Detection of pre-harvest cold damage in avocado fruit using an online near-infrared spectrometer

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ABSTRACT

The occurrence of pre-harvest cold damage (PCD) in avocado orchards in South Africa has increased in recent years. This is likely due to expansion into marginal areas for avocado production and changes in climatic conditions. The problem is exacerbated in on-years when the crop cannot be harvested before the first frost, due to limitations in picking and post-harvest capacity and market demand. Fruit with PCD cannot be sorted visually because there is not a regular external symptom. It may be possible to detect PCD using an online near-infrared spectrometer (NIR) and sort fruit accordingly, once the instrument is calibrated. In this experiment, fruit from three orchards with PCD were selected and scanned by a Taste Technologies T1 NIR and the internal PCD was evaluated. The detection of frost damaged fruit was possible, although there was an increased misclassification in fruit with very slight PCD damage. This limit of detection must still be determined. It is recommended that fruit be rotated while passing under the NIR to increase the volume of the individual fruit that is scanned.

INTRODUCTION

The growth of the South African avocado industry in the last 40 years has resulted in avocados being grown in locations that traditionally would not have been considered suitable for avocado production. These new plantings are generally proving profitable, but there are increased associated risks with planting in marginal areas. In recent years, PCD has become a significant problem, particularly in the Tzaneen area, Limpopo Province. PCD has occurred in low-lying areas and orchards with poor air drainage, rendering all the fruit from those orchards not fit for market, resulting in significant financial loss. Internally, the vascular bundles and flesh turn brown and harden, rendering the fruit inedible. The external symptom of PCD is a red, maroon, bronze or black discolouration of the skin (White *et al.*, 2009), which is different to sunburn; however, this symptom does not occur consistently, making visual sorting inaccurate.

Online NIR is able to sort fruit and vegetables according to internal quality once the instrument has been correctly calibrated. Near-infrared light is shone on to the fruit and interacts with the compounds in the fruit; the altered light spectrum is detected by the instrument. This spectrum is calibrated to physical, destructive values using mathematical and statistical methods. For more information, please refer to Blakey *et al.* (2008).

MATERIALS AND METHODS

Post-harvest cold damage induction

In an attempt to artificially induce cold damage symptoms in fruit, 'Hass' fruit were harvested from an early maturing orchard and placed at -15°C for 4, 6 or 8 h in a chest freezer. Fruit were returned to room temperature for three days and then cut to determine whether this treatment induced similar symptoms to pre-harvest cold damage.

Fruit source

In the main experiment, 'Hass' fruit with natural pre-harvest cold damage were used. These fruit were from Westfalia orchards that were located near dams; details are provided in Table 1.

Table 1. Source of fruit, the date fruit were scanned, and the number of fruit from each orchard.

Fruit source	Date scanned	No. of fruit
Ballygowan	8 July 2010	130
MacNoon	7 June 2011	500
Waterval	8 July 2011	480

Scanning, evaluation and model development

A Taste Technologies Ltd (Auckland, New Zealand) T1 NIR spectrometer was used for this experiment. The instrument was mounted on a single lane packline at

Westfalia Estate. Fruit were placed into the packline cups and scanned with the 'short side' up (Figure 1), rotated 180° longitudinally and scanned again. Fruit were cut longitudinally and transversally. The short side and long side were both rated on a scale of 0 - 3 (where 0 = no symptom) for internal pre-harvest cold damage (IPCD; Table 2; Figure 2). Model development was performed by Taste Technologies. A model was developed for each fruit source.

RESULTS AND DISCUSSION

Post-harvest cold damage induction

The symptoms caused by the post-harvest freezing did not resemble the IPCD and this approach was abandoned. The results presented here are hence only for natural IPCD.

General observations

IPCD occurred more frequently on the short side of the fruit (Figure 1), generally only extending to the long side if the IPCD was severe. The fruit from Ballygowan in 2010 were severely affected by frost (Table 3), with 39% of all fruit halves scanned having IPCD. Many of the fruit had external symptoms of frost damage, although this was not consistent with internal symptoms. The PCD was much less in 2011, with fruit from both orchards having slight frost damage, compared to 2010. The incidence of IPCD in the fruit from MacNoon in 2011 was 11% and from Waterval 6%. As the severity of IPCD is of little concern commercially, *i.e.* all fruit with IPCD must be rejected, results refer to IPCD-free and IPCD-damaged fruit.

Detection of IPCD with NIR

The model generated from the calibration of the instrument allocates a value to each fruit scanned. While the visual classification of IPCD is discrete (0, 1, 2 or 3), the values generated by the model are continuous, so a cut off value, dividing IPCD-free and IPCD fruit, must be set to maximise the accuracy of sorting. The principle is illustrated in Figure 3, using the fruit from MacNoon. The accuracy of the model to detect and sort fruit with IPCD declines as the set cut

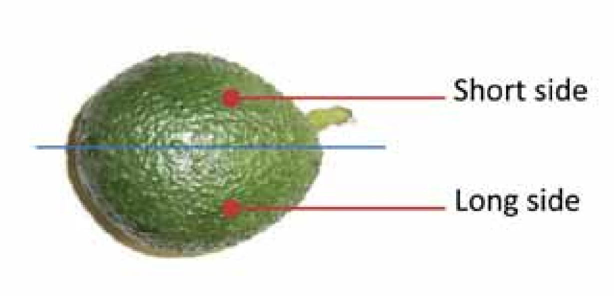

Figure 1. Explanation of short side and long side of an avocado fruit.

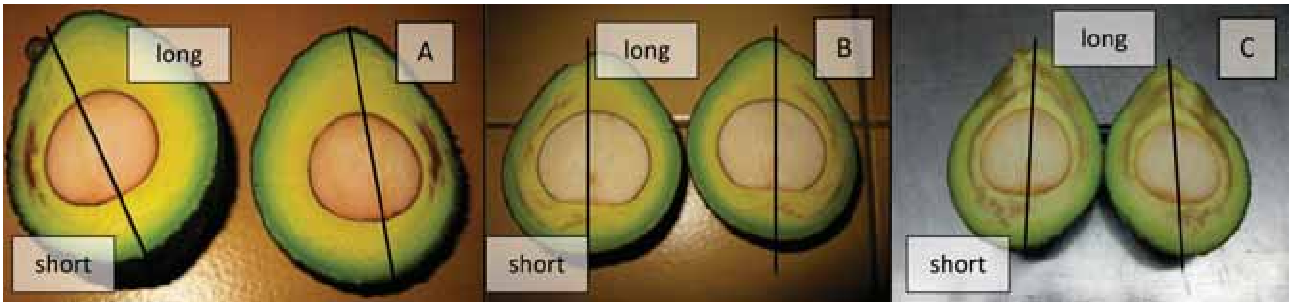

Figure 2. Photographs and ratings of internal pre-harvest cold damage. (A) short side 1, long side 0; (B) short side 3, long side 0; (C) short side 3, long side 2.

Table 2. Rating scale of internal pre-harvest cold damage with approximate percentage of damaged tissue of half an avocado fruit.

Rating	Damaged tissue (%)
0	0
1	1-33
2	34-66
3	67-100

Table 3. Percentage of fruit halves at each rating of internal pre-harvest cold damage.

Fruit source	IPCD severity rating			
	0	1	2	3
Ballygowan	61	12	10	17
MacNoon	89	7	2	2
Waterval	94	6	0	0

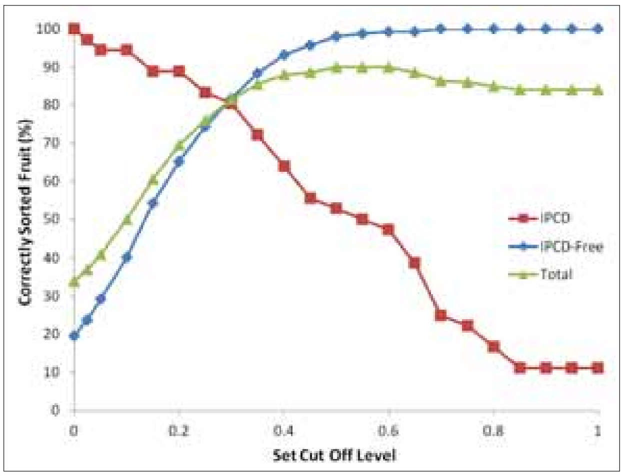

Figure 3. Correctly sorted fruit with internal pre-harvest cold damage (IPCD), fruit without IPCD, and the total. Fruit were harvested from MacNoon Estate on 7 June 2011.

Table 4. Correctly and misclassified fruit from each orchard in 2010 and 2011.

Fruit source	Correctly classified fruit (%)	Misclassified fruit (%)		Set cut level
		IPCD	IPCD-free	
Ballygowan	92.6	3.7	3.7	0.45
MacNoon	69.5	2	28.5	0.20
Waterval	86.2	13.8	0	0.20

Table 5. Effect of fruit orientation on the accuracy of detection of internal pre-harvest cold damage (IPCD) in fruit from Ballygowan in 2010.

	Short side up (%)	Long side up (%)	Either side up (%)
IPCD	85	75	66
IPCD-free	95	93	95

off level increases from 0 to 1, while the inverse occurs with fruit without IPD. Considering all the fruit, the highest accuracy was achieved using a cut off level between 0.50 and 0.60. However, the objective is to remove fruit with IPCD from the line, at the expense of some IPCD-free fruit. Therefore, it would be prudent to set the cut off level, for this model, to 0.20 which would result in 65% of the fruit without IPCD, 89% of the fruit with IPCD, and 70% of the total fruit being correctly sorted. With the addition of fruit to the model, it should be possible to increase the accuracy of the model, but the determination of ultimate level of accuracy would require further testing using a greater number of fruit.

The ability of the NIR to sort fruit according to the presence of IPCD is related to the extent of the damaged tissue. This is due to the fact that only about 30% of the fruit volume is detected with one scan. If the volume of damaged tissue is low (conservatively estimated to be less than 10%), there is a possibility that this volume of tissue will not be detected by the NIR. This explains the low predictive ability for the fruit with IPCD from Waterval (Table 4), where only 6% of the fruit halves had IPCD and affected less than 10% of the fruit volume. The limit of detection must be determined in further investigations to determine whether the NIR instrument is capable of meeting the requirements of the PPECB with regards to IPCD.

Need for fruit rotation

The accuracy of detection for fruit with IPCD decreased from 85% when the fruit was orientated with the short side up, to 75% when the fruit was orientated with the long side up, to just 66% when either side was considered (Table 5). It is therefore advisable to have the fruit rotate under the instrument to increase the accuracy of the detection, by increasing the fruit volume that is detected with one scan. This would be true for any localised damage on the fruit. This is an important consideration during the fitting of the NIR instrument to the packline, because it will require additional engineering to the packline, especially if the instrument is to be retro-fitted to an existing packline.

CONCLUSION

Internal frost damage can be detected with online NIR. The level of detection with regards to fruit volume affected still needs to be determined. It is advised that the fruit are rotated under the NIR instrument to increase the volume of fruit that is scanned. Further testing will continue in the 2012 season, which is an on-year, and is anticipated to have more fruit with IPCD due to an increased volume of fruit hanging into June and July.

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