Storage quality of fresh-cut cabbage and lettuce processed in a commercial produce plant and stored at various temperatures

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Abstract

Fresh-cut cabbage and lettuce products that were processed in a commercial produce plant were stored at 1°C, 5°C, 10°C, and 15°C to evaluate the influence of storage temperature on their storage quality. The CO_2 accumulation in packages containing fresh-cut products approached 11 to 16% for fresh-cut cabbage and 4 to 6% for fresh-cut lettuce by the end of storage at all temperatures. Fresh-cut cabbage and lettuce products stored at 1°C and 5°C maintained initial low bacterial counts throughout the storage period, while the bacterial counts for both products increased during storage at 10°C and 15°C. The bacterial populations of fresh-cut cabbage were 0.5 to 0.8 logs higher than those of fresh-cut lettuce. Sublethally injured bacteria were not detected on any samples. No browning was observed with fresh-cut cabbage, whereas slight browning occurred with fresh-cut lettuce on only the last day of storage. These results indicate that marketed fresh-cut cabbage and lettuce could meet the optimal CO_2 concentration in packages and it would be desirable to store fresh-cut products at low temperature ranging from 1°C to 5°C to enable better quality maintenance.

Key words: fresh-cut products, CO_2 concentration, storage temperature, microbial quality, visual quality

1. Introduction

It is crucial to preserve microbial and visual quality of fresh-cut produce during storage. There are many reports on the effects of disinfectants [1-4], storage temperature [5], and storage atmospheric composition [6, 7] on the quality of fresh-cut vegetables. In general, it is recognized that a combination of two and more disinfectants is more effective than one alone [3, 4] due to the synergistical effect to reduce microbial counts. For example, Izumi [8] reported that a combination of 1% fumaric acid agent and electrolyzed slightly acidic water with 13 ppm of available chlorine or a combination of 0.05% calcined calcium agent and ozonated water with 5 ppm of ozone was recommended for fresh-cut lettuce or fresh-cut cabbage, respectively. In addition to the sanitizing treatments, it has also been reported that the high CO_2 atmosphere of > 10% in modified atmosphere (MA) packages would be helpful in inhibiting growth of spoilage bacteria of fresh-cut vegetables including cabbage and lettuce during storage due to dissolved CO_2 in the aqueous phase of the produce and microorganisms [9]. However, these documentations are results from bench tests at a laboratory level, not at a commercial level.

According to a survey of the bacterial counts of fresh-cut vegetables sold at retail stores, there was a large difference in the bacterial counts among products, in which the number of mesophiles and coliforms ranged from 3.5 to 9.0 log CFU g^{-1} and from 1.0 to 7.2 log CFU g^{-1}, respectively [10]. Although there are microbial surveys of fresh-cut vegetable products at retail stores [11], there is a paucity of information on the microbial and visual quality of commercially prepared fresh-cut products during storage and distribution.

Fresh-cut produce has been popular in Japan over the past two decades and the current annual sales of fresh-cut cabbage and lettuce are the major contributor in the Japanese fresh-cut produce industry. In the present study, we determined the effects of storage temperature (1°C, 5°C, 10°C and 15°C) on quality changes of fresh-cut cabbage and lettuce products processed in a commercial produce plant. Another concern for ensuring the microbial quality of marketed fresh-cut products is the presence of sublethally injured bacteria as the result of exposure to chemical and chilling stresses. The injured bacteria can resuscitate and subsequently multiply in a suitable environment, and may increase the risk of underestimating the microbiological quality of the products [12]. Thus, we also evaluated sublethally injured coliform bacteria on the fresh-cut cabbage and lettuce products during storage.

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2. Materials and methods

2.1 Preparation of vegetable samples

Products of shredded cabbage (ca 2 mm wide and 50 mm long) and chopped lettuce (ca 50 mm wide and long) were obtained from a commercial produce plant (Orto Inc., Wakayama, Japan). Fresh-cut cabbage and lettuce packed in polypropylene bags with 30 µm thick and 40 µm thick, respectively, were transported to the laboratory at Kindai University within 1 h after production of the product. Three replicated packages each were stored at 1°C for 7 days, 5°C for 5 days, 10°C for 3 days, and 15°C for 2days. Expanded temperatures were included, because fresh-cut products are held commercially at 10°C and sometimes at 15°C in Japan although the ideal storage temperature is 1°C except for the chilling-sensitive produce.

2.2 CO_2 analysis in MA packages

The CO_2 concentration in packages was measured daily during the storage period using a gas chromatograph (GC-8AIT; Shimadzu, Kyoto, Japan) equipped with a thermal conductivity detector. The column used for CO_2 analysis was Porapak Q (60/80 mesh, 3.2 mm × 1.5 mm; Shimadzu, Kyoto, Japan) at 90°C.

2.3 Storage quality

2.3.1 Microbial counts

Fresh-cut samples were taken periodically to evaluate microbial counts. A 10 g sample was homogenized in 90 mL sterile saline solution (0.85% NaCl in water) in a sterile stomacher bag with a stomacher (Exnizer-400; ORGANO, Tokyo, Japan). Serial dilutions from each sample were made in sterile saline solution. Counts of mesophilic bacteria and coliform bacteria were measured by standard method agar (SMA) medium (Nissui Pharmaceutical, Tokyo, Japan) incubated at 37°C for 48 h and XM-G medium (Nissui Pharmaceutical, Tokyo, Japan) incubated at 37°C for 24 h, respectively. Injured coliform bacteria were enumerated using a one-step TAL method with TAL medium, which involves a layer of selective medium (XM-G) with nonselective medium (SMA containing 0.03% sodium pyruvate) overlaid on the top of it, after incubation at 37°C for 24 h [13]. When injured target cells were inoculated directly onto the TAL medium, the injured cells resuscitated and grew on the nonselective medium and then formed typical reaction colonies when the selective agents from selective medium diffused to the nonselective medium. Therefore, the number of injured bacteria was represented by the difference between the counts on TAL medium and selective medium as the control.

2.3.2 Browning evaluation

Browning discoloration of fresh-cut products was evaluated daily on a rating scale of 0 = none, 1 = slight, 2 = moderate, and 3 = severe. A score 1 was considered to be the limit of marketability.

2.4 Statistical analysis

Statistically significant differences ($P \leq 0.05$) were determined for the microbial population. The mean values were compared using the Tukey's honestly significant difference method.

3. Results

3.1 CO_2 concentration in MA packages

The CO_2 concentration in packages containing fresh-cut cabbage and lettuce increased during storage at all temperatures. With fresh-cut cabbage, the CO_2 concentration in packages reached a 14% at 1°C, 16% at 5°C, 11% at 10°C, and 16% at 15°C by the end of storage (Fig. 1A). In contrast, with fresh-cut lettuce, the CO_2 concentration in packages approached a 4% and 4.5% equilibrium at 1°C and 5°C, respectively, on day 3 and accumulated to 6% at 10°C and 15°C on the day 2 and day 3, respectively (Fig. 1B). The CO_2 accumulation was 5 to 11% lower with fresh-cut lettuce than with fresh-cut cabbage at all temperatures.

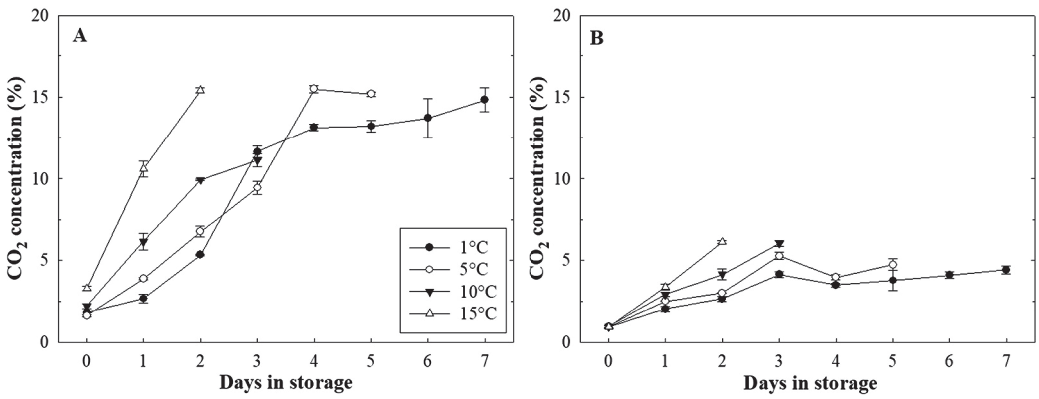

Fig. 1. CO_2 concentration in MA packages containing fresh-cut cabbage (A) and fresh-cut lettuce (B) during storage at various temperatures. Vertical lines represent standard error of the mean (n = 3).

3.2 Storage quality

3.2.1 Microbial quality

Counts of bacteria of fresh-cut cabbage during storage at various temperatures were shown in Fig. 2. Regarding coliform bacteria, no significant difference was observed in the viable counts between XM-G medium and TAL medium, demonstrating that no injured bacteria were present. Thus, counts of coliforms were judged by the number of colonies on XM-G medium. Bacterial counts of fresh-cut cabbage stored at low temperatures (1°C and 5°C) did not increase from the initial counts of 3.3 to 3.7 log CFU g^{-1} throughout the storage period. In comparison, bacterial counts at high temperatures (10°C and 15°C) increased to 5.5 log CFU g^{-1} for mesophiles and 5.3 log CFU g^{-1} for coliforms at 10°C, and 6.8 log CFU g^{-1} for mesophiles and 6.0 log CFU g^{-1} for coliforms at 15°C by the end of storage.

Since no injured bacteria were observed on fresh-cut lettuce, coliform bacterial counts were judged in the same manner as fresh-cut cabbage (Fig. 3). Bacterial counts of fresh-cut lettuce during storage followed essentially the same trends as fresh-cut cabbage. At low temperatures (1°C and 5°C), bacterial counts did not increase during storage, especially for coliforms that remained at levels below the detection limit (< 3.0 log CFU g^{-1}) by the end of storage. In high temperatures (10°C and 15°C) storage, the microbial population on the last day of storage was 5.0 log CFU g^{-1} for mesophiles and 4.5 log CFU g^{-1} for coliforms at 10°C and 6.0 log CFU g^{-1} for mesophiles and 5.3 log CFU g^{-1} for coliforms at 15°C. The counts of fresh-cut lettuce were 0.5 to 0.8 logs lower than those of fresh-cut cabbage.

3.2.2 Visual quality

Browning of fresh-cut cabbage was not observed throughout the storage period at all temperatures, while slight browning occurred with fresh-cut lettuce on only the last day of storage when the lettuce samples stored at 10°C and 15°C became unmarketable (Table 1).

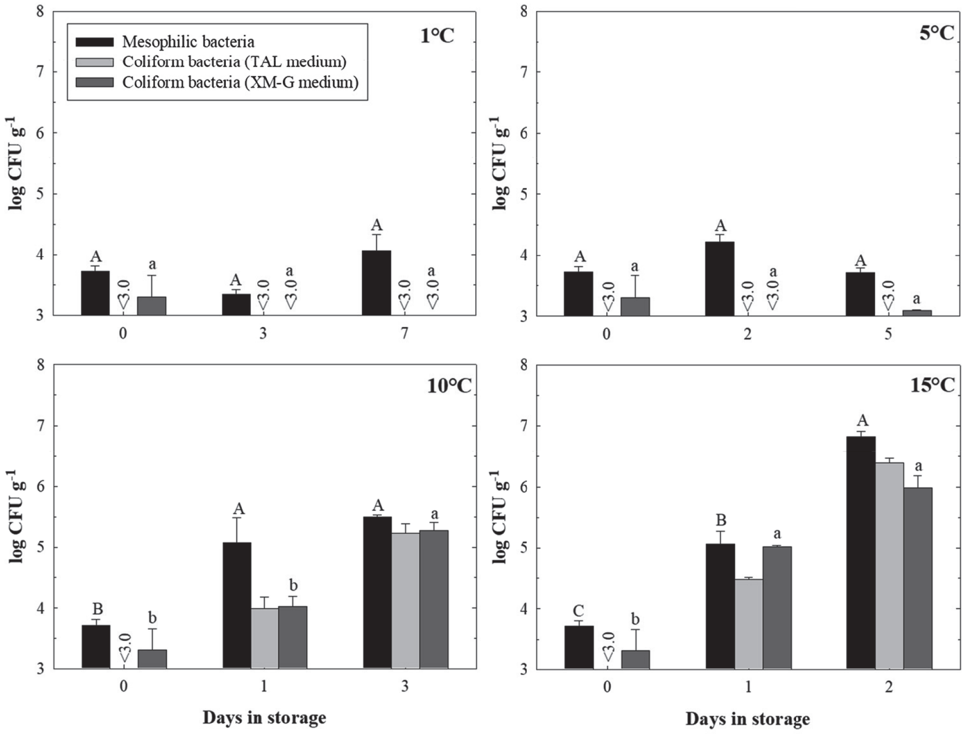

Fig. 2. Counts of bacteria of fresh-cut cabbage during storage at various temperatures. Less than 3.0 log CFU g^{-1} means below the level of detection. Different letters (capital letters for mesophiles and small letters for coliforms) within each medium at each graph are significantly different ($P \leq 0.05$). Vertical lines represent standard error of the mean (n = 3).

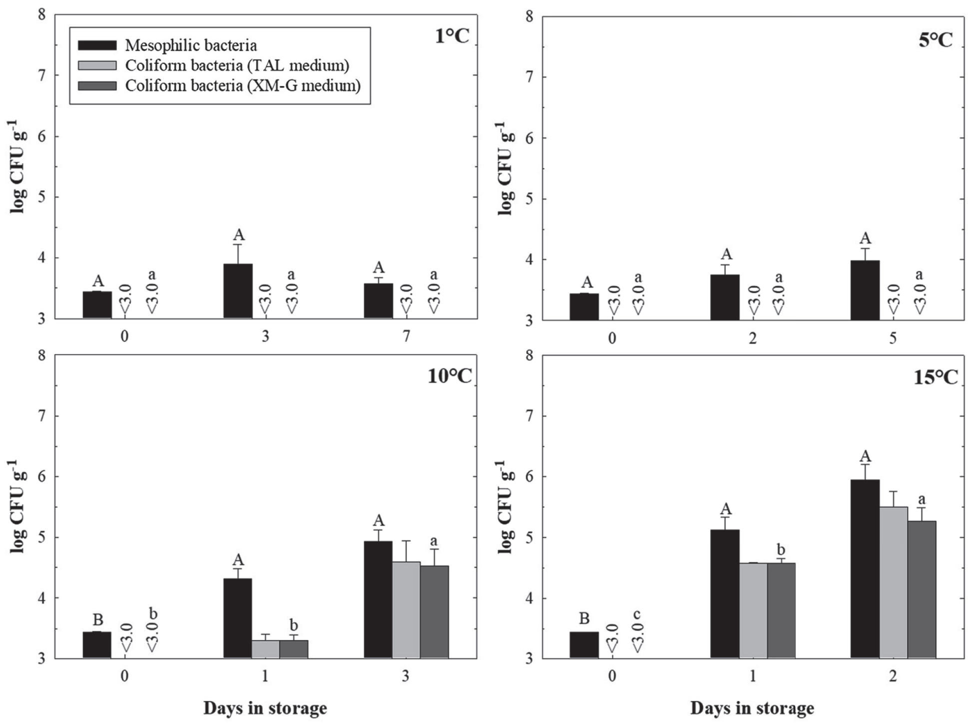

Fig. 3. Counts of bacteria of fresh-cut lettuce during storage at various temperatures. Less than 3.0 log CFU g^{-1} means below the level of detection. Different letters (capital letters for mesophiles and small letters for coliforms) within each medium at each graph are significantly different ($P \leq 0.05$). Vertical lines represent standard error of the mean (n = 3).

Table 1. Browning score of fresh-cut cabbage and lettuce on the last day of storage

Storage temperature	Days in storage	Fresh-cut cabbage*	Fresh-cut lettuce*
1°C	7	0	0.3
5°C	5	0	0.3
10°C	3	0	1
15°C	2	0	1

*0: none, 1: slight, 2: moderate, 3: severe

4. Discussion

We have recommended the necessity of adjusting the disinfectant concentration to a level lethal to bacteria so as not to cause sublethal cell injury and the practice of chill temperature and MA with high CO_2 levels of > 10% to lead a bacteriostatic effect for fresh-cut produce during storage on the basis of the results in a laboratory level study. In Japanese commercial produce plants, improved technologies on sanitizing and MA packaging are continually being made to attain high quality products to serve. This study was carried out to clarify whether the marketed fresh-cut products processed in a commercial produce plant could meet the optimal environmental conditions (CO_2 concentration and temperature) to control produce quality during storage.

The atmospheric composition of fresh-cut products in MA packages can affect their microbial and visual quality. The CO_2 accumulation in packages containing fresh-cut products approached 11 to 16% for fresh-cut cabbage and 4 to 6% for fresh-cut lettuce during the storage period at all temperatures. The CO_2 concentrations were similar for the recommended levels for MA packaging to reduce microbial growth and brown discoloration of fresh-cut cabbage (10 to 15% CO_2) and fresh-cut lettuce (5 to 10% CO_2) [(7)], indicating that the marketed packages would achieve the desired equilibrium CO_2 atmosphere. The difference in CO_2 accumulation between fresh-cut cabbage and lettuce is probably due to the difference in respiration rates of the vegetables and gas permeability of the film used.

Microbial quality of fresh-cut products was evaluated based on counts of mesophiles and coliforms at various temperatures. Initial microbial counts of mesophiles of fresh-cut cabbage and lettuce products were 3.7 log CFU g^{-1} and 3.4 log CFU g^{-1}, respectively, and those of coliforms were close to or below 3.0 log CFU g^{-1}. Sublethally injured bacteria were not seen on any samples on the initial day and during subsequent storage. These facts suggest that the chemical disinfectant treatment in the plant was imposed in sufficient level to kill bacteria without chemical injury. The number of bacteria during storage did not increase at low temperatures (1°C and 5°C) and increased at high temperatures (10°C and 15°C). This trend was similar to that observed in a laboratory study [(7,8,14)] regardless of the different disinfectants tested, although the bacterial counts in this study were comparatively less than those of the previous reports, in particular at 5°C and 10°C storage. On the other hand, counts of retail fresh-cut vegetables vary widely among produce. Counts of mesophiles and coliforms ranged from 6.5 to 8.2 log CFU g^{-1} and 1.0 to 4.9 log CFU g^{-1}, respectively, in fresh-cut cabbage and from 3.5 to 7.5 log CFU g^{-1} and 1.0 to 5.2 log CFU g^{-1} in fresh-cut lettuce [(10)]. These various bacterial populations might be attributed to storage time and temperature of the product at retail outlets.

The shelf life of fresh-cut cabbage and lettuce is limited by the occurrence of browning. Brown discoloration was not developed in fresh-cut cabbage stored at all temperatures and fresh-cut lettuce stored at 1°C and 5°C throughout the storage period. Little browning may have been involved in low temperature and cytoplasmic pH due to the high CO_2 concentration in packages, leading to the decrease of phenyl alanine ammonia-lyase activity and thereby less total phenolic content [(15)]. Since Izumi *et al.* [(7)] reported that bacterial contamination enhanced the elicitation of phenolic compounds and subsequent browning of cut lettuce, fresh-cut lettuce stored at 10°C and 15°C may have developed brown discoloration in association with a large number of bacteria at high temperatures.

When comparing fresh-cut cabbage with fresh-cut lettuce for storage quality, reduction of microbial proliferation and browning discoloration should be taken into account for fresh-cut cabbage and fresh-cut lettuce, respectively, during storage. Therefore, it is important that fresh-cut products be kept at low temperature ranging from 1°C to 5°C during storage and distribution.

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和文抄録

カット野菜工場で加工され異なる温度で貯蔵されたカットキャベツおよびカットレタスの品質

佐藤聖、泉秀実

カット野菜工場で加工されたカットキャベツ製品およびカットレタス製品を 1°C、5°C、10°C および 15°C で貯蔵し、製品の貯蔵品質に対する貯蔵温度の影響を評価した。カット野菜製品の包装内の貯蔵最終日の CO_2 濃度は、すべての貯蔵温度でカットキャベツ製品は 11 から 16%、カットレタス製品は 4 から 6%に達した。1°C および 5°C で貯蔵したカットキャベツ製品およびカットレタス製品の菌数は、貯蔵期間を通して低い初発菌数を維持した。一方、10°C および 15°C 貯蔵では両製品とも貯蔵期間中に菌数が増加した。カットキャベツ製品の菌数は、カットレタス製品よりも 0.5 から 0.8 log 高かった。また、損傷菌はいずれのサンプルからも検出されなかった。カットキャベツ製品では褐変が観察されなかったが、カットレタス製品では貯蔵最終日にわずかに褐変が観察された。これらの結果は、市販のカットキャベツおよびカットレタス製品は包装内の最適 CO_2 濃度を満たしていること、また、よりよい品質維持を可能にするためにはカット野菜製品を 1°C から 5°C の低温で貯蔵することが望ましいことを示している。

キーワード：カット野菜製品、CO_2 濃度、貯蔵温度、微生物的品質、外観品質

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