

Effects of packaging materials and types on postharvest nutritional quality of mini Pakchoi *Brassica chinensis*

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Abstract: The baby leaves of mini Pakchoi *Brassica chinensis* are gaining popularity due to its pleasant appearance, flavour, tender texture and nutrition. Effects of retail packaging on the nutritional quality of *Brassica chinensis* at 4°C were studied. Samples were packaged using polyethylene bags (PE-B), polystyrene foam tray covered with polyethylene film (PE-C/PS-T), perforated oriented polypropylene bags (POPP-B) and biaxially oriented polystyrene box (BOPS-B). Weight losses, respiration rate, chlorophyll and carotenoid, vitamin C and nitrate were determined during storage period. After 10 d storage, the weight loss for samples packaged in PE-B was 0.89%, followed by PE-C/PS-T with weight losses of 6%. A significant reduction (>10%) in moisture was observed for the samples packaged in POPP-B and BOPS-B. The variation in respiration rate during storage seemed to form a trend with a sharp decline up to the fourth day. The difference in the reduction of chlorophyll and carotenoid was not significant among the four packages. BOPS-B had a better protective effect on vitamin C loss. The nitrate concentration during storage was within the official limit.

Keywords: *Brassica chinensis*, packaging, vitamin C, chlorophyll, carotenoid, nitrate-nitrogen

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1 Introduction

Green leafy vegetables of Brassica-family, which traditionally consumed particularly in China for several thousand years, are now popular all over the world. *Brassica* leafy vegetables play an increasingly important role in our daily diet because of their high nutritional and medicinal value. Previous studies have shown an inverse association between the consumption of *Brassica* leafy vegetables and the risk of cancer^[1-3]. A number of

bioactive compounds such as anticarcinogenic glucosinolates and beneficial carotenoids are abundant in the *Brassica* leafy vegetables^[4-6]. The baby leaves of mini Pakchoi (*Brassica campestris* L. ssp. *chinensis* Makino var. *communis* Tsen et lee) is called Jimacai in China. It is one of the most popular green leafy vegetables because of its pleasant appearance, flavour, and texture. It is also gaining increasing popularity in Western diets^[7,8].

Fresh *Brassica chinensis* has a short shelf life due to its easily perishable and unavoidable exposure to unfavourable conditions after harvest. Additionally, *Brassica chinensis* cultivation base and supply could be heavily influenced by bad weather. An emergent and efficient way is to harvest *Brassica chinensis* ahead of bad weather and store them at appropriate conditions until the next turn of *Brassica chinensis* growth. For these reasons, there is a need to find the best way to maintain *Brassica chinensis* quality up to 10 days.

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Temperature management is the simplest and easiest way to maintaining vegetable quality and minimizing postharvest losses, and it can also reduce respiration rates and yellowing of vegetables. The most frequently used temperature of leafy vegetables store in commercial cold chains and home refrigerators is 4°C. Besides, appropriate packaging could also keep the quality of intact and minimally processed vegetables and extend their shelf life^[9,10]. Based on the current situation of green leafy vegetables sold in supermarkets, this study selected 4°C and common retail packaging of *Brassica chinensis* preservation. In China, the packaging materials of leafy green vegetables are polyethylene bags, polystyrene foam tray covered with polyethylene film, perforated oriented polypropylene bags, and biaxially oriented polystyrene box, currently. Polyethylene and polypropylene are well-known packaging materials and were commonly studied in vegetable storage of them.

The postharvest weight losses, shrinkage and deterioration of *Brassica chinensis* are strongly affected by dehydration, as fresh *Brassica chinensis* have a water content $\geq 90\%$. The most effective way of quality evaluation is moisture loss. Secondly, loss of quality is often a consequence of photosynthetic reserves being consumed by respiration. Thirdly, pigments degradation can lead to loss of favourable leaf colour. Chlorophyll degradation has been deemed the most serious postharvest alteration in rocket leaves resulting in yellowing. Carotenoids, as provitamin A, have a high nutritional value as it is the major source of dietary vitamin A in most countries. Thus, the variation in leaf pigment content during storage can reflect leaf function and provide information concerning the physiological state of leaves. Fourthly, vitamin C is one of the major antioxidants and has other health benefits that are being actively investigated. It is abundant in *Brassica* vegetables. Lastly, as reports showed nitrate accumulation in vegetables is widespread, and many countries have developed limits on nitrate concentrations in fresh leafy vegetables, nitrate is considered a factor in this study. It is undesirable to produce vegetables with accumulated nitrate as vegetable quality and safety will be compromised. A previous study investigated the

effect of storage temperature on carotenoids and glucosinolates in *Brassica chinensis* and suggested that *Brassica chinensis* should be packaged in polyethylene bags and stored at 4°C^[11]. However, research of different retail packaging materials comparison on *Brassica chinensis* preservation and nutritional quality during storage at 4°C is less.

The objectives of this study were to determine the effect of different retail packaging materials and types on *Brassica chinensis* nutritional quality during storage at 4°C, and to provide experimental basis for cold chain facilities, including cold storage, for large scale *Brassica chinensis* preservation and logistics.

2 Materials and methods

2.1 Materials and pre-treatments

Fresh *Brassica chinensis* test samples were supplied by Pujiang Vegetable Base of Shanghai City Supermarket Co., Ltd. (Shanghai, China). The fresh baby leaves were manually picked at the commercial stage when the plants reached 10 cm height and 6-7 leaves were expanded. After harvest, the materials were directly transported to laboratory in half an hour under refrigerated conditions at 4°C without any pre-treatment. Leaves were immediately weighed and packed into four different retail packaging and then stored in the refrigerator in darkness at 4°C for 10 d. The four packagings were: (1) PE-B: Polyethylene (PE) bags (30 cm × 25 cm) with oxygen transmission rate of 3.42 pmol/(s·m²·Pa); (2) PE-C/PS-T: Polystyrene (PS) foam tray (20 cm × 13 cm) covered with PE film with oxygen transmission rate of 18.85 pmol/(s·m²·Pa); (3) POPP-B: Perforated oriented polypropylene (POPP) bags (30 cm × 25 cm) with 9 holes in a diameter of 7 mm on the bag; and (4) BOPS-B: Biaxially oriented polystyrene (BOPS) box (19 cm × 12 cm × 4 cm) which lids were closed by a tag paper. The quality indices of water content, weight losses, respiration rate, chlorophyll and carotenoid content, vitamin C content, and nitrate concentration were sampled on 0, 1st, 2nd, 3rd, 4th, 5th, 7th, and 10th day. The test vegetables with different packages were set for each sampling day separately at the first day. Each determination was performed in triplicate.

2.2 Reagents

2,6-Dichlorophenol-indophenol sodium salt dehydrate was purchased from Tokyo Chemical Industry Co., Ltd (Tokyo, Japan). All other reagents were analytical grade and were obtained from Sinopharm Chemical Reagent Co., Ltd. (Shanghai, China). Water was purified using a Milli-Q water purification system (Millipore Co. Milford, USA).

2.3 Determination of weight losses

Initial weight (W_0) and storage weight at the sampling day prior to analysis (W_t) of each packaged *Brassica chinensis* were measured using an electronic weighing balance (AL204-IC, Mettler Toledo, Switzerland). Results were expressed as percentage of weight losses (WL) according to the following Equation:

$$WL(\%) = \frac{W_0 - W_t}{W_0} \times 100 \quad (1)$$

2.4 Respiration measurements

The respiration rate (mg/kg·h) can be expressed as O₂ consumption rate or CO₂ production rate. After the removal of samples from the package at 30 min interval, the expression of the latter referred to the alkaline trap method/CO₂ absorption method. This allows its adaptation to ambient atmosphere at each sampling day. Ten milliliters of 0.4 M NaOH solution was added to the container with lid, then 10 g of *Brassica chinensis* was hung over the alkaline solution and sealed in the container for an hour. The trapped CO₂ release was measured by titrating the NaOH solution with 0.1 M oxalic acid after one hour. Also, a control without sample was prepared. The results were expressed as:

$$\text{Respiration rate} = \frac{(V_0 - V_t) \times 2.2}{M} \times 1000$$

where, V_0 is the titration volume of control, mL; V_t is the titration volume of samples, mL; M is the fresh weight of each sample, g.

2.5 Determination of chlorophyll and carotenoid

The total concentration of chlorophyll and carotenoid content were determined spectrophotometrically using the 95% ethanol extracts of the fresh leaves. Chlorophyll a, chlorophyll b and carotenoid concentrations were determined immediately at 665 nm, 649 nm and 470 nm, respectively. The concentration was calculated

according to the method of Miazek and Ledakowicz^[12]. The extraction procedure is as follows: the fresh leaves were randomly selected from the samples in each package, cut and well mixed; about 0.2 g of fragment was placed in a morta and ground along with quartz sands, CaCO₃ powder, and 95% ethanol to a fine pulp; then, all the pulp was transferred to a 25 mL brown volumetric flask through filtration and 95% ethanol was added to make up the rest of the liquid volume; the pulp residue was nearly colorless.

2.6 Determination of vitamin C

Vitamin C content was determined as ascorbic acid content using the 2, 6-dichlorophenol-indophenol method. About 10 g of samples were ground with 5 mL of 2% oxalic acid in a clean morta and the final pulp was transferred into 100 mL volumetric flask. The solution was made up with 2% oxalic acid and the extract was collected through suction filtration for later use. Ten milliliters of the filtrates was titrated against the 2, 6-dichlorophenol-indophenol dye to a pink end point, which was standardized using an ascorbic acid standard. The amount of ascorbic acid was expressed as mg per 100 g on a fresh weight basis.

2.7 Determination of nitrate-nitrogen

The nitrate-nitrogen concentration of *Brassica chinensis* was measured using a Smartchem-200 Automated Discrete Analyzer (Alliance Instruments, Frepillon, France). The instrument utilizes a dedicated sample prep module for the determination of nitrates by cadmium reduction with multi-tasking and high throughput rates. The fresh samples were lyophilized and ground to a fine powder before being extracted. About 0.2 g sample powder was extracted with 10 mL ultrapure water in boiling water bath for 30 min followed by another 30 min extraction by ultrasonic method. Without any clarification procedures, the extracts of nitrate-nitrogen were then filtered through filter paper. The filtrate was diluted using ultrapure water before the instrumental analysis.

2.8 Statistical analysis

The data were reported as the mean values with standard error (SE) of three replicates. Analysis of variance (one-way ANOVA procedure) followed by least

significant difference (LSD) test with a significance level of $p \leq 0.05$ was performed using SPSS version 18.0 software (SPSS Inc, 2009, Chicago, IL, USA).

3 Results and discussion

3.1 Effects of packaging materials and types on weight losses

Fresh *Brassica chinensis* has a high water content level of 92.88%. Thus, packaging is the most effective way to avoid water loss which led to the main weight losses of vegetables^[13]. The weight losses could be mainly caused by evaporation, dehydration and respiration. Results of the weight losses indicated continuous increase as the storage time increased (Figure 1). During the storage, the samples packaged in POPP-B and BOPS-B had a rapid and significant increase in weight losses compared to the samples packaged in PE-B and PE-C/PS-B. After 10 days storage, minimum weight losses (0.89%) in *Brassica chinensis* was observed in PE-B, while the maximum weight losses (16.12%) was in POPP-B.

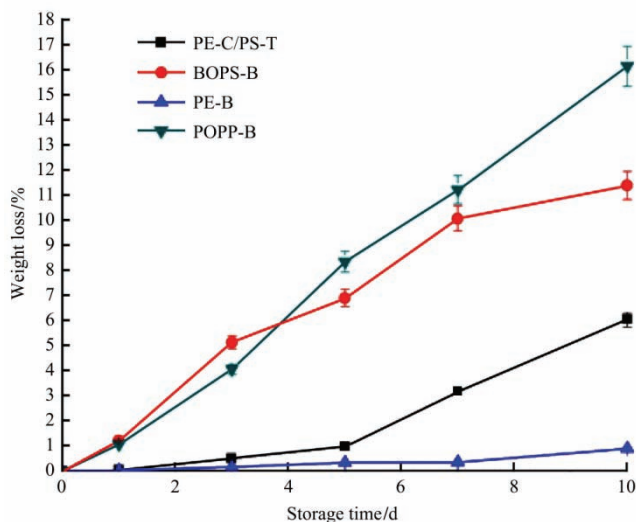


Figure 1 Effects of different retail packaging materials on weight losses of *Brassica chinensis*

The large difference in weight losses of *Brassica chinensis* between the PE-B and POPP-B was primarily attributed to the half-open state of the POPP-B which had 9 holes (7 mm diameter) on the bag. Similarly, the higher weight losses change in *Brassica chinensis* packed in BOPS-B was mainly due to the poor airtight of the box lids. In comparison, the lower weight losses in PE-B and PE-C/PS-T could be attributed to closer environment

and to less water evaporation. Normally, 3%-5% of weight losses in fresh vegetables would result in leaf shrinking and a decrease in the vegetable quality and consumer acceptability. The shelf life using BOPS-B and POPP-B at 4°C for *Brassica chinensis* is no more than three days. In comparison, the shelf life could be extended to 10 days using PE-B and PE-C/PS-T.

3.2 Effects of packaging materials on respiration

Figure 2 shows the respiration rates under the four packaging conditions. The experimental values were fitted by fourth order polynomial function for PE-C/PS-T, BOPS-B and POPP-B, and fifth order polynomial function for PE-B, using DataFit version 9.0.59. The variation trends were almost the same except for a slight difference.

The respiration rate showed an obvious decrease to the lowest point in the first 4 d, after which the respiration rate maintained a relatively low and stable value. The obvious decline after 1 d storage indicated that the common commercial packagings all have notable effect on inhibiting cell respiration. The potential reduction of respiration rate was attributed to the atmosphere which was richer in CO₂ and poorer in O₂ in the packaging. This is due to the accumulation of respiration and inactive transfer of gases through the packaging. Similar to previous report^[14], a transitory increase in respiration rate was observed during the storage such as the slight increase after the fourth day in this study. This may be due to the consumption of internal nutrient because of insufficient O₂ and the growth of spoilage microbes. Previous study also found that the build-up of CO₂ in the packaging could lead to decay and off-flavor caused by cell membrane damage and physiological injuries^[15].

Considering the impact of the different packagings, BOPS-B gave the lowest respiration rate trough at the fourth day. This might be explained by the inhibited gas exchange and self-modified atmosphere. This explanation also applies to PE-B which had a more satisfactory stable respiration rate after 4-day storage.

3.3 Effects of packaging materials on chlorophyll and carotenoid content

Figure 3a shows a reduction in chlorophyll content of

Brassica chinensis after 10 d storage. Figure 3b shows an increase in carotenoid content increased during the

first three days and then gradually declined in the following days.

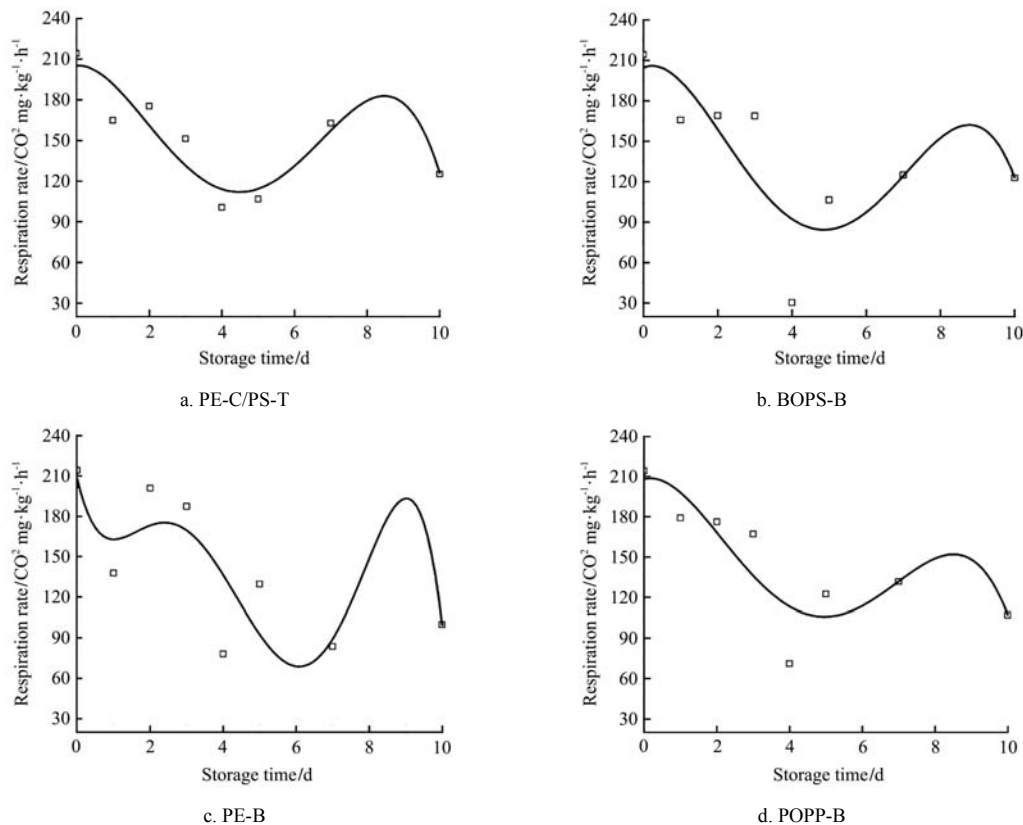


Figure 2 Effects of different retail packaging materials on respiration rate of *Brassica chinensis*

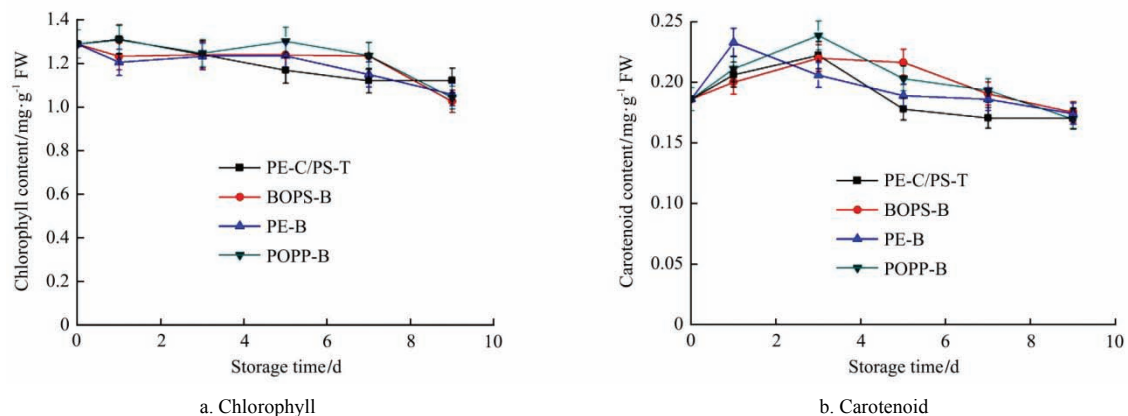


Figure 3 Effects of different retail packaging materials on content of chlorophyll (a) and carotenoid (b) of *Brassica chinensis*

Similarly, a previous study found that a substantial maintenance of chlorophyll content of fresh-cut spinach leaves was observed during 4 d of storage under different packaging treatments^[16]. During postharvest life, the leaf pigments undergo degradation that leads to leaf discoloration. The phenomenon of decline in chlorophyll and carotenoid content has been observed in many leafy vegetables. Environmental factors such as light, temperature and humidity are responsible for the loss of pigments during storage. The results indicate that chlorophyll and carotenoid are tightly correlated with

each other. This might be due to carotenoid protecting chlorophyll from photo-oxidation. Storage in darkness at 4°C only resulted in a slight deterioration in visual quality for all packagings during 10 d storage, with the total chlorophyll and carotenoid loss of 13%-20% and 5%-9%, respectively. This was similar to the pigment retention pattern observed by two previous studies under air refrigerated conditions^[17,18].

3.4 Effects of packaging materials on vitamin C content

A mild decline in vitamin C content in *Brassica*

chinensis was observed in all packagings during 10 d storage (Figure 4).

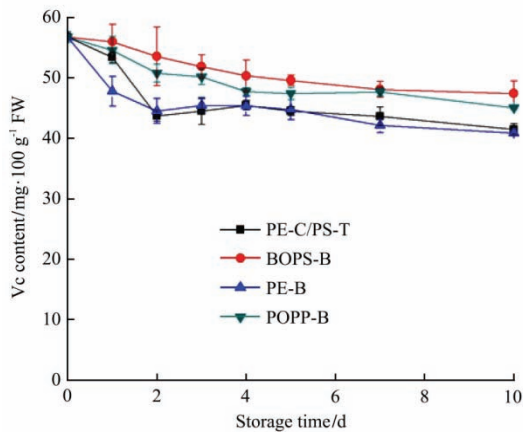


Figure 4 Effects of different retail packaging materials on vitamin C content of *Brassica chinensis*

The initial content of vitamin C was 56.79 mg/100 g FW and the loss was 26.92%, 16.48%, 28.00% and 20.64% for PE-C/PS-T, BOPS-B, PE-B and POPP-B, respectively. According to previous study^[19], the vitamin C loss of *Brassica chinensis* without packaging could be higher than 50%. The four packagings retained vitamin C content without significant loss. It is widely known that vitamin C is prone to oxidation which mainly leads to the degradation of the nutrient. During the first 2 d storage, significant decrease was observed on vitamin C content in PE-C/PS-T and PE-B. This may be due to the relatively higher O₂ level in the packaging. After the fourth day, the variation in vitamin C content in all packagings was almost the same. This could also be attributed to the similar pattern of respiration rate. Figure 4 also indicates that BOPS-B had a better protective effect on vitamin C loss among the four commercial packagings.

3.5 Effects of packaging materials on nitrate concentration

Nitrate content is considered as an important qualitative index of plant based-foods^[20]. Nitrate concentration variation in *Brassica chinensis* was very similar in all packagings, with an increase on the first day and a sharp decrease on the second day followed with a stable concentration (Figure 5).

Nitrogen is an important element that can alter plant composition more than any other element. In the initial storage, the strong respiration activity of *Brassica*

chinensis resulted in the consumption of organics. This led to the decrease in nitrate-nitrogen content. With the progressive depression of the plant's respiration, the accumulation of nitrate-nitrogen began. In China, nitrate accumulates in vegetables due to the excessive use of fertilizers, and a tentative standard was proposed. Previous study showed that nitrate-nitrogen contents in four fresh leafy vegetables ranged from 1297 mg/kg to 5658 mg/kg^[21], which is consistent with our results. The nitrate concentration in the *Brassica chinensis* under all packaging treatments complied with relevant standards without significant differences.

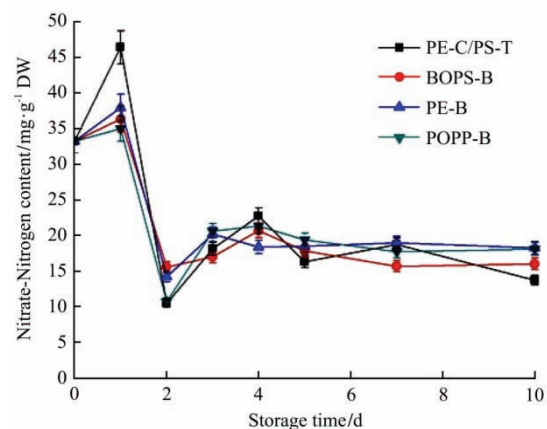


Figure 5 Effects of different retail packaging materials on nitrate concentration of *Brassica chinensis*

4 Conclusions

In general, deterioration of *Brassica chinensis* was mainly associated with water loss and respiration rate. The greenness and vitamin C content of this vegetable were well preserved by packagings. In addition, the nitrate concentration did not accumulate to an unacceptable level during the storage. However, the quality of *Brassica chinensis* was indeed reduced at the end of the storage. The results imply that low temperature plus commercial packaging treatment were beneficial to maintain the quality of *Brassica chinensis* within a 10 d storage time.

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