science, engineering and health studies

Research Article

*Science, Engineering and Health Studies*
*https://lio1.tci-thaijo.org/index.php/sehs*
*ISSN (Online): 2630-0087*

# Quality attributes of fresh-cut cabbages treated with acetic acid containing maltodextrin and chitosan

*Supattra Satianteerapap[1], Piyachat Chai-Uea[1], Chaiyong Taechapairoj[2], Chaiwat Bandaiphet[2] and Doungjai Thirathumthavorn[1*]*

[1] Department of Food Technology, Faculty of Engineering and Industrial Technology, Silpakorn University, Nakhon Pathom 73000, Thailand
[2] Department of Biotechnology, Faculty of Engineering and Industrial Technology, Silpakorn University, Nakhon Pathom 73000, Thailand

***Corresponding author**: Doungjai Thirathumthavorn thirathumtha_d@su.ac.th*

***Received**: 1 September 2022*
***Revised**: 8 December 2022*
***Accepted**: 12 December 2022*
***Published**: 30 December 2022*

***Citation**: Satianteerapap, S., Chai-Uea, P., Taechapairoj, C., Bandaiphet, C., and Thirathumthavorn, D. (2022). Quality attributes of fresh-cut cabbages treated with acetic acid containing maltodextrin and chitosan. Science, Engineering and Health Studies, 16, 22030012.*

## ABSTRACT

Fresh-cut products are prepared in response to consumer health concerns and the demands in parallel with changes in consumer lifestyles. However, these products undergo processing that causes tissue damage, resulting in browning and increased susceptibility to microbial growth. Therefore, we investigated the application of maltodextrin and chitosan-containing acetic acid (Ac) to prolong the qualities of fresh-cut cabbages in this study. Ac containing maltodextrins with dextrose equivalent DE 10 and 18, and chitosan (DE10-Ac, DE18-Ac, and CH-Ac, respectively) was used to treat fresh-cut cabbages, which were then combined with those treated with distilled water (control) and 0.1% Ac during storage at 6±1°C for 10 days. The results suggested that cabbage leaves treated with DE10-Ac, DE18-Ac, and CH-Ac had significantly higher water vapor resistance than the control and Ac-treated cabbage leaves. Except for CH-Ac, the samples soaked in acetic acid containing solutions significantly reduced the discoloration of cabbage leaf stalks during storage. The total aerobic bacteria in most samples after storage for 10 days were <6 log cfu/g. DE10-Ac was effective in preventing cut surface browning and water loss reduction, and shelf-life extension of fresh-cut cabbage.

**Keywords:** fresh-cut; cabbage; maltodextrin; chitosan; acetic acid

## 1. INTRODUCTION

Cabbage is the most important vegetable in the Brassicaceae family (Cruciferaceae) (Ibrahim et al., 2004) that is commonly used in fresh salads (Jovanovic et al., 2016). The quality of fresh-cut cabbage deteriorates over time, which is indicated by the browning of the cut surface, water loss, and a reduction in the firmness that limits its shelf-life (Manolopoulou and Varzakas, 2011; 2013; Li et al., 2020).

Polyphenol oxidases (PPOs) cause enzymatic browning, which affects fresh-cut product qualities (Ibrahim et al., 2004, Manolopoulou and Varzakas, 2014). Physical and chemical treatments or a combination of both are commonly used to control enzymatic browning. Physical treatment includes edible coatings. Chemical treatment involves the use of compounds that can either inhibit the enzyme or remove the substrate (Manolopoulou and Varzakas, 2014). Dipping in an acid solution, that is, 0.1% acetic acid (Ac) and 1% citric acid could delay the browning of fresh-cut cabbage (Ibrahim et al., 2004; Manolopoulou and Varzakas, 2011). Edible coatings reduce detrimental changes and, consequently, extend the

shelf-life of fresh-cut fruits and vegetables by providing a semipermeable barrier. These coatings also act as a carrier for antibrowning agents (Roble-Sanchez et al., 2013; Yousuf et al., 2018). Several polysaccharides, proteins, and lipids can be applied to extend the shelf-life of foods by acting as barrier to solutes, gases, and vapors (Yousuf et al., 2018). However, there is limited information available on the application of both edible coatings and antibrowning agents to prolong the shelf-life of fresh-cut cabbage.

Maltodextrin is prepared by hydrolyzing starch, and it has a dextrose equivalent (DE) of <20 (Wang and Wang, 2000). It has a bland taste (Wang and Wang, 2000), a medium molecular weight, and forms a thin coating with good oxygen-barrier properties (Kramer, 2009; Shah et al., 2016). Murray and Luft (1973) investigated the shelf-life extension of fruit slices and nutmeats coated with maltodextrin. The coating solution containing maltodextrin, methylcellulose, and ascorbic acid decreased the surface discoloration of apple slices (Brancoli and Barbosa-Canovas, 2000). Maltodextrin (3%) with 0.1 M calcium chloride coating on fried purple sweet potato chips reduces the oil uptake and improves the sensory overall acceptability (Mustaffa et al., 2019).

Chitosan is a cationic polysaccharide (Yuan et al., 2016) with antimicrobial properties (Treviño-Garza et al., 2017). Chitosan coating can be used to reduce the microbial count of broccoli (Moreira et al., 2011). In addition, the application of chitosan-contained nisin and ε-polylysine on fresh-cut carrots could inhibit the development of white blush (Song et al., 2017). This research aimed to study the effect of the application of maltodextrin and chitosan-contained Ac on the attributes of fresh-cut cabbages stored at 6±1°C.

## 2. MATERIALS AND METHODS

### 2.1 Materials

Cabbage heads (*Brassica oleracea* L. var. capitata) were bought from a local market in Nakhon Pathom, Thailand. The vegetable was selected based on size (400-600 g/head) with no physical damage. Maltodextrin DE10 was purchased from Nutrition SC Co., Ltd. (Nakhon Pathom, Thailand). Maltodextrin DE18 was purchased from Vicchi Enterprise Co., Ltd. (Bangkok, Thailand). Chitosan, with a deacetylation degree of 90.24%, was obtained from Marine Bio Resource Co., Ltd. (Samut Sakhon, Thailand). Ac (J.T. Baker) was used as an antibrowning agent.

### 2.2 Preparation of the treatment solutions

The treatment solutions used for dipping fresh-cut cabbages were water (control), 0.1% v/v Ac, 10% w/v maltodextrin DE18 in Ac (DE18-Ac), 10% w/v maltodextrin DE10 in Ac (DE10-Ac), and 0.25% w/v chitosan in Ac (CH-Ac). All these solutions contained 200 ppm Tsunami and 0.5% w/v calcium chloride. The maltodextrin solutions were prepared by mixing 20 g of the maltodextrin powder (DE10 or DE18) in 90 mL of distilled water at 25°C under magnetic stirring. After the complete dissolution of maltodextrin, 100 mL of 0.2% v/v Ac containing 1% $CaCl_2$ was added to the mixture. The mixture was stirred for about 30 min to obtain a homogenous coating solution, and then adjusted to 200 mL with distilled water to obtain 0.1% v/v Ac and 0.5% $CaCl_2$. The chitosan solution was prepared by dissolving chitosan in 0.1% v/v Ac.

### 2.3 Sample preparation

The cabbages were trimmed, washed, and peeled. Then, they were cut into leaf (1 x 3 cm, Figure 1A) and leaf stalk (5-mm thickness, 3-cm length, Figure 1B) sections with a sharp knife. Each section was dipped into the following solutions: water (control), Ac, DE18-Ac, DE10-Ac, and CH-Ac for 10 min at 25°C (at a sample/solution ratio of 1:5) and drained at a temperature of 25°C and 80% RH. The treated samples (15±5 g) were packed in low-density polyethylene (LDPE) bags (8 x 15 inches) and stored in the climatic test cabinet (Model TK120-TK252, NÜVE, Turkey) at 6±1°C under 75% RH for 10 days.

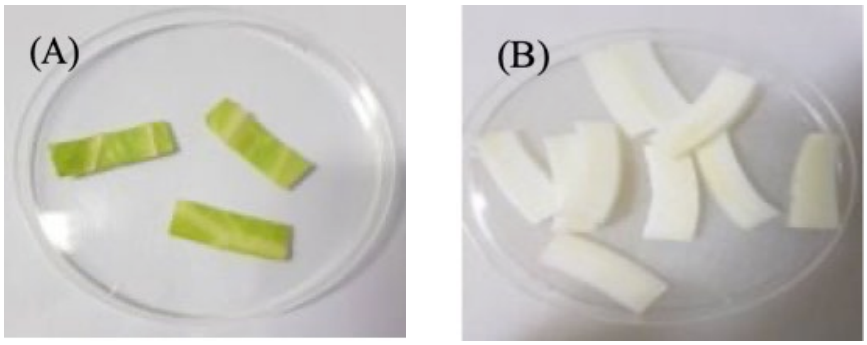



**Figure 1.** The cut sections of (A) cabbage leaf and (B) leaf stalk

### 2.4 Water vapor resistance (WVR)

The WVR method was followed Avena-Bustillos et al. (1993), albeit with some modification. Briefly, the cabbage leaf (1 x 3 cm) and leaf stalk (0.3 x 2 x 1 cm) samples were held on an individual weighing small basket in the climatic test cabinet at 10±1°C, 95% RH, and an air velocity of 64.5 m/min. During a period of 3 h, a basket was removed from the climatic test cabinet and weighed at 30-min intervals. The dimensions (length, width, and thickness) of each cabbage leaf and leaf stalk were measured. The slope (weight loss rate) of the plot between weight loss and time was calculated. WVR was calculated using the following formula:

$$WVR = \left[\frac{\left(Aw\frac{\%RH}{100}\right)Pwv}{RT}\right]\left(\frac{A}{J}\right)$$

where, WVR = water vapor resistance (s/cm)

*Aw* = water activity of cabbage, 0.992 (Chirife and Fontan, 1982)
*%RH* = storage relative humidity (95% RH)
*Pwv* = saturated water vapor pressure at 10°C (9.2115 mm Hg)
*R* = universal gas constant (3464.629 mm Hg-cm$^3$ g/K)
*T* = storage temperature [283 K]
*A* = surface area of the tested sample (cm$^2$)
*J* = weight loss rate (g/s)

### 2.5 Color analysis

The cut surface color of the cabbage slices was analyzed by the Hunter Lab Colorimeter (ColorFlex EZ System, USA) on the CIE Lab scale. The calibration of the equipment was performed with the standard white and black plates. All measurements were recorded in L*, a*, and b* CIE coordinates.

### 2.6 Microbiological analysis

The total aerobic bacterial count of fresh-cut cabbages was evaluated (Banerjee et al., 2016). Fresh-cut cabbages were weighed for 10 g and mixed with 90 mL of sterile peptone water solution and then homogenized. Each dilution was poured into Petri dishes containing plate count agar and incubated for 24 h at 37°C.

### 2.7 Statistical analysis

Each experiment was conducted in two reported experiments for each different treatment. Data were analyzed using the statistical analysis software (SPSS 16). The mean values were compared by using Duncan's multiple-range test.

## 3. RESULTS AND DISCUSSION

### 3.1 Results of WVR

Water loss in vegetables is protected by the outer periderm or cuticle (Ben-Yehoshua, 1987). These barriers are reduced after cutting; therefore, fresh-cut products are extremely susceptible to weight loss and reduced freshness, appearance, and texture of leafy vegetables (Manolopoulou and Varzakas, 2013).

The WVR value indicates the ability of water vapor to pass through the barrier of the surface. The higher WVR values of the samples present less water loss. Table 1 presents the WVR values of both the cabbage leaf and leaf stalk stored at 10±1°C and 95% RH. The Ac application tended to reduce the WVR. The WVR values of cabbage leaf of DE18-Ac, DE10-Ac, and CH-Ac were significantly higher than those of Ac, which could be because of either chitosan or maltodextrin present on the sample, which acted as a barrier to improve the resistance of leaf slices to water vapor (Poverenov et al., 2014). However, there were no significant differences in the WVR values between all cabbage leaf stalks ($p$>0.05), indicating that these treatments did not improve the WVR, which could be attributed to rapid water loss through the entire open and cut surface of the cabbage leaf stalk for this measurement.

**Table 1.** Water vapor resistance of cabbage leaf and leaf stalk during storage at 10±1°C and under 95%RH

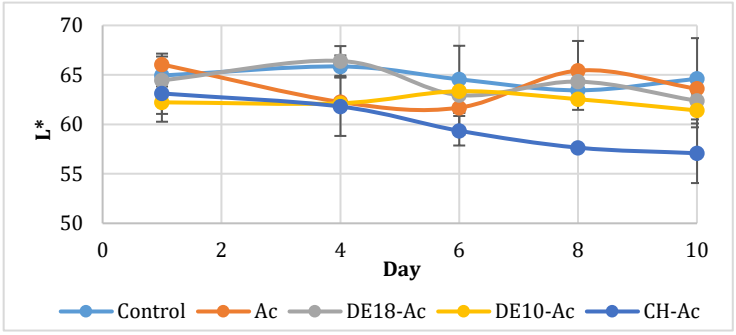
| Treatment | WVR (s/cm) | |
|---|---|---|
| | Cabbage leaf | Cabbage leaf stalk $^{NS}$ |
| Control | 0.1589±0.0064 $^{bc}$ | 0.0615±0.0127 |
| Ac | 0.1418±0.0078 $^{c}$ | 0.1105±0.0604 |
| DE18-Ac | 0.1746±0.0030 $^{ab}$ | 0.0670±0.0016 |
| DE10-Ac | 0.1807±0.0026 $^{ab}$ | 0.0652±0.0066 |
| CH-Ac | 0.1865±0.0151 $^{a}$ | 0.0700±0.0079 |

Different superscript lowercase letters indicate a statistically significant difference in the same column ($p$≤0.05). ns = non-significant difference in the same column ($p$>0.05).

### 3.2 Color analysis

The L*, b*, and a* color values were normally used to observe the discoloration of the cut surfaces of fresh produces. A decrease in the L* color values was recorded, indicating a darkening of the tissues during storage. The results suggested that most of the cabbage leaves had no significant difference in terms of the L* color values during storage, except for CH-Ac (Figure 2A). After storage for 8 days, CH-Ac revealed the lowest L* value. The decrease in the L* values of cabbage leaf stalk during storage was pronounced (Figure 2B), indicating that the sample coated with CH-Ac did not prevent enzymatic browning of the samples; on the contrary, it accelerated surface discoloration. This could be as a results of chitosan solution being more viscous (5.965 cps) than the other solutions (the viscosity of control, Ac, DE18-Ac, and DE10-Ac were 0.376, 0.393, 1.060, and 1.285 cps, respectively), resulting in the higher pick-up of the acid contained in the solution. The higher acid content could damage the cut surface of the produce (Plotto et al., 2010).

(A)



(B)

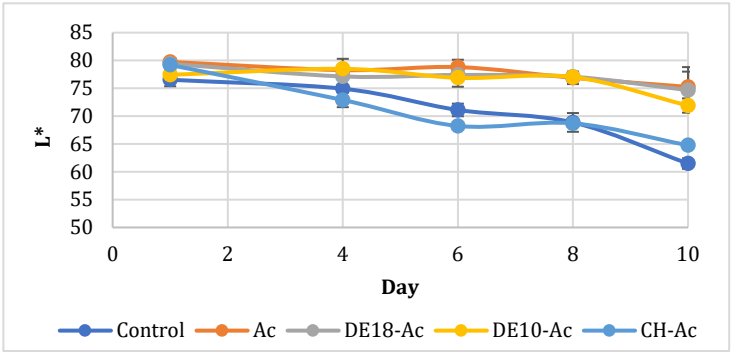



**Figure 2.** Color changes in the lightness (L*) of the sample (A) cabbage leaf slices and (B) cabbage leaf stalk during storage at 6±1°C for 10 days

The b* color values indicated the changes in the color spectrum from yellow to blue. The results indicated that the b* values of the cabbage leaf declined with storage time (Figure 3A). Similarly, Ibrahim et al. (2005) discovered that the discoloration is caused by chlorophyll degradation. The b* color values of the leaf stalk (Figure 3B), on the other hand, increased significantly during storage, possibly in relation to the greater browning in these samples.

(A)

(B)

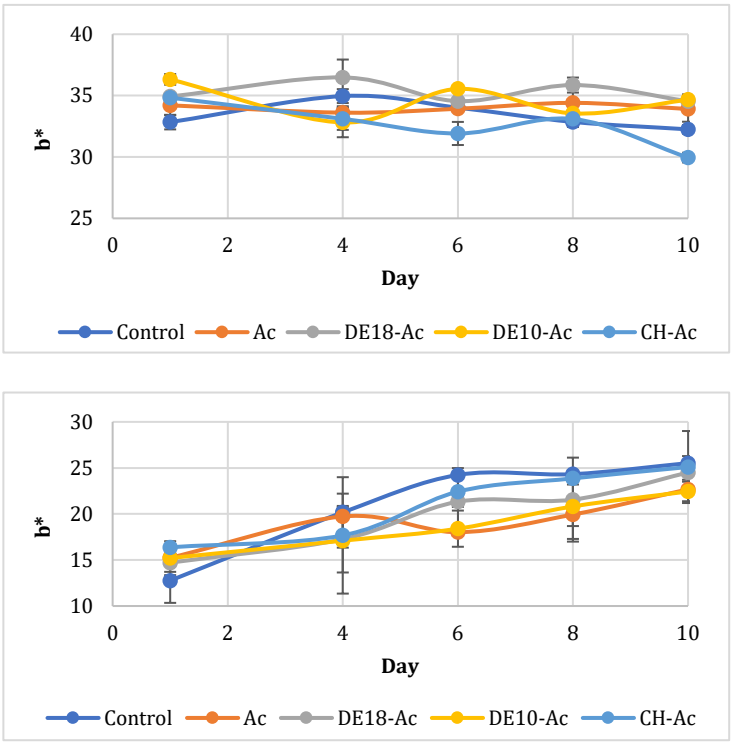



**Figure 3.** Color changes in the b* values of the sample (A) cabbage leaf slices and (B) cabbage leaf stalks during storage at 6±1°C for 10 days

The a* values were applied to indicate the browning reaction because the main discoloration was related to red and brownish colors. As depicted in Figures 4A and B, the a* color values of both the cabbage leaf slice and leaf stalk increased during the storage period. At day 10, the a* color values of the cabbage leaf treated with CH-Ac were significantly higher than those of the others. The leaf stalks treated with DE18-Ac, DE10-Ac, and Ac revealed less change in the a* values over the storage period, when compared to that of the control. These results implied that the solutions containing Ac could effectively improve the cut surface of cabbage slices during storage. The quality of fresh-cut cabbages treated with CH-Ac was affected by browning and black speck development during storage. Black specks appear like a black spot on cabbage and are usually found on white stems and yellowish leaves, which affect the overall quality more than that by browning (Kim and Klieber, 1997). The exact underlying causes, however, remained unclear, which may be a result of the combination of storage and environmental conditions such as high rates of nitrogen fertilizer (Studstill et al., 2020). It is well known that the chitosan molecular structure contains an amino group that serves as a nitrogen source, which may cause the development of black spots on fresh-cut chitosan-coated cabbage samples.

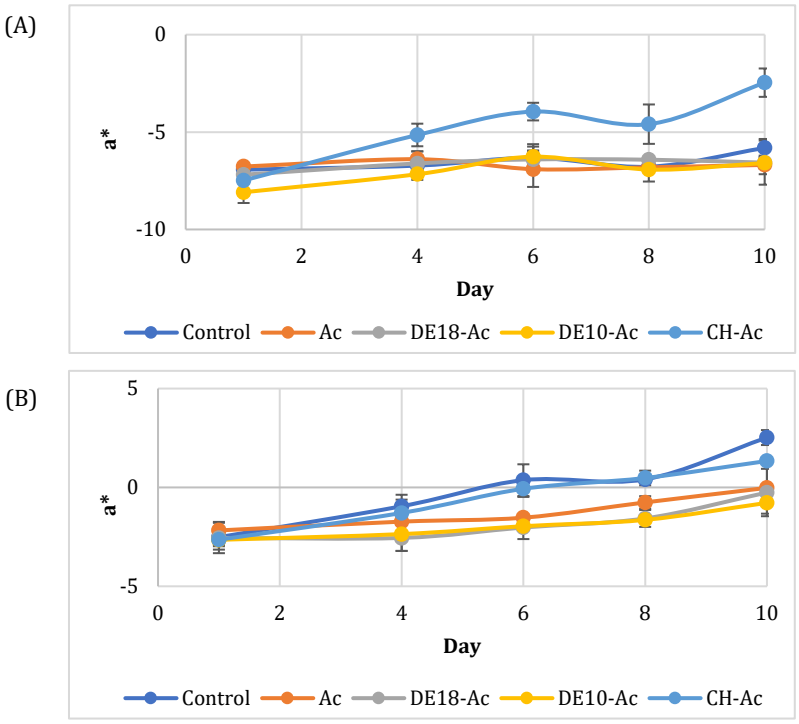



**Figure 4.** Color changes in the a* values of (A) cabbage leaf slices and (B) cabbage leaf stalk during storage at 6±1°C for 10 days

Finally, the hue angle (h°) was one of the suitable parameters to measure the color change of the cut surface of minimally processed cabbage (Manolopoulou and Varzakas, 2011). The hue angle values of all treatments declined during the storage period and became significantly noticeable in the cabbage leaf stalk (Figures 5A and B). The values of the hue difference from day 0 to day 10 were 0.46–7.63 and 5.53–10.03 for leaf and leaf stalk sections, respectively, possibly as a result of chlorophyll degradation (Manolopoulou and Varzakas, 2013). The color of both the leaf and leaf stalk sections treated with DE18-Ac and DE10-Ac retained better color, indicating that maltodextrin (DE18 or DE10) contained Ac effectively prevented the color change of fresh-cut cabbage during storage.

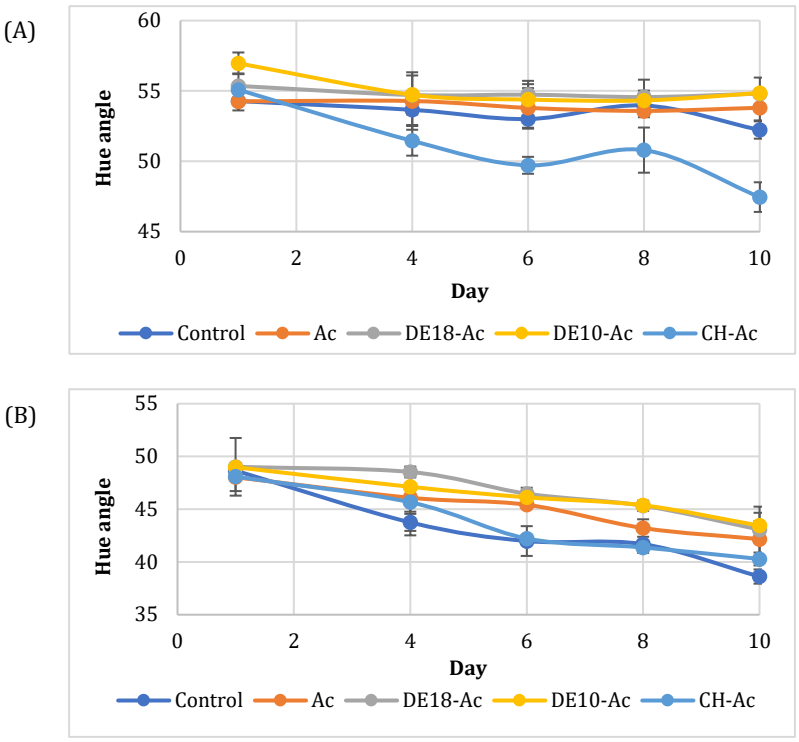



**Figure 5.** Changes in the hue angle of (A) cabbage leaf slices and (B) cabbage leaf stalk during storage at 6±1°C for 10 days

### 3.3 Microbiological analysis

Microbiological safety is an important consideration to preserve fresh-cut cabbage because it contains nutrients essential for microorganism growth. The acceptance limit for microorganisms in minimally processed fruit and vegetable is 6 log cfu/g (Koh et al., 2017). As shown in Figures 6A and B, the total aerobic bacterial count in all samples was <6 log cfu/g during storage, except for cabbage leaf stalk coated with DE18-Ac. Furthermore, both the sections of cabbage treated with CH-Ac and Ac had a lower microbial count relative to the control. The antimicrobial properties of chitosan and Ac should account for effectiveness in reducing microorganism growth. Chitosan can inhibit microorganisms owing to its cationic characteristic. Furthermore, the chitosan solutions with low pH can inhibit microbial growth as a result of the antimicrobial properties of Ac involving the disruption of the membrane permeability (Yildiz and Wiley, 2017).

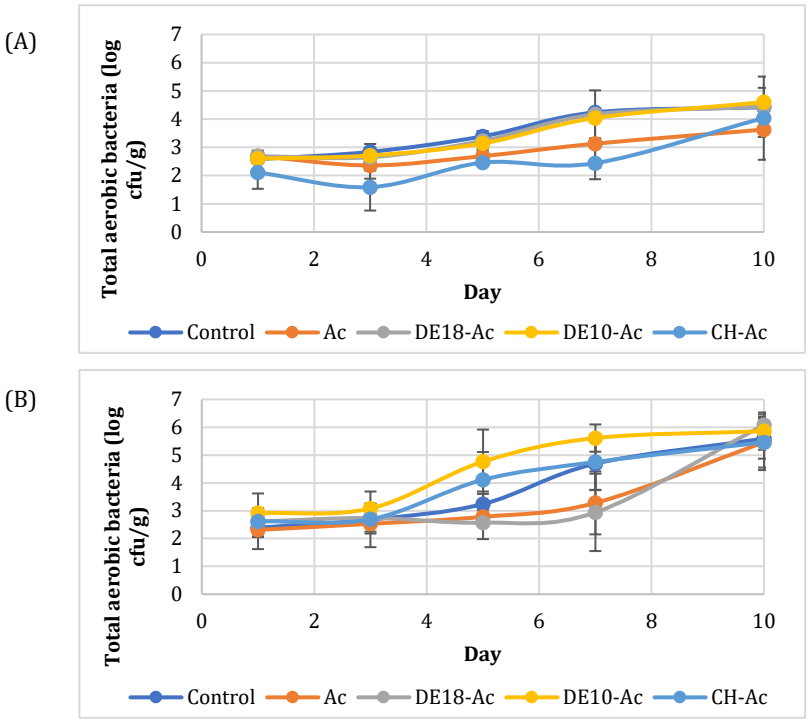



**Figure 6.** Total aerobic bacteria count of (A) cabbage leaf slices and (B) cabbage leaf stalk during storage at 6±1°C for 10 days

## 4. CONCLUSION

The solutions containing Ac (Ac, DE10-Ac, and DE18-Ac) maintained the quality of fresh-cut cabbage by reducing the browning of the cut surfaces during storage at 6±1°C over 10 days. Most of the samples had a microbial count within the acceptable limit during storage. The DE10-Ac could improve the quality and prolong the shelf-life of fresh-cut cabbage by 10 days by improving the water resistance of the sample.

## REFERENCES

Avena-Bustillos, R. J., Cisneros-Zevallos, L. A., Krochta, J. M., and Saltveit, M. E. (1993). Optimization of edible coatings on minimally processed carrots using response surface methodology. *Transactions of the ASAE*, 36(3), 801-805.

Banerjee, A., Chatterjee, S., Variyar, P. S., and Sharma, A. (2016). Shelf life extension of minimally processed ready-to-cook (RTC) cabbage by gamma irradiation. *Journal of Food Science and Technology*, 53(1), 233-244.

Ben-Yehoshua, S. (1987). Transpiration water stress and gas exchange. In *Postharvest Physiology of Vegetables* (Weichmann, J., ed.), pp.113-170. New York: Marcel Dekker.

Brancoli, N., and Barbosa-Cánovas, G. V. (2000). Quality changes during refrigerated storage of packaged apple slices treated with polysaccharide films. In *Innovations in Food Processing* (Barbosa-Canovas, G. V. and Gould, G. W., eds.), pp. 243-254. Pennsylvania: Technomic Publishing Co.

Chirife, J., and Fontan, C. F. (1982). Water activity of fresh foods. *Journal of Food Science,* 47(2), 661-663.

Ibrahim, R., Osman, A., Saari, N., and Abdul Rahman, R. (2004). Effects of anti-browning treatments on the storage quality of minimally processed shredded cabbage. *Journal of Food, Agriculture and Environment,* 2(2), 54-58.

Ibrahim, R., Osman, A., Saari, N., and Abdul Rahman, R. (2005). Effect of packaging films on the physical characteristics and sensory aspects of shredded cabbage at different storage conditions. *Journal of Food, Agriculture and Environment,* 3(1), 58-65.

Jovanovic, G. D., Klaus, A. S., and Niksic, M. P. (2016). Antimicrobial activity of chitosan films with essential

oils against Listeria monocytogenes on cabbage. *Jundishapur Journal of Microbiology,* 9(9), e34804.

Kim, B. S., and Klieber, A. (1997). Quality maintenance of minimally processed Chinese cabbage with low temperature and citric acid dip. *Journal of the Science of Food and Agriculture,* 75(1), 31-36.

Koh, P. C., Noranizan, M. A., Nur Hanani, Z. A., Karim, R., and Rosli, S. Z. (2017). Application of edible coatings and repetitive pulsed light for shelf life extension of fresh-cut cantaloupe (*Cucumis melo* L. *reticulatus* cv. Glamour). *Postharvest Biology and Technology,* 129, 64-78.

Kramer, M. E. (2009). Structure and function of starch-based edible films and coatings. In *Edible Films and Coatings for Food Applications* (Embuscado, M. E. and Huber, K. C., eds.), pp. 113-134. New York: Springer Science+Business Media, LLC.

Li, H., Li, X., Wang, R., Xing, Y., Xu, Q., Shui, Y., Guo, X., Li, W., Yang, H., Bi, X., and Che, Z. (2020). Quality of fresh-cut purple cabbage stored at modified atmosphere packaging and cold-chain transportation. *International Journal of Food Properties*, 23(1), 138-153.

Manolopoulou, E., and Varzakas, T. (2011). Effect of storage conditions on the sensory quality, colour and texture of fresh-cut minimally processed cabbage of the addition of ascorbic acid, citric acid and calcium chloride. *Food and Nutrition Sciences,* 2(9), 956-963.

Manolopoulou, E., and Varzakas, T. (2013). Effect of modified atmosphere packaging (MAP) on the quality of 'ready-to-eat' shreded cabbage. *International Journal of Agricultural and Food Research,* 2(9), 30-43.

Manolopoulou, E., and Varzakas, T. (2014). Application of antibrowning agents in minimally processed cabbage. *Journal of Food and Nutritrional Disorders,* 3(1), 1000231.

Moreira, M. D. R., Roura, S. I., and Ponce, A. (2011). Effectiveness of chitosan edible coatings to improve microbiological and sensory quality of fresh cut broccoli. *LWT - Food Science and Technology,* 44(10), 2335-2341.

Murray, D. G., Luft, L., and Low D. E. (1973). Corn starch hydrolysates: Multi-functional carbohydrates aid in food formulation. *Food Technology,* 27, 32-39.

Mustaffa, N. A. N., Khairi, N. S. M., Zolkiffli, F. F., Alikasturi, A. S., Anuar, M. R., and Shaharuddin, S. (2019). Characterisation of maltodextrin-edible coated purple sweet potato chips; Effect of calcium chloride concentration. *Materials today: Proceedings*, 19, 1481-1488.

Plotto, A., Narciso, J. A., Rattanapanone, N., and Baldwin, E. A. (2010). Surface treatments and coatings to maintain fresh-cut mango quality in storage. *Journal of the Science of Food and Agriculture,* 90(13), 2333-2341.

Poverenov, E., Danino, S., Horev, B., Granit, R., Vinokur, Y., and Rodov, V. (2014). Layer-by-layer electrostatic deposition of edible coating on fresh cut melon model: Anticipated and unexpected effects of alginate-chitosan combination. *Food and Bioprocess Technology,* 7, 1424-1432.

Roble-Sanchez, R. M., Rojas-Grau, M. A., Odriozola-Serrano, I. O., Gonzalez-Aguilar, G., and Martin-Belloso, O. (2013). Influence of alginate-based edible coating as carrier of antibrowning agents on bioactive compounds and antioxidant activity in fresh-cut Kent mangoes. *LWT-Food Science and Technology*, 50(1), 240-246.

Shah, U., Naqash, F., Gani, A., and Masoodi, F. A. (2016). Art and science behind modified starch edible films and coatings: A review. *Comprehensive Reviews in Food Science and Food Safty,* 15(3), 568-580.

Song, Z., Li, F., Guan, H., Xu, Y., Fu, Q., and Li, D. (2017). Combination of nisin and ε-polylysine with chitosan coating inhibits the white blush of fresh-cut carrots. *Food Control,* 74, 34-44.

Studstill, D., Simonne, E., Brecht, J., and Gilreath, P. (2020). *Pepper Spot ("Gomasho") on Napa Cabbage1*. [Online URL: edis.ifas.ufl.edu] accessed on November 16, 2020.

Treviño-Garza, M. Z., García, S., Heredia, N., Alanís-Guzmán, M. G., and Arévalo-Niño, K. (2017). Layer-by-layer edible coatings based on mucilages, pullulan and chitosan and its effect on quality and preservation of fresh-cut pineapple (*Ananas comosus*). *Postharvest Biology and Technology,* 128, 63-75.

Wang, Y. J., and Wang, L. (2000). Structures and properties of commercial maltodextrins from corn, potato, and rice starches. *Starch - Stärke,* 52(8-9), 296-304.

Yildiz, F., and Wiley, R. (2017). *Minimally Processed Refrigerated Fruits and Vegetables,* 2nd, New York: Chapman and Hall, pp. 53-93.

Yousuf, B., Qadri, O. S., and Srivastava, A. (2018). Recent developments in shelf-life extension of fresh-cut fruits and vegetables by application of different edible coatings: A review. *LWT-Food Science and Technology,* 89, 198-209.

Yuan, G., Chen, X., and Li, D. (2016). Chitosan films and coatings containing essential oils: The antioxidant and antimicrobial activity, and application in food systems. *Food Research International,* 89, 117-128.