

Quality of minimally processed cabbage (*Brassica oleracea* var. *Capitata*) stored at different temperatures

[Mutu kubis (*Brassica oleracea* var. *Capitata*) yang diproses secara minimum dan disimpan pada suhu yang berbeza]

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Key words: minimally processed, cabbage (*Brassica oleracea* var. *Capitata*), physical and chemical changes, CO₂ and O₂ concentrations, ethylene production rate, storage temperatures

Abstract

Physiological changes that occurred during storage of minimally processed (MP) cabbage var. *Capitata* were studied at different storage temperatures (2, 5, 7, 10, 15 and 25 °C). Different forms of cutting, i.e. chopped and shredded were evaluated. The MP cabbage stored at 2, 5 and 7 °C were evaluated every four days, while samples stored at 10, 15 and 25 °C were evaluated every two days. Quality evaluation was based on physical and chemical changes, ethylene (C₂H₄) production rate, carbon dioxide (CO₂) and oxygen (O₂) concentrations.

Shredded cabbage stored at 2 °C can be prolonged for 36 days, while the chopped cabbage can be stored for 30 days and had the lowest percentage of weight loss, C₂H₄ production rate and CO₂ concentration compared to other storage temperatures. There were significant differences ($p < 0.05$) in the C₂H₄ production rate, CO₂ and O₂ concentrations, pH, total titratable acidity (TTA) and ascorbic acid (AA) contents of MP cabbage with different forms of cutting stored at different temperatures. However, there were no significant differences ($p > 0.05$) between the forms of cutting on percentage of weight loss of MP cabbage stored at different temperatures. Shredded cabbage showed a better form of cutting in which the percentage of weight loss (0.19%), pH (5.74), TTA (0.10%) and O₂ concentration (18.83%) were slightly lower compared to chopped form (0.26%, 6.15, 0.12% and 19.54%, respectively). There was also significant differences ($p < 0.05$) in all parameters of MP cabbage with duration of storage.

Introduction

Minimally processed (MP) vegetables can be defined as those vegetables that may have been cleaned, peeled, cut, sliced, packed, or processed by any means short of killing the tissue (Shewfelt 1987). Minimal processing usually increases the degree of perishability, causes disruption of cell tissue and breakdown of cell membranes (Wong et al. 1994). The degree of tissue breakdown

and the extent of tissue exposed caused by minimal processing may increase the surface dehydration, total moisture loss (Barry-Ryan and O'Beirne 1998), respiratory rate (Wong et al. 1994) and ethylene production (Gordon 1992). The purpose of minimal processing is to deliver to the consumer a fresh like product with an extended shelf life and at the same time ensure food safety, convenience and freshness, and maintain sound nutritional and sensory quality.

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Various approaches have been used to control the undesirable physiological changes that adversely affect the quality of lightly processed products (Burns 1995). Importantly, selecting the most appropriate cultivar for light processing can significantly aid efforts to maintain product quality. Refrigeration, humidity control and addition of chemical, such as ascorbic acid and calcium, have been used successfully to preserve product quality and enhance shelf life (Burns 1995). Desirable modified atmospheres can be predicted and created within and around commodities by selecting appropriate packaging (Burns 1995). Suitable storage temperature and types of packaging are important factors in maintaining the quality and extending the shelf life of MP vegetables (Osornio and Chaves 1998).

Therefore, the aim of this study was to evaluate the quality of MP cabbage stored at different temperatures. Quality evaluations were based on the physical and chemical changes, the rate of respiration and ethylene production. Physiological behaviour and temperature surrounding the products were also monitored during the storage study.

Materials and methods

Handling operations

Commercial maturity cabbages (*Brassica oleracea* var. *Capitata*) used in the study were bought from the local market in Sungai Besi, Kuala Lumpur. Samples were brought to the MARDI laboratory at Serdang, Selangor. Upon arrival at the laboratory, the cabbages were sprayed and washed with chlorinated water to remove dirt and also to reduce microbial populations prior to cutting. The samples were sorted and only cabbages that were free from mechanical injuries were used in this study. They were cut into two different forms (chopped and shredded) and then immersed in chilled water containing 1% calcium chloride (CaCl₂) for about 1–2 min. The cut cabbages were then drip dried to remove excess water prior to packing.

Packing treatments

The cut cabbages were packed in 500 ml polypropylene (PP) containers. Each pack had an average net weight of 120 g. Storage studies were conducted at six different temperatures (2, 5, 7, 10, 15 and 25 °C). Samples stored at 2, 5 and 7 °C were evaluated every four days, while those stored at 10, 15, 25 °C were evaluated every two days. The analyses were done in triplicates.

Physical and chemical analyses

The percentages of weight loss of the cabbage sample were obtained by measuring the difference in weight before and after storage. Chemical analyses were carried out on the same day as the weight loss. Samples for chemical analyses were blended using a kitchen blender. The pH value was measured using an Orion digital pH meter (model SA 520) and total titratable acidity was determined by titrating a known volume of homogenates solution with 0.1 N NaOH to an end point of pH 8.1 using digital burette (Shaw et al. 1987). Experiments were performed in triplicates. The ascorbic acid content was determined by titrating with 2,6-dichlorophenolindophenol (Ranganna 1977).

Gases in the package

The gases in the package were measured daily. The gas samples (O₂, CO₂ and C₂H₄) were drawn by a syringe through a septum in the package. C₂H₄ gas was detected by injecting 1 ml of the sample into a Perkin Elmer Auto System_XL gas chromatography fitted with flame ionization detector (FID) and a stainless steel column packed with Porapak T of 100/120-mesh size. Simultaneously, CO₂ was detected using the thermal conductivity detector (TCD) with a stainless steel column packed with Porapak R of 80/100-mesh size. The flow rate of the purified helium gas was 30 ml/min and the column oven was operated at 50 °C and 100 °C for CO₂ and C₂H₄ gases, respectively. O₂ gas sample was also detected using the TCD

gas chromatograph (Varian 1420) fitted with a 1,500 mm x 3 mm stainless steel column packed with Porapak R of 80/100-mesh size. Helium was also used as a carrier gas at the same flow rate and the injector temperature was 35 °C. Three replications were used for each experiment.

Rate of respiration and ethylene production

Rates of respiration and ethylene production were measured using a closed system. Cut samples (average weight 120–150 g) were packed in the polypropylene containers. The lids of the containers were tightly closed for 2 h prior to the gas measurement. Three containers were used to represent a replication in the experimental design. Respiration rate was measured by the concentrations of CO₂ and O₂ liberated by the cut samples. The respiration (CO₂ and O₂ concentrations) and C₂H₄ production rates were measured as described above.

Statistical analysis

The experiment was designed using a split-plot design with two factorials (forms of cutting and storage temperature). For data analyses, the Statistical Analysis System program was used (SAS Inst. 1985). The values obtained were subjected to analyses of variance and tested using Least Significant Difference (Gomez and Gomez 1984).

Results and discussion

Percentage of weight loss

There was a significant difference ($p < 0.05$) in percentage of weight loss of MP cabbage with different forms of cutting during storage period at 2 °C (*Figure 1*). The percentage of weight loss of shredded form was lower (0.19%) compared to the chopped form (0.26%) (*Table 1*). The storage life of shredded form stored at 2 °C can be prolonged for 36 days, while the chopped cabbage can be stored for 30 days and had the lowest percentage of weight loss, C₂H₄ production rate and CO₂ concentration, and

highest in concentration of O₂ and also in AA content.

The results showed that the percentage of weight loss of MP cabbage stored at 2 °C was lower (0.01–0.05%) at day 4 and then increased until the end of storage period (0.49–0.59%) (*Figure 1*). Similar trends were also observed in MP cabbage stored at 5, 7, 10, 15 and 25 °C. These trends were similar to results obtained by Razali et al. (2003) on MP long bean stored at 2, 5, 10, 15 and 25 °C, and Izumi and Watada (1994) when carrot shreds were stored at 0, 5 and 10 °C.

Reducing water loss is one of the most important aspects related to modified atmosphere packaging of minimally processed products. The limiting factor that contributed to shorter storage life of the sample stored at 25 °C and 15 °C was serious wilting due to the high weight loss (0.70%). Lower percentage of weight loss in MP cabbage stored at 2 °C resulted in better and fresher overall appearance.

pH and TTA values

The pH values were significantly different ($p < 0.05$) among MP cabbage with different forms of cutting during storage period at 2, 5, 7, 10, 15 and 25 °C (*Figure 2*). pH values in chopped cabbage were slightly higher (5.96–6.44) than the shredded form (5.34–5.74). However, the pH values in shredded form were slightly lower (5.34, 5.46, 5.51 and 5.56) when stored at 7, 10, 15 and 25 °C, respectively compared to storage at 2 and 5 °C (5.73 and 5.74, respectively) (*Table 1*). The pH did not change very much during storage and the trend was similar to that reported by Carlin et al. (1989) on grated carrot, King et al. (1991) on cut lettuce and Bolin and Huxsoll (1991) on salad-cut lettuce.

The pH of shredded cabbage fluctuated during storage at all temperatures (*Figure 2*). This was in agreement with Izumi and Watada (1994), who reported the same trend in pH value of carrot shreds during storage at 0, 5 and 10 °C. Similar trend was also

Minimally processed cabbage at different storage temperatures

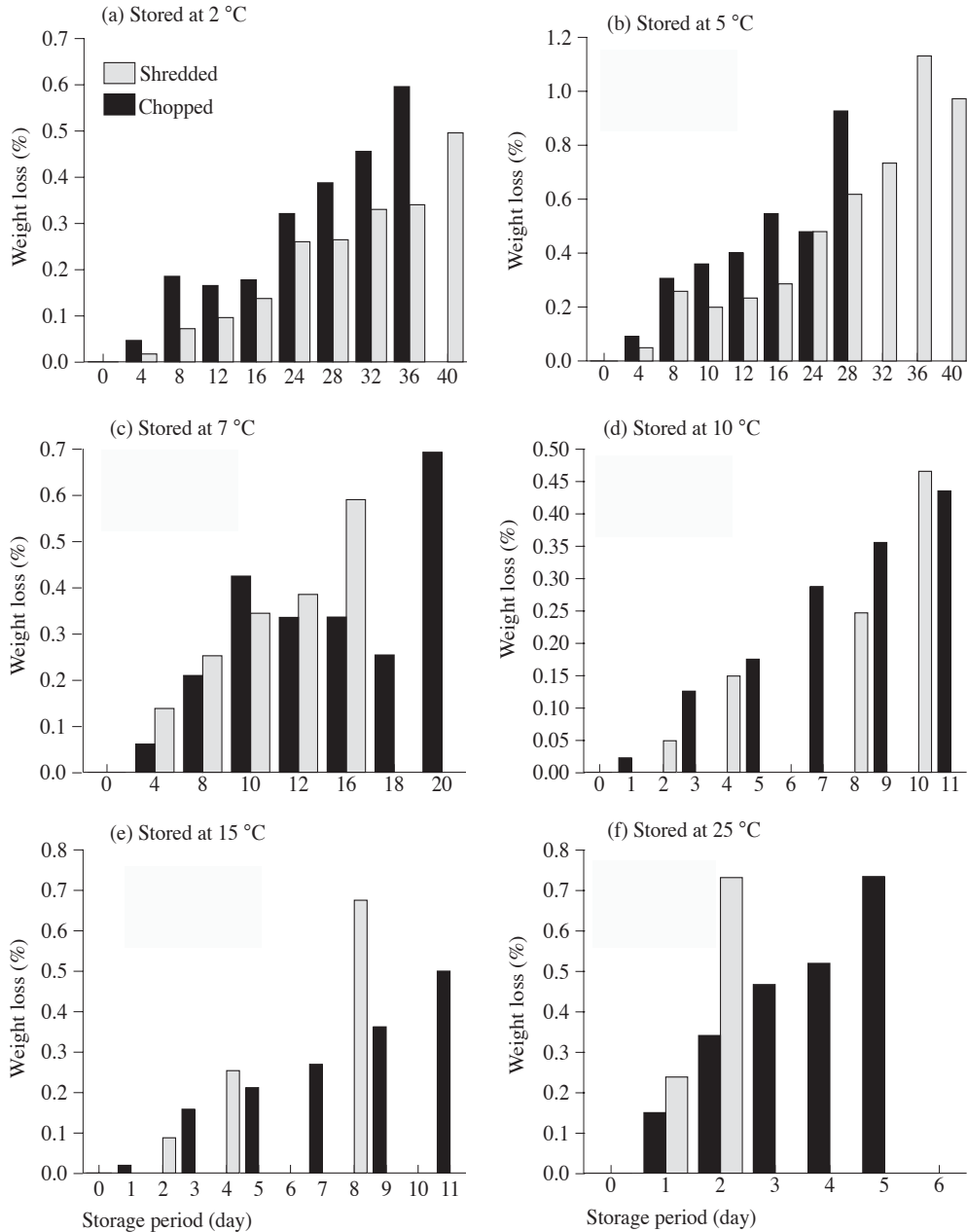


Figure 1. Effects of different forms of cutting on percentage of weight loss of minimally processed cabbage stored at different temperatures during the storage period

reported by Razali et al. (2003) on MP long bean (trimmed form) stored at 2, 5, 10 and 25 °C. However, the pH value increased significantly ($p < 0.05$) after 4 days of storage at 2 and 5 °C (5.62 and 5.68, respectively), whereas at 7, 10 and 15 °C

they decreased until the end of storage period. The decrease in pH values contributes to the reduction in bacterial spoilage (Izumi and Watada 1994). These results were in line with TTA where the values were lower when the pH was

Table 1. Changes in the percentage of weight loss, pH, total titratable acidity, ascorbic acid content, C₂H₄ production rate, O₂ and CO₂ concentrations of minimally processed cabbage from different forms of cutting stored at different storage temperatures

Storage temperature/ Forms of cutting	Weight loss (%)	pH	Total titratable acidity (%)	Ascorbic acid (mg/100 g)	C ₂ H ₄ (µl/kg/hr)	CO ₂ (%)	O ₂ (%)
2 °C							
Chopped	0.26a	6.15a	0.12a	11.01a	0.029a	0.14b	19.54a
Shredded	0.19b	5.74b	0.10b	6.48b	0.004b	0.21a	18.83b
5 °C							
Chopped	0.45a	6.23a	0.11a	11.15a	0.031a	0.38a	18.66a
Shredded	0.41a	5.73b	0.09a	6.64b	0.027a	0.27b	18.23a
7 °C							
Chopped	0.29a	6.27a	0.10a	10.28a	0.030b	0.35b	18.66a
Shredded	0.28a	5.46b	0.10a	6.89b	0.629a	1.02a	18.70a
10 °C							
Chopped	0.27a	5.96a	0.10a	6.95a	0.283a	1.29a	17.53b
Shredded	0.26a	5.51a	0.10a	6.79a	0.062b	1.05b	19.07a
15 °C							
Chopped	0.25a	6.01a	0.10a	6.82a	0.087b	2.05a	17.44b
Shredded	0.22a	5.56b	0.11a	6.42a	1.410a	0.88b	18.64a
25 °C							
Chopped	0.37a	6.44a	0.08a	8.41a	0.599b	2.72b	17.35a
Shredded	0.32a	5.34b	0.14a	5.83b	0.903a	7.39a	16.42b

Each value was the mean of three replicates. Means with the same letter within a row for each column are not significantly different at 5% level ($p < 0.05$)

higher for both forms of cutting of MP cabbage. The TTA of MP cabbage with different forms of cutting showed significant differences ($p < 0.05$) during storage at 2, 7, 10, 15 and 25 °C (Figure 3). There were also significant differences ($p < 0.05$) in TTA between the chopped and shredded cabbages stored at 2, 15 and 25 °C. The TTA of the shredded form was lower (0.09–0.10%) compared to the chopped form (0.11–0.12%) when stored at 2 and 5 °C (Table 1). However, there were no significant differences ($p > 0.05$) between the forms of cutting of MP cabbage stored at 5, 7 and 10 °C. The TTA of minimally processed cabbage also showed a fluctuating trend where it increased and decreased significantly with duration of storage at all temperatures (Figure 3). At 2 °C, the results showed that at the beginning of storage, the TTA was lower (0.07%) at day 0 and then

increased and decreased until the end of storage period (0.12–0.14%).

Ascorbic acid

The ascorbic acid (AA) content slowly increased at the beginning of the storage period and then decreased until the end of the storage period (Figure 4). However, there were significant differences ($p < 0.05$) in AA content of MP cabbage stored at 2, 5, 7, 10, 15 and 25 °C. The AA of MP cabbage stored at 2 °C was lower (5.67 mg/100 g) at day 0 and then increased to 7.46 mg/100 g at day 4. The content decreased and increased until the end of storage period (6.96–8.23 mg/100 g). Reduction in ascorbic acid content is always associated with increased of surface browning (Wong et al. 1994). Similar results were observed in MP cabbage stored at 5, 7, 10, 15 and 25 °C. Different forms of cutting significantly

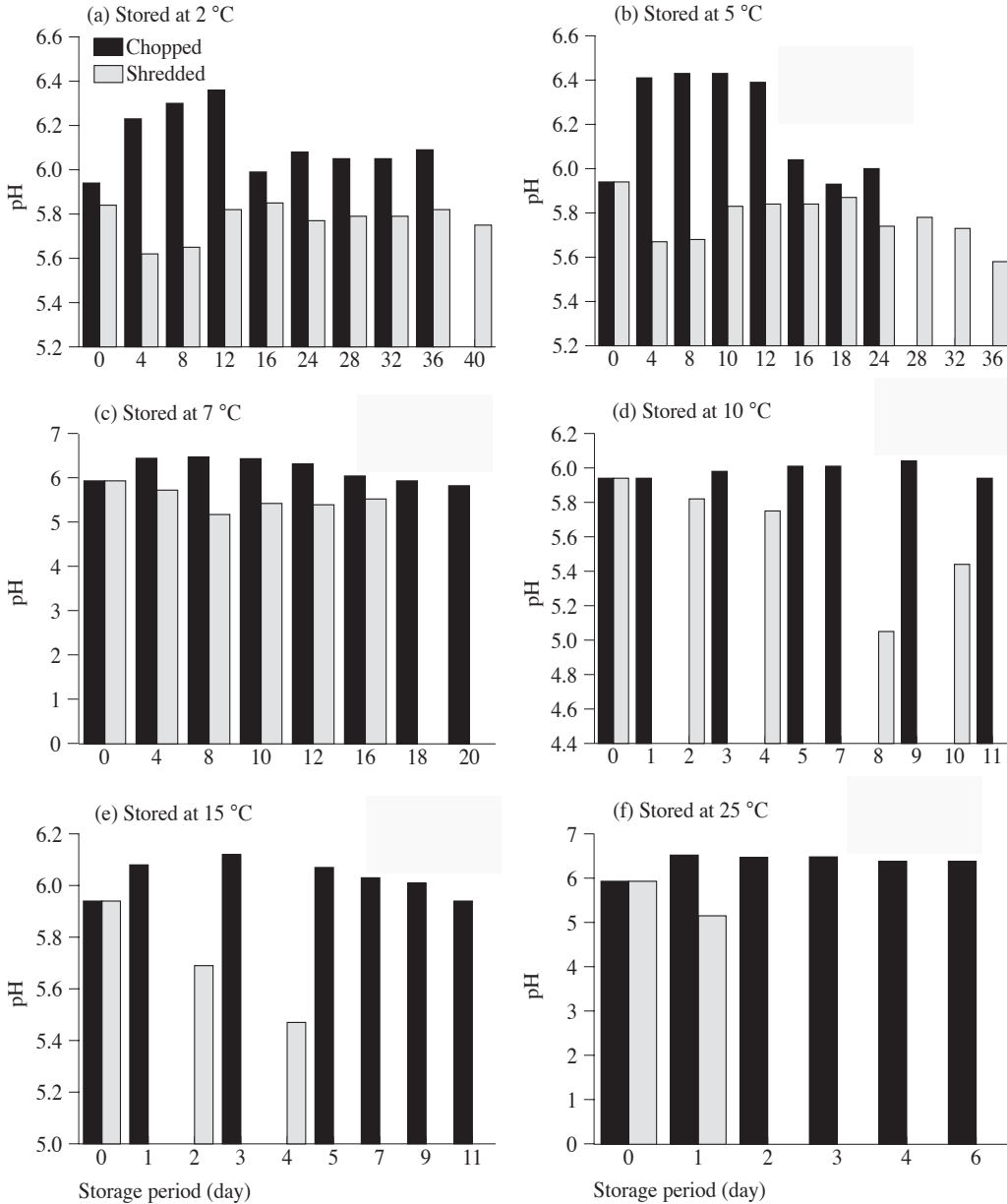


Figure 2. Effects of different forms of cutting on pH of minimally processed cabbage stored at different temperatures during the storage period

affected ($p < 0.05$) the AA content during the storage period. However, there was no significant difference ($p > 0.05$) in AA content between the forms of cutting of MP cabbage stored at 10 and 15 °C (Table 1).

Ethylene production rate

The production rate of ethylene (C_2H_4) of MP cabbage showed an irregular pattern with duration of storage at all storage temperatures for both forms of cutting (Figure 5). There was no C_2H_4 production at the beginning of storage of shredded

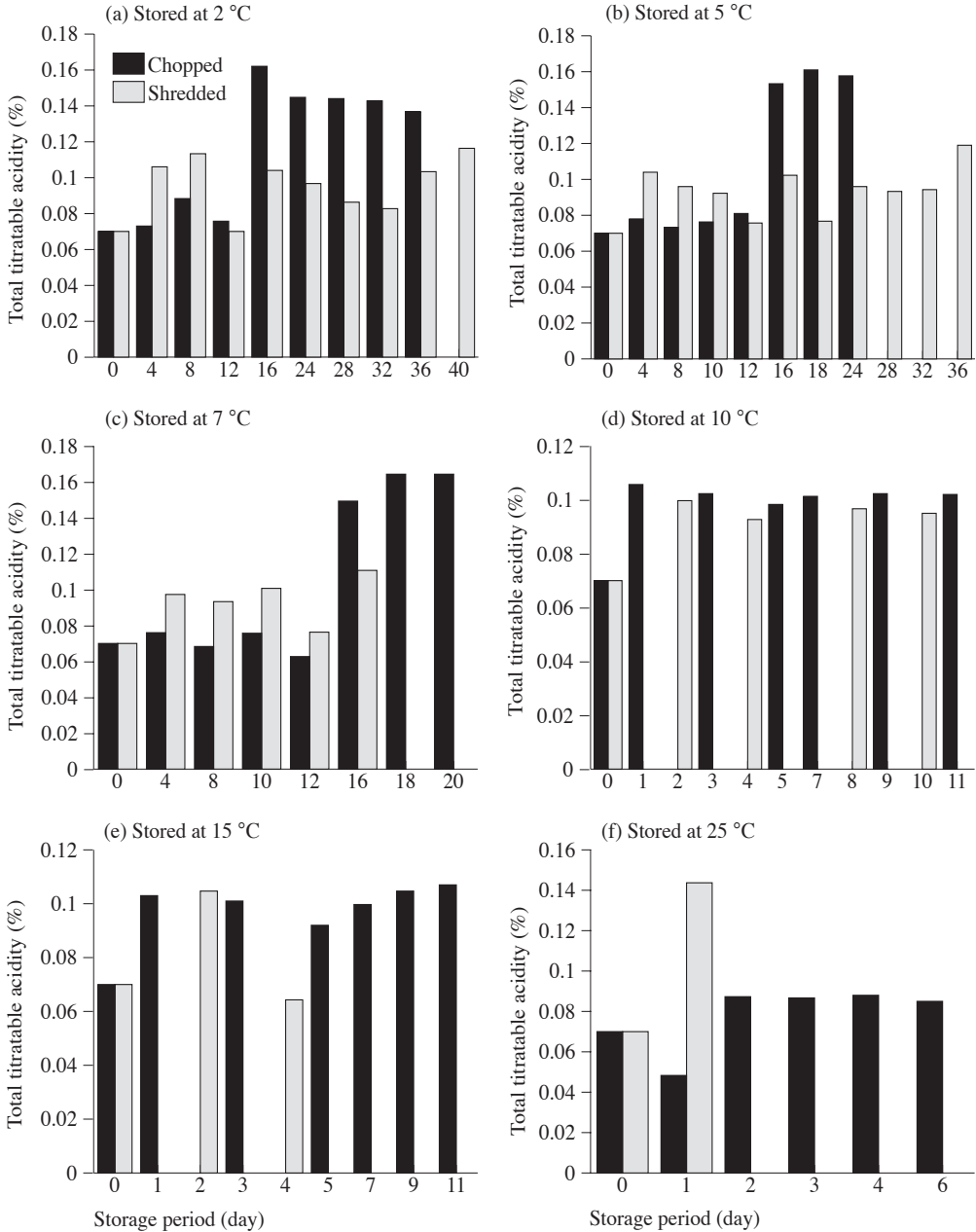


Figure 3. Effects of different forms of cutting on total titratable acidity of minimally processed cabbage stored at different temperatures during the storage period

cabbage stored at 2 °C. However, in chopped cabbage, C₂H₄ was produced until day 12. The C₂H₄ production rate of shredded cabbage was slightly higher (0.629, 1.41 and 0.90 µl/kg/h) when stored at 7, 17 and 25 °C, respectively and lower (0.004, 0.027 and

0.062 µl/kg/h) when stored at 2, 5 and 15 °C, respectively (Table 1). However, there was significant difference (*p* < 0.05) in C₂H₄ production rate of MP cabbage with different forms of cutting during storage at all temperatures. The increased rate of C₂H₄

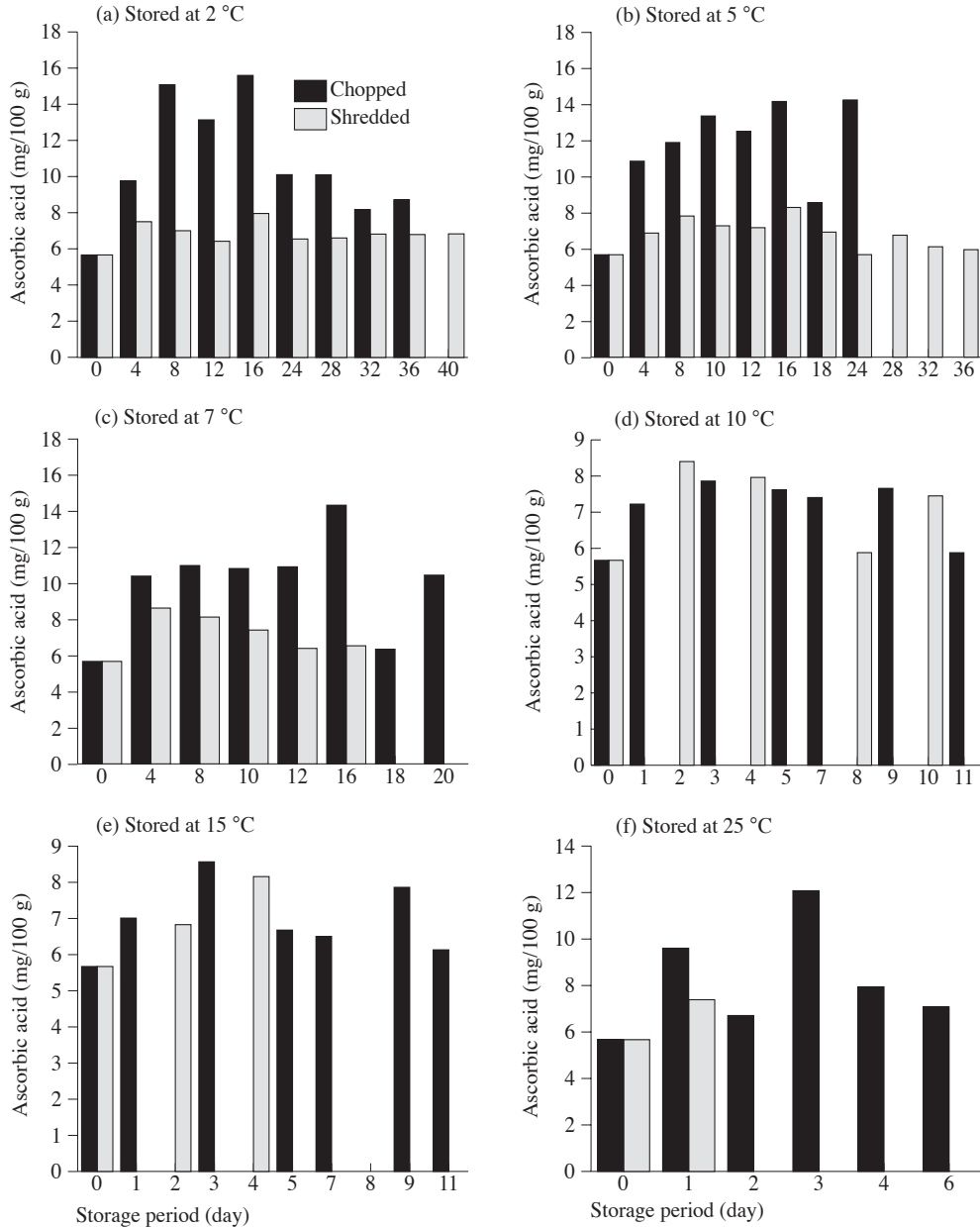


Figure 4. Effects of different forms of cutting on ascorbid acid (AA) content of minimally processed cabbage stored at different temperatures during the storage period

production in response to mechanical injury has been reported for a variety of produce and it has an effect on their physiology and quality (Baldwin 1994).

Carbon dioxide concentration

The CO₂ concentration of MP cabbage stored at 2 °C showed an irregular pattern for both forms of cutting, where the shredded form increased (0.47%) at the beginning of storage at day 4 and then decreased (0.20%) at day 8 (Figure 6). The

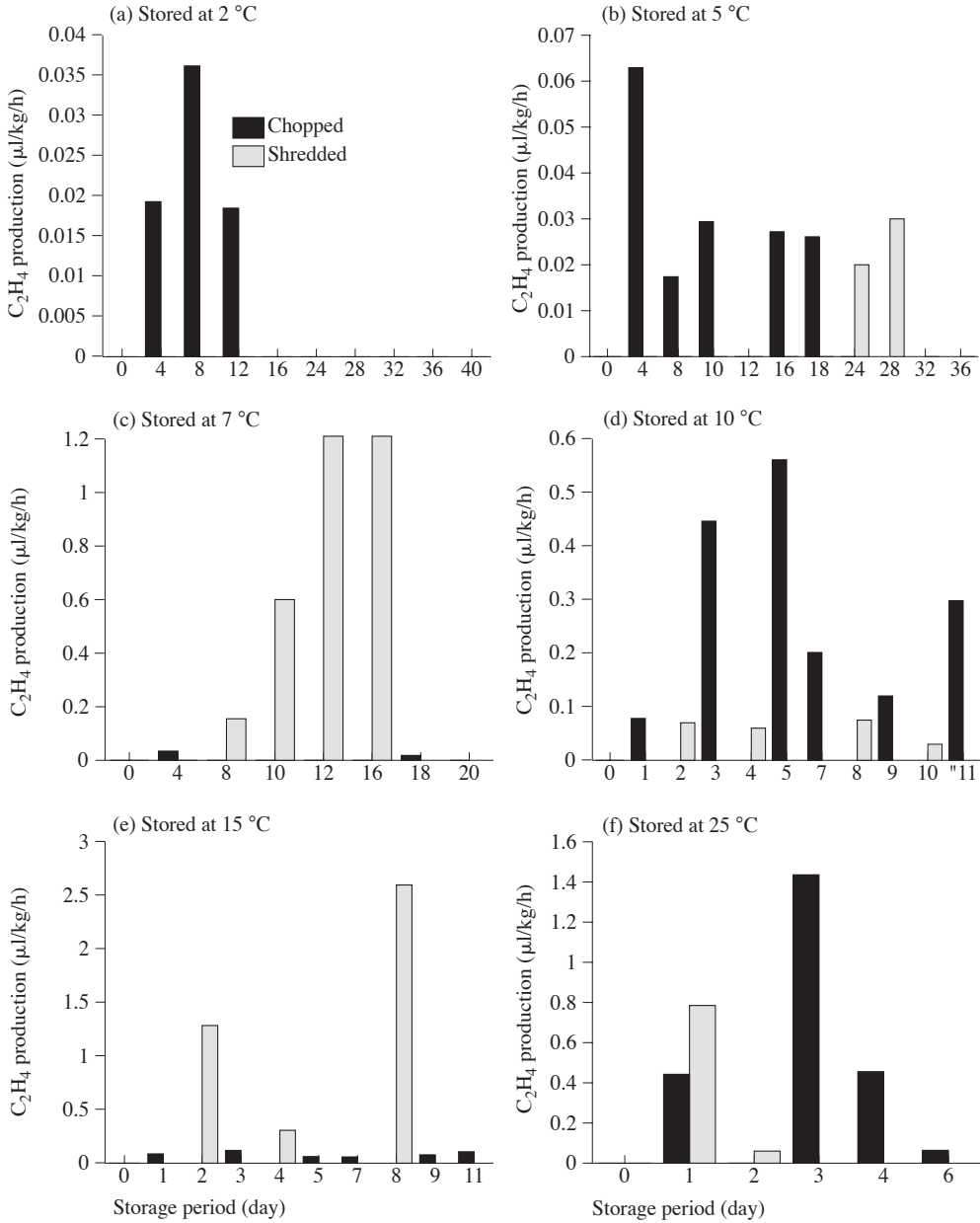


Figure 5. Effects of different forms of cutting on ethylene (C_2H_4) production rate of minimally processed cabbage stored at different temperatures during the storage period

concentration then increased to 0.27% at day 12 and decreased to 0.12% until the end of storage period (day 40). According to Razali et al. (2003), the production rate of C_2H_4 and CO_2 concentration of MP long bean with the ring and trimmed forms packed in 250 ml PP container had an irregular pattern

during storage at 2, 5, 10, 15 and 25 °C. The MP cabbage with different forms of cutting also showed the same trend when stored at 5, 7, 10, 15 and 25 °C. The increase in the CO_2 concentration reflected the defence mechanism being triggered by the wounding tissue of the minimally processed product

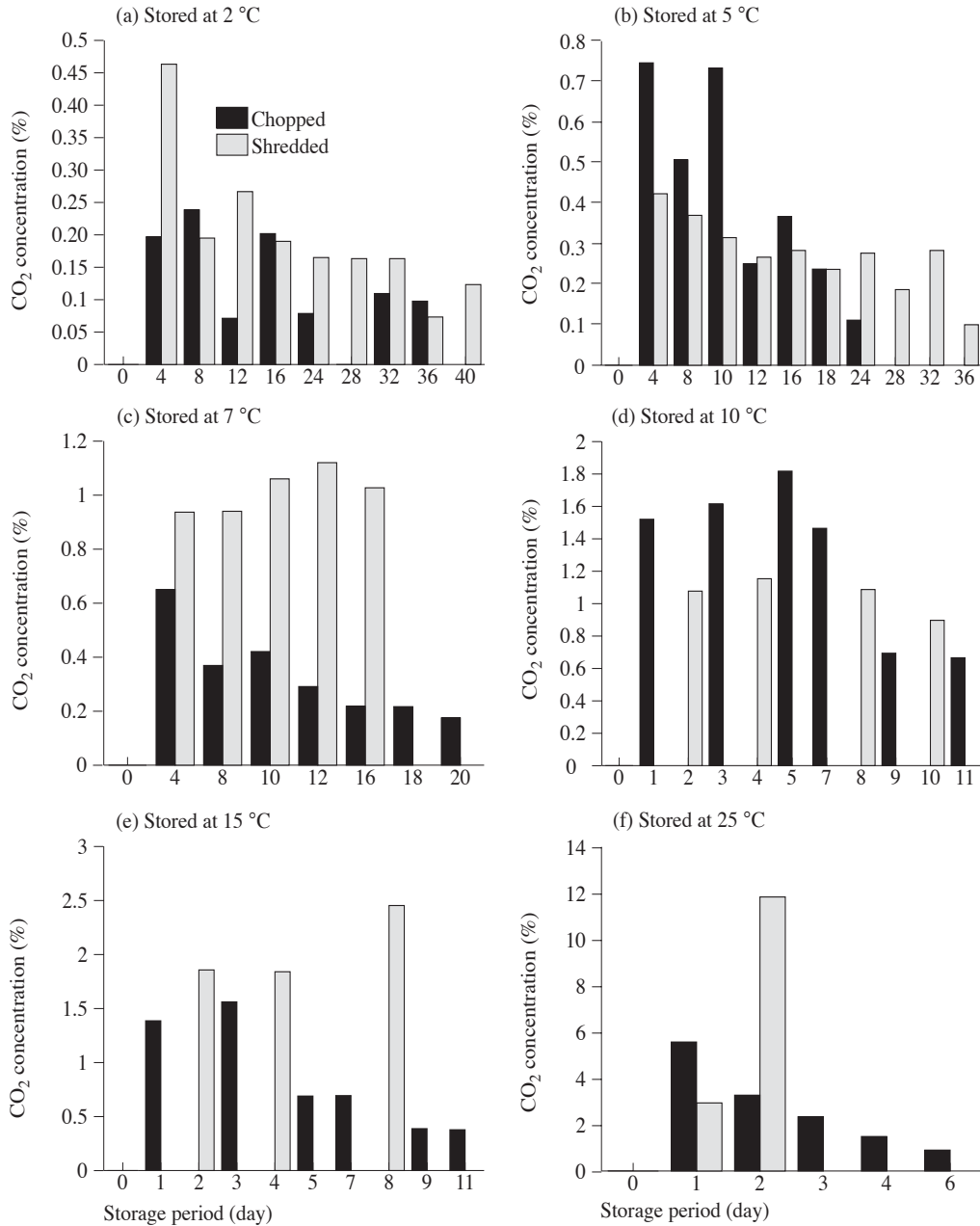


Figure 6. Effects of different forms of cutting on carbon dioxide (CO₂) concentration of minimally processed cabbage stored at different temperatures during the storage period

(Rolle and Chism 1987). The CO₂ concentration of shredded cabbage was slightly higher (0.21%) compared to the chopped cabbage (0.14%) stored at 2 °C. The result was similar to shredded cabbage stored at 7 and 25 °C (Table 1).

Oxygen concentration

The O₂ concentration of MP cabbage with different forms of cutting showed an irregular pattern when stored at 2 °C, where shredded cabbage increased (19.45%) at the beginning of storage on day 4 and then

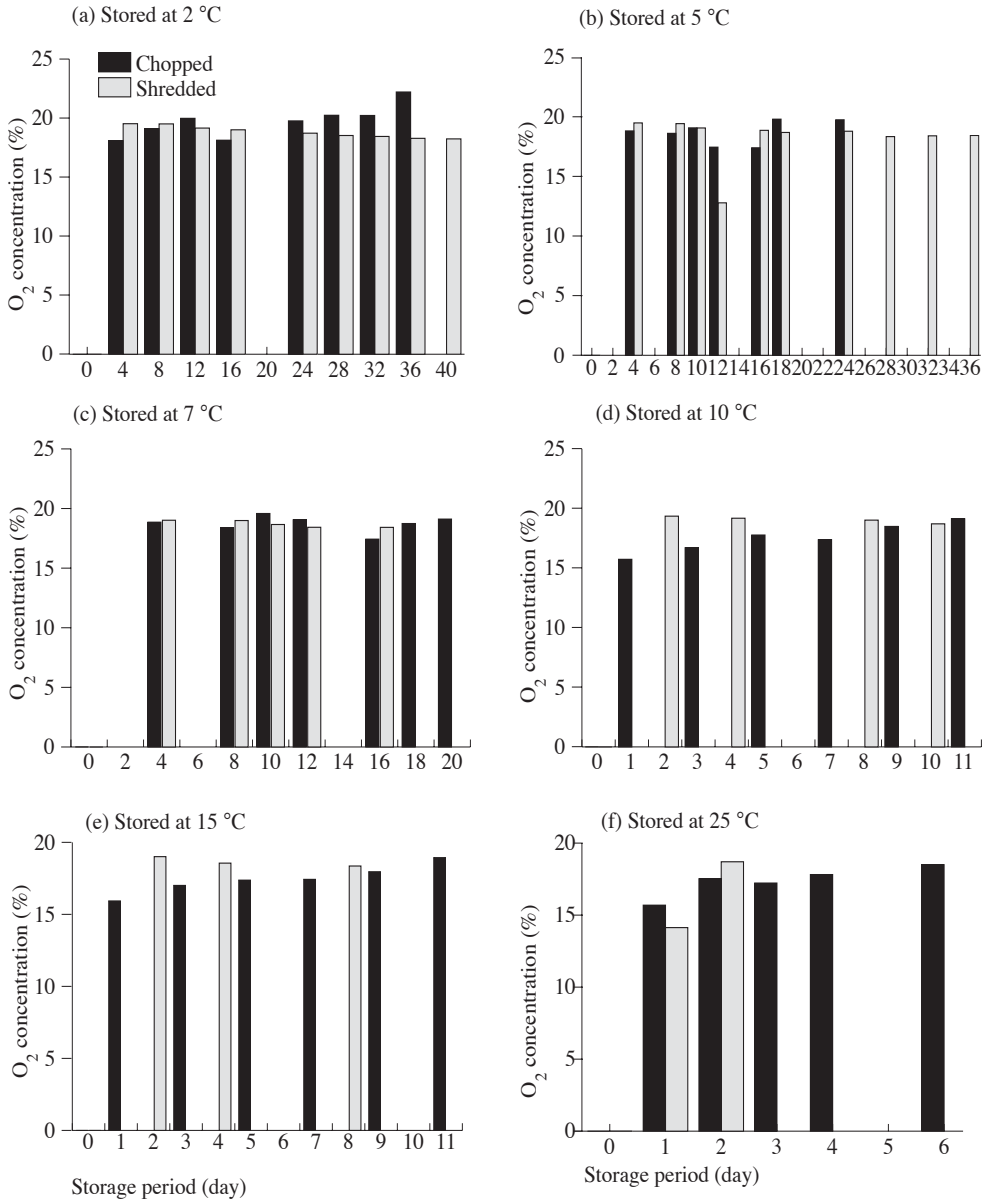


Figure 7. Effects of different forms of cutting on oxygen (O_2) concentration of minimally processed cabbage stored at different temperatures during the storage period

decreased (18.97%) at day 8. The O_2 concentration then increased and decreased until the end of storage period (Figure 7). Therefore, the O_2 concentration also showed the same trend when the MP cabbage stored at 5, 7, 10, 15 and 25 °C. Razali et al. (2003) reported an irregular pattern of O_2 concentration in ring and trimmed MP long

bean during storage period when stored at 2, 5, 10, 15 and 25 °C. The O_2 concentration in shredded cabbage were lower (18.83, 18.23 and 16.42%) than chopped cabbage (19.54, 18.66 and 17.35%) when stored at 2, 5 and 25 °C, respectively (Table 1).

Conclusion

Temperature was the most significant factor influencing shelf life and quality of minimally processed (MP) cabbage. There were significant differences ($p < 0.05$) in the pH, TTA, AA content, C_2H_4 production rate, CO_2 and O_2 concentrations of shredded and chopped MP cabbage forms stored at different temperatures. Quality of MP cabbage changed significantly ($p < 0.05$) with the increase in the storage temperatures and also duration of storage. The best storage temperature was at 2 °C as the MP cabbage with different forms of cutting maintained their appearance and remained in good condition even after 36–40 days of storage. This was followed by storing at 5 °C (24–30 days; 3–4 weeks), 7 °C (18–20 days; 2–3 weeks), 10 and 15 °C (8–10 days) and 25 °C (2–6 days). However, the shredded cabbage was the most suitable form with good appearance and could be extended up to 36 days of storage life when stored at 2 °C, while the chopped cabbage can be stored for 30 days and had the lowest percentage of weight loss, C_2H_4 production rate and CO_2 concentration compared to other storage temperatures.

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Abstrak

Perubahan fisiologi kubis var. Capitata yang diproses secara minimum dikaji semasa penyimpanan pada suhu yang berbeza (2, 5, 7, 10, 15 dan 25 °C). Bentuk hirisan yang berbeza iaitu cencangan dan carikan telah dinilai. Kubis yang disimpan pada suhu 2, 5 dan 7 °C dinilai setiap empat hari, manakala sampel yang disimpan pada 10, 15 dan 25 °C dinilai dua hari sekali. Penilaian mutu merangkumi perubahan fizikal dan kimia, kadar pengeluaran etilena (C₂H₄) serta kepekatan karbon dioksida (CO₂) dan oksigen (O₂).

Kubis yang diproses secara carikan dapat disimpan selama 36 hari manakala bentuk cencangan pula dapat disimpan selama 30 hari pada suhu 2 °C dengan peratus kehilangan berat, kadar pengeluaran C₂H₄ dan kepekatan CO₂ yang sangat rendah berbanding dengan penyimpanan pada suhu yang lain. Terdapat perbezaan bererti ($p < 0.05$) bagi kadar pengeluaran C₂H₄, kepekatan CO₂ dan O₂, pH, jumlah asid tertitrat (TTA) dan kandungan asid askorbik (vitamin C; AA) bagi kubis yang dihiris berlainan bentuk yang disimpan pada suhu yang berbeza. Walau bagaimanapun, tiada perbezaan bererti ($p > 0.05$) antara bentuk hirisan yang berlainan terhadap peratus kehilangan berat bagi kubis yang diproses secara minimum yang disimpan pada suhu yang berbeza. Kubis yang dicarik merupakan bentuk hirisan yang lebih baik dengan peratus kehilangan berat (0.19%), pH (5.74), TTA (0.10%) dan kadar kepekatan O₂ (18.83%) yang rendah berbanding dengan bentuk cencangan (0.26%, 6.15, 0.12% dan 19.54%, masing-masing). Terdapat juga perbezaan bererti ($p < 0.05$) dalam semua parameter bagi kubis yang diproses secara minimum semasa tempoh penyimpanan.