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The effect of controlled atmospheres on respiration and rate of quality change in 'Unique' feijoa fruit

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ABSTRACT

Gas exchange rates and quality changes of feijoa fruit (*Acca sellowiana*, cv. Unique) stored at 5 °C under 16 different controlled atmosphere (CA) conditions were monitored to identify the commercial potential of CA to extend the storage life. A combination of low O_2 and low CO_2 provided the largest benefit in reducing weight loss (from 1.7 to 1.2%), reducing the change in hue values (from 4° to 2°) and reducing the incidence of blemished fruit (from 30 to 20%) as compared to regular air storage.

1. Introduction

The feijoa (*Acca sellowiana*, also commonly known as the "pineapple guava") is an evergreen shrub of the Myrtaceae family, endemic to high altitude regions of Uruguay and southern Brazil (Harman, 1987). The fruit are oval-round green berries crowned by persistent calyx lobes (Downs et al., 1988). The green skin encloses a layer of white granular flesh containing sclereids, with seeds embedded in a jelly located in a central cavity made up of three to five locules. As the fruit develops, the locules turn from white to clear, to brown, then to dark brown followed by darkening of the pericarp tissue.

Current best storage practice is considered to be in air at 4 °C, which results in a storage life of approximately 4 weeks with a further shelf-life of 5 d at 20 °C (Klein and Thorp, 1987; Hoffmann et al., 1996). Chilling injury in the form of sunken skin tissue that changes colour to brown then black may occur in fruit stored below 4 °C (Klein and Thorp, 1987). Controlled atmosphere (CA) or modified atmosphere (MA) technologies provide one avenue of investigation for extending the storage life of the fresh feijoa fruit as these techniques have been observed to be successful for other tropical and sub-tropical fruit (Yahia, 1998; Kader, 2003) including the closely related guava (*Psidium guajava* L.; Singh and Pal, 2008). CA conditions for long-term storage of feijoa have yet to be defined as there is a scarcity of research in the area (Galvis-Venegas, 2003). In preliminary trials, in which fruit were held in two low oxygen atmospheres (2.1 kPa O_2 and 4.8 kPa O_2 both complemented with N_2) ripening during both storage and subsequent shelf-life was delayed (Thorp and Bieleski, 2002). MA packages of feijoa flushed with 8 kPa O_2 and 5 kPa CO_2 and stored at 6 °C, showed potential shelf-life extension (Galvis-Venegas, 2003). This paper investigates the influence of 16 different gas mixtures on feijoa (cv. Unique) fruit quality during storage at 5 °C to assist in identifying optimal gas conditions for the fruit.

2. Materials and methods

2.1. Fruit

Export quality feijoas (*A. sellowiana*, Berg., cv. Unique) were obtained from a commercial grower located in New Plymouth, New Zealand on 23 April 2002. Fruit were harvested at the maturity that is considered the best for storing fruit by employing "touch picking" (gently pulling sideways on the fruit, resulting in harvesting fruit immediately prior to natural fruit drop). Fruit were transported to the laboratory on the following day as graded packed fruit. On arrival, fruit were randomised between treatments, labelled, and initial fruit quality characteristics were measured before the fruit were placed under the different gas conditions.

2.2. Controlled atmosphere treatments

On the day fruit arrived at the laboratory, 16 PVC containers (volume = 0.0135 m^3) were packed with 30 fruit each (average fruit

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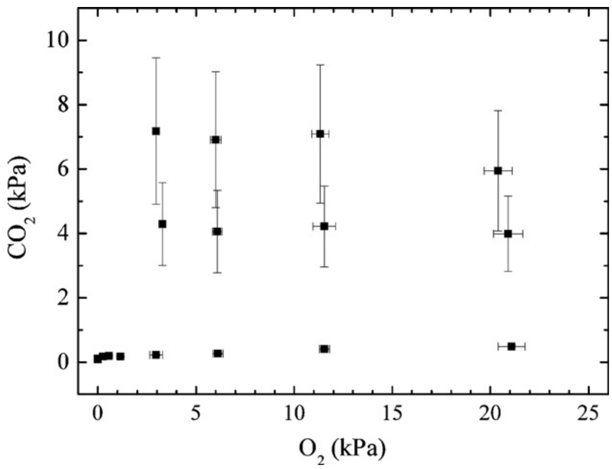

Fig. 1. CA conditions. The symbols indicate the average O_2 and CO_2 conditions as measured during the weekly routine checks, and the error bars indicate the standard deviation of these measurements (12 in total) throughout the 56 d of the experiment.

weight = 71.3 g) and stored at an air temperature of 5 °C, using a range of different atmospheres. A separate sample of 30 fruit was stored in its original box (a single layer cardboard tray) in the same cold room for control measurements during the experiment. The main purpose of the air-stored control fruit was to indicate for how long the experiment in the closed PVC containers should be run to generate maximum differences between the treatments applied, with the air-stored control fruit expected to represent the fastest ripening scenario. Based on the observations of the control fruit the CA experiment was concluded after 56 d (8 weeks) of storage.

Fruit were stored in CA for 56 d using a flow-through system. Gas mixtures were generated by mixing flows of dry air (as an oxygen source), O_2-free N_2 and food grade CO_2 (BOC, Palmerston North, New Zealand). A complete matrix of 12 treatments consisting of four different O_2 levels (nominally 2, 6, 11 and 21 kPa O_2) and three different CO_2 levels (0.2, 4 and 7 kPa CO_2) were created. A further four mixes of 0, 0.25, 0.5 and 1.25 kPa O_2 (nominally) with 0.2 kPa CO_2 were established to assess effects at very low oxygen levels. All gas mixtures were bubbled through water prior to delivery to the tubes, to create a high humidity gas mixture.

The CA conditions were held constant throughout the duration of the experiment (Fig. 1). Gas conditions inside the containers were checked twice weekly by removing samples using 100 μL glass syringes and analysing them as described below. At the same time, respiration rates of the fruit were measured by temporarily closing the tubes to allow accumulation of CO_2 and depletion of O_2 by about 0.5 kPa. Depending on the CA conditions, this measurement required approximately 2 h.

2.3. Gas analysis

All gas samples were analysed using an O_2 electrode (Citicell C/S type, City Technology Ltd., London, UK) in series with a miniature infrared CO_2 transducer (Analytical Development Company, Hoddesdon, UK), with O_2-free N_2 as the carrier gas (flow rate = 35 mL min^{-1}). Output signals were linear over the range applied and analysed using HP integrators (Hewlett–Packard, model 3396A). Commercially prepared β-standards (BOC, Palmerston North, New Zealand) were used for calibrating the gas analysers. All samples were collected in duplicate through two sample ports fitted to the containers. When duplicates differed by more than 0.1 kPa, new samples were taken and the system was checked for possible leaks or calibration errors until consistent results were obtained.

2.4. Fruit quality measurements

All fruit stored under CA conditions were measured at 20 °C for initial and final (after 56 d of storage) weight, firmness and colour. The separate batch of control fruit was monitored for firmness twice weekly throughout storage, while skin colour was measured at the start and end of the storage period.

Firmness was measured with a single controlled 2 mm compression of the fruit between two flat surfaces. Measurements were conducted with a TA-XT2 texture analyser (Stable Microsystems, Surrey, UK). Both skin and internal flesh colour was measured as hue angle (°) using a chromameter (model CR-200, Minolta, Osaka, Japan) calibrated with a green calibration standard (Commission Internationale de l'Éclairage units of Y = 29.9, x = 0.273, y = 0.369; using illuminant light C). Skin colour was assessed at three locations of each fruit with the average hue angle reported. Internal colour was measured immediately after the fruit was halved by a transverse slice. The average luminosity of both sides of the slice was taken as an indicator of internal darkening of the fruit, with low values indicating more dark flesh. Weight was measured with a PG503-S Mettler-Toledo scale (Ohio, USA) with an accuracy of ±0.001 g.

A disorder attributed to CO_2 injury was scored by estimating the percentage surface area affected and the depth of the injured tissue of individual fruit. The injury comprised of both browning and a sunken surface of the skin. The percentage surface area affected was estimated using the following six classes: 0, 0–10, 10–25, 25–50, 50–75, 75–100%. Incidence of rots (number of fruit with visible rots) was also recorded.

2.5. Data analysis

Fruit that were observed to have severe injuries were removed from the population before estimation of colour and firmness. Statistical analysis was focused on the portion of the gas conditions that represented the complete matrix of gas conditions. The general linear model (GLM) procedure of Minitab (Inc., State College, Pennsylvania) was used to ascertain significant effects caused by each of the atmosphere gases (O_2 and CO_2) and significant interaction effects. Significant differences between treatments were identified using Tukeys' test at 95% confidence level. Significant differences in incidence of injury were analysed with the calculation of the Chi-square statistic for pooled sets of data at each O_2 and CO_2 atmosphere.

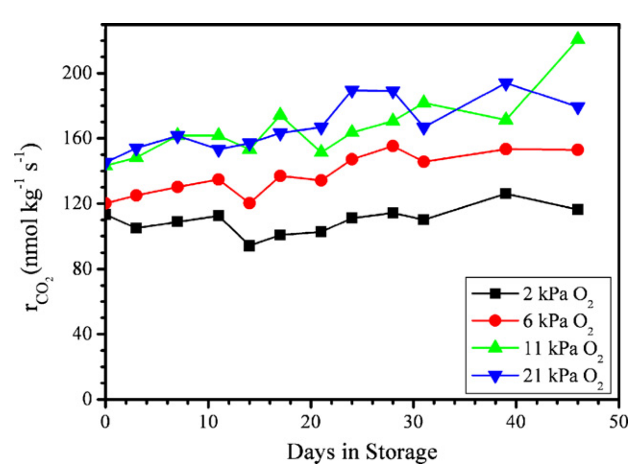

Fig. 2. Rate of respiration (r_{CO_2}) of 'Unique' feijoa fruit during 56 d of storage at 5 °C, 0.2 kPa CO_2 and four different O_2 partial pressures. Similar responses were observed in the other gas treatment mixtures used in the experiment (data not shown).