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Effects of postharvest curing treatment on flesh colour and phenolic metabolism in fresh-cut potato products

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The flesh colour and phenolic metabolism in potato tuber during curing and after cut were investigated. Result indicated that postharvest curing not only changed phenolic metabolism during curing, but also improved fresh-cut colour for 12 days after fresh cut. Significantly lower PAL and higher phenolic content and PPO activities during curing treatment and fresh-cut potatoes were detected compared to the control, which lead to the lower browning in the slices from curing treated potatoes. HPLC analysis revealed that amounts of total phenolics, chlorogenic acid, gallic acid and protocatechuic acid were induced by curing and highly accumulated in the curing treated potatoes. Our results demonstrated that phenolic metabolism played an important role in the control of browning of fresh cut potato after curing.
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1. Introduction

Potato (*Solanum tuberosum*) is the third largest food crop in world. In 2010, the worldwide production of potatoes reached 324 million tones. As global living standards increase, so too is the demand for fresh-cut potatoes. However, just like many fruits and vegetables, fresh-cut potatoes are prone to browning after cut. This turns out to be the major limitation for their shelf life (Cantos, Tudela, Gil, & Espín, 2002; Ma, Wang, Hong, & Cantwell, 2010; You et al., 2012) and prevents fresh-cut potatoes from being a more popular consumer choice. Browning may be the symptom of an ongoing degenerative process such as the damaging of cell compartmentalization (Marangoni, Palma, & Stanley, 1996), as well as the interaction of phenolic compounds (substrates) and polyphenol oxidases (PPO) that are activated after the cut surface contacted with oxygen (Degl'Innocenti, Pardossi, Tognoni, & Guidi, 2007). Browning may also be the result of an active inductive process, requiring de novo synthesis of PAL and the consequent accumulation of phenolic compounds (Saltveit, 2000). Although high phenolic compound activities are associated with high potential of browning (Thybo, Christiansen, Kaack, & Petersen, 2006), they also have positive benefits such as enhancing the antioxidant capacity of plant tissue, mainly related to its role of eliminating reactive oxygen species (ROS) and free radicals (Rechner, Pannala, & Rice-Evans, 2001). Many polyphenols, especially phenolic acids, are directly involved in the response of plants to different types of stress. These chemicals contribute to healing by lignifications of damaged areas, and possess antimicrobial properties by increasing concentrations after pathogen infection. Chlorogenic acid and caffeic acid are highly accumulated in potato peel, rather than in the flesh inside of the potatoes. Phenolic oxidation reactions alter the quantity of polymerized substances, which in turn directly impacts the quality of foods, particularly in colour and organoleptic characteristics. Such changes may be beneficial (as is the case with black tea) or undesirable (browning of fruit) to consumer acceptability. For fresh-cut potatoes, a correlation between browning and PAL activity is found only during the first 4 days after wounding (Cantos et al., 2002). No significant correlation was found between either rate or degree of browning and PPO, POD and total or individual phenolics. The mechanism of browning in potato tuber fresh-cut is still very obscure.

Various approaches have been applied to extend the shelf life of fresh-cut potatoes. These methods include use of chemical compounds and plant extracts (Oms-Oliu et al., 2010), as well as modified atmosphere packaging that exclude oxygen from the environment (Kang & Saltveit, 2003; Ma et al., 2010). However, these anti-browning means are generally constrained due to their high cost, low efficiency or potential health hazards. Therefore, it is

Abbreviations: PAL, phenylalanine ammonia lyase; PPO, polyphenol oxidase; 4Cl, 4-coumarate coenzyme A ligase; C4H, cinnamate 4-hydroxylase; CK, control; EL, electrolyte leakage; PVPP, polyvinyl polypyrrolidone; NaOCl, sodium hypochlorite.

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desirable to develop a simple, safe and cost-effective method to extend the shelf life of fresh-cut potatoes for commercial use.

Curing is a normal practice after potato harvested to promote dormancy and extend postharvest storage life, by preventing decay caused by microorganism during storage (Hide & Cayley, 1983, 1987). Curing at 15 °C for 14 days in dry conditions reduced the incidence of skin spot from 70% prick wounds infected down to 4%. In damp conditions, however, curing only reduced the problem down to 53% (Hide & Cayley, 1987). Kim and Lee (1992) reported that reconditioning of potato improved chip colour by reduce no enzymatic browning during high temperature frying. However, the biochemical changes related to phenolic metabolism and enzymatic browning in cured potato tuber flesh and after cutting remains unclear.

To date, no information is available on the effect of postharvest curing treatment on fresh-cut potatoes in terms of colour, detailed physiological and biochemical changes. Accordingly, the objective of the present study is to investigate the effect of postharvest curing on the colour of fresh-cut potatoes, and to understand possible mechanism by measuring respiration, membrane leakage, PAL, PPO activities and phenolic content during curing and the subsequent fresh-cut shelf life period.

2. Materials and methods

2.1. Plant material and curing treatment

Potatoes (*S. tuberosum, cv* Netherlands #7) were purchased from freshly harvested local wholesale market, Tai'an, Shandong Province, China. After transported to the laboratory, non-damage and non-defective tubers were selected for 10-days curing treatment and then used for fresh-cut experiment. The potato fresh cut experiments using curing treated potato tubers were repeated for four years from 2010 to 2013. The flesh colour and phenolic metabolism changes related to browning were investigated with freshly harvested potatoes both during curing of intact potatoes and after curing period for fresh-cut potatoes in the year of 2013, in which the individual phenolic compounds were analysed by High Performance Liquid Chromatography (HPLC). The results of different experiments in different years were very similar in colour value, overall visual quality, and PPO, PAL activity of fresh-cut potatoes. The data presented here were from the results of 2013 to make sure all information comes from same plant materials.

Curing treatment: Potatoes were packed in Polyethylene (PE) plastic bags and put in a thermostat-controlled cabinet for 10 days. One group was stored at 16 ± 1 °C for curing, while the other group was stored at 2–3 °C (commercial storage temperature in China) as control (CK). Three samples were taken at 0, 5, 10 days, during curing treatment period.

2.2. Fresh cut experiment

After 10 days curing treatment, potato tubers were removed from both temperature storage (curing and control) and used for fresh-cut experiment. The tubers were hand-peeled and cut into 5 mm thick slices, which were immediately rinsed in 50 ppm NaOCl (pH 7.0) for 5 min. The excess water was removed by draining and blotting with cheesecloth, and the slices were packed into PE bags, stored at 2–3 °C. The slices were removed from cold storage after 0, 3, 6, 9 and 12 days. Randomly selected individual slices (8 pieces) per replicate and 3 replicates per sample were collected and analyzed. The analysis included determination of colour change, respiration, and conductivity as well as total and individual phenolic compounds, PPO, PAL enzyme activities.

2.3. Visual quality assessment

Visual quality was examined in accordance with the sensory evaluation standards (Ma et al., 2010). The overall visual quality was evaluated on a 9–1 scale, with 9 as freshly cut, equaled to excellent, with no defects; 7 as very good, with minor defects; 5 as fair, with moderate defects; 3 equaled poor, with major defects; and 1 indicated inedible. A score of 5 was considered the limit of salability and shelf-life was defined at the days required to reach a score of 5.

2.4. colour measurement

The surface colour of slices was determined with a Minolta CR-400 colourimeter. The L^*(lightness), a^* (reddish–greenish) and b^* (yellowish–bluish) indexes of the CIELAB colourimetric system were used to evaluate the colour change of the potato samples. Each slice was measured twice (each side), 8 individual slices from each replicate were measured. (16 measurements were carried out for each replication and three replications for each treatment at each time point.)

2.5. Enzyme assays

Randomly selected potato slices were collected at 0, 3, 6, 9, 12 days after fresh cut and frozen immediately by liquid nitrogen. The samples were then grinded with liquid nitrogen into frozen powder by an analytic mill (IKA A11 basic; IKA Werke GmbH & Co. KG, Staufen, Germany), and stored at −80 °C until used. PPO activity was analysed based on the method described by Galeazzi, Sgarbieri, and Constantinides (1981). One g of frozen powder was homogenized with 4 mL of phosphate buffer (pH 7.0) and 0.1 g insoluble polyvinylpolypyrrolidone (PVPP), centrifuged at 10,000×*g* for 15 min at 4 °C, and the supernatant was used for analysis. The reactive mixture consisted of 0.1 ml of enzyme extracts, 2 ml of 200 mM phosphate buffer (pH 6.8) and 0.5 mL of 20 mM catechol solution. Enzyme activity was measured by the increase in absorbance at 410 nm. One unit of enzyme activity was defined as the increase in absorbance of 0.01 per min under assay conditions. PPO activity was expressed as unit of activity per mg protein per h. Protein content was measure as described by (Bradford, 1976) from the same extraction buffer at pH 7.0.

PAL activity was measured as previously described by Martinez-Tellez and Lafuente (1997), with slight modifications. 1 g frozen powder described as above PPO assay was homogenized with 4 mL of 50 mM borate buffer (pH 8.5), centrifuged at 10,000×*g* for 15 min at 4 °C. 2 ml buffer (pH 8.5) and 1 ml of 20 mM L-phenylalanine was added to two individual tubes, 0.3 ml of enzyme solution (from supernatant) was added to one of the tubes and 0.3 ml water was added to the other tube. Absorbance at 290 nm was measured twice (before and after reaction tubes were incubated at 40 °C for 1 h). One unit of PAL activity was defined as the amount of enzyme produced as an increase of 0.01 absorbance units in 1 h. PAL activity was expressed as unit of activity per mg protein per h.

2.6. Determination of phenolic

HPLC method was used for individual phenolic compounds analysis. The phenolic compounds were extracted according to the method (Zhou, Zeng, Shi, & Xie, 2008) with minor modifications. 0.2 g frozen flesh powder obtained in same method as enzyme assay were vortexed with 0.8 ml methanol (MeOH, 80%, formic acid 1%) then extracted over night at 4 °C in refrigerator. The extraction mixture was sonicated at 30 °C for 30 min, and centrifuged at 10,000×*g* for 30 min. The residue was re-extracted with

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