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The potential for commonly measured at-harvest fruit characteristics to predict chilling susceptibility of 'Hort16A' kiwifruit

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ABSTRACT

The propensity for physiological disorders to arise during low temperature storage of kiwifruit is a significant commercial risk. The potential to use fruit characteristics (flesh colour, soluble solids content (SSC), dry matter and firmness) estimated non-destructively at harvest as markers for the susceptibility of 'Hort16A' kiwifruit to chilling injury (CI) has been investigated for individual fruit. While the fruit that developed CI during storage were some of the least advanced fruit on each orchard, the flesh colour, SSC, firmness and dry matter of the susceptible fruit differed considerably among orchards, such that there was not a clear minimum or maximum threshold for which fruit did or did not develop CI across all orchards. There was a large 'orchard factor' in the susceptibility of fruit to CI that was as important, if not more important, than the flesh colour, SSC, firmness and dry matter values. The 'orchard factor' may derive from a combination of environmental conditions and/or orchard management practices, in conjunction with fruit growth and development. Hence it is concluded that a generally applicable at-harvest prediction of 'Hort16A' fruit susceptibility to CI is not possible from an at-harvest non-destructive estimation of flesh colour, SSC, firmness and dry matter.

1. Introduction

Since its introduction, the yellow-fleshed 'Hort16A' kiwifruit has been cleared for harvest on the basis of flesh colour, with a goal of minimising the proportion of green fleshed fruit that reach the market (Banks and Abbott, 2001). The marketing of 'Hort16A' as a yellow-fleshed fruit determines that flesh colour will always be a major determinant of harvest time, either for fruit to be fully degreened at harvest, or have the capacity to degreen after harvest. Flesh colour on its own is not a robust predictor of fruit maturity and is only loosely linked with other fruit characteristics including soluble solids content (SSC) and firmness (Burdon and Lallu, 2011; Burdon et al., 2014). Additional markers indicative of postharvest performance are required to supplement the clearance to harvest by flesh colour. A major aspect of postharvest performance is that after storage, fruit have the capacity to ripen to a good eating quality and be free from disorders. Even early harvested green-fleshed 'Hort16A' fruit can have the capacity to soften and ripen to a good eating quality (Burdon, unpub. data). However, as with other fruit (Reid, 2002) the earlier that 'Hort16A' kiwifruit are harvested, the greater the risk of chilling disorders that will limit fruit quality after storage. Chilling damage in 'Hort16A' kiwifruit can have symptoms similar to that described as low temperature breakdown in 'Hayward' (Lallu, 1997).

In general, 'Hort16A' fruit are more temperature sensitive than 'Hayward' fruit, hence the current difference in storage temperatures of 0 °C, or just below, for 'Hayward' and 0.5–1.0 °C for 'Hort16A' (Patterson et al., 2003). The chilling tolerance of 'Hort16A' fruit is also reduced by the early harvesting of fruit which still require degreening off the vine at temperatures above 5 °C (de Silva et al., 2007). The process of degreening fruit off the vine delays exposure to low storage temperatures and may function as a period of conditioning that reduces CI expression (Burdon and Lallu, 2011).

Previously, physiological disorders (Maguire et al., 2005) and rots (Fullerton et al., 2007) have been recorded as causing 'significant losses' in 'Hort16A' fruit. More recently, however, rots and disorders are seldom seen, although the susceptibility of fruit to low temperatures remains an issue. In early reports chilling sensitivity was associated with fruit that had a green flesh colour and therefore were considered to be immature (Maguire et al., 2005), but chilling disorders can also occur in fully degreened fruit.

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Near infra-red spectroscopy (NIR) technology has been investigated extensively for use with ‘Hayward’ and ‘Hort16A’ kiwifruit (Osborne et al., 1998; McGlone and Kawano, 1998; McGlone et al., 2002), and other fruit (reviewed by Nicolai et al., 2007), and in particular, the ability to estimate non-destructively the flesh colour, SSC and dry matter (DM) of ‘Hort16A’ kiwifruit at harvest (Clark et al., 2004; McGlone et al., 2007). Non-destructive firmness measuring devices based on other technologies are available, and more recently there have been commercial claims for the separation of kiwifruit by firmness using NIR (Taste Technologies Ltd., Onehunga, Auckland).

NIR and non-destructive firmness technologies allow the estimation of flesh colour, SSC, DM and firmness of individual fruit prior to storage, and these estimates may then be related to the quality of those specific fruit at the end of storage. This approach contrasts with the commonly used alternative of deducing the role of fruit composition in disorder susceptibility on the basis of proportions of disordered fruit in batches related to the mean and variability of samples of fruit measured destructively for composition at harvest (Burdon et al., 2013). If robust relationships exist between storage disorders and fruit composition at-harvest as predicted by NIR, NIR spectra or non-destructive firmness measurements, it raises the possibility of being able to segregate and remove susceptible fruit prior to storage.

In this project, the potential to use fruit characteristics estimated non-destructively at harvest as markers for the susceptibility of ‘Hort16A’ fruit to storage disorders has been investigated using individual fruit.

2. Methods

2.1. Fruit

Twelve samples of ‘Hort16A’ kiwifruit (*Actinidia chinensis*, Planch. var. chinensis ‘Hort16A’), each of 1000 fruit, were obtained from commercial orchards in the Bay of Plenty region, New Zealand, during the 2008 harvest season. Fruit were harvested on three occasions (H1, H2 and H3); four samples of fruit were harvested on 7 May (H1; O1, O2, O3 and O4), four on 14 May (H2; O5, O6, O7 and O8) and four on 20 May (H3; O9, O10, O11 and O12). The samples O1 to O12 are referred to as orchard samples, although O1, O5 and O9 came from the same orchard on different dates. On each orchard, fruit were taken from approximately three bays, with about eight vines being sampled, avoiding vines at the edge of the block. For O1, O5 and O9, the samples were taken from the same vines at each harvest. On the day of harvest, fruit were transferred to the Mount Albert Research Centre, Auckland in 25 kg capacity plastic crates and 1000 fruit per orchard transferred into single layer trays with pocket packs, but not polyliners, and all fruit numbered individually. The numbered fruit were left in the trays overnight at 20 °C. The at-harvest composition of the fruit is given in Table 1.

2.2. Non-destructive estimation of flesh colour, soluble solids content and dry matter

The day after harvest, fruit were passed across an NIR grading test line (Taste Technologies Ltd., Onehunga, Auckland) and the NIR reflectance spectra for each fruit collected. After completion of gathering the NIR data, flesh colour, SSC, dry matter and firmness were determined destructively for 50 fruit per 1000 fruit sample. The remaining 950 fruit per orchard were placed into storage at 1 °C after a polyliner had been put into each tray. Predictions of flesh colour, SSC and dry matter (designated pFC, pSSC and pDM) were achieved by working within individual orchard samples using the 50-fruit destructive sample.

Table 1
At-harvest flesh colour, soluble solids content (SSC), firmness and dry matter of ‘Hort16A’ kiwifruit harvested on three occasions (H1–H3) from 12 orchards (O1–O12). Values are means for 50 fruit per orchard.

Harvest	Orchard	Flesh colour (°h)	SSC (%)	Firmness (N)	Dry matter (%)
H1	O1	106.5	9.3	63.8	15.7
	O2	102.1	12.6	54.9	16.6
	O3	102.3	12.8	58.9	17.3
	O4	102.1	12.2	52.0	16.5
H2	O5	102.1	10.7	56.9	16.4
	O6	100.4	15.3	42.2	18.0
	O7	101.9	12.3	43.2	16.4
	O8	102.0	10.7	46.1	15.4
H3	O9	100.8	13.4	40.2	16.5
	O10	104.2	9.7	54.0	14.6
	O11	103.0	13.0	37.3	15.8
	O12	100.4	15.7	29.4	17.4

2.3. Non-destructive estimation of firmness

Non-destructive firmness measurements were made on 120 fruit from samples O1, O2, O3 and O4 prior to storage using an Aweta acoustic firmness sensor (AFS™; Aweta, Nootdorp, The Netherlands).

2.4. Measurement of flesh colour, soluble solids content, dry matter and firmness

Flesh colour (°hue) was measured using a Minolta CR300 Chroma Meter after removal of skin and flesh to a depth of 2 mm. Flesh colour was measured twice at the mid-point of each fruit, with two measurements taken at 90° to each other. Soluble solids content of a combined sample of juice from the stylar and stem ends of each fruit was determined using an Atago digital refractometer (0–50%, “pocket” PAL-1 Atago). Dry matter was determined by drying a 2 mm slice from the middle of the fruit at 65 °C for approximately 24 h. Fruit firmness was determined after removal of skin and flesh to a depth of approximately 1 mm using a fruit texture analyser (Güss model GS14, South Africa) fitted with a 7.9 mm Effegi penetrometer probe. Firmness was measured twice at the mid-point of each fruit, with two measurements taken at 90° to each other. Firmness data are presented in N.

2.5. Disorder assessment

Disorder assessments after 16 weeks of storage at 1 °C quantified individual physiological, pathological and physical disorders. Disorders were recorded individually or as categories including: rots (recorded by position on the fruit–stalk end, body or stylar end), softs (soft fruit <3 N and fruit with soft patches), skin disorders (pitting, lenticel spots, raised spots and hypersensitive marks) and chilling injury (CI; tissue showing granular patches or water soaking assessed after cutting the fruit transversely about 1/3 of the way along the fruit from the stylar end). The predominant disorder was CI, with very low incidences of all other disorders. Hence analysis has focused on the presence or absence of CI, with no assessment of severity.

2.6. Data analysis

The data have been illustrated graphically using box plots to show the distributions of data within individual samples. The box is determined by the 25th and 75th percentiles, the whiskers by the 5th and 95th percentiles and the 1st and 99th percentiles by crosses. The mean is represented by the symbol within the box, the median