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Influence of allicin on quality and volatile compounds of fresh-cut stem lettuce during cold storage

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Chemical compounds studied in this article:
Diallyldisulfide (PubChem CID: 16590)
Diallylsulfide (PubChem CID: 11617)
β-Elemene (PubChem CID: 10583)
Ethanol (PubChem CID: 702)
1-Butanol (PubChem CID: 263)
Ascorbic acid (PubChem CID: 54670067)
1-Hexanol (PubChem CID: 8103)
Hexanal (PubChem CID: 6184)
Chlorophyll a (PubChem CID: 6477652)
Chlorophyll b (PubChem CID: 46926108)

ABSTRACT

Lettuce (*Lactuca sativa* L. var. *angustana Irish*) was cut into slices and treated with water (control), 2 g/l and 10 g/l allicin respectively, followed by cold storage for 6 days (4 °C, >90% relative humidity). Allicin showed a positive effect on color, while it did not influence fresh weight loss and firmness. The contents of ascorbic acid, soluble protein and soluble sugar in lettuce were maintained by allicin, and degradation of chlorophyll was also delayed. Volatile components were analyzed by gas chromatography-mass spectrometry (GC–MS). The content of two main quality contributors, 1-hexanol and hexanal were much higher in allicin treated samples than control, while the generation of some volatiles such as ethanol, 1-butanol and β-elemene that brings negative influence on the fragrance was significantly inhibited. Conclusively, Allicin treatment helped maintain appearance color, nutrition characteristics and volatile aroma compounds preferred by consumers, therefore this technology could be developed for maintaining the quality of minimally processed lettuce.

1. Introduction

Minimally processed lettuce has gained a large share of the fresh-cut vegetables market, and a growing demand for this time saving and convenient product has occurred in many countries. Convenience, however, comes at the expense of a series of quality attributes. Browning has been suggested as the main factor limiting the quality of fresh-cut lettuce through enzymatic oxidation of phenolic compounds (Chen, Zhu, Zhang, Niu, & Du, 2010), but other factors such as the growth of microorganism, the degradation of chlorophyll and texture, the loss of nutritional ingredient and aroma could also shorten storage life of the product (Buta, Moline, Spaulding, & Wang, 1999). Consumers often buy the first time based on the appearance, but repeat purchases are driven by specific quality factors such as texture, flavor, and nutritional value (Beaulieu, 2006; Waldron, Parker, & Smith, 2003). Hence, various approaches have been extensively explored to inhibit the enzymatic browning as well as to improve the intrinsic qualities of fresh-cut lettuce.

It is well-known that fresh-cut vegetables can develop staleness or loss of freshness within very short storage time, even when stored under refrigerated conditions. The rapidly expanding fresh-cut vegetable industry has considerably increased interest in the physiological and biochemical changes including aroma loss (Lamikanra & Richard, 2002). The flavor properties depend on a delicate balance of relative amounts of volatile compounds and the odor threshold of each individual volatile (Lamikanra & Richard, 2002; Moya-León, Vergara, Bravo, Montes, & Moggia, 2006). The

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volatile compounds of stem lettuce have received little attention in spite of great commercial value of stem lettuce. In limited reports, it was found that stem lettuce can produce many volatile compounds of different chemical structure, with aldehydes as well as alcohols exerting the major roles on their aroma. Among them, 1-hexanol, 1-hexanal, 3-hexenal are the main contributors to the aroma of stem lettuce in fresh cut samples (Yang, 2008). In leafy lettuce, Lonchamp, Barry-Ryan, and Devereux (2009) reported that the main indicators of freshness were dimethylethylphenol and 2,2,4-Trimethyl-3-carboxyisopropyl isobutyl ester pentanoic acid, while the main quality loss markers were cis-3-dodecene and β-elemene. Deza-Durand and Petersen (2011) found that C6 aldehydes and alcohols from lipoxygenase (LOX) activity such as 3-hexenal, 2-hexenol and 2-hexenol increased after mechanical cutting in iceberg lettuce. Moreover, the concentrations of two products of anaerobic metabolism, acetaldehyde and ethanol, increased in stressful conditions in salad lettuce (López-Gálvez, Peiser, Nie, & Cantwell, 1997).

The use of natural ingredients such as green tea extracts (Martín-Diana, Rico, & Barry-Ryan, 2008) and whey protein (Altunkaya, 2011) have been carried out to improve the quality of minimally processed lettuce. Allicin, a commonly utilized flavor enhancer in food industry, is a natural compound extracted from garlic. It is mainly composed of four sulfur-containing ingredients: diallylsulfide, diallyldisulfide, diallyltrisulfide, and diallyltetrasulfide. Allicin is known to possess antimicrobial, antioxidant and anticancer properties in many previous studies (Park, Yoo, Shim, & Chin, 2008). Allicin has been shown to maintain the quality and extend the shelf life of fresh pork (Park et al., 2008), dry sausages (Aguirrezábal, Mateo, Domınguez, & Zumalacárregui, 2000) and fresh grape (Ren, Wang, He, & Fang, 2009). For stem lettuce, it was demonstrated that allicin effectively protects fresh-cut lettuce from tissue oxidative browning and microbiological spoilage in our previous study (Peng et al., 2014). However, the influence of allicin treatment on volatile aroma compounds and nutrients content of fresh-cut lettuce still await further investigation. In the present study, we evaluated the effect of allicin treatment on the profile of volatile metabolites of fresh-cut lettuce during cold storage. In addition, quality attributes in allicin treated fresh-cut stem lettuce and control lettuce were evaluated.

2. Materials and methods

2.1. Plant material and experimental design

Mature lettuce (*Lactuca sativa* L. var. *angustana Irish*) was purchased, cleaned, peeled, sliced and treated with allicin as described previously (Peng et al., 2014). In brief, 3-cm thick lettuce slices were immersed in distilled water, 2 g/l allicin and 10 g/l allicin solution respectively for 2 min. After being air-dried, the slices were immediately packaged and stored at 4 °C for later analyses.

2.2. Appearance

The slices were photographed with a digital camera at 0, 2, 4 and 6 d in order to show the external direct-viewing impression of the morphology influenced by allicin.

2.3. Fresh weight loss

Weight loss was expressed as the percentage loss of the initial total fresh weight. For each measurement, ten slices per treatment group were used. Each experiment was performed in triplicate.

2.4. Firmness

Firmness of fresh-cut lettuce was evaluated using a TA.XT Plus/50 Texture Analyzer (Stable Micro Systems Ltd., Surrey, England, UK) by measuring the hardness for a 4-mm cylindrical probe to penetrate 6 mm into the cut surface at a pre-test speed 2 mm/s, test speed 2 mm/s and post-test speed 10 mm/s. The trigger force was 5 g and the maximum penetration force was measured and taken as firmness (N), as measured in previous studies by Wu, Zhang, and Wang (2012). Ten measurements were performed for each sample.

2.5. Ascorbic acid evaluation

Ascorbic acid was analyzed according to the 2, 6-dichlorophenolindophenol titrimetric method (AOAC, 1995). A five gram of fresh-cut lettuce sample was homogenized in 40 ml of 20 g/l oxalic acid. A 10 ml aliquot of the filtrated was titrated with dye until the distinct rose pink color persisted for 15–30 s. Results were reported as mg/100 g fresh weight (FW).

2.6. Soluble protein content

Five grams of lettuce slice were homogenized in 100 ml 50 mmol/l PBS (pH 7.8). After centrifugation at 12 000 × g for 20 min, the supernatants were collected for the soluble protein assay according to Bradford (1976), using bovine serum albumin as protein standard. Results were expressed as soluble protein mass on a fresh weight basis (mg/g FW).

2.7. Soluble sugar evaluation

One gram of fresh-cut sample was homogenized in 20 ml 800 ml/l ethanol and the solution was collected, and then the solution was heated for 10 min in a boiling water bath. After cooling, the solution was centrifuged for 10 min at 1509 g and the supernatant was collected to determine the soluble sugar using anthranone colorimetry with glucose as a standard (Hao, Kang, & Yu, 2006). One ml of the supernatant was mixed with 4 ml of 0.4 g/l anthrone in concentrated sulfuric acid. The mixture was heated for 10 min at 100 °C. Samples were then cooled and absorbance at 620 nm was measured. Results were expressed as glucose mass on a fresh weight basis (mg/g FW).

2.8. Chlorophyll content

Chlorophyll was extracted from 10 g of lettuce slice by homogenizing it in 50 ml of acetone. The homogenate was filtered through four layers of cheesecloth and washed twice with acetone to a total volume of 200 ml, and absorbance was read at 645 and 663 nm with an UV-VIS recording spectrophotometer (Hartmut, 1983). Chlorophyll content was calculated applying the formula as follows:

$$\mathrm{chla}(\mathrm{mg}/100\mathrm{g}\cdot\mathrm{FW}) = \frac{(12.7 \times \mathrm{OD}_{663} - 2.69 \times \mathrm{OD}_{645}) \times 100 \times V(\mathrm{volume},\mathrm{ml})}{W(\mathrm{weight},\mathrm{g})}$$

$$\mathrm{chlb}(\mathrm{mg}/100\mathrm{g}\cdot\mathrm{FW}) = \frac{(20.2 \times \mathrm{OD}_{663} + 8.02 \times \mathrm{OD}_{645}) \times 100 \times V(\mathrm{volume},\mathrm{ml})}{W(\mathrm{weight},\mathrm{g})}$$

$$\mathrm{Total}(\mathrm{mg}/100\mathrm{g}\cdot\mathrm{FW}) = \mathrm{chla} + \mathrm{chlb}$$