

Effect of Active Packaging on Quality of Chinese Kale

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ABSTRACT

*The aim of this work was to study the influence of passive MAP, perforated polyethylene package and three different oxygen transmission rate active packaging on the quality of fresh Chinese kale (*Brassica oleracea* L. var. *alboglabra*) stored at 5°C. Chinese kale was trimmed off defects and undesirable parts, then packaged 500 grams in each type of packaging, namely unperforated polypropylene package, four perforated polyethylene package (Doi Kham Brand) and active packaging with different oxygen transmission rates (OTR): 10,000-12,000, 12,000-14,000, 8,000-13,000 and 14,000-16,000 cc/m²-day then sealed. Five packaging treatments together with passive atmosphere within the package were applied. Weight loss, wilting, physiological disorders, bacterial decay, visual appearance, color change, total soluble solids, chlorophyll, vitamin C content and shelf life were monitored. Yellowing of leave in a short time was a major problem of Chinese kale. The amounts of vitamin C and chlorophyll tended to decrease with storage time, which correlated with the diminishing green color. Chinese kale packaged in active packaging had longer storage life compared to passive MAP polypropylene package and perforate PE package, which differed significantly ($P<0.05$) from each other. High oxygen transmission rate of film was generally related to a high quality produce. Active packaging with OTR of 8,000-13,000 cc/m²-day was the best treatment for overall visual quality.*

Key words: Active packaging, Chinese kale, Quality, OTR, Storage life

INTRODUCTION

Chinese kale (*Brassica oleracea* L. var. *alboglabra*) is among the 10 most important market garden vegetables in some Southeast Asian countries. For Thailand, Chinese kale is a popular leafy vegetable among Thai consumers. The area under Chinese kale in 1994 was 81,619 rai and had steadily increased during the last five-year period by 38.9 percent to reach 113,336 rai in 1998. Production areas are widely distributed in all regions of Thailand, with 31,524 rai in the Central region, 21,130 rai in the North, 15,894 rai in the East, 24,505 rai in the Northeast, 26,342 rai in the West and 7,095 rai in the South (FAO, 2011). Chlorophyll degradation during storage is a major postharvest problem of Chinese kale which rapidly occurs within a few days. In addition, Chinese kale undergoes rapid quality changes after harvest, e.g. discoloration, toughening and water loss, and thus has a short shelf life. Prompt deterioration after harvest can be triggered by high temperatures in the field during harvest (Kader et al., 1974).

Selection of packaging with essential importance to develop a gas composition able to maintain quality and assure a long shelf life to the packaged product is very important (Martines-Romero et al., 2003). Packaging commonly available for commercial is non-perforated and perforated polyethylene and polypropylene. Del Nobil et al. (2009) also stated that the selection of the appropriate packaging system is very important to maintaining quality of horticultural crops. Different head

space condition can be achieved in the package depending on the interactions between respiratory activity of the packaged produce and gas transfer through the polymeric matrix. The superposition of both processes leads to an increase of CO₂ and a reduction of O₂. Toivonen and DeEll (2001) reported that, as a result of produce respiration, matching of the commodity characteristics to the permeability of the film could result in the passive evolution of an appropriate atmosphere within sealed package. Therefore, the choice of film is a key factor to obtain optimum modification of the atmosphere within sealed package and avoid extremely low levels of O₂ and/or high levels of CO₂, which could induce anaerobic metabolism with possible off-flavor generation, and risk of anaerobic microorganism proliferation.

In response to the dynamic changes in current consumer demand and market trends, the area of active packaging is becoming increasingly significant. As an emerging technology, active packaging has been of increasing interest in Thailand. Active Packaging is defined as a mode of packaging in which package, the product and the environment interact to extend shelf life, and/or enhance safety and/or sensory properties, while maintaining the quality of the produce (Suppakul et al., 2003). Although the beneficial effects of active MAP technique for keeping quality of fruit and vegetables are well known, studies on the application of active and modified atmosphere packaging on Chinese kale are few. The objective of this research was to investigate the effect of passive MAP, perforated polyethylene package and three different oxygen transmission rate active packaging on the quality of fresh Chinese kale stored at 5°C.

MATERIALS AND METHODS

Plant Materials

Chinese kale harvested at commercial maturity stage in May, 2011 in an experimental field of Mae Sapok Royal Project Development Center, the Royal Project Foundation, Chiang Mai province and immediately transported by truck to the collection center, the Royal Project Foundation. Subsequently, the samples were immediately transported to the laboratory in Chiang Mai University (15 minutes), Chiang Mai province.

Experimental setup

Chinese kale were graded, trimmed off defects and undesirable parts, then clean and put into ready-to-sell packages, the following package were used: Perforated polyethylene bag (Doi Kham brand) of 40 µm (making in it 12 holes with the diameter of 0.5 mm), polypropylene of 50 µm, and four oriented polyethylene of 25 µm with different OTR ranging from 8,000 to 16,000 cc/m²-day (Table 1). Approximately 500 grams of Chinese kale were weighed in each bag sized 8 x 15cm having a surface area of 130 cm² then sealed and stored at 5°C until the end of its storage life. Physico-chemical properties were analyzed every day as follows: weight loss percentage, color was expressed as L value (L*), chroma (C*) and hue angle (ho) using a colorimeter. (Chromameter, Minolta CR-310), ascorbic acid was extracted and analysed according to a method described by AOAC (2000), the total soluble solids content was measured by making a slurry of the whole leaves and drops on a digital refractometer, chlorophyll was extracted and analysed following Whitham et al. (1971). Shelf life was determined by using 5 trained panels. The intensity of the attributes were physical appearance, odor, color, firmness used as "overall quality" was determined using a hedonic scale from 1 to 5, where 1 = "very poor" and 5 = "excellent". The samples "overall quality" was considered as an average of the above-mentioned sensorial attribute values as evaluated by the panelist. A score equal to three was used as the threshold for produce acceptability. Oxygen and carbon dioxide headspace concentration of packaged Chinese kale were measured using a Headspace Gas Analyser (PBI Dansensor, Checkmate, Denmark). Three replicates were made at each sampling. A completely randomized design (CRD) was used as an experimental design. All analyses were carried out in triplicate. The data calculated from the fitting procedure were compared by one-way variance analysis (ANOVA). A Duncan's multiple range test with the option of homogeneous groups ($P < 0.05$), was used to determined significance between samples.

Table 1. Value of oxygen transmission rate (OTR) at 23°C with 0% RH and water vapor transmission rate (WVTR) at 23°C with 85% RH.

| Type of packaging | Thickness (µm) | OTR (cc/m ² -day) | WVTR (g/m ² -day) |
|-------------------------------|----------------|------------------------------|------------------------------|
| Polypropylene (Passive MAP) | 50 | N/A | 7-8 |
| OPE1 (with antifogging agent) | 25 | 10,000-12,000 | 5-7 |
| OPE2 (with antifogging agent) | 25 | 12,000-14,000 | 6-8 |
| OPE3 (with antifogging agent) | 25 | 8,000-13,000 | N/A |
| OPE4 (with antifogging agent) | 25 | 14,000-16,000 | 7-8 |

RESULTS AND DISCUSSION

Effect of packaging on the quality of Chinese kale

Weight loss

Weight loss percentage was lower for Chinese kale stored in passive MAP (PP) and OPE bags than in perforated plastic bags since the passive MAP bags (PP) and OPE bags reduced the water vapor gradient between the outside surface of the product and the air. High weight loss rate is one of the problems of Chinese kale, which affects its marketability. As shown in Table 2, Chinese kale packed in PE (control) stored in air had the highest weight loss of 4.23% after 3 days of storage. The effect of film protection on Chinese kale was evident when data relative to packaged sample were compared to those relative to the one store in perforated PE bag. However, there were some differences between films, the five selected systems in providing good barrier to water permeation; Chinese kale packed in OPE1, OPE2, and OPE3 had weight loss percentage less than 1 after stored for 13 days.

Total soluble solids

The total soluble solids concentration generally remained constant during storage period, however tended to decrease after 13 days of storage. Total soluble solids concentrations from Chinese kale stored in perforated PE bag and OPP3 were significantly different and found to be the highest of 5.43% in Chinese kale in OPP3 and lowest of 4.43% in perforated PE bag (Table 2).

Ascorbic acid content

The ascorbic acid content decreased during storage, with a slower rate of decrease in Chinese kale stored in passive MAP (PP) and all OPE bags compared to perforated PE bag (control) (Table 3). The amounts of vitamin C tended to decrease with storage time. Vitamin C amount from Chinese kale stored in OPE1, OPE3, and passive MAP (PP) were significantly different and found to be the highest in PP and OPE3 and the lowest in perforated PE bag (control) after 3 days of storage at 5°C (Table 3).

Chlorophyll content

The chlorophyll a, b and total chlorophyll tended to decrease with storage time, which correlated with the diminishing green color. It was found that passive MAP (PP) and all types of active packaging caused a significantly ($P < 0.05$) smaller loss of chlorophyll a and total chlorophyll than Chinese kale packed in perforated PE bag under refrigerated air storage at 5°C. Chinese kale stored in passive MAP (PP) and OPE bags maintained its chlorophyll content better than the control samples. This was due to the lower O₂ concentration in combination with the higher concentration of CO₂ in the packages, which can reduce the degradation of chlorophyll (Zhuang et al., 1994; Paradis et al., 1996). Chinese kale changed color from green to yellow when stored in perforated PE bag at the temperatures of 5°C for 3 days, and remained green for 14 days when stored in active packaging OPE3.

Table 2. Physical properties of Chinese kale packed in different packaging type at 5°C after 3 days of storage.

| Type of packaging | Weight loss (%) | Total soluble solids (%) |
|-----------------------------|------------------------|--------------------------|
| Perforated PE (Control) | 4.23±0.32 ^a | 4.67±0.24 ^b |
| Polypropylene (Passive MAP) | 0.06±0.02 ^b | 5.00±0.12 ^{ab} |
| OPE1 | 0.05±0.02 ^b | 4.97±0.15 ^{ab} |
| OPE2 | 0.16±0.04 ^b | 4.60±0.21 ^{ab} |
| OPE3 | 0.18±0.03 ^b | 5.43±0.03 ^a |
| OPE4 | 0.06±0.02 ^b | 4.57±0.29 ^b |

Different letters in the same column denote significant differences at $P = 0.05$

Table 3. Chemical properties of Chinese kale packed in different packaging type at 5°C after 3 days of storage.

| Type of packaging | Ascorbic acid (mg/100 g) | Chlorophyll a (mg/100 g) | Chlorophyll b (mg/100 g) | Total chlorophyll (mg/100g) |
|-----------------------------|--------------------------|--------------------------|--------------------------|-----------------------------|
| Perforated PE (Control) | 11.25±3.90 ^c | 0.03±0.009 ^c | 0.05±0.001 | 0.08±0.007 ^c |
| Polypropylene (Passive MAP) | 48.75±4.71 ^a | 0.11±0.002 ^a | 0.04±0.001 | 0.16±0.030 ^a |
| OPE1 | 43.13±6.58 ^a | 0.09±0.009 ^{ab} | 0.05±0.001 | 0.14±0.019 ^{ab} |
| OPE2 | 37.50±6.43 ^{ab} | 0.09±0.008 ^{ab} | 0.04±0.000 | 0.13±0.013 ^{ab} |
| OPE3 | 46.98±0.00 ^a | 0.07±0.009 ^b | 0.03±0.001 | 0.11±0.015 ^{bc} |
| OPE4 | 19.37±7.36 ^{bc} | 0.01±0.009 ^{ab} | 0.05±0.001 | 0.15±0.016 ^{ab} |

Different letters in the same column denote significant differences at $P = 0.05$

Shelf life

Shelf life determined by using trained evaluators. The intensity of the attributes physical appearance, odor, color, firmness used as “overall quality” was determined using a hedonic scale from 1 to 5, where 1 = “very poor” and 5 = “excellent”. The samples “overall quality” has to be considered as an average of the above-mentioned sensorial attribute values as evaluated by the panelist. A score equal to three was used as the threshold for produce acceptability. The “overall quality” score of Chinese kale packaged in perforated PE (control), passive MAP (PP), OPE1, OPE2, OPE3, OPE4 bags stored at 5°C for 3 days, 13 days and 14 days were illustrated in Table 4.

Yellowing and wilting of leave in a short time were major problems of Chinese kale stored under refrigerated air packed in PE bags, which had shelf life of only 3 days. The tissue yellowing found on the Chinese kale leave resulting from the degradation of chlorophyll. The excess weight loss reduced firmness and caused wilting of Chinese kale. The odor was the main cause responsible for quality loss of Chinese kale packed in PP bag. Too low O₂ concentration and too high CO₂ concentration could induce off-flavor therefore reducing shelf life of the Chinese kale packed in PP bag. This sample was very compromised by wilting phenomenon that is strictly related to produce weight loss. Another. Yellowing and Wilting of leave of Chinese kale packed in OPE4 as shown in Figure 1d, Chinese kale leave turning yellow after 12 days of storage compared to the other samples (OPE1, OPE2 and OPE3) which remained green for 13 days of storage (Figure 1a, b, c). This is due to the fact that O₂ concentration in OPE4 reached 20% after 11 days of storage, therefore resulted in less green and more yellowing of the Chinese kale leaf packed in OPE4 before the other treatment. Firmness and wilting were two main factors influencing the acceptability of Chinese kale packed in OPE1, OPE2, and OPE3.

Table 4. Overall quality score of Chinese kale packaged in perforated PE (control), Passive MAP (PP), OPE1, OPE2, OPE3, OPE4 bag stored at 5°C for 3 days, 13 days and 14 days.

| Type of packaging | Overall quality score after 3 days of storage | Overall quality score after 6 days of storage | Overall quality score after 13 days of storage |
|-----------------------------|---|---|--|
| Perforated PE (Control) | 1.8±0.20 ^b | N/A | N/A |
| Polypropylene (Passive MAP) | 4.8±0.20 ^a | 2.40±0.98 ^b | N/A |
| OPE1 | 4.8±0.20 ^a | 4.2±0.37 ^a | 2.8±0.37 ^a |
| OPE2 | 4.8±0.20 ^a | 3.8±0.20 ^{ab} | 2.8±0.37 ^a |
| OPE3 | 4.6±0.40 ^a | 3.8±0.20 ^{ab} | 3.0±0.32 ^a |
| OPE4 | 4.4±0.25 ^a | 4.0±0.32 ^a | 1.8±0.37 ^b |

Different letters in the same column denote significant differences at $P = 0.05$

Table 5. Shelf life of Chinese kale packed in different packaging type at 5°C after 3 days of storage.

| Type of packaging | Shelf life (days) |
|-----------------------------|-------------------------|
| Perforated PE (Control) | 2.6±0.25 ^d |
| Polypropylene (Passive MAP) | 6.6±0.25 ^c |
| OPE1 | 13.8±0.48 ^a |
| OPE2 | 13.6±0.68 ^{ab} |
| OPE3 | 14.2±0.37 ^a |
| OPE4 | 12.0±1.00 ^b |

Different letters in the same column denote significant differences at $P = 0.05$

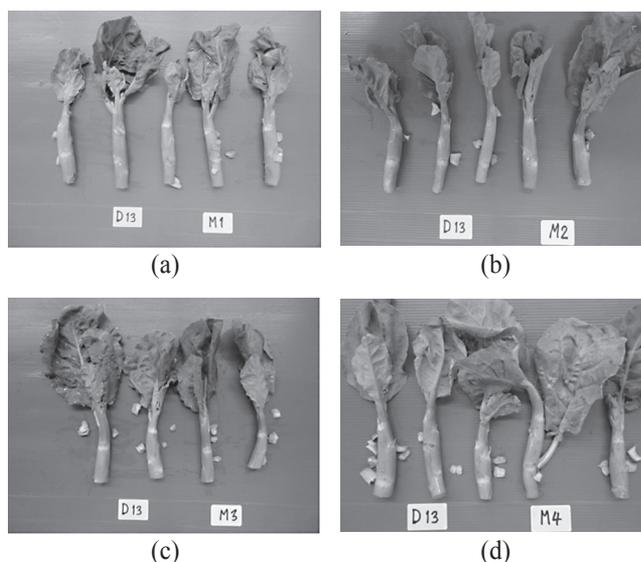


Figure 1. Appearance of Chinese kale packed in OPE1 (a), OPE2 (b), OPE3 (c), OPE4 (d) stored at 5°C for 13 days.

Headspace gas composition

The head space oxygen concentration concentrations decreased then reached equilibrium in all bags. For Chinese kale packed in all active packaging OPE1, OPE2, OPE3, OPE4, the O₂ concentrations reached equilibrium concentration of about 16, 17.6, 16 and 17.6%, respectively after 2 days of storage, owing to the high OTR of the film. The O₂ concentrations in PP bag reached equilibrium concentration of about 9% after 4 days of storage. Chinese kale packed in passive MAP (PP) bags had the highest CO₂ of about 7% after 3 days of storage, then reached equilibrium of about 5% after 4 days of storage. For Chinese kale packed in all active packaging OPE1, OPE2, OPE3, OPE4, the CO₂ concentrations reached equilibrium concentration of about 1.1, 1.0, 1.3 and 0.8%, respectively after 4 days of storage. As illustrated from the results, the O₂ concentration decreased rapidly to about 16-17% during the first 40 hours in all OPE bags and to about 9% in PP bags due to the fact of a high respiration rate of the produce. The head space gas composition is strictly related to both gas transmission rate through the film and respiration rate of packaged produce. The higher the barrier properties of a packaging were, the faster was the decrease in the headspace O₂ concentration and the increase in the headspace CO₂ concentration. The phenomena can be illustrated from the result of Chinese kale packed in PP and all OPP bags, PP bag had higher barrier properties than all OPE bags caused the decreasing in O₂ concentration and the increase in the headspace CO₂ concentration faster than all OPE bags.

CONCLUSION

Effects of active packaging and passive MAP (PP) were measured on Chinese kale quality. All sample treatments were stored at refrigerated temperature (5°C) during the storage period. The importance quality parameters were monitored to compare the influence of passive MAP (PP), atmospheric air in perforated polyethylene package and three different oxygen transmission rates active packaging on quality retention. Results showed that the selection of proper material is a key to achieve head space conditions that can control the respiration rate, water loss, and color retention. Among the treatments, OPP3 represent the best packaging to prolong shelf life of Chinese kale for about 14 days as opposed to about 3 days for shelf life of Chinese kale packed in the perforated PE bag (control). Therefore, shelf life of Chinese kale packed in OPP3 could be extended by approximately 5 times with respect to the perforated PE bag.

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