**Acta Alimentaria** 52 (2023) 2, 163–176
DOI: 10.1556/066.2022.00203

AKADÉMIAI KIADÓ

# Optimisation of edible coating conditions using statistical Response Surface Methodology for shelf life extension of fresh-cut guava

J. Kumari and Pooja*

Department of Microbiology, PAU, Ludhiana-141004, India

## ORIGINAL RESEARCH PAPER

Received: October 18, 2022 • Accepted: April 18, 2023
Published online: June 2, 2023


**ABSTRACT**

In the present study, six different edible coatings were evaluated to assess their microbicidal efficiency on pre-treated disinfected fresh cut guava. Among all coatings viz. alginate, pectin, carboxy methylcellulose, carrageenan, and starch, chitosan showed significant microbial growth inhibition and preservation of physico-chemical characteristics of fresh cut guava. Further, optimisation of coating parameters i.e. concentration (% w/v) and dipping time (min) was performed using Response Surface Methodology. It revealed that the fresh-cut guava dipped in 1% (w/v) chitosan for 3 min had desirability level of 91% and extension of its shelf life up to 9 days, as compared to 5 days shelf life of uncoated fresh-cut guava, maintaining all its physico-chemical parameters and microbial growth under the permissible level. Validation of optimised conditions was conducted at 5.0 kg scale that resulted in firmness of 1.90 (kg), 2.6 g/100 g sugars content, 8.0 °Brix total soluble solids content, 3.4 pH, 4.1 log CFU $g^{-1}$ total plate count, 3.1 log CFU $g^{-1}$ yeast and moulds count, and 3.1 log CFU $g^{-1}$ total coliforms count on fresh-cut guava at 9th day of refrigeration storage. Shelf life analysis revealed that chitosan coated fresh cut guava can stay fresh till 10th day under refrigeration with maintaining all its nutritive, microbiological, and sensory properties in the acceptable range.

**KEYWORDS**

edible coatings, fresh-cut guava, pre-treatment, optimisation, chitosan

* Corresponding author. E-mail: poojanikhanj@pau.edu, poojanikhanj.217@gmail.com

## 1. INTRODUCTION

Fruits are an essential part of our daily diet and are high in demand nowadays. They are considered to be the pool of vitamins, minerals, flavonoids, antioxidants, fibre, and flavours. Nowadays, fresh-cut fruits are in great demand among the consumers since they are ready to eat, fresh, and highly nutritious. International fresh-cut Produce Association (IFPA) defines fresh-cut fruits as those products, which have undergone cutting, peeling, or trimming to convert them into 100% useable product, which is further packed and offered to the consumers to provide them with highly nutritious products. The most predominant factors determining the quality of fresh products are their texture, flavour, colour, nutritional value, appearance, and microbial safety. These quality factors highly depend upon the ripening stage of the plant, stage of maturity, plant variety, and harvesting conditions (Lin and Zhao, 2007). The main reason behind the quality loss of fresh-cut fruit includes microbial growth, rapid deterioration rates, and dehydration (Musacchi and Serra, 2018) that is also related to the weight loss (Guerreiro et al., 2017). Most common inhabitants of fresh cut fruit surfaces include *Listeria monocytogenes*, *Salmonella* spp., *Cryptospiridia* spp., *Campylobacter* spp. and *E coli* O157: H7, etc. Guava (*Psidium guajava* L.) is a delicious fruit inherent to Central and South America. Punjab ranks sixth in being the largest guava producing state in the country with an estimated production of 0.18 million metric tonnes of guava from an area of 0.008 million hectares (NHB, 2015). Various approaches used for quality preservation of fresh cut fruits that include disinfection treatments, modified atmospheric packaging (MAP), controlled atmosphere, low-temperature storage, and use of radiation are known methods to reduce harmful changes like colour loss, microbial growth, and dehydration in the fresh-cut fruits and vegetables. Edible coatings are one of the post-harvest management techniques, which aid the improvement of shelf life and quality of fruits (Kumar and Bhatnagar, 2014). The effectiveness of coating material depends on temperature, thickness, alkalinity, type of coating, the variety of fruit, and the storage conditions (McHugh and Senesi, 2000). Due to less oxygen, the rate of ethylene production declines and water loss is minimised in coated fruit and vegetables. Hence, the coated fruit remains fresh, firm, and nutritious for a longer period. Edible coatings serve as a conveyance for delivering active components, flavours, drugs, and nutraceuticals (Wongphan and Harnkarnsujarit, 2020). Gum from a variety of sources is used and has been found to be an effective coating material. Such types of gum include those obtained from *Aloe vera* (Benitez et al., 2013), basil seed, locust bean (Rojas-Argudo et al., 2009). Banasaz et al. (2013) used Psyllium seed gum as edible coating for fresh-cut 'Red Delicious' apples and also made a comparison with chitosan and pectin coatings. Olivas et al. (2007) reported on the effectiveness of alginate coatings in extending the shelf life of fresh-cut 'Gala' apples without causing any anaerobiosis. Various researchers utilised and studied the potential of edible coatings on different types of fruit and vegetables alone or along with some antimicrobial agents to enhance the shelf life of the fresh cuts during storage and retailing of fresh cut fruit and vegetables.

Therefore, the present study is designed for screening, optimising and evaluating of the different types of edible coatings over the fresh-cut guava in order to develop a standardised protocol for its coating to extend the shelf life under refrigeration conditions.

# 2. MATERIALS AND METHODS

## 2.1. Materials

Guava cultivars (Punjab varieties) were obtained from the local market of Ludhiana, Punjab. Healthy, ripened, and equally sized pieces were selected after hand sorting and discarding defective fruits. After sorting, the fruit were washed with potable water to remove dirt from the surface, the calyx was removed and the fruits were cut into small equal sized pieces with a sterilised knife (wiped with 90% ethanol) on sterilised chopping board.

## 2.2. Selection of fruits and coating

Selection of ripened pieces based upon the TSS, firmness, and maturity index of the fruits. Thereafter, the fresh cut guava pieces were disinfected with 100 ppm sodium hypochlorite solution by dipping for 30 min at 10 °C according to a standardised protocol (Saini, 2021). Six different edible coatings, namely alginate, chitosan, pectin, carboxy methylcellulose, starch, and carrageenan, were taken for the research study on the basis of their different biochemical properties. Seven different treatments were planned including an uncoated control and six treatments with different coatings with their preparation methods as follows:

T1: Control (washing FCF with distilled water only)
T2: Alginate: Alginate coating solutions were prepared by mixing sodium alginate (2% w/v) powder in distilled water while heating on a hot plate for 10 min at 70 °C until the mixture was clear. Thereafter, glycerol (2% v/v) was added in the solution. When cooled, it was used to coat the freshly cut fruit (Tapia et al., 2008).
T3: Chitosan: The chitosan solution (1%) was prepared by slowly adding 100 mL (1% w/v) of citric acid solution having pH of 3.5–4.0 to 1 g of chitosan in a 200 mL beaker, then stirring upon a magnetic stirrer until it became clear (Qi et al., 2011).
T4: Pectin: Pectin coating solution was prepared by dissolving pectin (2 g/100 mL water) powder in distilled water while heating at 70 °C with stirring until the solution was clear. Glycerol was also added as a plasticiser to the solution of pectin (Oms-Oliu et al., 2008).
T5: Carboxymethyl cellulose (CMC): Coating solution was prepared by mixing CMC powder in distilled water (1% w/v) followed by heating at 85 °C for 30 min with stirring until the solution was clear. 2.5 mL of glycerol was added as a plasticiser (Saba and Sogvar, 2016).
T6: Starch: Aqueous suspensions of corn starch 5% (w/w) was prepared and gelatinised at 95 °C for 30 min in thermostatic water bath by continuous mixing. After gelatinisation, the suspension was cooled to 50 °C and 0.28 g glycerol per gram of corn starch (dry basis) was added as plasticiser to the suspension (Garcia et al., 2006).
T7: Carrageenan: 2.0% (w/v) of carrageenan powder was mixed with distilled water while heating at 80 °C for 10 min and stirring continuously using a magnetic stirrer. The pH of the solution was set to 5.6 with 5% w/v anhydrous citric acid. Later on glycerol (2% v/v) was added to the solution. The final volume of the solution was made to 500 mL (Lin et al., 2017).

## 2.3. Optimisation of coating conditions using statistical design

The coatings were freshly made and freshly cut guava slices were dipped in the coating solutions of different concentrations (1–5%) for different time interval (3–15 min) (Table 1) according to

*Table 1.* Process design for optimisation of coating conditions

| Run | Concentration | Dipping time |
|---|---|---|
| 1 | 5 | 15 |
| 2 | 3 | 9 |
| 3 | 3 | 9 |
| 4 | 3 | 9 |
| 5 | 3 | 17.4853 |
| 6 | 0.171573 | 9 |
| 7 | 1 | 3 |
| 8 | 5 | 3 |
| 9 | 3 | 9 |
| 10 | 3 | 0.514719 |
| 11 | 5.82843 | 9 |
| 12 | 3 | 9 |
| 13 | 1 | 15 |

the statistical design created by using Response Surface Methodology (RSM) under Central Composite Rotable Design (CCRD); followed by air drying for 15 min before packing them in air tight food grade polyethylene terephthalate (PET) containers. Slices immersed in distilled water were taken as control. Control (uncoated) and coated samples were stored under refrigeration conditions at 5–7 °C for 1 week or till deterioration of the samples. Based on efficacy in controlling microbial population, edible coating showing maximum microbial inhibition without altering the physicochemical properties of fresh cut guava was further selected for optimisation studies viz. dipping time and concentration of the coating.

An experimental set of 13 runs having different combinations of concentration of coating and dipping time was carried out using 100 mL of coating solution for 250 g of fresh cut guava. Optimal conditions in terms of concentration (% w/v) and dipping time (min) that inhibit microbial growth with maintaining physicochemical properties of fresh cut guava during its storage were selected. Seven parameters, namely pH, total soluble solids (TSS), firmness, total sugars, ascorbic acid, microbial count in terms of total plate count (TPC), yeasts and moulds (Y&M), and total coliforms were estimated.

## 2.4. Analytical methods

pH was determined using a bench top model pH meter. Total soluble solids contents were determined by using an Erma hand refractometer ranging from 0 to 32 °B. Firmness was measured by using a Penetrometer device. Total sugars contents were calculated using the phenol sulphuric acid method of Dubois et al. (1956). Ascorbic acid was determined using 2, 6-dichlorophenol indophenol dye (AOVC, 1966). The quantitative assay of the microbial count in coated and uncoated samples was carried out by serial dilution technique. Plate count agar, yeast and mould agar, and Eosin Methylene Blue agar (Sisco Research Laboratories Pvt Ltd.) were used for the microbial enumeration on the fresh cut guava pieces using serial dilution technique. The microbial count was noted after 48–96 h of incubation period at the respective incubation temperature of each plate.

$$\text{Microbial colonies } \left(\text{CFU g}^{-1}\right) = \frac{\text{No. of colonies} \times \text{Dilution factor}}{\text{Weight of sample (g)}}$$

The values were later converted into log values (CFU $g^{-1}$) for further analysis of results.

Sensory analysis was performed by a semi trained panel of 10 judges that evaluated the sensory attribute on the basis of aroma, flavour, appearance, colour, texture, and texture and taste on a 9 point hedonic scale. Scores given by the 10 panellists on each interval day were statistically analysed and mean values were obtained for all quality parameters.

## 3. RESULTS AND DISCUSSIONS

Freshly cut guava pieces were disinfected with sodium hypochlorite solution of 100 ppm by dipping for 30 min at 10 ± 1 °C to reduce microbial load. Results revealed that microbial load was reduced by 0.44 log CFU $g^{-1}$ of total plate count, 0.80 log CFU $g^{-1}$ of yeasts and moulds, and 0.70 log CFU $g^{-1}$ total coliforms after disinfection. The pre-treated pieces were coated with different coatings, viz. alginate, chitosan, pectin, carboxy methylcellulose, starch, and carrageenan according to the literature (Benitez et al., 2013). All coatings were able to inhibit the microbial growth as compared to uncoated fruit with maintaining physicochemical and sensory properties of the fresh cut guava. Evaluation of the coatings showed that alginate, pectin, and chitosan showed microbial inhibition over fresh cut guava. However, chitosan coating showed maximum microbial inhibition with 4.30 log CFU $g^{-1}$ TPC, 2.80 log CFU $g^{-1}$ Y&M, and 2.90 log CFU $g^{-1}$ coliform count at the 9th day of storage period, whereas the control (uncoated) samples had 5.39 log CFU $g^{-1}$ TPC, 4.30 log CFU $g^{-1}$ Y&M, and 4.07 log CFU $g^{-1}$ coliform count at the same time (Kumari, 2022). The microbial count observed in coated samples was within acceptable limits as per FSSAI and USFDA guidelines even after 9 days of storage. Chitosan gave significantly better results in terms of microbial inhibition over fresh cut guava as compared to other coatings used. Hence, chitosan was selected for further optimisation studies of coated fresh cut guava. Pre-treated disinfected freshly cut guava pieces were dipped into chitosan solution of variable concentrations for different periods of time according to the RSM plan. Responses were analysed in terms of microbial parameters, i.e. TPC, Y&M, and total coliforms count, along with physicochemical parameters, namely firmness, total sugars content, TSS, and pH (Table 2).

Minimum log values for TPC, Y&M, and total coliforms counts were reported at the concentration of 1% (w/v) chitosan solution with dipping time of 5.32 min for fresh cut guava after storage under refrigeration for 9 days keeping all physico-chemical and nutritive properties maintained. All model values of ANOVA table analysis (Table 3) were significant and lack of fit was found to be non-significant for all parameters with adjusted $R^2$ and predicted $R^2$ being in reasonable agreement. Multiple regression analysis of the model leads to derivation of Equations (a) to (g), where C depicts concentration of the disinfectant and D depicts dipping time:

Final equation in terms of actual factors for pH:

$$\text{pH} = +1.49127 + 0.785533\ \text{C} + 0.201070\ \text{D} - 0.037500\ \text{C} * \text{D} - 0.051250\text{C}^2 - 0.001528\ \text{D}^2 \quad \text{(a)}$$

*Table 2.* Effect of concentration and dipping time of fresh cut guava with chitosan coating on physicochemical and microbial parameters

| Run | Conc (% w/v) | Dipping time (min) | pH | TSS (°Brix) | Firmness (kg) | Total sugars (g/100 g) | TPC (log CFU $g^{-1}$) | Y&M (log CFU $g^{-1}$) | Coliforms (log CFU $g^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.17 | 9 | 3.4 | 8.1 | 1.3 | 3.0 | 4.0 | 3.2 | 3.0 |
| 2 | 1 | 3 | 2.5 | 8.5 | 1.9 | 2.7 | 4.0 | 3.3 | 3.1 |
| 3 | 3 | 17.4 | 4.4 | 7.1 | 0.0 | 3.0 | 4.2 | 3.2 | 3.2 |
| 4 | 5 | 15 | 4.1 | 6.7 | 0.6 | 3.2 | 4.1 | 3.2 | 3.3 |
| 5 | 3 | 9 | 4.0 | 6.6 | 1.9 | 3.4 | 4.2 | 3.3 | 3.2 |
| 6 | 1 | 15 | 4.3 | 7.4 | 0.4 | 3.2 | 4.2 | 3.1 | 3.0 |
| 7 | 3 | 9 | 4.0 | 6.5 | 1.8 | 3.2 | 4.1 | 3.4 | 3.3 |
| 8 | 5.8 | 9 | 4.0 | 6.3 | 2.1 | 3.1 | 4.1 | 3.3 | 3.3 |
| 9 | 5 | 3 | 4.1 | 6.7 | 2.9 | 3.0 | 4.2 | 3.4 | 3.2 |
| 10 | 3 | 9 | 4.1 | 6.5 | 1.8 | 3.3 | 4.1 | 3.4 | 3.2 |
| 11 | 3 | 9 | 4.2 | 6.5 | 1.8 | 3.3 | 4.1 | 3.4 | 3.2 |
| 12 | 3 | 9 | 4.0 | 6.6 | 1.9 | 3.4 | 4.1 | 3.4 | 3.2 |
| 13 | 3 | 0.51 | 3.6 | 7.8 | 2.5 | 2.7 | 4.2 | 3.4 | 3.2 |

TSS: Total soluble solids; TPC: Total plate count; Y&M: Yeast and moulds; CFU $g^{-1}$: Colony forming units per gram

*Table 3.* RSM responses in terms of model values, adjusted $R^2$, and predicted $R^2$ for physicochemical and microbial parameters of fresh cut coated guava

| Parameters | Model values | $R^2$ values | Predicted $R^2$ values | *P* value |
|---|---|---|---|---|
| TSS (° Brix) | 608.77 | 0.9977 | 0.9948 | 0.0014 |
| TPC (log CFU $g^{-1}$) | 7.93 | 0.8500 | 0.6367 | 0.0084 |
| pH | 27.00 | 0.9507 | 0.7095 | 0.0204 |
| Firmness (kg) | 900.42 | 0.9984 | 0.9906 | 0.0092 |
| Y&M (log CFU $g^{-1}$) | 14.48 | 0.9118 | 0.7165 | 0.0014 |
| Coliforms (log CFU $g^{-1}$) | 16.16 | 0.9203 | 0.8126 | 0.0010 |
| Sugars (g/100 g) | 15.78 | 0.9185 | 0.6645 | 0.0032 |

Final equation in terms of actual factors for firmness:

$$\text{Firmness} = +3.33424 + 0.923474\ C + 0.101080\ D - 0.037500\ C * D - 0.044062\ C^2 - 0.018090\ D^2 \quad (b)$$

Final equation in terms of actual factors for TSS:

$$\text{TSS} = +10.26291 - 1.01660\ C - 0.339791\ D + 0.022917\ C * D + 0.082500\ C^2 - 0.012639\ D^2 \quad (c)$$

Final equation in terms of actual factors for total sugars:

$$\text{Total sugars} = +2.10956 + 0.258214\ C + 0.150297\ D - 0.006250\ C * D - 0.029062\ C^2 - 0.006007\ D^2 \quad (d)$$

Final equation in terms of actual factors for TPC:

$$\text{TPC} = +3.89848 + 0.123839\ \text{C} + 0.000833\ \text{D} - 0.006250\ \text{C} * \text{D} - 0.008750\ \text{C}^2 + 0.001111\ \text{D}^2 \quad \text{(e)}$$

Final equation in terms of actual factors for Y&M:

$$\text{Y\&M} = +3.17964 + 0.128214\ \text{C} + 0.008899\ \text{D} + 5.46177\text{E} - 17\ \text{C} * \text{D} - 0.017812\ \text{C}^2 - 0.001285\ \text{D}^2 \quad \text{(f)}$$

Final equation in terms of actual factors for coliforms:

$$\text{Total coliform} = +3.04858 + 0.075892\ \text{C} - 0.004375\ \text{D} + 0.004167\ \text{C} * \text{D} - 0.010312\ \text{C}^2 - 0.000451\ \text{D}^2 \quad \text{(g)}$$

Similarly, Fig. 1 (a) to (g) represent the effect of dipping time and concentration of the coating (independent variables) on the pH, firmness, total sugars, TSS, and microbial counts (TPC, Y&M and total coliforms; dependent variables). It has been observed that with increase in the concentration of the coating the pH also increased, while TSS and total sugars contents decreased due to increased levels of citric acid, in which the coating has been prepared. However, microbial count of fresh cut guava decreased with the increase in concentration up to a level of 2% (w/v). With increase in the dipping time the pH increased, while firmness decreased and sugar content increased after a period of 12 min. However, microbial counts did not follow any particular trend with the increase of the dipping time for chitosan coating.

Numerical optimisation of the RSM experiment was done keeping in mind that log values of microbial counts (TPC, Y&M, and total coliforms) should be at minimum and physicochemical parameters, namely firmness, TSS, pH, and total sugars, should be kept in range. Results indicated that the fresh-cut guava dipped for 5.324 min in 1% w/v concentration of chitosan was optimal as coating conditions with the desirability of 91%. Optimised results were validated upon a 5 kg fruit scale (in containers of 500 g containing 300 g of fresh cut guava) that resulted in firmness of 4.2 (kg), sugars 2.6 g/100 g, TSS 8.0 °Brix, pH 3.4, ascorbic acid 195.4 mg/100 g, TPC 4.1 log CFU $g^{-1}$, Y&M 3.1 log CFU $g^{-1}$, and total coliforms 3.1 log CFU $g^{-1}$ in fresh cut guava. Chitosan is known to form smooth and shiny coatings without any crack formation on the surface (Ribeiro et al., 2007).

Shelf life analysis of pre-treated fresh cut chitosan coated guava under optimised coating conditions (1% chitosan solution for 5 min) was studied. Microbial analysis of uncoated samples of guava had counts of 3.53, 2.21, and 2.34 log CFU $g^{-1}$ for TPC, Y&M, and total coliforms, respectively, on the 0th day of storage that increased to 5.21 log CFU $g^{-1}$ TPC, 3.11 log CFU $g^{-1}$ Y&M, and 3.21 log CFU $g^{-1}$ total coliforms at the 6th day of storage (Tables 4 and 5). While the chitosan coated fresh cut guava had its microbial load within acceptable limits even after 9th–10th day of storage: 3.44 log CFU $g^{-1}$ TPC, 2.90 log CFU $g^{-1}$ Y&M, and 2.87 log CFU $g^{-1}$ coliforms (according to USFDA and FSSAI guidelines). Physicochemical parameters showed non-significant difference in values of firmness 1.95–1.86 kg, TSS 10.9–11.2 °Brix, pH 4.26–4.28, titratable acidity 0.16–0.18%, total phenols 336–340 mg/100 g and total sugars 3.20–3.23 g/100 g contents in coated fresh cut guava (Table 3). Taking into consideration microbial and physicochemical parameters, it was found that fresh cut guava was fit for consumption up to the 10th day of storage. Sensory analysis of coated and uncoated samples was carried by semi trained panel of ten judges. Sensory score of both coated and uncoated fresh cut guava at day 0 got 8 points on the hedonic scale

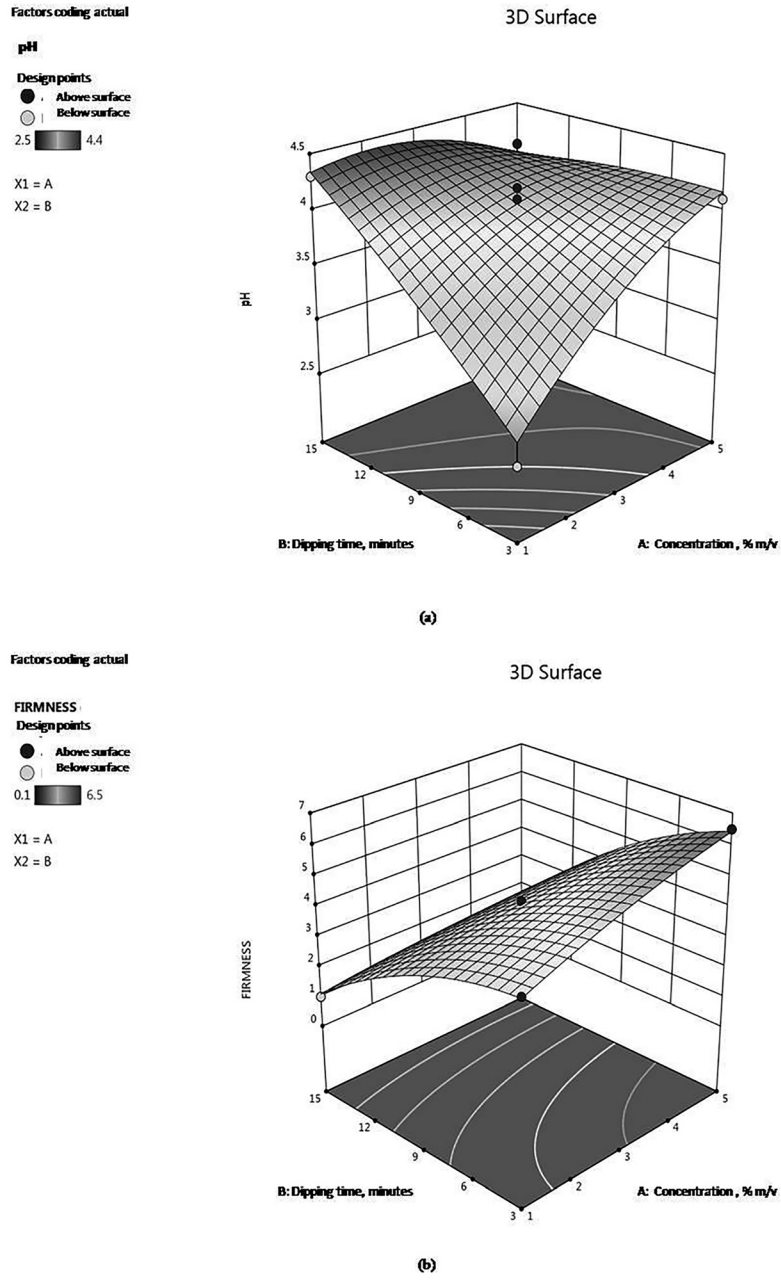
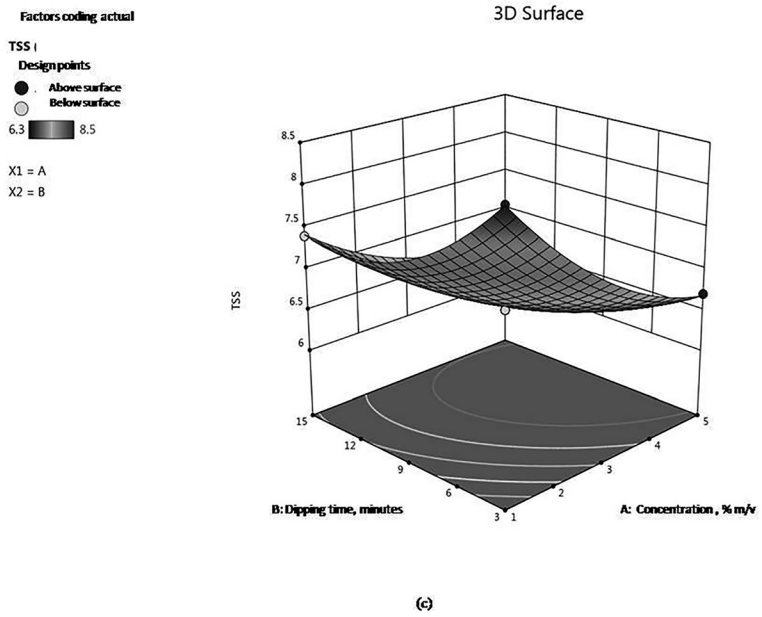
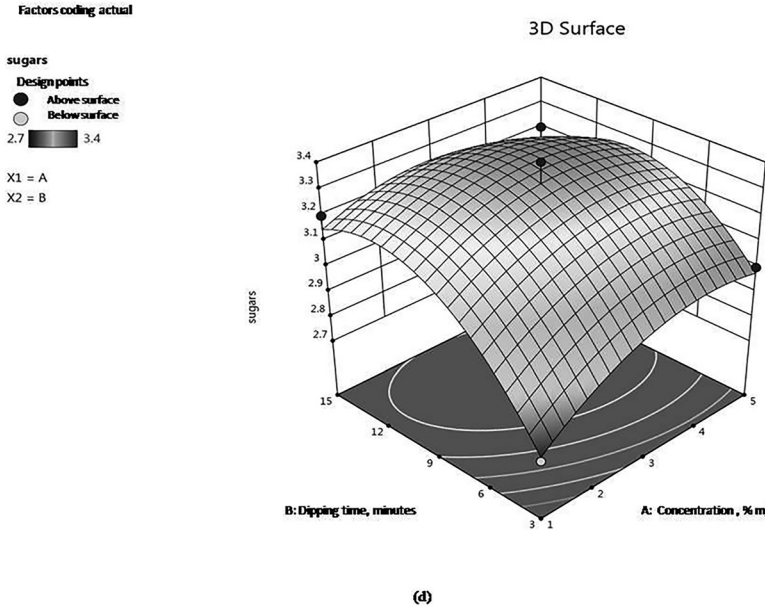



*Fig. 1.* (a) Effect of concentration and dipping time on pH; (b) firmness; (c) TSS; (d) total sugars; (e) TPC; (f) Y&M; (g) coliforms

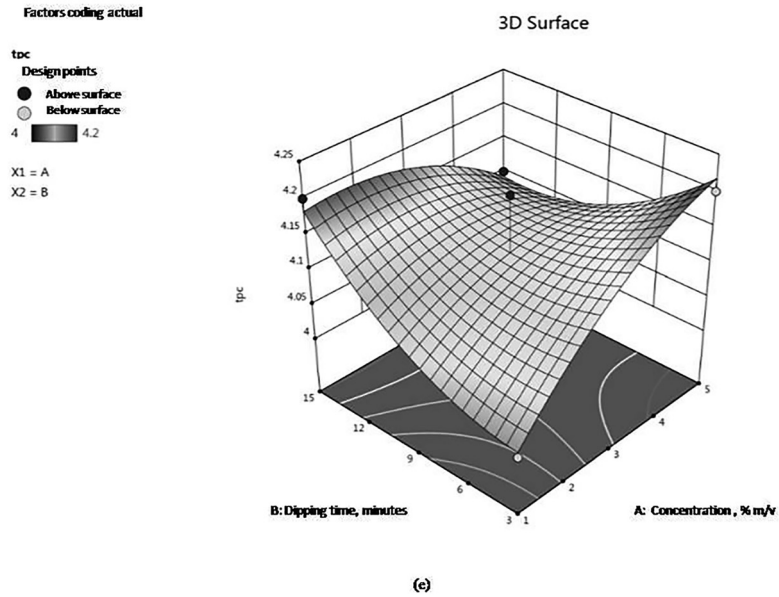



(c)

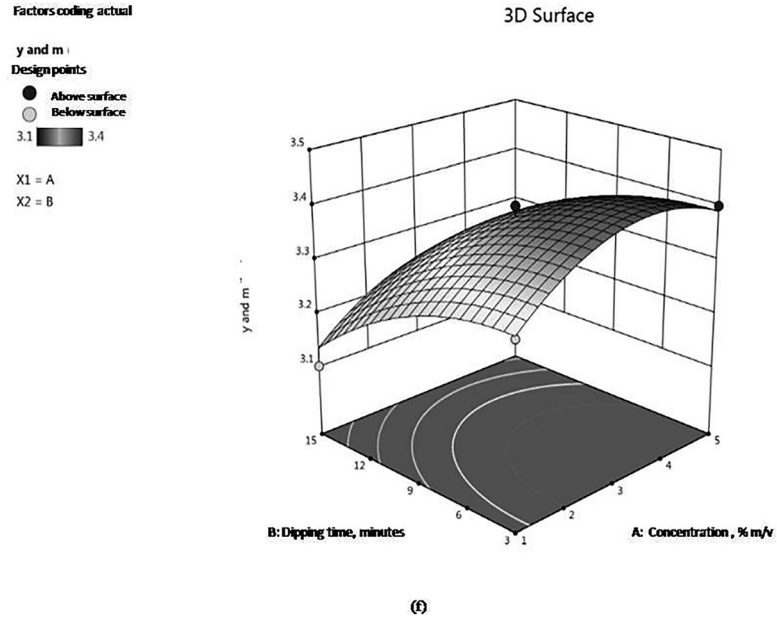



(d)

*Fig. 1.* Continued




(e)




(f)

*Fig. 1.* Continued

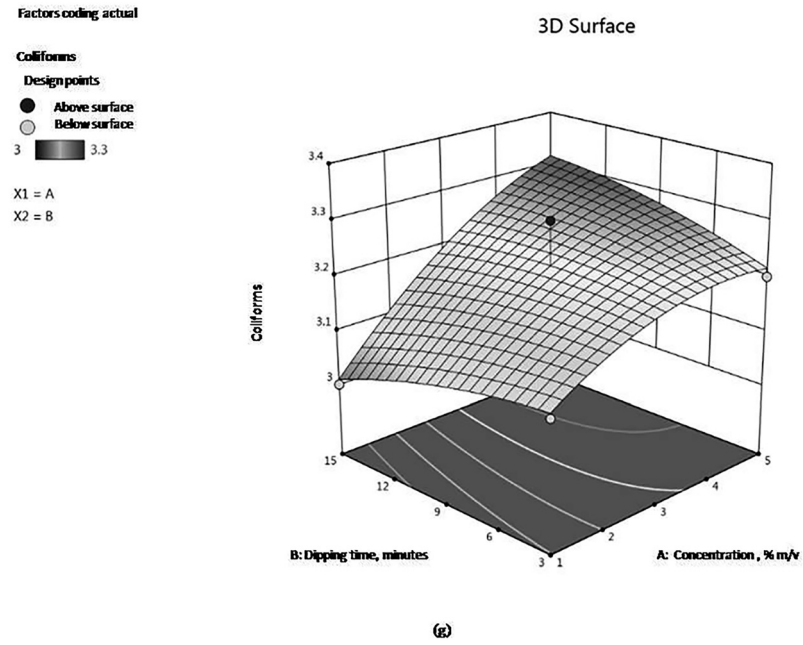



*Fig. 1.* Continued

*Table 4.* Shelf life analysis of chitosan coated fresh cut guava under refrigeration conditions

| Parameter | Coated 0 day | Storage under refrigeration at 5–7 °C (days) | | | | CD (5%) |
|---|---|---|---|---|---|---|
| | | 3 | 6 | 9 | 12 | |
| TSS (° B) | 10.9 ± 0.1 | 11.0 ± 0.1 | 11.1 ± 0.1 | 11.1 ± 0.1 | 11.2 ± 0.1 | 0.17 |
| pH | 4.27 ± 0.01 | 4.27 ± 0.01 | 4.26 ± 0.01 | 4.26 ± 0.01 | 4.26 ± 0.01 | NS |
| Titratable acidity (%) | 0.18 ± 0.01 | 0.17 ± 0.01 | 0.17 ± 0.01 | 0.16 ± 0.01 | 0.16 ± 0.01 | NS |
| Firmness (kg) | 1.9 ± 0.1 | 1.9 ± 0.1 | 1.9 ± 0.1 | 1.8 ± 0.1 | 1.8 ± 0.1 | NS |
| Total phenols (mg/100 g) | 339.0 ± 0.1 | 339.0 ± 0.1 | 338.0 ± 0.1 | 337.0 ± 0.1 | 336.0 ± 0.1 | 0.17 |
| Total sugars (g/100 g) | 3.21 ± 0.01 | 3.21 ± 0.01 | 3.22 ± 0.01 | 3.23 ± 0.01 | 3.23 ± 0.01 | NS |
| Ascorbic acid (mg/100 g) | 195.30 ± 0.05 | 195.20 ± 0.1 | 190.19 ± 0.1 | 185.16 ± 0.15 | 181.10 ± 0.1 | 0.19 |
| Ripening index (TSS/acidity) | 60.56 ± 0.01 | 64.70 ± 0.01 | 65.29 ± 0.01 | 65.30 ± 0.01 | 68.04 ± 0.01 | 1.67 |
| Weight loss (%) | 0.3 ± 0.1 | 0.3 ± 0.1 | 0.4 ± 0.1 | 0.4 ± 0.1 | 0.5 ± 0.1 | NS |
| Sensory score (out of 9) | 8 | 7 | 7 | 7 | 6 | 1.23 |

All values are means of triplicates; *NS: Non significant; CD: Critical difference at 5% level of significance

*Table 5.* Microbiological analysis of chitosan coated and uncoated fresh cut guava during shelf life studies

| Parameters | Uncoated | | | CD (5%) | Coated | | | | | CD (5%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 3rd | 6th | | 0 | 3rd | 6th | 9th | 12th | |
| TPC (log CFU $g^{-1}$) | 3.53 | 4.74 | 5.21 | 1.23 | 3.0 | 3.3 | 3.39 | 3.44 | 3.50 | 0.34 |
| Yeast and mould count (log CFU $g^{-1}$) | 2.21 | 2.38 | 3.11 | 0.89 | 1.5 | 1.77 | 2.67 | 2.90 | 3.00 | 1.22 |
| Coliform count (log CFU $g^{-1}$) | 2.34 | 2.61 | 3.21 | 1.09 | 2.0 | 2.20 | 2.39 | 2.87 | 3.32 | 1.05 |

TPC: Total Plate Count; CD: Critical difference at 5% level of significance; CFU $g^{-1}$: Colony forming units per gram

showing that treatment did not affect the sensory attributes of the sample. At the 9th day of storage, coated fresh cut guava scored 7 points that was a good sensory score with reference to physicochemical parameters from the consumers' point of view. Shelf life studies show that chitosan pre-treated fresh cut guava can be consumed till the 10th day of storage. Chitosan could retard browning, thereby maintaining sensory quality and retaining the levels of ascorbic acid, total soluble solids, and acidity in sliced Chinese water chestnuts (Pen and Jiang, 2003).

Numerous efforts have been made over the centuries to use different materials to coat fruit, which can potentially modify the internal gas composition to increase shelf life. "Semper Fresh" and "TAL Pro-Long" are commercially available coating materials that are sucrose fatty acid esters (SFAE) mixtures. Alginate coatings were effective in extending the shelf life of fresh-cut 'Gala' apples without causing any anaerobiosis (Olivas et al., 2007). Chitosan-based coating (2% w/v) could extend shelf life, thereby maintaining quality and to some extent the decay of fresh-cut mushrooms (Eissa, 2007). The application of edible coatings formulated by blending alginate and acerola puree on acerola fruit decreased weight loss, ripening rate, and decaying processes, increased ascorbic acid retention, hence, extending the shelf life of acerola fruit (Azeredo et al., 2012). The present study revealed that coating fresh cut guava with 1% (w/v) chitosan for 5.0 min was able to limit the microbial growth on the fruit during the studied storage period at refrigeration temperature of 5–7 °C. Similar results have been reported in the case of mandarin fruit coated with alginate enriched with *Fircus hirta* fruit extract (Chen and Nussinovitch, 2016).

Coating of fresh cut fruit keeps microbial growth within the acceptable limits resulting in an increase in shelf life while retaining sensory characteristics and nutritional value. Thus, chitosan coated fresh cut guava led to an increase in the shelf life of the respective fruit helping to develop the fresh cut market in Northern India.

## 4. CONCLUSIONS

Fresh cut guava's shelf life can be increased by the use of edible coatings while keeping its nutritive components intact. Disinfected (with 100 ppm sodium hypochlorite for 25–30 min) fresh cut guava showed low microbial load on the surface. Pre-treated fresh cut guava coated with 1% chitosan with dipping time of 3 min resulted in the extension of its shelf life with 4–5 days while maintaining its quality parameters and keeping its microbial load under permissible limits, helping retailers of fresh cuts to have them available to the customers for a longer period.

## ACKNOWLEDGEMENTS

The authors acknowledge Punjab Horticultural Postharvest Technology Centre and Department of Microbiology, PAU, Ludhiana for providing necessary facilities and infrastructure for conduction of studies.

## REFERENCES

Azeredo, H.M.C., Miranda, K.W.E., Ribeiro, H.L., Rosa, M.F., and Nascimento, D.M. (2012). Nanoreinforced alginate–acerola puree coatings on acerola fruits. *Journal of Food Engineering,* 113(4): 505–510. https://doi.org/10.1016/j.jfoodeng.2012.08.006.

AOVC (1966). *Methods of vitamin assay*. Association of Vitamin Chemists Inc. (Ed.) Interscience Publishers, New York. pp. 79–81.

Banasaz, S., Hojatoleslami, M., Razavi, S., Hosseini, E., and Shariaty, M. (2013). The effect of Psyllium seed gum as an edible coating and in comparison to chitosan on the textural properties and color changes of Red Delicious apple. *International Journal of Farming and Allied Sciences*, 2: 651–657.

Benitez, S., Achaerandio, I., Sepulcre, F., and Pujola, M. (2013). *Aloe vera* based edible coatings improve the quality of minimally processed 'Hayward' kiwifruit. *Postharvest Biology and Technology*, 81: 29–36.

Chen, S. and Nussinovitch, A. (2016). Permeability and roughness determinations of wax-hydrocolloid coatings, and their limitations in determining citrus fruit overall quality. *Food Hydrocolloids*, 15: 127–137.

Dubois, M., Giles, K.A., Hamilton, J.K., Rebers, P.A., and Smith, F. (1956). Colorimetric method for determination of sugars and related substances. *Analytical Chemistry*, 28: 350–356.

Eissa, H.A. (2007). Effect of chitosan coating on shelf life and quality of fresh-cut mushroom. *Journal of Food Quality*, 30: 623–645.

Garcia, M.A., Pinnoti, A., and Zaritzky, N.E. (2006). Physicochemical, water vapor barrier and mechanical properties of corn starch and chitosan composite films. *Starch*, 58: 453–463.

Guerreiro, A.C., Gago, C.M.L., Faleiro, M.L., Miguel, M.G.C., and Antunes, M.D.C. (2017). The effect of edible coatings on the nutritional quality of '*Bravo de Esmolfe*' fresh-cut apple through shelf-life. *LWT – Food Science and Technology*, 75: 210–219.

Kumar, S. and Bhatnagar, T. (2014). Studies to enhance the shelf life of fruits using *Aloe vera* based herbal coating: a review. *International Journal of Agriculture and Food Science Technology*, 5(3): 211–218.

Kumari, J. (2022). *Evaluation of edible coatings for microbiological and physicochemical quality maintenance of fresh cut fruits*. M.Sc. thesis, Punjab Agricultural University, Ludhiana.

Lin, D. and Zhao, Y. (2007). Innovation in the development and application of edible coating for fresh and minimally processed fruits and vegetables. *Comprehensive Reviews in Food Science and Food Safety*, 6(3): 60–75.

Lin, M.G., Lasekan, O., Saari, N., and Khairunniza-Bejo, S. (2017). Effect of chitosan and carrageenan based edible coatings on post-harvested longan (*Dimocarpus longan*) fruits. *CYTA Journal of Food*, 16(1): 490–497.

McHugh, T.H. and Senesi, E. (2000). Apple wraps: a novel method to improve the quality and extend the shelf life of fresh-cut apples. *Journal of Food Science*, 65(3): 480–485.

Musacchi, S. and Serra, S. (2018). Apple fruit quality: overview on pre-harvest factors. *Science Horticulturae*, 234: 409–430.

NHB (2015). World wide web source for national horticulture board data. https://nhb.gov.in/area-pro/NHB_Database_2015.pdf.

Olivas, G.I., Mattinson, D.S., and Barbosa-Canovas, G.V. (2007). Alginate coatings for preservation of minimally processed 'Gala' apples. *Postharvest Biology and Technology,* 45: 89–96.

Oms-Oliu, G., Soliva-Fortuny, R., and Martin-Belloso, O. (2008). Using polysaccharide- based edible coatings to enhance quality and antioxidant properties of fresh cut melon. *LWT – Food Science and Technology*, 41(10): 1862–1870.

Pen, L.T., and Jiang, Y.M. (2003). Effects of chitosan coating on shelf life and quality of fresh-cut Chinese water chestnut. *LWT – Food Science and Technology*, 36: 359–364.

Qi, H.P., Hu, W.Z., Jiang, A.K., Tian, M.X., and Ying, Q.L. (2011). Extending shelf life of fresh cut 'Fuji' apples with chitosan coatings. *Innovative Food Science and Emerging Technology*, 12: 62–66.

Ribeiro, C., Vicente, A., Teixeira, A., and Miranda, C. (2007). Optimisation of edible coating composition to retard strawberry fruits senescence. *Postharvest Biology and Technology*, 44: 63–70.

Rojas-Argudo, C., del Rio, M.A., and Perez-Gago. M.B. (2009). Development and optimization of locust bean gum (LBG)-based edible coatings for postharvest storage of 'Fortune' mandarins. *Postharvest Biology and Technology*, 52: 227–234.

Saba, M.K. and Sogvar, O.B. (2016). Combination of carboxy methylcellulose based coatings with calcium and ascorbic acid impacts in browning and quality of fresh cut apples. *LWT – Food Science and Technology*, 66: 165–171.

Saini, S. (2021). Optimization of pretreatment for quality maintenance of fresh-cut fruits under refrigeration conditions. M.Sc. thesis, Punjab Agricultural University, Ludhiana.

Tapia, M.S., Rojas Graü, M.A., Carmona, A., Rodríguez, F.J., Soliva-Fortuny, R., and Martin-Belloso, O. (2008). Use of alginate and gellan based coatings for improving barrier, texture and nutritional properties of fresh cut papaya. *Food Hydrocolloids*, 22: 1493–1503.

Wongphan, P. and Harnkarnsujarit, N. (2020). Characterization of starch, agar and maltodextrin blends for controlled dissolution of edible films. *International Journal of Biological Macromolecules*, 156: 80–93.