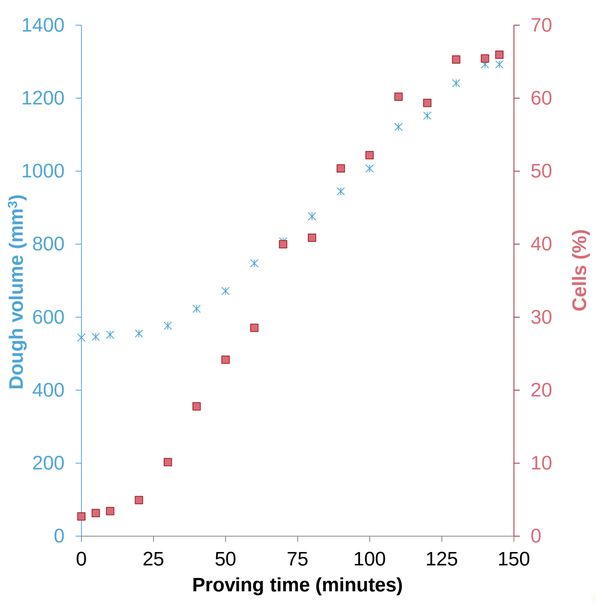
Dough orthoslices at different proving times

What is Feret shape?

Feret shape measures the deviation of a shape from a sphere.

A sphere has a Feret shape of 1

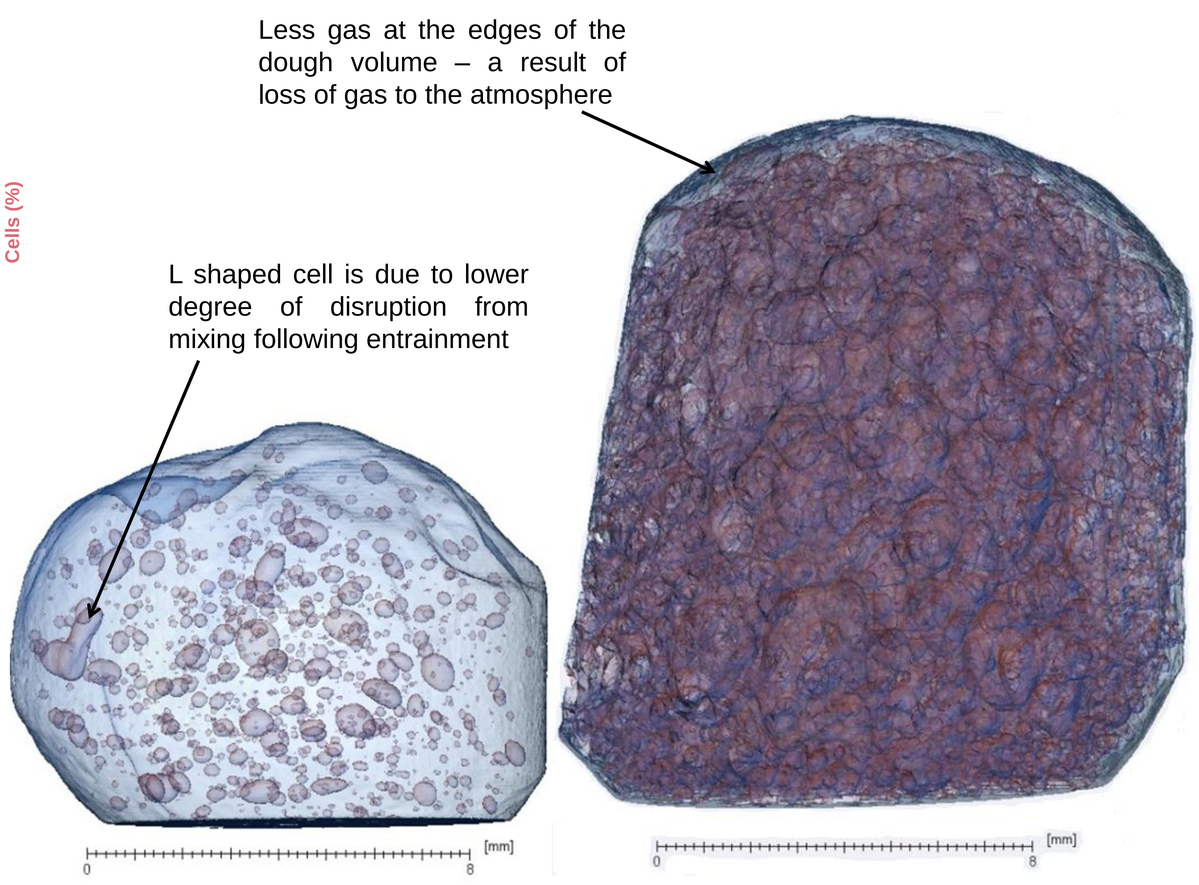
Feret shape is defined as:
1/minimum Feret diameter divided into the maximum diameter at 90º



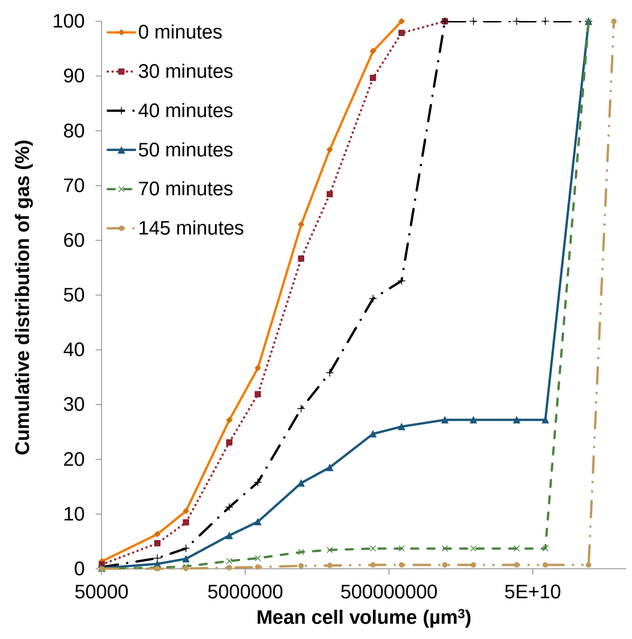
Dough volume and proportion of cells present during proving

A 250% increase in dough volume was observed during proving.

The rate of volume increase was slow in the first 20 minutes, but quickened as time progressed and the proportion of cells making up the dough increased from 3% to 66%.



Dough volume and its composition at 0 and 145 minutes during proving. The crumb is labelled in blue and the cells in red.



Cumulative distribution of gas for groups of different mean cell volumes at different proving times

A change in the gas distribution during proving occurred.

At the start of the proving, gas was distributed over a range of cell volumes.

As proving time increased, the tendency for gas to be located in larger cell volumes increased.

Conclusions

- As dough proving progressed, gas cells became less spherical, grew in size and decreased in number.
- The dough volume increased 250% over proving, a result of the increase in the proportion of gas in the dough.
- Over proving the gas distribution in cells shifted from a range of cell volumes initially to larger cell volumes at the end of proving.

Acknowledgements

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