Can mealiness be nipped in the bud?

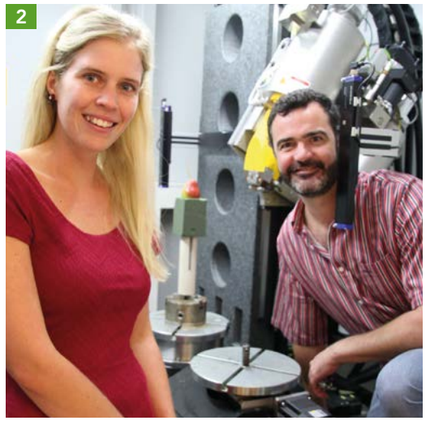
Where and how pears grow, and how they are harvested and stored, are all clues to the early detection, and even prevention, of a costly post-harvest disorder.

'FORELLE', A SMALLISH bi-colour pear with a distinctively sweet aroma and taste, is the second most produced pear in South Africa by volume. Popular as it is, the cultivar has one flaw. It is prone to mealiness, a condition that results in the fruit flesh becoming dry, soft and floury.

Previous research has revealed that mealiness is caused by the loss of cell-to-cell adhesion, and fruit that will become mealy has a higher porosity in the neck even before ripening. Researchers also agree that the condition has its roots in pre-harvest conditions, but they don't exactly know which conditions and hence cannot predict susceptibility.

At present, the industry deals with the problem by subjecting 'Forelle' pears to a mandatory 12-week cold-storage period to prevent mealiness from appearing, or by keeping the pears firm with SmartFresh™ (Forelle Early Market Access protocol).

1 Dr Elke Crouch, project leader.
2 Dr Letitia Schoeman and Dr Walter Fourie, both post-PhD researchers, applied their knowledge of X-ray micro and nano computed tomography to detect mealiness in 'Forelle' pears.



However, some markets do not like pears firm and sweet, but prefer them to be soft and juicy. It is, therefore, not difficult to understand how valuable it would be to have a way of predicting mealiness susceptibility in the packhouse, and to sort pears accordingly before they even start their journey to the consumer's table.

Dr Elke Crouch, a lecturer and researcher at the Department of Horticultural Sciences at Stellenbosch University, has been investigating the mealiness phenomenon for a number of years.

In a previous project, jointly financed by the Post-Harvest Innovation Programme and Hortgro Science, her research team established that mealiness was a condition that existed prior to ripening in some 'Forelle' pears. Importantly, they also found that its development was associated with larger-celled fruit and those with large air spaces around their cells, and that in 'Forelle', specifically, mealiness development seemed to be linked to a high total soluble sugar (TSS) content.

These were important findings, given that TSS in fruit can be determined accurately with non-destructive NIR spectroscopy methods, while X-ray computed tomography (CT) scanning can detect the air spaces in fruit. Unfortunately, the latter technology is not available to the fruit industry on a commercial basis yet.

Consequently, it is important to find supplementary ways to determine the post-harvest mealiness risk at harvest, and to reduce it as much as possible.

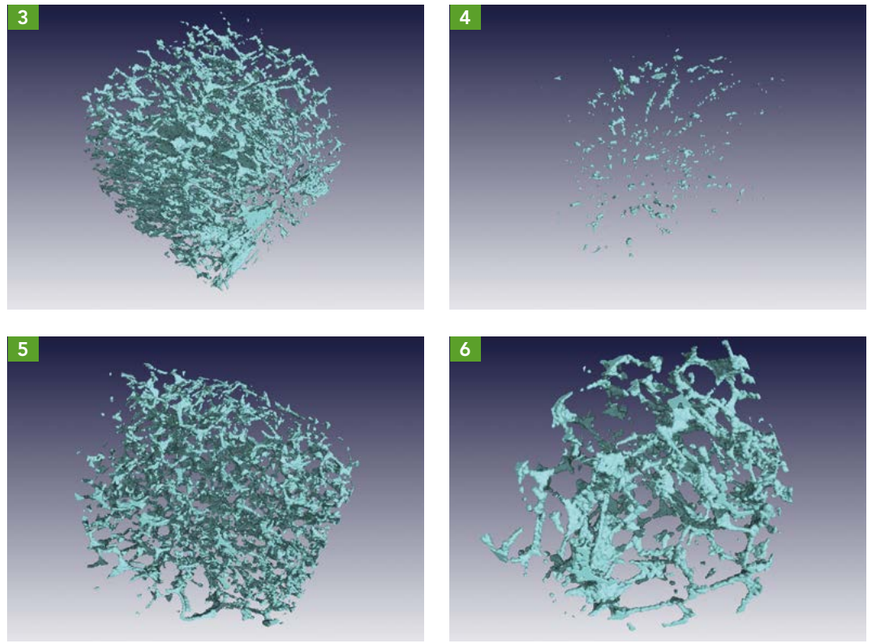
The project

With this objective in mind, Elke proposed a study that would investigate the link between mealiness and where in the canopy a pear grows and matures.

"We don't know why some fruit on a tree is predisposed to mealiness and others not, and neither do we know if fruit position influences ripening rate or tissue density," says Elke. "However, the fact that 'Forelle' seems to have rosier cheeks – in most cases indicating higher TSS concentrations – when they grow on the perimeter of the tree suggests a link between position and mealiness development."

In addition to position, pollination, type of flower in a cluster, number of fruit in a cluster, carbon assimilation due to sink strength, and ripening rate differences are factors that may affect fruit anatomy and physiology, and thus possibly mealiness susceptibility.

The link between TSS, a more intense blush and fruit position made colour an ideal focus for the new study that was designed to test predictors of mealiness. A successful outcome could lead to custom harvesting and storage protocols in order to reduce the risk of mealiness development, while also improving fruit quality after storage and ripening. The accuracy of current pre-sorters have to be tested in order to do this as pear pre-sorters are not commonly available.



Above: Three-dimensional images of the porosity distribution (illustrated in aqua blue) in the neck (**3**, **5**) and equator (**4**, **6**) regions of a pollinated (**3**, **4**) and non-pollinated (**5**, **6**) fruit. The fruit was scanned on the GE Nanotom at the Stellenbosch University Central Analytical Facilities.

Project objectives, methodology and findings

The project, once more financed by the Post-Harvest Innovation Programme and Hortgro Science, had four objectives that each required a specific methodology.

PROJECT TITLE
Post-harvest 'Forelle' mealiness development, detected at harvest by CT-X ray scanning and semi-commercial colour pre-sorting influenced by canopy position at harvest as well as pollination

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DURATION
One year and nine months

PHI PROGRAMME & INDUSTRY CONTRIBUTIONS
R852 408 & R262 408

LEAD INSTITUTIONS
Stellenbosch University (Department of Horticultural Sciences) and Hortgro Science

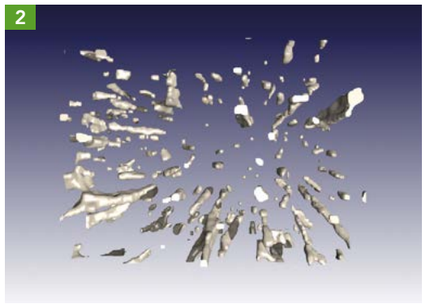
BENEFICIARY
The pome fruit industry

FOCUS AREAS
Post-harvest physiology

HUMAN CAPITAL DEVELOPMENT
One MSc student (Rudolph Cronjé), three post-doc researchers (Young Career Development) (Letitia Schoeman, Walter Fourie, Tavagwisa Muziri)

PUBLICATIONS
Pending

PRESENTATIONS
Three



Visualisation of the porosity in the neck region of a mealy (**1**) and non-mealy (**2**) 'Forelle' pear. The fruit was scanned on the GE Nanotom at a resolution of three micron. The scanner is located at the Stellenbosch University Central Analytical Facilities.

3 A mealy 'Forelle' pear does not release juice when squeezed or chewed. All mealiness determinations are done organoleptically by tasting, or visually by squeezing wedges of tissue and measuring juice weight.

OBJECTIVE 1: Map the fruit canopy positions in terms of fruit temperature, light interception, fruit tissue structure and porosity, fruit ripening potential and fruit mealiness development after ripening as well the relation to mealiness.

Trial 1: Fruit was tagged in five positions of 10 tree canopies with uniform height and shape in one row. Eight pears per tree position were marked and used to measure light irradiation with a quantum sensor attached to a light meter. Fruit surface temperature of the portion of the fruit facing the current position of the sun was measured by using a high performance infrared thermometer.

Light irradiation and fruit surface temperature were measured three times a week, approximately four times a day, on cloudless days between 07:00 and 18:00, from mid-January until early March 2016.

Canopy temperature and relative humidity were measured continuously from mid-January until early March 2016 by means of tiny tags.

A total of 400 tagged pears – 80 fruit from each fruit position – were harvested at optimum harvest maturity on 2 March 2016. Maturity indexing was conducted at harvest and again after eight weeks of cold-storage at -0,5°C, plus seven and 11 days of ripening at 20°C. Standard maturity parameters were measured, such as the fruit background colour, blush percentage, flesh firmness and TSS.

Micro-computed tomography was used to visualise fruit tissue density at harvest, after storage and after ripening. Nano-computed tomography was used to assess the quantitative porosity and cellular histology in the neck region of interest for fruit from different canopy positions.

Findings:

- Outer canopy fruit was more prone to mealiness, and was associated with the highest temperature and irradiance levels.
- Mealy fruit had more porous neck tissue compared to non-mealy fruit.
- Euler values indicating connectivity of pore space, cell size per volume and cell size did not differ significantly for fruit from different canopy positions.
- However, the consistent differences in Euler values indicating differences in porosity did suggest that inside and outside fruit may indeed be different.

Trial 2: To determine whether mealiness differences within the canopy are related to storage potential and ripening rate differences for fruit from different canopy positions.

Pears from the five positions were harvested at optimum and post-optimum maturity. They were evaluated for maturity and quality after storage (eight, 12 and 16 weeks at 0,5°C) and ripening (four, seven and 11 days at 20°C).

Findings:

- Canopy position seems to play a larger role in mealiness development than ripening potential of inside versus outside fruit.
- The outside fruit from the first harvest maturity did seem to exhibit differences in mealiness due to ripening and ethylene levels.
- Inside canopy fruit had higher levels of ethylene and not the highest level of mealiness.

OBJECTIVE 2: Determine whether pollination/seed count affects mealiness potential.

Two treatments were applied on the western and eastern side of ten randomly selected trees during September 2015.

For treatment one, flowers of five trees were emasculated and hand cross-pollinated with 'Early Bon Chretien' pollen. Treatment two consisted of emasculating flowers of the remaining five trees without receiving pollen.

A total of 1 800 flowers per treatment were used, and approximately 1 700 fruit were harvested at optimum maturity.

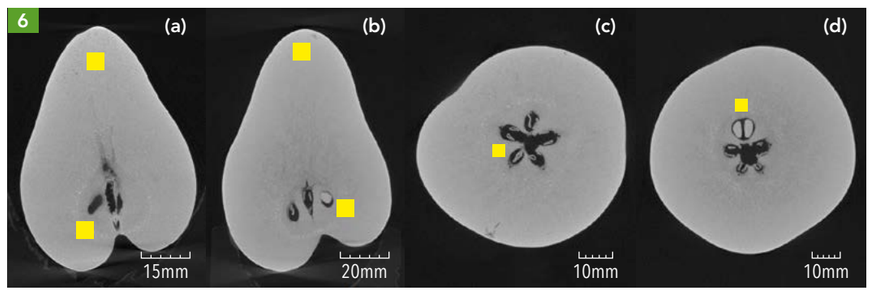
Maturity and quality indices were determined 12 hours after the fruit was taken out of cold-storage and left to reach room temperature, and again after seven days of ripening at 20°C. Maturity indexing at harvest and after eight weeks of storage at -0,5°C each consisted of 180 fruit from both sides of each tree. Double the amount of fruit was used after the seven-day ripening period, as the most mealiness was expected during this period.

X-ray micro-computed tomography (µCT) was used to visualise fruit tissue density. Nano-computed tomography was used for the quantitative porosity and cellular histology.

Findings:

- Pollinated fruit had a lower level of mealiness compared to emasculated fruit.
- There is a difference in tissue density between full viable seeds and parthenocarpic seeds (two types – longer or small type), with the region next to full seeds being denser.
- Pollinated fruit had a lower porosity than non-pollinated fruit in both the neck and equator regions, which may result in a lower incidence of mealiness (see Fig. 1 on page 95).
- The neck region (of both pollinated and non-pollinated fruit) had a higher porosity than the equator, which indicates different levels of mealiness in different regions in the fruit (see 6 below).

OBJECTIVE 3: Test the viability of commercial blush colour pre-sorters to determine mealiness susceptibility.



4&5 Rudolph Cronje, MSc student, studies the effect that the canopy position, light interception, fruit and canopy temperature, and pollination has on fruit quality, mealiness and ripening behaviour.

6 Illustration of the neck and region next to the seeds selected as region of interest (ROI) in a non-pollinated (**a**) and a pollinated fruit (**b**). The cross-sectional grey scale tomographic slice images also illustrate the ROIs next to the seeds in a non-pollinated (**c**) and pollinated pear (**d**). Differences in the grey level intensities indicate density variations (light grey = high density; darker grey = lower density), while black areas represent air voids.

1 'Forelle' fruit from emasculated flowers where anthers were removed and flowers not pollinated. The calyx end of the fruit is clearly affected.

'Forelle' pears were harvested from four different canopy positions in three orchards and sorted into four colour groups. The colour categories were related to mealiness development in ripened fruit in order to establish if colour can be used as a proxy for mealiness detection and, if so, how accurately a commercial colour pre-sorter can sort for mealiness before the condition develops.

Findings:

- Colour groups were related to mealiness development differences after ripening.
- The grading machine did not accurately detect the four colour groups. However, the machine's ability can be improved through modifications to the ramp, rolling action or camera configurations on packlines specifically used for pears.

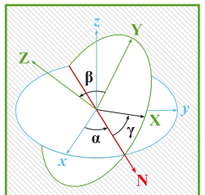
Conclusions

- Direct irradiance and higher temperatures make outside fruit possibly more susceptible to mealiness.
- Mealiness may not be directly linked to ripening. Ethylene levels of inside fruit are in many cases higher, yet they are never as mealy as outside fruit.
- Outside west-facing fruit consistently had the highest Euler number, smallest cell size and highest amount of cells/mm^3, while green inside fruit had the lowest Euler number, largest cells and lowest amount of cells/mm^3. This indicates that inside and outside fruit may indeed be different. However, a larger sample size may be required in order to statistically prove that fruit structure is different for different canopy positions.
- Pollinated fruit had a lower mealiness incidence, perhaps pointing to pollinated fruit having a better source of hormones during fruit set and development, which may influence porosity.
- CT scanning shows important histological differences between mealy and non-mealy fruit. The mealy fruit shows lower density regions in the neck, attributed to higher porosities.
- Blush colour is related to mealiness development after ripening, making it ideal for pre-sorting. Apple colour pre-sorters are, however, not suitable for bi-colour pear sorting. Pear pre-sorters that overcome this will be tested for classification accuracy.

These studies are to be repeated to confirm findings.

The most important preliminary recommendation is that for fruit harvested on the outside canopy, or fruit that is well blushed, the protocols that reduce mealiness incidence should be followed carefully. These are:

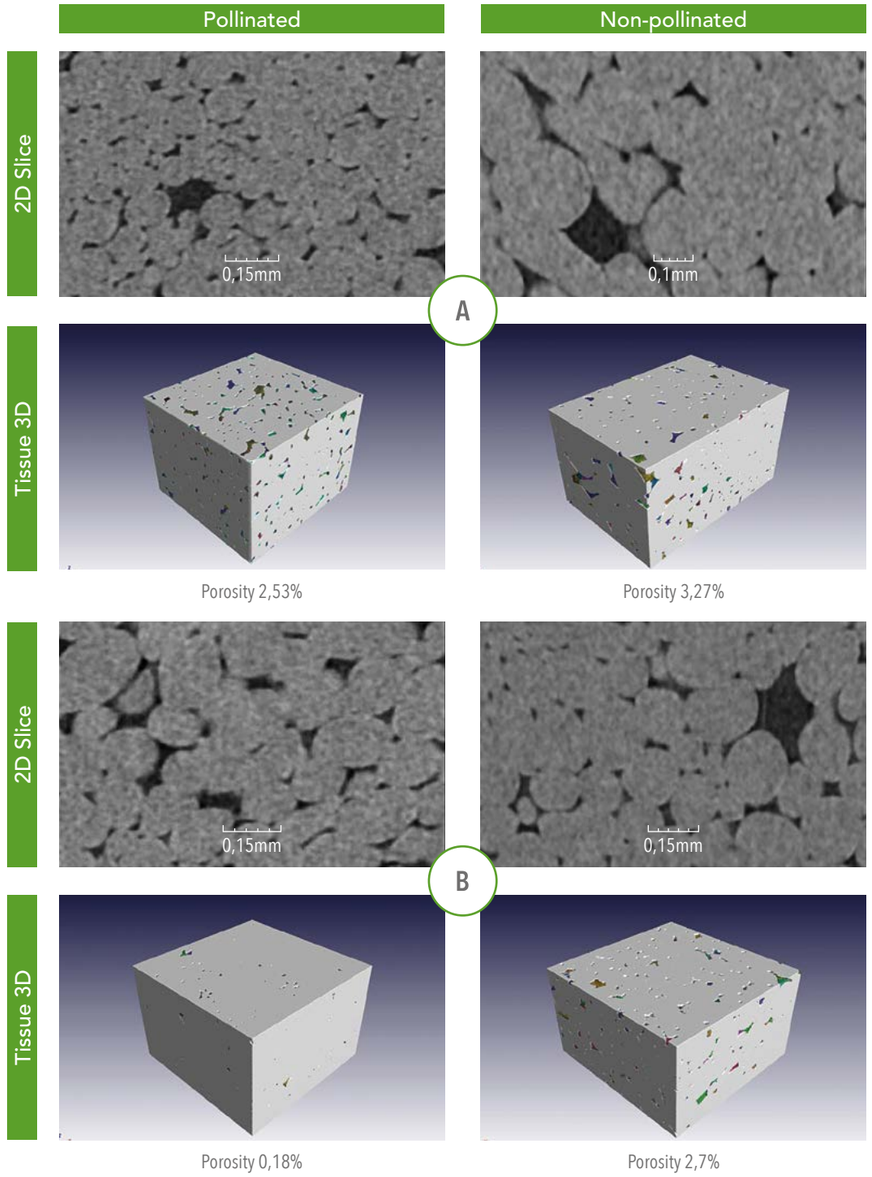
- Harvest at optimum maturity – not over-mature.
- Store fruit for longer than 12 weeks at -0,5°C.
- Orchards that qualify for the 'Forelle' Early Market Access (FEMA) protocol should use this for recommended markets as fruit are eaten crisp and sweet.



WHAT IS AN EULER NUMBER?

It is an indicator of connectedness of a 3D complex structure. Higher values indicate poorly connected structures and lower values better connected structures.

Figure 1: Porosity in the neck areas (A) and equator (B) of pollinated and non-pollinated 'Forelle' pear fruit



Two-dimensional (2D) slice images and three-dimensional (3D) volume renderings of the tissue and porosity distribution in the neck ROI of a pollinated and non-pollinated fruit. The fruit was scanned on the GE Nanotom at the Stellenbosch University Central Analytical Facilities.

Two-dimensional (2D) slice images and three-dimensional (3D) volume renderings of the tissue and porosity distribution in the equator ROI of a pollinated and non-pollinated fruit. The fruit was scanned on the GE Nanotom at the Stellenbosch University Central Analytical Facilities.