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Exploring the impacts of combined treatments of edible coatings and calcium compounds on the strawberry storability

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ABSTRACT

Purpose: Unfortunately, the quick quality loss in strawberry fruit decreases its marketability. The purpose of this study is to investigate the effects of pre- and post-harvest treatments on the enhancement of fruit storability. **Research method:** Pre-harvest treatment of calcium chloride (Ca) 2% and nano calcium (nCa) 0.01%, and post-harvest treatments of Chitosan (CH) 1% and Carboxymethyl cellulose (CMC) 1% on strawberry storability were investigated for 15 days and under 95% relative humidity at 1 °C. Traits of fruits such as weight loss, firmness, decay amount, total soluble solid, anthocyanin concentration, total phenol, ascorbic acid and antioxidant activity were measured. **Findings:** 15 days after treatment, treated samples showed decreased weight loss (WL), which was 18% for the untreated sample and 12% for treated samples. A delayed decline in firmness was observed in treated samples and nCa+CH treatment had the highest firmness 15 days after cold storage. Fruit decay was the most in the control sample and the least in Ca+CH treatments. Total soluble solids and anthocyanin increased in control, but remained stable in treated samples. Total phenol (TP) amount was the least in control. CH treated samples had the highest level of TP. Ca+CMC treated samples gradually showed higher level of vitamin C (AA) than other treatments. **Research limitations:** There was not limitations. **Originality/Value:** These results proved that using edible coatings of CMC and CH, and pre-harvest treatment with Ca and nCa increase the storability of strawberry, and can be used commercially to increase storage time.

Keywords:
Calcium chloride, Carboxymethyl cellulose, Chitosan, Nano calcium

INTRODUCTION

Strawberry (*Fragaria* × *ananassa*) is a flowering fruit (angiosperm) belongs to the Rose family (Rosaceae). This genus has 20 other species (Chandler et al., 2012). Strawberry is a rich source of beneficial compounds like vitamin C, Vitamin A, β-Carotene and phenolic compounds such as anthocyanin and antioxidants (Sogvar et al., 2016a, 2016b). However, the storage life of strawberry is short, and fruit softness, physiological disorders and pathogen infections quickly decrease its quality (Vu et al., 2011). Strawberry is infected by pathogens during storage. *Botrytis cinerea, Rhizopus sp*. and *Cladosporium* are major causes of fungi infection of this fruit (Maas, 2004; Sommer et al., 1992). Up to now, several methods have been investigated to increase the shelf life of strawberry: using low storage temperature, chemical treatments, modified atmosphere, moisture and ethylene absorbent, radiation and using edible coatings (Bahmani et al., 2022). Strawberry is commercially treated by fungicides of thiabendazole and azoxystrobin to control post-harvest decay, notwithstanding the harmful effects of these compounds on humans and the environment (Hosseini et al., 2020). Consequently, pre and post-harvest treatments using natural antimicrobial preservatives appears essential to control physiological processes and microbial infection (Lin et al., 2007). However, pre-harvest treatments have more important effects than post-harvest treatments because preharvest treatments can improve fruit quality, but postharvest treatments can only maintain fruit quality (Arah et al., 2015). Edible coatings can be served as a protective layer for declining respiration, transpiration, microbial growth and changes in fruit color (Embuscado et al., 2009). As a result, they can increase the storability of fruits and vegetables by decreasing mechanical damages at harvest and postharvest processes to improve the fruit marketability (Seyed et al., 2021).

Cellulose-derived edible coatings have been widely used to postpone maturity and maintain fresh crops such as pear (Zhou et al., 2008) cherry (Yaman et al., 2002) and other fruits. CH based edible coatings have recently attracted considerable attention because of their increasing fruits and vegetables shelf life, and their characteristics such as nontoxicity, biodegradability and eco-friendly nature (Bagheri et al., 2021). CH is a natural liner heteropolysaccharide with more than one repeating unit (Felicia et al., 2022), and with β-(1→4)-linked D-glucosamine and N-acetyl-D-glucosamine bonds that have antimicrobial (Aghababaei et al., 2022) and antifungal (Vitti et al., 2024) properties. CH attaches to the cellular membrane, and penetrates into the cell combining with RNA, DNA and other intracellular macromolecules; consequently, interferes with microbial metabolism such as mRNA synthesis (Wu et al., 2022). In addition, using its reactive groups, CH limits microorganism growth (Felicia et al., 2022). Using this compound causes the activation of crucial enzymes of the defense mechanisms of fruit such as Phenylalanine ammonia-lyase (Fajardo et al., 1995). By forming a layer around the fruit, CH decreases the respiration rate by declining the permeability of oxygen and carbon dioxide. Also, CH inhibits harmful microbial growth in fruit and controls the rate of fruit decay. Scientists believe that CH can affect the quality of fruits, vegetables and sliced fruit (Jianglian et al., 2013).

Another noted edible coating is CMC. CMC is an anionic long-chain polymer derived from cellulose (Ruan et al., 2019). This linear polymer has a heavy molecular weight and is water-soluble; its pure compound is whiteish cream and a free-flowing powder. CMC-derived edible coatings are non-toxic, biodegradable, nonallergic, tasteless, and odorless (Koushesh Saba et al., 2016; Wu et al., 2022). Interestingly, CMC has antisenescence and antifungal properties that postpone fruit maturation, maintain fruit firmness and decreases fermentation in fruit tissues (Tesfay et al., 2017). This compound limits gas exchange between fruit and the environment; therefore, it is necessary for the regulation of oxygen and water in the fruit. In addition, it is commercially available and cheap (Panahirad et al., 2019). Up to now, CMC has served in research focusing on fruits such as plum, peach, papaya, pear, mandarin, tomato, avocado, grape, cucumber, and sweet cherry (Panahirad et al., 2021).

Other important compounds that were used in this study were calcium and nano calcium. Calcium is an essential element in the fruit cell wall and organelle biosynthesis. Ca also forms pectin in plants, and calcium bridges by interaction with carboxyl groups, and finally maintaining fruit structure (Eroğul et al., 2024). It also decreases physiological failures and fruit cell wall decomposition (Liu et al., 2017). Ca decreases metabolism and respiration rate in fruit which further maintains fruit. Up to now, this element has served to maintain fruits and vegetables (Gao et al., 2019). An increase in Calcium content of the fruit brings about post-harvest tolerance to diseases such as grey mould (Dunn et al., 2004). Nano calcium is a commercialized form of the calcium, which has not widely been used to investigate its impacts on fruit storage life.

The goal of this study is to investigate coincident effects of pre-harvest treatments of Ca and nCa and post-harvest treatments of CH and CMC on the storage life of strawberry fruit (*Fragaria* X *ananassa* Duch.) at 95% humidity and 1 ˚C.

MATERIALS AND METHODS

Plant material

In 2022, one-year-old strawberry shrubs from a farm with furrow irrigation were chosen, and were irrigated two times a week; the ridges were 70 cm wide and 15 m long, and the distance between shrubs was 20 cm. Four days before harvest, fruits were given pre-harvest treatments in a commercial orchard in Shian village in Eastern Zhavarud rural district, in the Central District of Sanandaj County, Kurdistan Province, Iran (35°10'15.8"N 46°45'59.0"E, 2400 m above sea level, and with 244.4 mm annual precipitation). When 75 % of the fruit surface was red, strawberry (*Fragaria ananassa* CV. 'Parous') fruits were harvested. The fruit was given post-harvest treatments in the horticultural sciences laboratory at the University of Kurdistan, Sanandaj, Iran.

Treatments

In this study, fruits were given three pre-harvest treatments, which were calcium chloride 2% (w/v), nano calcium 0.01% (w/v), and distilled water as a control sample. 3 blocks were created, which were 47 m long, and every block was divided into three 15 m long areas, in every area, one of the treatments was given 3 days before harvesting. Similarly, three post-harvest treatments were given to the fruit, which was chitosan 1% (CH), carboxymethyl cellulose 1% (CMC), and distilled water. Finally, 5 treatments were provided including: control, calcium chloride 2% + carboxymethyl cellulose 1% (Ca+CMC), calcium chloride 2% + chitosan 1% (Ca+CH), nano calcium 0.01% + carboxymethyl cellulose 1% (nCa+CMC), and nano calcium 0.01% + chitosan 1% (nCa+CH). The experiment was arranged in a randomized complete block design (RCBD) at 95% humidity and 1 ˚C with 5 treatments and three replications and at least 21 fruits for each treatment.

Weight loss (WL)

All fruits were weighed on the day of harvesting (W1) and at 0,1,3,6,9,12 and 15 days after storage (W2) using a digital balance (A&D FX2000i, Japan), and WL was calculated using the following equation (1) (Sogvar et al., 2016a):

$$WL = (W1 - W2) / W1 \times 100 \qquad (1)$$

Firmness

To measure the fruit firmness, five fruits of each replicate were used. The firmness of two opposite sides of fruits was evaluated by a texture analyzer machine (Santam, STM-1, Iran) at a constant speed of 20 mm/min. Eventually, average firmness replicates were reported as newton (N) (Sogvar et al., 2016a).

Fruit decay and total soluble solids (TSS)

Fruit decay was evaluated by a numerical scoring index (Lin et al., 2013). The 0-4 scale was served to define decay rate: 0=none, 1=slight (about 5 % decay), 2=moderate (5-20 % decay), 3=moderate severe (20-50 % decay), and 4=extreme (> 50 % decay). Finally, the decay rate was calculated by the following equation (2):

$$\text{Decay} = ((\%\text{ fruits with minimal decay} \times 1) + (\%\text{ fruits with mild decay} \times 2) + (\%\text{ fruits with mildly severe decay} \times 3) + (\%\text{ fruits with maximal decay} \times 4))/5 \quad (2)$$

Fruit juice was served to analyze TSS by a digital refractometer (Brix 0–32 %, Atago, Japan).

Total anthocyanin concentration (TAC)

Fruit juice was extracted to evaluate TAC by the pH differential method (Cheng et al., 1991) with two specific buffers (pH=1: 15.21 mL hydrochloric acid 0.2 N and 4.16 mL potassium chloride 0.2 N, and pH=4.5: 21.12 mL hydrochloric acid 1 N and 48.96 mL sodium acetate 1 M). 0.5 g of fruit was homogenized and added to each buffer, centrifuged and the absorbance of samples was measured by spectrophotometer (UV-2100, New Jersey) at 510 and 700 nm in implied buffers. Then, TAC was expressed as mg/kg of pelargonidin-3-glucoside using the following equation (3):

$$A = \text{pH } 1.0\ (A_{510\text{ nm}} - A_{700\text{ nm}}) - \text{pH } 4.5\ (A_{510\text{ nm}} - A_{700\text{ nm}})$$

$$\text{TAC (mg/Kg)} = (A/22400a)\ (10^{3})\ (433.2b) \quad (3)$$

a= absorbance of pelargonidin-3-glucoside
b= molecular weight of pelargonidin-3-glucoside

Ascorbic acid (AA) measurement

About 2 mL infiltrated fruit extract was mixed with 2 mL stabilizing trichloroacetic acid (0.5M), titrated with 2,6-dichlorophenolindophenol (DCPIP) and the AA amount was expressed as mg/100 g fresh weight (AC, 1990).

Determination of total phenol (TP) concentration

0.25 g of fruit was homogenized and added to methanol-distilled water-HCl 80-19-1 % (v/v) solution and centrifuged. Folin-Ciocalteu reagent was used to evaluate TP amount, and absorbance was measured at 750 nm (Singleton et al., 1999).

Antioxidant capacity (AC)

For evaluating AC, the radical scavenging method of 2,2-diphenyl-1-picryl-hydrazyl (DPPH) was served (Sanchez-Moreno), and absorbance (at 515 nm) of the samples were obtained by Unico UV- 2100, USA spectrophotometer. According to the below equation, the percentage of inhibition of DPPH radical was stated as result.

$$AC = (A\ DPPH - A\ sample / A\ DPPH) \times 100 \qquad (4)$$

Statistical analysis

Data were analyzed by SAS 9.4 software (SAS Institute Inc., Cary USA) by the ANOVA method. Storage period (days) and treatments were variables of the investigation. Mean values were evaluated and described as mean ± standard error (n = 3). To investigate treatments, the least significant difference (LSD) test at P value 0.01 was applied.

RESULTS AND DISCUSSION

Weight loss (WL)

The most WL was for untreated samples 15 days after storage which was 18.64% g fresh weight, but there were no significant differences among treated samples. Nonetheless, the impact of CH+nCa on decreasing weight loss was more than other treatments (Fig. 1A). The WL of fruit during storage is due to losing water because the fruit on the harvesting day contains so much water which evaporates during storage (Vasey, 2006). Edible coatings form layers around the fruit that inhibit evaporating water from the fruit surface; therefore, limiting weight loss in fruit tissues (Rikhotso et al., 2019). CH acts as a semipermeable layer creating an appropriate atmosphere around the fruit and reducing WL (Pizato et al., 2022). According to a study, the positive impacts of CH+Ca were greater than the effects of CH or Ca alone (Chong et al., 2015). Also, the effects of nCa on declining weight loss were more than Ca (Ranjbar et al., 2020) which was in correspondence with this study, and it seems that nCa is more effective than Ca. In the present study, the impact of CH on maintaining fruit weight was more than CMC, this result is in contrast with the (Rikhotso et al., 2019) study. Studies have shown that Ca acts as a secondary messenger in cell signaling, and increases cell division; consequently, decreasing fruit WL (Saure, 2005). According to a study (Hussain et al., 2012), nCa was more effective than Ca in maintaining fruit weight, which was reportedly due to more absorption of nCa by the fruit than that of Ca. In contrast, in the present study, the effects of Ca on declining WL were more than that of nCa that is maybe due to the low release of Ca^{2+} ions by nano calcium in comparison to calcium chloride that brings about higher and quick effect of calcium chloride (Gupta et al., 2025; Haydar et al., 2024).

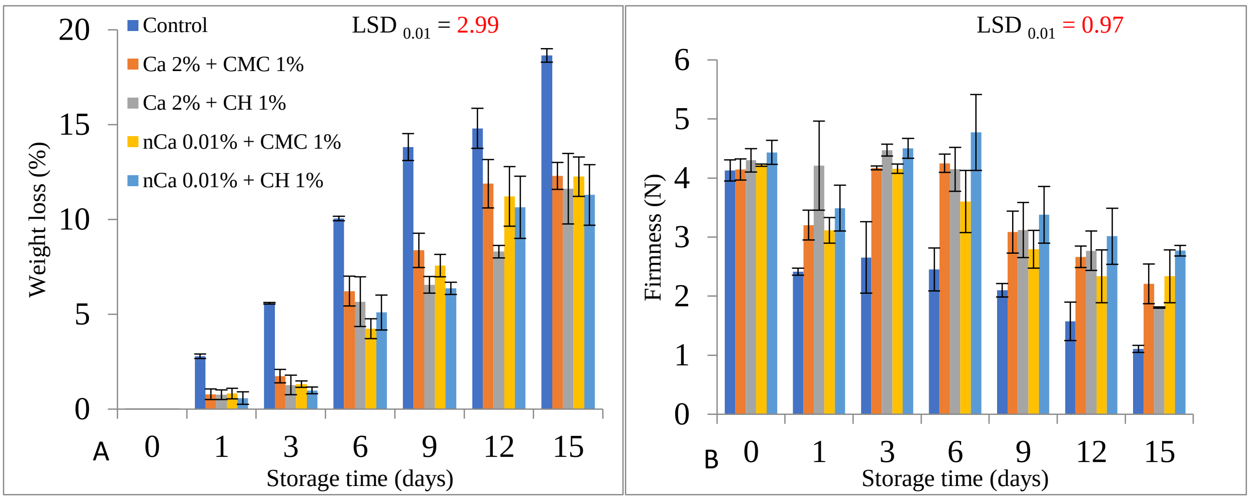

Fig. 1. Weight loss (A) and firmness (B) in strawberry fruit untreated, treated with 2 % Ca+ 1 % CMC, 2 % Ca+ 1 % CH, 0.01 % nCa+1 % CMC and 0.01 % nCa+1 % CH. Fruit stored at 4 ± 1 °C up to 15 days. Data represent the means ± SE, n = 3.

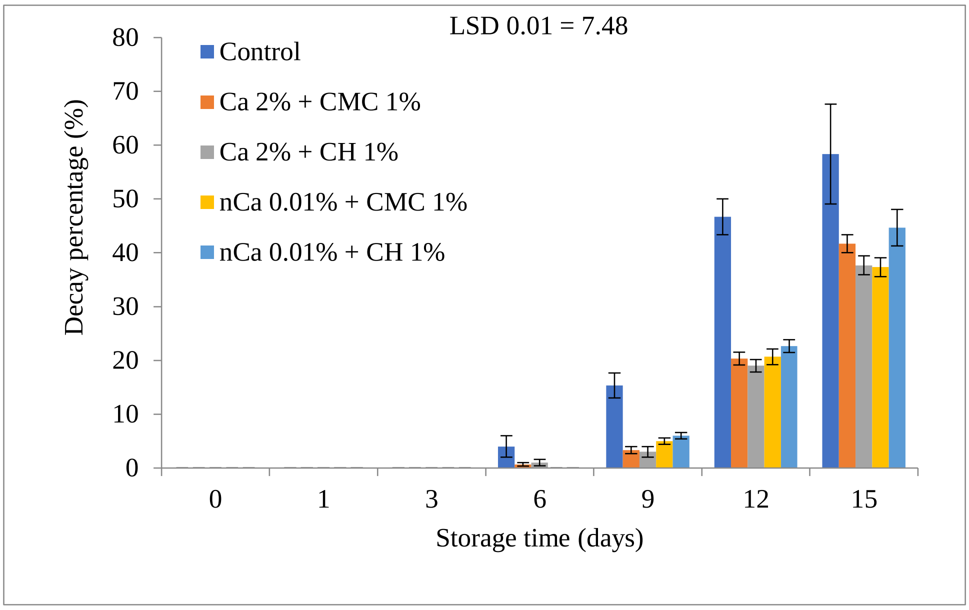

Fig. 2. Decay changes in strawberry fruit untreated, treated with 2 % Ca+ 1 % CMC, 2 % Ca+ 1 % CH, 0.01 % nCa+1 % CMC and 0.01 % nCa+1 % CH. Fruit stored at 4 ± 1 °C up to 15 days. Data represent the means ± SE, n = 3.

Firmness

Firmness initially increased and subsequently decreased during cold storage. The highest amount of firmness except for one of the days was observed in nCa+CH treatment which was 4.43 N on the first day and then increased to 4.77 N on the sixth day after storage, then decreased to 2.77 on the 15th day. The least firmness was observed in the control sample 15 days after treatment which was 1.1 N (Fig. 1.B). According to a study, the impact of CH 2% on firmness was more than CH 2% + Ca 1% (Silva et al., 2015). In another study, the impact of CH+Ca on the firmness of strawberry tissues was more than CH (Ribeiro et al., 2007). A decline in the firmness of strawberry is due to loss of cell wall firmness that is improved by several enzymes such as pectin methylesterase, cellulase, and polygalacturonase, and CH decreases their activity. CH attaches to the pectin of the cell wall, and forms complexes that inhibit the attachment of pectinolytic enzymes such as polygalacturonase to pectin; therefore, maintains pectin in the fruit cell wall (Saleem et al., 2021). CMC by its chemical structure maintains fruit firmness. It forms hydrogen bonds in the surface and inner tissues of the fruit, and maintains fruit firmness (Arnon et al., 2015). CH decreases oxygen amount in the fruit, thus decreasing the activity of metabolic processes, and maintaining fruit firmness (Jiang et al., 2020). Ca brings about the firmness of the fruit cell wall and middle lamella structures; in other words, during fruit maturation pectin methyl-esterase enzyme produces more pectin carboxyl group, and Ca increases cell wall firmness by attaching to these groups (Çezik et al., 2024; Lara et al., 2004).

Fruit decay

Colour is one of the essential determinants of the consumer acceptance, which indicates fruit freshness. The rate of deterioration of fruit shows infection, and the presence of insects in the region (Chen et al., 2011). In this study, fruit decay increased during storage time, and the highest decay amount was observed in the untreated samples which were 58.33%. Moreover, the Ca+CH treatment showed the least decay (Fig. 2). Fruit decay is often created by fungi, but edible coatings, especially nano coatings, decrease water and oxygen supply, thus decreasing humidity around the fruit, and limiting fungi growth (Yang et al., 2010). The antibacterial properties of CH decreases bacterial growth and reduces fruit decay (Tharanathan et al., 2003). Edible coatings and calcium chloride inhibit the growth of mesophilic bacteria; therefore, decreasing fruit decay (Alharaty et al., 2020). With its antifungal properties, CMC inhibits fungal growth and decreases fruit decay (Li et al., 2023; Panahirad et al., 2019). Studies have shown that different untreated fruits such as loquat, grape, kiwi, and peach have been infected with fungi (Du et al., 1997; Romanazzi et al., 2002). In addition, some amount of fruit decay is due to the browning and yellowing of fruits, which is due to the oxidation of phenolic compounds by oxidase enzymes, and as a result of oxidase activity, melanin is produced and changes fruit color. Ca inhibits the oxidation of phenolic compounds by phenol oxidase which limits melanin production, and helps maintain the fruit color (Ranjbar et al., 2020).

Total soluble solids (TSS)

TSS increased in the untreated sample, and on the first and fifteenth days was 6.5 and 7.9, respectively. But in treated samples, TSS increased at first and then decreased; it was 6.2 for all treatments on the harvesting day, then reached 7.48, 7.11, and 7.9 on the sixth day for Ca+CMC, nCa+CMC, and nCa+CH, and decreased to 7.01, 7.2 and 6.6 at the fifteenth day, respectively (Fig. 3). In a study, in the first two days, TSS increased and then decreased (Li et al., 2021). In mature fruit, carbohydrates such as glucose, fructose, sucrose, and small proportion of soluble proteins form TSS amount. Generally, TSS affects the sweetness of the fruit (Hadiwijaya et al., 2020). During storage time and maturation, polyuronides and hemicelluloses of the cell wall gradually solve and TSS decreases (Tanada-Palmu et al., 2005). Furthermore, water loss leads to an increase in TSS. Increment in TSS is a sign of fruit maturation. In addition, during storage, organic matters break down into sugars, and sugars involve in respiration cycle, further increasing TSS amount (Pizato et al., 2022). Studies have shown that the use of CMC edible coating (Kumar et al., 2018), and the addition of calcium chloride reduce TSS amount (Koushesh Saba et al., 2016). Ca and nCa reduce respiration, metabolism, and monosaccharide and polysaccharide hydrolysis, postpone fruit maturation, and decrease TSS amount (Amini et al., 2016; Ranjbar et al., 2018). Edible coatings of CMC and CH limit water loss in fruit, and inhibit TSS amount in fruit (Sogvar et al., 2016b). CH decreases respiration and catabolic processes, and postpones the increment of TSS amount (Kumar et al., 2017). Studies have shown that CH impacts on delaying respiration is more than that of CMC (Shahbazi, 2018). Lots of factors control TSS amount in harvested fruit. In this study, the level of TSS increased in untreated samples that maybe were due to water loss, but from the day 9th edible coatings showed their effect on limiting water loss.

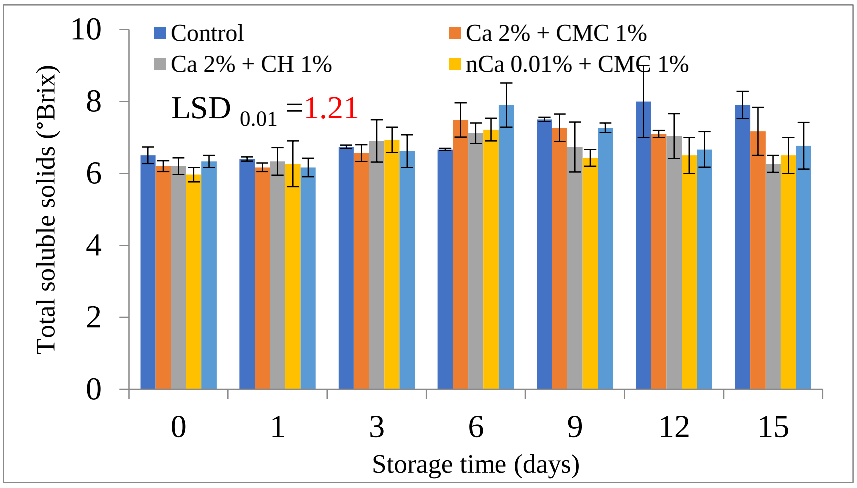

Fig. 3. Total solids soluble (TSS (°Brix)) in strawberry fruit untreated, treated with 2 % Ca+ 1 % CMC, 2 % Ca+ 1 % CH, 0.01 % nCa+1 % CMC and 0.01 % nCa+1 % CH. Fruit stored at 4 ± 1 °C up to 15. days. Data represent the means ± SE, n = 3.

Total anthocyanin concentration (TAC)

TAC changes during storage were not significant. TAC amounts in untreated samples increased during the time, and were 0.12 g/kg on the harvesting day and increased to 0.19 g/kg 15 days after harvest (Fig. 4A). According to previous studies, TAC biosynthesis pathway continues after harvesting, and anthocyanins are synthesized in the anthocyanin and flavonoid pathways, resulting in an increased amount of anthocyanin. As a result, TAC amounts in mature fruit are higher (Cordenunsi et al., 2005). On the other hand, anthocyanin increase is possible during fruit storage because of further water loss, physiological stress, higher senescence, and cell membrane degradation. Nevertheless, in the present study, anthocyanin amounts remained stable meaning that using edible coating and treatments limits either increment or decline in anthocyanin amounts (Nguyen et al., 2020). In a study, the amount of TAC in Chitosan-treated strawberry at first increased, and then decreased (Eshghi et al., 2014). Anthocyanin pigments create red and blue colours in crops, and every change in their amounts is due to the oxidation of phenolic compounds by POD and PPO enzymes, and continued of biosynthesis during storage (Li et al., 2021). Studies have shown that Ca and nCa reduce anthocyanin amounts (Ranjbar et al., 2020). Ca reduces ethylene production and cellular transpiration in fruit; consequently, postpones fruit maturation, and senescence. In other words, Ca decreases anthocyanin amount, so inhibits color changes related to maturation (Cheour et al., 1991). Similarly, CMC and CH suppress cellular respiration and retard TAC synthesis, thus postpone fruit maturation. The results of the present study are in correspondence with (Kumar et al., 2017; Liu et al., 2014) studies, in another study (Amiri et al., 2022) TAC amount remained stable in uncoated samples, but increased in coated samples.

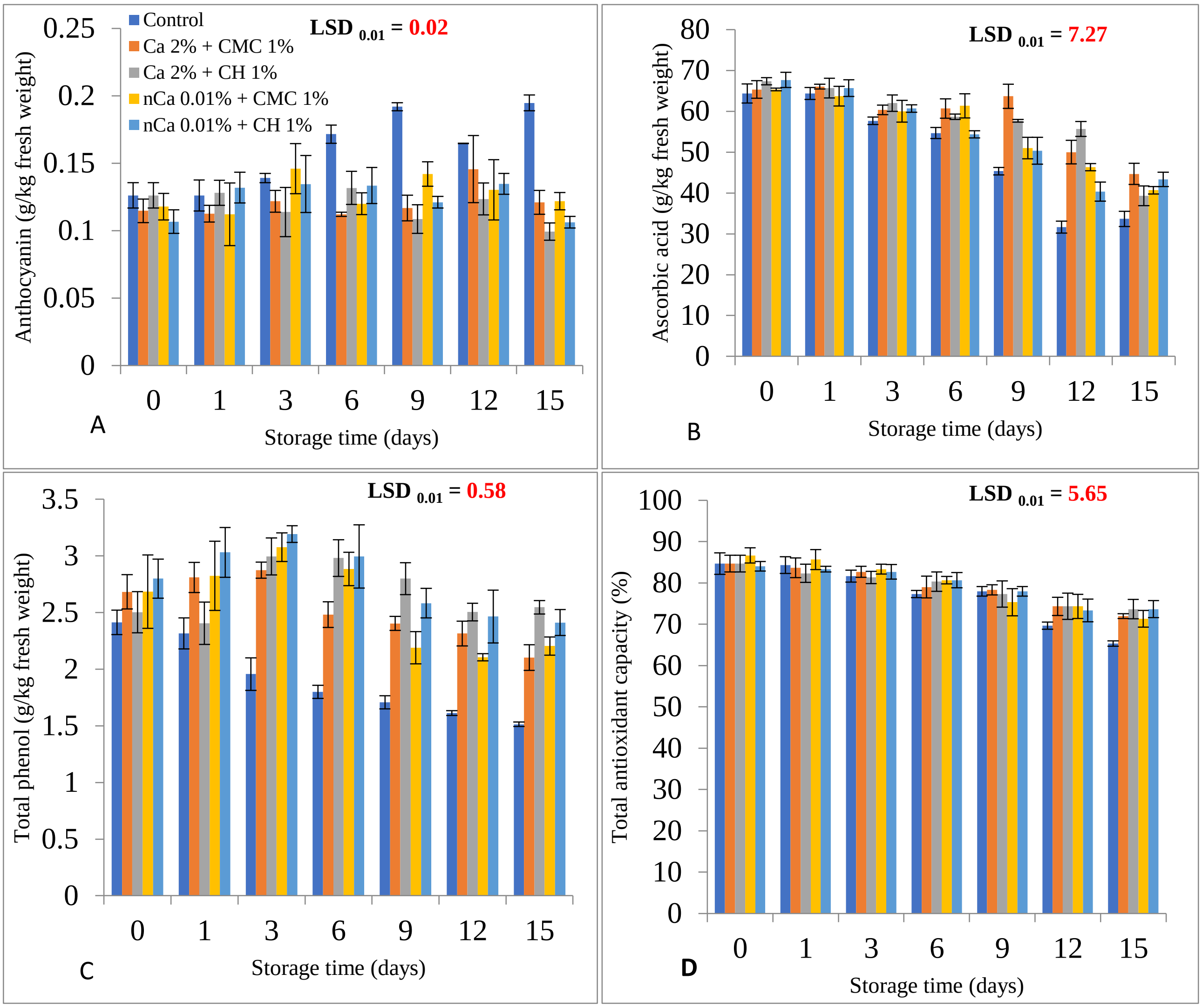

Fig. 4. Total anthocyanin content (A), ascorbic acid (B), total phenol (C) and antioxidant capacity (D) in strawberry fruit untreated, treated with 2 % Ca+ 1 % CMC, 2 % Ca+ 1 % CH, 0.01 % nCa+1 % CMC and 0.01 % nCa+1 % CH. Fruit stored at 4 ± 1 °C up to 15 days. Data represent the means ± SE, n = 3.

Ascorbic acid (AA)

In this study, AA amount decreased during storage, and its amount was 64.33 g/kg on the harvesting day and reached 33.66 g/kg 15 days after storage. But by utilizing edible coatings and the addition of Ca or nCa the decline in AA became less Fig. 4B. During storage, the amount of AA increases given that in the presence of O2 autoxidation of AA will occur, therefore its amount increases (Sayyari et al., 2022). This result is in correspondence with several other studies (Sayyari et al., 2022; Zhang et al., 2015). AA is one of the nutritional elements in fruits and vegetables, and one of the most important fruit antioxidants which neutralize reactive oxygen species and free radicals during fruit storage, and its amount decreases during storage (Ahmadi Soleimanie et al., 2020; Seyed et al., 2021). Water loss increases oxidation activity in fruit, which decreases AA amount (Nunes et al., 1995). However, the use of edible coatings and Ca retarded AA degradation (Koushesh Saba et al., 2016). CMC and CH decrease AA degradation by reducing oxygen and enzymatic activity in fruit (Freire et al., 2005). Both edible coatings of CH and CMC maintain AA amounts in fruit by limiting gas exchange. In other words, due to low permeability to O2, CH and CMC decrease the activity of AA oxidation enzymes and maintain AA content (Li et al., 2021;

Tokatlı et al., 2021). Studies have shown that using Ca increases AA amount in apple. Limiting oxygen exchange in fruit delays oxidation processes and decreases AA degradation (Poovaiah, 1986), also Ca prevents loss of antioxidants such as ascorbic acid in fruits (Amiri et al., 2022). Recent studies have shown that AA amount decreased in both treated and untreated samples while CMC+Ca treated apples showed less decline in AA, and the most decline was observed in untreated samples (Koushesh Saba et al., 2016).

Total phenol (TP) and antioxidant capacity (AC)

The highest TP was observed in the nCa+CH treatment, which was 3.07 g/kg on the third day of storage. TP amount continuously decreased in untreated samples while in treated samples its amount increased by the first 3 days of storage, and then decreased. This result is flatly in contrast to the study by (Popescu et al., 2022), in which the TP amount of CH-based treatments first decreased and then increased. In the present study, the TP amount in treated samples was greatly more than in untreated samples. Its amount in CH treatments was more than in CMC treatments (Fig. 4C). Phenol has a crucial effect on taste, color, acidity, bitterness, and astringency. Also, absorbing reactive oxygen species during maturation has an essential role as an antioxidant (Swallah et al., 2020). After harvest, TP decreases due to oxidation reactions (Ali et al., 2021), and cellular structure destruction (Bahmani et al., 2022). Edible coatings create a protective layer on the surface of the fruit that decrease oxygen, and increase carbon dioxide around the fruit; consequently, postponing fruit maturation and lowering fruit aging. In addition, a decline in oxygen amount around the fruit decreases the availability of polyphenol oxidase, so decreases the oxidation rate (Jiang et al., 2001), and retards TP decline. Using Ca and nCa increase cell wall polysaccharides, thus increasing cell wall firmness in fruit, which decrease consumption and oxidation of phenolic compounds by the cell wall. Moreover, Ca postpones aging in fruit, causing a decline in TP consumption by the cell wall. Furthermore, Ca indirectly decreases phenol oxidase activity (Ranjbar et al., 2018; Ranjbar et al., 2020). Also, it has been reported that in CH-treated fruit phenylalanine ammonia-lyase has more activity (Romanazzi et al., 2002). During storage, AC decreased in untreated samples, and 84.66% at the harvesting day to 65.33% 15 days after storage while in treated samples it decreased from about 85% at the harvesting day to about 72% 15 days after storage; nevertheless, there was no significant difference between treated samples (Fig. 4D). Studies have shown that berries are rich sources of natural antioxidants (Wang et al., 1996). Free radicals and reactive oxygen species increase in fruit during storage and maturation (Tian et al., 2013), which increase senescence, cell membrane damage, and fruit tissue decay. Antioxidant compounds neutralize free radicals and free oxygen species, as a result, their amount decreases during storage and maturation (Spinardi, 2004). Ca treatment maintains antioxidants, and retards antioxidant decline (Pareek, 2017). Recent studies on strawberry have shown that the addition of 3 or 4% of calcium chloride to nano chitosan increases antioxidant maintenance in strawberry (Nguyen et al., 2020). It has been shown that nCa is more effective than Ca in maintaining antioxidants (Ranjbar et al., 2018). CMC and CH protect the antioxidant capacity of fruit (Amiri et al., 2021; Kumar et al., 2017). They decrease membrane permeability and subsequently decrease gas exchange, which decrease oxidation and increase antioxidant protection. Furthermore, CMC itself inhibits antioxidant degradation enzymes, and also, degrades H_2O_2 and reduces the production of H_2O_2 and O_2 (Amiri et al., 2021). On the other hand, CH has a great affinity to bond with metals because of its free amino groups, as a result, it has antioxidant activity (Tokatlı et al., 2021).

CONCLUSION

This study showed that the application of pre-harvest treatments of Ca or nCa and post-harvest treatments of CH or CMC retarded fruit WL, limited decline in fruit firmness, decreased fruit decay, inhibited increment of TSS, limited decline in vitamin C, TP, and AC. According to this study, these treatments increase the storage life of strawberry. But there was no significant difference among treated samples. Nonetheless, the impacts of CH were more than CMC in increasing fruit storability, but between the Ca and nCa treated samples; Ca was more effective for some traits, while nCa was more effective for others. For example, in the percentage of fruit waste firmness, the Ca+CH treatment was more effective, whereas in WL and TP, nCa was more effective than Ca. Finally, the obtained results indicate that the impact of CH on increasing fruit storability is greater than that of CMC.

Conflict of interest

The authors declare that they have no competing interests.

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REFERENCES

AC, A. (1990). Vitamin C (ascorbic acid) in vitamin preparations and juices. *Official methods of analysis, 15th edn. AOAC, Arlington*.

Aghababaei, L., Hasani, M., Shotorbani, P. M., Basti, A. A., & Hamedi, H. (2022). Antioxidant and antimicrobial characteristics of chitosan and galbanum gum composite coating incorporated with cumin essential oil on the shelf life of chicken fillets. *Journal of Food Measurement and Characterization*, 1–14. https://doi.org/10.1007/s11694-022-01295-4

Ahmadi Soleimanie, S., Vafaee, Y., & Koushesh Saba, M. (2020). Preharvest application of sodium nitroprusside improves tomato fruit quality and alleviates chilling injury during cold storage. *International Journal of Vegetable Science*, *26*(4), 364–378. https://doi.org/10.1080/19315260.2019.1636444

Alharaty, G., & Ramaswamy, H. S. (2020). The effect of sodium alginate-calcium chloride coating on the quality parameters and shelf life of strawberry cut fruits. *Journal of Composites Science*, *4*(3), 123. https://doi.org/10.3390/jcs4030123

Ali, S., Anjum, M. A., Ejaz, S., Hussain, S., Ercisli, S., Saleem, M. S., & Sardar, H. (2021). Carboxymethyl cellulose coating delays chilling injury development and maintains eating quality of 'Kinnow'mandarin fruits during low temperature storage. *International journal of biological macromolecules*, *168*, 77–85. https://doi.org/10.1016/j.ijbiomac.2020.12.028

Amini, F., Bayat, L., & Hosseinkhani, S. (2016). Influence of preharvest nano calcium applications on postharvest of sweet pepper (Capsicum annum). *Nusantara Bioscience*, *8*(2), 215–220. https://doi.org/10.13057/nusbiosci/n080213

Amiri, S., Nicknam, Z., Radi, M., Sayadi, M., Bagheri, F., Khorrami, N. K., & Abedi, E. (2021). Postharvest quality of orange fruit as influenced by salicylic acid, acetic acid, and carboxymethyl cellulose coating. *Journal of Food Measurement and Characterization*, 1–19. https://doi.org/10.1007/s11694-021-00966-y

Amiri, S., Rezazad Bari, L., Malekzadeh, S., Amiri, S., Mostashari, P., & Ahmadi Gheshlagh, P. (2022). Effect of Aloe vera gel-based active coating incorporated with catechin nanoemulsion and calcium chloride on postharvest quality of fresh strawberry fruit. *Journal of Food Processing and Preservation*, *46*(10), e15960. https://doi.org/10.1111/jfpp.15960

Arah, I. K., Amaglo, H., Kumah, E. K., & Ofori, H. (2015). Preharvest and postharvest factors affecting the quality and shelf life of harvested tomatoes: a mini review. *International Journal of Agronomy*, *2015*(1) 478041. https://doi.org/https://doi.org/10.1155/2015/478041

Arnon, H., Granit, R., Porat, R., & Poverenov, E. (2015). Development of polysaccharides-based edible coatings for citrus fruits: A layer-by-layer approach. *Food Chemistry*, *166*, 465–472. https://doi.org/10.1016/j.foodchem.2014.06.061

Bagheri, R., Ariaii, P., & Motamedzadegan, A. (2021). Characterization, antioxidant and antibacterial activities of chitosan nanoparticles loaded with nettle essential oil. *Journal of Food Measurement and Characterization*, *15*(2), 1395–1402. https://doi.org/10.1007/s11694-020-00738-0

Bahmani, R., Razavi, F., Mortazavi, S. N., Gohari, G., & Juárez-Maldonado, A. (2022). Evaluation of proline-coated chitosan nanoparticles on decay control and quality preservation of strawberry fruit (cv. Camarosa) during cold storage. *Horticulturae*, *8*(7), 648. https://doi.org/10.3390/horticulturae8070648

Çezik, F., & Saraçoğlu, O. (2024). The effect of pedicel length and post-harvest calcium chloride application on the storage life of strawberry fruit. *Applied Fruit Science*, *66*(3), 843–853. https://doi.org/10.1007/s10341-024-01088-7

Chandler, C. K., Folta, K., Dale, A., Whitaker, V. M., & Herrington, M. (2012). Strawberry. In *Fruit breeding* (pp. 305–325). Springer.

Chen, F., Liu, H., Yang, H., Lai, S., Cheng, X., Xin, Y., Yang, B., Hou, H., Yao, Y., & Zhang, S. (2011). Quality attributes and cell wall properties of strawberries (*Fragaria annanassa* Duch.) under calcium chloride treatment. *Food Chemistry*, *126*(2), 450–459. https://doi.org/10.1016/j.foodchem.2010.11.009

Cheng, G.W., & Breen, P.J. (1991). Activity of phenylalanine ammonia-lyase (PAL) and concentrations of anthocyanins and phenolics in developing strawberry fruit. *Journal of the American Society for Horticultural Science*, *116*(5), 865–869. https://doi.org/10.21273/JASHS.116.5.865

Cheour, F., Willemot, C., Arul, J., Makhlouf, J., & Desjardins, Y. (1991). Postharvest response of two strawberry cultivars to foliar application of $CaCl_2$. *HortScience*, *26*(9), 1186–1188. https://doi.org/10.21273/HORTSCI.26.9.1186

Chong, J. X., Lai, S., & Yang, H. (2015). Chitosan combined with calcium chloride impacts fresh-cut honeydew melon by stabilising nanostructures of sodium-carbonate-soluble pectin. *Food Control*, *53*, 195–205. https://doi.org/10.1016/j.foodcont.2014.12.035

Cordenunsi, B. R., Genovese, M. I., do Nascimento, J. R. O., Hassimotto, N. M. A., dos Santos, R. J., & Lajolo, F. M. (2005). Effects of temperature on the chemical composition and antioxidant activity of three strawberry cultivars. *Food Chemistry*, *91*(1), 113–121. https://doi.org/10.1016/j.foodchem.2004.05.054

Du, J., Gemma, H., & Iwahori, S. (1997). Effects of chitosan coating on the storage of peach, Japanese pear, and kiwifruit. *Journal of the Japanese Society for Horticultural Science*, *66*(1), 15–22. https://doi.org/10.2503/jjshs.66.15

Dunn, J. L., & Able, A. J. (2004). Pre-harvest calcium effects on sensory quality and calcium mobility in strawberry fruit. V International Strawberry Symposium 708,

Embuscado, M. E., & Huber, K. C. (2009). *Edible films and coatings for food applications* (Vol. 9). Springer. https://doi.org/10.1007/978-0-387-92824-1

Eroğul, D., Gundogdu, M., Sen, F., & Tas, A. (2024). Impact of postharvest calcium chloride treatments on decay rate and physicochemical quality properties in strawberry fruit. *BMC Plant Biology*, *24*(1), 1088. https://doi.org/10.1186/s12870-024-05792-0

Eshghi, S., Hashemi, M., Mohammadi, A., Badii, F., Mohammadhoseini, Z., & Ahmadi, K. (2014). Effect of nanochitosan-based coating with and without copper loaded on physicochemical and bioactive components of fresh strawberry fruit (*Fragaria x ananassa* Duchesne) during storage. *Food and Bioprocess Technology*, *7*(8), 2397–2409. https://doi.org/10.1007/s11947-014-1281-2

Fajardo, J., Waniska, R., Cuero, R., & Pettit, R. (1995). Phenolic compounds in peanut seeds: enhanced elicitation by chitosan and effects on growth and aflatoxin B1 production by *Aspergillus flavus*. *Food Biotechnology*, *9*(1-2), 59–78.

Felicia, W. X. L., Rovina, K., Nur'Aqilah, M. N., Vonnie, J. M., Erna, K. H., Misson, M., & Halid, N. F. A. (2022). Recent advancements of polysaccharides to enhance quality and delay ripening of fresh produce: A review. *Polymers*, *14*(7), 1341. https://doi.org/10.3390/polym14071341

Freire, M., Lebrun, M., Ducamp, M.-N., & Reynes, M. (2005). Evaluation of edible coatings in fresh cuts mango fruits. Information and Technology for Sustainable Fruit and Vegetable Production, FRUTIC 5, 12-16 September 2005, Montpellier, France.

Gao, Q., Xiong, T., Li, X., Chen, W., & Zhu, X. (2019). Calcium and calcium sensors in fruit development and ripening. *Scientia Horticulturae*, *253*, 412–421. https://doi.org/10.1016/j.scienta.2019.04.069

Gupta, S., Kant, K., Kaur, N., Jindal, P., Ali, A., & Naeem, M. (2025). Nano-calcium applications in modern agriculture: a review. *Plant Nano Biology*, 100147. https://doi.org/10.1016/j.plana.2025.100147

Hadiwijaya, Y., Putri, I., Mubarok, S., & Hamdani, J. (2020). Rapid and non-destructive prediction of total soluble solids of guava fruits at various storage periods using handheld near-infrared instrument. IOP Conference Series: Earth and Environmental Science,

Haydar, M. S., Ghosh, D., & Roy, S. (2024). Slow and controlled release nanofertilizers as an efficient tool for sustainable agriculture: Recent understanding and concerns. *Plant Nano Biology*, *7*, 100058. https://doi.org/10.1016/j.plana.2024.100058

Hosseini, S., Amini, J., Koushesh Saba, M., Karimi, K., & Pertot, I. (2020). Preharvest and postharvest application of garlic and rosemary essential oils for controlling anthracnose and quality assessment of strawberry fruit during cold storage. *Frontiers in Microbiology*, *11*, 1855. https://doi.org/10.3389/fmicb.2020.01855

Hussain, P., Meena, R., Dar, M., & Wani, A. (2012). Effect of post-harvest calcium chloride dip treatment and gamma irradiation on storage quality and shelf-life extension of Red delicious apple. *Journal of food science and technology*, *49*(4), 415–426. https://doi.org/10.1007/s13197-011-0289-0

Jiang, Y., & Li, Y. (2001). Effects of chitosan coating on postharvest life and quality of longan fruit. *Food Chemistry*, *73*(2), 139–143. https://doi.org/10.1016/j.scienta.2017.08.037

Jiang, Y., Yu, L., Hu, Y., Zhu, Z., Zhuang, C., Zhao, Y., & Zhong, Y. (2020). The preservation performance of chitosan coating with different molecular weight on strawberry using electrostatic spraying technique. *International Journal of Biological Macromolecules*, *151*, 278–285. https://doi.org/10.1016/j.ijbiomac.2020.02.169

Jianglian, D., & Shaoying, Z. (2013). Application of chitosan based coating in fruit and vegetable preservation: a review. *Journal of Food Processing Technology*, *4*(5), 227. https://doi.org/10.4172/2157-7110.1000227

Koushesh Saba, M., & Sogvar, O. B. (2016). Combination of carboxymethyl cellulose-based coatings with calcium and ascorbic acid impacts in browning and quality of fresh-cut apples. *LWT-Food Science and Technology*, *66*, 165–171. https://doi.org/10.1016/j.lwt.2015.10.022

Kumar, P., Sethi, S., & Sharma, R. (2018). Inhibition of browning in fresh-cut apple wedges through edible coatings and anti-browning agents. *Indian Journal of Horticulture*, *75*(3), 517–522. https://doi.org/10.5555/20183359501

Kumar, P., Sethi, S., Sharma, R., Srivastav, M., & Varghese, E. (2017). Effect of chitosan coating on postharvest life and quality of plum during storage at low temperature. *Scientia Horticulturae*, *226*, 104–109. https://doi.org/10.1016/j.scienta.2017.08.037

Lara, I., Garcıa, P., & Vendrell, M. (2004). Modifications in cell wall composition after cold storage of calcium-treated strawberry (Fragaria× ananassa Duch.) fruit. *Postharvest Biology and Technology*, *34*(3), 331–339. https://doi.org/10.1016/j.postharvbio.2004.05.018

Li, R., Chen, C., Chen, M., Wu, R., Sun, Y., Zhu, B., & Yao, Z. (2023). Fabrication of carboxymethyl chitosan/oxidized carboxymethyl cellulose composite film and its assessment for coating preservation of strawberry. *Journal of Food Science*, *88*(5), 1865–1878.

Li, Y., Rokayya, S., Jia, F., Nie, X., Xu, J., Elhakem, A., Almatrafi, M., Benajiba, N., & Helal, M. (2021). Shelf-life, quality, safety evaluations of blueberry fruits coated with chitosan nano-material films. *Scientific Reports*, *11*(1), 1–10. https://doi.org/10.1038/s41598-020-80056-z

Lin, D., & Zhao, Y. (2007). Innovations in the development and application of edible coatings for fresh and minimally processed fruits and vegetables. *Comprehensive reviews in food science and food safety*, *6*(3), 60–75. https://doi.org/10.1111/j.1541-4337.2007.00018.x

Lin, Y.-F., Hu, Y.-H., Lin, H.-T., Liu, X., Chen, Y.-H., Zhang, S., & Chen, Q.-X. (2013). Inhibitory effects of propyl gallate on tyrosinase and its application in controlling pericarp browning of harvested longan fruits. *Journal of Agricultural and Food Chemistry*, *61*(11), 2889–2895.

Liu, H., Chen, F., Lai, S., Tao, J., Yang, H., & Jiao, Z. (2017). Effects of calcium treatment and low temperature storage on cell wall polysaccharide nanostructures and quality of postharvest apricot (Prunus armeniaca). *Food Chemistry*, *225*, 87–97. https://doi.org/10.1016/j.foodchem.2017.01.008

Liu, K., Yuan, C., Chen, Y., Li, H., & Liu, J. (2014). Combined effects of ascorbic acid and chitosan on the quality maintenance and shelf life of plums. *Scientia Horticulturae*, *176*, 45–53. https://doi.org/10.1016/j.scienta.2014.06.027

Maas, J. L. (2004). Strawberry disease management. *Diseases of Fruits and Vegetables: Volume II*, 441–483. https://doi.org/10.1007/1-4020-2607-2_12

Nguyen, V. T., Nguyen, D. H., & Nguyen, H. V. (2020). Combination effects of calcium chloride and nano-chitosan on the postharvest quality of strawberry (*Fragaria x ananassa* Duch.). *Postharvest Biology and Technology*, *162*, 111103. https://doi.org/10.1016/j.postharvbio.2019.111103

Nunes, M., Brecht, J., Morais, A., & Sargent, S. (1995). Physical and chemical quality characteristics of strawberries after storage are reduced by a short delay to cooling. *Postharvest Biology and Technology*, *6*(1-2), 17–28. https://doi.org/10.1016/0925-5214(94)00048-W

Panahirad, S., Dadpour, M., Peighambardoust, S. H., Soltanzadeh, M., Gullón, B., Alirezalu, K., & Lorenzo, J. M. (2021). Applications of carboxymethyl cellulose-and pectin-based active edible coatings in preservation of fruits and vegetables: A review. *Trends in Food Science & Technology*. https://doi.org/10.1016/j.tifs.2021.02.025

Panahirad, S., Naghshiband-Hassani, R., Ghanbarzadeh, B., Zaare-Nahandi, F., & Mahna, N. (2019). Shelf life quality of plum fruits (Prunus domestica L.) improves with carboxymethylcellulose-based edible coating. *HortScience*, *54*(3), 505–510. https://doi.org/10.21273/HORTSCI13751-18

Pareek, S. (2017). *Novel postharvest treatments of fresh produce*. CRC Press. https://doi.org/10.1201/9781315370149

Pizato, S., Vega-Herrera, S. S., Chevalier, R. C., Pinedo, R. A., & Cortez-Vega, W. R. (2022). Impact of chitosan coatings enriched with clove Essential oil on quality ofminimally processed strawberries. *Brazilian Archives of Biology and Technology*, *65*. https://doi.org/10.1590/1678-4324-2022210278

Poovaiah, B. (1986). Role of calcium in prolonging storage life of fruits and vegetables. *Food Technol*, *40*(5), 86–89. https://doi.org/10.5555/19870344749

Popescu, P.-A., Palade, L. M., Nicolae, I.-C., Popa, E. E., Miteluț, A. C., Drăghici, M. C., Matei, F., & Popa, M. E. (2022). Chitosan-based edible coatings containing essential oils to preserve the shelf life and postharvest quality parameters of organic strawberries and apples during cold storage. *Foods*, *11*(21), 3317. https://doi.org/10.3390/foods11213317

Ranjbar, S., Rahemi, M., & Ramezanian, A. (2018). Comparison of nano-calcium and calcium chloride spray on postharvest quality and cell wall enzymes activity in apple cv. Red Delicious. *Scientia Horticulturae*, *240*, 57–64. https://doi.org/10.1016/j.scienta.2018.05.035

Ranjbar, S., Ramezanian, A., & Rahemi, M. (2020). Nano-calcium and its potential to improve 'Red Delicious' apple fruit characteristics. *Horticulture, Environment, and Biotechnology*, *61*(1), 23–30. https://doi.org/10.1007/s13580-019-00168-y

Ribeiro, C., Vicente, A. A., Teixeira, J. A., & Miranda, C. (2007). Optimization of edible coating composition to retard strawberry fruit senescence. *Postharvest Biology and Technology*, *44*(1), 63–70. https://doi.org/10.1016/j.postharvbio.2006.11.015

Rikhotso, M. M., Magwaza, L. S., Tesfay, S. Z., & Mditshwa, A. (2019). Evaluating the efficacy of chitosan and CMC incorporated with moringa leaf extracts on reducing peteca spot incidence on 'Eureka'lemon. *Journal of Food Science and Technology*, *56*(11), 5074–5086. https://doi.org/10.1007/s13197-019-03980-7

Romanazzi, G., Nigro, F., Ippolito, A., Divenere, D., & Salerno, M. (2002). Effects of pre-and postharvest chitosan treatments to control storage grey mold of table grapes. *Journal of Food Science*, *67*(5), 1862–1867. https://doi.org/10.1111/j.1365-2621.2002.tb08737.x

Ruan, C., Zhang, Y., Sun, Y., Gao, X., Xiong, G., & Liang, J. (2019). Effect of sodium alginate and carboxymethyl cellulose edible coating with epigallocatechin gallate on quality and shelf life of fresh pork. *International Journal of Biological Macromolecules*, *141*, 178–184. https://doi.org/10.1016/j.ijbiomac.2019.08.247

Saleem, M. S., Anjum, M. A., Naz, S., Ali, S., Hussain, S., Azam, M., Sardar, H., Khaliq, G., Canan, İ., & Ejaz, S. (2021). Incorporation of ascorbic acid in chitosan-based edible coating improves postharvest quality and storability of strawberry fruits. *International Journal of Biological Macromolecules*, *189*, 160–169. https://doi.org/10.1016/j.ijbiomac.2021.08.051

Sanchez-Moreno, C. larrauri, JA, Saura-Calixto, F.,(1998) A procedure to measure the antiradical efficiency of polyphenols. *Journal of the Science of Food and Agriculture*, *76*(2), 270–276.

Saure, M. C. (2005). Calcium translocation to fleshy fruit: its mechanism and endogenous control. *Scientia Horticulturae*, *105*(1), 65–89. https://doi.org/10.1016/j.scienta.2004.10.003

Sayyari, M., Esna-Ashari, M., & Tarighi, T. H. (2022). Impacts of salicylic acid, chitosan, and salicyloyl chitosan on quality preservation and microbial load reduction in strawberry fruits during cold storage. *Journal of Food Processing and Preservation*, *46*(7), e16710. https://doi.org/10.1111/jfpp.16710

Seyed, R. H., Rastegar, S., & Faramarzi, S. (2021). Impact of edible coating derived from a combination of Aloe vera gel, chitosan and calcium chloride on maintain the quality of mango fruit at ambient temperature. *Journal of Food Measurement and Characterization*, 1–11. https://doi.org/10.1007/s11694-021-00861-6

Shahbazi, Y. (2018). Application of carboxymethyl cellulose and chitosan coatings containing Mentha spicata essential oil in fresh strawberries. *International Journal of Biological Macromolecules*, *112*, 264–272. https://doi.org/10.1016/j.ijbiomac.2018.01.186

Silva, R., Silva, S., Melo, F., Guimarães, G., Madruga, M., Lima, R., & Beaudry, R. (2015). Influence of biodegradable coatings on the volatiles profile of fresh-cut 'Paluma' guava. In III International Conference on Fresh-Cut Produce: Maintaining Quality and Safety 1141, (pp, 319-326).

Singleton, V. L., Orthofer, R., & Lamuela-Raventós, R. M. (1999). Analysis of total phenols and other oxidation substrates and antioxidants by means of folin-ciocalteu reagent. *Methods in Enzymology*, *299*, 152–178. https://doi.org/10.1016/S0076-6879(99)99017-1

Sogvar, O. B., Koushesh Saba, M., & Emamifar, A. (2016a). Aloe vera and ascorbic acid coatings maintain postharvest quality and reduce microbial load of strawberry fruit. *Postharvest Biology and Technology*, *114*, 29–35. https://doi.org/10.1016/j.postharvbio.2015.11.019

Sogvar, O. B., Koushesh Saba, M., Emamifar, A., & Hallaj, R. (2016b). Influence of nano-ZnO on microbial growth, bioactive content and postharvest quality of strawberries during storage. *Innovative Food Science & Emerging Technologies*, *35*, 168–176. https://doi.org/10.1016/j.ifset.2016.05.005

Sommer, N., Fortlage, R., & Edwards, D. (1992). Postharvest diseases of selected commodities.

Spinardi, A. (2004). Effect of harvest date and storage on antioxidant systems in pears. In V International Postharvest Symposium, June 2004, 682, (pp, 135-140).

Swallah, M. S., Sun, H., Affoh, R., Fu, H., & Yu, H. (2020). Antioxidant potential overviews of secondary metabolites (polyphenols) in fruits. *International Journal of Food Science*, *2020*. https://doi.org/10.1155/2020/9081686

Tanada-Palmu, P. S., & Grosso, C. R. (2005). Effect of edible wheat gluten-based films and coatings on refrigerated strawberry (Fragaria ananassa) quality. *Postharvest Biology and Technology*, *36*(2), 199–208. https://doi.org/10.1016/j.postharvbio.2004.12.003

Tesfay, S., Magwaza, L., Mditshwa, A., & Mbili, N. (2017). Carboxyl methylcellulose (CMC) incorporated with moringa leaf and seed extracts as new postharvest organic edible coating for avocado (*Persea americana* Mill.) fruit. VII International Conference on Managing Quality in Chains (MQUIC2017) and II International Symposium on Ornamentals in 1201, (pp. 161-168).

Tharanathan, R. N., & Kittur, F. S. (2003). Chitin—the undisputed biomolecule of great potential. *Critical Reviews in Food Science and Nutrition*, *43*(1), 61–87. https://doi.org/10.1080/10408690390826455

Tian, S., Qin, G., & Li, B. (2013). Reactive oxygen species involved in regulating fruit senescence and fungal pathogenicity. *Plant Molecular Biology*, *82*(6), 593–602. https://doi.org/10.1007/s11103-013-0035-2

Tokatlı, K., & Demirdöven, A. (2021). Influences of chitosan coatings on functional compounds of sweet cherries. *Journal of Food Science and Technology*, *58*(5), 1808–1818. https://doi.org/10.1007/s13197-020-04692-z

Vasey, C. (2006). *The water prescription: For health, vitality, and rejuvenation*. Simon and Schuster.

Vitti, A., Coviello, L., Triunfo, M., Guarnieri, A., Scieuzo, C., Salvia, R., Falabella, P., & Nuzzaci, M. (2024). In vitro antifungal activity and in vivo edible coating efficacy of insect-derived chitosan against *Botrytis cinerea* in strawberry. *International Journal of Biological Macromolecules*, *279*(13515), 8. https://doi.org/10.1016/j.ijbiomac.2024.135158

Vu, K., Hollingsworth, R., Leroux, E., Salmieri, S., & Lacroix, M. (2011). Development of edible bioactive coating based on modified chitosan for increasing the shelf life of strawberries. *Food Research International*, *44*(1), 198–203. https://doi.org/10.1016/j.foodres.2010.10.037

Wang, H., Cao, G., & Prior, R. L. (1996). Total antioxidant capacity of fruits. *Journal of Agricultural and Food Chemistry*, *44*(3), 701–705. https://doi.org/10.1021/jf950579y

Wu, J., Zhang, L., & Fan, K. (2022). Recent advances in polysaccharide-based edible coatings for preservation of fruits and vegetables: A review. *Critical Reviews in Food Science and Nutrition*, 1–16. https://doi.org/10.1080/10408398.2022.2136136

Yaman, Ö., & Bayoındırlı, L. (2002). Effects of an edible coating and cold storage on shelf-life and quality of cherries. *LWT-Food Science and Technology*, *35*(2), 146–150. https://doi.org/10.1006/fstl.2001.0827

Yang, F. M., Li, H. M., Li, F., Xin, Z. H., Zhao, L. Y., Zheng, Y. H., & Hu, Q. (2010). Effect of nano-packing on preservation quality of fresh strawberry (*Fragaria ananassa* Duch. cv Fengxiang) during storage at 4 C. *Journal of Food Science*, *75*(3), C236–C240. https://doi.org/10.1111/j.1750-3841.2010.01520.x

Zhang, Y., Zhang, M., & Yang, H. (2015). Postharvest chitosan-g-salicylic acid application alleviates chilling injury and preserves cucumber fruit quality during cold storage. *Food Chemistry*, *174*, 558–563. https://doi.org/10.1016/j.foodchem.2014.11.106

Zhou, R., Mo, Y., Li, Y., Zhao, Y., Zhang, G., & Hu, Y. (2008). Quality and internal characteristics of Huanghua pears (*Pyrus pyrifolia* Nakai, cv. Huanghua) treated with different kinds of coatings during storage. *Postharvest Biology and Technology*, *49*(1), 171–179. https://doi.org/10.1016/j.postharvbio.2007.12.004