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Preharvest treatment of growth regulators influences postharvest quality and storage life of cashew apples

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ABSTRACT

Growth regulators may influence fruit development and thus, their postharvest quality. This study aimed to evaluate the effects of preharvest treatment with aminoethoxyvinylglycine (AVG) or gibberellic acid (GA3) on postharvest quality and life of apples of two cashew cultivars, CCP 76 e BRS 189, during cold storage. Growth regulators (180 mg L^{-1}) were applied at maturation stage 1 and apples were harvested at stage 7, ripe. Ripe, treated and control, apples were stored at $3 \pm 2\,^{\circ}C$ for CCP 76 and at $5 \pm 2\,^{\circ}C$, for BRS 189 and evaluated at harvest (0 day) and every 5 days up to 20 days of storage. The influence of growth regulators preharvest treatment on cashew apples differed among cultivars. For BRS 189 apples, GA3 treatment slowed down mass loss, as treated samples lost 0.72% while control lost 0.81%; and avoided the development of undesirable characteristics during storage. GA3-treated samples were statistically firmer, 13.61 N than control, 9.93 N; and together with AVG-treated samples showed a significantly reduced pectin methyl esterase (PME) activity to 1492.88 UA mg^{-1} P when compared to control 2129.87 UA mg^{-1} P. For cv. CCP 76, GA3 treatment also slowed down mass loss, as treated samples lost 0.85% and control, 0.99%, however apples were inapt for consumption after 15 days of storage. GA3-treated samples were statistically firmer, 15.40 N than control, 11.38 N. The constituents of the antioxidant metabolism of both cashew apples varieties were mainly affected by storage period, but not by growth regulators. Therefore, results of preharvest AVG treatment on cashew apple physiology and quality were inconsistent. However, GA3 treatment improved postharvest quality of CCP 76 e BRS 189 cashew apples through reduction of mass loss and firmness loss, without any negative impact on physicochemical variables. GA3 exerted a greater influence on BRS 189 apples which showed, besides lower mass and firmness loss, a better visual appearance and lower cell wall hydrolase PME activity, during storage.

1. Introduction

The cashew tree (*Anacardium occidentale* L.) is native to Brazil, where it plays an important role in economy as a cash crop to the northeastern region. The cashew is constituted of true fruit or nut which has the main economic relevance; and the pseudofruit or fleshy peduncle, also referred to as cashew apple.

The cashew apple has significant ascorbic acid and carotenoids contents and a high antioxidant potential (Lopes et al., 2012). Phenolic compounds as phenolic acids, flavonoids, and tannins also have been identified in cashew apple (Brito et al., 2007; Michodjehoun-Mestres et al., 2009). Despite the nutritional composition, cashew apples are not as commercially important as the nut, mainly due to their high perishability. Besides the great fragility of cashew apple, the growing/producing season is restricted to the second semester of the year, and there is a lack of adequate postharvest managing techniques which, all together contribute to almost 80% loss of apple production. Thus, technologies have been employed as means to maintain postharvest quality as well as extend the storage life of cashew apple, as refrigeration (Moura et al., 2010), gamma radiation (Souza et al., 2009), modified storage atmosphere (Moura et al., 2009) and preharvest calcium application (Figueiredo et al., 2007).

At preharvest, plant growth regulators have been used alone or combined aiming to slow down ripening and preserve the

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fruit quality after harvest. Recently, the plant growth regulators 1-aminoethoxyvinylglycine (AVG) or gibberellic acid (GA3) have been applied to peach, banana and plum in different developmental stages as means to extend their storage life (Amarante et al., 2005; Huang et al., 2014; Steffens et al., 2011). Although, cashew apples do not show an increase in ethylene production nor in respiratory rate during ripening, they responded to exogenous ethylene which affected color changes during maturation process (Nath et al., 2006).

AVG is known to inhibit the ethylene synthesis retarding the physiological events triggered by this hormone, as those specifically related to climacteric fruit maturation or other ubiquitously related to all fruit, as abscission. Inhibition of abscission process is relevant to non-climacteric fruits with short and concentrated production period, as cashew. In apples, AVG reduced preharvest drop, delayed maturation and maintained postharvest quality for longer storage period (Yildiz et al., 2012). AVG increased firmness of plum and peach (Ozturk et al., 2012; Çetinbas et al., 2012) and slowed down ripening of plum, apple, peach and persimmon (Steffens et al., 2011; Petri et al., 2010; Cline 2006). In general, fruits treated at the preharvest with AVG show greater firmness, titratable acidity and soluble solids content, as well as lower incidence of rot and physiological disorders (Steffens et al., 2011).

Meanwhile, gibberellins as GA3 promote flower bud development and fruit establishment, increased stem length of grapes and reduced skin disorders in citrus (Dayan et al., 2012; Mesejo et al., 2010; Zoffoli et al., 2009). GA preharvest treatment was effective in maintaining firmness of plums (Steffens et al., 2011), delaying color changes and preserving quality of bananas (Huang et al., 2014). A firmer fruit allows an extended harvest and storage period and, consequently, improves marketing conditions.

Despite the data on plant growth regulators effect on fruit physiology, the influence of preharvest AVG or GA3 applications on postharvest quality of cashew apple has not been investigated. Thus, this work aimed to investigate the effects of AVG and GA3 preharvest application on postharvest quality and the storage life of cashew apple.

2. Material and methods

2.1. Plant material and treatments

This study was conducted at the Experimental Station of Embrapa Tropical Agroindustry in Pacajus-CE, Brazil (lat. 4°11′26,62”S, lon. 38°29′50,78”W), with an annual precipitation average of 652 mm. The soil was Typic Quartzipisamment according to Brazilian System of Soil Classification (Solos, 2013). Pseudofruit from trees of dwarf cashew *(Anacardium occidentale* L.) cultivars CCP 76 and BRS 189 were used in this study. Cultivar CCP 76 trees were 20 years old, spaced at 6 × 4 m, while those of cultivar BRS 189 were 9 years old and spaced at 8 × 6 m, under non-irrigated conditions.

Preharvest growth regulators application were performed on cashews at stage 1, green-colored apple and nut (Lopes et al., 2012) and five days later, they were harvested (approximately 40 days after anthesis) at stage 7, ripe and fully colored apple, orange for CCP 76 and red for BRS 189. Based on a preliminary experiment, where AVG and GA3 were tested at concentrations of 60, 120 and 180 mg L^{-1} on BRS 189 and CCP 76 cashew apples, the 180 mg L^{-1} concentration resulted in firmer apples at stage 7, the commercial products ReTain® with active ingredient AVG and ProGibb® with active ingredient GA3, both at 180 mg L^{-1} in water plus surfactant 0.5% Tween 20 (v/v), were applied manually with a costal sprayer onto the canopy of trees of each cashew cultivar.

A total of 200 trees were used in this study which were divided into 5 plots, a plot of 40 trees was non-treated control group; for cv. BRS 189, 40 trees were treated with AVG and 40 trees treated with GA3; and for cv. CCP 76, 40 trees were treated with AVG and 40 trees with GA3. Plots on the same row where separated by at least one tree, and rows of treated trees were separated from other rows by an untreated row in the middle, to avoid any drift effects.

Ripe cashew apples (stage 7) from all treatments were manually harvested, placed in polypropylene trays covered with PVC film (15 μ) and stored at 3 ± 2 °C for CCP 76 or at 5 ± 2 °C, for BRS 189 (UR 90 ± 2%) during 20 days. Samples consisted of four repetitions (trays) with three apples, each and evaluations were done at harvest (0 day) and every 5 days up to 20 days of storage, when pulp was processed in domestic centrifuge Walita® and stored at −18 °C, until analyses.

2.2. Quality attributes

Soluble solids content was determined by refractometry, as described by AOAC (2005) using a digital refractometer (Atago® model N1, Kirkland, USA) with automatic temperature compensation and results were expressed in °Brix (concentration of sucrose w/w). Titratable acidity (TA) was evaluated as determined by AOAC (2005) and results were expressed as% of malic acid. Total sugar content was quantified by Anthrone method through absorbance at 620 nm and results were expressed as% fresh mass (FM) (Yemm and Willis, 1954). Mass loss was calculated considering the weight at harvest and after 20 days of storage, and results were expressed as %. Appearance was assessed subjectively through a scale of four grades, as grade 0 means good visual appearance, apparent resistance to mechanical damage, pleasant flavor, absence of damages; and grade 4 means juice leakage, fungal growth, unpleasant flavor, inapt for consumption. Apples were considered apt for consumption up to grade 2. Total protein content was determined according to Bradford (1976) using bovine serum albumin as standard and results in mg g^{-1} FM were used to calculate specific activity of the enzymes evaluated.

2.3. Firmness and associated variables

Firmness was evaluated five times on opposite sides of each apple with a penetrometer (Magness-Taylor model FT-011) to measure the maximum force required to penetrate tissue to a depth of 5 mm using a 8-mm diameter cylindrical, results were expressed in Newton (N).

Biological membrane integrity was estimated by the lipid peroxidation (LP) degree determined by the formation of malondialdehyde (MDA) based on the method described by Zhu et al. (2008). Processed pulp (2 g) was homogenized in 10 mL of 0.1% trichloroacetic acid (TCA) and centrifuged at 3300*g* for 20 min, at 4 °C. The supernatant (750 μL) was collected and added to 3 mL 0.5% thiobarbituric acid (TBA) in 20% TCA and incubated at 95 °C for 30 min. Following incubation, tubes were immediately cooled in ice bath and centrifuged at 3000*g* for 10 min. Absorbance at 532 nm was measured, corrected for unspecific turbidity by subtracting from absorbance at 600 nm and MDA content was calculated using an extinction coefficient of 155 nmol cm^{-1} and expressed as nmol MDA g^{-1} FM.

Cell wall integrity was evaluated through the specific activities of cell wall hydrolases. Polygalacturonase (PG, E.C. 3.2.1.15) activity was evaluated as samples (12 g) were homogenized with 25 mL of ice-cold water. The homogenate was filtered through Whatman No. 1 filter paper, centrifuged at 3248*g* for 10 min at 4 °C and then, the precipitate was suspended in 10 mL of distilled water and centrifuged as before. The precipitate was suspended in 20 mL of 1.0 N NaCl, stirred for 1 min and then, adjusted to pH 6.0 and let to rest