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Effect of edible coatings chitosan and calcium gluconate on shelf life and quality of mango (*Mangifera indica* L.) cv. Banganpalli

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Abstract
An experiment was conducted to study the effect of edible coatings chitosan and calcium gluconate on ascorbic acid and sugars of mango (*Mangifera indica* L.) cv. Banganpalli at College of Horticulture-Rajendranagar, SKLTSHU, Siddipet District, Telangana. The experiment was conducted with completely randomized design including six treatments with different concentrations of edible surface coatings and observations were recorded at every three days interval up to end of shelf life. Among different treatments lowest PLW (3.65%), least browning score (4.87), spoilage% (46.98), highest firmness (8.62 kg/cm^2), shelf life (17.41), highest TSS (21.86 ^{0}Brix) were recorded by T_2 - dipping in 2% edible chitosan coating, followed by T_1 - dipping in 1% edible chitosan and least was recorded on 3rd day of storage by T_6 - control. Post-harvest coating of mango fruits with chitosan has resulted in increased shelf life and quality compared to calcium gluconate and control.

Keywords: Mango, edible coating, chitosan, calcium gluconate

Introduction
Mango (*Mangifera indica* L.) is the king of fruits belongs to the family Anacardiaceae. It is considered as one of the most important tropical fruit of the world, originated in South East Asia. Mango holds special importance in India due to its origin, attachment to culture, heritage, unique taste, exotic flavour, its nutrition and extensive cultivation and it also widely accepted by other parts of the world. It has good nutritional value and is grown in tropical and sub-tropical countries around the world.

As ango is a climacteric fruit, it is necessary for us to study and have knowledge about the shelf life of mango with different treatments to decrease postharvest losses. Shelf life defines as the time period between fruit harvest and starting of fruit rot. Shelf life is a deciding factor for marketing and processing of mango. About 27% of loss has to be faced by producers and traders due to improper handling, storage or lack of technical knowledge (Zafrul *et al.*, 2020) [27].

One of the most innovative methods which hastens fruit ripening, extends the shelf life of fruits is application of edible coatings. One of the promising fruit coating agents which is being used widely is chitosan (Fekry, 2018) [9]. Chitosan a natural is produced from chitin shells of shrimp and other crustaceans by deacetylation process. Chitosan has several advantages over other polysaccharides such as bio-degradability, bio-compatibility, and no toxicity.

Chitosan and its derivatives are used for the increase of shelf life of a wide range of vegetables and fruits by impede decay. So, one of the interesting function of this biopolymer is product conservancy, because of its ability to be used as a coating material. The function of chitosan as an antimicrobial material as in ascribed to amino groups or hydrogen bonding between chitosan and extracellular polymers (Prashanth *et al.*, 2022) [18]. As a biopolymer, chitosan has excellent film-forming properties and can form a semipermeable film on fruit which may modify the internal atmosphere, as well as decrease weight loss and shrivelling due to transpiration and improve overall fruit quality.

Gluconic acid is one of the various organic acids, gluconic acid is produced by gram-negative bacteria by phosphate solubilization. Gluconic acid and its salts (gluconates) are extensively being used in agriculture as micronutrient agents as they are chelated agents they are suitable for soil, foliar applications and drip irrigation. These micronutrient gluconates are completely assimilated by crops as they are in the form of chelates, hence they are required in lower quantities compared to inorganic compounds (Elisha *et al.*, 2014; Prasanna *et al.*, 2022) [8, 17].

The use of chelated particles especially chelated gluconates is more easily absorbed by plant leaves or roots as they are rich in organic matter. In the process of chelation, the positive charge of micro-nutrients is removed and allows a neutral or slightly negative charged chelated to move through the leaf and root pores more rapidly. As these plant pores are charged negatively, positively charged micronutrients get attached at the pore entrance and becomes difficult to the plant for assimilation, when chelated micronutrients are used there will be no restriction barrier as they are neutral in charge. These micronutrient chelated gluconic acid are available in different forms like calcium gluconate, potassium gluconate, magnesium gluconate, ferrous gluconate manganese gluconate, zinc gluconate and sodium gluconate.

Chitosan is a proven edible coating in improving the shelf life of mango (Zhu *et al.*, 2008 and Zafrul *et al.*, 2020) [28, 27], research has also been done on use of calcium gluconates as edible coating in improving the quality and shelf life of guava (Fekry, 2018) [9]. In present study an effort has been made to compare chitosan and calcium gluconate as an edible surface coating to record its effect in improving shelf life and quality of mango.

Materials and Methods

The experiment was conducted at College of Horticulture, Sri Konda Laxman Telangana State Horticultural University, Rajendranagar, and Telangana during the years 2021-22 and 20122-23. Mango fruits used for research were procured from Fruit Research Station-Sangareddy, Telangana.

The experiment was conducted in completely randomized design with six treatments, three replications which includes T_1 - Dipping in 1% edible chitosan coating, T_2 - Dipping in 2% edible chitosan coating, T_3 - Dipping in 2% calcium gluconate, T_4 - Dipping in 1% edible chitosan coating + 2% calcium gluconate, T_5 - Dipping in 2% edible chitosan coating + 2% calcium gluconate, T_6 - Control.

Preparation of chitosan solution

For preparation of 1% and 2% chitosan solution dissolve 10g of chitosan powder in 0.1M 5.74ml acetic acid and 1 litre of distilled water.

Preparation of calcium gluconate solution

For the preparation of 1% and 2% calcium gluconate solution diluting 10ml of calcium gluconate in 1 liter of distilled water (Fekry, 2018) [9].

Method of Application of edible coatings

For each treatment, seven fruits were selected and the fruits were washed thoroughly under running tap water to remove the adherent dirt material. Fruits were treated with 1% and 2% chitosan solution for 10 minutes and then allowed to air dry for 20-30 minutes in the shade, similarly, fruits were dipped in 1% and 2% calcium gluconate solution for 10 minutes and air-dried. The analysis of the fruits was done at every 3 days intervals. 3 fruits in each treatment were undisturbed for evaluation of physiological loss in weight, spoilage and shelf life. The remaining was used for analyzing the physical and quality parameters.

Physiological loss in weight (%)

The weight of the fruit was recorded on the day of analysis and subtracted from the initial weight taken at the time of harvest. The loss of weight in grams about initial weight was calculated and expressed as a percentage.

$$\text{PLW (\%)} = \frac{\text{(Initial weight - weight after storage)}}{\text{Initial weight}} \times 100$$

Firmness (kg cm^{-2})

Fruit firmness at random was measured on three fruits from each replicate by measuring the penetration force with a penetrometer (Deccan Techno Corporation, 0-20 kg) equipped with a probe of 8.0 mm diameter and expressed in kg cm^{-2}).

Shelf life (days)

The shelf life was determined by recording the number of days the fruits remained in good condition without spoilage in each replication during storage. When the fruit reached a stage that is unsuitable for marketing, it was considered as the end of shelf life which was judged by visual scoring.

Spoilage (%)

The number of fruits spoiled in replication was counted and expressed in percentage. The spoilage of fruits was determined based on the following visual observations.

1. Shrivelling of the fruits.
2. Fungal infection and subsequent rotting of fruits.
3. Over ripening and subsequent splitting of fruits.
4. Browning and discoloration of fruits.

$$\text{Spoilage (\%)} = \frac{\text{Number of spoiled fruits}}{\text{Total number of fruits}} \times 100$$

Browning

Browning of each fruit was scored using a 5 points hedonic scale given below (Ramma, 2004; Butta *et al.*, 1999) [23, 6].

Score Description

1. No browning
2. Slight browning
3. 25% browning
4. 25-50% browning
5. 50-75% browning
6. > 75% browning

Total soluble solids (0Brix)

The percentage of total soluble solids (TSS) was determined by using a digital refractometer and expressed as percent TSS (0 Brix).

Titrable acidity (%)

Ten grams of fruit pulp was taken and ground well and then transferred to the volumetric flask. The volume was made up to 100 ml in a volumetric flask. The contents were filtered through Whatman No.1 filter paper and an aliquot of 10 ml was taken into the conical flask to which 2-3 drops of phenolphthalein indicator was added and titrated against 0.1 N NaOH till a pink colour, as the endpoint. The titrable acidity was estimated in terms of percent citric acid (Ranganna, 1986) [24].

$$\text{Acidity} = \frac{\text{Titre value x Normality of NaOH x 0.0064}}{\text{Volume of aliquot taken}} \text{ x 100}$$

3.7.4.6 Brix: Acid Ratio
The brix acid ratio was calculated by dividing the T.S.S value by the acid value (Titratable Acidity).

$$\text{B: A ratio} = \frac{\text{T.S.S. Value}}{\text{Acid value}}$$

Organoleptic evaluation
The organoleptic characters *viz.*, colour and appearance, texture, taste, flavour and overall acceptability of mango fruits at the end of their shelf life were evaluated on five points hedonic scale using the score card mentioned below (Ranganna, 1986) [24].

Hedonic scale Scores
Highly acceptable 5
Acceptable 4
Fairly acceptable 3
Poorly acceptable 2
Not acceptable 1

Results and Discussion
Physiological loss in weight (%)
The effect of post-harvest application of edible coating chitosan and calcium gluconate on PLW of mango in at different intervals is conferred in Table 1 was found significantly different among the treatments.
It is evident from the data that there was a gradual increase in PLW from 3rd to 15th day of storage. The lowest (3.65%) PLW was recorded on 3rd day and the significantly highest (14.57%) and (14.35%) PLW was recorded on 15th day in treatment T_1 - dipping in 1% edible chitosan coating and T_2 - dipping in 2% edible chitosan coating respectively, as the days proceeded the PLW of fruits increased gradually.
On 3rd day among different treatments lowest PLW was noted by T_2 - dipping in 2% edible chitosan coating (3.65%) which was significantly superior to other treatments followed by T_5 - dipping in 2% edible chitosan coating + 2% calcium gluconate (3.72%) and highest PLW was recorded by T_6 - control (5.03%) followed by T_4 - dipping in 1% edible chitosan coating + 2% calcium gluconate (4.85%).
On 6th day lowest PLW was recorded by T_2 - dipping in 2% edible chitosan coating (5.02%) followed by T_1 - dipping in 2% edible chitosan coating (6.58%) which was on par with T_5 - dipping in 1% edible chitosan coating + 2% calcium gluconate (6.72%) and highest PLW was noted by T_6 - control (10.61%) followed by T_4 - dipping in 1% edible chitosan coating + 2% calcium gluconate (9.49%).
On 9th day of storage, T_2 - dipping in 2% edible chitosan coating (7.36%) recorded the least PLW which is on par with T_5 - dipping in 2% edible chitosan coating + 2% calcium gluconate (7.51%) and T_1 - dipping in 1% edible chitosan coating (8.11%) and T_6 - control (11.55%) recorded the highest PLW which was on par with T_4 - dipping in 1% edible chitosan coating + 2% calcium gluconate (11.32%). On 12th day T_2 - dipping in 2% edible chitosan coating (9.41%) recorded the lowest PLW followed by T_1 - dipping in 1% edible chitosan coating (9.55%) and T_4 - dipping in 1% edible chitosan coating + 2% calcium gluconate (13.85%) recorded the highest PLW. While T_6 - control shows end of shelf life.
On 15th day of storage lowest PLW was recorded by T_2 - dipping in 2% edible chitosan coating (14.35%) and the highest PLW was recorded by T_1 - dipping in 1% edible chitosan coating (14.57%). While T_3, T_4 and T_5 shows end of shelf life.
Mango fruits coated with edible chitosan has given better results when compared with calcium gluconate. Among chitosan coated fruits 2% chitosan-coated fruits are found to be best on 1% chitosan-coated fruits as chitosan coating reduces the loss of water and carbon reserves by transpiration and respiration respectively as it acts as a barrier between atmosphere and fruit surface, which resulted in reduced loss of weight in fruits. Zafrul *et al.* (2020) [28] reported that weight loss in mango fruits was slow in 1.5% chitosan treated fruits, while it was fast in fruits coated with 0.75% chitosan. Fruit weight loss were found to be higher in higher concentrations of chitosan when compared to t lower concentrations of chitosan (Baviskar *et al.*, 1995) [5].
Ali *et al.*, 2011 revealed that there was proper maintenance of appearance and quality of fruits with decrease in moisture loss and respiration rate by application of 1.5% and 2% chitosan coatings that to the control, similar results were noted by Prashanth *et al.*, 2022 [18] in dragon fruit.

Firmness (kg cm^{-2})
The data pertaining to fruit firmness in Table 4.3.1 and Fig 32 revealed the effect of edible chitosan and calcium gluconate on mango fruits at different intervals have significant difference among all the treatments.
It was evident from the data that there was a gradual decrease of fruit firmness from 3rd to 15th day of storage. The highest (8.62 kg cm^{-2}) firmness was recorded on 3rd day by T_2 - dipping in 2% edible chitosan and the lowest (1.21 kg cm^{-2}) and (1.43 kg cm^{-2}) firmness was recorded by T - dipping in 2% edible chitosan coating and T_1 - dipping in 1% edible chitosan coating respectively as the days proceeded the firmness of fruits decreased gradually.
On 3rd day among different treatments the highest firmness was observed in T_2 - dipping in 2% edible chitosan coating (8.62 kg cm^{-2}) followed by T_1 - dipping in 1% edible chitosan (8.21 kg cm^{-2}) and lowest the firmness was recorded by T_3 - dipping in 2% calcium gluconate (7.02 kg cm^{-2}) which was on par with T_6 - control (7.03 kg cm^{-2}).
On 6th day of storage T_2 - dipping in 2% edible chitosan (6.72 kg cm^{-2}) recorded the highest firmness which was on par with T_1 - dipping in 1% edible chitosan coating (6.41 kg cm^{-2}) and least firmness was recorded by T_6 - control (4.81 kg cm^{-2}) which was on par with T_3 (5.10 kg cm^{-2}), T_4 (5.10 kg cm^{-2}) and T_5 (5.19 kg cm^{-2}). On 9th day T_2 - dipping in 2% edible chitosan coating (4.90 kg cm^{-2}) showed the highest firmness followed by T_1 - dipping in 1% edible chitosan coating (4.52 kg cm^{-2}) and T_6 - control (2.41 kg cm^{-2}) showed the least firmness followed by T_3 - dipping in 2% calcium gluconate (3.44 kg cm^{-2}).
On 12th day of storage T_2 - dipping in 2% edible chitosan coating (2.71 kg cm^{-2}) recorded the highest firmness followed by T_1 - dipping in 1% edible chitosan coating (2.64 kg cm^{-2}) and T_3 - dipping in 2% calcium gluconate (1.83 kg cm^{-2}) recorded the least firmness. While T_6 - control shows end of shelf life.
On 15th day highest firmness was recorded by T_2 - dipping in 2% edible chitosan coating (1.43 kg cm^{-2}) and lowest was recorded by T_1 - dipping in 1% edible chitosan coating (1.21 kg cm^{-2}). While T_3, T_4 and T_5 shown end of shelf life.

Gradual decrease in firmness is by gradual degradation of protopectin into pectin by polygalacturonate enzyme. As firmness of fruits is directly proportional to quality of fruits, surface coating of fruits decreases the metabolic activity of fruits which in turn reduces the respiration rate and maintains the firmness of fruits. Fast decrease of firmness was found in mangoes coated with calcium gluconate and 1% chitosan. On other hand, the rate of firmness changes was slower in mango fruits coated with 2% chitosan. This firmness loss is slow in T_2 - dipping in 2% edible chitosan coating because of lowest PLW by T_2 *i.e.*, (14.35 kg cm^{-2}) on 15th day of storage (table 1).

Similar results were found by Zafrul *et al.* (2020) [28] in mangoes coated with 1% chitosan which were slower which coated with 1.5% and 2% and Prashanth *et al.*, 2022 [18] observed a similar trend in dragon fruit that the highest firmness was observed with fruits treated with chitosan-coated with 4%. Similar results was noted in mango by Baldwin *et al.* (1999) [4] and table grapes by Romanazzi *et al.* (2009) [25].

Table 1: Effect of edible coating chitosan and calcium gluconate on physiological loss in weight (%) and firmness (kg/cm^2) of mango (*Mangifera indica* L.) cv. Banganpalli

	Physiological Loss in Weight (%)					Firmness (kg/cm^2)				
Treatments	**3rd Day**	**6th Day**	**9th Day**	**12th Day**	**15th Day**	**3rd Day**	**6th Day**	**9th Day**	**12th Day**	**15th Day**
T_1	4.44^{Cc}	6.58^{Dd}	8.11^{Cc}	9.55	14.57	8.21^{Bb}	6.41^{Ab}	4.52^{Bb}	2.64	1.21
T_2	3.65^{Dd}	5.02^{Ee}	7.36^{Dd}	9.41	14.35	8.62^{Aa}	6.72^{Aa}	4.90^{Aa}	2.71	1.43
T_3	4.58^{Cc}	8.09^{Cc}	10.10^{Bb}	13.79	*	7.02^{Ee}	5.10^{Bc}	3.44^{Ee}	1.83	*
T_4	4.85^{Bb}	9.49^{Bb}	11.32^{Aa}	13.85	*	7.51^{Dd}	5.10^{Bc}	4.13^{Cc}	2.33	*
T_5	3.72^{Dd}	6.72^{Dd}	7.51^{Dcd}	9.66	*	7.91^{Cc}	5.19^{Cd}	3.72^{Df}	2.27	*
T_6	5.03^{Aa}	10.61^{Aa}	11.55^{Aa}	*	*	7.03^{Ee}	4.81^{d}	2.41^{Ff}	*	*
S.E.M±	0.048	0.199	0.232			0.058	0.085	0.054		
CD(P=0.05)	0.148	0.620	0.724			0.180	0.262	0.165		

Note: * - end of shelf life. (Each data point is average of two years)

Browning

The data pertaining to browning of mango treated with edible coatings chitosan and calcium gluconate stored at room temperature is presented in Table 2.

Browning score was given based on the scale which ranges from 1-5. Generally browning of fruits increases significantly along with the storage period. Lowest browning of fruits was recorded in T_2 - dipping in 2% edible chitosan coating followed by T_1 - dipping in 1% edible chitosan coating from 3rd to 15th day and highest browning of fruits was recorded in control till 9th day after the shelf life of the control fruits ended.

On 3rd day there was no sign of browning recorded in all the treatments. On 6th day of the storage there was no sign of browning in T_2 and T_5, whereas least browning was recorded in T_1 - dipping in 1% edible chitosan coating (0.63) which was on par with T_4 - dipping in 1% edible coating chitosan + 2% calcium gluconate (1.00) and highest browning was recorded in T_6 - control (1.40).

On 9th day all treatments started showing signs of browning except T_2 - dipping in 2% edible chitosan coating. Among all the treatments least browning was recorded in T_4 - dipping in 1% edible coating chitosan + 2% calcium gluconate (2.00) followed by T_5 (2.50) and T_3 (2.50), whereas highest browning was recorded in T_6 - control (3.50).

On 12th day of the storage T_2 - dipping in 2% edible chitosan coating (2.80) recorded the least browning followed by T_5 - dipping in 2% edible chitosan coating + 2% calcium gluconate (3.20) and highest browning was recorded by T_4 - dipping in 1% edible coating chitosan + 2% calcium gluconate (4.00) followed by T_3 - dipping in 2% calcium gluconate (3.90). While T_6 - control fruits shows end of shelf life.

On 15th day least browning was recorded by T_2 - dipping in 2% edible chitosan coating (4.26) and lowest was recorded by T_1 - dipping in 1% edible chitosan coating (4.87). While T_3, T_4 and T_5 shows end of shelf life.

Least browning was recorded by T_2 - dipping in 2% edible chitosan coating because of lowest physiological loss in weight by T_2 (14.35%) and highest firmness (1.43 kg cm^{-2}) on 15th day of storage (Table 4.3.1 and 4.3.2). Fruits treated with chitosan show least browning in fruits during storage compared to other treatments (Huaqiang *et al.*, 2004) [13]. Browning of fruits was little more in calcium gluconate coated fruits compared to chitosan, this may be due to chitosan acts a strong barrier between fruit and atmosphere which limits loss of water through evaporation and respiration which delays ripening, therefore fruit deterioration and browning delays (Hesami *et al.*, 2021) [11].

Spoilage (%)

Spoilage per cent of mango fruits treated with edible coatings chitosan and calcium gluconate is presented in the Table 2.

Spoilage percent increases throughout the storage period, with no signs of spoilage on 3rd and 6th day. On 9th day of storage least spoilage per cent was recorded by T_4 - dipping in 1% edible coating chitosan + 2% calcium gluconate (27.66%) and highest was recorded by T_6 - control (33.33%). Whereas there was no symptom of spoilage on all other treatments.

On 12th day T_1 - dipping in 1% edible chitosan coating (38.26%) recorded the least spoilage per cent and highest was recorded by T_4 - dipping in 1% edible coating chitosan + 2% calcium gluconate (56.23%). While there was no symptom of spoilage in T_2, T_6 - control shows end of shelf life.

On 15th day least spoilage was recorded by T_2 - dipping in 2% edible chitosan coating (46.98%) and highest was recorded by T_1 - dipping in 1% edible chitosan coating (57.39%). While T_3, T_4 and T_5 shows end of shelf life.

Among all the treatments, fruits treated with chitosan reported least spoilage in storage compared to other treatments as there was no symptom of spoilage until 12th day storage in fruits treated with chitosan, this may be due to formation of a barrier between atmosphere and fruit surface which reduces respiration rate and methylene synthesis. Present results are in close conformity with results obtained by Hesami *et al.* (2021) [11] in beer fruits treated with 1% chitosan and stored at 5°C which had no decay symptom until 21 days of storage. Fruits treated with chitosan reported the lowest decay in mangosteen, with increasing concentrations of chitosan there was significant decrease of decay (Efendi and harmawati. 2010) [7].

Table 2: Effect of edible coating chitosan and calcium gluconate on browning, spoilage (%) and shelf life (days) of mango (*Mangifera indica* L.) cv. Banganpalli

Treatments	Browning				Spoilage (%)			Shelf life (days)
	6th Day	9th Day	12th Day	15th Day	9th Day	12th Day	15th Day	
T_1	0.63^{Cc}	1.43^{Dd}	3.70	4.87	0^{Cc}	38.26	57.39	16.91^{Ab}
T_2	0^{Dd}	0^{Cc}	2.80	4.26	0^{Cc}	0	46.98	17.41^{Aa}
T_3	0.86^{Bb}	2.50^{Bb}	3.90	*	0^{Cc}	53.64	*	13.23^{Ce}
T_4	1.00^{Bb}	2.00^{Cc}	4.00	*	27.66^{Bb}	56.23	*	15.72^{Bc}
T_5	0^{Dd}	2.50^{Bb}	3.20	*	0^{Cc}	26.71	*	15.22^{Bd}
T_6	1.40^{Aa}	3.50^{Aa}	*	*	33.33^{Aa}	*	*	12.02^{Df}
S.E.M±	0.093	0.136			0.694			0.159
CD(P=0.05)	0.287	0.424			2.138			0.496

Note: * - end of shelf life. (Each data point is average of two years)

Shelf life (days)

The data related to shelf life shown in Table 2 and Fig 1 revealed the effect of edible coatings chitosan and calcium gluconate was found significantly differed among the treatments.

Shelf life was significantly different for all the treatments whereas highest shelf life was recorded by T_2 - dipping in 2% edible chitosan coating (17.41 days) followed by T_1 - dipping in 1% edible chitosan coating (16.91 days) and lowest shelf life was recorded by T_6 - control (12.02 days) followed by T_3 - dipping in 2% calcium gluconate (13.23 days).

Shelf life defines the period of fruit harvest to fruit rot. Generally under favourable conditions fruits starts decay and fastens up under the favourable conditions, but chitosan treatment immediately after harvest slows down the transpiration and respiration of fruit which increases fruits shelf life and decreases the fruit rot.

Zafrul *et al.*, (2020) [28] revealed that extended shelf life of 10 days was recorded in mangoes coated with 2% chitosan followed by 1.5% with 9.67 days. The increased shelf life was noted in mangoes coated with the high concentration of chitosan and similar results were found by Xing *et al.* (2011) [26] in jujube fruits and by Hoa *et al.* (2022) [12] in mango.

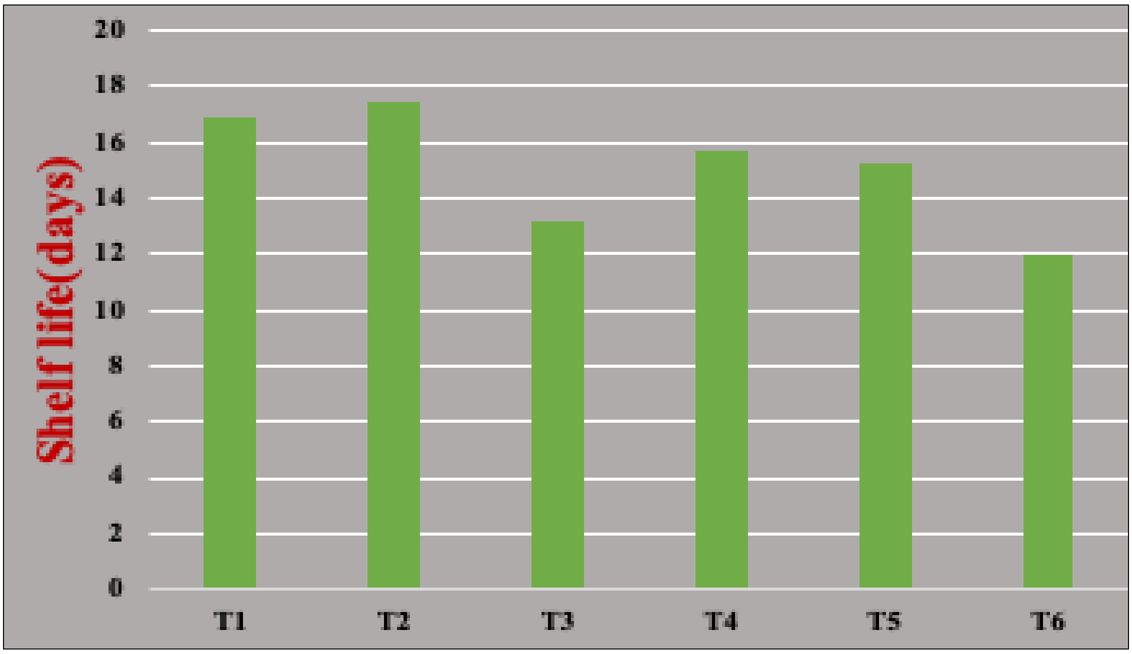

Fig 1: Effect of edible coating chitosan and calcium gluconate on shelf life (days) of mango (*Mangifera indica* L.) Cv. Banganpalli

Total soluble solids (^{0}Brix)

The synergistic effect of edible coating chitosan and calcium gluconate on total soluble solids is presented in the Table 3 and Fig 2. Significant difference was found with respect to total soluble solids among all the treatments. It was evident from the data that there was gradual increase of total soluble solids from 3rd day to 9th day of storage and then it starts decreasing.

On 3rd day of storage lowest total soluble solids was recorded by T_2 - dipping in 2% edible chitosan coating (11.37 ^{0}Brix) which was on par with T_5 - dipping in 2% edible chitosan coating + 2% calcium gluconate (11.48 ^{0}Brix) and highest was recorded by T_6 - control (12.02 ^{0}Brix) followed by T_3 - dipping in 2% calcium gluconate (13.60 ^{0}Brix). On 6th day T_5 - dipping in 2% edible chitosan coating + 2% calcium gluconate (13.51 ^{0}Brix) recorded least total soluble solids and highest was recorded by T_6 - control (12.02 ^{0}Brix) followed by T_3 - dipping in 2% calcium gluconate (18.57 ^{0}Brix) which was on par with T_1 (18.23 ^{0}Brix) and T_2 (17.91 ^{0}Brix).

On 9th day of storage lowest total soluble solids was recorded by T_2 - dipping in 2% edible chitosan coating (21.13 ^{0}Brix) followed by T_1 - dipping in 1% edible chitosan coating (21.78 ^{0}Brix) which was on par with T_5 - dipping in 2% edible chitosan coating + 2% calcium gluconate (22.13 ^{0}Brix) and highest total soluble solids was recorded by T_6 - control (24.63 ^{0}Brix) which was on par with T_3 - dipping in 2% calcium gluconate (24.28 ^{0}Brix).

On 12th day T_1 - dipping in 1% edible chitosan coating (24.90 ^{0}Brix) recorded the highest total soluble solids followed by T_2 -

dipping in 2% edible chitosan coating (24.20 ^{0}Brix) and lowest total soluble solids was recorded by T_4 - dipping in 1% edible coating chitosan + 2% calcium gluconate (22.30 ^{0}Brix) followed by T_3 - dipping in 2% calcium gluconate (22.81 ^{0}Brix). While T_6 - control shows end of shelf life.

On 15th day highest total soluble solids was recorded by T_1 - dipping in 1% edible chitosan coating (21.86 ^{0}Brix) and lowest was recorded by T_2 - dipping in 2% edible chitosan coating (21.30 ^{0}Brix). While T_3, T_4 and T_5 shows end of shelf life.

There was initial increase of TSS which may be due to the breaking of starch and polysaccharides into sugars and organic acids, later TSS starts declining, this decline may be due to utilization of sugars in evapotranspiration. Fruits treated with high concentration of chitosan have slow increase and decrease in TSS compared to untreated fruits (Gurjar *et al.*, 2018) [10].

Our results were similar with Ali *et al.* (2011), where untreated and low concentration chitosan coated papaya fruit had significantly higher TSS compared to the fruit with higher concentrations of chitosan. Results of Aleryani *et al.* (2008) [1] in papaya, Baez-Sanudo *et al.* (2009) [3] in banana and Khalifa *et al.* (2016) [14] strawberry were in same conformity with ours results.

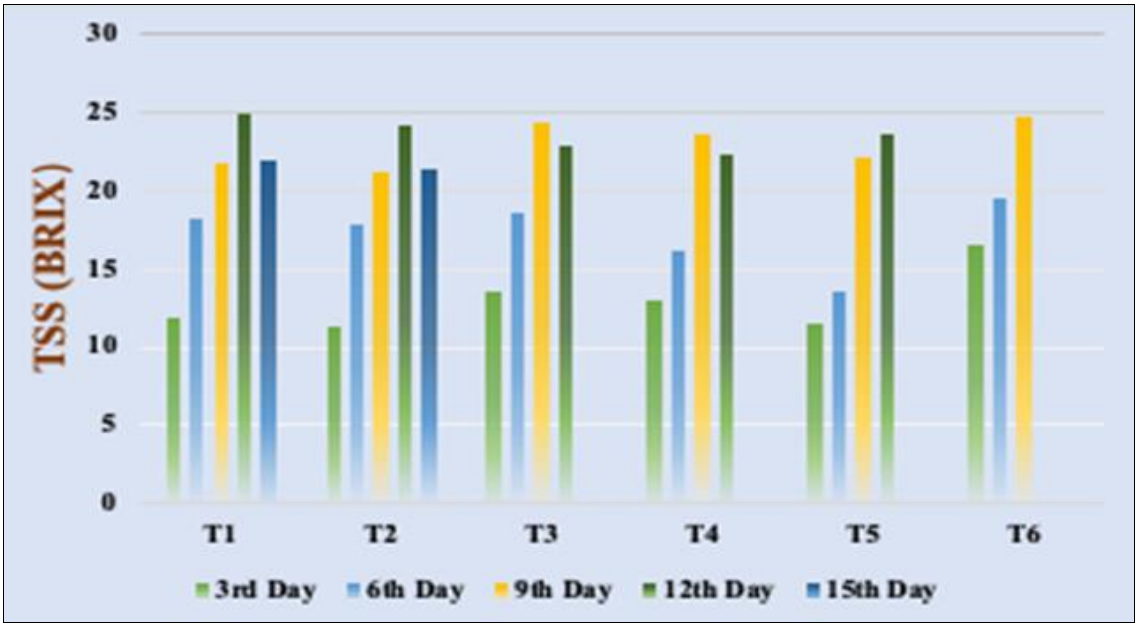

Fig 2: Effect of edible coating chitosan and calcium gluconate on TSS of mango (*Mangifera indica* L.) cv. Banganpalli

Titrable acidity (%)

The data shown in the Table 3 revealed that effect of edible coating chitosan and calcium gluconates on titrable acidity. Acidity of fruits decreases with the progress in the storage period. There was no significant difference among the treatments on 3rd and 6th day, whereas on 9th day least acidity was recorded by both T_1 - dipping in 1% edible chitosan coating (0.22%) and T_2 - dipping in 2% edible chitosan coating (0.22%) and highest acidity was recorded by T_5 - dipping in 2% edible chitosan coating + 2% calcium gluconate (0.32%) which was on par with T_6 - control (0.31%). On 12th day of the storage least acidity was recorded by T_2 - dipping in 2% edible chitosan coating (0.15%) followed by T_2 - dipping in 2% edible chitosan coating (0.16%) and highest acidity was recorded by T_4 - dipping in 1% edible coating chitosan + 2% calcium gluconate (0.23%) followed by T_3 - dipping in 2% calcium gluconate (0.21%). While T_6 - control shows end of shelf life.

On 15th day highest acidity was recorded by both T_1 - dipping in 1% edible chitosan coating (0.13%) and T_2 - dipping in 2% edible chitosan coating (0.13%). While T_3, T_4 and T_5 shows end of shelf life.

Decrease in acidity of fruits may be due to the increase of sugars during ripening. This decrease was limited in surface coated fruits than control. Prashanth *et al.* (2022) [18] observed that dragon fruits treated with 4% chitosan recorded lower acidity when compared with untreated fruits.

During fruit maturity there was higher amount of acidity, but as the fruits proceeds towards ripening, amount of acid will decrease. This decrease in acidity might be due to increase in the total sugar content of the fruits (Pradeep and Manu, 2018) [19]. Similar results with hight concentration of chitosan was recorded by Sinee and Anuvat (2009) [21] in banana.

Table 3: Effect of edible coating chitosan and calcium gluconate on total soluble solids (^{0}Brix) and titrable acidity (%) of mango (*Mangifera indica* L.) cv. Banganpalli

	Total soluble solids (^{0}Brix)					Titrable acidity (%)				
Treatments	**3rd Day**	**6th Day**	**9th Day**	**12th Day**	**15th Day**	**3rd Day**	**6th Day**	**9th Day**	**12th Day**	**15th Day**
T_1	11.78^{Cd}	18.23^{Cb}	21.78^{Cc}	24.90	21.86	0.32	0.29	0.22^{Cc}	0.16	0.13
T_2	11.37^{Cd}	17.91^{Cc}	21.13^{Dd}	24.20	21.30	0.32	0.29	0.22^{Cc}	0.15	0.13
T_3	13.60^{Bb}	18.57^{Bd}	24.28^{Aa}	22.81	*	0.27	0.26	0.24^{Cc}	0.21	*
T_4	12.99^{Bc}	16.14^{Dd}	23.56^{Bb}	22.30	*	0.30	0.31	0.26^{Bb}	0.23	*
T_5	11.48^{Cd}	13.51^{Ee}	22.13^{Cc}	23.58	*	0.33	0.31	0.32^{Aa}	0.18	*
T_6	16.43^{Aa}	19.46^{Aa}	24.63^{Aa}	*	*	0.28	0.30	0.31^{Ba}	*	*
S.E.M±	0.197	0.160	0.161			0.016	0.020	0.004		
CD(P=0.05)	0.608	0.492	0.696			NS	NS	0.013		

Note: * - end of shelf life. (Each data point is average of two years)

Brix acid ratio

Effect of edible coating chitosan and calcium gluconate on brix acid ratio I of mango is presented in the Table 4. It is the ratio of TSS and acidity which increased with the storage period.

There was significant difference among all the treatments with respect to brix acid ratio. It is evident from the data that there is an increasing trend of brix acid ratio in all the treatments from 3rd to 15th day of their storage period.

On 3rd day the of storage brix acid ratio was low in T_2 - dipping in 2% edible chitosan coating (35.95) followed by T_5 - dipping in 2% edible chitosan coating + 2% calcium gluconate (36.60) and high in T_6 - control (57.40) followed by T_3 - dipping in 2% calcium gluconate (50.31).

On 6th day T_5 - dipping in 2% edible chitosan coating + 2% calcium gluconate (43.82) recorded the lowest brix acid ratio followed by T_4 - dipping in 1% edible coating chitosan + 2% calcium gluconate (52.35) and highest was recorded by T_3 - dipping in 2% calcium gluconate (70.17) followed by T_6 - control (57.40).

On 9th day minimum brix acid ratio was recorded by T_5 - dipping in 2% edible chitosan coating + 2% calcium gluconate (72.86) followed by T_6 - control (77.86) and maximum brix acid ratio was recorded by T_3 - dipping in 2% calcium gluconate (99.36) followed by T_4 - dipping in 1% edible coating chitosan + 2% calcium gluconate (96.56)

On 12th day of the storage the least brix acid ratio was recorded by T_4 - dipping in 1% edible coating chitosan + 2% calcium gluconate (96.95) followed by T_3 - dipping in 2% calcium gluconate (108.61) and the highest acidity was recorded by T_2 - dipping in 2% edible chitosan coating (161.33) followed by T_1 - dipping in 1% edible chitosan. While T_6 - control shows end of shelf life.

On 15th day least brix acid ratio was recorded by T_2 - dipping in 2% edible chitosan coating (163.85) followed by T_1 - dipping in 1% edible chitosan coating (168.15). While T_3, T_4 and T_5 shows end of shelf life.

Brix acid ratio increases as TSS increases in storage period. This increase was constant initially, but later it showed decreasing trend. Treated fruits showed slow rate of decrease over control fruits Mandal *et al.* (2018) [16]. Similar results were noted by Mandal *et al.* (2015) [15] in pineapple.

Organoleptic evaluation

Results of organoleptic evaluation of mango treated with chitosan and calcium gluconate including colour and appearance, texture, taste, flavour and overall acceptability are presented in the Table 4.

Organoleptic evaluation was done by at the end of shelf life by a committee of five judges for all the treatments and 1-5 scores were given accordingly. Scores for colour, texture, taste and flavour were given by sensory evaluation whereas over acceptability scores were given by considering all the characters like colour, taste, flavour, texture, aroma etc. There was a significant difference among all the treatments with respect to colour, taste, flavour, texture and overall acceptability.

Among all the treatments with respect to organoleptic evaluation T_2 - dipping in 2% edible chitosan coating is recorded best score foe colour and appearance, texture, taste, flavour and overall acceptability followed by T_1 - dipping in 1% edible chitosan coating and T_5 - dipping in 2% edible chitosan coating + 2% calcium gluconate and lowest score was recorded by T_6 - control.

In case of colour and appearance T_2 - dipping in 2% edible chitosan coating (4.26) recorded the highest score followed by T_1 - dipping in 1% edible chitosan coating (4.10) and least score was recorded by T_6 - control (3.03).

T_2 - dipping in 2% edible chitosan coating (4.03) recorded the maximum score with respect to texture followed by T_4 - dipping in 1% edible coating chitosan + 2% calcium gluconate (3.23) which was on par with T_5 (3.20) and T_1 (3.06) and minimum score was recorded by T_6 - control (2.50).

Score of taste was recorded highest in T_5 - dipping in 2% edible chitosan coating + 2% calcium gluconate (4.23) which was on par with T_2 - dipping in 2% edible chitosan coating (4.16) and lowest score was recorded by T_6 - control (3.20) which was on par with T_3 - dipping in 2% calcium gluconate (3.20).

With respect to flavour highest score was recorded by T_1 - dipping in 1% edible chitosan coating (4.23) followed by T_1 - dipping in 1% edible chitosan coating (4.20) and lowest score was recorded by T_6 - control (2.76). T_2 - dipping in 2% edible chitosan coating (4.23) recorded the maximum score with respect to overall acceptability followed by T_5 - dipping in 2% edible chitosan coating + 2% calcium gluconate (3.36) and minimum score was recorded by T_6 - control (2.63). These results are in conformity with the findings of Srinivasa *et al.* (2002) [22] who reported that mango fruits treated with 1.5% chitosan attained maximum score by the panellists in all tested parameters like colour, taste, texture and flavour even after 5 weeks of cold storage and by Ali *et al.* (2011) in papaya.

Table 4: Effect of edible coating chitosan and calcium gluconate on brix acid ratio and organoleptic evaluation of mango (*Mangifera indica* L.) cv. Banganpalli

	Brix acid ratio					Organoleptic evaluation				
Treatments	3rd Day	6th Day	9th Day	12th Day	15th Day	Colour and appearance	Texture	Taste	Flavour	Overall acceptability
T_1	36.87^{Dd}	63.01^{Cc}	96.27^{Bb}	155.63	168.15	4.10^{Ab}	3.06^{Cb}	3.23^{Dc}	4.23^{Aa}	3.10^{Cc}
T_2	35.95^{Ee}	61.02^{Dd}	95.28^{Cc}	161.33	163.85	4.26^{Aa}	4.03^{Aa}	4.16^{Ba}	4.20^{Aa}	4.23^{Aa}
T_3	50.31^{Bb}	70.17^{Aa}	99.36^{Aa}	108.61	*	3.06^{De}	2.70^{Dc}	3.20^{Dc}	3.36^{Cd}	2.76^{Dd}
T_4	42.31^{Cc}	52.35^{Ee}	96.56^{Dd}	96.95	*	3.36^{Cd}	3.23^{Bb}	3.63^{Cb}	3.30^{Bc}	3.03^{Cc}
T_5	36.60^{Ff}	43.82^{Ff}	72.86^{Ff}	131.0	*	3.76^{Bc}	3.20^{Bb}	4.23^{Aa}	3.76^{Bb}	3.36^{Bb}
T_6	57.40^{Aa}	65.57^{Bb}	77.86^{Ee}	*	*	3.03^{De}	2.50^{Dd}	3.20^{Dc}	2.76^{De}	2.63^{Ee}
S.E.M±	0.011	0.013	0.011			0.042	0.059	0.034	0.035	0.035
CD(P=0.05)	0.035	0.039	0.034			0.128	0.180	0.106	0.107	0.108

Note: * - end of shelf life. (Each data point is average of two years)

Conclusion

- The effect of edible coatings chitosan and calcium gluconate shelf life and quality was found significantly differed among the treatments.
- Among different treatments lowest physiological loss in weight (3.65%), highest firmness (8.62 kg/cm^2) and maximum shelf life (17.41 days) were recorded by T_2 - dipping in 2% edible chitosan coating and least was recorded on 3rd day of storage by T_6 - control.
- Least browning (4.87) and spoilage% (46.98%) was

observed in T_2 - dipping in 2% edible chitosan coating on 15^{th} days of storage.

- Changes in total soluble solids, brix acid ratio, sugars and ascorbic acid content was slow in T_2 - dipping in 2% edible chitosan coating compared to T_6 - control in which changes are rapid during storage. Highest TSS (21.86 ^{0}Brix), brix acid ratio (168.15). There was no significant difference among treatments with respect to acidity.
- Organoleptic evaluation was recorded best when fruits are coated with 2% edible chitosan coating with score of (4.26), (4.03), (4.16), (4.20) and (4.23) in colour, texture, taste, flavour and overall acceptability respectively.

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