Plotting the causes of pitting

Rind pitting is a citrus fruit disorder that develops post-harvest during shipping. If its causes can be identified, citrus growers would feel the difference in their pockets.

POST-HARVEST PHYSIOLOGICAL RIND disorders, such as staining and pitting, affect most citrus cultivars and have a significantly negative impact on return on investment for producers.

Despite this, many questions are still being asked about the causes of these physiological disorders.

Over the last decade, several publications have indicated that citrus fruit quality, and specifically susceptibility to rind disorders, depends on pre-harvest conditions, including ambient temperature, specific temperature and relative humidity (RH) changes.

However, data published in Spain and Florida has highlighted the importance of rind water content. These studies revealed that the dehydration of the rind during low RH conditions, followed by rehydration at high RH conditions, can result in turgor stress in the transition cellular zone between the flavedo and albedo. This stress is thought to cause cellular collapse, which manifests in visible staining or pitting lesions on the fruit rind.

In addition, mineral nutrient levels in the rind have been found to influence susceptibility to post-harvest rind breakdown.

In a preliminary study during 2012 it was found that pitting and staining in 'Nadorcott' mandarin were influenced by the type of rootstock (known to influence water supply to fruit), as well as post-harvest handling practices (low vs. high RH). The results indicated a significantly higher susceptibility of fruit from rough lemon rootstocks compared to fruit from the Carrizo citrange rootstock.

Furthermore, fruit that was waxed within 24 hours after harvest, and thus suffered relatively little dehydration, showed significantly lower levels of rind disorders compared to fruit that was waxed later on.

The data concurred with findings on different citrus rind disorders, where a dramatic water loss due to high vapour pressure deficit (VPD) resulted in an inadequate adjustment of the water status of the rind, leading to cellular collapse and tissue damage.

Taking the existing body of work into account, Dr Paul Cronjé, a researcher at Citrus Research International (CRI), developed a couple of hypotheses to be tested:

1. Post-harvest handling practices could aggravate the incidence of rind disorders. Therefore, known and implementable post-harvest practices, such as removal of field heat and reduction of fruit VPD, could decrease post-harvest citrus rind disorders.
2. Incorrect nitrogen (N) fertilisation could result in an increased sensitivity of mandarin fruit to post-harvest physiological rind disorders due to its impact on rind colour.

In addition, Dr Cronjé wanted to shine the light of enquiry on the influence of pre-harvest water stress on the citrus fruit rind as it undergoes post-harvest stresses, as well as the potential of the pre-harvest application of synthetic plant hormones to improve the rind condition.

Given that the post-harvest application of thiabendazole (TBZ) is known to reduce chilling injury in citrus, it was decided to include TBZ in the study as well.

At the beginning of 2015, Dr Cronjé received funding from the PHI Programme and industry for an 18-month study with five objectives:

1. Gather information on the impact of post-harvest water stress on pitting of citrus fruit.
2. Determine whether the same cultivars produced on farms in the same area show a variation in sensitivity.
3. Determine the impact of pre-harvest water stress on rind sensitivity of mandarin.
4. Determine the impact of N application on rind quality.
5. Determine the efficacy of TBZ application on pitting of Valencia oranges.

Mandarin methodology

'Nules Clementine' and 'Nadorcott' mandarins, harvested in the Citrusdal and Riebeeck Kasteel areas, were used for the study.

Soil applications of N at 20kg·ha^{-1} and 40kg·ha^{-1} were done on 21 January and 26 March in 2015 and 2016. This was in addition to the standard 250kg·ha^{-1} N provided by the producer. During 2015 a 1% urea foliar application was sprayed.

After harvesting, the fruit was dehydrated at 25°C and 60% to 80% RH for two days, followed by rehydration at 100% RH for one day. Subsequently, the fruit was stored at either -0,6°C or 4°C for a 30-day period.

To determine the impact of pre-harvest water stress, the soil below the trees was covered with plastic sheets three weeks prior to harvest to exclude rainfall and irrigation.

The effect of post-harvest stress was established by dehydrating and rehydrating fruit at 0,7kPa to 1,1kPa VPD for different periods after harvest. Wax was applied on day 5; thereafter, fruit was stored at 4°C for 30 days.

Valencia methodology

Various plant growth regulators, as well as the post-harvest application of TBZ, were tested to determine which, if any, could reduce susceptibility to pitting.

The oranges were all subjected to post-harvest hydration–rehydration stress to induce pitting.

Mandarin results

In general, no significant differences in fruit colour or size were recorded across the areas and seasons studied.

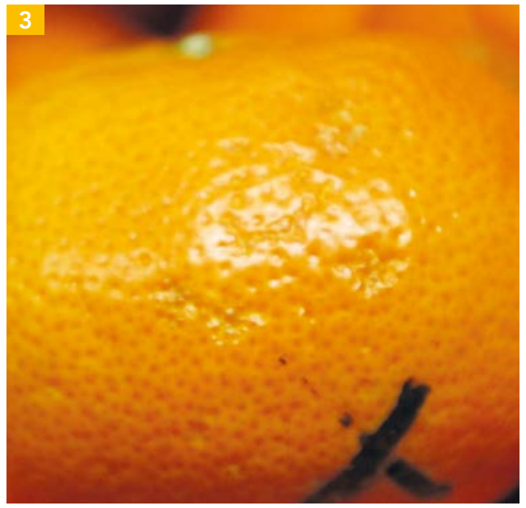
Furthermore, no consistent differences were seen among the N treatments after the fruit had been stored at either -0,6°C or 4°C. Mineral nutrient analysis recorded that N applications did not increase the N levels in the leaves, indicating that the N concentrations could be increased in future projects to determine a threshold level. The study, therefore, did not confirm the expected decrease in rind colour due to increased N application.

Although incidences of pitting were recorded, they were generally at levels too low for all the treatments to warrant being included in the data analysis and therefore could not be correlated with N treatments. However, the lack of disorders did indicate that N treatment and storage temperature did not lead to higher pitting susceptibility.

It was also not possible to link pre-harvest rind mineral content with additional N applications with the eventual incidence of rind pitting during storage. The interaction between N application and irrigation indicates that available soil moisture plays a role in N uptake.

Studies on post-harvest disorders are

1 Dr Paul Cronjé, project leader.



Rind pitting on Valencia oranges (**2**) and Mandarin oranges (**3**).

PROJECT TITLE
Reducing the post-harvest rind pitting of Valencia and Mandarin citrus fruit

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DURATION
21 months

PHI PROGRAMME & INDUSTRY CONTRIBUTIONS
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BENEFICIARY
The citrus fruit industry

FOCUS AREA
Post-harvest physiology

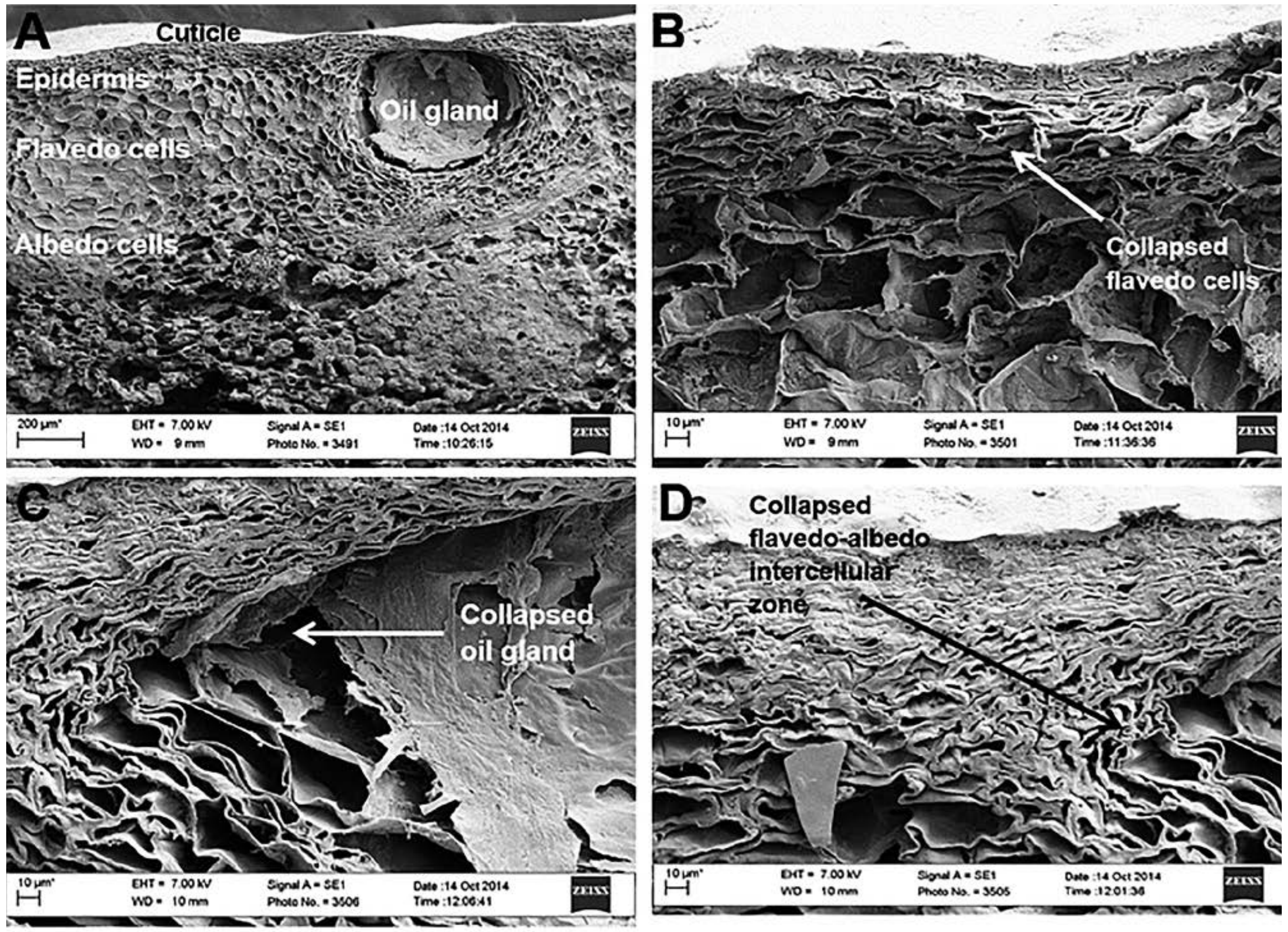
HUMAN CAPITAL DEVELOPMENT
Three MSc Agric students

PUBLICATIONS
Two

PRESENTATIONS AND PAPERS
Nine

Figure 1: A-D

Scanning electron microscopy (SEM) comparative cross-sections of different cellular sections of 'Nadorcott' mandarin fruit rind after storage at -0,6°C for 30 days, showing no rind disorder lesions (A) and collapse of the rind due to rind disorders (B–D).



extremely difficult due to their erratic (and low) incidence between seasons. Although this study could establish certain correlations between factors influencing rind quality (climatic influence, moisture loss and colour) and rind disorder incidence, no single factor emerged as the main underlying cause of rind disorders.

However, the "induction" of rind disorders in some instances by stressing the fruit pre-harvest, and the lack of expected decreased rind colour due to increased N application, can be regarded as positive results. This information can help unravel the factors that predispose citrus fruit rind to progressive post-harvest disorders.

Valencia results

The study confirmed that cultivar plays a significant role in pitting susceptibility, with 'Benny' Valencia being more susceptible than 'Turkey' Valencia.

More mature fruit on the outside of the canopy seems to be more affected, possibly because of greater exposure to changes in environmental conditions, resulting in increased water stress pre-harvest. This aspect should receive more focused research attention.

The synthetic auxins 2,4-D and 3,5,6-TPA significantly reduced rind pitting when applied at 10mg·L^{-1}, possibly due to increased sink strength, increased transport of water and nutrients, and increased cell growth in the rind.

An application of 10mg·L^{-1} 2,4-D or 3,5,6-TPA after physiological fruit drop is recommended to reduce pitting susceptibility. In addition, fruit should be packed and placed within the cold chain as soon as possible to minimise post-harvest environmental variation and water stress that result in dehydration.

Post-harvest application of the systemic fungicide TBZ reduced post-harvest pitting in 'Benny' Valencia oranges and a dip treatment at 2000µg·mL^{-1} for one minute directly after harvest is recommended.

However, TBZ applied in wax after stress treatment did not have a similar effect.

Conclusion

Even though the symptom development or lesions of rind pitting look similar, the mechanism responsible for the cellular collapse is probably unrelated in the different cultivars, even within cultivar groups such as mandarin and Valencia oranges.

In general, high moisture loss during the time from pick to pack is problematic and influences pitting incidence. From these results the indications are that TBZ does have a clear mitigating impact on pitting and should be used as advised.

To reduce potential financial losses due to post-harvest pitting, producers should determine the likelihood of fruit to develop the disorder. This should be done for each orchard by factoring in cultivar knowledge, orchard history and environmental conditions. With this information, producers can then minimise the risk through management practices such as reducing the time between harvest, application of TBZ and optimising the cold chain.

Once the risk of fruit to develop pitting has been determined, the producer and exporter should formulate a strategy to manage the supply of fruit to high-risk markets. The UK, for instance, has little or no tolerance for rind pitting, but is also the market that yields the highest rate of return.

Fruit from orchards with a history of developing pitting should rather be exported to the Middle East or EU markets where lower penalties are imposed on fruit that arrives with pitted rind.

In extreme cases, it would make best financial sense to sell fruit from highly susceptible orchards at the packhouse.

WATER LOSS IN FRUIT

Water loss occurs when moisture moves out of a fruit towards the drier atmosphere. The temperature of the fruit and ambient environmental conditions are the factors that primarily influence the VPD value and the eventual water loss.

Citrus fruit, being a hesperidium berry with a leathery rind, primarily loses water from the rind instead of the pulp. The water content of the rind is therefore directly related to any water loss from the fruit.

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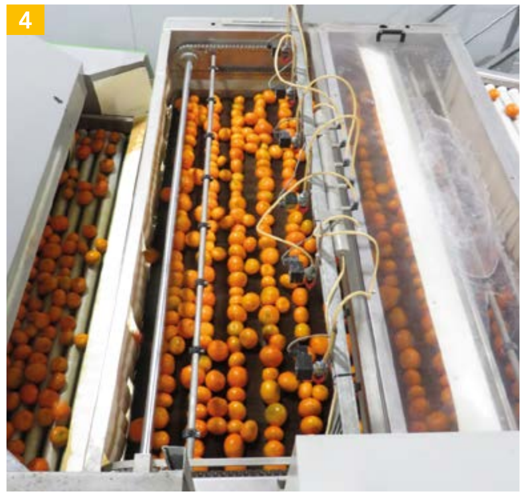

The three MSc Agric students taking part in this PHI Programme-funded project, are Jacques Ehlers (**1**), Helen Marais (**2**), and Jéanine Joubert (**3**). **4** Waxing citrus fruit within 24 hours after harvest yields fruit that suffers relatively little dehydration and shows significantly lower levels of rind disorders compared to fruit that is waxed later on.