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Impact of controlled atmosphere scheduling on strawberry and imported avocado fruit

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ABSTRACT

British grown strawberry cv. Sonata and Chilean avocado cv. Hass were exposed to controlled atmospheres (CA) of 15 kPa CO_2 + 5 kPa O_2 (5 °C) and 10 kPa CO_2 + 5 kPa O_2 (5 or 20 °C), respectively, at early, middle or late stages during postharvest storage of avocados and at early and middle stages for strawberries. Real-time respiration rate (RR) was measured during CA storage and regular fruit sampling carried out to assess disease severity, objective colour, ethylene production and firmness. The automated *in situ* set-up used allowed continuous recordings of real-time respiration measurements without disruption to the CA environment. Cold stored strawberry fruit treated for 2.5 d with CA midway through the storage period were firmer and maintained a more vibrant colour despite bursts of increased RR. Furthermore, just 2.5 d of CA was sufficient to extend the shelf-life of strawberries (based on disease incidence) by a further 3 d, as compared to control. Irrespective of timing, RR of avocado stored at 20 °C was reduced while under CA environment; and early CA exposure maintained firmness yet increased the incidence of internal discolouration 7 d after removal from CA. At 5 °C, avocado skin colour and internal discolouration were positively affected by the mid CA treatment. These results are discussed in the context of the targeted use of CA, compared to control, for extending shelf-life, and reducing waste of these two different fruit produces. Furthermore, reducing the length of time required for CA application, which has not previously been explored in avocado or strawberries, would potentially be more energy efficient/cost effective.

1. Introduction

With an ever-increasing global population, new methods to improve food availability and reduce waste have become a priority. One significant cause of food losses occurs when food quality is compromised due to inefficient postharvest handling, including inappropriate gas storage composition and packaging (Terry et al., 2011).

Strawberries (*Fragaria* x *ananassa* Duch.) and imported avocado (*Persea americana* Mill.) are two high value but contrasting fresh produce types available in the UK, with remarkable differences not only in their physiology but also in their supply chain. In the UK market, a significant proportion of strawberry fruit are grown in the UK so that berries can reach the retailer and consumer within 4–7 d from harvest. Whilst, imported avocado undergo a longer transit period (*ca.* one month by ship) from the Southern Hemisphere (viz. South America, South Africa) before arriving at British packing houses, where they can be further stored, ripened and packaged. These two produce types also vary significantly in their physiology and metabolic responses during ripening. For instance, as a climacteric fruit, the respiration rate of avocado can exceed 184 mg kg^{-1} h^{-1} at 20 °C at the onset of ripening (Valle-Guadarrama et al., 2013) coinciding with high levels of ethylene production (> 1180 μg kg^{-1} h^{-1}; Valle-Guadarrama et al., 2013; Basuki et al., 2016). In contrast, strawberry fruit, which are currently classed as non-climacteric, produce lower levels of CO_2 (up to *ca.* 129 mg kg^{-1} h^{-1} at 23 °C) and significantly lower levels of ethylene (Kader 2002; Thompson 2003; Terry et al., 2007). Consequently, these two perishable products provide a useful comparison for gas exchange under different storage conditions including controlled atmosphere (CA).

Low temperature (< 5 °C) is widely used to extend strawberry and avocado storability (Kader 2002; Thompson 2003; Castellanos et al., 2017). However, cold storage alone is often not sufficient to store and transport produce such as avocados between intercontinental markets. Furthermore, cold storage of avocado fruit can lead to chilling injury (CI) (Basuki et al., 2016). Optimum CA conditions for normal ripening of avocado are between 2.5 and 5 kPa O_2, and 5 and 7.5 kPa CO_2, yet incidence of CI was not retarded (Basuki et al., 2016). CA environments (e.g. high CO_2) are known to reduce microbial decay (viz. *Botrytis cinerea)* in strawberries (Almenar et al., 2006; Barrios et al., 2014) and stem-end rot (viz. *Botryodiplodia theobromae* and *Lasiodiplodia*

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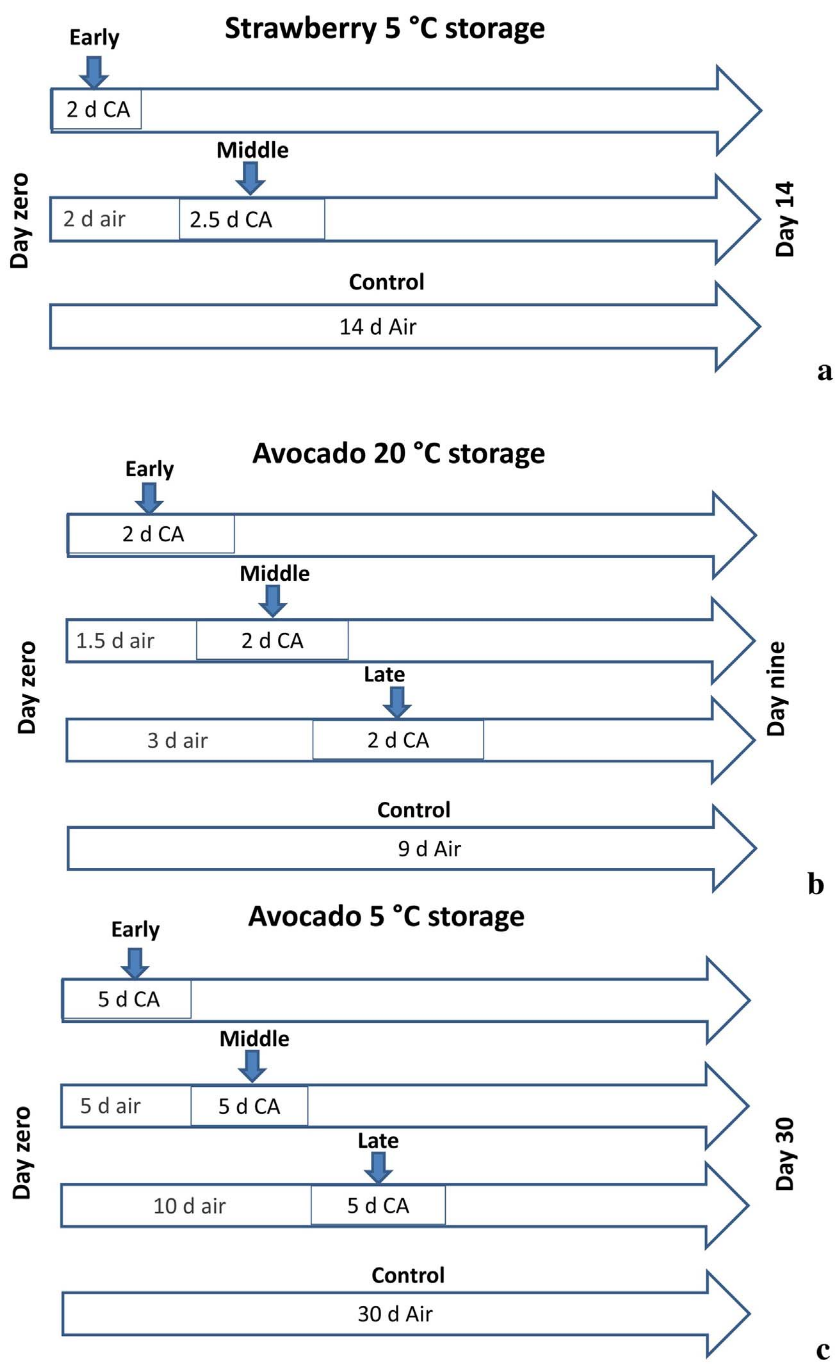

Fig. 1. Schematic of controlled atmosphere scheduling for strawberry (a) and imported avocado fruit stored at 5 °C (b) and 20 °C (c) for different time periods (days [d]).

theobromae) in avocado (Pesis et al., 2002). However, levels exceeding 15 kPa CO_2 can result in CO_2 injury (Barrios et al., 2014).

Depending on the type of produce, metabolic state can significantly vary throughout storage resulting in different challenges for MAP and CA storage. Use of CA to maintain quality of both strawberry and avocado have been developed, but limitations still exist. The efficacy of CA is affected by avocado maturity and cultivar differences which can lead to a build-up of CO_2 and ethylene if gas exchange is not sufficient (Meir et al., 1997; Hertog et al., 2003). Thus, high levels of ethylene generated during the climacteric increase can hasten ripening and senescence. Therefore, successful storage under CA or MAP would require an environment/packaging with rapid gas exchange (Espinosa-Cruz et al., 2014). Strawberry fruit, on the other hand, despite their lower ethylene and CO_2 levels, are highly perishable and especially prone to postharvest disease; hence market shelf-life is very limited. There is a paucity of up to date research investigating the effects of CA on the respiration rate of strawberry and avocado throughout the supply chain and during post-harvest storage. Furthermore, there is a lack of information on how the application of differential CA environments during post-harvest life could conserve strawberry and avocado quality. Targeted CA application has previously been found to be as effective as continuous CA to extend shelf-life of onion during cold storage (Chope et al., 2007); however, this has not been explored for avocado or strawberry fruit. Understanding the effects of respiratory gases on fruit physiology is key to the development of optimum packaging to extend post-harvest shelf-life (Castellanos et al., 2017). The objective of this work was to use real time respiration rate technology as a tool to assess physiological changes throughout cold storage and shelf life of both imported avocado and UK-grown strawberry fruit, and to elucidate the impact of physiologically targeted CA on industrially relevant quality