Soft figs shelf life increasing with and 1-methylcyclopropene and cold storage

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ABSTRACT

The best sensorial Brown Turkey figs for the fresh market are the ones harvested soft. However, at this maturity stage, they have a very short shelf life, from two to seven days, depending on environmental conditions, which make their marketing very difficult. This research's goal was to increase the shelf life of soft 'Roxo de Valinhos' figs, a 'Brown Turkey' plant material grown in Brazil, stored under refrigeration, by applying 1-methylcyclopropene (1-MCP), an ethylene inhibitor. Soft 'Roxo de Valinhos' figs were submitted to 1-MCP at 0; 0.5; 1.0 and 1.5 μg. L^{-1} for 24 h in airtight, under refrigeration at 4 ± 1 ºC. Subsequently, fruits were stored for up to 17 days at 4 ± 1 ºC. After removing from refrigerated conditions, fruits were kept for one day at room temperature (22 ºC), and then they were evaluated to determine their physical and chemical features. 1-MCP at 1.5 μg. L^{-1} was able to increase the soft figs shelf life to 12 days.

Keywords: *Ficus carica* L.; 'Brown turkey'; 'Roxo de valinhos'; soft figs; 1-MCP; ethylene inhibitor.

INTRODUCTION

'Brown Turkey' figs (*Ficus carica* L.) are among the main fig's cultivar worldly grown (Silva *et al.*, 2017; Norberto *et al.*, 2018) due to their high rusticity, vigor, and productivity, besides their excellent quality for fresh consume, and industrial processing (Souza *et al.*, 2014; Curi *et al.*, 2019).

Fruits intense metabolic activity is the most important factor for the rapid decreasing in commercial quality, and is directly related to ethylene synthesis, leading to senescence, losses, and decreasing of the storage period (Girardi *et al.*, 2003). Figs climacteric peak routinely occurs before the commercial maturity, in this way they are physiologically mature before fruit softening (Crisosto *et al.*, 2010; Ertan *et al.*, 2019). Due to their soft pulp firmness, Brown Turkey figs are usually harvested when they have 20 to 70% external reddish color (Freiman *et al.*, 2012; Tofanelli *et al.*, 2018). But the best sensorial features in terms of sweetness, acidity, and pulp firmness, occurs when it they are completely soft, what means completely mature (Ingrassia *et al.*, 2017; Sortino *et al.*, 2017). At this point they have a very short shelf life at ambient temperature (from two to four days), which eventually can reach seven days when stored under refrigeration (Lima *et al.*, 2005; Ozkaya *et al.*, 2014; Silva *et al.*, 2018). This fruit characteristic makes almost impossible to transport and sell soft figs under good conditions and, usually, they are affordable just to those who can pick them up directly from the fig tree, and readily eat them.

It is known that works seeking to increase 'Brown Turkey' and 'Roxo de Valinhos' figs shelf life did not solve the problem yet (Ingrassia *et al.*, 2017; Sortino *et al.*, 2017). The 1-methylcyclopropene (1-MCP), an ethylene-inhibiting molecule, has been tested on the 'Bardakci' (Gözlekçi *et al.* 2008); 'Bursa Siyahi' (Ozkaya *et al.*, 2014); 'Albacor' (Villalobos *et al.*, 2018); 'Qing Pi' (Song *et al.*, 2020), 'Brown Turkey', and 'Roxo de Valinhos' fig fruits, obtaining less than seven days of shelf life (Sozzi *et al.*, 2005; Tofanelli *et al.*, 2018). Besides,

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1-MCP effects over post-harvest fig quality depends on the fig cultivar, maturity stage, and storage conditions (Brandes & Zude-Sasse, 2019; Massolo *et al.*, 2019). It is possible to store early harvested firm figs by applying 1-MCP at 5 µl L^{-1} of 1-MCP for 19 days, but soft figs did not increase its shelf life in response to 1-MCP (Sozzi *et al.*, 2005).

The most grown fig in Brazil is 'Roxo de Valinhos', a 'Brown Turkey' plant material introduced by Italian immigrants (Ferraz *et al.*, 2020). The aim of this study was to increase soft 'Roxo de Valinhos' figs' shelf life stored under cold conditions by applying 1-MCP for more than 10 days.

MATERIAL AND METHODS

'Roxo de Valinhos' fig fruits were harvested from five-year-old trees. Only soft fruits, with at least 80% of external reddish color, were harvested. In the laboratory 308 fruits without any injury were selected and placed inside 28 commercial cardboard fig boxes (19 x 9.5 x 3.0 cm) (11 fruits per box) without plastic wrapping. Seven boxes were placed inside each of four hermetic containers, which would receive SmartFresh® that contains 0.14% active ingredient. SmartFresh® at 0 (control); 0.5; 1.0 and 1.5 µg.L^{-1} of active ingredient were previously diluted in 10 mL of distilled water at 40 °C. These concentrations were applied over two sheets of paper towels, which were affixed inside the containers' lids, and then tight closed, to obtain the necessary hermetic condition. Containers were kept at 4 ± 1 °C for 24 hours, when all cardboard boxes were removed, and stored for until 17 days at 4 ± 1 °C. After 0, 2, 5, 8, 11, 14, and 17 days one cardboard box was removed from the cold storage and kept at room temperature (22 °C) during one day for later evaluation of fruit firmness, total soluble solids (SST), total titratable acidity (AT), ratio (ratio between SST and AT), and weight loss (Zenebon *et al.*, 2008). Fruit firmness was performed with the CT3 Brookfield® texturometer with a 10 mm long tip with a setting of 50 mm.min^{-1}, with two opposite readings in the fruit equatorial zone after removing the skin, averaging to obtain the final value. Fruit juice was immediately extracted using a centrifuge and SST was measured with a manual refractometer (°Brix), afterwards AT was measured and expressed in % malic acid (Zenebon *et al.*, 2008). To evaluate weight loss, three figs from each 1-MCP concentration, in addition to the eight fruits per treatment, were previously weighted, and kept under cold temperature until the final storage period and weighted again.

Research was carried out in a completely randomized design, in a 4 x 7 factorial system, with four 1-MCP concentrations (0; 0.5; 1.0 and 1.5 ìg. L^{-1}) and seven refrigerated storage periods (0, 2, 5, 8, 11, 14 and 17 days) with eight fruits per treatment.

Results obtained were subjected to variance analysis, F Test, and polynomial regression analysis with the Software for Analysis of Variance for Balanced Data - Sisvar.

RESULTS AND DISCUSSION

It is known that 1-MCP decreases figs' respiratory rate and ethylene production (Song *et al.*, 2020), allowing to suppose that the respiratory rate and the metabolism decreased in this study. This 1-MCP physiological effect was confirmed by the lower weight loss and soluble solids increasing after the cold storage (Figure 1 and Figure 2).

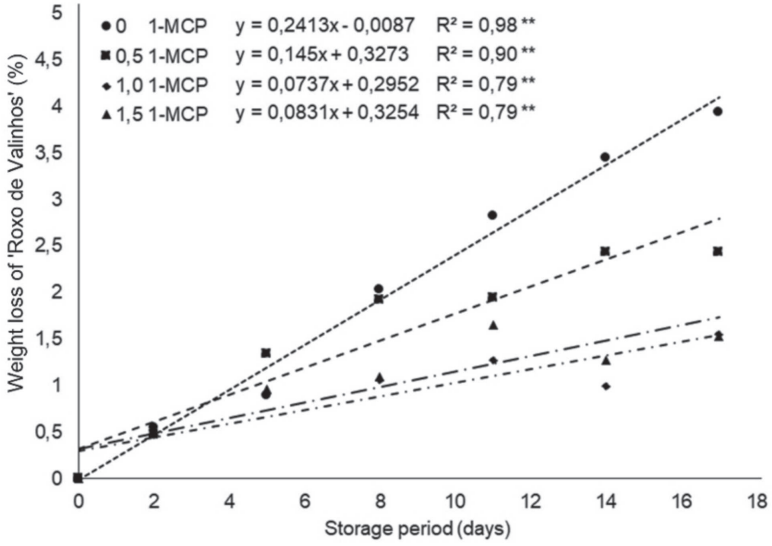

Figure 1: 'Roxo de Valinhos' figs weight loss after applying 1-methylcyclopropene (1-MCP) for 24 h, subsequently kept for up to 17 days stored at 4 ± 1 °C, followed by one day at room temperature.

'Roxo de Valinhos' figs positively answered to 1-MCP by decreasing their weight loss (Figure 1). 'Roxo de Valinhos' figs responded to the 1-MCP and to the refrigerated storage (Figure 1). The highest weight loss without 1-MCP was 3.9%, similar to the one found in 'Qing Pi' figs (4%) without 1-MCP after 16 days storage (Song *et al.* 2020). 1-MCP at the highest doses decreased the weight loss to less than 1.5% after 17 days storage, what is a great result comparing with previous studies. This probably is due to the 1-MCP effect over the fruit metabolism, dehydration and respiration (Ozkaya *et al.*, 2014; Gözlekçi *et al.*, 2008). It is considered that it acts directly on ethylene synthesis, decreasing the ACC oxidase enzyme activity, a catalyst for ACC (1-aminocyclopropane-1-carboxylic acid), and so declining the respiratory peak.

In addition to affecting weight loss, 1-MCP and storage period also influenced the soluble solids content of 'Roxo de Valinhos' figs (Figure 2). Figs without 1-MCP showed an increase in soluble solids, followed by a decrease until the end of the storage period. Soluble solids content after applying 1-MCP showed the expected behavior (Figure 2). Possibly, the respiration rate was lower, and sugar consume for metabolism was delayed, culminating in an increase in the content of soluble solids until the end of the storage. Similar results were observed in figs 'Bursa Siyahi' (Ozkaya *et al.*, 2014) and 'Qing Pi' (Song *et al.*, 2020), demonstrating that the application of 1-MCP delayed the sugar degradation, consequently, delaying their senescence.

Contrary to the soluble solids content, the titratable acidity responded only to the storage period with a small

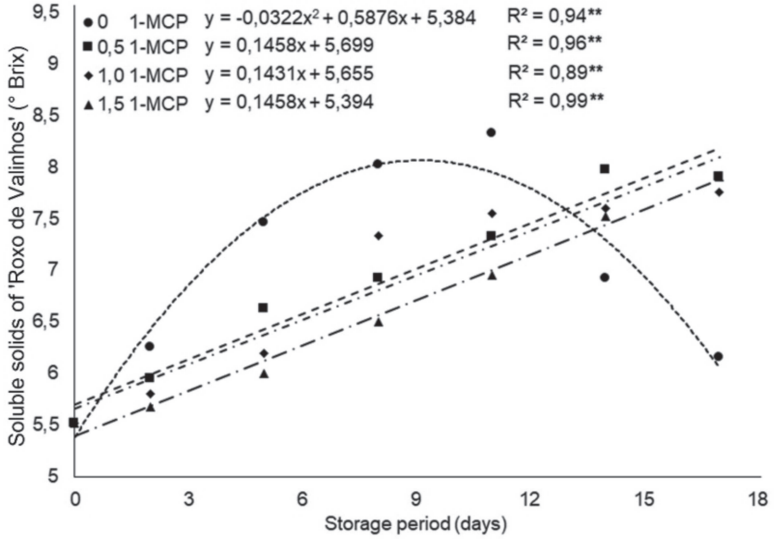

Figure 2: 'Roxo de Valinhos' figs soluble solids content after applying 1-methylcyclopropene (1-MCP) for 24 h, subsequently kept for up to 17 days stored at 4 ± 1 °C, followed by one day at room temperature.

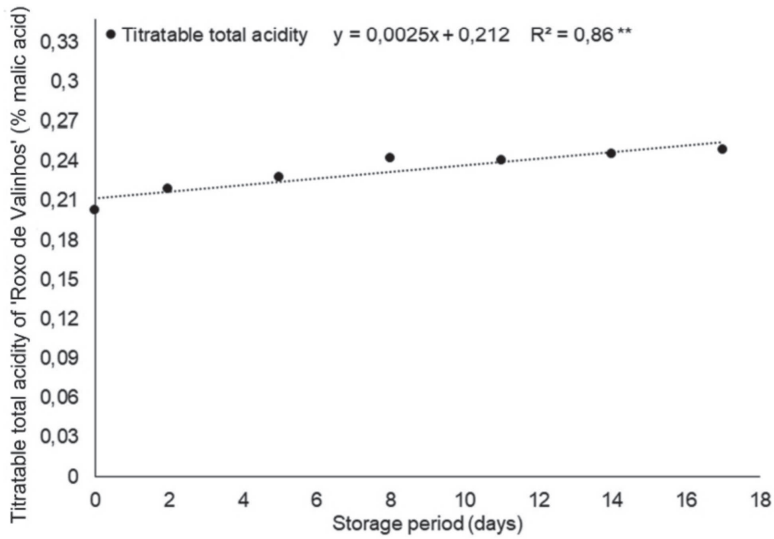

Figure 3: 'Roxo de Valinhos' figs titratable acidity after applying 1-methylcyclopropene (1-MCP) for 24 h, subsequently kept for up to 17 days stored at 4 ± 1 °C, followed by one day at room temperature.

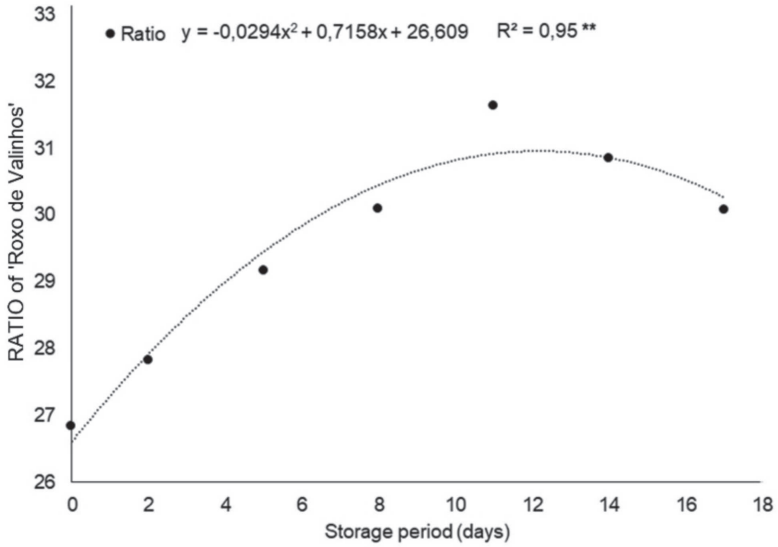

Figure 4: 'Roxo de Valinhos' figs ratio (SST/ AT) after applying 1-methylcyclopropene (1-MCP) for 24 h, subsequently kept for up to 17 days stored at 4 ± 1 °C, followed by one day at room temperature.

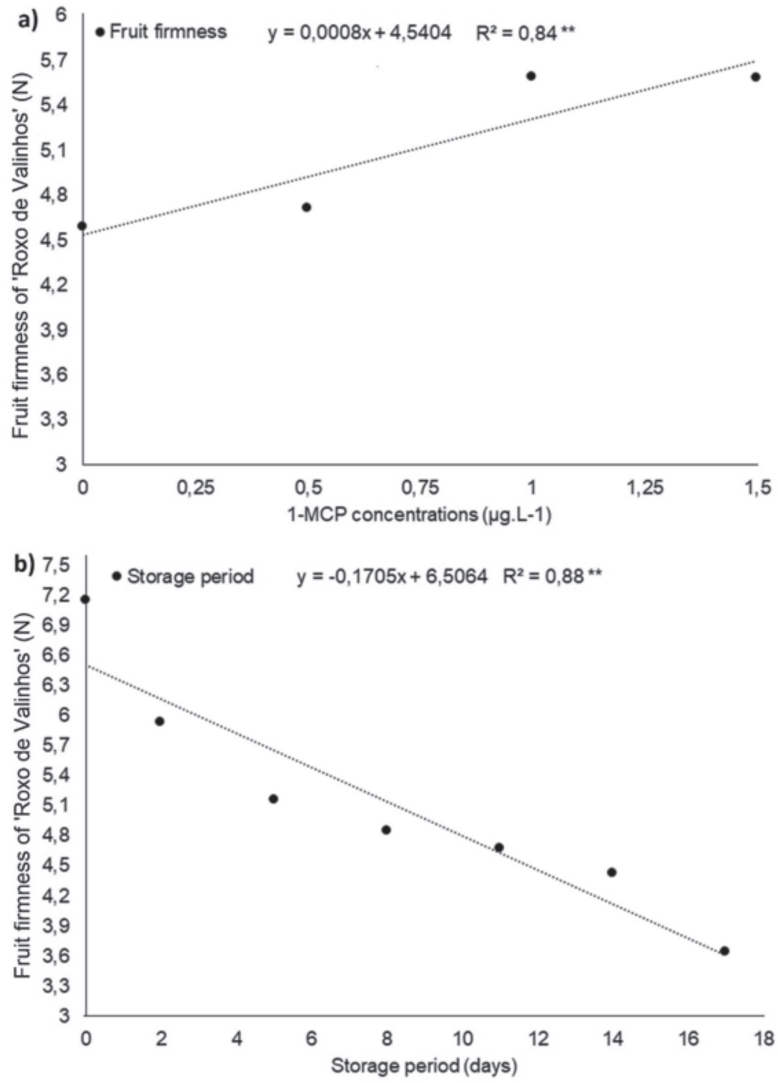

Figure 5: 'Roxo de Valinhos' fruit firmness a) 1-methylcyclopropene (1-MCP) doses; b) storage at 4 ± 1 ° C, for up to 17 days, followed by one day at room temperature.

increase from the beginning to the end of the 17-day storage period (Figure 3). Similarly, it was observed that figs' acidity did not change at all during the storage period (Pinto *et al.*, 2020). However, this was not always observed in all fig cultivars, as may be seen in 'Bardakci' (Gözlekçi *et al.*, 2008), 'Bursa Siyahi' (Ozkaya *et al.*, 2014), 'Albacor' (Villalobos *et al.*, 2018) and 'Qing Pi' (Song *et al.*, 2020), the titratable acidity increased along the storage period, demonstrating that it might be a cultivar characteristic.

With the increase in the soluble solids content, the ratio reached its best relation after 12.1 days of cold storage (Figure 4). A high SST/ AT ratio in fruits is very important and desirable, being one of the most used forms for flavor evaluation (Antunes *et al.*, 2010; Freitas *et al.*, 2015). The same was observed in 'Mission', 'Brown Turkey', 'Calimyrna' and 'Kadota', where riper figs had higher ratio of soluble solids to total acidity than less ripe figs (Crisosto *et al.*, 2010). In a sensory analysis carried out with 'Melanzana' figs, it was identified that the fruits that most pleased the evaluators were those with the highest ratio (Ingrassia *et al.*, 2017), indicating greater sweetness of the fruit in relation to its acidity (Curi *et al.*, 2019).

1-MCP affected figs firmness (Figure 5a), increasing it with the highest 1-MCP dose, and decreasing it during the cold storage (Figure 5b). Fruit's firmness is linked to the ethylene, and the same effect was observed in 'Bardakci' (Gözlekçi *et al.*, 2008), 'Bursa Siyahi' (Ozkaya *et al.*, 2014) and 'Qing Pi' (Song *et al.*, 2020) figs. Ethylene controls the pectin methylesterase (PME) and polygalacturonase (PG) enzymes activity, which promote the pectic substances degradation in the cell wall and, consequently affecting the fruits softening (Antunes *et al.*, 2010; Terra *et al.*, 2014; Álvarez-Herrera *et al.*, 2016).

The good 1-MCP effects related here, which were quite different from other authors that were unable to maintain 'Brown Turkey' figs quality by applying 1-MCP for longer than 7 days (Sozzi *et al.*, 2005), might be explained because we maintained fruits under cold chain. It is known that the low temperature during first hours just after the harvest is crucial to keep fruit quality during the storage (Spagnol *et al.*, 2018), just when 1-MCP is usually applied. The previous worst answer observed in 'Roxo de Valinhos' by Tofanelli *et al.* (2018) can also be attributed to this. In such way, it is very important to apply 1-MCP under cold temperature and keep figs under low temperature to increase their shelf life.

CONCLUSION

'Roxo de Valinhos' figs can be stored under refrigerated condition for up to 12 days by applying 1-meticyclopropene at 1.5 μg. L^{-1}.

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