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Methyl jasmonate enhances wound-induced phenolic accumulation in pitaya fruit by regulating sugar content and energy status

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ABSTRACT

Pitaya fruit pretreated with methyl jasmonate (MeJA) were subjected to wounding stress and effects on quality, energy metabolism and phenolic accumulation were investigated. Results showed that MeJA pretreatment effectively inhibited the wound-induced decrease of ascorbic acid, organic acids and prevented the deterioration of flesh color of fresh-cut pitaya fruit. Simultaneously, MeJA pretreatment effectively accelerated the consumption of sugars, stimulated higher enzyme activities in energy metabolism, triggered higher energy status and further enhanced the wound-induced phenolic accumulation in fresh-cut pitaya. These findings demonstrated that MeJA pretreatment could partially maintain most of the quality attributes of fresh-cut pitaya fruit. Moreover, MeJA together with wounding stress can synergistically induce the utilization and transformation of sugars to provide essential precursors and energy for the wound-induced phenolic accumulation in fresh-cut pitaya fruit.

1. Introduction

Pitaya fruit (*Hylocereus undatus*) is a well known tropical fruit with great commercial value owing to its special nutritional and functional components (Dembitsky et al., 2011) and fresh-cut pitaya fruit has become more popular recently on account of its convenience and freshness. During fresh-cut processing, the tissue is inevitably subjected to wounding stress, which will induce defense responses to produce more secondary metabolites at the injured site or site adjacent to defend and heal the wounding damage (Saltveit, 1997; Cisneros-Zevallos, 2003). It has been confirmed that wounding stress induces phenolic biosynthesis and enhances antioxidant capacity in various fresh-cut fruits and vegetables such as lettuce (Zhan et al., 2012), mango (Robles-Sánchez et al., 2013), potato (Torres-Contreras et al., 2014), carrot (Surjadinata and Cisneros-Zevallos, 2012; Han et al., 2017) and pitaya fruit (Li et al., 2017a,b). These findings indicated that wounding can be used as an effective and practical means to enhance the phenolic accumulation and improve the nutritional quality while maintaining the sensory quality of certain postharvest product in short-term storage.

The biosynthesis of phenolics in plants depends on the phenylpropanoid pathway together with the primary metabolism including glycolysis, pentose phosphate pathway and shikimate pathway (Becerra-Moreno et al., 2012; Jacobo-Velázquez and Cisneros-Zevallos, 2012). Sugars are the major substrates in primary metabolism, utilization of sugars in glycolysis and pentose phosphate pathway can produce essential precursors and serve as substrates for the biosynthesis of phenolics (Jacobo-Velázquez and Cisneros-Zevallos, 2012). Moreover, the transformation of sugars and organic acids through glycolysis and tricarboxylic acid cycle play crucial roles in the production of energy which is essential for physiological metabolism (Ferrier, 2013). Energy supply in plant cells is closely associated with physiological metabolism of postharvest fruits and vegetables (Jiang et al., 2007). It was reported that insufficient energy supply resulted in the browning of longan pericarp while pure oxygen could effectively decrease skin browning by enhancing the energy status (Su et al., 2005). Yi et al. (2010) found that adequate endogenous adenosine triphosphate (ATP) could increase the level of total phenolics in litchi fruit, sufficient exogenous energy supply is essential for retarding the pericarp browning and improving desease resistance in postharvest litchi fruit. Wounding stress could effectively stimulate the production of energy in cut carnation flowers and exogenous ATP treatment retarded its senescence and effectively extended the postharest longevity (Song et al., 2008). In consequence, sufficient energy supply is essential for quality maintenance or defense response under biotic or abiotic stress.

As one of the phytohormones in plant, methyl jasmonate (MeJA) has been confirmed to be an important signaling molecule participating in plant defense reactions responding to environmental stress (Cheong and Choi, 2003). Jin et al. (2009a,b) has reported that MeJA could effectively

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Table 1
Effect of MeJA pretreatment and wounding stress on nutritional quality parameters and flesh color of pitaya fruit during 48 h of storage at 15 °C.[a]

Storage (hour)	Treatment	Total phenolics (g kg^{-1})	AsA (g kg^{-1})	L*	a*	b*
0	Control	0.69 ± 0.014	0.15 ± 0.002	65.64 ± 1.62	−3.78 ± 0.17	6.58 ± 0.28
12	Control	0.76 ± 0.036bA	0.14 ± 0.002aA	64.90 ± 2.15abA	−3.79 ± 0.22aB	6.40 ± 0.19bA
	MeJA	0.83 ± 0.038bcA	0.14 ± 0.002aA	65.47 ± 1.19aA	−3.82 ± 0.16aA	6.63 ± 0.29abA
	Wounding	0.91 ± 0.011aB	0.13 ± 0.002bA	63.27 ± 2.62bA	−3.81 ± 0.20aA	6.95 ± 0.38aC
	MeJA + Wounding	0.97 ± 0.016aB	0.13 ± 0.003bA	63.90 ± 2.36abA	−3.88 ± 0.15aA	6.71 ± 0.46abB
24	Control	0.77 ± 0.015cA	0.14 ± 0.004aA	64.91 ± 1.55aA	−3.83 ± 0.11aB	6.49 ± 0.19cA
	MeJA	0.75 ± 0.028cB	0.15 ± 0.002aA	64.92 ± 2.26aA	−3.79 ± 0.12aA	6.57 ± 0.33cA
	Wounding	1.02 ± 0.045bA	0.13 ± 0.003bA	62.98 ± 3.22aA	−3.79 ± 0.13aA	7.38 ± 0.47aB
	MeJA + Wounding	1.12 ± 0.034aA	0.13 ± 0.004bA	63.75 ± 2.65aA	−3.77 ± 0.18aA	6.92 ± 0.36bB
36	Control	0.78 ± 0.016cA	0.14 ± 0.002aA	64.86 ± 2.93aA	−3.88 ± 0.14aB	6.57 ± 0.19cA
	MeJA	0.75 ± 0.017cB	0.14 ± 0.002aA	65.67 ± 3.01aA	−3.91 ± 0.12aA	6.46 ± 0.28cA
	Wounding	1.03 ± 0.007bA	0.12 ± 0.002cA	62.08 ± 4.90aA	−3.89 ± 0.12aA	7.72 ± 0.34aAB
	MeJA + Wounding	1.14 ± 0.030aA	0.13 ± 0.001bA	64.14 ± 3.75aA	−3.82 ± 0.23aA	7.28 ± 0.43bA
48	Control	0.67 ± 0.019cB	0.14 ± 0.004aA	65.10 ± 2.61abA	−3.61 ± 0.23aA	6.57 ± 0.34cA
	MeJA	0.75 ± 0.055cB	0.14 ± 0.004aA	66.03 ± 3.43aA	−3.88 ± 0.17bA	6.62 ± 0.25cA
	Wounding	0.99 ± 0.025bA	0.12 ± 0.000cA	62.87 ± 2.59bA	−3.80 ± 0.12bA	7.95 ± 0.48aA
	MeJA + Wounding	1.10 ± 0.015aA	0.13 ± 0.002bA	64.04 ± 1.74abA	−3.85 ± 0.15bA	7.44 ± 0.38bA

[a] Data are expressed as the mean ± SE (n = 3). Values with different letters indicate statistically significant differences at $p < 0.05$. Lowercase letters represented significant difference among treatment factors, capital letters represented significant difference among storage time factors.

Table 2
Effect of MeJA pretreatment and wounding stress on the content of sugars in pitaya fruit during 48 h of storage at 15 °C.[a]

Storage (hour)	Treatment	TSS (%)	Sugars (g kg^{-1})	
			Fructose	Glucose
0	Control	15.29 ± 0.09	28.13 ± 0.86	104.36 ± 4.99
12	Control	15.03 ± 0.30aB	24.68 ± 0.82aC	96.53 ± 1.79aA
	MeJA	14.08 ± 0.08bC	22.98 ± 1.64aC	97.78 ± 5.14aA
	Wounding	12.70 ± 0.11cA	22.83 ± 0.82aA	89.83 ± 1.77abA
	MeJA + Wounding	11.81 ± 0.16dA	16.09 ± 0.93bA	83.81 ± 2.18bB
24	Control	14.50 ± 0.15aC	25.44 ± 1.15aBC	100.06 ± 1.69aA
	MeJA	14.31 ± 0.32aB	24.83 ± 0.49abB	101.05 ± 3.63aA
	Wounding	12.66 ± 0.05bA	22.26 ± 0.49bA	88.02 ± 1.18bA
	MeJA + Wounding	11.97 ± 0.09cA	16.87 ± 0.58cA	86.11 ± 1.68bA
36	Control	15.77 ± 0.22aA	26.63 ± 0.73aB	99.40 ± 2.15abA
	MeJA	13.99 ± 0.12bC	24.56 ± 0.58aB	101.89 ± 2.89aA
	Wounding	12.73 ± 0.16cA	18.68 ± 0.25bB	89.26 ± 2.75bcA
	MeJA + Wounding	11.84 ± 0.16dA	16.10 ± 0.47cA	83.91 ± 3.59cB
48	Control	15.06 ± 0.17aB	29.36 ± 0.90aA	96.33 ± 2.64aA
	MeJA	14.81 ± 0.22bA	27.63 ± 0.73aA	93.42 ± 2.15abB
	Wounding	12.81 ± 0.12cA	21.05 ± 0.67bA	85.81 ± 2.16bcA
	MeJA + Wounding	11.78 ± 0.14dA	16.00 ± 1.25cA	80.67 ± 3.06cC

[a] Data are expressed as the mean ± SE (n = 3). Values with different letters indicate statistically significant differences at $p < 0.05$. Lowercase letters represented significant difference among treatment factors, capital letters represented significant difference among storage time factors.

increase the level of total phenolics induced by pathogen attack or chilling stress in peach fruit. Research on wounding stress also showed that MeJA treatment significantly stimulated the wound-induced biosynthesis of phenolics in fresh-cut purple-flesh potatoes (Reyes and Cisneros-Zevallos, 2003), carrots, celery, lettuce and nectarine (Heredia and Cisneros-Zevallos, 2009a,b). Jacobo-Velázquez et al. (2015) also found that JA in combination with wounding stress play crucial roles in modulating the ROS level and activating the primary and secondary metabolisms to induce higher phenolic accumulation in wounded carrots. However, most of the previous studies were focused on the secondary metabolism of phenolic biosynthesis under abiotic stress, little research was done about the relationships among the wound-induced carbohydrate utilization, energy status and phenolic accumulation in fresh-cut fruits. It is still unclear how MeJA regulate the sugar content and energy metabolism of fresh-cut pitaya fruit under wounding stress. Consequently, this study aimed to research the effect of MeJA pretreatment on the content of total phenolics, sugars and organic acids, in association with energy metabolism of fresh-cut pitaya fruit, in order to evaluate the carbohydrate utilization and energy status in relation to phenolic accumulation in pitaya fruit under abiotic stress.

2. Materials and methods

2.1. Chemical reagent

Sodium carbonate (Na_2CO_3), Folin-Ciocalteu reagent, 1,10-phenanthroline, Iron (iii) chloride ($FeCl_3$), trismetyl aminomethane, sucrose, D-mannitol, ethylenediamine tetraacetic acid and polyvinylpyrrolidone were obtained from Beijing Solarbio Science & Technology CO., Ltd. (Beijing, China). Magnesium sulfate (Mg_2SO_4), Sodium orthovanadate (Na_3VO_4), Sodium nitrate ($NaNO_3$), Potassium chloride (KCl), *p*-Phenylenediamine, Sodium succinate and ammonium molybdate were obtained from Shanghai Macklin Biochemical Co., Ltd. (Shanghai, China). Ethanol, phosphoric acid and perchloric acid were obtained from Guangdong Guanghua Sci-Tech Co., Ltd. (Guangzhou, China). Methyl jasmonate, acetonitrile, methanol, and other chemicals were obtained from Sigma Chemical Co. (St. Louis, MO, USA). Acetonitrile and methanol were reagents of HPLC-grade; the other chemical reagents were of reagent grade.