Journal of Food Measurement and Characterization (2022) 16:1920–1929
https://doi.org/10.1007/s11694-021-01276-z

ORIGINAL PAPER

Chitosan coatings incorporated with salicylic acid enhanced postharvest quality of pear under different storage conditions

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Received: 5 October 2021 / Accepted: 20 December 2021 / Published online: 3 February 2022

Abstract

Pear being climacteric in nature has short storage life resulting in rapid loss of fruit quality after harvest. The present study aimed to determine the efficacy of composite coating of chitosan (CH) and salicylic acid (SA) on storage life and overall fruit quality of pear under cold and supermarket storage conditions. Application of combined CH + SA coatings delayed ripening index and reduced physico-chemical changes in stored pear fruit related to ripening in terms of soluble solid content, total sugars, titratable acidity as compared to pure CH or SA and control fruit. In addition, composite coatings had a positive impact on maintaining the fruit colour and sensory attributes over an extended period and efficiently enhanced the storage life up to 67 and 20 days of cold and supermarket storage conditions, respectively.

Keywords Chitosan · Pear · Ripening index · Salicylic acid · Sensory · Storage life

Introduction

Pear is a popular fruit in the domestic as well as international market owing to its crispy texture, subtle aroma, delicious flavour, and rich nutritional compounds [1]. Punjab Beauty pear is a low chill cultivar grown in the north-western provinces of the country and the fruit known for its comprehensive qualities. The fruit matures in the third week of July when high temperature and humidity prevails in region. Such unfavourable conditions initiate rapid deterioration in fruit quality making fruit prone to postharvest losses and therefore limiting its storage life. Pear being categorized as climacteric fruit undergoes considerable physico-chemical alterations in a short duration of time due to the activation of various metabolic reactions and biochemical pathways [2]. Postharvest losses in pear fruit are majorly owed to the ripening and senescence process such as loss of sugars and organic acids. The unpleasing appearance of fruit caused by textural losses and colour change directly impacts the sensorial attributes rendering in diminutive price in the fresh fruit market. These undesirable changes in fruit not only limit the export of fruit but also its transportation to distant markets within the country.

The use of chemical preservatives to maintain postharvest fruit quality in pears often raises health risks [3]. Adhering to the health and food safety legislation of the country, edible coatings are sought to be the most suitable postharvest technique in preserving fruit quality attributes for prolonged storage [4]. Chitosan is a polysaccharide based edible coating. It's a polymer of (4,1) -N-acetyl-d-glucosamine, obtained from the chitin of crustaceans [4]. In addition to its biocompatible, biodegradable, and non-toxic nature, it regulates the permeation of respiratory gases and forms an effective barrier against moisture loss thus lowering several metabolic reactions and respiratory activities accompanying the fruit ripening process [5]. Chemically, salicylic acid is an ortho-benzoic acid ($C_6H_4(OH)CO_2H$) regulating various plant growth and development processes [6]. SA has received particular recognition in the field of postharvest management of horticultural commodities due to its ability to eliminate any oxidative stress by activating the antioxidant systems and preventing the biosynthesis of ethylene [7]. Therefore, SA plays a pivotal role in the retention of postharvest quality attributes as well as the postponement of the fruit ripening process [8]. Enrichment of CH with SA forms a composite coating and enhances the functional properties of CH [9]. Also, the beneficial effects of composite coatings in the preservation of fruit quality have been documented

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earlier in fruits such as *Syzygium cuminii* [9], litchi [10], grapeberries [11] and pistachionut [12], fresh cut kiwifruit [13] cucumber [14]. However, till date, no literature has been reported regarding the efficacy of composite CH and SA coatings on maintenance of postharvest quality in pear fruit. Also, the present investigation on the storage of pear was conducted under both cold and supermarket storage conditions. Cold storage ensures a prolonged supply of fresh pears in the market and averts glut and transportation bottlenecks during peak seasons, thereby providing remunerative prices to the growers. While the emerging trend of supermarkets has metamorphosized the food retail logistics and transformed the consumer's preference towards food products. High value fruits are aesthetically staged in these supermarkets and moreover, the application of composite coatings improves the cosmetic appearance of fruit and maintains freshness and quality for an extended period of time as compared to ambient conditions. Hence, the present study was planned to probe the effectiveness of composite coatings of CH and SA on the postharvest life and quality indices of pear fruit stored under cold and supermarket conditions.

Material and method

Plant material and experimental procedure

Pear cv. Punjab Beauty fruits were randomly handpicked along with stalks from the Fruit Research Farm of Punjab Agricultural University, Ludhiana (30.90°N, 75.86°E), (India) at maturity stage (SSC: 13.6 ± 0.16% and Firmness: 66.45 ± 3.0 N). Immediately after harvest, fruits were transferred to the Post Harvest Laboratory. Fruits were visually sorted to ensure uniformity in size and colour while the blemished, diseased, or fruits with physical defects were discarded. The sorted fruits were sanitized with 100 ppm sodium hypochlorite disinfectant solution for 5 min to remove any surface contaminants and then shade dried. On the day of harvest, 80 untreated fruits were immediately sampled and analysed for quality attributes. The remaining fruits were divided into two lots to assess the effect of SA incorporated CH coatings and single CH or SA treatments during storage. Under each storage condition, fruits were divided into six groups. Fruits in the first four groups were administered with single CH (1.0% and 2.0%) and combined CH + SA (1.0% + 2.0 mM and 2.0% + 2.0 mM) coatings with the aid of fine bristle brush. Whereas fruits in the other two groups were dipped in SA 2.0 mM and distilled water (control). Each treatment was replicated four times and the individual replicate consisted of 20 fruits. After treatments, fruits were air-dried and packed in 3-ply paper lined corrugated fibre board boxes with 5% perforation. Boxes from the first lot were immediately placed in the cold storage conditions (0–1 °C, 90–95% RH) and the second lot was placed under supermarket storage conditions (20–22 °C, 80–85% RH), respectively. Under cold storage conditions, fruits were analyzed for different quality attributes on the 30th, 45th, 60th, and 67th day, while under supermarket conditions, analysis was done on the 5th, 10th, 15th, and 20th day of storage. At each sampling date, ten fruits from each replicate were initially detected for peel colour and further pulp was homogenised and assayed for SSC, TA, juice pH and sugars.

Preparation of coating formulations

Solutions of chitosan obtained from Sigma–Aldrich Chemical Co. (Steinheim, Germany) were prepared by dissolving 10 g (CH 1.0%) and 20 g (CH 2.0%) of CH powder in 1000 mL of 3% (V/V) glacial acetic acid solution. The mixture was homogenized with a magnetic stirrer. For the enhancement of strength and flexibility of the coating emulsions, glycerol (0.5%) was added as a plasticizer. For SA treatments of 2.0 mM concentration, the corresponding weight of the SA powder placed in the beaker was dissolved in 1.0 L of distilled water and consistently stirred with the magnetic stirrer for 5 min at 40 °C on a hot plate. For composite coatings, CH (1.0% and 2.0%, respectively) were prepared and added with SA (2.0 mM) solution in a proportion such as to make up the final volume as 1.0 L. All the emulsions were adjusted at 5.6 pH using 0.1 N sodium hydroxide solution [11].

Evaluation of fruit quality parameters

Soluble solids content (SSC)

For each treatment pear juice was extracted and assessed for SSC in four biological replicates. Readings were noted on digital hand refractometer (Model: PAL—1 Make: Atago Co., L., Tokyo, Japan) and expressed as percentage [15].

Total sugars and reducing sugars

Total sugars were estimated by the phenol–sulphuric acid method [16] and expressed in percentage. Clarified juice aliquot measuring 30 µL were admixed with 5% phenol reagent, followed by the addition of 5 mL concentrated sulphuric acid. The test tubes were incubated at room temperature for 30 min and the absorbance was recorded at 490 nm using a spectrophotometer (Spectronic 20D$^+$, Thermo Scientific, USA). For estimation of reducing sugars, aliquot measuring 1 mL was added with 1 mL of copper reagent, mixed and placed in boiling water for 10 min. Afterward, the samples were cooled at room temperature and added with 1 mL

Nelson Reagent. Absorbance was noted at 520 nm (Spectronic 20D$^+$, Thermo Scientific, USA) [17].

Titratable acidity (TA), juice pH, and ripening index

For TA estimation, 2 mL of the extracted pear juice taken in a conical flask was added with two drops of phenolphthalein indicator. The mixture was further titrated against 0.1 NaOH with a continuous shaking till the light pink colour appeared. TA was expressed as per cent maleic acid and calculated with the following formula: TA (%) = [(0.0067 × 0.1 N NaOH)/ Volume of juice taken (mL)] × 100 [18]. The ratio of SSC and TA was expressed as ripening index and juice pH was analysed using a pH meter (Phan pH Analyzer, Labindia).

Peel colour

Peel colour was noted at three equidistant sites on the equatorial region of the pear fruit with the help of Colour Flex 45°/0° spectrophotometer (Hunter Lab Colour Flex, Hunter Associates Inc., Reston, VA, USA) after calibrating on white and black tile. Readings were taken at L^*, a^* & b^* coordinates of hunter colour values on the day of harvest and thereafter on 30th, 45th, 60th, 67th day of cold storage and on 5th, 10th, 15th and 20th day of supermarket storage conditions. Where L^* value forms the vertical axis and ranges from 0 (black) to 100 (white), a^* value (red to green axis) and b^* value (yellow to blue axis) represent colour coordinates on the colour chart.

Sensory evaluation

For all the treated and untreated samples stored under cold and supermarket conditions, sensory evaluation was done by a panel of eight judges based on their interest and familiarity in pear fruit profiling. Members who participated in sensory evaluation belonged to the Punjab Agricultural University and consisted of an equal number of males and females between age groups of 30 to 55 years. For maintaining authenticity, each sample was coded and randomly placed on a white tray. Judges were provided with two slices of fruit from each treatment. The assessment was made on the basis of colour, texture, aroma, taste, and overall acceptability, and the panellists were requested to give scores for each attribute on a continuous hedonic scale ranging from 0 to 9 [19]. Sensory evaluation was done on the day of harvest and then on the 30th, 45th, 60th, and 67th day of cold storage condition and on 5th, 10th, 15th, and 20th day supermarket storage conditions. The scores for all the sensory attributes under each treatment and storage conditions were compiled and evaluated to generate a radar chart in Microsoft Excel Office 2010.

Statistical analysis

The present experiment was laid out in a completely randomized design containing four replications. Results recorded under different fruit quality attributes were collected for two years during 2019 and 2020. The data were pooled and statistically analyzed for significance ($p \leq 0.05$) using analysis of variance (ANOVA). The means were separated by least significant differences (LSD) tests using statistical analysis software (SAS version 9.3 for Windows).

Results

Soluble solids content (SSC), total sugars, and reducing sugars

The pear fruit exhibited an initial rise in SSC and sugars followed by a decline towards the end of the storage period regardless of treatments or storage intervals. This might be due to the hydrolysis of complex insoluble polysaccharides into simple soluble mono and disaccharides [15] followed by a decline at later stages of storage caused by the complete breakdown of starch and carbohydrate utilization in the respiration process [20]. SSC in all the fruit under both cold and supermarket conditions increased during the early period of storage (Fig. 1) but the rate of increase in SSC was more under supermarket storage conditions. Under cold storage conditions, SSC increased in combined CH + SA coated fruit up to 60 days of storage, while in single CH or SA and control fruit, the SSC increased only up to 45 days, followed by a decline. On the 67th day of storage, maximum SSC (13.27%) was maintained in CH 2.0% + SA 2.0 mM coated fruit, while minimum SSC (13.07%) was recorded in control. Under supermarket storage conditions, SSC increased rapidly and the fruit coated with pure CH coating or SA dip peaked on the 10th day of storage, followed by a decline. While in composite coated fruit, SSC increased up to 15 days of storage. At later stages of storage, SSC declined in all the coated and uncoated fruit, however, the pace of utilization of SSC was more rapid in control fruit as compared to CH 2.0% + SA 2.0 mM coated fruit.

Total sugars in pear increased with the advancement of ripening during the initial stages of storage under both cold and supermarket conditions (Tables 1, 2). The CH + SA coated fruit exhibited a slow rise in total sugars content and peaked 15 days ahead (60th day of storage) as compared to individual CH or SA treated and untreated fruit, where total sugars peaked on the 45th day of storage. Under supermarket storage conditions, total sugars increased rapidly and the peak in single CH or SA and control fruit was marked 5 days earlier than observed in composite coatings. This is attributed to the faster hydrolytic conversion of starch into

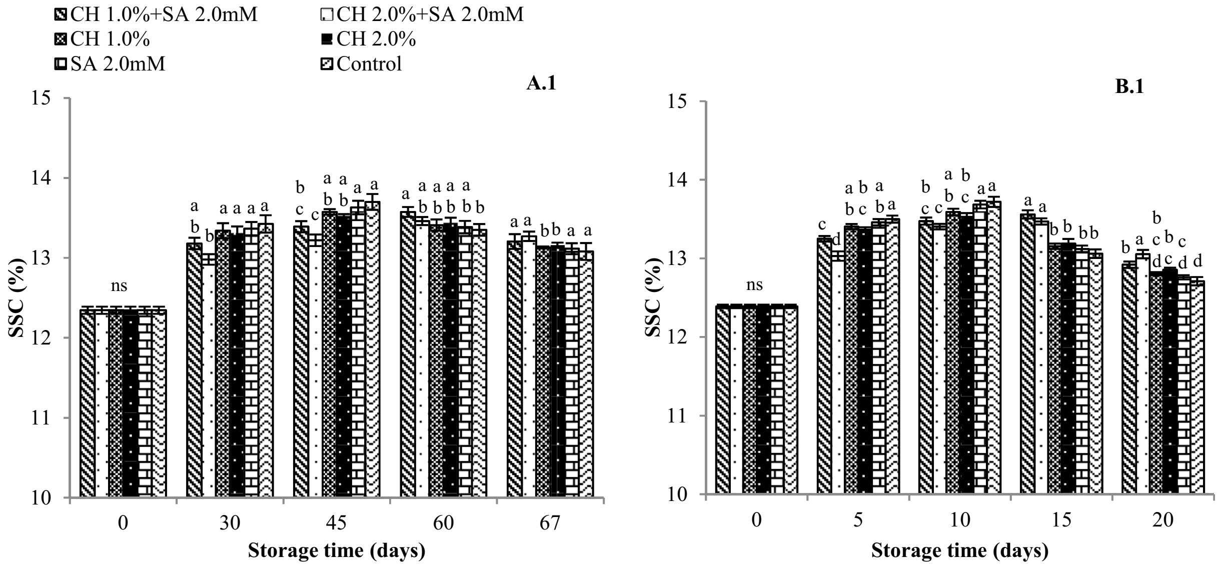

Fig. 1 SSC in pear fruit coated with CH or SA alone and CH + SA during **a** cold storage conditions (0 – 1 °C, 90 – 95% RH) for 67 days and **b** supermarket storage at 20 – 22 °C, 80 – 85% RH for 20 days. Data is expressed as mean of quadruplicate sample ± standard errors. Vertical bars represent standard errors of means ($p \leq 0.05$)

sugars associated with the accelerated respiration process at higher temperatures [21]. Depletion of total sugars at the later stages of storage under both cold and supermarket conditions was rapid and fruits retained only 8.69% and 8.32% total sugars on the 67th and 20th day of storage as compared to fruit coated with CH 2.0% + SA 2 mM coatings, where maximum total sugars content (9.30 and 8.91%, respectively) were maintained.

Likewise, reducing sugars in CH or SA alone and control fruit increased up to 45 days of cold storage (Tables 1, 2). While the maximum reducing sugars in CH + SA coated fruit was marked on the 60th day of storage, followed by a decline. Under supermarket storage conditions the reducing sugars in single CH or SA and control fruit increased up to 10 days, while in CH + SA coatings, the reducing sugars increased slowly and peaked on the 15th day of storage followed by a decline. At the end of the 67th and 20th day of cold and supermarket storage period, maximum reducing sugars (6.94 and 6.55%) were maintained in CH 2.0% + SA 2 mM coated fruit, while in untreated fruit the decline was more rapid and therefore minimum reducing sugars content (6.46 and 6.20%) was registered. A delayed rise in SSC, total sugars, and reducing sugars in composite coated fruit might be caused by the oxygen barrier property of CH coating on fruit surface [11] and sustained release of SA might have suppressed the ethylene mediated fruit ripening process [7]. The results are in agreement with the finding of Lo'ay and Taher [22] in guava and Shen and Yang [11] in grapes where maximum sugars were retained in the fruits applied with CH + SA coatings.

Titratable acidity (TA) and juice pH

TA is an important quality index reflecting the fruit flavour and is mainly contributed by maleic acid [23]. TA in all coated and uncoated fruit decreased throughout the 67 and 20 days of cold and supermarket storage conditions (Fig. 2). In comparison to cold storage, the rate of decline in TA was faster in supermarket stored fruit. At the end of 67 and 20 days of cold and supermarket storage period, CH 2.0% + SA 2.0 mM coated fruit retained maximum TA of 0.23 and 0.20%, respectively). The slow decline in TA in CH + SA coated fruit might be ascribed to the protective oxygen barrier forming ability of the coatings and therefore inhibiting the oxygen supply for respiration as well as restricting the availability of organic acids for the metabolic process [24]. Maximum depletion of organic acids was recorded in control fruit, where the least TA was registered on the 67th (0.12%) and 20th day (0.08%) of cold and supermarket storage conditions.

Juice pH increased as the TA in fruit declined under cold and supermarket storage (Tables 1, 2). Under both conditions, the rise in juice pH in composite coated fruit was lower as compared to CH or SA alone. At the end of 67 and 20 days of cold and supermarket storage period, maximum juice pH (4.52 and 4.55, respectively) was noted in control fruit, while minimum juice pH (4.35 and 4.39, respectively) was recorded in CH 2.0% + SA 2.0 mM which might be due to semi-permeable film formed on the fruit surface, thus modifying the internal atmosphere and lowering the breakdown of organic acids. Similar results were documented

Table 1 Variation in fruit colour (*L**, *a**, *b**), total sugars, reducing sugars, and juice pH in pear fruit coated with CH or SA alone and CH + SA during cold storage at 0 – 1 °C, 90 – 95% RH for 67 days

Parameter	Treatment	Storage time (days)				
	CH (%) + SA (mM)	0	30	45	60	67
*L** value	CH 1.0 + SA 2.0	65.16 ± 0.42 ns	68.59 ± 0.28 bc	69.88 ± 0.20 b	70.83 ± 0.17 b	71.29 ± 0.59 b
	CH 2.0 + SA 2.0		67.40 ± 0.29 c	67.89 ± 0.26 c	68.94 ± 0.19 c	69.28 ± 0.54 c
	CH 1.0		69.64 ± 0.45 ab	71.13 ± 0.32 ab	72.12 ± 0.20 a	72.59 ± 0.30 ab
	CH 2.0		69.30 ± 0.45 ab	71.02 ± 0.40 ab	71.96 ± 0.35 a	72.43 ± 0.17 ab
	SA 2.0		69.82 ± 0.26 a	71.37 ± 0.08 a	72.44 ± 0.42 a	72.91 ± 0.36 a
	Control		70.07 ± 0.58 a	71.65 ± 0.69 a	72.65 ± 0.25 a	73.14 ± 0.54 a
*a** value	CH 1.0 + SA 2.0	– 8.52 ± 0.17 ns	– 6.85 ± 0.25 cd	– 6.40 ± 0.18 c	– 5.64 ± 0.36 cd	– 4.95 ± 0.27 c
	CH 2.0 + SA 2.0		– 7.39 ± 0.27 d	– 6.98 ± 0.16 c	– 6.30 ± 0.20 d	– 5.72 ± 0.34 d
	CH 1.0		– 5.62 ± 0.28 ab	– 5.17 ± 0.37 ab	– 4.64 ± 0.22 ab	– 4.18 ± 0.23 ab
	CH 2.0		– 6.04 ± 0.22 bc	– 5.63 ± 0.19 b	– 5.00 ± 0.21 bc	– 4.34 ± 0.24 bc
	SA 2.0		– 5.40 ± 0.25 ab	– 4.99 ± 0.16 ab	– 4.47 ± 0.27 ab	– 3.97 ± 0.21 ab
	Control		– 5.20 ± 0.35 a	– 4.85 ± 0.25 a	– 4.15 ± 0.21 a	– 3.56 ± 0.19 a
*b** value	CH 1.0 + SA 2.0	38.47 ± 0.08 ns	41.62 ± 0.30 b	42.59 ± 0.32 c	43.56 ± 0.11 d	44.40 ± 0.18 b
	CH 2.0 + SA 2.0		40.44 ± 0.10 c	41.12 ± 0.46 d	41.91 ± 0.06 e	42.53 ± 0.41 c
	CH 1.0		42.61 ± 0.10 a	43.53 ± 0.09 ab	44.53 ± 0.14 bc	45.42 ± 0.58 ab
	CH 2.0		42.40 ± 0.45 ab	43.12 ± 0.16 bc	44.10 ± 0.26 cd	45.04 ± 0.62 ab
	SA 2.0		42.73 ± 0.29 a	43.85 ± 0.26 ab	45.04 ± 0.30 ab	45.93 ± 0.82 ab
	Control		43.06 ± 0.21 a	44.17 ± 0.37 a	45.36 ± 0.39 a	46.27 ± 0.61 a
Total sugars (%)	CH 1.0 + SA 2.0	8.14 ± 0.04 ns	9.08 ± 0.04 c	9.63 ± 0.09 bc	9.86 ± 0.09 a	9.15 ± 0.08 ab
	CH 2.0 + SA 2.0		8.70 ± 0.04 d	9.31 ± 0.08 c	9.66 ± 0.12 ab	9.30 ± 0.09 a
	CH 1.0		9.43 ± 0.01 ab	9.85 ± 0.07 ab	9.59 ± 0.08 b	8.86 ± 0.06 c
	CH 2.0		9.37 ± .010 b	9.78 ± 0.14 ab	9.63 ± 0.09 ab	8.92 ± 0.07 bc
	SA 2.0		9.50 ± 0.05 ab	9.91 ± 0.16 ab	9.50 ± 0.04 b	8.81 ± 0.12 c
	Control		9.63 ± 0.15 a	9.99 ± 0.11 a	9.45 ± 0.08 b	8.69 ± 0.13 c
Reducing sugars (%)	CH 1.0 + SA 2.0	5.84 ± 0.05 ns	6.66 ± 0.06 c	7.17 ± 0.05 b	7.31 ± 0.01 a	6.82 ± 0.09 ab
	CH 2.0 + SA 2.0		6.36 ± 0.04 d	6.93 ± 0.03 c	7.22 ± 0.07 ab	6.94 ± 0.08 a
	CH 1.0		6.92 ± 0.03 b	7.30 ± 0.05 a	7.18 ± 0.08 b	6.56 ± 0.08 c
	CH 2.0		6.89 ± 0.04 b	7.27 ± 0.04 ab	7.20 ± 0.08 ab	6.61 ± 0.07 bc
	SA 2.0		6.97 ± 0.05 ab	7.37 ± 0.05 a	7.15 ± 0.13 b	6.52 ± 0.09 c
	Control		7.08 ± 0.04 a	7.39 ± 0.04 a	7.12 ± 0.08 b	6.46 ± 0.05 c
Juice pH	CH 1.0 + SA 2.0	4.20 ± 0.01 ns	4.28 ± 0.01 cd	4.31 ± 0.01 bc	4.37 ± 0.01 ab	4.41 ± 0.02 bc
	CH 2.0 + SA 2.0		4.25 ± 0.02 d	4.27 ± 0.01 c	4.31 ± 0.02 b	4.35 ± 0.03 c
	CH 1.0		4.34 ± 0.02 ab	4.36 ± 0.02 ab	4.41 ± 0.03 a	4.49 ± 0.01 a
	CH 2.0		4.32 ± 0.01 bc	4.35 ± 0.02 ab	4.40 ± 0.04 a	4.46 ± 0.03 ab
	SA 2.0		4.35 ± 0.02 ab	4.38 ± 0.01 a	4.43 ± 0.02 a	4.50 ± 0.01 a
	Control		4.37 ± 0.01 a	4.40 ± 0.01 a	4.44 ± 0.02 a	4.52 ± 0.02 a

Data are expressed as mean ± SE of quadruplicate assays. Values in same column with different letters indicates statistically significant differences at $p \leq 0.05$

in guava [22] and grapes [11] where CH + SA treated fruit recorded higher TA during storage.

Ripening index

In the present study, the ripening index of pear fruit increased with the storage period irrespective of the storage conditions (Fig. 2) caused by the incessant decline in TA and a concomitant rise in SSC [25]. However, the pace of rise in RI was faster in supermarket stored fruit. Composite CH + SA coated fruit exhibited a slower increase in RI over 67 and 20 days of cold and supermarket storage conditions as compared to their individual CH coats or SA dips. The lower rise in RI in composite coated fruit may be attributed to the synergistic effect of CH and SA in delaying the respiration and ripening related metabolic

Table 2 Variation in fruit colour (*L**, *a**, *b**), total sugars, reducing sugars, and juice pH in pear fruit coated with CH or SA alone and CH + SA during supermarket storage at 20 – 22 °C, 80 – 85% RH for 20 days

Parameter	Treatment	Storage time (days)				
	CH (%) + SA (mM)	0	5	10	15	20
L * value	CH 1.0 + SA 2.0	65.30 ± 0.13 ns	68.79 ± 0.47^{bc}	70.59 ± 0.37^{bc}	72.63 ± 0.65^{cd}	76.07 ± 0.30^{c}
	CH 2.0 + SA 2.0		67.61 ± 0.30^{c}	69.04 ± 0.72^{c}	71.21 ± 0.62^{d}	74.32 ± 0.44^{d}
	CH 1.0		70.00 ± 0.52^{ab}	72.42 ± 1.33^{ab}	74.57 ± 0.54^{abc}	77.58 ± 0.52^{ab}
	CH 2.0		69.76 ± 0.37^{ab}	71.74 ± 0.71^{ab}	73.99 ± 0.92^{bc}	77.09 ± 0.30^{bc}
	SA 2.0		70.10 ± 0.62^{ab}	73.04 ± 0.49^{ab}	74.99 ± 0.53^{ab}	78.04 ± 0.30^{ab}
	Control		70.34 ± 0.37^{a}	73.63 ± 0.97^{a}	76.05 ± 0.77^{a}	78.62 ± 0.55^{a}
*a** value	CH 1.0 + SA 2.0	− 8.57 ± 0.05 ns	− 6.80 ± 0.12^{b}	− 6.06 ± 0.25^{c}	− 5.42 ± 0.20^{b}	− 4.82 ± 0.22^{b}
	CH 2.0 + SA 2.0		− 7.08 ± 0.16^{b}	− 6.24 ± 0.23^{c}	− 5.77 ± 0.14^{b}	− 4.95 ± 0.27^{b}
	CH 1.0		− 5.58 ± 0.20^{a}	− 5.19 ± 0.27^{b}	− 4.44 ± 0.14^{a}	− 3.51 ± 0.17^{a}
	CH 2.0		− 5.54 ± 0.13^{a}	− 5.11 ± 0.14^{ab}	− 4.41 ± 0.22^{a}	− 3.63 ± 0.34^{a}
	SA 2.0		− 5.31 ± 0.20^{a}	− 4.58 ± 0.24^{ab}	− 4.08 ± 0.42^{a}	− 3.22 ± 0.31^{a}
	Control		− 5.08 ± 0.33^{a}	− 4.41 ± 0.36^{a}	− 3.99 ± 0.18^{a}	− 3.01 ± 0.16^{a}
*b** value	CH 1.0 + SA 2.0	38.49 ± 0.16 ns	40.72 ± 0.39^{b}	42.78 ± 0.13^{b}	43.74 ± 0.40^{c}	44.91 ± 0.24^{b}
	CH 2.0 + SA 2.0		40.69 ± 0.53^{b}	42.13 ± 0.35^{b}	43.10 ± 0.39^{c}	43.87 ± 0.51^{b}
	CH 1.0		42.23 ± 0.36^{a}	44.80 ± 0.27^{a}	46.15 ± 0.42^{b}	47.39 ± 0.13^{a}
	CH 2.0		42.24 ± 0.32^{a}	44.87 ± 0.49^{a}	46.04 ± 0.32^{b}	47.64 ± 0.55^{a}
	SA 2.0		42.77 ± 0.52^{a}	45.52 ± 0.39^{a}	46.94 ± 0.28^{ab}	47.92 ± 0.72^{a}
	Control		42.96 ± 0.47^{a}	45.65 ± 0.13^{a}	47.34 ± 0.29^{a}	48.10 ± 0.70^{a}
Total sugars (%)	CH 1.0 + SA 2.0	8.28 ± 0.01 ns	9.09 ± 0.04^{c}	9.73 ± 0.02^{c}	10.04 ± 0.06^{a}	8.75 ± 0.07^{ab}
	CH 2.0 + SA 2.0		8.90 ± 0.03^{d}	9.47 ± 0.03^{d}	9.88 ± 0.04^{b}	8.91 ± 0.09^{a}
	CH 1.0		9.62 ± 0.04^{b}	9.95 ± 0.03^{b}	9.48 ± 0.07^{cd}	8.51 ± 0.07^{cd}
	CH 2.0		9.52 ± 0.03^{b}	9.91 ± 0.05^{b}	9.57 ± 0.03^{c}	8.60 ± 0.09^{bc}
	SA 2.0		9.75 ± 0.05^{a}	10.02 ± 0.03^{ab}	9.41 ± 0.04^{de}	8.43 ± 0.08^{cd}
	Control		9.85 ± 0.06^{a}	10.13 ± 0.07^{a}	9.28 ± 0.02^{e}	8.32 ± 0.08^{d}
Reducing sugars (%)	CH 1.0 + SA 2.0	5.95 ± 0.01 ns	6.66 ± 0.06^{d}	7.24 ± 0.04^{bc}	7.42 ± 0.03^{a}	6.44 ± 0.08^{ab}
	CH 2.0 + SA 2.0		6.53 ± 0.06^{d}	7.06 ± 0.06^{c}	7.29 ± 0.05^{ab}	6.55 ± 0.05^{a}
	CH 1.0		7.05 ± 0.04^{bc}	7.39 ± 0.09^{ab}	7.15 ± 0.06^{bc}	6.29 ± 0.05^{cd}
	CH 2.0		6.96 ± 0.05^{c}	7.37 ± 0.06^{ab}	7.18 ± 0.09^{bc}	6.35 ± 0.04^{bc}
	SA 2.0		7.14 ± 0.04^{ab}	7.42 ± 0.05^{ab}	7.10 ± 0.06^{c}	6.22 ± 0.02^{cd}
	Control		7.20 ± 0.03^{a}	7.46 ± 0.06^{a}	7.04 ± 0.04^{c}	6.20 ± 0.01^{d}
Juice pH	CH 1.0 + SA 2.0	4.23 ± 0.01 ns	4.34 ± 0.02^{b}	4.38 ± 0.03^{bc}	4.41 ± 0.02^{bc}	4.44 ± 0.01^{bc}
	CH 2.0 + SA 2.0		4.29 ± 0.01^{c}	4.33 ± 0.02^{c}	4.36 ± 0.03^{c}	4.39 ± 0.02^{c}
	CH 1.0		4.39 ± 0.02^{a}	4.44 ± 0.02^{a}	4.47 ± 0.02^{ab}	4.51 ± 0.04^{a}
	CH 2.0		4.37 ± 0.01^{ab}	4.42 ± 0.01^{ab}	4.45 ± 0.03^{ab}	4.49 ± 0.02^{ab}
	SA 2.0		4.40 ± 0.02^{a}	4.45 ± 0.02^{a}	4.48 ± 0.02^{a}	4.53 ± 0.01^{a}
	Control		4.42 ± 0.02^{a}	4.47 ± 0.01^{a}	4.50 ± 0.01^{a}	4.55 ± 0.03^{a}

Data are expressed as mean ± SE of quadruplicate assays. Values in same column with different letters indicates statistically significant differences at $p \leq 0.05$

process [26]. The increase in RI in control fruit over 67 and 20 days cold and supermarket storage conditions, was ~ 2.0 and 2.5 times higher than fruit coated with CH 2.0% + SA 2.0 mM. Similar findings were reported by Lo'ay and Taher [22] in guava, where lower SSC/ TA was recorded in CH + SA treated fruit in comparison to untreated fruit.

Surface colour

Peel colour is an important attribute in terms of quality assessment and a major criterion determining consumer acceptance. The surface lightness (*L** value) of pear fruit increased as the ripening advanced under both cold and supermarket storage conditions (Tables 1, 2). The increase in

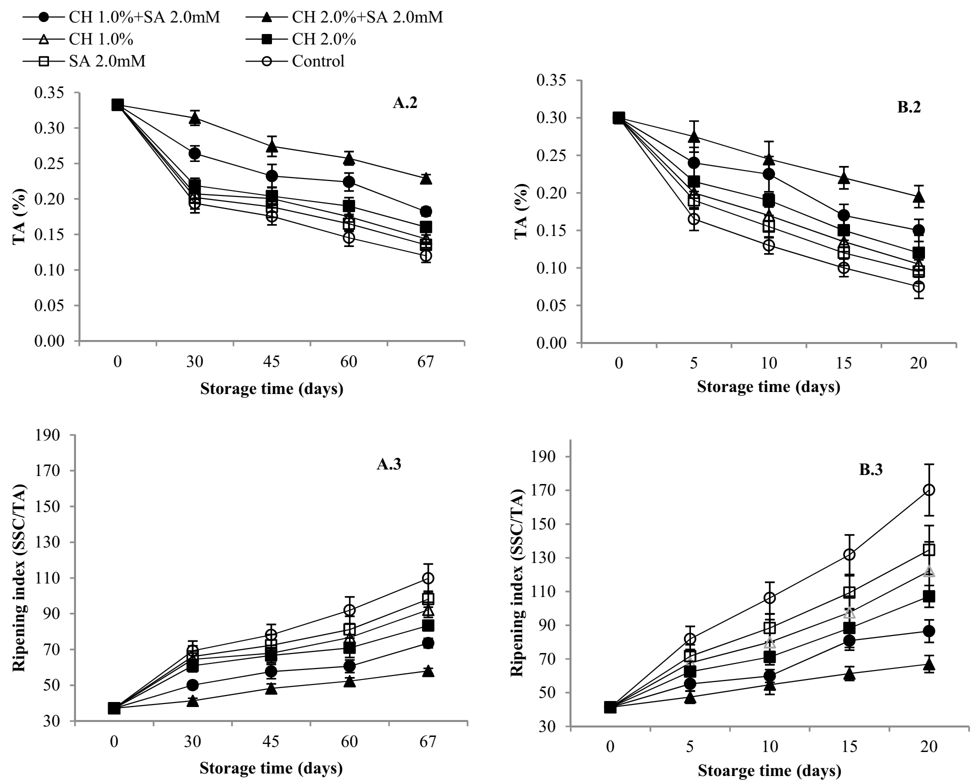

Fig. 2 TA and Ripening index (SSC/TA) in pear fruit coated with CH or SA alone and CH + SA during **a** cold storage conditions (0 – 1 °C, 90 – 95% RH) for 67 days and **b** supermarket storage at 20 – 22 °C, 80 – 85% RH for 20 days. Data is expressed as mean of quadruplicate sample ± standard errors. Vertical bars represent standard errors of means ($p \leq 0.05$)

*L** value in composite coated fruit was slower as compared to individual CH or SA treatments. From the day of harvest to 67 days of cold storage period the lowest rise in *L** value (65.16 to 69.28) was noted in CH 2.0% + SA 2 mM coated fruit, while the maximum hike (65.16 to 73.14) was noted in control fruit. While the rise in *L** value in fruit stored under supermarket conditions was slightly higher as compared to cold stored fruit. During 20 days storage period the maximum rise (16.94%) in *L** value was registered in control fruit whereas minimum *L** value (12.14%) was recorded in CH 2.0% + SA 2 mM coated fruit.

Similarly, the colour values of *a** and *b** coordinates increased gradually with the progression of storage period irrespective of the coatings or storage conditions (Tables 1, 2). Under both storage conditions, the rise in *a** and *b** colour value in composite CH + SA coated fruits were slower as compared to CH or SA alone. Whereas the maximum rise in *a** and *b** value was registered in control fruit over 67 (58.22% and 10.91%) and 20 days (64.87% and 16.94%) of cold and supermarket storage conditions. Moreover, at the end of 67 and 20 days storage period, minimum *a** (− 5.72 and − 4.95, respectively) and *b** (42.53 and 43.87, respectively) values were registered in fruit with CH 2.0% + SA 2 mM coatings. The probable reason behind the slow transition in colour in composite coated fruit is the decreased permeation of oxygen by CH film on the surface and increased CO_2 levels which in turn interacts with the ethylene binding sites and decreases the ethylene evolution [24]. Also, the sustained release of SA regulates ethylene synthesis, thereby reducing the metabolic breakdown of chlorophyll pigments and the unmasking of carotenoids responsible for yellowness in fruit [27].

Sensory quality (SQ)

Sensory evaluation is an important attribute of fruit quality estimation and provides a better understanding of the role of sensory traits in consumer acceptance as well as food preferences. SQ in pear is generally defined in terms of taste, aroma, textural and visual aspects thus determining the overall acceptability of the fruit [28]. SQ rating of pears increased during the early phase of ripening regardless of treatments as well as storage conditions. The reason for the rise in SQ rating might be attributed to the excellent visual as well as textural attributes of fruit during the initial phase of ripening. Also, an increase in sugars level combined with the decrease in acidity leads to an ideal SSC/TA blend imparting an overall flavour to the fruit. While at later stages of ripening, the SQ declined as the fruit loses its visual quality by the breakdown of green colour chlorophyll pigments [24]. Also, the decline in textural quality is caused by cellular disintegration of cellulosic and pectic substances accompanied by moisture loss leading to fruit softening and shrivelled appearance [29]. Moreover, the taste and aroma of the fruit are affected because of the complete utilization of sugars and acids as a substrate for respiration which disturbs the sugar-acid ratio thus leading to low SQ scores as well as consumer appreciation [30, 31]. Under cold storage conditions (Fig. 3), control fruit and SA treated fruit scored highest SQ on the 30th day of storage, while CH + SA and single CH coated fruits received maximum SQ scores up to 45 days of storage, followed by a decline. At the end of 67th day of storage, CH 2.0% + SA 2 mM coated fruit maintained the maximum SQ (7.10), while the control fruit scored the lowest (6.05). Under supermarket conditions (Fig. 4), SQ was maintained for a shorter period of time as fruit with single CH coat or SA dip and control fruit scored maximum on 5th day of storage. While in composite coated fruit SQ rating increased up to 10 days of storage, followed by a decline. Similar to the cold storage conditions the maximum SQ scores were received by fruit coated with CH 2.0% + SA 2 mM whereas the control fruit received the lowest score (4.56) from the panellists for all the SQ parameters. The efficacy of composite coatings in retention of overall acceptability in pear fruit over 67 and 20 days storage period might be attributed to the excellent film forming ability of CH imparting glossiness to the fruit which not only enhances the cosmetic appearance of fruit but also modifies the internal atmosphere [32, 33]. CH loaded with SA exhibits an anti-senescence effect and slows down various physiological and biochemical changes associated with fruit ripening. Our findings concurred with the results of Shen and Yang [11] in grape berries, where CH + SA treated berries attained maximum sensory scores as compared to single CH or SA and control.

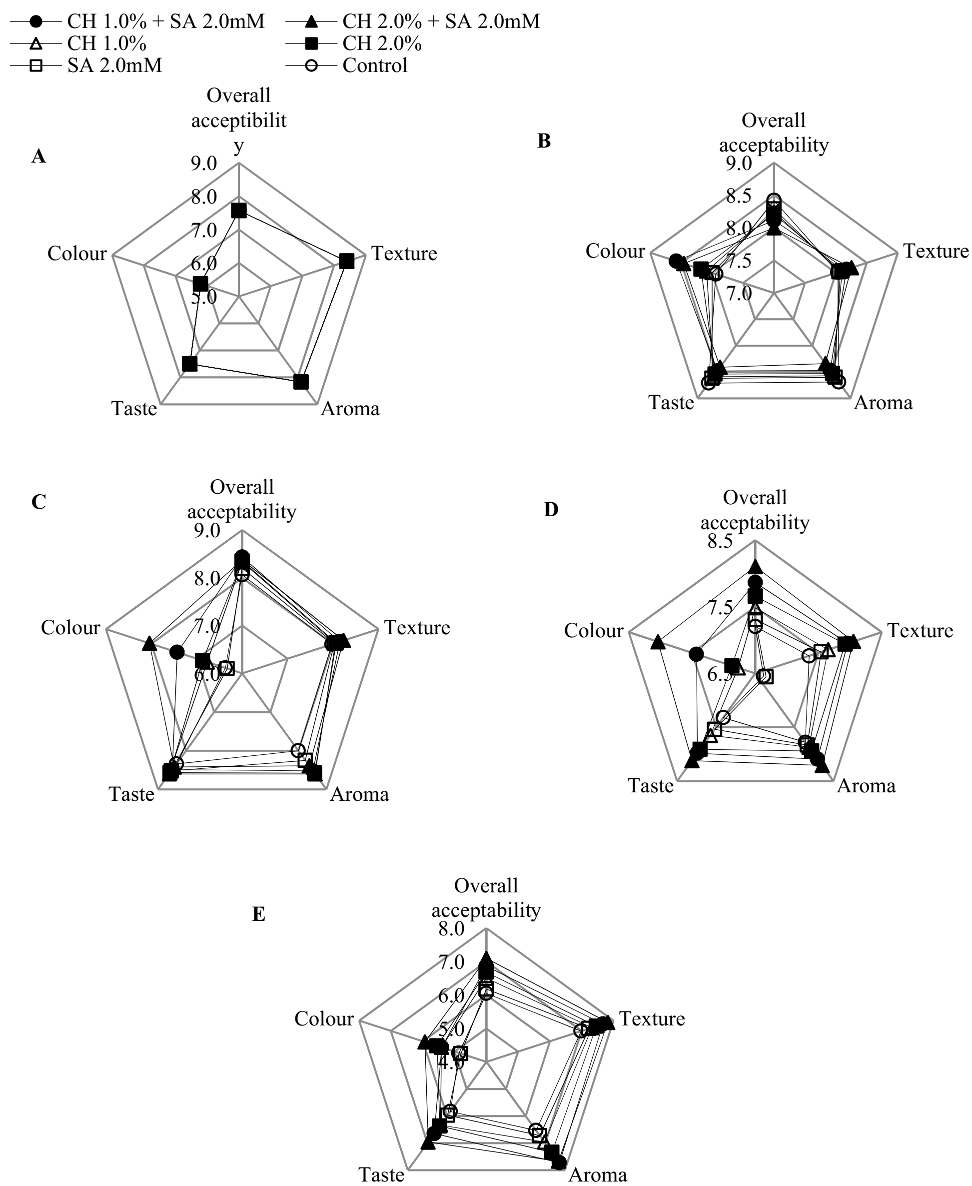

Fig. 3 Variation in sensory attributes (texture, aroma, taste, colour and overall acceptability) rating on 9-point Hedonic scale in pear fruit coated with CH or SA alone and CH + SA during **A** 0, **B** 30, **C** 45. **D** 60, and **E** 67 days of cold storage conditions at 0 – 1 °C, 90 – 95% RH

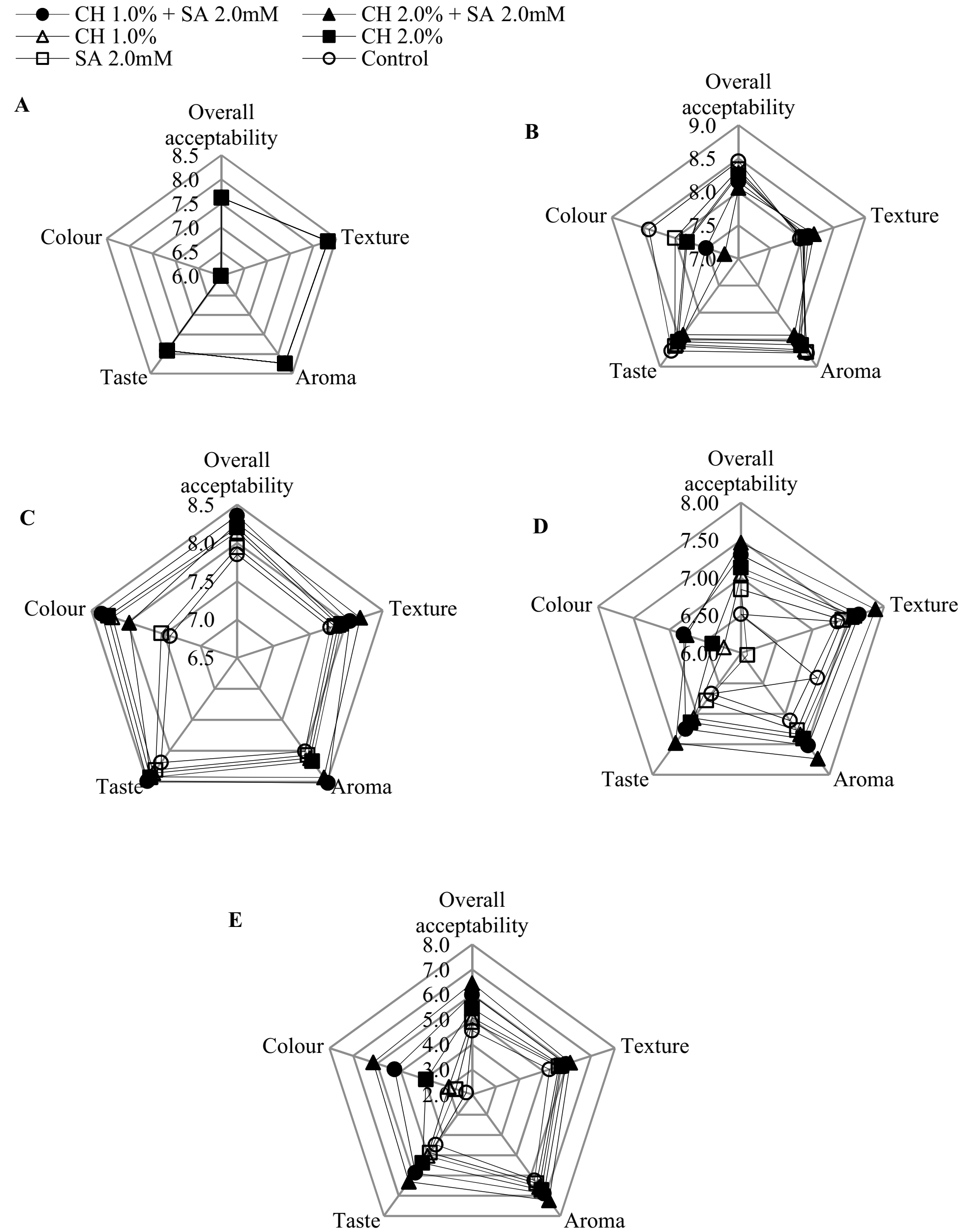

Fig. 4 Variation in sensory attributes (texture, aroma, taste, colour and overall acceptability) rating on 9-point Hedonic scale in pear fruit coated with CH or SA alone and CH + SA during **A** 0, **B** 5, **C** 10, **D** 15, and **E** 20 days of supermarket storage at 20 – 22 °C, 80 – 85% RH

Conclusion

Results from the present study reflected the ability of composite CH + SA coatings in delaying the changes in fruit quality attributes related to ripening and demonstrated a good potential in maintaining the overall acceptability of fruit up to 67 and 20 days of cold and supermarket storage conditions, respectively. Composite coatings maintained the green colour of fruit for an extended period of time as compared to pure CH or SA and control fruit. Overall, CH 2.0% + SA 2.0 mM coating was most efficient in the postponement of fruit ripening process and retained superior quality attributes in pears in terms of SSC, sugars, TA, and juice pH. Thus, SA incorporation in CH coatings proved an effective approach and offers a promising alternative to be commercialized as an environment friendly formulation in quality preservation and extension of storage life of pear fruit. Further investigations are needed for the evaluation of the microscopic structural morphology of CH + SA coated and uncoated pear fruit to gain a better understanding of the potential benefits of composite coatings.

Acknowledgements The authors are thankful to Punjab Agricultural University, Ludhiana, India for providing the necessary research facilities.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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