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ScienceDirect
Food Chemistry 105 (2007) 521–527
Food Chemistry
www.elsevier.com/locate/foodchem

Effects of ethylene and 1-methylcyclopropene (1-MCP) on lignification of postharvest bamboo shoot

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Received 30 November 2006; received in revised form 29 January 2007; accepted 2 April 2007

Abstract

The effects of 1-methylcyclopropene (1-MCP) and ethylene on quality and lignification of postharvest bamboo shoot (*Phyllostachys praecox* f. *prevernalis*.) were examined during storage at 20 °C. Disease incidence and respiration rate of control bamboo shoot increased, while total sugar (TS) content decreased quickly. Reducing sugar (RS) content and ethylene production increased at first and then decreased quickly. Increased shoot firmness after harvest was positively correlated with higher lignin and cellulose contents. Accumulation of lignin in flesh tissue was also positively correlated with activities of phenylalanine ammonia lyase (PAL), cinnamyl alcohol dehydrogenase (CAD) and peroxidase (POD). Ethylene treatment enhanced firmness, respiration rate and ethylene production increase, promoted TS decrease, but retarded disease incidence. 1-MCP treatment resulted in lower firmness, higher disease incidence and TS content, inhibited respiration rate and ethylene production, delayed the activities of PAL, CAD and POD, and retarded lignin and cellulose accumulation. The present findings show that ethylene is involved in bamboo shoot lignification, and suggest that 1-MCP could be used commercially to control this important postharvest physiological disorder in bamboo shoot.

Keywords: Bamboo shoot; Lignification; 1-methylcyclopropene; Ethylene

1. Introduction

Bamboo shoot is the young, tender stalk emerging from nodes of the (pseudo-) rhizome of bamboo plants. The edible parts consist of meristematic cell tissue with regions of rapid cell division and differentiation, enveloped in protective, non-edible leaf sheaths (Kleinhenz et al., 2000). They are frequently used in Asian cuisine. Commercially canned bamboo shoot is common, but fresh, locally grown bamboo has far better flavour and texture and the market share of fresh shoots may increase in the future.

Studies on causes of postharvest deterioration of quality in bamboo shoots are limited. In local markets of China, bamboo shoot is usually stored and sold at ambient temperatures. However, during transport from production sites into urban centres, the deterioration of bamboo shoot is characterized by an unusual increase in firmness and toughness of the flesh from the cut end toward the tip during storage. The increase in firmness may be the result of tissue lignification due to a wound (Xi, Luo, Cheng, Feng, & Zhang, 2001). The plant hormone ethylene is produced in response to various kinds of environmental stress, including wounding (Henstrand & Handa, 1989), and wound-induced ethylene is involved in plant lignification (Liu & Jiang, 2006). Therefore, inhibiting ethylene biosynthesis or its action may play an important role in slowing the lignification process and extending storage-life of bamboo shoot. Lignin comprises polyphenolic polymers derived from the oxidative polymerization of different monolignols, including *p*-coumaryl alcohol, coniferyl alcohol and sinapyl alcohol (Whetten & Sederoff, 1995). The biochemistry of lignin biosynthesis is a complex process, involving the action of several enzymes of primary phenylpropanoid metabolism, as well as of lignin biosynthetic branching enzymes (Boudet, 2000). Following the

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doi:10.1016/j.foodchem.2007.04.007

deamination of phenylalanine to cinnamic acid by phenylalanine ammonia-lyase (PAL), the lignin biosynthetic branching pathway is operative and the key enzymes involved are hydroxylases, *O*-methyl transferases, COA ligases and alcohol dehydrogenases (Kuboi & Yamada, 1978). In addition, peroxidases are also involved in the last step for the polymerisation of cinnamyl alcohols to form lignin (Imberty, Goldberg, & Catesson, 1985).

1-Methylcyclopropene (1-MCP) has been shown to compete with ethylene for the binding site on the ethylene receptor in plant tissue, which prevents ethylene from exerting its physiological action (Sisler & Serek, 1997). 1-MCP has a non-toxic mode of action, a negligible residue and is active at very low concentrations (E.P.A., 2002); it has been considered non-toxic for humans and the environment (Blankenship & Dole, 2003). It has been used experimentally on fruits and vegetables including, broccoli (Fan & Mattheis, 2000; Ku & Wills, 1999), parsley leaf (Ella, Zion, Nehemia, & Amnon, 2003), green asparagus (Liu, Lv, & Jiang, 2003), lettuce (Saltveit, 2004), and cucumber (Nilsson, 2005). These reports indicate that 1-MCP has commercial potential to control ripening and senescence in harvested fruits and vegetables.

To our knowledge, there is no study on the role of 1-MCP in postharvest quality loss and lignification of bamboo shoots. To understand whether 1-MCP can be commercially practical for bamboo shoot, it is important to determine how it affects the lignification process, so that it can be used in a predictable and reliable manner by the industry. The present study was performed to characterise the physiological and biochemical responses of bamboo shoot to ethylene and 1-MCP treatment and to evaluate its ability as a postharvest tool for regulating the lignification of bamboo shoot. The effects of 1-MCP and ethylene treatment on firmness, disease incidence, total sugar (TS) and reducing sugar (RS) content, respiration and ethylene production, lignin and cellulose content, and the activities of PAL, CAD and POD were examined during storage at 20 °C.

2. Materials and methods

2.1. Plant materials

Bamboo shoot (*P. praecox* f. *prevernalis.*) was harvested from a plantation in Lin'an, Zhejiang Province of China. The shoot was then packed in fiberboard cartons, and transferred to the laboratory in 3 h, where shoot of uniform size and freedom from blemishes were selected.

The shoots were divided into nine sets of 120. Three replicates were used for each of the following treatments: (1) control shoot (0 $\mu l\, l^{-1}$ of 1-MCP or ethylene), (2) 1 $\mu l\, l^{-1}$ of 1-MCP, (3) 500 $\mu l\, l^{-1}$ of ethylene, applied for 8 h at 20 °C in an airtight 200 l container. The treated shoots were then stored at 90% relative humidity at 20 °C for 12 days. Shoot firmness, disease incidence, respiration and ethylene production were assessed every three days. Shoot flesh samples (about 100 g each) were frozen in liquid nitrogen and stored at −70 °C until used for the measurement of total sugar (TS), reducing sugar (RS), lignin and cellulose contents, and PAL, CAD and POD activities.

2.2. Texture measurement

Texture measurements were conducted using a texture analyzer (TA-XT2i, Stable Micro Systems Ltd, UK), incorporating a 5 mm diameter probe. Firmness was measured on the middle of the shoot. At least eight shoots were measured for each treatment and the firmness was expressed as Newton (N).

2.3. Disease incidence

Disease incidence was measured by observing visible fungal growth or bacterial lesions on the shoot surface, and the percentage of infected shoot was recorded every 3 days.

2.4. RS and TS contents determination

Frozen shoot samples (5 g) were ground and extracted for 30 min with 50 ml of ethanol at 25 °C. The mixture was centrifuged at 14,000*g* for 15 min and 5 ml of the supernatant were brought to 50 ml with H_2O. The content of RS was determined spectrophotometrically at 520 nm, using dinitrosalicylic acid as a colouring agent, according to Miller (1959). For TS determination, the samples were first hydrolyzed with 0.1 M HCl for 10 min and then processed as described above. Results were expressed as g of glucose per 100 g fresh fruit.

2.5. Respiration and ethylene evaluation

Respiration was measured as CO_2 production. Three pairs of bamboo shoots (two bamboo shoots per chamber) from each treatment were enclosed in a chamber and air was passed through the chamber. The effluent air was connected to a GXH-3051 (Institute of Junfang Scientific Instrument of Beijing, China) infrared gas analyzer (IRGA) and respiratory rate was measured. The results were expressed as ml of $CO_2\, h^{-1}\, kg^{-1}$ fresh weight.

For ethylene determination, three pairs of bamboo shoots (two shoots per jar) from each treatment were enclosed in about 1000 ml air-tight jars for 1 h at 20 °C. A 1 ml gas sample, collected by syringe, was taken for ethylene determination. The samples were injected into a SP 6800-A gas chromatograph (Lunan Chemical Engineering Instrument Ltd, Shandong Province, China) equipped with a flame ionization detector and an alumina column.

2.6. Lignin and cellulose determination

About 5 g of frozen samples were extracted four times with 50 ml 1% (v/v) 11 M HCl in methanol for 1 h, each