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Light exposure reduced browning enzyme activity and accumulated total phenols in cauliflower heads during cool storage

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ABSTRACT

Effects of continuous light exposure (24 μmol m^{-2} s^{-1}) on browning enzyme activity and total phenol (TP) content in fresh cauliflower heads were investigated during 7 d storage at 7 °C using darkness as the control. Results showed that light exposure inhibited polyphenol oxidase activity (PPO) by 26% and peroxidase (POD) by 16%, as well as lowering the browning index (BI) by 33%, compared to darkness, at the end of storage. Light exposure also induced 43%, 35%, and 20% increases in phenylalanine ammonia lyase (PAL) activity at 1, 3, and 5 d storage, respectively, thus accumulating 41% more *de novo* TP content than in darkness after 7 d storage. In addition, vitamin C content deteriorated during storage under both light and dark conditions, with light exposure preserving vitamin C content 30% more than in darkness. However, light exposure accelerated fresh weight loss, with the largest value of 1.8% at the end of storage.

1. Introduction

Consumers demand fresh and high quality produce with minimal changes in nutritional and sensory properties during processing and storage. Non-thermal processing is considered to keep produce quality attributes better than traditional thermal processing (Oms-Oliu et al., 2010). Light exposure is an emerging non-thermal approach to preserve the overall quality of fresh fruit and vegetables by inactivating undesirable enzymes and delaying nutrient deterioration (Manzocco et al., 2009; Zhan et al., 2012a,b). In comparison with traditional chemical methods, light exposure treatment has advantages of non-toxicity, cheapness, freedom of residues, and is environmentally friendly (Manzocco et al., 2009).

Cauliflower (*Brassica oleracea* L.) is popular vegetable mainly sold fresh, although there has been increasing interest in commercialization as a minimally processed or frozen product in recent years (Sanz-Cervera et al., 2007). The main postharvest problem of fresh cauliflower is tissue browning, along with floret opening, stem firmness loss, and undesirable odor development, which directly decreases shelf-life and consumer purchase.

Our previous research found that a combination of 24 μmol m^{-2} s^{-1} continuous light exposure and 7 °C storage temperature was effective in preserving minimally processed broccoli sensory and nutritional quality (Zhan et al., 2012b). Cauliflower is very similar to broccoli in characteristics; in both cases the edible part is the immature inflorescence. The most notable difference is the presence of pigmentation in broccoli and the total absence of pigments in cauliflower.

The objective of this study was to investigate the influence of continuous 24 μmol m^{-2} s^{-1} light exposure on fresh cauliflower head browning during 7 d cool storage. Browning enzymes such as polyphenol oxidase (PPO), peroxidase (POD), and phenylalanine ammonia lyase (PAL) activities, total phenols (TP), as well as browning index (BI) were assayed. In addition, the vitamin C content and fresh weight loss were also analyzed.

2. Materials and methods

2.1. Sample preparation

Cauliflower (*B. oleracea* L.) heads were harvested at commercial maturity stage. The harvested heads were defoliated and selected for uniformity of color and size. Each selected head was wrapped with perforated polypropylene film separately to imitate commercial packaging conditions. A total of 90 heads were prepared and randomly divided into two groups. These two groups, 45 heads in each group, were arranged in one layer under light (24 μmol m^{-2} s^{-1}) and dark conditions at 7 °C, respectively. The light illumination was obtained from T8 fluorescent lights with power of 36 W and luminous flux of 2088 LM (Foshan Electrical

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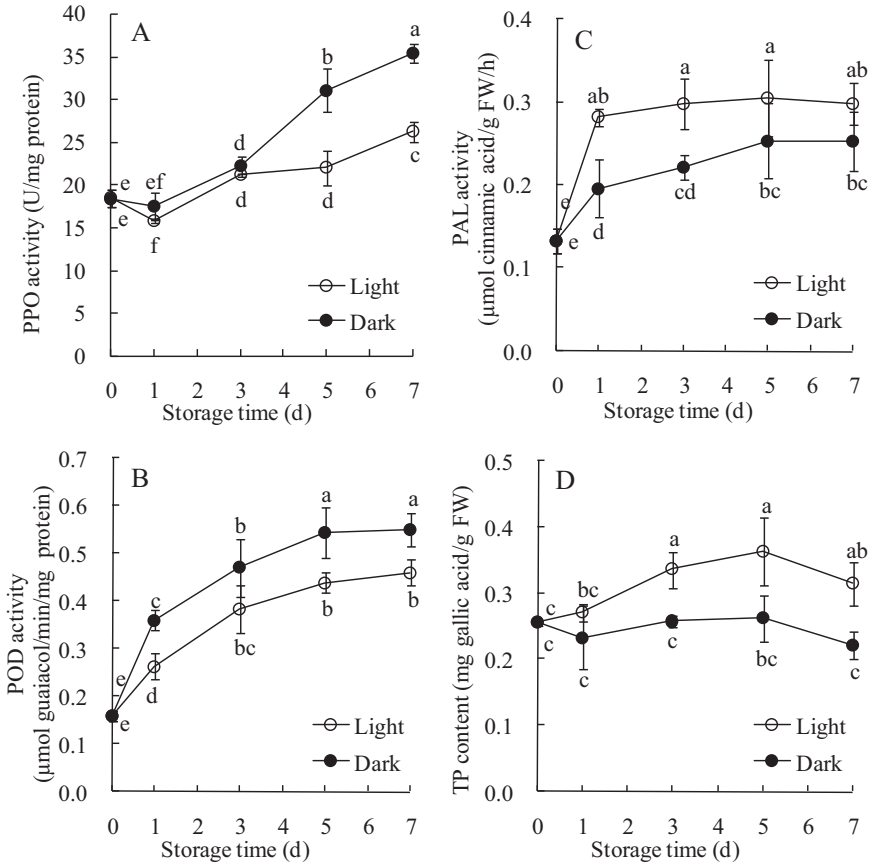

Fig. 1. Effects of light exposure on PPO (A), POD (B), and PAL (C) activities and TP content (D) in cauliflower heads stored at 7 °C for 7 d. Each value is the mean ($n = 3$) ± SD.

and Light Co. Ltd., Foshan, China) equipped in light chambers. The light intensities reached on the package film surface were measured with an illuminometer (TES-1330A, TES electrical electronic corp. Taibei, Taiwan).

2.2. PPO, POD, and PAL activities, TP and protein content assay

PPO, POD, and PAL enzymes were extracted and assayed according to the method of Zhan et al. (2012a) with slight modifications. In brief, at each sample day, cauliflower heads from each treatment were divided into individual florets, which were mixed before sampling. For PPO and POD enzyme extraction, 100 g of fresh florets were homogenized in 200 mL of 50 mM sodium phosphate buffer (PBS, pH 7.0). For PAL extraction, 100 g of fresh florets were homogenized in 200 mL of 50 mM PBS (pH 8.0). The total phenolic content was measured using the Folin–Ciocalteu procedure (Singleton and Rossi, 1965). Briefly, 100 g of fresh florets were homogenized and extracted in 100 mL methanol and the extract was centrifuged at 15,000 × *g* at 4 °C for 20 min. The assay involved a mixture of 100 μL aliquot of the methanol extract with 500 μL of Folin–Ciocalteu reagent. After standing for 3 min, 400 μL of 7.5% sodium carbonate/water (w/v) was added and the contents of the tubes were thoroughly mixed before incubation at 20 °C for 30 min. The absorbance at 760 nm wavelength was read and the result was expressed as milligrams gallic acid per gram of fresh weight. The soluble protein content of enzyme extracts was assayed according to the Bradford (1976) method.

2.3. BI, vitamin C content, and fresh weight loss assay

Cauliflower head browning often started from a spot, thus direct color measurement was not truly representative of browning degree. To overcome this shortcoming, head tissue browning was assessed visually using a browning index (BI) by measuring total browning areas on each head. BI was estimated as in our previous description (Zhan et al., 2012a). For each condition, triplicates including 9 heads were scored according to their browning area based on the following browning scale standard: 0 = no browning, 1 = browning spots, 2 = slight browning (<1/5), 3 = moderate browning (1/5–1/4), 4 = moderate-serious browning (1/4–1/2), 5 = serious browning (>1/2). The BI was calculated by the following formula: BI = ∑(browning scale × percentage of corresponding of heads within each scale). Heads with BI more than 2.0 were considered unmarketable.

Vitamin C content was measured by 2,6-dichlorophenolindophenol titration (AOAC, 1995). Fresh weight loss was estimated by regularly weighing the same heads at various storage time.

2.4. Data analysis

The data were analyzed using SPSS (version 11.0) and the results were expressed as the means ± SD. One-way ANOVA was applied to compare the effect of light condition on measured parameters using least significant difference (LSD) test at 0.05 confidence level.

3. Results and discussion

3.1. Effect of light exposure on PPO and POD activity

PPO activity increased from 1 to 7 d storage regardless of storage conditions. As expected, the light treatment significantly inhibited PPO activity from 5 d storage, lowering PPO activity by 29% and 26% at 5 and 7 d storage respectively, compared with darkness, (Fig. 1A).

POD activity in cauliflower heads stored under both light and dark conditions displayed similar increasing patterns during the whole storage. Light exposure