

Effect of Packaging Materials on the Quality and Shelf Life of Fresh-Cut Vegetables

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Abstract —The fresh-cut products market has seen significant growth over the past decade, expanding from foodservice to retail shelves, convenience stores, and mobile fruit vans. Controlling temperature, atmosphere, relative humidity, and sanitation is crucial for maintaining the quality, safety, and shelf life of fresh-cut produce. The effect of different types of packaging on the quality and shelf life of fresh-cut lettuce, onion, and mixed cabbage with carrot was investigated. All fresh-cut produce was packaged in three types of packaging (A-Best[®], Fresh & Fresh[®], Active Pak[®], and A-Best[®] at 5°C) and then stored at 4°C to simulate the refrigerated shelf in convenience stores. The result found that fresh-cut lettuce, onion, and mixed cabbage with carrot in A-Best at 5°C showed the highest overall acceptability both externally and internally, significantly. On the other hand, A-Best[®] and A-Best[®] at 5°C effectively retarded the rate of browning symptom of the cut surfaces. The results suggest that combined treatments showed better results than those in the single treatment and have commercial potential in improving the shelf life and maintaining the quality of fresh-cut produce.

Index Terms — Quality Control, Fresh-Cut, Postharvest Processing, Packaging, Modified Atmosphere

I. INTRODUCTION

Fresh-cut produce is commonly sold in open-air markets and food stalls across many Asian countries and is increasingly available in supermarkets. In particular, fresh-cut fruits have grown in popularity in the region's urban centers. When displayed without

refrigeration, these products generally do not remain viable beyond the day of display.

Fresh-cut vegetables command a greater market share than fresh-cut fruits in Thailand [1]. As consumer demand for ready-to-eat products increases, the fresh-cut market in Thailand is projected to experience sustained growth. The range of fresh-cut vegetables has expanded considerably, including items such as carrots, celery, broccoli, lettuce, and various salad mixes. Innovations in packaging and processing have improved shelf life and quality, making these products more appealing to consumers. For example, the development of modified atmosphere packaging helps maintain freshness by controlling oxygen (O₂) and carbon dioxide (CO₂) gas within the package [2].

Fresh-cut produce generally exhibits higher respiration rates than whole, unprocessed produce. This increased respiration accelerates metabolic activity, leading to rapid senescence. In addition, a higher respiration rate contributes to an accelerated loss of flavor, comprising acids, sugars, and other important elements, as well as a decline in nutritional value. Moreover, ensuring the quality and nutritional stability of fresh-cut produce during storage is more demanding than for its whole counterparts [3].

Packaging is effective in maintaining the quality and extending the shelf life of fresh-cut vegetables by reducing O₂ and increasing CO₂ in the package [4]. Modified Atmosphere Packaging (MAP) for fresh products involves adjusting the internal atmosphere of the package to optimize product preservation. This is achieved through the natural interaction between the product's respiration rate and the gas exchange properties of the packaging material. MAP can be implemented using either active or passive methods [5], [6]. However, postharvest problems of packaged fresh-cut lettuce, onion, and mixed cabbage with

carrot in the retail or convenience store include browning, physiological disorders, non-optimal storage conditions, and inappropriate packaging materials.



Fig. 1. Display of fresh-cut products in a modern trade in Thailand [7].

II. RESEARCH OBJECTIVE

The present study aims to investigate the effect of packaging materials on the quality and shelf life of fresh-cut products.

III. MATERIALS AND METHODS

A. Plant Materials and Treatment Conditions

Plant Materials

Fresh lettuce, onion, cabbage, and carrot were purchased from the wholesale market in Pathum Thani province, Thailand. After purchase, all commodities were brought to the laboratory at the School of Bioresources and Technology, King Mongkut's University of Technology Thonburi (Bang Khun Thian) within 2 hours of transportation.

Fresh-Cut Products are Prepared for Processing

Fresh-cut products were prepared by longitudinal slicing using a sharp knife. Then, all fresh-cut vegetables were immersed in 2% calcium chloride (CaCl_2) solution as a preservative and curing agent at 25°C for 15 minutes. Then, all fresh-cut were controlled in a drain basket, dried, and 100 grams each were put into different packaging as follows: A-Best[®], Fresh & Fresh[®], Active Pak[®] at 25°C , and A-Best[®] with 5°C (Applying cold water at 5°C). After packaging, all treatments were stored at a constant temperature of 4°C and 65-80% relative humidity (RH) until the end of the experimental period.

B. Gas Composition Analyses

At each sampling point, the levels of O_2 and CO_2 accumulation within the packages of fresh-cut were monitored. Gas measurements were conducted using a PBI-Dansensor CheckMate II (Denmark) by inserting the instrument's needle directly into the packaging.

C. Sensory Acceptance

Overall acceptability was rated by an untrained panel of 15 judges using a 9-point hedonic scale [8], with number 9 = "like very much" and number 1 = "dislike very much".

D. Statistical Analysis

All statistical analyses were conducted using JMP statistical software (SAS Institute Inc., Cary, NC, USA). Data were analyzed using Student's t-test and Analysis of Variance (ANOVA). When ANOVA indicated significant differences ($P < 0.05$), mean separation was performed using the Tukey-Kramer test.

IV. RESULTS AND DISCUSSION

A. Concentration of O_2 in Fresh-Cut Packaged

The O_2 concentration in the A-Best[®] and A-Best[®] with 5°C package of lettuce (Fig. 2), onion (Fig. 3), and mixed cabbage with carrot (data not shown) gradually decreased throughout the experimental period. While in Fresh & Fresh[®], Active Pak[®] resulted in slightly decreased O_2 concentration and higher than that in A-Best[®] and A-Best[®] with 5°C package (Fig. 1 and Fig. 2). Low oxygen levels are a key strategy for managing the shelf life of fresh produce in MAP. In early MAP applications, the main objective of reducing O_2 was to slow the respiration rate of fruits and vegetables, thereby preserving quality and extending shelf life [9]. However, low O_2 also suppresses the growth of aerobic microorganisms [10].

Recent studies have indicated that low O_2 conditions may inhibit the development of desirable flavors in fresh melons [11] or contribute to undesirable flavors in baby spinach [12]. This suggests that new technologies utilizing low O_2 levels should be tailored to the specific characteristics of each type of produce to avoid triggering anaerobic respiration.

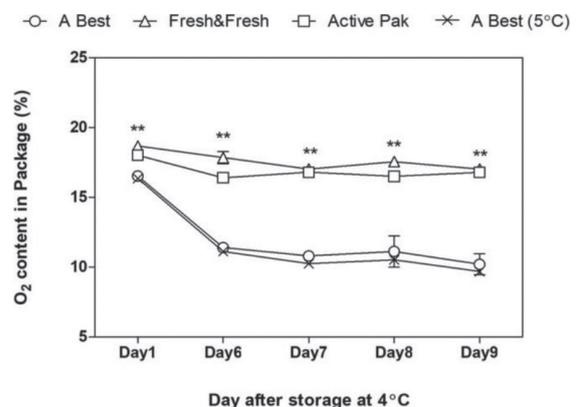


Fig. 2. Levels of O_2 concentration in fresh-cut lettuce packed in different material packages and stored at 4°C for 9 days. Each symbol is the mean of three replicate measurements; vertical lines represent SE. (○) A-Best[®], (Δ) Fresh & Fresh[®], (□) Active Pak[®], and (*) A-Best[®] at 5°C

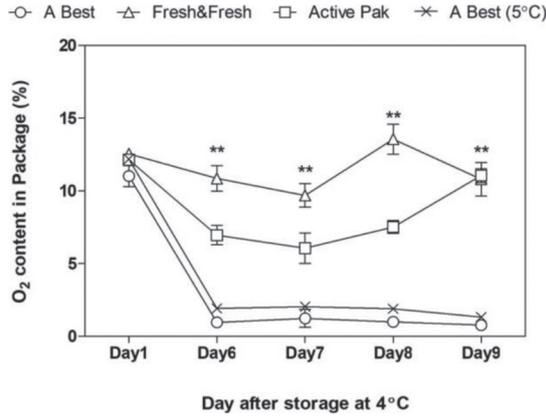


Fig. 3. Levels of O₂ concentration in fresh-cut mixed cabbage with carrot packed in different material packages and stored at 4°C for 9 days. Each symbol is the mean of three replicate measurements; vertical lines represent SE. (○) A-Best®, (Δ) Fresh & Fresh®, (□) Active Pak®, and (*) A-Best® at 5°C

● Concentration of CO₂ in Fresh-Cut Packaged

The carbon dioxide concentration in the package of fresh-cut lettuce was about 4%, then it decreased slightly until the end of the observation, and there was no significant difference between the package A Best® and A-Best® at 5°C. However, the lower CO₂ concentration of 1.5-2% was found in Fresh & Fresh® and Active Pak® (Fig. 4). Similarly with lettuce, the CO₂ concentration in fresh-cut mixed cabbage with carrot showed higher in A Best® and A-Best® with 5°C but the difference between treatments was significant (data not shown).

Overall, there are many similarities between the effects of low O₂ and high CO₂ on the suppression of various metabolic processes in fruits and vegetables [13]. Respiration is generally inhibited by low O₂ and high CO₂ environments [14].

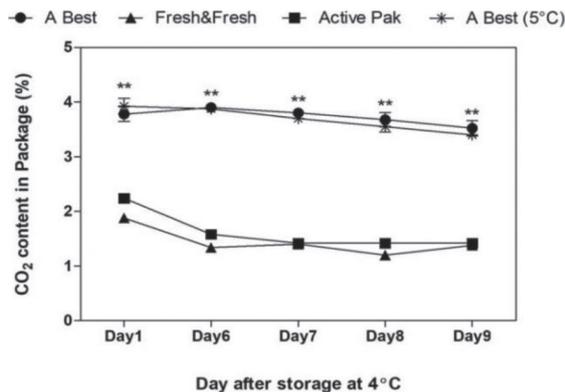


Fig. 4. Levels of CO₂ concentration in fresh-cut lettuce packaged in different material packaging and stored at 4°C for 9 days. Each symbol is the mean of three replicate measurements; vertical lines represent SE. (○) A Best®, (Δ) Fresh & Fresh®, (□) Active Pak®, and (*) A-Best® at 5°C

Initially, the respiration rate of the product is much higher than the package permeation rates for CO₂ and O₂. This results in the accumulation of CO₂ and depletion of O₂ within the package [10].

Reduced O₂ and increased CO₂ concentrations must be stringent enough to slow metabolism, resulting in reduced chlorophyll loss along with decreased pigment accumulation and prolonged shelf-life [15].

● Overall Acceptance of Fresh-Cut

According to the consumer survey, consistent appearance, freshness, and aroma are important quality attributes for fresh-cut lettuce, onions, mixed cabbage, and carrots. According to several researchers [16], [17], in addition to a fresh appearance, an acceptable texture of the fresh-cut items and nutritional value are also important.

The initial scores for overall acceptability outside of fresh-cut lettuce (Fig. 5), onion (data not shown), and mixed cabbage with carrot (data not shown) on a scale of 1-9 were 9 for all treatment materials. The scores for A-Best® and Active Pak® drastically decreased to 6.3 and 6.2 after 6 days of storage. For lettuce, fresh-cut lettuce wrapped in A-Best® at 5°C had the highest final score on the last day of storage with 6, followed by A-Best®, Fresh & Fresh®, and Active Pak® (Fig. 5).

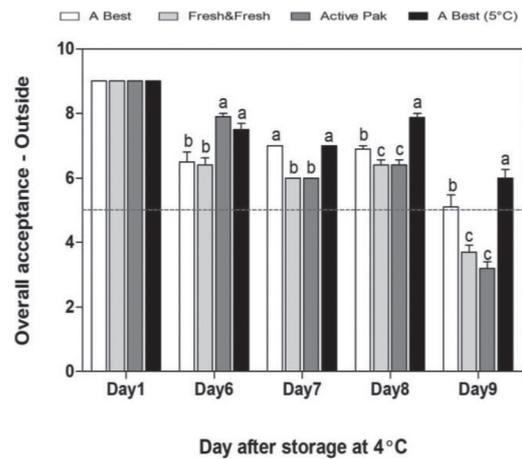


Fig. 5. Total acceptance both outside in fresh-cut lettuce packed in different material packaging and stored at 4°C for 9 days.

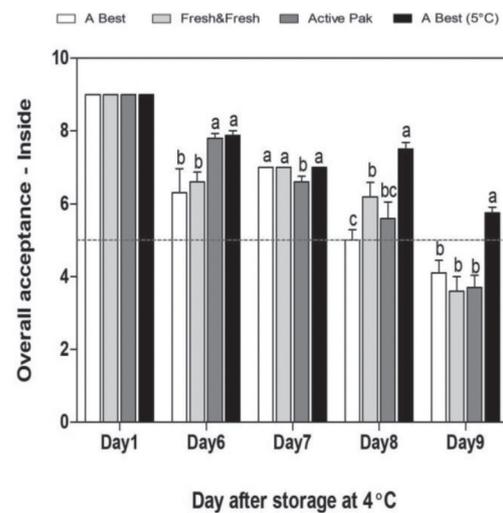


Fig. 6. Total acceptance both inside in fresh-cut lettuce packed in different material packaging and stored at 4°C for 9 days.

Similarly, with the overall acceptability outside, overall acceptability inside, A-Best® with 5°C shows earned the highest final scores on the last day of storage with 5.8, but no difference between treatment and all other treatments (Fig. 6).



Fig. 7. Overall appearance of fresh-cut onions packaged in A Best®, Fresh & Fresh®, Active Pak®, and A-Best® at 5°C and stored at 4°C for 9 days.



Fig. 8. Overall appearance of fresh-cut onions packaged in A Best®, Fresh & Fresh®, Active Pak®, and A-Best® at 5°C and stored at 4°C for 9 days.

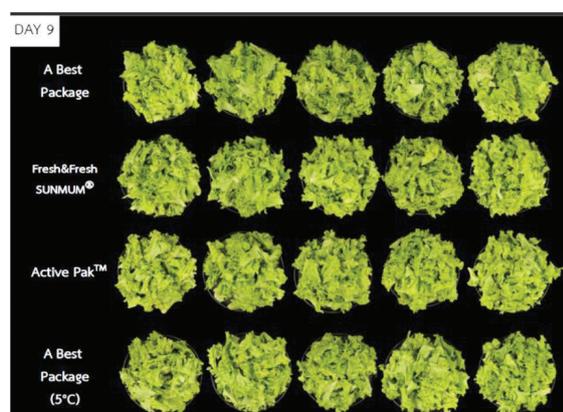


Fig. 9. Overall appearance of fresh-cut lettuce packaged in A Best®, Fresh & Fresh®, Active Pak®, and A-Best® at 5°C and stored at 4°C for 9 days.

V. CONCLUSION

The quality of fresh-cut lettuce, onion, and mixed cabbage with carrot is determined by a combination of attributes, properties, and characteristics that influence consumer value. Among these, “appearance” and “freshness” have been identified as the most important factors at the point of purchase. This study evaluated the effectiveness of three packaging materials in preserving these attributes in fresh-cut produce. The results showed that A-Best® and A-Best® at 5°C were the most effective in maintaining overall quality, including appearance, cut surface color, and freshness. Future research will explore the impact of adding antioxidants, fungicides, and vitamins to improve the nutritional value of fresh-cut produce.

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