Original Research Paper

Effect of three Cutting Ways on the Quality of Fresh-Cut Green Pepper During Room Temperature Storage

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Abstract: Fresh-cut (FC) pepper is favored by consumers all over the world for its convenience, freshness and nutritional value. Previous studies have mostly focused on the influence of preservation approaches on microorganism and quality control of fresh-cut green peppers. Yet, there have been few studies on how the cutting ways affect the quality and antioxidant ability of FC green peppers during storage. To investigate the impact of three common cutting ways (piece, dicing and shredding, corresponding to 0.90, 3.2 and 4 $cm^2\ g^{-1}$ damage intensity) on the qualities of green peppers, sensory evaluation, weight loss, Vitamin C, chlorophyll, total phenols and flavonoids content were determined during 25°C storage for 3 days. Cutting operation caused fast quality deterioration, with shredding being the most severe. While the synthesis of total phenols and flavonoids was significantly stimulated after cutting, which brought about enhancement of 27, 26 and 43% of total phenols and 56, 60 and 83% of flavonoids in piece, dicing and shredding group at day 3 respectively. The above results indicated that the damage intensities significantly related with fresh-cut green peppers quality.

Keywords: Fresh-Cut, Green Peppers, Damage Intensities, Storage Quality

Introduction

Green pepper (*Capsicum annuum*, L.), a Solanaceae family vegetable, is widely planted and consumed all over the world for its high nutritional value including antioxidants (i.e., vitamin C, flavonoids, phenols and carotenoids), minerals and fibers, very suitable for cooking, raw eating and salad (Castro *et al*., 2008; Oboh *et al*., 2007). Green pepper is a cold-sensitive vegetable that is prone to dehydration, drying, softening and redness during postharvest storage, circulation and sales, resulting in a decrease in its commercial value and edible quality (Manolopoulou *et al*., 2010). To address unnecessary losses in the circulation and sales processes, green peppers are increasingly popular in Fresh-Cut (FC) forms in the market except for being sold as intact vegetables.

FC fruits or vegetables, also named minimally-processed products, ready-to-eat or ready-to-use fruit or vegetable foods that are made from raw fruits or vegetables and processed by classifying, washing, trimming, shelling, slicing, conservation, packing, etc., then by low-temperature transportation to refrigerated containers for sale (Lamikanra, 2002). FC fruit and vegetables are convenient, natural, nutritional, fresh and highly available (100% edible), which meet people's needs in pursuing a natural, nutritious and fast-paced lifestyle (Cisneros-Zevallos, 2021).

However, a series of processing treatments do great damage to the intrinsic screen of fruits or vegetables that make them a good place for microorganism growth (De Corato, 2020). Besides, cutting operation inevitably causes wounds, increases the respiration rate of tissues and significantly increases the perishability of fruits or vegetables (Manolopoulou *et al*., 2012). Different cutting ways cause different damage intensities, which leads to different physiological effects on the tissue. Earlier researches have primarily concentrated on the function of preservation approaches on microbial and quality control of fresh-cut green peppers (De Corato, 2020). Yet, limited researches have been conducted on how different cutting ways affect the quality and antioxidant capacity of FC green peppers during storage.

FC Fruits or vegetables ideally should maintain a shelf life of no less than 4-7 days, with a preference for extended longevity (Ahvenainen, 1996). Low-temperature storage is effective for inhibiting microbial activity and slowing down the quality deteriorative reactions in FC vegetables (Artés-Hernández *et al*., 2017). However, consumers may store FC green peppers in the refrigerator or at room temperature after buying them at home. In this

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study, green peppers are freshly cut in different ways (piece, dicing, shredding) and stored at room temperature (25°C, 90% relative humidity), the influence of different cutting ways on the nutritional qualities and antioxidant-related indexes of FC green peppers were studied. This study aims to clarify the best cutting way for FC green peppers in terms of quality and provide a theoretical basis for the storage, preservation and circulation of FC green peppers for consumers and production practitioners.

Materials and Methods

Material and Processing

Fresh green peppers (*Capsicum annuum*, L.) without damage and defects were selected, washed using distilled water and dried in air. Subsequently, the green peppers were aimlessly assigned to four groups. The first group did not undergo any treatment, named Control Group (CG), the second group was cut into pieces (4 cm in length, 3 cm in width, 0.3 cm in thickness, named PG), the third group was used to dice (1 cm in length and width, 0.3 cm in thickness, named DG) and the fourth group was used to shred (6 cm in length, 0.5 in width, 0.3 cm in thickness, named SG). All cutting operation was performed by a stainless-steel knife. The intensity of the wounds was represented by the ratio of the newly exposed surface area formed by the wound to the weight of the tissue (cm^2/g) (Surjadinata and Cisneros-Zevallos, 2003). The damage intensity of CG, PG, DG and SG is 0, 0.9, 3.2 and 4.0 cm^2/g, respectively. All samples were then placed into polyethylene preservation bags (30*20 cm*0.01 mm) tied with a rubber band to sustain elevated relative humidity within the freshness bag (80-90%) and stored at 25°C for three days. On days 1, 2 and 3 of 25°C storage, the quality indicators of every sample were determined in triplicate.

Sensory Evaluation and Weight Loss Determination

Weight loss was calculated by subtracting the final weight from the initial weight of the sample, with the results presented as a percentage.

Sensory evaluation was conducted based on color, freshness, decay and odor on the basis of a method reported by Li *et al*. (2021) with some adjustments. The total score of sensory evaluation is the sum of scores for each part (color, odor, freshness and decay), with a maximum score of 40.

Vitamin C (Vc) Assay

The Vc content was assessed using the titration method with 2,6-dichlorophenolindophenol dye, following the procedure outlined by Mashabela *et al*. (2015) with small modifications. 2 g sample and 30 mL oxalic acid solution (20 g/L) were homogenized in an ice bath, moved to a 50 mL centrifuge tube and centrifuged at 5000 r/min at 4°C for 10 min, after which the solution was collected. Then 10 mL of supernatant was pipetted into a 100 mL conical flask and titrated with standardized 2,6-dichlorophenol indophenol solution until a faint red hue persisted for 15 seconds. The amount of dye used was recorded and a 10 mL solution of 20 g/L oxalic acid served as blank control.

The Vc content of the samples was calculated according to the titrimetric dosage of the dye and represented as the mass of Vc in a 100 g sample (fresh weight) (mg/100 g).

Chlorophyll Assay

The content of total chlorophyll was confirmed according to the method reported by Li *et al*. (2021) with some alterations. 1 g pepper sample was placed on a pre-cooled mortar and 5 mL extraction consisting of acetone and ethanol (V: V = 2:1) was added as the extraction solution, ground well on ice, followed by centrifugating at 5000 rpm at 4°C for 10 min. The supernatant was taken for determination of absorbance at 645 nm (chlorophyll a) and 663 nm (chlorophyll b) using UV-visible spectrophotometry. Total chlorophyll content was reported as mg per gram.

Measurement of Total Phenols and Flavonoids

Total phenols and flavonoids were quantified using the method outlined by K.C.J. *et al*. (2007). In this procedure, 2 g samples were homogenized with a pre-chilled 1% HCl-methanol solution in an ice bath and then transferred to a 50 mL centrifuge tube. The samples were rinsed with additional 1% HCl-methanol solution, which was also added to the centrifuge tube. The volume was adjusted to the appropriate mark, mixed thoroughly, and allowed to extract at 4°C for 20 minutes while shaking. Following this, the mixture was centrifuged at 5000 rpm for 10 minutes at 4°C, and the resulting solution was collected. A 1% HCl-methanol solution served as a blank reference. The absorbance of the solution was recorded at 280 nm and 325 nm.

Total phenolic content was represented by the absorbance at 280 nm; while flavonoid content was indicated by the absorbance at 325 nm. The concentrations of total phenols and flavonoids was calculated using standard curves of gallic acid and rutin, respectively. The total phenolic content was reported as µg GAE/g FW, and the flavonoids content was presented as mg LE/g FW.

Statistical Analysis

All data were analyzed by Microsoft Excel 2019 and variance analysis was performed with Duncan's multiple range test ($p<0.05$) via SPSS 18.0 software (SPSS Inc., Chicago, IL, USA), results were expressed as means ± SD. Figures were made using Origin Pro 2022 (OriginLab, Northampton, MA, USA).

Results and Discussion

Effect of Different Cutting Ways on Sensory Evaluation and Weight Loss of Peppers During Storage

In this study, the sensory qualities of peppers were evaluated from four aspects: Color, odor, freshness and decay, these four attributes affect consumer acceptance and the value of these products (Barrett *et al*., 2010). Green peppers that are bright and green, fresh without wilting, no decay and no off-flavors have a sensory score of 36-40. Studies have shown that compared with intact fruits or vegetables, cutting operations lead to tissue browning, nutrient loss and microbial proliferation by virtue of disruption of tissue structure and physiological and biochemical changes (Moon *et al*., 2020; Rico *et al*., 2007). The sensory qualities of each group declined over time (Fig. 1). Figures (2a-c) are radar plots of sensory scores of 4 groups on days 1, 2 and 3 stored at room temperature. Water damage was most severe in SG (Fig. 1) and odor changes were most pronounced in DG when stored until day 3 (Fig. 2C). Green peppers in DG from the 2nd day began to appear shrinkage phenomenon, to the end of storage on the 3rd day has been part of the tissue rot, severe browning and it has a strong smell of corruption (Figs. 1-2a-c). SG from the 1st day began to appear water damage phenomenon, to the 3rd day, the water damage phenomenon was obvious, most of the pulp had been seriously decayed, the degree of browning was deep and only the skin and its connection with the part of the pulp, basically no food value (Figs. 1-2a-c). Severe tissue browning phenomena were also noted in fresh-cut apples (Hu *et al*., 2021) and potatoes (Zhao *et al*., 2021). By contrast, green pepper in PG was in relatively good condition at the conclusion of the storage with regards to water damage and odor. The CG was in good condition and a small amount of water damage appeared only on the third day of storage, which still had certain nutritional value and food value.

Green peppers in CG showed the highest sensory scores throughout the storage period, followed by PG (Fig. 2d). The sensory quality of DG was notably superior to that of SG on the first day, but no significant differences in sensory scores were observed between the two groups on the following two days (Fig. 2d). Similar findings were observed in fresh-cut pumpkin, where the ratings for appearance, color, taste, texture and overall quality in pieces (the lowest damage intensity) were higher than strip and slice, which suggested the pumpkin cut into piece exhibited the highest visible quality (Hu *et al*., 2023).

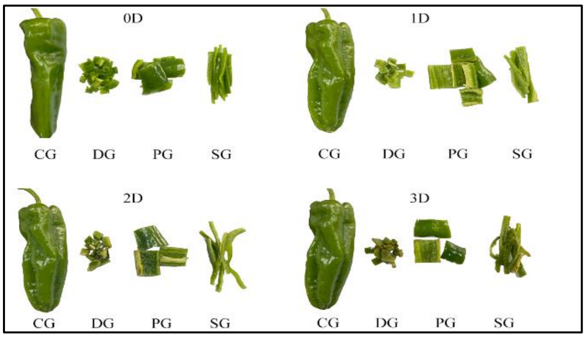
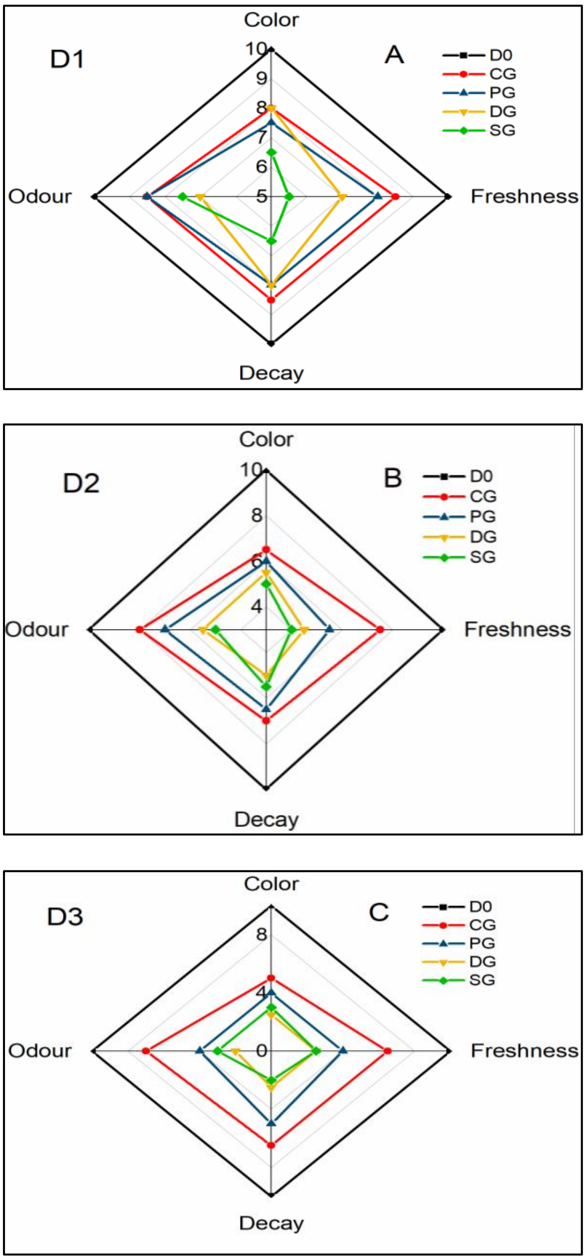


Fig. 1: Photos of CG, DG, PG and SG peppers during room-temperature storage



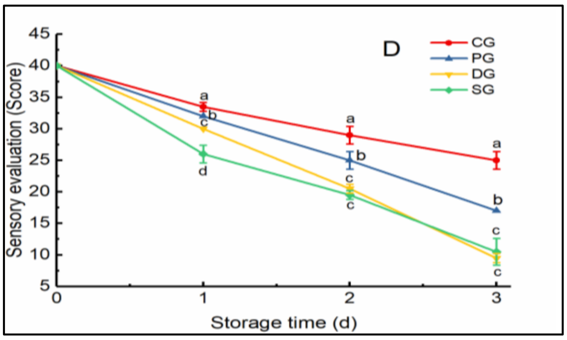


Fig. 2: Effect of cutting ways on sensory characteristics (A, B, C) and total sensory score (D) of green peppers during storage. The results are presented as the mean values with standard deviations based on three replicates. Any significant differences were determined using Duncan's test at a significance level of 0.05 between CG, PG, DG, and SG with different lowercase letters

Effect of Different Cutting Ways on Weight Loss of Cutting Peppers During Storage

As can be seen in Fig. 3, the weight loss rate of each group gradually increased over time. Compared with DG and SG, PG had the lowest rate of weight loss, which was less than 3% on the third day of storage. CG group had the least weight loss of all the experimental groups, with a weight loss of only 1.7% on day 3. Both DG and SG showed weight loss rates of a trend of first fast, then slow and then fast, while DG and CG were always relatively smooth. This may be due to shredded and diced cuts being subjected to more mechanical damage than the other two groups during cutting and the contact surface with air was larger than that of the CG and DG groups, resulting in stronger respiration and a higher rate of weight loss (Moon *et al*., 2020; Rico *et al*., 2007). In contrast, piece cutting was the cutting style with the lowest weight loss rate at 25°C storage. Hu *et al*. (2023) found that cutting with the highest damage intensity also has the highest weight loss, consistence with our results that SG showed the highest weight loss on the third day of storage (Fig. 3).

Effect of Different Cutting Ways on the Content of VC During Storage

Fruits and vegetables are a significant source of both essential macro-nutrients and micro-nutrients, Vc belongs to the "micro" nutrient and is a crucial nutrient for the human body (Barrett *et al*., 2010; Guan *et al*., 2021). Green peppers are rich in Vc, which is very sensitive to heat, light and oxygen, quickly being degraded by exposure to these factors and also decomposed with the storage time, so it can be used as an indicator to assess the storage quality of green peppers (Barrett *et al*., 2010). In our study, the Vc content of green peppers in the 4 groups showed a tendency to increase and then decrease with the prolongation of storage (Fig. 4). Compared with the control peppers, three cutting treatments obviously reduced the content of Vc throughout the storage. Among them, the Vc content of the PG group was constantly higher than other cutting groups all over the storage process and on day 3, the Vc content of the PG group was notably higher than that in the CG group. The shredding treatment had the greatest inhibition effect on the Vc content of green peppers, causing Vc content to drop 78.7 mg/100 g on the 3rd day. The Vc content of CG was basically higher than that of the other three groups, which indicated that compared with intact fruits, the greater intensity of the damage of mechanically cut samples resulted in a greater contact surface between oxygen and the substrate, which was more prone to the loss of nutrients. VC content in fresh-cut peppers was lower than the intact ones during the storage period were also found in fresh-cut pumpkin (Hu *et al*., 2023). In terms of Vc content, it can be deduced that pieces are the most suitable cutting method for storage of fresh-cutting green peppers.

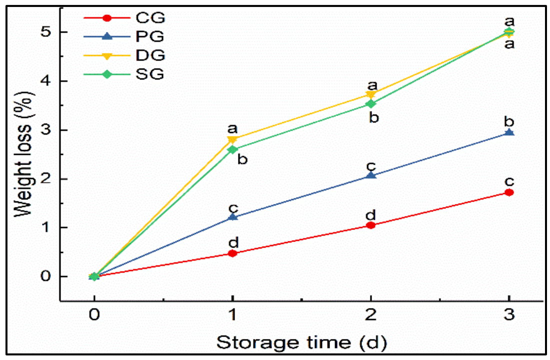


Fig. 3: Effect of cutting ways on weight loss of CG, PG, DG and SG peppers during storage. The results are presented as the mean values with standard deviations based on three replicates. Any significant differences were determined using Duncan's test at a significance level of 0.05 between CG, PG, DG, and SG with different lowercase letters

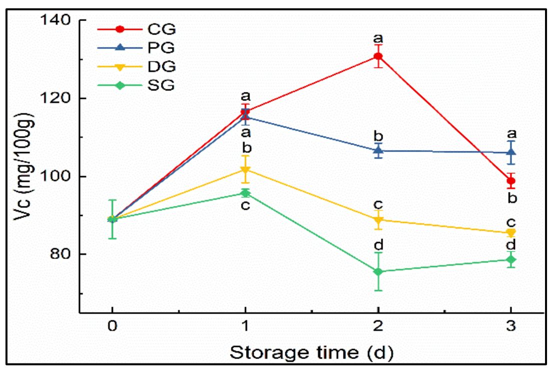


Fig. 4: Effect of cutting ways on the content of Vc during storage. The results are presented as the mean values with standard deviations based on three replicates. Any significant differences were determined using Duncan's test at a significance level of 0.05 between CG, PG, DG, and SG with different lowercase letters.

Effect of Different Cutting Ways on the Content of Chlorophyll During Storage

Chlorophyll is a green pigment contained in plants, which not only provides the appearance of bright color for green peppers, but also possesses a certain antioxidant ability, so it was used as an important index for the freshness and quality determination of green peppers in this study (Peng *et al*., 2015). Figure 5 illustrates the fluctuations in chlorophyll content over the storage duration. Overall, the chlorophyll content of the samples in CG and PG uniformly exhibited a pattern of initially rising followed by a decline with increasing storage date. Whereas the chlorophyll content of DG and SG was generally reduced over the 3 days. Among the 4 groups, the chlorophyll of peppers in the CG group was notably higher than that of the three cutting groups. By the initial storage day, the chlorophyll level of peppers in PG was significantly higher than that of DG and SG but decreased rapidly from 0.12 mg/g on the first day to less than 0.09 mg/g on day 3. Pieces were effective in keeping the chlorophyll content of peppers at a high level on days 0-1, but the loss of chlorophyll from PG peppers increased considerably from day 2 onwards.

Vegetables undergo an irreversible senescence process during postharvest storage, which is accompanied by a rapid degradation of chlorophyll, so that part of the chlorophyll is eventually degraded to the non-fluorescent product NCCS linear colorless tetra pyrrole material, thus losing its green color (Kräutler, 2016). The metabolism of pigments in peppers during storage is influenced by the physiological condition of the peppers as well as other pre-harvest and pre-treatment factors, including plant respiration rate, ethylene release rate, lipid peroxidation and other physiological indicators (Chen *et al*., 2018). As one of the organic sources that sustain respiration after harvesting of vegetables, chlorophyll is depleted in the respiratory chain involved in the aerobic decomposition of pyruvate (Padmasree *et al*., 2002) and after cutting, the mechanical damage creates a stressful environment that accelerates the decomposition of chlorophyll. Besides, chlorophyll also degrades when exposed to oxygen and enzymes such as chlorophyllase (Gong and P.M.J, 2003). In this study, cutting leads to increased exposure of the peppers to oxygen and accelerated degradation of the peppers.

Effect of Different Cutting Ways on the Content of Total Phenols and Flavonoids

Phenolic compounds (total phenols, flavonoids, etc.,) as well as anthocyanins are secondary metabolites prevalent in fruits and vegetables, which are related to the color development, flavor formation, ripening and aging of fruits and vegetables and have an important impact on the nutritional value of fruits and vegetables, as well as providing the main components of the antioxidant capacity (Bursal *et al*., 2013). During ambient storage, the content of total phenols and flavonoids in green peppers changed as shown in Figs. 6-7. By comparison, total phenols and flavonoids showed the same change trends. Throughout the storage period, the total phenol and flavonoid contents of cutting samples increased more than those of CG (Figs. 6-7). It's reported that cutting causes mechanical damage, which belongs to the postharvest abiotic stress, fresh fruits and vegetables are living organisms, which induce the body's stress defense response to adversity and produce a series of physiological and biochemical reactions by accelerating cellular secondary metabolism, prompting the accumulation of biologically active secondary metabolites, such as polyphenols, flavonoids and anthocyanins and enhancing the antioxidant properties of freshly cut fruits and vegetables from the perspective of nutritional health (Li *et al*., 2019). This experiment found that within the first two days of storage, the total phenol and flavonoid content of PG accumulated faster, located in the forefront of the groups, on the second day of PG phenol content of 273, flavonoid content of 2.89; on the contrary, the second day of SG of total phenol content of 234, flavonoids content of 2.47 were the lowest for the second day of the groups. However, on the 3rd day of storage, the total phenol and flavonoid contents of SG increased rapidly, with the total phenol content increasing to 323 and the flavonoid content rising to 3.6, significantly higher than that of PG and DG. In contrast, on day 3 the control group showed a rapid decrease in total phenol and flavonoid content, with total phenol content falling from 257-225 and flavonoid content dropping from 2.7-1.9 (Figs. 6-7).

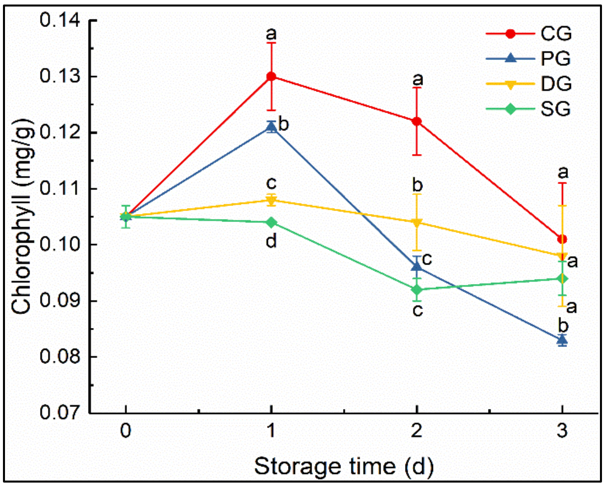


Fig. 5: Effect of cutting ways on the content of chlorophyll during storage. The results are presented as the mean values with standard deviations based on three replicates. Any significant differences were determined using Duncan's test at a significance level of 0.05 between CG, PG, DG and SG with different lowercase letters

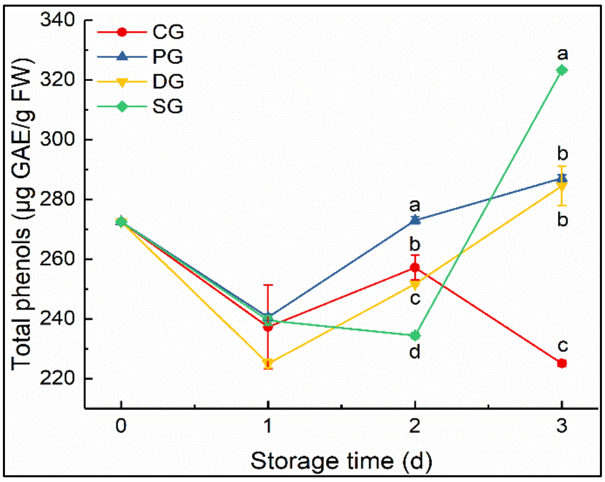


Fig. 6: Effect of cutting ways on the content of total phenols during storage. The results are presented as the mean values with standard deviations based on three replicates. Any significant differences were determined using Duncan's test at a significance level of 0.05 between CG, PG, DG, and SG with different lowercase letters

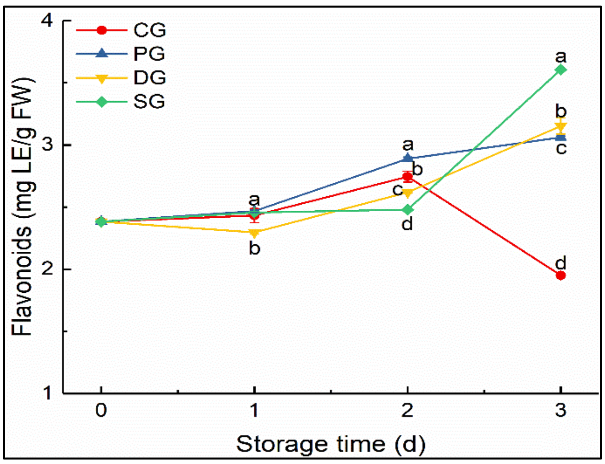


Fig. 7: Effect of cutting ways on the content of flavonoids during storage. The results are presented as the mean values with standard deviations based on three replicates. Any significant differences were determined using Duncan's test at a significance level of 0.05 between CG, PG, DG, and SG with different lowercase letters

It's reported that the accumulation of phenolic compounds and flavonoids induced by wound stress is a noteworthy phenomenon in many fresh-cut fruit and vegetables, such as cabbage (Guan *et al.*, 2023), potato (Hu *et al.*, 2021), pumpkin (Hu *et al.*, 2023) and pitaya (Chai *et al.*, 2021), which depends on plant tissue and storage conditions. Higher temperatures such as 20°C accumulated more phenols compared to lower temperatures (Li *et al.*, 2017). In consistency with these findings, total phenols and flavonoids of intact green peppers showed a general decline trend, while in the three cutting groups, they accumulated dramatically. Here, we found a positive correlation between wound intensities and accumulation of total phenols and flavonoids, shredding can effectively accelerate the accumulation of total phenols and flavonoids and enhance the antioxidant capacity of green peppers than pieces and dicing. Similar to the results of Surjadinata and Cisneros-Zevallos (2012), who showed that the antioxidant capacity of carrot tissue was found to rise in correlation with the level of cutting damage inflicted, the damage intensity of shredding was higher than that of dicing and pieces in this study and shredding also enhanced the antioxidant activity of green peppers.

Conclusion

In this study, the sensory evaluation, weight loss, Vc content, chlorophyll content, total phenols and flavonoids content of fresh-cut peppers with different cutting ways were determined during 25°C storage. Fresh-cutting operations reduced the sensory quality, increased weight loss and inhibited the Vc and chlorophyll content of green peppers. However, cutting stimulated the production of total phenols and flavonoids. Under the storage condition of 25°C, cutting in pieces can effectively slow down the decline of sensory quality and weight loss rate, reduce Vc loss and have a promotion effect on the accumulation of total phenols and flavonoids content, thus improving the level of antioxidant activity of green pepper, which is a better way of fresh-cut green peppers compared with dicing and shredding and it is recommended to have a shelf life of 2 days. The results of the study may provide guidance for the storage, preservation and distribution of fresh-cut green peppers for the home and food industry.

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Author's Contributions

Yue Yang: Conducted the experiments and completed the initial draft.

Shuai Han: Conceived the concept of the article and contributed to proofreading the manuscript.

Huitao Gao: Conducted a portion of the experiments.

Hongfang Cai: Conceived the concept of the article and revised the manuscript.

Ethics

This is an original article. The corresponding author confirms that all authors have reviewed and approved the manuscript. There are no ethical issues involved.

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