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ScienceDirect
LWT 40 (2007) 460–464
LWT
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Effect of packaging on shelf-life of minimally processed Bok Choy (*Brassica chinensis* L.)

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Received 10 July 2005; received in revised form 25 November 2005; accepted 9 December 2005

Abstract

Different methods of packaging were investigated for their effectiveness in inhibiting quality deterioration of minimally processed Bok Choy (*Brassica chinensis* L.). Modified atmosphere packaging (MAP) flushed with 5% O_2 and 2% CO_2 resulted in a reduction of respiration rate and ion leakage of minimally processed Bok Choy stored at 10 °C. The chlorophyll content and F_v/F_m value of minimally processed Bok Choy in MAP decreased much slowly than those of Bok Choy sealed directly in polyethylene (PE) bag or in perforated oriented polypropylene (POPP) bag. Weight loss of Bok Choy in MAP and sealed directly in PE were only 1.3%, while that in POPP reached a high value of 11% during the storage of 10 days. The shelf-life of minimally processed Bok Choy in MAP, sealed directly in PE and in POPP bag at 10 °C were 10, 6 and 4 days, respectively, according to the sensory quality evaluation.
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Keywords: Modified atmosphere packaging; Physiology; Sensory quality; Shelf-life; Bok Choy; Minimally processed

1. Introduction

Bok Choy, a non-head Chinese cabbage, also named as pak choi or Chinese white cabbage, is an important leafy vegetable widely grown in south China in summer and autumn since ancient times (You & Yang, 2001). Its white stalks bear a strong resemblance to celery while the dark green, crinkly leaves are similar to Romaine lettuce. Bok Choy's popularity comes from its light, sweet flavor, crisp texture and nutritional value that is abundant in minerals and vitamins, such as vitamin B_2. However, the vegetable is perishable after harvest because of its susceptibility to shriveling, yellowing and decay (Shen, Wang, & Huang, 1999).

Yellowing is an important factor leading to the short shelf-life of Bok Choy, caused by the degradation of chlorophyll during its storage (Wang & Herne, 1989). The yellowing rate of leafy vegetables can be retarded through modification of storage condition, such as low temperature and controlled atmosphere storage. The yellowing of Bok Choy could be reduced when stored under low oxygen (O'Hare, Smith, & Wong, 1995) or high carbon dioxide (Wang & Herne, 1989) at 10 °C. The senescence caused by shriveling and over-depletion of nutrition substances is also an important factor limited to the shelf-life of Bok Choy. Plastic film packaging can inhibit the shriveling of Bok Choy caused by water loss (Shen et al., 1999).

Minimally processed or fresh-cut fruits and vegetables is a rapidly developing segment of the fresh produce industry. These products are manufactured by washing, sorting, peeling, slicing and packaged with plastic film or in plastic trays wrapped with films. Minimally processed vegetables distribute widely in developed countries, and are becoming also popular in China. The shelf-life of minimally processed vegetables decreases greatly after a series of preparation operation including distribution handling. Low temperature and modified atmosphere packaging (MAP) are extensively used to extend the shelf-life of many intact and minimally processed fruits and vegetables products because they reduce rates of respiration, cut surface deterioration and browning (Thompson, 1998). Low O_2 appears to reduce water loss in broccoli florets (Bastrash, Makhlouf, Castaigne, & Willemot, 1993) and

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doi:10.1016/j.lwt.2005.12.004

retard the degradation rate of chlorophyll in Bok Choy (Shen et al., 1999) and green mume (Wang, Lu, Ma, & Xi, 2002).

The objectives of this work were: (1) to determine the effectiveness of MAP in reducing the respiration and senescence of minimally processed Bok Choy; and (2) to evaluate effects of different packaging materials on chlorophyll content, chlorophyll fluorescence, weight loss and shelf-life of minimally processed Bok Choy.

2. Materials and methods

2.1. Sample preparation

Bok Choy (*Brassica chinensis* L. cv. Shanghaiqing) obtained from a wholesale market in Ningbo, Zhejiang, China was used for this study. Samples were sorted to eliminate damaged or yellowish ones, cleaned and washed in a 0.02% sodium hypochlorine solution and dried. After disinfecting, vegetables were divided into three lots: (1) approximately 110–130 g clean Bok Choy were put into polyethylene (PE) bags ($25 \times 35\,cm^2$) with a thickness of 0.04 mm and medium gas transmission rate, and then sealed; (2) approximately 110–130 g clean Bok Choy were put into the same bags as that in (1), flushed with 2 l of gas mixture containing 5% O_2 and 2% CO_2 into bags, and then sealed (MAP); (3) approximately 110–130 g clean Bok Choy were put into $230 \times 300 \times 0.03\,mm^3$ perforated oriented polypropylene (POPP) bags, with four holes in a diameter of 5 mm on each side of bag. After sealing, 15 bags per treatment were stored at 10 °C for up to 10 days. Each item was measured every 2 days after the evaluation of sensory quality changes. The experiment was repeated at three times.

2.2. Methods

The changes of in-package O_2 and CO_2 concentrations were measured using an oxygen and carbon dioxide analyser 9900 Model Check Mate (PBI-Dansensor Co., Denmark). Respiration rate of Bok Choy was measured using CO_2 absorption method after its removal from package for an hour interval and adaptation to ambient atmosphere. On a plate 10 ml of 0.4 mol/l NaOH solution was put, which was placed into a 10 l glass jar, then a Bok Choy sample (110–130 g) was hung over the plate and sealed in the jar. After 30 min, the plate was taken out and titrated with 0.1 mol/l oxalic acid. A control without samples and a repetition were done at the same time. The respiration rate was expressed as CO_2 mg/kg h.

At each sampling time, Bok Choy samples were assessed for percentage of weight loss, color, sensory quality, decay, percent of ion leakage, chlorophyll content and chlorophyll fluorescence. Samples were weighed before and after the storage intervals to calculate percentage of fresh weight loss.

Electrolyte leakage was determined on eight disks (50 mm in diameter) taken with a cork borer from the surface of leaves. Disks were immersed in 20 ml of ddH_2O in glass vials, which were agitated at 20 °C for 1 h. Electrolyte leakage was measured as the amount of increased conductivity (μs/cm) of the solution. After that, disks were boiled for 20 min and cooled to room temperature and the total conductivity was measured. The electrolyte leakage was expressed as the percent of the total conductivity leaked per hour (Hong & Gross, 1998).

Bok Choy were inspected by a panel of three trained personnel for overall preference every 2 days using a nine-point hedonic scale where 9 = like extremely, freshest, green, as newly harvested; 7 = like moderately, fresh, light yellow on the top of some leaves; 5 = neither like nor dislike, some parts of leaves de-greened, but still acceptable; 3 = dislike moderately, 30% of leaves de-greened, shriveled and decay; and 1 = dislike extremely, more than 50% of leaves de-greened, shriveled and decay (Meilgaard, Civille, & Carr, 1991). A score of 6 was considered the limit of salability.

Chlorophyll fluorescence (F) was evaluated by chlorophyll fluorescence instrument PAM-2000 (Walz, German). Leaves were placed in darkness for 5 min before F_0, the dark-adapted yield of chlorophyll fluorescence was measured, then were illuminated with a brief pulse of extremely bright light ($>4000\,\mu mol/m^2\,s$) before F_m, the maximum yield of chlorophyll fluorescence was measured. The efficiency of photosynthesis was expressed as fluorescence parameters ratio F_v/F_m, where $F_v = F_m - F_0$. Chlorophyll pigments were extracted by grinding 0.5 g samples in 5 ml cold 80% acetone with a mortar and pestle, filtering the homogenate, rewashing the residue with 80% acetone until the residue was colorless and bringing the final volume to 25 ml. Aliquots of the combined extracts were used for photometric analysis (Arnon, 1949). The result was expressed as milligram chlorophyll per gram fresh weight.

2.3. Statistical analysis

The experiment was conducted in a completely randomized block design. All results were tested by analysis of variance (ANOVA procedure), and the means were separated using Fisher's LSD at $P \leqslant 0.05$.

3. Results and discussion

3.1. Respiration rate changes

Fig. 1 shows the respiration rates under different packages. The respiration rate of MAP Bok Choy was significantly lower than those of other treatments after 2 days at 10 °C. This indicates good effect on inhibiting respiration rate of Bok Choy by MAP, which is consistent with the earlier finding that modified atmosphere inhibited respiration in fresh-cut produce (Smyth, Song, & Cameron, 1998). The lower respiration rate in MAP Bok Choy might result from the low oxygen and higher carbon dioxide

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