Sensory quality and flavour of alginate coated and repetitive pulsed light treated fresh-cut cantaloupes (*Cucumis melo* L. Var. *Reticulatus* Cv. Glamour) during storage

Pei Chen Koh¹ · Mohd Adzahan Noranizan¹ · Roselina Karim¹ · Zainal Abedin Nur Hanani¹

Revised: 12 March 2019 / Accepted: 19 March 2019 / Published online: 13 April 2019
© Association of Food Scientists & Technologists (India) 2019

Abstract Fresh-cut fruits are popular due to the convenience provided. However, fresh-cut processes damage fruit tissues and reduce the shelf life of products. Pulsed light (PL) treatment is a decontamination method of foods. PL treatment given repetitively at a certain interval during storage could further extend the shelf life of fresh-cut fruits. Edible coating preserves fresh-cut fruits by providing mechanical strength and reducing respiration and water loss. This study was to evaluate the effects of alginate coating combined with repetitive pulsed light (RPL) on sensory quality and flavour of fresh-cut cantaloupes during storage. Cantaloupes were treated with alginate (1.86%, w/v) and RPL (0.9 J/cm² at every 48 h up to 26 days) alone or in combination. Flavour analysis of fresh-cut cantaloupes was carried out every 12 days during storage at 4 ± 1 °C while sensory analysis was performed on day 32. Alginate coating and/or RPL retained sugar contents (17.92–20.01 g/kg FW for fructose, 18.77–19.98 g/kg FW for glucose and 23.02–29.41 g/kg FW for sucrose) in fresh-cut cantaloupes during storage. Combination of alginate with RPL reduced accumulation of lactic acid although alginate coating was more effective to minimise changes of other organic acids in fresh-cut cantaloupes. The combined treatment was also more effective than individual treatment in retaining total aroma compound concentration of fresh-cut cantaloupes during storage with the highest relative

concentration, i.e. 3.174 on day 36. Overall, the combined alginate coating and RPL was effective to maintain the fresh-like sensory quality of fresh-cut cantaloupes with insignificant overall acceptability compared to the control.

Keywords Repetitive pulsed light · Alginate coating · Fresh-cut cantaloupes · Sensory · Flavour · Aroma

Introduction

Fresh-cut fruits have become increasingly popular due to consumer demand for nutritious and convenient products (Corbo et al. 2010). However, fresh-cut fruits are easy to spoil due to physiological and biochemical changes during fresh-cut processing (Corbo et al. 2010). These changes directly influence the sensory quality of the products. Consumers usually select a product based on the appearance at first sight and subsequent purchases are determined by the quality factors such as flavour and textural characteristics (Beaulieu and Lancaster 2007). Hence, it is essential to improve the sensory quality of the product to meet the demand by consumers.

Apart from safety, physicochemical and nutritional qualities, the sensory characteristic of fresh-cut fruits is one of the important qualities of fresh produce. Affective test or also known as acceptance, preference or hedonic tests measure the consumer preference or degree of liking/disliking of a product (Lawless and Claassen 1993). The flavour profile of a product, which is related to sensory characteristics is also an important quality to monitor as it is greatly influenced by physiological, physicochemical and microbiological changes in the products. Flavour of fruit is a combined result of the composition of sugars, acids and volatile compounds (Beaulieu and Baldwin

✉ Pei Chen Koh
kohpeichen14@gmail.com

✉ Mohd Adzahan Noranizan
noraadzahan@upm.edu.my

¹ Department of Food Technology, Faculty of Food Science and Technology, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia

2002). Sugars and organic acids affect the perception of sweetness and sourness in fruits. Cantaloupe, a kind of melon, contains unique flavour and high sugar levels. The organic acid in melon is usually low. Changes of aroma in fresh-cut cantaloupes are due to changes in the concentration of acetate and non-acetate esters, alcohols, aldehydes and sulphur-containing compounds (Amaro et al. 2013). Effects of different treatments on the flavour of fresh-cut melons during storage have been reported in several studies (Amaro et al. 2013; Beaulieu et al. 2011; Lamikanra et al. 2000).

In general, the treatments that can improve or maintain the physicochemical quality of fresh-cut fruits will also preserve the sensory quality and flavour of the products. Pulsed light treatment is a decontamination technique that inactivates microorganisms by applying short time pulses of an intense broad spectrum ranging from UV to near-infrared (Gómez et al. 2012). The efficiency of PL treatment on microbial inactivation of fresh-cut fruits has been reported. A new application of PL treatment, i.e. repetitive pulsed light (RPL) was reported to be more effective than single pulsed light treatment on inactivating microorganisms in fresh-cut cantaloupes (Koh et al. 2016b). Koh et al. (2016b) demonstrated that RPL could inactivate microorganisms on fresh-cut cantaloupes repetitively every 48 h during storage and thus slowed down microbial growth and retained other physicochemical qualities of the fruits. The edible coating is another preservative technique for fresh-cut fruits by forming a selective barrier to moisture, O₂ and CO₂ selectively, improving mechanical quality, trapping volatiles and carrying functional compounds (Olivas and Barbosa-Cánovas 2005).

Previous findings demonstrated that hurdle technology by combining alginate coating and RPL treatment prolonged shelf life of fresh-cut cantaloupes in terms of microbiological, physicochemical and nutritional qualities during storage of 28 days (Koh et al. 2017). The use of edible coating was to preserve the textural quality of the fruit, while RPL helped in reducing microbial counts. It is not known whether these treatments have any effects on the sensory and flavour qualities of the fresh-cut fruit during storage of 28 days or longer. The determination of sensory and flavour qualities is crucial to obtain fresh-cut cantaloupes with good eating quality and highly acceptable by consumers. Therefore, the objective of this study was to evaluate the effects of alginate coating combined with RPL treatment on the sensory quality and flavour of fresh-cut cantaloupes during chilled storage of 36 days.

Materials and methods

Coating preparation

The coating formulation used was based on the optimisation carried out previously for combination with RPL treatment on shelf life extension of fresh-cut cantaloupes. Alginate coating was prepared by mixing alginate (1.86%, w/v) with distilled water under continuous stirring at 70 °C until the solution became clear. Glycerol (1.47%, w/v) and sunflower oil (0.025%, w/v) were added to the alginate solution. Glycerol was added as a plasticiser while sunflower oil was added to improve water barrier properties of coatings. Distilled water was used to top up the mixture until the total volume of solution was 1 L. The coating mixture was homogenised utilising Diax 900 homogeniser (Heidolph Instruments, Schwabach, Germany) at 24,000 rpm for 5 min and degassed under vacuum.

Sample preparation

Cantaloupes (*Cucumis melo* L. *reticulatus* cv. Glamour) were harvested from a commercial farm in Klang, Malaysia and stored at 4 ± 1 °C for 24–48 h before used. The cantaloupes used in this study were selected based on the weight of fruit (> 2.0 kg for one whole fruit) and netting of rind (full netting covering the whole fruit). All the fruits and cutting appliances were washed with running potable water. The fruits were then cut into half by using a sharp knife following by removal of the seeds. The fruits were scooped into spherical shape using a melon baller to produce cantaloupe balls with a diameter of 3 cm (Koh et al. 2016a). A layer of coating was formed on the surfaces of spherical cantaloupes by dipping the spheres in the coating solution for 2 min. The cantaloupes were then dipped in 2% (w/v) CaCl₂ solution for 2 min after removal of the excess coating solution by dripping the cantaloupes for 1 min. CaCl₂ is required for gelling of the alginate coating. The coated cantaloupes were air-dried for 30 min at ambient temperature (26 ± 1 °C) on a grid shelf. Packages of cantaloupes were prepared by packing about 150 g of coated spheres in each polypropylene bag (thickness of ~ 40 µm) and then sealed. The O₂ and CO₂ permeabilities of the bag are 100 cc/m² d atm and 190 cc/m² d atm, respectively.

Apparatus

Pulsed light treatment was conducted by utilising Steribeam SBS XeMatic-2L-A system (SteriBeam Systems GmbH, Baden-Württemberg, Germany). The pulsed light machine contained two xenon lamps, i.e. one above and

another one below a sample shelf that functioned to hold samples. The sample shelf is 10 cm away from each of the lamps. The emitted spectrum consisted of broad wavelengths from 180 nm to 1100 nm with a total fluence of 0.3 J/cm² for a pulse.

Pulsed light treatment

The packaged and coated cantaloupes were exposed to repetitive pulsed light treatment as described by Koh et al. (2016b). A fluence of 0.9 J/cm² was applied every 48 h during storage until day 26. Throughout the storage, total 13 times of PL treatments with a total cumulative PL fluence of 11.7 J/cm² were applied to the samples. The RPL treatment was stopped on day 26 although the storage period was 36 days as the maximum cumulative dose permitted for PL treatment of food approved by FDA was 12 J/cm².

Storage study

All the samples (untreated, RPL alone, alginate coating alone and alginate coating with RPL) were stored at 4 ± 1 °C for a duration of 36 days. The storage duration of 36 days was applied as the previous study demonstrated that the microbial counts of fresh-cut cantaloupes treated with alginate coating and RPL reached 6 log cfu/g on day 36 (Koh et al. 2018). Flavour analysis (sugar contents, organic acid contents and aroma profile) of fresh-cut cantaloupes were carried out at every 12 days during storage while sensory analysis was carried out at the end of the storage period.

Methods of analysis

Sugar contents

Sugar contents (fructose, glucose and sucrose) of fresh-cut cantaloupes were analysed using HPLC based on the method described by Chen et al. (2007) with some modifications. The blended cantaloupe (10 g) was mixed with 5 mL of deionised water and filtered through 0.45 µm Millipore filter after centrifugation at 3000×g for 10 min. The aliquot with the volume of 20 µL was injected into a HPLC system equipped with Waters 600 controller (Waters, Massachusetts, USA), Shimadzu LC-6A pump (Shimadzu, Kyoto, Japan), Waters 410 refractive index detector (Waters, Massachusetts, USA) and Borwin software (Jasco, Maryland, USA). The column used was LiChrospher® 100 NH₂ (4 mm × 250 mm × 5 µm) (Merck Millipore, Massachusetts, USA). The mobile phase was 80% (v/v) acetonitrile with a flow rate of 1.0 mL/min at 28 ± 1 °C.

Organic acid contents

Organic acid contents (oxalic, tartaric, malic, malonic, lactic, citric and succinic acids) of fresh-cut cantaloupes were analysed using HPLC based on the method described by Wang et al. (2014) with some modifications. Organic acids contents were measured as it could affect taste and metabolic changes of a fruit. The aliquot used for organic acid contents determination was from the same blended cantaloupe prepared for sugar contents determination. The aliquot with the volume of 20 µL was injected into an Agilent series HPLC system (Agilent, California, USA) equipped with Agilent G1322A degasser, Agilent G1311A quaternary pump, Agilent G1315D photodiode array detector and Agilent software. The column used was Purospher® STAR RP-18 (4.6 mm × 250 mm × 5 µm) (Merck Millipore, Massachusetts, USA). The mobile phase was 0.008 N sulphuric acid (pH 2.5) with a flow rate of 0.8 mL/min at 35 °C and the peaks were detected by the detector at 210 nm.

Aroma profile

Aroma profile of fresh-cut cantaloupes was analysed using GC–MS according to the method of Beaulieu and Lancaster (2007) with some modifications. Cantaloupes were quickly blended and 3 g of the slurry was placed in 10-mL glass vials containing 1.1 g of NaCl and benzothiophene as internal standard (final concentration of 100 ppb). The vials were closed with a cap containing a Teflon/silicon septum. The vials were placed on a Combi-Pal auto-sampler (CTC Analytics AG, Zwingen, Switzerland) and equilibrated to a temperature of 40 °C for 10 min with an oscillation of 100 rpm. Then, a 1-cm 100 µm polydimethylsiloxane (PDMS) SPME fibre was inserted into the vial through the septum for extraction of headspace for 30 min at 40 °C (close to the temperature of the human palate in which mastication happens). The fibre was then desorbed at 250 °C for 1 min in the injection port of a Trace GC Ultra GC–MS (Thermo Scientific, Massachusetts, USA) installed with TG-5MS (5% phenyl methyl polysiloxane, Thermo Scientific, Massachusetts, USA) column (30 m, 0.25 mm i.d., 0.25 µm film thickness) for 38 min run. The injection port was set as splitless mode and helium was used as the carrier with a flow rate of 1.0 mL/min. The initial oven temperature was 50 °C held for 1 min, then ramped to 100 °C at 5 °C/min, then to 250 °C at 10 °C/min and finally held for 15 min. The TSQ Quantum XLS quadrupole mass spectrometer (Thermo Scientific, Massachusetts, USA) was set with the electron ionisation mode of 70 eV (electron volts), source temperature of 240 °C, continuous scan from *m/z* (mass to charge ratio) 30 to 300. The GC–MS data was collected from

Thermo Xcalibur software (Thermo Scientific, Massachusetts, USA) and searched based on NIST version 2.0 mass spectral data (NIST, Maryland, USA). The relative concentrations of aroma compounds to the internal standard were calculated.

Sensory analysis

Sensory analysis was conducted using a 9-point hedonic scale with scale 1 labelled as ‘dislike extremely’ while scale 9 labelled as ‘like extremely’. Seven samples with different treatments and storage days, i.e. untreated and alginate coating alone (day 0), RPL alone, alginate coating alone and alginate + RPL (day 12), alginate + RPL (day 24) and alginate + RPL (day 32) were randomly served to 50 untrained panellists in one session. The 7 samples were selected based on reasons as below following the data collected in the previous study conducted by the same authors (Koh et al. 2018):

- Untreated and alginate coating alone (day 0) served as controls.
- On day 12, samples treated with RPL alone had a high fluid loss, which is around 6%. Samples with this treatment after day 12 are not acceptable in term of physical quality.
- On day 12, samples treated with alginate alone had microbial counts of 6 log cfu/g. Samples with this treatment after day 12 are not safe for consumption.
- For alginate + RPL samples, the microbiological and physicochemical qualities remained acceptable until day 32, at which microbial count was below 6 log cfu/g.

The attributes evaluated were aroma, appearance, colour, firmness, juiciness, taste and overall acceptability. The panellists were instructed and explained to assess aroma based on both orthonasal and retronasal aroma. The definition of each attribute was also explained verbally to all panellists. The panellists were also asked to cleanse their palate using clean water provided in between the assessment of samples.

Statistical analysis

The experiments were performed in triplicates. The data were analysed using Minitab version 16.0 statistical package (Minitab Inc., Pennsylvania, USA) based on analysis of variance and expressed as mean value $\pm$ standard deviation. The confidence level for statistical significance was set at a probability value of 0.05. Tukey’s test was used to determine the significant difference between the data.

Results and discussion

Sugar contents

The main sugars present in cantaloupes are sucrose, glucose and fructose (Lamikanra et al. 2000). Figure 1 shows the effects of alginate coating and RPL treatment on the sugar contents of fresh-cut cantaloupes. The untreated samples showed a significant reduction ($p \leq 0.05$) of sucrose content throughout storage. On the other hand, the glucose and fructose contents of untreated samples were increased at the beginning of storage until day 24 and then started to decrease on day 36. These observations were due to progressive break down of sucrose into fructose and glucose and consumption of the sugars as a result of respiration of microorganisms and fruit tissues in untreated samples during storage. Microbial growth is known to conduct sugar fermentation with the consumption of sugar as the nutrient (Lamikanra et al. 2000). As the storage time increases to day 36, the sucrose concentration was very low due to the consumption of fructose and glucose during respiration of microorganisms and fruit tissues.

Other samples also showed a decrease of sucrose content and an increase of fructose and glucose contents but with a much lesser extent compared to untreated samples during storage due to their lower microbial growth and respiration. Throughout the storage, samples with RPL alone had slightly higher sugar contents compared to the coated samples without and with RPL (Fig. 1). This could be due to the washing effect during the coating process of coated samples, which may have caused leaching of sugars from the fruit surface. The alginate + RPL samples had significantly lower sucrose content and higher fructose and glucose contents ($p \leq 0.05$) compared to coated samples without RPL as storage time increased to day 36. According to Lapcık et al. (1990), a glycosidic bond can be broken by UV-radiation. This could explain the effect of RPL on lower sucrose content and higher fructose and glucose contents in alginate + RPL samples by breaking the glycosidic bond between fructose and glucose in sucrose. However, sucrose content in samples with RPL alone remained high and was not significantly different ($p > 0.05$) compared to the samples with coating alone. The high water loss and low microbial growth in the samples with RPL alone could cause the sugars to be concentrated. Considering the decrease of sucrose content and increase of fructose and glucose contents, the total sugar contents were retained in all treated samples.

Fig. 1 Effects of alginate coating and repetitive pulsed light (RPL) application on sugar contents (**a** fructose, **b** glucose and **c** sucrose) of fresh-cut cantaloupes

Organic acid contents

Citric acid is present in all types of melons and the levels of organic acids such as malic, succinic, malonic, formic, glycolic and oxalic acids are varied (Lamikanra et al. 2000). Figure 2 shows the effects of alginate coating and RPL treatment on organic acid contents of fresh-cut cantaloupes. As shown in Fig. 2, fresh-cut cantaloupes had highest citric acid concentration and followed by malic acid. Other than sugar consumption, organic acids are also used by respiration of fruit tissues and microorganisms (Barry-Ryan and O'Beirne 1998), leading to a decrease of organic acids after harvest. In this study, the citric acid content was decreased for all samples during storage. Lactic acid bacteria (Costantini et al. 2009) and yeasts (Huis in't Veld 1996) are known to utilise citric acids for fermentation.

The coated samples without and with RPL maintained significantly higher ($p \leq 0.05$) citric acid concentrations throughout the storage. Although samples with RPL alone were reported to have low microbial growth (Koh et al. 2017), it had a similar citric acid level in comparison to the

untreated samples at the end of storage. This could be explained by the RPL effect as citric acid is suggested to be degraded by photolysis reaction with exposure to wavelength below 242 nm (Quici et al. 2007). This also explains the slight lower citric acid concentration in alginate + RPL samples compared to the samples with coating alone. With a combination of alginate coating and RPL, the effect of RPL on citric acid was reduced.

Malic acid and lactic acid concentrations in uncoated samples decreased and increased significantly ($p \leq 0.05$), respectively during storage with more pronounced changes shown by untreated samples. The simultaneous increase of lactic acid content and reduction of malic acid content imply the occurrence of malo-lactic fermentation by lactic acid bacteria (Lamikanra et al. 2000). The high microbial growth in untreated samples (Koh et al. 2017) explained its greatest reduction of malic acid content and increase of lactic acid content compared to other samples. On the other hand, the malic acid concentrations in the coated samples without and with RPL were increased as storage time increased. The accumulation of malic acid in the coated samples could be due to the synthesis of malic acid during

Fig. 2 Effects of alginate coating and repetitive pulsed light (RPL) application on organic acid contents (**a** citric, **b** malic, **c** lactic, **d** succinic, **e** malonic, **f** oxalic and **g** tartaric acids) of fresh-cut cantaloupes

fruit ripening. Malate synthase expression was reported to be induced during fruit ripening leading to the production of malate by catalysing glyoxylate condensation reaction with acetyl-CoA in the peroxisome, which transforms stored lipids to carbohydrates (Pua et al. 2003). For samples with RPL alone, they had high water loss as reported by Koh et al. (2017), which resulted in partial loss of malic acid leading to lower malic acid concentration compared to the coated samples as storage time increased. Although the malic acid concentration in samples with alginate alone had increased during storage, the increase in the lactic acid concentration was more pronounced than in samples treated with RPL alone and alginate + RPL samples due to its high microbial growth (Koh et al. 2017). Lactic acid bacteria are known to degrade sugars such as glucose and fructose leading to the production of lactic acid and acetic acid (Dharmadhikari 2016). This increase of lactic acid concentration in samples with coating alone is due to fermentation of sugars and was supported by the reduction of sugar contents. The samples showed lower fructose and glucose concentrations at the end of storage compared to the samples with RPL alone and alginate + RPL samples. Among all the samples, alginate + RPL samples had the least increment of lactic acid during storage, which contributed by its slow microbial growth (Koh et al. 2017).

The succinic acid concentrations in all the samples were increased significantly ($p \leq 0.05$) throughout the storage (Fig. 2d). This was due to the increasing headspace CO_2 concentration in the packages during storage (Koh et al. 2017). It is known that high CO_2 level can lead to increased concentration of succinic acid due to the inhibition effect of CO_2 on succinic dehydrogenase (Lange and Kader 1997). The accumulation of succinic acid due to high CO_2 concentration was also reported in apricot and peach fruits (Wankier et al. 1970). At the end of storage, untreated samples showed the highest concentration of succinic acid. The rapid increase of CO_2 concentration in the untreated samples (Koh et al. 2017) could explain its greater inhibition effect on succinic dehydrogenase. In addition, microbial fermentation is known to produce succinic acid. This could also explain the greater succinic acid accumulation in untreated samples due to its highest microbial growth during storage as reported by Koh et al. (2017). Other samples did not have a significant difference ($p > 0.05$) for succinic acid concentration at the end of storage.

As displayed in Fig. 2e, the malonic acid concentrations were increased for all fresh-cut cantaloupes. The accumulation of malonic acid in orange and cantaloupe was also reported by Sasson and Monselise (1976) and Lamikanra et al. (2000), respectively. Sasson and Monselise (1976) suggested that the accumulation of malonic acid in fruits as fruits senesce could be due to the reduced biosynthetic

activities of compounds such as lipid, phenolic and etc. which involve malonic acid via its activated derivative, i.e. malonyl-CoA. During storage, the RPL-treated samples without and with coating had a greater increase of malonic acid accumulation compared to the untreated samples and samples with coating alone. UV treatment is known to induce synthesis of phenolic compounds in plants due to the application of abiotic stress (Jimenez-Garcia et al. 2013). Hence, induction of phenolic compounds production by RPL could cause greater malonic acid production since phenolics can be produced via malonate/acetate pathway (Jimenez-Garcia et al. 2013), which involves malonic acid. As a consequence, higher levels of malonic acid could be accumulated in the RPL-treated samples during storage.

Based on Fig. 2f, oxalic acid concentrations were decreased throughout the storage for all the fresh-cut cantaloupes. Degradation of oxalic acid is due to the oxidation and decarboxylation processes that are catalysed by oxalate oxidase and oxalate decarboxylase, respectively (Chakraborty et al. 2013). Bacteria and fungi were reported to produce oxalate oxidase (Koyama 1988; Vaisey et al. 1961) and oxalate decarboxylase (Maloney 1994). The high microbial growth of untreated samples as discovered by Koh et al. (2017) supported the great reduction of an oxalic acid level throughout storage. Although samples treated with RPL alone were reported to have low microbial growth during storage (Koh et al. 2017), it had a greater reduction of oxalic acid compared to untreated samples and samples with coating alone during storage. This was due to the light effect of RPL treatment. Oxalic acid can undergo photo-degradation when exposing to UV radiation and causes its conversion to CO_2 (Kumar et al. 2015). Similarly, the lower oxalic acid concentration in alginate + RPL samples compared to samples with coating alone could be due to the RPL effect. In the combination of alginate coating and RPL treatment, the RPL effect on oxalic acid was reduced, which resulted in the maintenance of higher oxalic acid concentration compared to samples with RPL alone during storage. At the end of storage, there was no RPL application for the samples treated with RPL alone and alginate + RPL samples leading to the higher oxalic acid concentration compared to the untreated samples and samples with coating alone, respectively.

As shown in Fig. 2g, tartaric acid concentrations were slightly increased during storage for all the fresh-cut cantaloupes. The increase of tartaric acid level was also reported in pear during storage (Chen et al. 2009). The increase of tartaric acid concentration could be contributed by its chemical properties whereby it tends to form salts that are difficult to be decomposed by any known enzymes (Selçuk and Erkan 2016). The coated samples without and with RPL showed a greater increase of tartaric acid concentrations compared to the uncoated samples during

storage, which could be contributed by the effect of the coating. The addition of calcium in the alginate coating could stabilise calcium tartrate. In addition, the high water loss in untreated samples and samples with RPL alone as determined in the previous study (Koh et al. 2017) could cause some loss of tartaric acid, which is water soluble.

Based on the findings of organic acid contents, untreated samples showed a remarkable increase of lactic acid and succinic acid contents during storage which explained the more pronounced decrease of pH and increase of titratable acidity in fresh-cut cantaloupes (Koh et al. 2017). On the other hand, the absence of extreme changes in organic acid contents of RPL-treated samples with and without coating during storage contributed to the maintenance of pH and titratable acidity (Koh et al. 2017).

Aroma profile

Table 1 displays the aroma profile of fresh-cut cantaloupes as influenced by alginate coating and RPL treatment during storage. As shown in Table 1, the major aroma compounds in fresh-cut cantaloupes were ethyl hexanoate, nonanal, (Z)-3-nonen-1-ol, (E)-2-nonenal, β -cyclocitral, geranyl acetone and β -ionone. Between these compounds, ethyl hexanoate, nonanal, (Z)-3-nonen-1-ol and (E)-2-nonenal are among the characteristic impact aroma compounds of melon (Beaulieu and Lancaster 2007; Saftner et al. 2006). These compounds were present in all samples throughout the storage. The presence of ethyl hexanoate, nonanal, (Z)-3-nonen-1-ol and (E)-2-nonenal in cantaloupes were also reported by some researchers (Saftner et al. 2006). Different compounds with different ratio are important in determining the specific characteristic aroma of fruit. In this context, the total concentration of aroma compounds is important to consider the overall aroma profile of the fruit. Refer to Table 1, all the samples had a low total concentration of aroma compounds at the beginning of storage. As the storage time increased to day 12, all samples showed enhancement of aroma compound production. The production of aroma compounds could be due to the increased metabolic activity (Beaulieu 2006). The increase of respiration in fresh-cut fruits provides more energy for glycolysis and tricarboxylic acid cycle leading to increasing of ready acetyl-CoA for the formation of amino acid precursors and thus the production of volatile compounds (Beaulieu 2006). Beaulieu (2006) also found that aromatic volatile concentrations were increased during ripening of fresh-cut cantaloupes. In this study, other characteristic impact aroma compounds of melon such as ethyl butanoate and ethyl 2-methylbutanoate were also increased in fresh-cut cantaloupes as storage time increased to day 24. When storage time further increased to day 24, the total aroma compound concentrations were decreased for untreated

samples and samples treated with RPL alone. As storage time increases, fruits senesce leading to lower available starch, sugar and substrates as well as reduced glycolysis and tricarboxylic acid cycle pathway for formation of aroma compounds (Beaulieu 2006). Although samples treated with RPL alone had lower respiration as indicated by lower CO₂ production compared to untreated samples (Koh et al. 2017), the RPL-treated samples also had a low total concentration of aroma compounds due to the loss of aroma compounds to the environment.

On day 24, the coated samples without and with RPL maintained high and similar total concentrations of aroma compounds. An edible coating is known to trap aromatic compounds in a food product. In addition, calcium is able to slow down tissue senescence in fruits (Rico et al. 2007). This is supported by the reduction in respiration rate of the coated samples as indicated by the lower CO₂ production during storage (Koh et al. 2017). The total concentrations of aroma compounds in the untreated samples and samples with RPL alone were further decreased at the end of storage. This denotes that RPL treatment did not help in maintaining the total concentration of aroma compounds in fresh-cut cantaloupes. Both coated samples without and with RPL also showed a reduction of total aroma compound concentrations on day 36 but with a greater extent was shown by the coated samples without RPL. The greater reduction of total aroma compound concentration in coated samples without RPL could be due to its higher microbial growth as reported by Koh et al. (2017), which accelerates fruit senescence compared to alginate + RPL samples. These findings suggest that the combined alginate coating and RPL was the most effective treatment in retaining higher total aroma compound concentration in fresh-cut cantaloupes during storage.

Sensory acceptance

Table 2 shows the effects of alginate coating and RPL treatment on the preference of fresh-cut cantaloupes using hedonic test. The attributes selected for sensory evaluation of fresh-cut cantaloupes, i.e. untreated and alginate coating alone (day 0), RPL alone, alginate coating alone and alginate + RPL (day 12), alginate + RPL (day 24) and alginate + RPL (day 32), were aroma, appearance, colour, firmness, juiciness and taste. All the samples showed an insignificant difference ($p > 0.05$) in terms of preference for appearance, firmness, and juiciness. Thus, it can be suggested that the presence of an alginate coating layer on the surface of coated samples did not affect the perception of panellists on the appearance of fresh-cut cantaloupes. Figure 3 demonstrates the appearances of these samples during storage. Although the texture analyser detected higher firmness value for coated samples compared to

Table 1 Effects of alginate coating and repetitive pulsed light (RPL) application on aroma profile of fresh-cut cantaloupes

Volatile compound	Sensory attributes	Relative concentration ^a							
		Day 0				Day 12			
		U ^b	R ^c	A ^d	AR ^e	U ^b	R ^c	A ^d	AR ^e
3-Methylbutanol	Burnt, cocoa, floral, malt	nd	nd	nd	nd	nd	nd	nd	nd
2-Methylpropyl acetate (isobutyl acetate)	Sweet, fruity	nd	nd	nd	nd	nd	nd	nd	nd
*Methyl 2-methylbutanoate	Fruity, sweet	nd	nd	nd	nd	nd	nd	nd	nd
Hexanal	Green, leafy	0.123	0.110	0.184	0.364	nd	0.753	0.415	0.330
*Ethyl butanoate	Fruity, sweet	0.063	nd	nd	nd	0.264	nd	nd	nd
*Ethyl 2-methylbutanoate	Green, fruity	nd	nd	nd	0.018	0.171	0.078	nd	0.024
*(E)-2-hexenal	Grassy	0.026	0.010	0.010	nd	nd	nd	0.016	nd
1-Hexanol	Herbaceous, woody	nd	nd	nd	nd	0.139	0.039	0.024	0.007
*3-Methylbutyl acetate (isoamyl acetate)	Fruity, sweet	nd	nd	0.010	nd	nd	0.005	nd	nd
Ethyl pentanoate (ethyl valerate)	Fruity, apple	nd	nd	nd	nd	nd	nd	nd	nd
Heptanal	Citrus, fat, green, nut	nd	0.008	0.019	0.045	0.015	0.067	0.031	nd
Methyl hexanoate	Pineapple, ethereal	nd	nd	0.016	nd	0.027	0.022	0.007	0.004
(E)-2-heptenal	Almond, fat, fruit	nd	nd	nd	0.037	nd	0.068	0.036	0.005
1-Octen-3-ol	Earthy	0.009	nd	0.027	0.014	0.008	0.029	0.016	0.006
2-Pentylfuran	Butter, floral, fruit, green bean	0.084	nd	0.078	nd	0.014	0.089	0.015	0.009
*Ethyl hexanoate	Fruity, apple	0.057	0.044	0.054	0.065	0.230	0.214	0.057	0.006
(E,E)-2,4-heptadienal	Fatty	0.003	0.005	0.007	0.017	0.016	0.035	0.017	0.007
*(E)-2-octenal	Dandelion, fat, fruit, grass, green, spice	0.023	0.014	0.025	0.055	0.059	0.122	0.069	0.045
Ethyl heptanoate	Wine-like, fruity	0.002	0.003	0.007	0.014	0.030	0.035	0.013	0.137
*Nonanal	Fatty, melon	0.070	0.131	0.059	0.095	0.110	0.223	0.110	0.327
Phenyl ethyl alcohol	Sweet, floral	nd	nd	nd	nd	nd	nd	0.020	nd
Methyl octanoate	Fruit, orange, wax, wine	0.061	0.017	0.056	0.018	0.020	0.040	0.019	0.079
*(Z)-3-nonen-1-ol	Melon	0.243	0.223	0.275	nd	0.013	0.031	0.389	0.060
*(E)-2-nonenal	Melon	nd	0.161	0.102	0.191	0.178	0.204	0.307	0.284
*(Z)-6-nonenol	Melon	nd	nd	nd	0.044	0.070	0.014	nd	nd
Ethyl benzoate	Floral, fruity	nd	nd	nd	nd	nd	nd	nd	0.257
Ethyl (Z)-4-octenoate	Fruity	nd	nd	nd	nd	nd	nd	0.004	nd
(E,E)-2,4-nonadienal	Green	nd	nd	nd	nd	nd	0.039	0.038	0.046
β-cyclocitral	Mint	0.159	0.109	0.118	0.080	0.257	0.247	0.116	0.195
Phenylethyl acetate (2-phenylethyl acetate)	Flower, honey, rose	nd	nd	nd	nd	nd	nd	0.015	nd
Geranyl isovalerate	Apple, fruit, rose	nd	nd	nd	nd	nd	0.027	nd	nd
(E,E)-2,4-decadienal	Coriander, deep fried, fat, oil, oxidized	nd	nd	nd	0.040	nd	nd	0.023	0.199
Ethyl decanoate	Oily, fruity	nd	nd	nd	nd	nd	nd	0.012	nd
Geranyl acetone	Fresh, rosy	0.380	0.148	0.163	0.276	0.470	0.616	0.407	0.474
β-ionone	Flower, raspberry	0.775	0.318	0.735	0.251	1.134	0.978	0.744	1.198
Ethyl dodecanoate	Sweet, floral	nd	nd	nd	nd	nd	nd	nd	nd
Total	–	2.078	1.301	1.945	1.624	3.225	3.975	2.920	3.699
Volatile compound	Sensory attributes	Relative concentration ^a							
		Day 24				Day 36			
		U ^b	R ^c	A ^d	AR ^e	U ^b	R ^c	A ^d	AR ^e
3-Methylbutanol	Burnt, cocoa, floral, malt	0.191	nd	nd	nd	nd	nd	nd	nd
2-Methylpropyl acetate (isobutyl acetate)	Sweet, fruity	0.033	nd	nd	nd	nd	nd	nd	nd
*Methyl 2-methylbutanoate	Fruity, sweet	nd	0.036	nd	nd	nd	nd	nd	nd
Hexanal	Green, leafy	nd	nd	0.745	nd	0.246	nd	nd	nd
*Ethyl butanoate	Fruity, sweet	0.210	0.228	nd	0.933	nd	0.013	0.246	0.497
*Ethyl 2-methylbutanoate	Green, fruity	0.139	0.404	0.201	0.445	0.011	0.119	0.365	0.302

Table 1 continued

Volatile compound	Sensory attributes	Relative concentration ^a							
		Day 24				Day 36			
		U ^b	R ^c	A ^d	AR ^e	U ^b	R ^c	A ^d	AR ^e
*(E)-2-hexenal	Grassy	nd	nd	nd	nd	nd	nd	nd	nd
1-Hexanol	Herbaceous, woody	0.069	0.132	0.246	0.158	0.010	0.166	0.318	0.340
*3-Methylbutyl acetate (isoamyl acetate)	Fruity, sweet	0.165	nd	nd	0.032	nd	nd	nd	nd
Ethyl pentanoate (ethyl valerate)	Fruity, apple	nd	nd	nd	0.063	nd	nd	nd	nd
Heptanal	Citrus, fat, green, nut	nd	nd	0.064	nd	0.020	nd	nd	0.029
Methyl hexanoate	Pineapple, ethereal	nd	0.014	0.015	0.015	0.006	0.008	0.020	0.019
(E)-2-heptenal	Almond, fat, fruit	nd	nd	0.029	0.053	0.025	nd	nd	nd
1-Octen-3-ol	Earthy	nd	0.004	0.036	0.030	0.009	nd	0.025	0.021
2-Pentylfuran	Butter, floral, fruit, green bean	nd	nd	0.060	0.035	0.009	nd	0.029	0.033
*Ethyl hexanoate	Fruity, apple	0.087	0.261	0.224	0.308	0.049	0.113	0.157	0.225
(E,E)-2,4-heptadienal	Fatty	0.040	0.005	0.016	0.023	0.017	nd	0.015	0.020
*(E)-2-octenal	Dandelion, fat, fruit, grass, green, spice	nd	0.016	0.079	0.056	0.037	0.016	0.039	0.078
Ethyl heptanoate	Wine-like, fruity	0.044	nd	0.065	0.064	0.010	nd	0.026	0.049
*Nonanal	Fatty, melon	0.068	0.117	0.089	0.140	0.088	0.068	0.074	0.103
Phenyl ethyl alcohol	Sweet, floral	nd	nd	nd	nd	nd	nd	nd	nd
Methyl octanoate	Fruit, orange, wax, wine	nd	0.014	0.035	0.022	0.024	0.016	0.027	0.033
*(Z)-3-nonen-1-ol	Melon	0.558	0.116	0.022	0.013	0.176	0.157	0.011	0.021
*(E)-2-nonenal	Melon	0.331	0.143	0.203	0.172	0.157	0.164	0.195	0.120
*(Z)-6-nonenol	Melon	nd	nd	nd	nd	nd	nd	nd	nd
Ethyl benzoate	Floral, fruity	nd	nd	0.288	0.229	nd	nd	0.212	0.309
Ethyl (Z)-4-octenoate	Fruity	nd	nd	nd	nd	0.003	0.007	nd	nd
(E,E)-2,4-nonadienal	Green	nd	nd	0.031	0.019	0.018	nd	nd	0.019
β-cyclocitral	Mint	0.064	0.142	0.100	0.111	0.096	0.090	0.049	0.100
Phenylethyl acetate (2-phenylethyl acetate)	Flower, honey, rose	nd	nd	nd	nd	0.004	nd	nd	nd
Geranyl isovalerate	Apple, fruit, rose	nd	nd	0.028	nd	nd	nd	nd	nd
(E,E)-2,4-decadienal	Coriander, deep fried, fat, oil, oxidized	nd	nd	0.145	0.078	nd	nd	nd	nd
Ethyl decanoate	Oily, fruity	0.148	0.042	nd	nd	0.010	0.033	nd	nd
Geranyl acetone	Fresh, rosy	0.255	0.322	0.414	0.285	0.292	0.205	0.285	0.283
β-ionone	Flower, raspberry	0.385	0.396	0.639	0.457	0.517	0.508	0.406	0.573
Ethyl dodecanoate	Sweet, floral	0.007	nd	nd	nd	0.028	0.019	nd	nd
Total	–	2.794	2.392	3.774	3.741	1.862	1.702	2.499	3.174

nd Not detected

*Characteristic impact flavour and aroma compounds of melon (*Cucumis melo*) as reported in literature (Beaulieu and Lancaster 2007; Saftner et al. 2006)

^aRelative concentration in respect to internal standard

^bU: untreated

^cR: repetitive pulsed light treatment

^dA: alginate coating

^eAR: alginate coating + repetitive pulsed light treatment

uncoated samples during storage (Koh et al. 2017), the panellists did not perceive any differences between the samples due to the greater sensitivity of instrumental measurement compared to oral perception.

In term of aroma, the fresh coated samples (day 0) had significantly lower ($p \leq 0.05$) score compared to untreated samples (day 0). The coating layer surrounding the surfaces

of fresh-cut cantaloupes could hinder the perception of aroma by the panellists. However, as the storage time increased, the development of aroma compounds resulted in insignificant difference ($p > 0.05$) of the mean aroma scores for coated samples without or with RPL in comparison to fresh samples, i.e. untreated (day 0). In term of preference for colour, all the samples treated with coating

Table 2 Effects of alginate coating and repetitive pulsed light (RPL) application on the sensory acceptability of fresh-cut cantaloupes using hedonic test

Attribute	Untreated	Alginate	RPL	Alginate	Alginate + RPL		
	Day 0	Day 0	Day 12	Day 12	Day 12	Day 24	Day 32
Aroma	6.38 ± 1.51a	5.13 ± 1.65b	6.09 ± 1.40ab	5.58 ± 1.53ab	5.73 ± 1.23ab	6.18 ± 1.80a	5.73 ± 1.94ab
Appearance	6.31 ± 1.31a	6.07 ± 1.53a	6.67 ± 1.09a	5.91 ± 1.46a	6.16 ± 1.31a	6.42 ± 1.47a	6.31 ± 1.58a
Colour	6.33 ± 1.41ab	6.22 ± 1.44ab	7.00 ± 1.00a	6.02 ± 1.45b	6.20 ± 1.25ab	6.71 ± 1.29ab	6.73 ± 1.50ab
Firmness	6.20 ± 1.63a	6.00 ± 1.82a	6.71 ± 1.25a	6.13 ± 1.83a	6.42 ± 1.82a	6.22 ± 1.41a	6.20 ± 1.82a
Juiciness	6.87 ± 1.20a	6.18 ± 1.71a	7.09 ± 1.10a	6.16 ± 1.54a	6.76 ± 1.50a	6.71 ± 1.60a	6.60 ± 1.85a
Taste	6.58 ± 1.31ab	5.73 ± 1.30b	7.09 ± 1.40a	5.71 ± 1.79b	5.67 ± 2.13b	5.80 ± 1.93b	5.73 ± 1.98b
Overall acceptability	6.56 ± 1.24ab	5.80 ± 1.24b	7.07 ± 1.10a	5.76 ± 1.68b	5.87 ± 1.84b	6.09 ± 1.77b	5.93 ± 1.88b

Different lowercase letters indicate significant differences within the same row ($p \leq 0.05$)

Fig. 3 Effects of alginate coating (AC) and repetitive pulsed light (RPL) application on appearances of fresh-cut cantaloupes

and/or RPL was an insignificant difference ($p > 0.05$) compared to the fresh samples, i.e. untreated (day 0). The coated samples without and with RPL generally scored a slightly lower mean score in taste acceptance compared to the uncoated samples. This could be due to the bitterness imparted as a result of the use of calcium chloride in the alginate coated sample (Saftner et al. 2003). However, all the treated samples were not significantly different ($p > 0.05$) compared to the fresh samples, i.e. untreated (day 0) in term of taste acceptability. This could be ascribed to the absence of extreme changes on sugar and

organic acid contents in the treated samples. Overall, all the selected treated samples (i.e. alginate coating and RPL treatment in individual or in combination) did not have a significant difference ($p > 0.05$) with the fresh untreated samples (day 0) in term of overall acceptability. Therefore, it can be proposed that the combination of alginate coating and RPL was effective to preserve the fresh-like quality of fresh-cut cantaloupes during storage as perceived by the untrained panellists.

Conclusion

Alginate coating and/or RPL treatment retained sugar contents in fresh-cut cantaloupes during storage. Alginate coating was more effective than RPL treatment on minimising organic acid changes of fresh-cut cantaloupes during storage. However, a combination of alginate coating with RPL treatment is necessary to maintain low lactic acid concentration in fresh-cut cantaloupes, which was 28.99 mg/100 g FW compared to 215.86 mg/100 g FW for untreated samples on day 36. Similarly, alginate coating showed a greater contribution in maintaining total aroma compound concentration of fresh-cut cantaloupes compared to RPL treatment. Nonetheless, the combination of these two treatments was more effective than the individual treatment in retaining total aroma compound concentration as storage time increased. The combined treatment preserved total aroma compound concentration of 3.17 for fresh-cut cantaloupes on day 36, which was 24 days longer compared to the untreated sample. Overall, the combination of alginate coating and RPL treatment was effective to maintain the fresh-like sensory quality of fresh-cut cantaloupes with minimal changes on sugar contents, organic acid contents and total aroma compound concentration up to 36 days of storage at 4 ± 1 °C.

Acknowledgements The authors are grateful to Universiti Putra Malaysia for supporting this study through Project GP-IPS/2015/9469100.

References

- Amaro AL, Fundo JF, Oliveira A, Beaulieu JC, Fernández-Trujillo JP, Almeida DPF (2013) 1-Methylcyclopropene effects on temporal changes of aroma volatiles and phytochemicals of fresh-cut cantaloupe. *J Sci Food Agric* 93(4):828–837. <https://doi.org/10.1002/jsfa.5804>
- Barry-Ryan C, O'Beirne D (1998) Quality and shelf-life of fresh cut carrot slices as affected by slicing method. *J Food Sci* 63(5):851–856. <https://doi.org/10.1111/j.1365-2621.1998.tb17913.x>
- Beaulieu JC (2006) Volatile changes in cantaloupe during growth, maturation, and in stored fresh-cuts prepared from fruit harvested at various maturities. *J Am Soc Hortic Sci* 131(1):127–139
- Beaulieu JC, Baldwin EA (2002) Flavor and aroma of fresh-cut fruits and vegetables. In: Lamikanra O (ed) *Fresh-cut fruits and vegetables: science, technology, and market*. CRC Press, Boca Raton, pp 391–425
- Beaulieu JC, Lancaster VA (2007) Correlating volatile compounds, sensory attributes, and quality parameters in stored fresh-cut cantaloupe. *J Agric Food Chem* 55(23):9503–9513. <https://doi.org/10.1021/jf8007025>
- Beaulieu JC, Ingber BF, Lea JM (2011) Physiological, volatile, and SEM surface effects resulting from cutting and dipping treatments in cantaloupe. *J Food Sci* 76(7):S415–S422. <https://doi.org/10.1111/j.1750-3841.2011.02308.x>
- Chakraborty N, Ghosh R, Ghosh S, Narula K, Tayal R, Datta A, Chakraborty S (2013) Reduction of oxalate levels in tomato fruit and consequent metabolic remodelling following overexpression of a fungal oxalate decarboxylase. *Am Soc Plant Biol* 162(1):364–378. <https://doi.org/10.1104/pp.112.209197>
- Chen J, Wang Z, Wu J, Wang Q, Hu X (2007) Chemical compositional characterization of eight pear cultivars grown in China. *Food Chem* 104(1):268–275. <https://doi.org/10.1016/j.foodchem.2006.11.038>
- Chen J, Feng Z, Wu J, Wang Z, Hu X (2009) Changes in the volatile compounds and physicochemical properties of Wujiuxiang pear fruits during storage. *Trans Chin Soc Agric Eng* 25(1):264–269. <https://doi.org/10.3969/j.issn.1002-6819.2009.05.49>
- Corbo MR, Speranza B, Campaniello D, Amato DD, Sinigaglia M (2010) Fresh-cut fruits preservation: current status and emerging technologies. In: Méndez-Vilas A (ed) *Current research, technology and education topics in applied microbiology and microbial biotechnology*. Formatex Research Center, Badajoz, pp 1143–1154
- Costantini A, García-Moruno E, Moreno-Arribas MV (2009) Biochemical transformations produced by malolactic fermentation. In: Moreno-Arribas MV, Polo MC (eds) *Wine chemistry and biochemistry*. Springer, New York, pp 27–57
- Dharmadhikari M (2016) Lactic acid bacteria and wine spoilage. <http://www.extension.iastate.edu/wine/lactic-acid-bacteria-and-wine-spoilage/>. Accessed 10 Jan 2017
- Gómez PL, Salvatori DM, García-Loredo A, Alzamora SM (2012) Pulsed light treatment of cut apple: dose effect on color, structure, and microbiological stability. *Food Bioprocess Technol* 5(6):2311–2322. <https://doi.org/10.1007/s11947-011-0598-3>
- Huis in't Veld JHJ (1996) Microbial and biochemical spoilage of foods: an overview. *Int J Food Microbiol* 33(1):1–18. [https://doi.org/10.1016/0168-1605\(96\)01139-7](https://doi.org/10.1016/0168-1605(96)01139-7)
- Jimenez-Garcia SN, Vazquez-Cruz MA, Guevara-Gonzalez RG, Torres-Pacheco I, Cruz-Hernandez A, Feregrino-Perez AA (2013) Current approaches for enhanced expression of secondary metabolites as bioactive compounds in plants for agronomic and human health purposes—a review. *Pol J Food Nutr Sci* 63(2):67–78
- Koh PC, Noranizan MA, Karim R, Hanani ZAN (2016a) Microbiological stability and quality of pulsed light treated cantaloupe (*Cucumis melo* L. *reticulatus* cv. Glamour) based on cut type and light fluence. *J Food Sci Technol* 53(4):1798–1810. <https://doi.org/10.1007/s13197-015-2139-y>
- Koh PC, Noranizan MA, Karim R, Hanani ZAN (2016b) Repetitive pulsed light treatment at certain interval on fresh-cut cantaloupe (*Cucumis melo* L. *reticulatus* cv. Glamour). *Innov Food Sci Emerg Technol* 36:92–103. <https://doi.org/10.1016/j.ifset.2016.05.015>
- Koh PC, Noranizan MA, Hanani ZAN, Karim R, Rosli SZ (2017) Application of edible coatings and repetitive pulsed light for shelf life extension of fresh-cut cantaloupe (*Cucumis melo* L. *reticulatus* cv. Glamour). *Postharvest Biol Technol* 129:64–78. <https://doi.org/10.1016/j.postharvbio.2017.03.003>
- Koh PC, Noranizan MA, Karim R, Hanani ZAN (2018) Combination of alginate coating and repetitive pulsed light for shelf life extension of fresh-cut cantaloupe (*Cucumis melo* L. *reticulatus* cv. Glamour). *J Food Process Preserv* 42(11):e13786. <https://doi.org/10.1111/jfpp.13786>
- Koyama H (1988) Purification and characterization of oxalate oxidase from *Pseudomonas* sp. OX-53. *Agric Biol Chem* 52(3):743–748. <https://doi.org/10.1080/00021369.1988.10868721>
- Kumar A, Hitkari G, Gautam M, Pandey G (2015) Synthesis of Ni-TiO₂ nanocomposites and photocatalytic degradation of oxalic acid in waste water. *Int J Innov Res Sci Eng Technol*

- 4(12):12721–12731. <https://doi.org/10.15680/IJIRSET.2015.0412097>
- Lamikanra O, Chen JC, Banks D, Hunter PA (2000) Biochemical and microbial changes during the storage of minimally processed cantaloupe. *J Agric Food Chem* 48(12):5955–5961
- Lange DL, Kader AA (1997) Effects of elevated carbon dioxide on key mitochondrial respiratory enzymes in “Hass” avocado fruit and fruit disks. *J Am Soc Hortic Sci* 122(2):238–244
- Lapčík L Jr, Omelka L, Kuběna K, Galatík A, Kellö V (1990) Photodegradation of hyaluronic acid and of the vitreous body. *Gen Physiol Biophys* 9(4):419–429
- Lawless HT, Claassen MR (1993) The central dogma in sensory evaluation. *Food Technol* 47(6):139–146
- Maloney PC (1994) Bacterial transporters. *Curr Opin Cell Biol* 6(4):571–582. [https://doi.org/10.1016/0955-0674\(94\)90079-5](https://doi.org/10.1016/0955-0674(94)90079-5)
- Olivas GI, Barbosa-Cánovas GV (2005) Edible coatings for fresh-cut fruits. *Crit Rev Food Sci Nutr* 45(7–8):657–670. <https://doi.org/10.1080/10408690490911837>
- Pua E-C, Chandramouli S, Han P, Liu P (2003) Malate synthase gene expression during fruit ripening of Cavendish banana (*Musa acuminata* cv. Williams). *J Exp Bot* 54(381):309–316
- Quici N, Morgada ME, Gettar RT, Bolte M, Litter MI (2007) Photocatalytic degradation of citric acid under different conditions: TiO₂ heterogeneous photocatalysis against homogeneous photolytic processes promoted by Fe(III) and H₂O₂. *Appl Catal B-Environ* 71(3):117–124. <https://doi.org/10.1016/j.apcatb.2006.09.001>
- Rico D, Martín-Diana AB, Barat JM, Barry-Ryan C (2007) Extending and measuring the quality of fresh-cut fruit and vegetables: a review. *Trends Food Sci Technol* 18(7):373–386. <https://doi.org/10.1016/j.tifs.2007.03.011>
- Saftner RA, Bai J, Abbott JA, Lee YS (2003) Sanitary dips with calcium propionate, calcium chloride, or a calcium amino acid chelate maintain quality and shelf stability of fresh-cut honeydew chunks. *Postharvest Biol Technol* 29(3):257–269. [https://doi.org/10.1016/S0925-5214\(03\)00041-3](https://doi.org/10.1016/S0925-5214(03)00041-3)
- Saftner R, Abbott JA, Lester G, Vinyard B (2006) Sensory and analytical comparison of orange-fleshed honeydew to cantaloupe and green-fleshed honeydew for fresh-cut chunks. *Postharvest Biol Technol* 42(2):150–160. <https://doi.org/10.1016/j.postharvbio.2006.02.011>
- Sasson A, Monselise SP (1976) Malonic acid, a proposed indicator of orange fruit senescence. *Experientia* 32(9):1116–1117. <https://doi.org/10.1007/BF01927576>
- Selçuk N, Erkan M (2016) Impact of passive modified atmosphere packaging on physicochemical properties, bioactive compounds, and quality attributes of sweet pomegranates. *Turk J Agric For* 40(4):475–488. <https://doi.org/10.3906/tar-1509-57>
- Vaisey EB, Cheldelin VH, Newburgh RW (1961) Oxalate oxidation by an obligately parasitic fungus *Tilletia contraversa*. *Arch Biochem Biophys* 95(1):66–69
- Wang Y, Wang J, Cheng W, Zhao Z, Cao J (2014) HPLC method for the simultaneous quantification of the major organic acids in Angeleno plum fruit. In: IOP conference series: materials science and engineering, vol 62, no 1, p 12035. <https://doi.org/10.1088/1757-899x/62/1/012035>
- Wankier BN, Salunkhe DK, Campbell WF (1970) Effects of controlled atmosphere storage on biochemical changes in apricot and peach fruit. *J Am Soc Hortic Sci* 95:604–609

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.