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SMART BIOACTIVE COATING FOR SHELF- LIFE EXTENSION AND QUALITY IMPROVEMENT OF PEAR (*Pyrus communis* L.) CV. BAGGUGOSHA

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ABSTRACT

The present study was conducted to evaluate the efficiency of different smart bio-active Coating materials in extending the post- harvest shelf life and quality improvement of pear. The experiment is carried out at post-harvest laboratory of College of Horticulture, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, Uttar Pradesh, India in the year 2024-2026, in Completely Randomized Design (CRD). The investigation comprising nine treatments, including Chitosan 0.25% + Acetic acid 1%, Chitosan 0.5% (T1) + Acetic acid 1.5%, Calcium chloride 1.5% (T2), Calcium chloride 2.5% (T3), Aloe vera gel 25%(T4), Aloe vera gel 50%(T5), Carboxymethyl cellulose 0.25% (T7), Carboxymethyl cellulose 0.5% (T8), along with a Control (T0) (untreated). The observation was recorded at 0 (initial), 5,15, 25, and 35 days after treatment. The finding revealed that all physical attributes exhibited gradual changes throughout storage; However, the application of coating significantly ($p < 0.05$) reduced the rate of deterioration compared to the control, Among all Carboxymethyl cellulose (CMC) 0.5% (T8) emerged most effective , in maintaining the Quality parameters of pear after 35 days storage followed by pear treated with Carboxymethyl cellulose (CMC) 0.25% (T7) , showing lower physiological loss in weight % (6.2% , 6.5%) , Fruit Shrinkage % (2.06, 2.13), Decay Percentage (30.40% , 33.20%), Specific gravity (1.083,1.080), and Fruit Firmness (3.95 kg/cm^2, 3.50 kg/cm^2). The superior performance of Carboxymethyl cellulose (CMC) 0.5% (T8) - coated fruits is may be attributed to the formation of a semi- permeable barrier around the fruit surface, which reduced respiration and transpiration rates, thereby slowing metabolic activities, enzymatic degradation, and senescence.

***Keywords* :** Pear, Transpiration rate, Carboxymethyl cellulose, Smart bioactive coating, physiological loss, post -harvest quality, shelf life.

Introduction

Pear (*Pyrus communis* L.) is an important temperate fruit belongs to the Rosaceae family. It is widely cultivated due to its appealing appearance, pleasant taste, and high nutritional value. It is consumed both as fresh and in processed and serves as a rich source of dietary fiber, carbohydrates, vitamins, minerals and antioxidant which contribute majorly to human health. Among all India is a leading fruit-producing country globally; it faces heavy post-harvest losses because of inadequate storage facilities, improper handling. It has been estimated that nearly 25–30% of fruits are lost annually, resulting in economic losses amounting to approximately Rs. 1.53 lakh crore (NABCONS, 2022). In pear fruits, post-harvest losses under ambient conditions range from 6.02% to 15.05% (Jha *et al.*, 2015). Therefore, the development of low- cost and eco-friendly technologies such as smart bioactive coatings has become important for reducing these losses and extending fruit shelf life.

Pear is believed to have originated in western Europe and parts of asia and is now commercially cultivated in many regions across the world. In India, it is mainly grown in Jammu & Kashmir, Himachal Pradesh, Uttarakhand, and North-Eastern hill regions. Among different varieties, Baggugosha is mostly prepared for its taste, texture, and market acceptability. The rapid post-harvest deterioration of Babugosha is primarily attributed to its climacteric respiratory pattern. It exhibits an intense increase in ethylene biosynthesis and respiration rates immediately after harvest, which breaks the quick breakdown of complex polysaccharides into simple sugars, leading to accelerated softening of the pulp. Moreover, the high activity of oxidative enzymes, such as polyphenol oxidase and peroxidase results in enzymatic browning and loss of tissue integrity under ambient temperatures (Kader, 2002). These physiological changes not only reduce fruit firmness but also increase susceptibility to moisture loss and microbial spoilage, thereby reducing the marketable shelf life of the fruits. Smart bioactive coating are considered an effective post-harvest technology because they form a thin semi-permeable layer around the fruit surface, which modifies the internal atmosphere of the fruit by regulating the exchange of gases and water vapour. This helps in reducing respiration rate, transpiration loss, and ethylene production, thereby delaying ripening and senescence. In addition to their physical barrier properties, several coating materials also possess beneficial chemical characteristics that improve fruit quality and storability. Chitosan, a natural polysaccharide derived from chitin, exhibits strong antimicrobial and antifungal properties due to the presence of amino groups, which inhibit the growth of spoilage microorganisms and reduce decay incidence. Aloe vera gel contains bioactive compounds such as polysaccharides, phenolics, organic acids, and antioxidants that help in maintaining membrane integrity and reducing oxidative damage in fruits. Calcium chloride plays a vital role in strengthening cell wall structure through the formation of calcium pectate, thereby maintaining fruit firmness and delaying tissue softening. Carboxymethyl cellulose (CMC), a cellulose derivative with excellent film-forming ability, acts as a moisture barrier and reduces physiological loss in weight by minimizing water evaporation from the fruit surface. Moreover, CMC coatings help maintain higher retention of sugars, acids, and overall fruit texture during storage. Although several studies have been conducted on smart bioactive coating in different fruits, limited information is available regarding their effect on pear cv. Babugosha under ambient storage conditions. Therefore, the present investigation was undertaken to evaluate the effectiveness of different smart bioactive coating materials in extending the shelf life and maintaining the physico-chemical quality of Babugosha pear fruits during ambient storage.

Material and Methods

An investigation entitled "Smart Bioactive Coating for Shelf-Life Extension and Quality Improvement of Pear (*Pyrus communis L.*) cv. Babugosha" was conducted in the Post-Harvest Laboratory, Department of Fruit Science, Sardar Vallabhbhai Patel University of Agriculture and Technology during July–August 2025. The experiment was laid out in a Completely Randomized Design (CRD) with nine treatments and three replications using healthy and uniform fruits of pear cv. Babugosha. The treatments comprised T_1: Control, T_2: Chitosan 0.5%, T_3: Chitosan 1.0%, T_4: Calcium chloride 1%, T_5: Calcium chloride 2%, T_6: Aloe vera gel 25%, T_7: Carboxymethyl cellulose (CMC) 0.25%, T_8: Carboxymethyl cellulose (CMC) 0.50%, and T_9: Aloe vera gel 50%. The treated fruits were stored under ambient conditions. Observations on physical and biochemical parameters were recorded at 0, 5, 15, 25, and 35 days after treatment application using standard methods described by AOAC (1985), Ranganna (1986), Campos *et al*. (2011), and Wang *et al*. (2021). The data were subjected to analysis of variance (ANOVA) following the procedure outlined by Gomez and Gomez (1996), and treatment means were compared at the 5% level of significance.

Coating Preparation and Application to the surface of Pear

Preparation of chitosan coating

Chitosan coating solution (500 ml) of each concentration (1% and 1.5%) was prepared by dissolving 5 g and 7.5 g of chitosan powder, respectively, in acetic acid solution, followed by the addition of distilled water to make the final volume up to 500 ml. The mixture was continuously stirred using a magnetic stirrer at room temperature until the chitosan flakes were completely dissolved. Thereafter, 1 g glycerol was added as a plasticizer to improve the flexibility and mechanical strength of the coating film (Aider 2010; Arvanitoyannis *et al*.,1998).

Preparation of Calcium chloride Coating

Calcium chloride coating solution of each concentration (1.5% and 2.5%) was prepared by dissolving 7.5 g and 12.5 g of calcium chloride powder (100% purity), respectively, in 500 ml of distilled water. The solution was stirred continuously on a magnetic stirrer for 1 hour to ensure complete dissolution. Thereafter, 1 g glycerol was added as a plasticizer to improve the strength and flexibility of the coating solution (Bakshi *et al*., 2005; Chong *et al*., 2015).

Preparation of Aloe vera gel solution

Aloe vera gel coating solution of each concentration (25% and 50%) was prepared by adding 125 ml and 250 ml of pure Aloe vera gel, respectively, to distilled water and making the final volume up to 500 ml. The prepared solution was stirred continuously on a magnetic stirrer for 1 hour to obtain a uniform mixture. Subsequently, 1 g glycerol was added as a plasticizer to improve the strength and flexibility of the coating film (Benítez *et al*., 2015; Misir *et al*., 2014).

Preparation of Carboxymethyl cellulose solution

Carboxymethyl cellulose (CMC) coating solution of each concentration (0.25% and 0.50%) was prepared by dissolving 12.5 g and 25 g of CMC powder (100% purity), respectively, in 500 ml of distilled water. The solution was continuously stirred on a magnetic stirrer for 1 hour to ensure complete dissolution and uniform consistency. Thereafter, 1 g glycerol was added as a plasticizer to improve the mechanical strength and flexibility of the coating solution (Campos *et al*., 2011; Chiabrando *et al*., 2016).

1. Physiological loss in weight (PLW)

PLW was determined by the following formula –

$$\boldsymbol{PLW}(\%) = \frac{\boldsymbol{Initial\ weight - Final\ weight}}{\boldsymbol{Initial\ weight}} \times 100$$

2. Decay %

Data on the spoilage of treated fruit was recorded on the 5th, 15th, 25th, 35th, day of the storage period and is expressed as percentage based on the visible symptoms of spoilage and unmarketable shrinkage.

3. Specific gravity

The ratio of a material's density to that of water is called specific gravity. There is no unit of specific gravity. Water has a density of 1 g/cm^3. The specific gravity of fruit and vegetable juices that have less alcohol or essential oils is always higher than unity. The specific gravity directly affects the soluble solids. The specific gravity increases with increasing soluble solid concentration. Pear were weighed separately in order to calculate their specific gravity. Pushing the Pear into the water caused it to submerge. After logging the amount of water displaced, the specific gravity of the water was determined.

$$\text{specific gravity} = \frac{Mass}{volume}$$

4. Fruit firmness (kg/cm^2)

Fruit firmness was recorded on 0, 5th, 15th, 25th and 35th day of ripening. Fruit firmness was measured by penetrometer.

5. Fruit shrinkage: The following formula will be used to calculate the percentage fruit shrinkage of the sampled fruits:

$$\text{Shrinkage} = \frac{\textit{Initial fruit diameter (mm)} - \textit{diameter at particular storage interval (mm}}{\textit{Initial diamater of the fruit (mm)}} \times 100$$

Result and Discussion

Effect of Smart bioactive coating on Physiological loss in weight (PLW)

A increase in PLW was observed (Tab.1 and Fig.1) throughout the storage period among all treatments, which is common post-harvest traits of climacteric fruits such as pear. The increase in PLW mainly due to the water loss through transpiration and respiration. Still, fruits treated with bioactive coating exhibited significantly reduce PLW compared to untreated fruits, it indicates the positive effect of coatings in retraining fruit quality and extending shelf life. Overall, among all the treatments, T_8 showed the lowest PLW (6.2%) on day 35, followed by T_7 (6.5%), While the maximum PLW was recorded in the control treatment (T0). The reduce in weight loss in coated fruit is due to the development of semi- permeable membrane around the fruit surface, which restrict water evaporation and exchange of gases. Thus reduce the transpiration and respiration. Nearly similar findings were reported by Tharanathan (2003), Dhall (2013), who stated that polysaccharide-based smart bioactive coating act as protective barriers that reduce moisture loss and extend the storage life of fruits.

Effect of Smart bioactive coating on Decay Percentage (%)

Decay percentage showed a steady increase (Tab.3 and Fig 3) during the entire storage period in all treatments. Still the fruits treated with coating materials exhibited knowingly lower spoilage compared to untreated fruits, denoting the positive effect of coatings in preserving fruit quality. In the initial days of storage of fruits, treated fruits very little decay, while control fruits developed visible symptoms of deterioration. At last day of storage, T0 shows the maximum decay percentage (100%), whereas the minimum decay was observed in Treatments T8 (30.4%), followed by T7 (33.2%). The reduce shrinkage observed in coated fruits may be due to the presence of thin semi-permeable layer on fruit surface, it minimises water loss through transpiration and respiration. The superior performance of CMC coating may be towards to their excellent film – forming characteristics and high moisture – retention ability, which help in reducing transpiration losses and minimising fruit decay during storage. However, Similar observations were reported by Maringgal *et al*. (2020), who stated that polysaccharide-based smart bioactive coating act as semi-permeable barriers that reduce moisture loss and preserve the post-harvest quality and shelf life of fruits during storage.

Effect of Smart bioactive coating on Fruit shrinkage (%)

Fruit shrinkage increased (Tab.2 and Fig.2) with time during the storage period in all treatments. Still the fruit coated with coating materials shows lower shrinkage than the uncoated fruit during the storage under ambient condition. Among all the different treatments, on day 35 ,T8 shows the minimum shrinkage (2.06%) followed by T7 (2.13%), While maximum fruit shrinkage observed in T0 (3.990). The lower shrinkage recorded in fruits coated with bio-coating materials is due the presence of thin semi permeable layer around the fruit surface which reduces the moisture losses through transpiration and respiration. The superior performance of CMC coatings may be attributed to their excellent film-forming characteristics and high moisture-retention ability, which help in reducing transpiration losses and maintaining fruit firmness during storage. However similar observations were reported by Maringgal *et al*. (2020), and Singh *et al*. (2023), who stated that polysaccharide- based bio- active coating act as semi-permeable barriers that reduce moisture loss and preserve the post-harvest quality and shelf life of fruits during storage.

Effect of Smart bioactive coating on Specific gravity

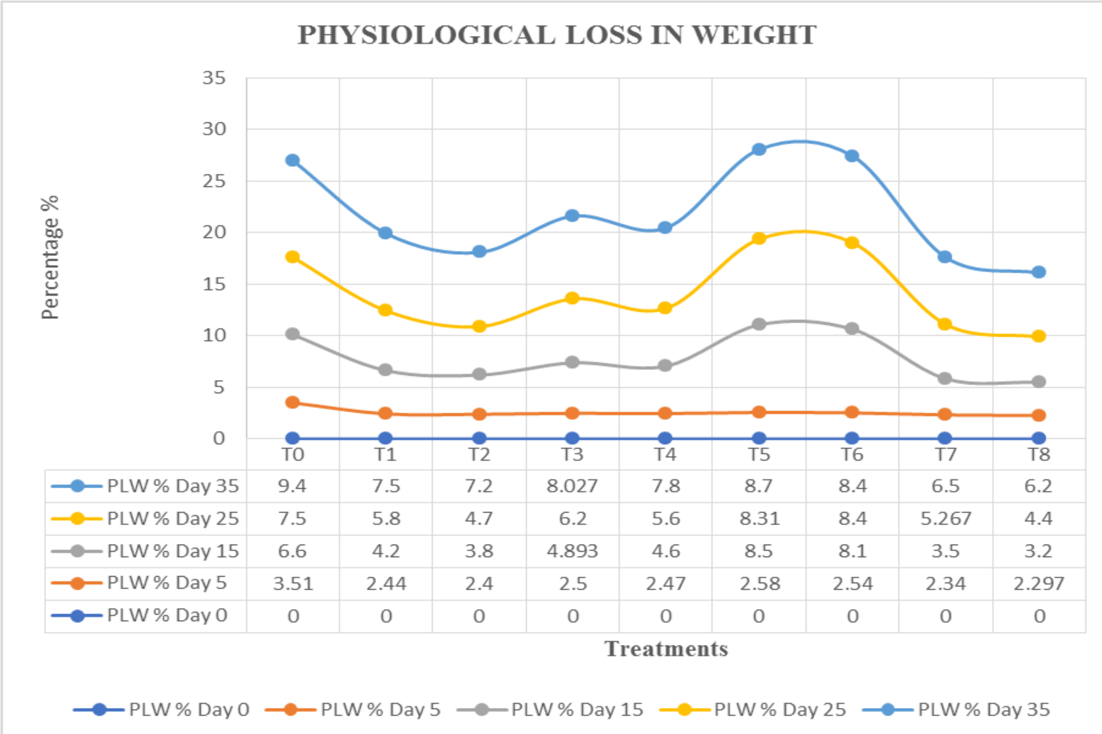
Specific gravity showed gradual decreases (Tab.5 and Fig.5) during the storage period. The decreasing in the specific gravity is due to the moisture loss, respiration and transpiration. However, Fruits coated with coating materials showed relatively higher specific gravity values compared to non-coated fruits. Among all the treatments on day 35 of storage T8 and T7 (CMC based coatings) recorded the highest specific gravity values (1.083 and 1.08), whereas T0 shows the lowest specific gravity values (1.01). The higher specific gravity in the coated fruits is due to the lower moisture loss and better retention of cellular structure. The effectiveness of CMC coated fruits is due to the formation of thin semi- permeable layer around the fruit surface which help in reducing the transpiration and respiration in fruit. In contrast, untreated fruits exhibited a continuous decline in specific gravity due to rapid water loss and faster metabolic degradation during storage. Similar observations were also reported by Campos *et al*. (2011), who concluded that smart bioactive coating coatings help maintain fruit firmness, density, and overall post-harvest quality by reducing moisture loss and slowing down physiological deterioration during storage.

Effect of Smart bioactive coating on Fruit firmness

Fruit firmness showed gradual decreases (Tab.4 and Fig.4) during the storage period. The decreasing in the Fruit firmness is due to the moisture loss, respiration and transpiration. However, Fruits coated with coating materials showed higher fruit firmness values compared to uncoated fruits. Among all the treatments on the later storage period it was observed that T8 showed the maximum fruit firmness (3.95kg/cm^2), followed by T7(3.5kg/cm^2), Whereas T0 recorded minimum fruit firmness (2.15kg/cm^2). The higher fruit firmness in coated fruits is due to the lower moisture loss and better preservation of cellular structure. The effectiveness of CMC coated fruits is due the formation of semi – permeable layer around the fruit surface which help in reducing water losses due transpiration and respiration. Despite this the uncoated fruit showed a drastic decrease in the firmness due to rapid loss in water during storage. Similar findings were reported by Mahfoudhi *et al*. (2014), who observed that smart bioactive coating coatings effectively maintain fruit firmness and delay ripening by minimizing moisture loss and slowing physiological and biochemical changes during storage.

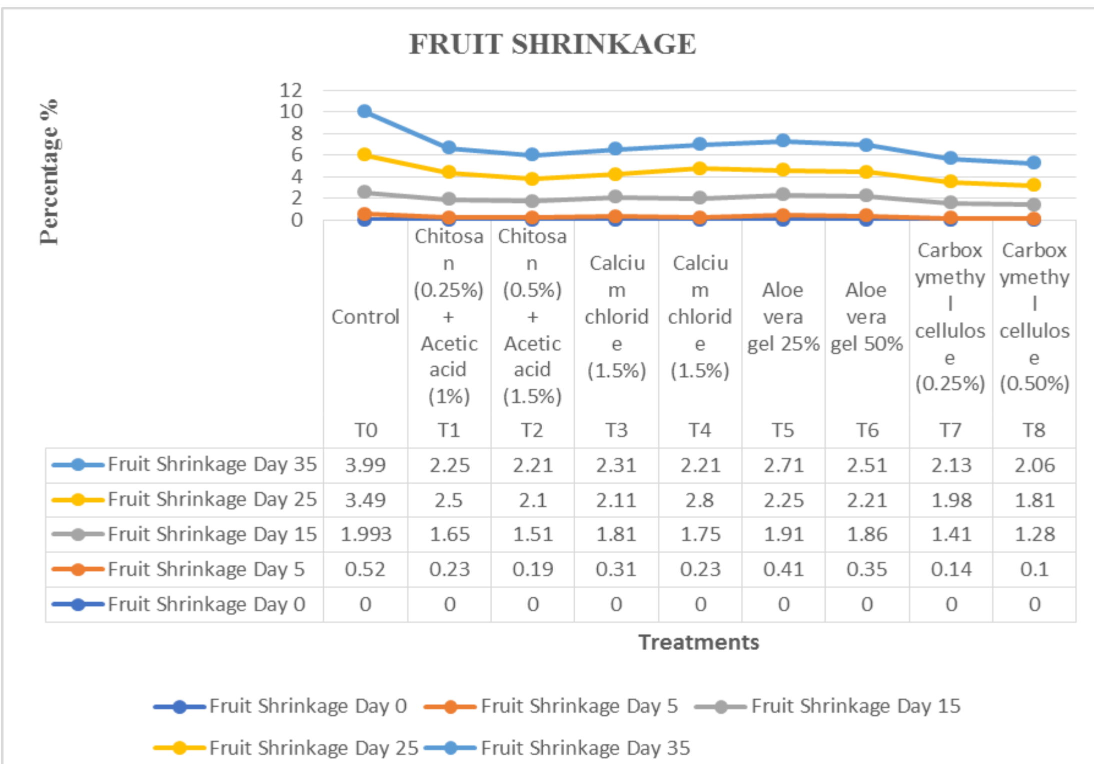
Conclusion

The results of the investigation showed that bio-active coating significantly improved the post- harvest quality and shelf life of pear fruits under ambient storage conditions. Among all treatments, Carboxymethyl cellulose (CMC) 0.5% (T8) proved most effective in maintaining physical character of fruits. Coated fruits showed lower physiological loss in weight and shrinkage, better firmness retention, and improved maintenance of specific gravity compared to untreated fruits. The superior performance of CMC coatings may be due to the formation of a semi-permeable protective layer on the fruit surface, which reduced respiration, transpiration, and other metabolic activities, thereby delaying ripening and extending storage life.



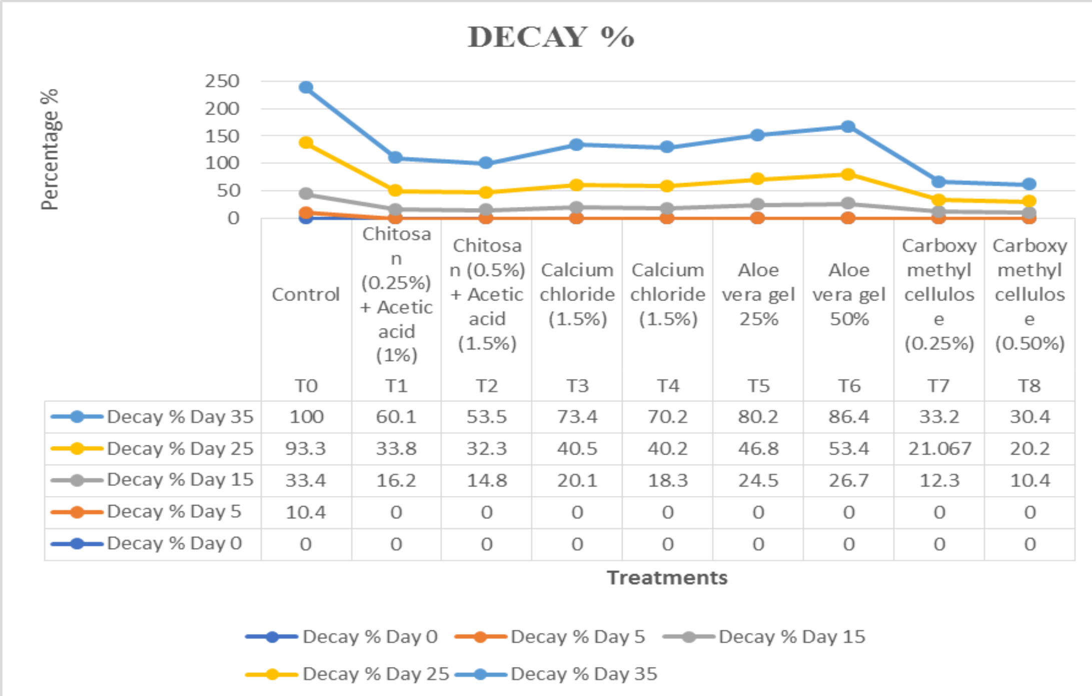
	T0	T1	T2	T3	T4	T5	T6	T7	T8
PLW % Day 35	9.4	7.5	7.2	8.027	7.8	8.7	8.4	6.5	6.2
PLW % Day 25	7.5	5.8	4.7	6.2	5.6	8.31	8.4	5.267	4.4
PLW % Day 15	6.6	4.2	3.8	4.893	4.6	8.5	8.1	3.5	3.2
PLW % Day 5	3.51	2.44	2.4	2.5	2.47	2.58	2.54	2.34	2.297
PLW % Day 0	0	0	0	0	0	0	0	0	0

Fig. 1: Effect of Different bio- active coating on Physiological loss in weight



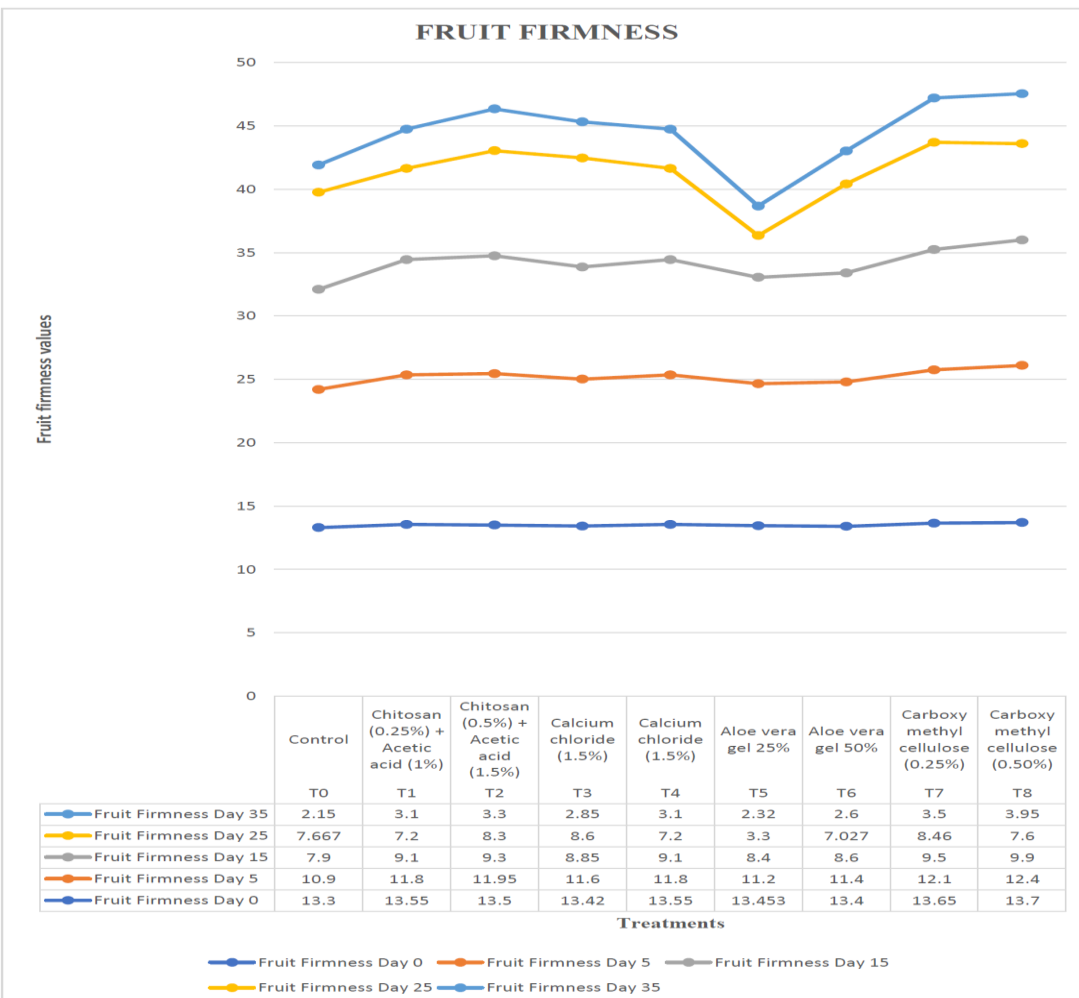
	Control T0	Chitosan (0.25%) + Acetic acid (1%) T1	Chitosan (0.5%) + Acetic acid (1.5%) T2	Calcium chloride (1.5%) T3	Calcium chloride (1.5%) T4	Aloe vera gel 25% T5	Aloe vera gel 50% T6	Carboxymethyl cellulose (0.25%) T7	Carboxymethyl cellulose (0.50%) T8
Fruit Shrinkage Day 35	3.99	2.25	2.21	2.31	2.21	2.71	2.51	2.13	2.06
Fruit Shrinkage Day 25	3.49	2.5	2.1	2.11	2.8	2.25	2.21	1.98	1.81
Fruit Shrinkage Day 15	1.993	1.65	1.51	1.81	1.75	1.91	1.86	1.41	1.28
Fruit Shrinkage Day 5	0.52	0.23	0.19	0.31	0.23	0.41	0.35	0.14	0.1
Fruit Shrinkage Day 0	0	0	0	0	0	0	0	0	0

Fig. 2: Effect of Different bio- active coating on Fruit Shrinkage



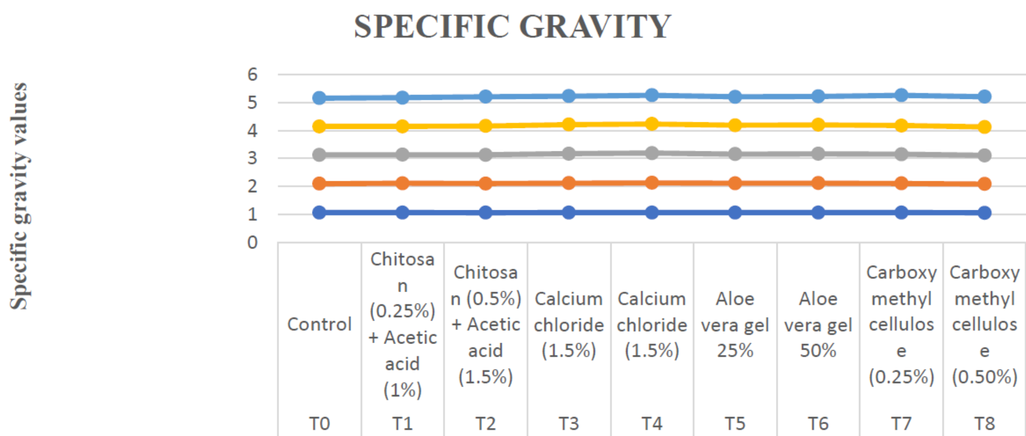
	Control T0	Chitosan (0.25%) + Acetic acid (1%) T1	Chitosan (0.5%) + Acetic acid (1.5%) T2	Calcium chloride (1.5%) T3	Calcium chloride (1.5%) T4	Aloe vera gel 25% T5	Aloe vera gel 50% T6	Carboxy methyl cellulose (0.25%) T7	Carboxy methyl cellulose (0.50%) T8
Decay % Day 35	100	60.1	53.5	73.4	70.2	80.2	86.4	33.2	30.4
Decay % Day 25	93.3	33.8	32.3	40.5	40.2	46.8	53.4	21.067	20.2
Decay % Day 15	33.4	16.2	14.8	20.1	18.3	24.5	26.7	12.3	10.4
Decay % Day 5	10.4	0	0	0	0	0	0	0	0
Decay % Day 0	0	0	0	0	0	0	0	0	0

Fig. 3 : Effect of Different bio- active coating on Decay %



	Control T0	Chitosan (0.25%) + Acetic acid (1%) T1	Chitosan (0.5%) + Acetic acid (1.5%) T2	Calcium chloride (1.5%) T3	Calcium chloride (1.5%) T4	Aloe vera gel 25% T5	Aloe vera gel 50% T6	Carboxy methyl cellulose (0.25%) T7	Carboxy methyl cellulose (0.50%) T8
Fruit Firmness Day 35	2.15	3.1	3.3	2.85	3.1	2.32	2.6	3.5	3.95
Fruit Firmness Day 25	7.667	7.2	8.3	8.6	7.2	3.3	7.027	8.46	7.6
Fruit Firmness Day 15	7.9	9.1	9.3	8.85	9.1	8.4	8.6	9.5	9.9
Fruit Firmness Day 5	10.9	11.8	11.95	11.6	11.8	11.2	11.4	12.1	12.4
Fruit Firmness Day 0	13.3	13.55	13.5	13.42	13.55	13.453	13.4	13.65	13.7

Fig. 4 and Tab. 4 : Effect of Different bio- active coating on Fruit Firmness



	Control T0	Chitosan (0.25%) + Acetic acid (1%) T1	Chitosan (0.5%) + Acetic acid (1.5%) T2	Calcium chloride (1.5%) T3	Calcium chloride (1.5%) T4	Aloe vera gel 25% T5	Aloe vera gel 50% T6	Carboxy methyl cellulose (0.25%) T7	Carboxy methyl cellulose (0.50%) T8
Specific Gravity Day 35	1.01	1.03	1.05	1.02	1.027	1.017	1.02	1.08	1.083
Specific Gravity Day 25	1.02	1.01	1.03	1.04	1.04	1.03	1.033	1.03	1.02
Specific Gravity Day 15	1.03	1.02	1.03	1.05	1.06	1.04	1.05	1.04	1.02
Specific Gravity Day 5	1.03	1.05	1.04	1.053	1.063	1.047	1.05	1.04	1.03
Specific Gravity Day 0	1.07	1.067	1.063	1.07	1.07	1.07	1.07	1.07	1.06

Fig. 5 and Tab. 5 : Effect of Different bio- active coating on Specific gravity

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Conflict of Interest

The author declares no competing interests.

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