Keeping up appearances

A project that set out to validate models that predict the rind quality of citrus fruit has confirmed the role that pre-harvest conditions, notably canopy position, play in maintaining the looks of mandarins, oranges and grapefruit.

1 Dr Lembe Magwza, project leader (centre), with Dr Samson Tesfay (left) and PhD student, Olaoluwa Olarewaju, who participated in the research.
2 Rind breakdown disorder only starts developing during storage, about three to five weeks after harvesting.

CONSUMERS BUY WITH their eyes. Whether they shop for furniture, fashion or, indeed, fresh fruit, appearance counts – and determines prices. Existing fruit grading systems handle fruit with slight external defects in one of two ways. It is either graded and marketed with unblemished fruit, thereby reducing the value of the entire batch, or it is graded and rejected together with seriously damaged fruit, causing unnecessary financial loses.

Against this backdrop, the University of KwaZulu-Natal, with the support of the citrus industry and the Post-Harvest Innovation Programme, is investing time and resources into finding ways to predict and detect physiological rind disorders that make export citrus less attractive, and limit storage potential.

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One of the main difficulties related to physiological rind conditions, such as rind breakdown disorder (RBD), is their progressive nature. RBD does not manifest during harvest or fruit grading in the packhouse; symptoms only start developing during storage, about three to five weeks after harvesting. In the case of export fruit, this window matches the commercial shipping period and the fruit's arrival at the point of sale. The result is customer complaints at best, and huge financial losses at worst.

Physiological rind disorders have long been the field of study of Dr Lembe Magwaza of the Agricultural Plant Sciences Department at the University of KwaZulu-Natal. Building on studies that have shown that different microclimatic conditions during the growing season and within a tree canopy influence the physico-chemical properties of citrus rinds and play a significant role in fruit susceptibility to physiological rind disorders in 'Nules Clementine' mandarins, Lembe's own research confirmed that 'Nules Clementine' mandarins harvested from inside the canopy had lower rind dry matter content (DMC) and were more susceptible to RBD.

These findings suggested that rind DMC at harvest could be used as a pre-symptomatic indicator of fruit susceptibility to RBD. As a possible benchmark to reduce RBD, Lembe recommended that rind DMC should not be below 30g/100g fresh weight (FW) at harvest.

The limitations of DMC limits

Valuable as it was, Lembe's DMC benchmark had its limitations, chief among them the measurement of DMC. Current practice entails conventional destructive techniques on representative samples of a batch of fruit. Although widely used, these techniques are time-consuming and the results only reflect the DMC properties of the specific fruit sample evaluated.

"Given how widely rind attributes vary between fruit batches, we had to find innovative and non-destructive tools for predicting rind quality parameters and fruit susceptibility to physiological rind disorders," says Lembe.

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This quest led him to considering near infrared spectroscopy (Vis/NIRS). Among non-destructive quality assessment techniques, Vis/NIRS is the most advanced with regard to instrumentation, applications, accessories and chemometric software packages. As such, it is widely used to carry out non-destructive, post-harvest quality assessments of fruit and vegetables.

Studies that Lembe conducted in 2011 and 2012 demonstrated the feasibility of Vis/NIRS to predict the rind physico-chemical profile of 'Nules Clementine' mandarins. Partial least squares (PLS) models to predict rind physico-chemical properties were developed using fruit in the Stellenbosch, Citrusdal, Paarl and Porterville areas, and very high prediction accuracy was obtained. The good correlation between spectral information and sugar concentrations and DMC demonstrated the potential of Vis/NIRS as a non-destructive tool to predict mandarins' susceptibility to physiological rind disorder. Principal component analysis (PCA) and PLS-discriminant analysis (PLS-DA) models were developed to sort fruit based on canopy position and susceptibility to RBD.

All these models, however, were validated using fruit from the same cultivar ('Nules Clementine') and the same four citrus-growing regions in the Western Cape.

The next phase

To be useful to the South African citrus industry as a whole, the models that Lembe had developed needed to be validated for the citrus-growing regions in KwaZulu-Natal, the Eastern Cape and Mpumalanga, and for other citrus fruit, such grapefruit and oranges. In addition, the potential of Vis/NIRS-based hyperspectral imaging to differentiate between structures with different densities – and thus its use to visualise rind microstructures associated with rind disorders – had to be explored.

This workload was formalised into a study that started in March 2015 with the overall aim of developing non-destructive methods to predict the quality of citrus fruit.

To achieve its aim, the study has three objectives:

- Validate and test the robustness of the Vis/NIRS PCA and PLS models developed for 'Nules Clementine' mandarin fruit to predict the rind quality of 'Benny' Valencia oranges and 'Marsh' grapefruit.
- Investigate the robustness of Vis/NIRS PCA and PLS models developed for the Western Cape to predict the rind quality of fruit harvested in other citrus-growing regions in South Africa.
- Investigate the feasibility of hyperspectral

PROJECT TITLE
Non-destructive prediction and monitoring of post-harvest rind quality of citrus fruit using Vis/NIR spectroscopy

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DURATION
Two years

PHI PROGRAMME & INDUSTRY CONTRIBUTIONS
R595 219 & R145 219

LEAD INSTITUTION
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BENEFICIARY
The citrus fruit industry

FOCUS AREA
Post-harvest physiology and pre-harvest aspects

HUMAN CAPITAL DEVELOPMENT
One PhD student and two MSc students

PUBLICATIONS AND PAPERS
Five

PRESENTATIONS
Three

3

1 2 3 4

3 Different levels of stem-end rind breakdown on 'Marsh' grapefruit after nine weeks of post-harvest storage. Left to right shows increasing intensity from no (1) to little (2), moderate (3) and severe (4).

1 Dr Magwaza scans intact 'Marsh' grapefruit with a laboratory benchtop reflectance near infrared spectrophotometer.
2 Different levels of rind pitting on 'Marsh' grapefruit after nine weeks of post-harvest storage. Left to right shows increasing intensity from none (1) to little (2), moderate (3) and severe rind pitting (4).

HARVEST AREAS

- **'Nules Clementine' mandarins** – Eastern and Western Cape.
- **'Benny' Valencia oranges** – Crocodile Valley Estates (Nelspruit), Mpumalanga, and Limpopo.
- **'Marsh' grapefruit** – KwaZulu-Natal, Limpopo and Mpumalanga.

spectroscopy to characterise rind quality and structural changes associated with chilling injury, rind breakdown and rind pitting disorders.

DISORDERS DISFIGURING CITRUS

The appearance of citrus fruit is marred by different types of post-harvest rind disorders, including:

- chilling injury,
- rind pitting in oranges and grapefruit,
- rind breakdown disorder (RBD) in 'Nules Clementine' mandarins, and
- peteca spots on lemons.

According to Lembe, this non-destructive technology development research has an important long-term aim. "Our eventual goal is the commercial implementation of non-destructive technology in packhouses. Armed with the robust, stable and accurate models for predicting rind quality that will come out of this study, we will approach the National Research Foundation (NRF) for funds to build a prototype for the practical and commercial in-line application of Vis/NIR spectroscopy."

Methodology

During May 2015, mandarins, oranges and grapefruit were harvested from orchards in the Eastern and Western Cape, Mpumalanga, Limpopo and KwaZulu-Natal.

In all orchards, 30 uniform trees were identified and marked for sampling. On each tree, 30 fruit of uniform size from the sun-exposed (outside) and six from shaded canopy positions (inside) were randomly selected and harvested at commercial maturity. The fruit was transported to the Post-harvest Research Laboratory at the University of KwaZulu-Natal and to Stellenbosch University where it was sorted and weighed, before being treated and stored according to post-harvest industry practices.

A further 100 blemish-free fruit, representing all orchards and cultivars, was selected for non-destructive evaluation with Vis/NIRS. Following the Vis/NIRS scanning, the fruit was stored for 12 weeks between -0,6 and 0,5°C, a temperature that is known to cause the highest degree of RBD, rind pitting or chilling injury incidence. During the 12 weeks, the fruit was scored biweekly for incidences of rind pitting and rind breakdown disorder. Disorders were scored by visual inspection on a subjective scale from none (0) to little (1), moderate (2), and severe (3) rind breakdown.

Results

The results showed that the physico-chemical properties of fruit are affected by position in the canopy. Fruit inside the canopy were greener and less mature, and weighed less than fruit on the outside.

Similarly, the evaluation of rind pitting and chilling injury showed that the outside fruit was less susceptible to physiological rind disorders.

Grapefruit from the same orchard differed in their susceptibility to chilling injury and rind pitting disorders. The difference correlated with parameters that indicated the fruit's physiological properties, which differed based on where the fruit was positioned on the tree.

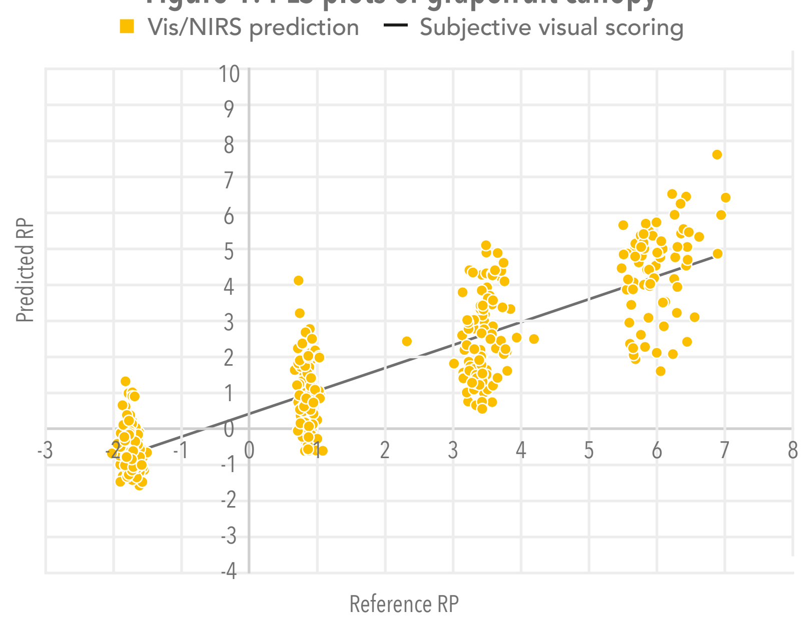
Fruit that grew inside the canopy in the two orchards in Limpopo and KwaZulu-Natal had higher chilling injury incidence (27% and 24%) compared to their counterparts outside the canopy (12% and 0%). In both sites, rind pitting was lower on inside (13% and 2% respectively) than on outside canopy fruit (19% and 9%). Fruit from inside the canopy had higher concentrations of sucrose, fructose and antioxidant activity, and lower dry matter, compared with outside canopy fruit.

The relationship of parameters to rind disorders was also examined as a way to predict the possibility that fruit could develop rind disorders. Parameters with positive correlations to rind pitting did not show a positive correlation to chilling injury, which prompted the idea of using parameters to predict possible disorder incidences.

Lembe's team successfully developed PLS models to predict internal quality parameters based on total antioxidant capacity, carotene, total carotenoids, chlorophyll a, chlorophyll b, dry matter, sucrose, glucose and fructose. Rind pitting, for example, was predicted with an accuracy of 78% (Fig. 1).

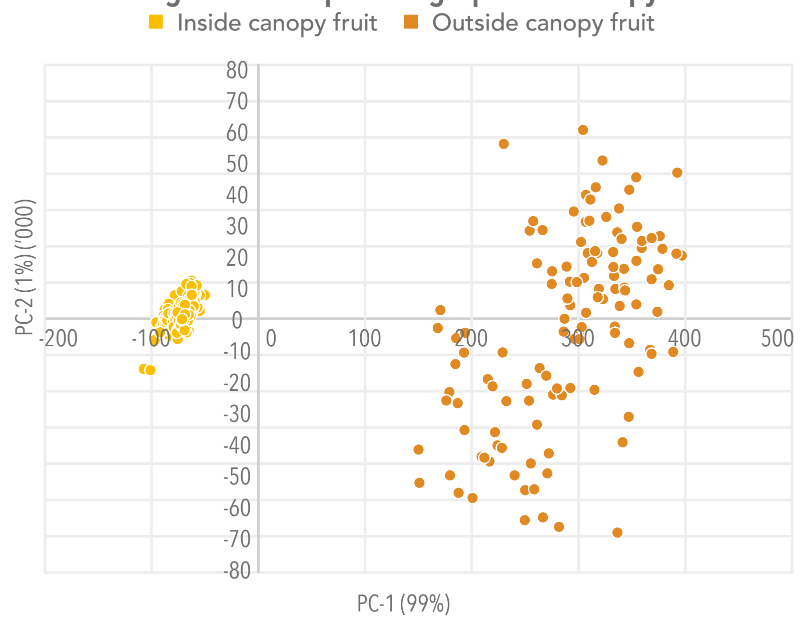
The spectral information from fruit harvested from different canopy positions indicated enough differences to confirm the potential of Vis/NIRS spectra to segregate fruit based on canopy position (Fig. 2). The ability of Vis/NIR spectroscopy, coupled with chemometric analysis, to cluster fruit based on original canopy position during sorting and packaging is recommended as a secondary approach to identify fruit with a high chance of developing rind pitting.

Figure 1: PLS plots of grapefruit canopy



The correlation of rind pitting values predicted using Vis/NIRS compared to subjective visual scoring.

Figure 2: PCA plots of grapefruit canopy



The principal components analysis shows the difference that canopy position makes to fruit quality.