Postharvest Biology and Technology 128 (2017) 54–62

Contents lists available at ScienceDirect

Postharvest Biology and Technology

journal homepage: www.elsevier.com/locate/postharvbio

Internal disorders of 'Rocha' pear affected by oxygen partial pressure and inhibition of ethylene action

Adriano Saquet[a,b], Domingos Almeida[b,*]

[a] Instituto Federal de Educação, Ciência e Tecnologia Farroupilha, Campus Panambi, Rua Erechim 860, 98280-000 Panambi, RS, Brazil
[b] Instituto Superior de Agronomia, Universidade de Lisboa, Tapada da Ajuda, 1349-017 Lisboa, Portugal

ARTICLE INFO

Article history:
Received 9 November 2016
Received in revised form 10 February 2017
Accepted 12 February 2017
Available online xxx

Keywords:
Adenylate energy charge
Controlled atmosphere storage
Fruit quality
Physiological disorders
Pyrus communis

ABSTRACT

Current technologies allowing the use of extremely low oxygen partial pressures (pO_2), the introduction of 1-methylcyclopronene (1-MCP), and the regulatory prohibition of diphenylamine are changing the conventional storage protocols for pear cultivars. Internal disorders, in particular, severely damage pear quality during controlled atmosphere storage. 'Rocha' pear (*Pyrus cummunis* L.) was stored for 136 d at −0.5 °C in air or under 3.0 and 0.5 kPa O_2 with 0.6 kPa CO_2. Fruits treated with 150 nL L^{-1} 1-MCP were also stored at 3.0 and 0.5 kPa O_2 after 32 d in air following the treatment. Internal disorders did not develop in fruit stored in air (20.8 kPa O_2) or at 0.5 kPa O_2 but affected 10.2% of the fruit stored in 3.0 kPa O_2 after 136 d. 1-MCP increased disorder incidence at 0.5 and at 3.0 kPa O_2. Four types of internal disorders occurred: core browning, white cavity, necrotic cavity, and flesh browning. Low O_2 reduced ethylene production and respiration rates which were further reduced by the treatment with 1-MCP. ATP concentration and adenylate energy charge were higher in fruit stored in air than in those at 3.0 and were generally lowest in fruit at 0.5 kPa O_2. The effect of pO_2 on energy metabolism prevailed over that of 1-MCP treatment. The linkage between ATP and adenylate energy charge (AEC) and the incidence of internal disorders was not strong, since under the same pO_2, 1-MCP enhanced the incidence of disorders with a negligible effect on adenylate nucleotides or AEC. It was not possible to establish a threshold of ATP concentration or AEC below which internal disorder develop. In conclusion, poststorage quality of 'Rocha' pear was better at the extremely low pO_2 of 0.5 kPa than at 3.0 kPa. 1-MCP was detrimental to internal disorders and blocked poststorage softening of 'Rocha' pear stored at 0.5 kPa O_2.

1. Introduction

The main European pear cultivars in the world market are suitable for long-term storage. At −1 to 0 °C and relative humidity higher than 90% pears can be stored in air for 3–6 months (Agar et al., 2000; Wang and Sugar, 2013), after which time postharvest life is limited by advanced ripening (Raese et al., 1999), decay (Spotts et al., 2007), and superficial scald (Calvo et al., 2015). Controlled atmosphere (CA) significantly extends the storage period of pears. The recommended partial pressures of oxygen (pO_2) and carbon dioxide (pCO_2) are specific for each cultivar and growing region. CA-recommendations for pears are rapidly evolving as new technologies allow more precise control of pO_2 and pCO_2, and the dynamic control of gas concentration based on fruit physiological responses, namely changes in chlorophyll fluorescence (Prange et al., 2003), respiratory quotient (Gasser et al., 2008; Weber et al., 2015), and the ethanol accumulation in the fruit or its release into the atmosphere (Veltman et al., 2003a). CA extends the storage life of pear but alters the main causes of postharvest life termination: internal disorders become a major limiting factor under these conditions (Franck et al., 2007; Lum et al., 2016).

'Rocha' pear grown in warm climates is sensitive to superficial scald and internal disorders and both must be addressed to assure poststorage quality. Diphenylamine (DPA), a standard postharvest treatment until 2013, was effective in reducing the incidence and severity of both storage disorders in 'Rocha' pear (Silva et al., 2010; Almeida et al., 2016) and CA-storage recommendations were developed for DPA-treated fruit. The recommended conditions were pO_2 of 2.5–3 kPa, and pCO_2 lower than 0.7 kPa (Silva et al., 2010; Almeida et al., 2016). However, under these CA-conditions the incidence of internal disorders can be high in the absence of DPA (Almeida et al., 2016).

* Corresponding author.
E-mail address: dalmeida@isa.ulisboa.pt (D. Almeida).

http://dx.doi.org/10.1016/j.postharvbio.2017.02.005
0925-5214/

Pears are generally less tolerant than apples to very low pO_2 (Streif et al., 2001; Thompson, 2010). This observation is consistent with the lower internal air volume, higher density, and higher resistance to O_2 diffusion of pear in relation to apple (Ho et al., 2006). Low pO_2 in storage rooms changes the energy status of pear fruit (Saquet et al., 2000; Veltman et al., 2003b), with detrimental consequences in membrane phospholipids and enhancement of internal disorders in 'Conference' pear (Saquet et al., 2003a) and 'Braeburn' apple (Saquet et al., 2003b). Therefore, storage conditions that improve the levels of energy stored in the adenylate nucleotides and the overall cell energy status in pear have been related to lower incidence of internal disorders (Saquet et al., 2000; Veltman et al., 2003b; Franck et al., 2007).

The ethylene action inhibitor 1-methylcyclopropene (1-MCP) became an effective treatment to prevent superficial scald and extend storage life in pear (Argenta et al., 2003; Isidoro and Almeida, 2006; Villalobos-Acuña., et al., 2011; Almeida et al., 2016). However, in contrast with apples, poststorage pear ripening can be impaired by 1-MCP (Chiriboga et al., 2011).

The extension of storage period of 'Rocha' pear in the absence of DPA requires the mitigation of superficial scald and internal disorders. 1-MCP and ultra-low pO_2 storage are two venues to achieve these goals. This study aimed to evaluate the effect of pO_2 and 1-MCP on internal disorders and on overall quality maintenance of 'Rocha' pear during storage. ATP, ADP, and AMP were assessed under several storage conditions in fruit with and without ethylene action inhibition to address the relationship between cell energy status and internal disorders.

2. Materials and methods

2.1. Fruit material

Pear (*Pyrus communis* L. 'Rocha') fruit were harvested at the mature-green stage from an orchard located in Cadaval, Oeste Region, Portugal. The maturity stage at harvest was measured in 3 replicates of 15 fruits each. Fruit had uniform size (60–65 mm), a starch index of 8.2 (1–10 scale), flesh firmness of 52.4 N, total soluble solids (TSS) of 11.2%, titratable acidity of 0.2% expressed in malic acid equivalents, and a skin hue angle of 106.4°. After harvest fruit were drenched with fludioxonil at 580 mg L^{-1} (Scholar®, Syngenta, Basel, Switzerland) and cooled to −0.5 °C.

2.2. 1-MCP treatment and storage conditions

Fruit were stored in 0.55 m^3 cabinets at −0.5 °C (±0.3 °C fluctuation) and 90–93% relative humidity, in air or under two CA-conditions: 0.5 kPa O_2 or 3 kPa O_2 with pCO_2 below 0.6 kPa in each instance (balance N_2). The pO_2 was lowered by flushing the cabinets with N_2 and the final pressure of 0.5 kPa O_2 or 3 kPa O_2 was reached within 26 and 18 h, respectively.

1-MCP generated from SmartFresh™ (Agrofresh, Inc., Springhouse, PA, USA) was applied at a dose of 150 nL L^{-1} for 24 h at −0.5 °C. After the treatment with 1-MCP, the fruit were maintained for 32 d in air before establishment of the CA-conditions indicated above according to the commercial recommendations to prevent ripening blockage. The storage temperature and gas partial

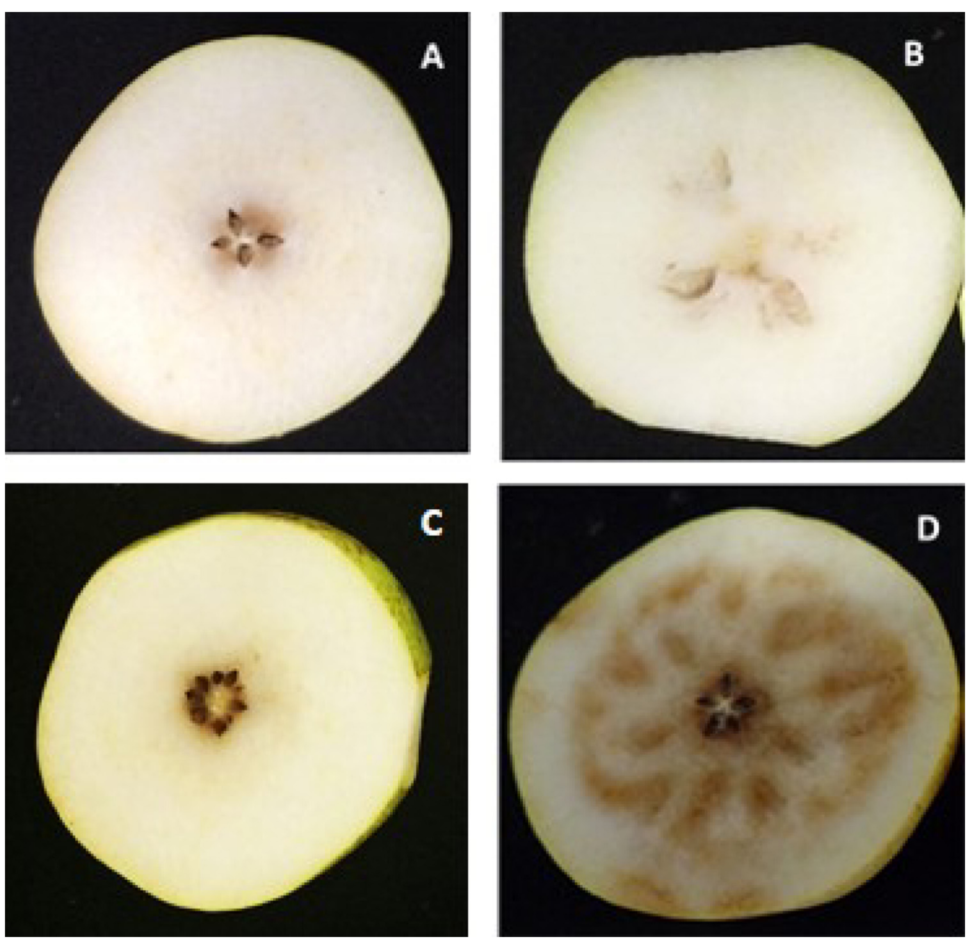

Fig. 1. Internal disorders observed in 'Rocha' pear. Core browning (A), white cavity (B), necrotic cavity (C) and flesh browning (D).