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Postharvest *trans*-resveratrol and glycine betaine treatments affect quality, antioxidant capacity, antioxidant compounds and enzymes activities of 'El-Bayadi' table grapes after storage and shelf life

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ABSTRACT

The effect of exogenous *trans*-resveratrol (1.6×10^{-5} M, 1.6×10^{-4} M and 1.6×10^{-3} M) and glycine betaine (GB) (10, 15 and 20 mM/L) treatments on quality, antioxidant capacity, antioxidant compounds and enzymes activities of 'El-Bayadi' table grapes after 30 days of cold storage plus 2 days of shelf life were evaluated. *trans*-resveratrol especially at medium and high rates decreased decay after storage compared to control. GB, only at the high rate, decreased decay. Weight loss was higher at the low rate of *trans*-resveratrol than control. However, GB had no effect on weight loss. TSS, acidity and pH slightly changed during storage and were not affected by *trans*-resveratrol and GB. Firmness decreased after storage compared to initial, but was higher at *trans*-resveratrol and GB treatments than control. Both *trans*-resveratrol and GB retained higher total phenols concentration after storage than control. The high rate of *trans*-resveratrol and GB retained higher total flavonoids concentration than control. Vitamin C concentration was not affected by the applied treatments. Both *trans*-resveratrol and GB increased peroxidase (POD) and polyphenoloxidase (PPO) activities compared to control. Polygalacturonase (PG) activity greatly decreased by *trans*-resveratrol treatments. Xylanase activity increased by the medium rate of *trans*-resveratrol and the high rate of GB. Antioxidant capacity measured by DPPH assay decreased after storage in control compared to initial, but was higher at *trans*-resveratrol than other treatments. GB at low rate showed higher antioxidant activity than control. Also, antioxidant capacity measured by ABTS assay decreased after storage in control compared to initial, but was higher at the high rate *of trans*-resveratrol than other treatments. It is concluded that exogenous *trans*-resveratrol and GB treatments retained quality of 'El-Bayadi' table grapes after cold storage and shelf life and being suggested as natural alternatives to synthetic chemicals.

1. Introduction

Table grapes (*Vitis vinifera* L.) possess high nutritional and healthiness values due to their high content of especially dietary antioxidants (Zhou and Raffoul, 2012; Fahmi et al., 2013). 'El-Bayadi' is one of the main white table grape cultivars growing in the kingdom of Saudi Arabia (KSA) especially in Taif region. This cultivar is characterized by high productivity and excellent sensory quality but, the berry skin is relatively thin that limits its storability and marketing (Al-Qurashi and Awad, 2013). Proper cold storage conditions are critical to maintain grapes quality and reduce postharvest losses. However, the cold storage life of table grapes is limited by fungal attacks especially *Botrytis cinerea*, softening and weight loss (Droby and Lichter, 2004). The use of synthetic chemicals e.g. fungicides, sulfur dioxide (SO_2) fumigation (Luvisi et al., 1992; Droby and Lichter, 2004) together with cold storage is rather restricted due to rising consumers concerns on both human health and the environment. Thus, alternative safer tools to control fungus attack and maintain grapes quality during cold storage and shelf life are critically required. Accordingly, pre or postharvest treatments with ethanol reduced postharvest decay in grapes (Karabulut et al., 2003; Lichter et al., 2002, 2003; Lurie et al., 2006; Chervin et al., 2009; Al-Qurashi and Awad, 2013) as well as in other fruit e.g. citrus and

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stone fruit (Yuen et al., 1995; Margosan et al., 1997). Inorganic salts such as calcium chloride and sodium bicarbonate treatments showed antimicrobial activity in some grapes cultivars (Nigro et al., 2006; Chervin et al., 2009; Al-Qurashi and Awad, 2013). The use of modified atmosphere packaging (MAP) treated with natural fungicides has been suggested as alternative tool to SO_2 fumigation (Artes-Hernandez et al., 2006). Controlled atmosphere (CA) storage inhibited pathogens growth on table grapes (Yahia et al., 1983). In this respect, rachis browning limits the use of CA storage (Crisosto et al., 2002; Retamales et al., 2003). Postharvest ultraviolet (UV-C) radiation treatment induced stress responses connected with the induction of pathogen resistance system (Nigro et al., 1998; Sanchez-Ballesta et al., 2006; Romanazzi et al., 2006, 2012; Crupi et al., 2013; Freitas et al., 2015). This treatment increases the biosynthesis of stilbenes (resveratrol) and other antioxidant polyphenolics that improve resistance of berry tissues to pathogens (Nigro et al., 1998; Romanazzi et al., 2006, 2012). Such bioactive antioxidant compounds are mainly located in the outer layers of berries and can play a critical role in human against degenerative diseases such as cancer and ageing (Bertelli et al., 1995; Jang et al., 1997; Hung et al., 2000). In grapes, the biosynthesis of stilbenes via the phenylpropanoid pathway (Langcake and Pryce, 1977) is considered a critical defense system against stress and fungal attack. Grapes stilbenes are deriving mainly from *trans*-resveratrol (3,4′,5-trihydroxystilbene) (Regev-Shoshani et al., 2003). Resveratrol is produced by both leaves and berries and mainly present in the berry skin (Romero-Perez et al., 2001). Resveratrol proved broad antifungal activity (a natural antibiotic) especially against *B. cinerea* (Gonzalez Urena et al., 2003; Jimenez et al., 2005). As antioxidant compound, resveratrol may also affect several physiological aspects of fruit during storage (Gonzalez Urena et al., 2003; Jimenez et al., 2005). Postharvest dipping in *trans*-resveratrol (1.6×10^{-4} M) maintained quality, sensory and nutritional value of apples, grapes and tomatoes compared to control (Jimenez et al., 2005). Also, *trans*-resveratrol reduced water loss and maintained firmness during storage with no negative impact on fruit (Jimenez et al., 2005). Cherukuri (2007) reported that exogenous *trans*-resveratrol treatment at different concentration (1.6×10^{-3} M, 1.6×10^{-4} M and 1.6×10^{-5} M) on Satsuma mandarin increased total phenolics, vitamin C and total carotenoids concentration and the antioxidant capacity of fruit. Glycine betaine (GB) is a natural compatible solute that function as a photosynthetic pigment and membrane stabilizing agent and osmoregulator in many plant species (Robinson and Jones, 1986; Genard et al., 1991; Ashraf and Foolad, 2007; Mansour, 2000; Mohanty et al., 2002; Yang et al., 2003). Exogenous application of GB enhanced low temperature tolerance of plants and frost damage of young grapes shoots (Mickelbart et al., 2006). Foliar spray of GB at 2 mM enhanced freezing tolerance of strawberry plants (Rajashekar et al., 1999). Also, foliar spray of GB at different rates (50 and 100 mM) increased antioxidant enzymes and enhanced photosynthesis of maize plants under salinity stress condition (Nawaz and Ashraf, 2009). There are, however, little available information on the effect of postharvest GB application on fruit and vegetables quality and storability. Hurme et al. (1999) reported that postharvest dipping of Shredded Iceberg lettuce in GB at 0 to 1.0 mM/L, packed in 25 microm polypropylene film and stored for 8 days at 5 °C, maintained sensory quality, especially at 0.2 M/L. Fugui et al. (2013) reported that postharvest dipping of ‘Zhongnong 8’ cucumbers in GB at 0, 5, 10, and 15 mM/L and stored at 4 °C decreased lipoxygenase (LOX) activity but increased peroxidase (POD) and catalase (CAT), restrained malondialdehyde (MDA) and hydrogen peroxide (H_2O_2) accumulations, especially at 10 mM/L. The objective of the current study was, therefore, to evaluate the response of ‘El-Bayadi’ table grapes to exogenous *trans*-resveratrol and GB treatment as an attempt to maintain and assure quality during storage. In this study, the effects of *trans*-resveratrol and GB on antioxidant capacity, antioxidant compounds and related enzymes activities of ‘El-Bayadi’ table grapes were evaluated.

2. Materials and methods

2.1. Plant materials and experimental procedure

A commercial drip irrigated vineyard of ‘El-Bayadi’ table grape cultivar was selected in Taif region, KSA during 2014 growing season. Uniform samples of bunches were picked at commercial maturation (13–14 Brix% and 0.6–0.7% acidity) and directly transferred to the horticulture laboratory at King Abdulaziz University, Jeddah. A completely randomized experimental design with four replicates (four bunches of each) was established. Bunches of each treatment/replicate were dipped either in *trans*-resveratrol (Baoji Guokang Bio-Technology Co., Ltd., China) solution (1.6×10^{-5} M, 1.6×10^{-4} M and 1.6×10^{-3} M; referring to 0.00365, 0.0365 and 0.365 g/L, respectively) or glycine betaine (Danisco, Finland) solution (10, 15, 20 mM/L; refereeing to 1.172, 1.757 and 2.343 g/L, respectively) for 10 s. A surfactant (Tween 20 at 1 ml/L) was added to all solutions. A control treatment in which bunches were dipped only in water plus Tween 20 surfactant was included. Following air draying, all treatments/replicates were weighted and stored in perforated plastic bags inside cardboard cartons with air holes for 30 days at 0 °C ±1 and 90–95% relative humidity (RH) plus 2 days of shelf life at 20 °C ±2 and 60–65% RH. Before dipping, samples of 30 berries per replicate were collected from all bunches for initial quality measurements. After 30 days of cold storage plus 2 days of shelf life, samples of 30 berries from each treatment/replicate were collected for quality measurements. Also, additional samples of berries were collected before and after storage and kept at −80 °C for later biochemical determinations.

2.2. Decay incidence and weight loss determination

The decay incidence by storage rot was recorded. The total loss in weight was calculated on initial weight basis.

2.3. Firmness, TSS, acidity and vitamin C measurements

Berry firmness was recorded independently in each of the 30 berries per replicate by a digital basic force gauge, model BFG 50N (Mecmesin, Sterling, Virginia, USA) supplemented with a probe of 11 mm diameter that measure the force required just to break the berry and the results expressed as Newton. A homogeneous sample was prepared from these 20 berries per replicate for measuring total soluble solids (TSS), acidity, vitamin C, total phenols, and soluble tannins. Total soluble solids (TSS) was measured as Brix% in fruit juice with a digital refractometer (Pocket Refractometer PAL 3, ATAGO, Japan). Titratable acidity was determined in distilled water diluted berry juice (1:2) by titrating with 0.1N sodium hydroxide up to pH 8.2, using automatic titrator (HI 902, HANNA Instrument, USA) and the results expressed as a percentage of tartaric acid (g of tartaric acid per 100 mL grape juice). Ascorbic acid (vitamin C) was measured by the oxidation of ascorbic acid with 2,6-dichlorophenol endophenol dye and the results expressed as mg/100 mL grape juice (Ranganna, 1979).

2.4. Preparation of the methanol extract

Two grams of berries peel tissue were extracted by shaking at 150 rpm for 12 h with 20 ml methanol (80%) and filtered through filter paper No. 1. The filtrate designated as methanol extract.