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The effect of packaging after 1-MCP treatment on color changes and chlorophyll degradation of broccoli (*Brassica oleracea* var. *italica* cv. Monopoly)

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Abstract

Broccoli is a highly perishable floral vegetable whose postharvest quality is influenced by transport and storage environment, particularly ethylene. Endogenously produced ethylene promotes sepal yellowing and shortens storage life whereas packaging delays color changes and prolongs storage life because of reduced respiration and ethylene production. We tested the effectiveness of the ethylene action inhibitor 1-methycyclopropene (1-MCP), as a complement to packaging to maintain postharvest quality of broccoli. 'Monopoly' broccoli (*Brassica oleracea* var. *italica*) heads were treated with 0.05 mg/l of MCP and packaged using three different packaging materials such as polyvinylchloride (PVC) films of 8.5 (P1) and 14 µm thickness (P2) and polyethylene (PE) bags (P3). After that broccoli heads were stored in a cold room set at 5°C temperature and 95-98% relative humidity (RH). Packaging especially in P1 bags after 1-MCP treatment delayed chlorophyll degradation and colour changes in broccoli. Hue angle of broccoli colour and chlorophyll loss were correlated. Also weight loss was reduced especially in P1 packaged broccoli.

Key words: Broccoli, *Brassica oleracea* var. *italica* cv. Monopoly, postharvest, storage, 1-MCP, packaging, colour, chlorophyll.

Introduction

Vegetables are important to the human diet, and many studies have shown that a close relation exists between the intake of vegetables and cancer prevention. Vegetables, particularly brassicas, contain great quantity of antioxidants [1-3]. Also broccoli (*Brassica oleracea* L.) belongs to Brassicaceae family and is a popular vegetable in many parts of the world [4] because of anticarcinogen effect since early 1980's [5]. Broccoli is a compact, rapidly developing floral vegetable and is harvested when flowering heads are immature and hence is highly perishable, with a storage life of 2-3 days in air at 20°C [6] and 3-4 weeks at 0°C [7]. The major limitation in storage at ambient temperature is rapid yellowing of flowering buds due to chlorophyll breakdown [6, 8] while at low temperature, loss of quality is due both to colour change from green to yellow and the onset of rotting [9].

Endogenous ethylene is suggested as having and important role in the colour change of stored broccoli [8, 10-12]. Application of exogenous ethylene has been shown to accelerate yellowing of broccoli [13, 14] and the effect has been attributed to stimulation of ethylene production [7, 15] and increased tissue sensitivity to ethylene[16]. Wills *et al.* [17] reported that <0.005 µl l^{-1} more than doubled the storage life of broccoli held at 20 and 5°C.

Packaging of broccoli has been reported to maintain quality and extend shelf life. These beneficial effects can be explained by modified atmosphere created inside the package as well as the resulting reduction in water loss. The composition of atmosphere inside a film-wrapped package depends on two processes - respiration of commodity and permeation of film [18]. Also shelf life can be potentially regulated through the use of compounds that inhibit ethylene action. The gaseous ethylene antagonist 1-methylcyclopropene (1-MCP) appears to be an effective inhibitor of ethylene action at extremely low levels [19-22]. 1-MCP prevented or delayed chlorophyll degradation and various types of colour changes in a wide range of crop species [23]. 1-MCP delayed chlorophyll degradation in coriander and leafy Asian vegetables [24] when ethylene was present. 1-MCP prevented broccoli yellowing both with and without exogenous ethylene. In this paper the effect of packaging of broccoli with three different packing materials after 1-MCP treatment on yellowing of broccoli florets of storage in a cold room set at 5°C temperature and 95-98% RH was reported.

Materials and Methods

Plant material: For the laboratory studies, broccoli (*Brassica oleracea* L. cv. Monopoly) was grown in Arslanbey Vocational School of Kocaeli University, Türkiye. The broccoli heads were harvested in November and sorted undamaged heads of uniform green colour for use in experiment.

1-MCP treatment: The source of 1-MCP was Smartfresh® (Agrofresh, Inc., a subsidiary of Rohm and HAAS, Gebze, Turkey), a powder which releases MCP gas when 2-3 ml water injected. Broccoli heads were placed at 20°C in a 100-litre plastic container together with the 0.05 mg/l of Smartfresh® in a Petri dish and container sealed, then immediately water injected on Petri dish, again sealed for 6 h.

Packaging materials and storage: Polyvinylchloride films (PVC, formula: Factor 1) (Pro-pack Inc., Istanbul, Turkey) of 8.5 and 14 µm thickness is as expressed in the text P1 and P2 and 10 kg sized perforated polyethylene bags (P3) were used as packaging material in this study. Two groups of broccoli were wrapped individually in 8.5 and 14 µm PVC shrinkable films and last group of broccoli was placed individually in perforated polyethylene bag. After 1-MCP and packaging treatment, the broccoli was placed in cold room set at 5°C temperature and 95-98% relative humidity.

Chlorophyll analyses: Broccoli heads were analyzed weekly about chlorophyll content. Florets (2 g) trimmed from whole heads per treatment were immersed in 10 ml acetone and shaked. This application was repeated two times before spectrophotometric examination. In most cases three heads from each treatment were analyzed.

Color measurement: Color readings of the broccoli heads were performed with a chromameter (Minolta CR-300, Minolta, Osaka, Japan), equipped with an 8-mm measuring head and a D65 illuminant. The meter was calibrated with manufacturer's standard white plate. Color changes were quantified in the L*, a*, b*, color space. Hue angle [$h^o = \tan^{-1}(b^*/a^*)$ when $a^*>0$ and $b^*>0$ or $h^o = 180^o + \tan^{-1}(b^*/a^*)$ when $a^*<0$ and $b>0$] was calculated from the a* and b* values [25]. The color of broccoli heads was objectively measured at five points over the surface of heads.

Weight loss: Three replicates per treatment were weighed at the beginning of the storage and at a weekly interval during storage. The weight loss (%) was calculated in reference to the initial weight of the broccoli heads.

Statistics: Statististical analyses performed on data included analysis of variance (ANOVA) and standard deviation calculations. The experimental design used for analytical measurements was completely randomized and repeated three times.

Results

Color expressed as hue angle was retained better in broccoli packaged in PVC of 14 µm thickness (P2) and PE bags (P3) than those packaged in PVC film of 8.5 µm thickness (P1). This retention was higher in P2 than in P3 during storage, but there was no significant differences obtained between different packaging materials. Thus 1-MCP treatment and packaging had effect on the hue angle of broccoli until the 14 days of storage (104.54±0.49; 103.04±1.73 and 103.31±1.69, respectively) after that time hue angle declined (Fig. 1a). Similar results were obtained for chlorophyll content of broccoli heads, but chlorophyll content was retained better in broccoli packaged in P1 than those in the other two packaging treatments. Hue angle correlated ($r^2 = 0.792$, n = 15) with total chlorophyll content of broccoli heads (Fig. 1a-b). Both hue angle and chlorophyll content declined after 14th days of storage as the florets began to yellow. Packaging of broccoli heads after 1-MCP treatment delayed yellowing (Fig. 1b).

The b* values expressing yellowing increased during storage in all packaging materials (Fig. 2), but broccoli in P1 had less yellowing compared to the other treatments during the storage. At the end of the storage b* values of broccoli heads were 16.00±1.38; 16.22±1.32 and 18.95±0.63 in P1, P2 and P3, respectively. Similar results were obtained from the C values of broccoli heads (Fig. 3) whereas a* values of broccoli heads declined during the storage (Fig. 4). However, a* values of broccoli packaged in P3 was higher than those in P1 and P2.

Weight loss occurred in broccoli heads in all packaging materials over time in storage (Fig. 5). Percentage of weight loss was reduced by packaging after 1-MCP treatment. Weight loss was highest in P2, after 21 days 4.37±0.41% in P2 but only 3.46±0.09% in P3 and 3.53±0.05% in P1.

Discussion

Yellowing of florets is a particularly important quality problem during transport and storage of fresh broccoli. Over the storage period, florets will become yellow and abscised from the head. The decrease in green pigmentation is probably because of ethylene induced loss of chlorophyll during storage [26]. Therefore, successful 1-MCP use requires a delay, but not irreversible inhibition, of the processes involved in pigment metabolism [27]. Chlorophyll fluorescence changes were delayed in 1-MCP-treated fruit kept at ambient temperatures [28, 29]. Little is known about the effect of 1-MCP on pigment metabolism [27]. However, Gong and Mattheis [30] and Hershkovitz *et al.* [31] have found that chlorophyllase activity was reduced in 1-MCP-treated broccoli florets and avocado fruit respectively. In this study the color (hue angle) and chlorophyll were retained better for the first 14 days and declined. 1-MCP prevented or delayed chlorophyll degradation and various types of colour changes in a wide range of crop species [23]. Chlorophyll degradation of broccoli was delayed in all 1-MCP-treated packages until 14th days of storage in our study. Also hue angle was correlated with the total chlorophyll content of broccoli florets in all packages previously reported by Tian *et al.* [16].

In our study, a* values of broccoli in all 1-MCP-treated packages declined, whereas b* and C values increased. Therefore, we found that b* values and apparent florets yellowing correlated (data not shown). 1-MCP inhibits the loss of green color of broccoli stored at 5°C [32]. Also we found the green color of broccoli heads (a* values) slowly declined until 21th days of storage. Also b* values showed only little increase until this time, but after that especially b* values of broccoli in PE bags increased fastly. Green color of broccoli heads retained better in PVC film of 8.5 µm.

Storage life of broccoli is suggested to be 3-4 weeks at 0°C [7]. In this study broccoli was stored at 5°C temperature and the evaluated storage life was 27 days. Therefore, packaging after 1-MCP treatment prolonged storage life at 5°C because of delayed color changes, chlorophyll degradation and also weight loss.

Fresh weight change is a crucial parameter, since loss in weight means also an economic loss, and additionally it has a strong effect on the florets appearance, due to shrinkage. Already a weight loss of 10% makes horticultural products unsaleable [33]. In our study weight loss of broccoli in all packages was in acceptable limits but packaging in PVC film (14 µm) gave higher weight loss. According to Jacobsson *et al.* [34], broccoli quality was maintained in modified atmosphere packaging but none of the studied packaging materials was able to maintain all the studied properties.

Conclusions

In conclusion, packaging of broccoli especially in PVC film of 8.5 µm after 1-MCP treatment delayed chlorophyll degradation and yellowing at least 14th days of storage at 5°C temperature. Also weight loss of broccoli was reduced by this treatment.

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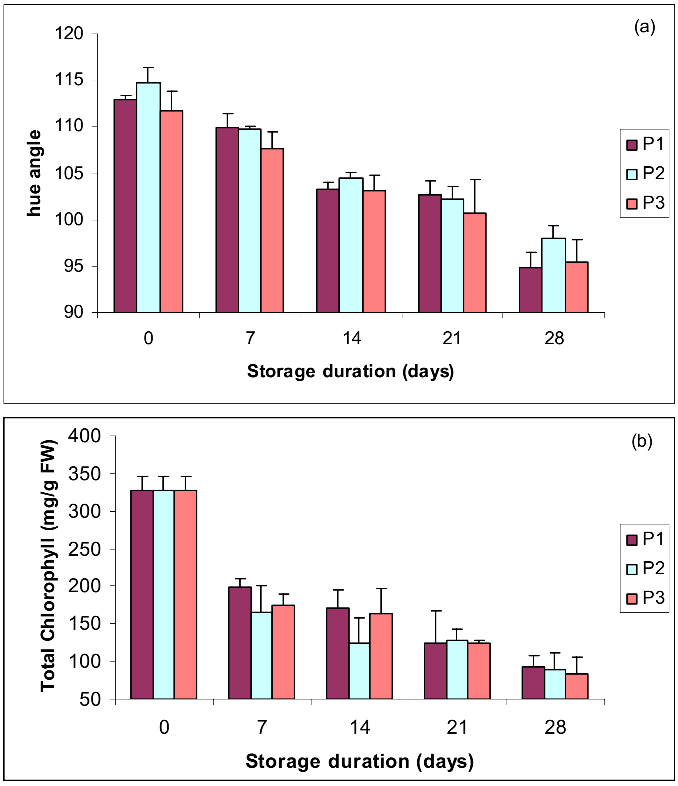

Figure 1. (a) Hue angle and (b) total chlorophyll content of broccoli packaged in three different packaging during storage: P1 = PVC film (8.5 µm), P2 = PVC film (14 µm) and P3 = PE bag. Each bar is the mean of three replications ± SE.

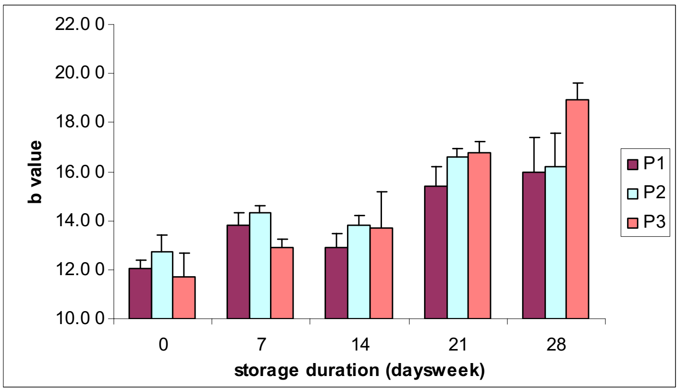

Figure 2. b values of broccoli packaged in three different packaging during storage: P1 = PVC film (8.5 µm), P2 = PVC film (14 µm) and P3 = PE bag. Each bar is the mean of three replications ± SE.

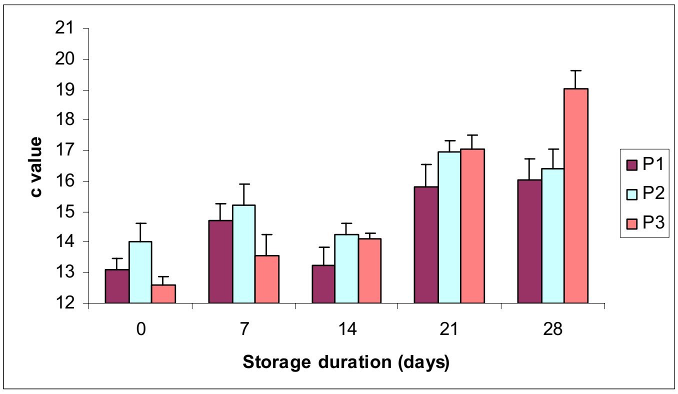

Figure 3. Color space c values of broccoli packaged in three different packaging during storage: P1 = PVC film (8.5 µm), P2 = PVC film (14 µm) and P3 = PE bag. Each bar is the mean of three replications ± SE.

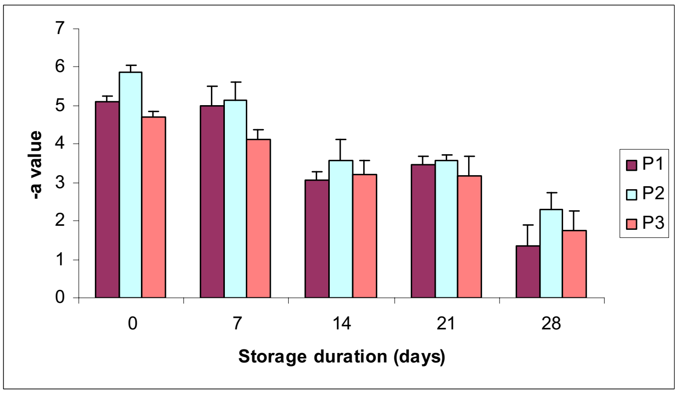

Figure 4. a values of broccoli packaged in three different packaging during storage: P1 = PVC film (8.5 µm), P2 = PVC film (14 µm) and P3 = PE bag. Each bar is the mean of three replications ± SE.

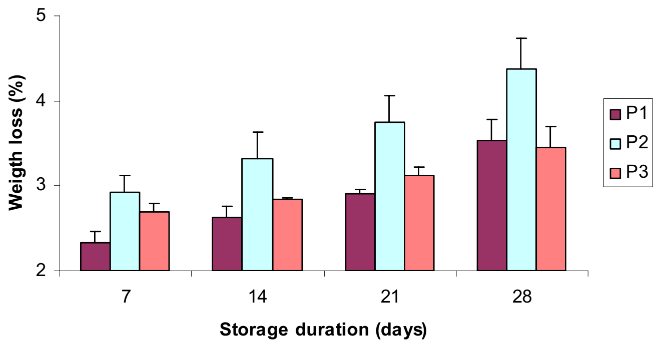

Figure 5. Weight loss of broccoli packaged in three different packaging during storage: P1 = PVC film (8.5 µm), P2 = PVC film (14 µm) and P3 = PE bag. Each bar is the mean of three replications ± SE.