PARAMETER EXPLANATION

There are 48 parameters originally determined by C-Cell monochrome.

These same measurements are made on the colour C-Cell along with additional colour related features.

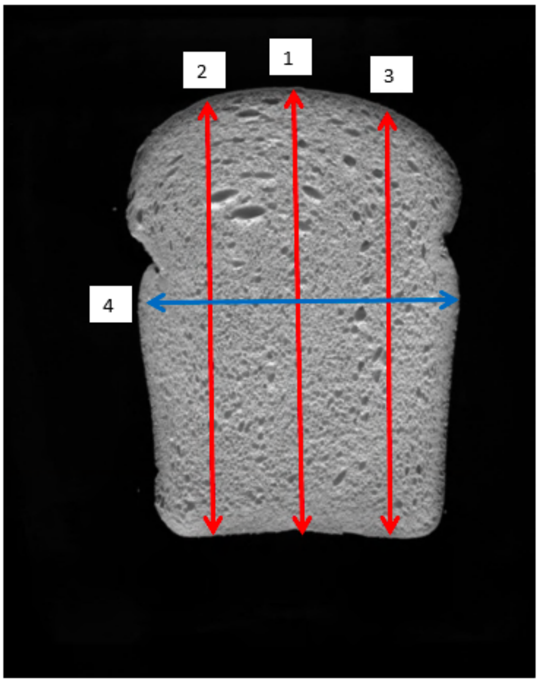
*NOTE: Measurements only applicable to colour instrument marked with **

SLICE DIMENSIONS

External dimensions have an important role in defining product perception. When purchasing a baked product, we look for the characteristic indicators specific to the type of bread such as size and shape to indicate product quality, crumb structure and taste assessments take place after the purchase.

Slice dimensions can also be a useful indicator of problems within the baking process such as:

1. Poor quality flour (low level or quality of protein)
2. High ash content
3. Inadequate mixing
4. Reduced yeast activity
5. Reduced elasticity of dough
6. Poor gas retention
7. Inadequate proof



1 = Height Max

1+2+3/3 = Height Av

4 = Width

Measurement	Descriptor	Units	Potential applications
Slice area	Total area of a product slice.	mm	Smaller areas indicate smaller products and will be linked with lower volume. Using several individual slice areas for a given product it is possible to provide an estimate of product volume though not with the accuracy that can be achieved by other means (e.g., seed displacement), see Volume measurement. You can normalise cell data by dividing slice area to remove volume effects, see Additional measurements.
Height (max)	The height of a product slice from its base to its highest point.	mm	Linked with product volume. Lower height indicates smaller pan bread products or flow in free-standing breads.
Height (avg)	The average height from product slice to 3 points of the top edge.	mm	Linked with product volume. Lower height indicates smaller pan bread products or flow in free-standing breads. An appropriate choice for lidded products when assessing uniformity of product height and shape.
Breadth	The distance from the left-most to the right-most point of the product.	mm	Helpful when assessing product uniformity in pan breads or flow with free-standing breads.
Height/breadth	Ratio of maximum product height to breadth.	Dimensionless	A lower height to breadth ratio will be linked with smaller volume pan products or flow with free-standing breads.
Wrapper length	A representation of the length of a tightly fitting bag or wrapper around the product.	mm	Perimeter length

Colour & Brightness

Colour *(Measured using top lit image)*

L*a*b* colour space is a commonly used scale found in the food industry to describe a products colour in three dimensions.

L* measures the brightness of a sample. (Darkest black = 0   Brightest white = 100

a* measures the change from red to green. (Negative a* values indicate red component and positive a* values indicate green component)

b* measures the change from yellow to blue (negative b* values indicate blue component and positive b* indicate the yellow component)

Measurement	Descriptor	Units	Potential applications
Crust colour	Individual sides Overall average L*a*b* colour of the crust	L*a*b*	Degree of surface cook
Crust thickness	Individual sides Overall average	mm	Oven temperature / residence time along with formulation will impact of crust colour.

Slice Brightness and contrast *(Measured using side lit image)*

These measurements are now replaced with L*a*b* in the colour system but still provide a useful measurement representing how crumb structure influences slice brightness. The Monochrome palette uses 256 shades of grey to define the range black (0) to white (256) and correlates with L* values when looking at full colour L*a*b* measurements.

Slice brightness measurement is the average grey level of all of the pixels within the image. Cell walls have higher values and the cells have lower values depending on the level of shadow created within cell, which relates to its volume.

Brightness values are influenced by 2 major factors:

1. Bran content

2. Crumb structure

Cell Contrast is the ratio: (mean cell brightness) / (mean wall brightness)

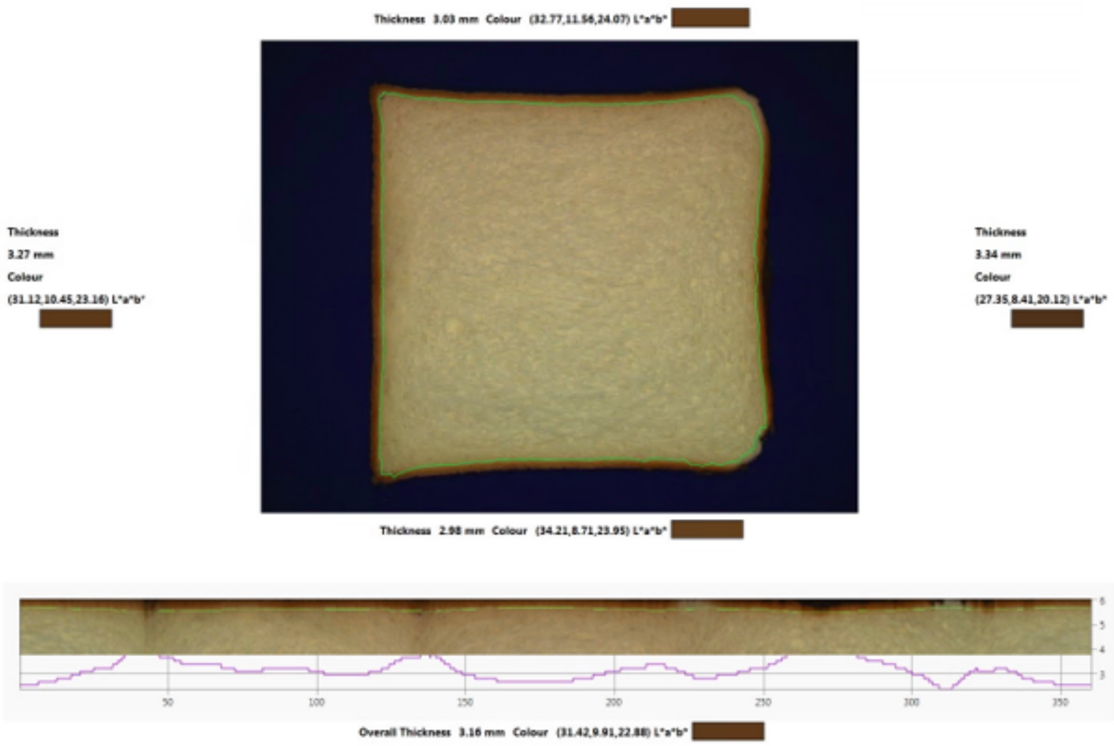
Higher values indicate shallower cells and hence smaller differences between cell walls and shallow cells

Measurement	Descriptor	Units	Potential applications
Brightness	An indication of light reflectance by a product slice.	Mean grey level of pixels	The value will be lower for products with a darker crumb (e.g., wholemeal compared with white bread) and for products with larger diameter or deeper cells. High correlation with L* Influenced by bran content and crumb structure
Cell contrast	Ratio of the mean brightness of the cells to the mean brightness of the cell walls.	Dimensionless	Higher values indicate shallower, less contrasting cells in the crumb.

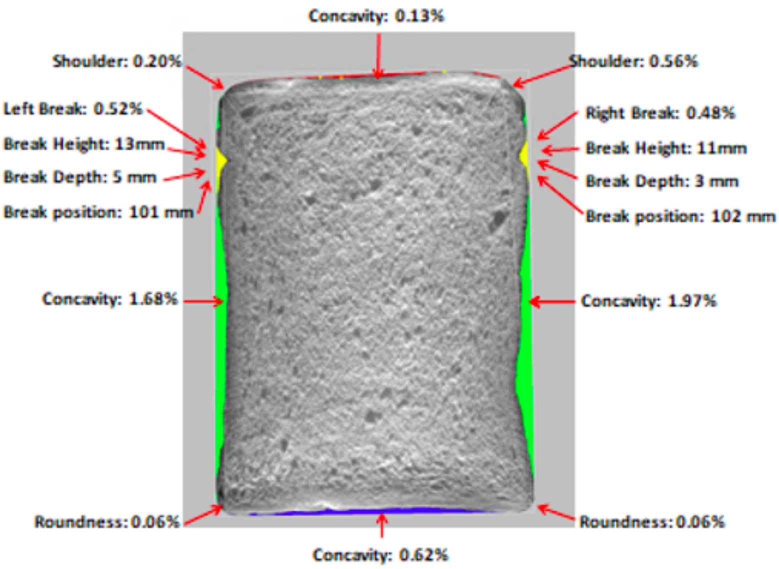
Crust unwrap *(Measured using top lit crust unwrap image)*

Crust unwrap is an algorithm that quantifies the colour and thickness of the crust. The border between crust and crumb are identified based on L*a*b* single pixel analysis and once this has been established the crust is “unwrapped and presented on a 2 dimensional display. Data from individual faces of the slice and an average combined figure are recorded.

Measurement	Descriptor	Units	Potential application
Colour (crumb)	L*a*b* colour of the slice		L= Lightness Range 0 – 100 (0 = Black 100 = White) a*= value between Red (positive values) and Green (negative values) b*= value between Yellow (positive values) and Blue (negative values)



Shape



Many of today's breads are characterised by their size and shape, and these qualities are strongly influenced by the properties of the flour, or more precisely its gluten properties.

The Glutenin/Gliadin composition provides the dough with a unique combination of elasticity and extensibility, and this determines dough functionality which can be seen in parameters such as side wall concavity, oven spring and roundness of bottom corners within tinned bread.

Side wall concavity may be caused by:

1. Under scaling forces the dough to cover a larger volume than it is capable off.

2. Overmixing of the dough causing weakening and hence poorer gas retention.

3. Low levels of protein in the flour (or poor protein quality)

Oven spring issues can be related to:

1. Incorrect dough mixing

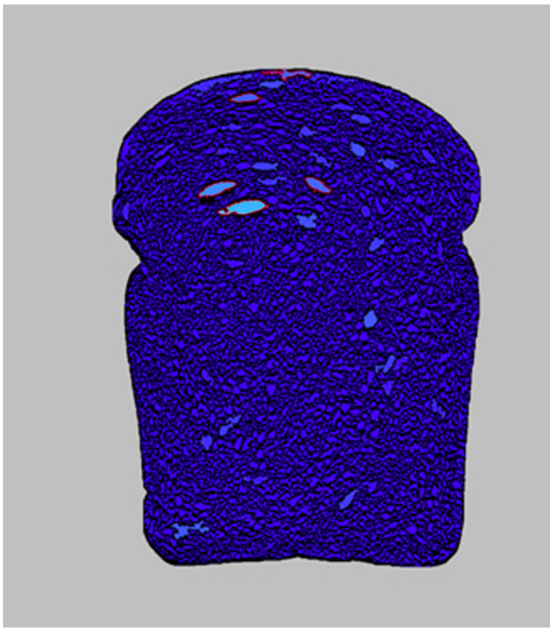
2. Incorrect water addition - dough too soft/stiff

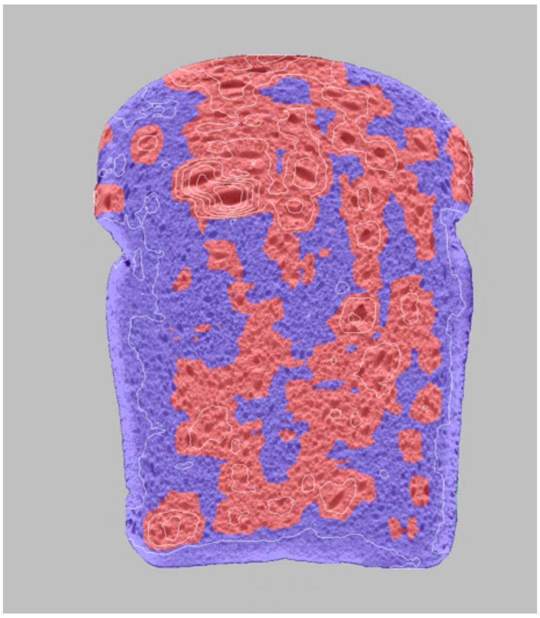
Measurement	Descriptor	Units	Potential applications
Total concavity	Total concavity associated with the product side walls, base and top.	Pixels	Useful with pan products, especially lidded pan breads.
Top concavity	The area of concavity associated with the top of the product.	Pixels	Linked with product volume. Greater concavity indicates greater downward collapse of the top of a product. Useful with pan products and can be linked with ingredient, recipe and process factors which affect product shape. In the case of a split top product will indicate the depth of the top split. May be used to assess the degree of collapse with cakes and similar products.
Left concavity	The area of concavity associated with the left-hand side of the product.	Pixels	Greater left concavity indicates a greater deviation of the left-hand side of the product from a straight line running from its bottom left to its top left corners. Useful with pan products and can be linked with ingredient, recipe and process factors which affect product shape.
Right concavity	The area of concavity associated with the right-hand side of the product.	Pixels	Greater right concavity indicates a greater deviation of the right-hand side of the product from a straight line running from its bottom right to it top right corners. Useful with pan products and can be linked with ingredient, recipe and process factors which affect shape.
Bottom concavity	The area of concavity associated with the bottom product.	Pixels	Greater concavity indicates greater deviation of the bottom of the product from a straight line running from left to right bottom corners of the product. Useful with pan products and can be linked with ingredient, recipe and process factors which affect shape.

Left break	The left break area as a percentage of the slice area. Included within Left concavity measurement.	%	Associated with oven spring in bread and fermented products.
Right break	The right break region as a percentage of the slice area. Included within the right concavity measurement	%	Associated with oven spring in bread and fermented products.
Left break height	The vertical extent of the left break.	mm	Associated with oven spring in bread and fermented products.
Right break height	The vertical extent of the right break.	mm	Associated with oven spring in bread and fermented products.
Left break depth	The horizontal extent of the left break.	mm	Associated with oven spring in bread and fermented products.
Right break depth	The horizontal extent of the right break.	mm	Associated with oven spring in bread and fermented products.

Top left shoulder	The roundness of the top left corner of the product.	mm^2	Useful with lidded breads and rectangular cross-sectioned products. Indicates the degree to which the top left corner deviates from a right angle. Higher values indicate greater deviation from a right angle.
Top right shoulder	The roundness of the top right corner of the product.	mm^2	Useful with lidded breads and rectangular cross-sectioned products. Indicates the degree to which the top right corner deviates from a right angle. Higher values indicate greater deviation from a right angle.
Bottom left roundness	The roundness of the bottom left corner of the product	mm^2	Useful with pan breads and rectangular cross-sectioned products. Indicates the degree to which the bottom left corner deviates from a right angle. Higher values indicate greater deviation from a right angle.
Bottom right roundness	The roundness of the bottom right corner of the product	mm^2	Useful with pan breads and rectangular cross-sectioned products. Indicates the degree to which the bottom right corner deviates from a right angle. Higher values indicate greater deviation from a right angle.

Cell Information





The Cell Image indicates how cells and cell walls are segmented based on their greyscale shade. The lighter cell walls are colour coded black and the cells are blue. The smallest cell identified have the darkest blue colouration (smallest cell measurable with C-Cell = 0.14mm diameter).

As the cells get larger their shading gets lighter. Cells highlighted with a red border or shaded in yellow indicate possible holes.

A hole is identified by comparing its size to the distribution of cell sizes for that specific sample being tested, By using this approach we can analyse very fine crumb structure as well as more open structured product without any setting changes being required.

The Volume map image depicts the distribution of cell volumes above or below the mean value. The 50% of cells with volumes above the mean value are colour coded red and the remaining 50% of cells with smaller volumes are colour coded blue. The Volume map is translated into a value in the Coarse/Fine Clustering parameter, high values represent clustering of coarse structure and low values indicate a more even distribution of coarse and fine cells. The volume map image is independent of average cell size – red and blue areas are always subdivided equally.

The number, size and shape of cells represent the combined effect of an industrial process using a variable raw material with the end goal being a well-defined characteristic crumb structure.

Although size and shape characterise the external appearance of bread, it is the crumb structure that provide the mechanical structure and mouthfeel that we recognise in its eating properties.

1. Number of cells will range from “hundreds” in open structures such a baguette or laminated products up to tens of thousands in Japanese tinned breads.

2. Average cell diameters will range from 1mm 20mm and above.

3. Cell shape is manipulated is some types of bread by sheeting the dough into a sheet, prior to rolling up and placing in the tin, this causes the cells to elongate along a similar axis.

4. “Holes” are cells with volume larger than typical of the slice**.**

Measurement	Descriptor	Units	Potential applications
Number of cells	The number of discrete cells detected within the slice. The cells are shown in the Cell image.		For a given product slice higher numbers are associated with finer cell structure.
Number of holes	The number of holes in the slice. The result may not be an integer and may not correspond exactly to the number of holes highlighted in the Cell image but will normally be like it.		An indicator of features not considered to be part of a given product slice cell structure. Higher numbers indicate a greater number of holes. Such holes may be associated with other undesirable features in the product slice.
Area of cells	The total area of cells as a percentage of the slice area.	%	Larger values indicate a more open cell structure in the product.
Area of holes	The area of holes as a percentage of the slice area.	%	Larger values may be associated with greater numbers of or larger sizes of holes.

Cell diameter	The average diameter of the cells identified in the slice.	mm	An indicator of the coarseness of the product cell structure. Higher values indicate coarser, more open cell structures.
Cell volume	A of the average volume of cells. The volume for which half of the total area of cells is represented by cells of smaller volume and half by cells of larger volume.	mm^3	An indicator of the coarseness of product cell structure.
Coarse cell volume	A measure of the volume of the coarser cells and holes within the slice. It is the volume for which three quarters of the total area of cells is represented by cells of small volume and one quarter by cells of larger volume.	mm^3	An indicator of the coarseness of the cell structure. Higher values indicate a cell structure with greater numbers and larger sizes of coarse cells and holes.

Total volume of holes	The combined volume of all the holes in the slice.	mm^2	Higher values are associated with larger numbers or larger sizes of holes.
Cell volume range	A measure of the variation in cell volumes within the slice. Represented in the Volume Contours image and expressed on the volume map scale.	mm^2	Higher values are associated with greater variability in the slice cell structure
Cell volume (map)	The volume at the threshold between red and blue shaded regions of the Volume Contours image. Cell Volume (map) = 1 + 3.5 * Cell volume	mm^2	Higher values are associated with greater numbers of holes and coarser, more open cell structure.
Relative Vol Range	The ratio of Cell Vol Range (map) to Cell Volume (map).	Dimension-less	Associated with the degree variation in cell volumes. Higher values indicate greater variation.

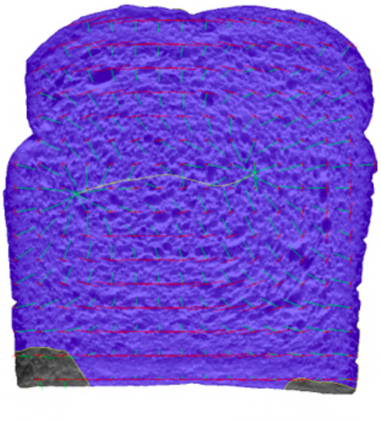
Coarse/Fine Clustering	A measure of the extent to which fine and coarse regions of the slice (as indicated in blue and red in the Volume Contours image) are strongly segregated.	Dimensionless	Most commonly associated with large areas of coarse or fine cell structure. Lower values indicate intermingled fine and coarse texture. Values can range from 0 to 1, with a value of 1 signifying a perfectly circular region of coarse or fine texture.
Wall thickness	The average thickness of cell walls (pixels).	mm	Higher values indicate thicker cell walls. In bread, associated with changes in dough development, oxidation, and dough processing.
Non-Uniformity	A measure of the lack of uniformity between fine and coarse texture (including holes) across the slice.	Dimensionless	High values indicate less uniformity of cell structure. The value is useful for comparing slices of similar types of products, but comparisons between products of differing type tend to be less easily interpreted.

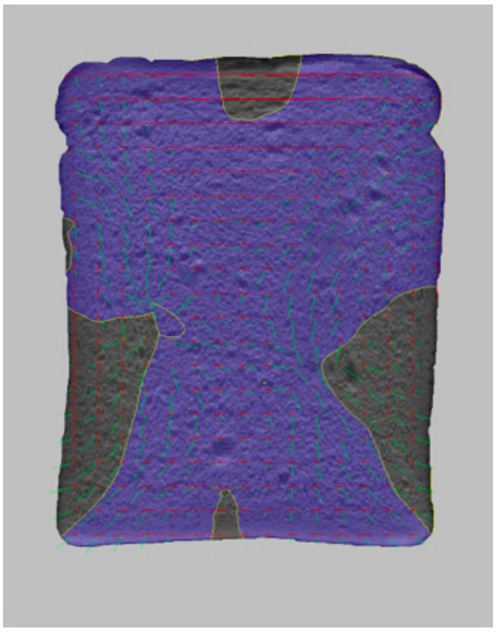
CELL ELONGATION

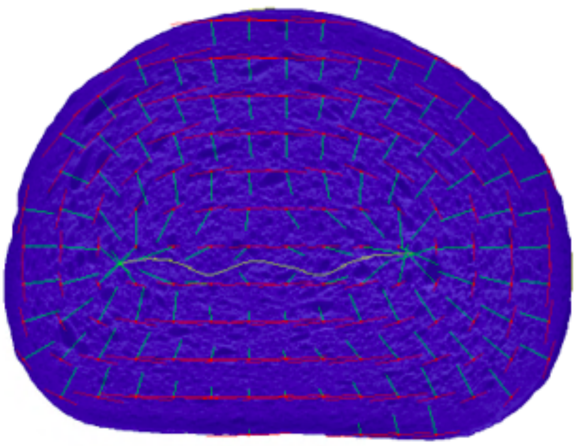
The random distribution of air cells produced in a fresh dough are a potential problem to the baker who is trying to produce a fine uniform crumb structured product. By introducing a moulding/ sheeting / rolling step the baker can mechanically manipulate the irregular cell distribution into a regular pattern of aligned cells. This in turn will create a far more reproducible dough resulting in higher yields

The special distribution for each cell is calculated and presented in the cell elongation image and Elongation table

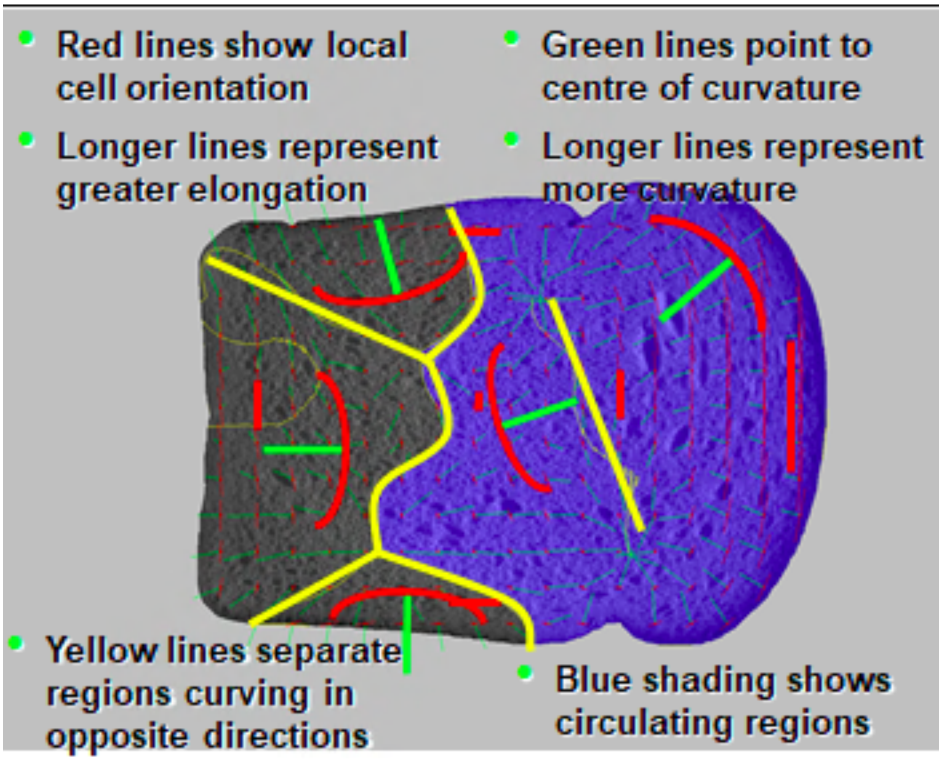
Examples of different cell elongation patterns







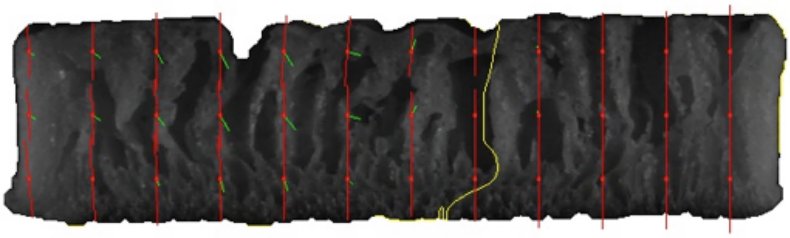
Explanation of differentiation lines within elongation image



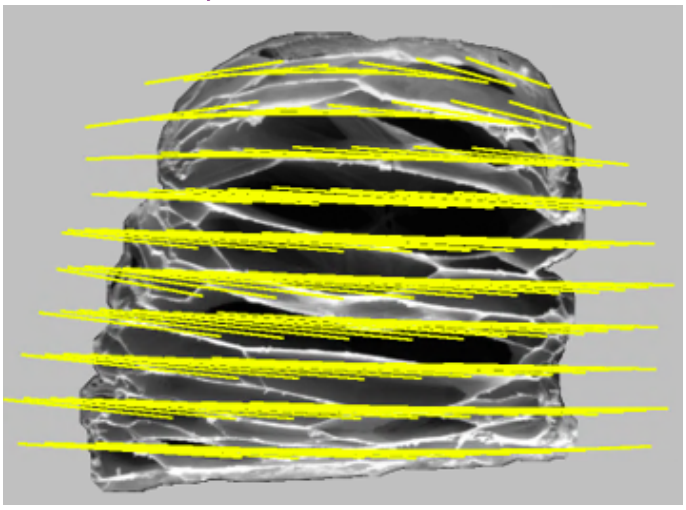
1. Red lines show local cell orientation
2. Longer lines represent greater elongation
3. Green lines point to centre of curvature
4. Longer lines represent more curvature
5. Yellow lines separate regions curving in opposite directions
6. Blue shading shows circulating regions

Examples of other types of cell orientation

Crumpet



Puff Pastry



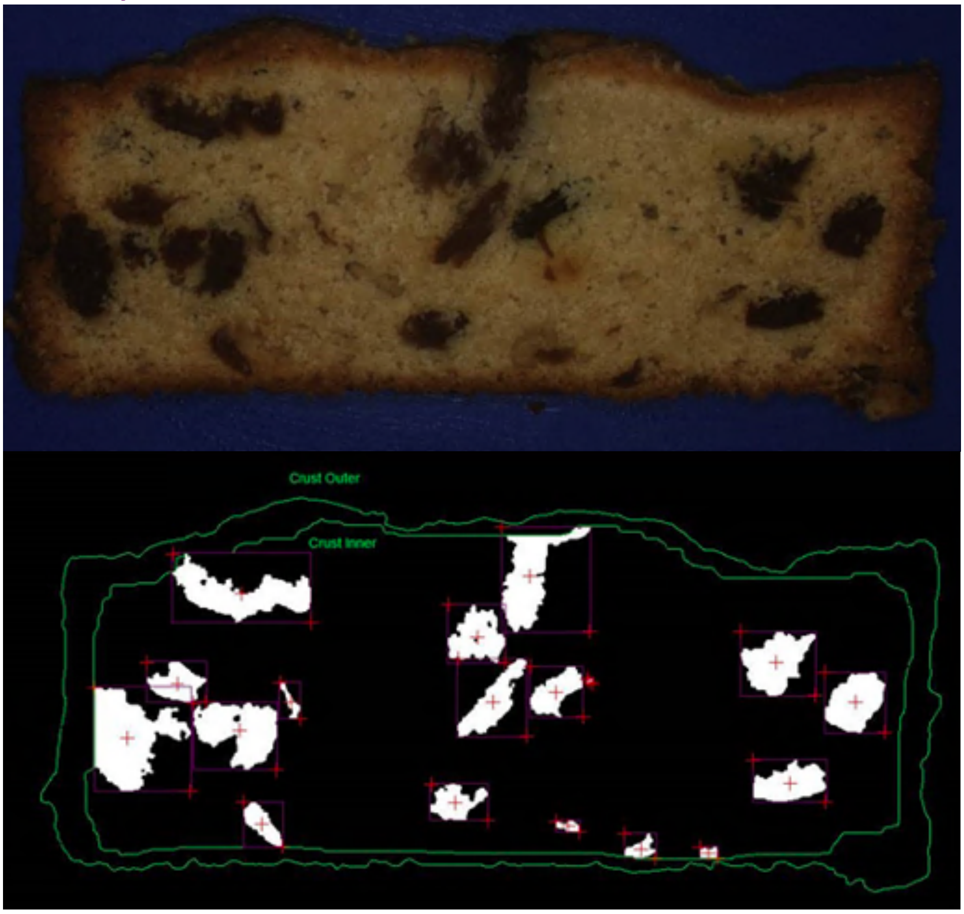
Cell Elongation & Orientation Explanation

Measurement	Descriptor	Units	Potential applications
Average cell elongation	The average length to breadth ratio of cells, independent of their relative orientation.	Dimensionless	Values close to 1 indicate rounded cells. Higher values indicate greater elongation.
Net cell elongation	The degree of overall elongation of the cell structure in a particular direction.	Dimensionless	Values close to 1 indicate no elongation or no preferred direction. Higher values indicate alignment of cells in a particular direction. The value will usually be lower than Average Cell Elongation because the contributions of cells with differing orientations tend to cancel out. Will be associated with the orientation of cells because of dough or batter processing.
Cell angle to vertical	The angle of the direction of Net Cell Elongation, measured clockwise from the slice vertical.	Degrees	Values are given in the range of –90 to +90 degrees. Values close to 0 represent a vertical orientation. Values close to ±90 represent a horizontal orientation. If the Net Cell Elongation is low, the orientation refers to a structure with little overall elongation and may be of limited significance.
Cell alignment	The extent to which cells are aligned in a parallel direction.	Dimensionless	Values range from 0 to 1. High values represent parallel alignment of cells in a single direction, commonly seen with laminated products. Lower values indicate greater variation in cell orientation. Strong alignment does not necessarily imply high cell elongation but is commonly associated with high values of Net Cell Elongation.
Vertical elongation	The degree of cell elongation parallel to the slice height.	Degrees	High positive values indicate strong elongation of cells in a vertical direction within the slice. High negative values indicate lesser cell elongation or alignment, or a structure aligned in a direction intermediate between the horizontal and vertical.

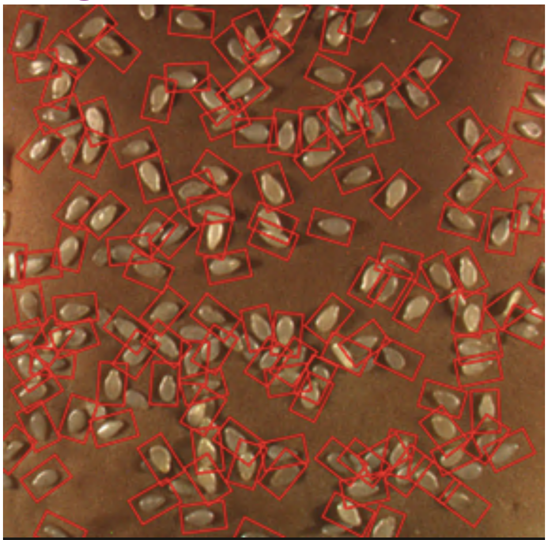
Inclusion / External Features

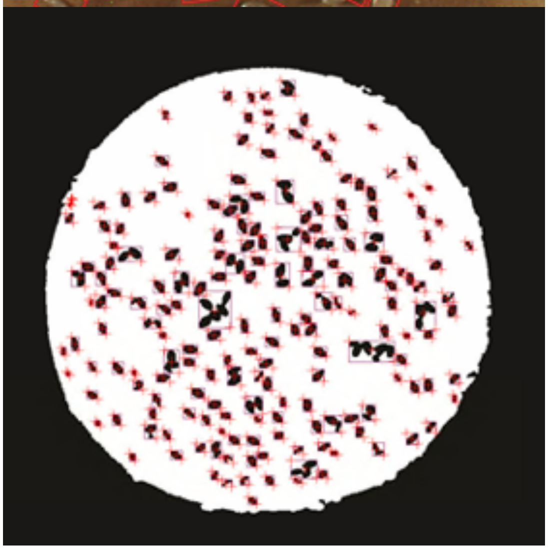
Measurement	Descriptor	Units	Potential application
Number of features	Quantification of number of inclusions or features		Monitor variation of features through the product
Area occupied	% Area occupied within total area of slice	%	Ability to check evenness of distribution throughout length of product
Average colour	Average colour of all inclusions	L*a*b*	Possible changes in product appearance or colour can be monitored
XY location	XY location related to pixel format		Problems like settling of fruit can be accurately quantified in relation to formulation
Uniformity of distribution	Evenness of distribution of feature within the slice	Dimensionless	Values close to 1 have even distribution of feature throughout the slice. Values closer to 0 indicate a none even distribution.

Cherry Cake



Burger Bun





Bread Score Application

Measurement	Descriptor	Units	Potential application
Single figure score	Customer defined scoring system	Customer dependant	Customer and product specific bespoke scoring system