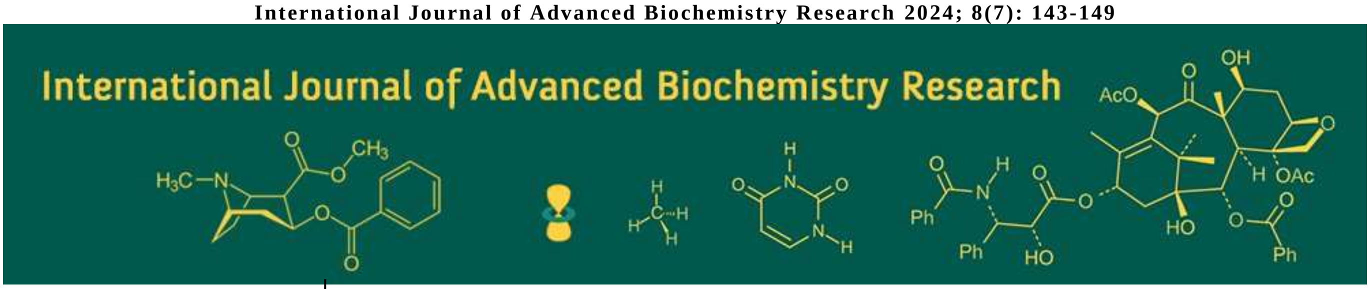

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Comparative evaluation of different edible coating treatments on postharvest quality of pointed gourd fruit

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Abstract
Pointed gourd, commonly known as ‘King of gourds’ is an economically important cucurbitaceous vegetable, native to India. It has a very limited postharvest life of 2 – 3 days at ambient condition. The rapid deteriorative changes after harvest causes loss of visual appeal, quality and marketability of pointed gourd within a very short period. The present study investigated the effect of sodium alginate, chitosan and carboxymethyl cellulose (CMC) coatings on postharvest quality of pointed gourd fruits during storage at ambient condition. In this experiment, pointed gourd fruits were coated with the above edible coating materials each at 1% and 2% concentrations, while control fruits were treated with distilled water. Following this, fruits were dried and stored at ambient temperature. The results showed that surface coating of pointed gourd with 1% chitosan significantly reduced weight loss of fruit compared to other treatments. This treatment also helped in preserving chlorophyll pigments and slowing down degradation of carotenoid pigments. The soluble solids content was better retained in coated fruits, with chitosan 1% showing the maximum retention. The total flavonoids content decreased over time but remained higher in coated fruits, especially with 1% chitosan and 2% CMC, compared to control. Overall, the findings of this study indicated that postharvest surface coating of pointed gourd fruit with 1% chitosan was highly effective in preserving desirable quality characteristics and extending storability of pointed gourd fruit during storage at ambient condition.

Keywords: Pointed gourd, shelf life, coating, chitosan, quality

1. Introduction
Pointed gourd (*Trichosanthes dioica* Roxb.) is an economically important and widely consumed perennial vegetable of Cucurbitaceae family. It is a perennial dioecious climber, the fruits of which are consumed as vegetable. It is mainly grown in India, China, Korea, Thailand, Indonesia, Nepal, Sri Lanka and Bangladesh. It is primarily cultivated as a summer vegetable crop in India and other parts of the world due to its high economic value and export potential. In India, pointed gourd is extensively cultivated in Bihar, West Bengal, Madhya Pradesh, Assam and Uttar Pradesh (Koley *et al*., 2009) [17]. In West Bengal and Bihar, it is one of the important vegetable crops, grown throughout the year except in the winter months. In India, the total production of pointed gourd is 725 thousand metric tons from an area of 62 thousand hectare (NHB, 2020-21). Immature pointed gourd fruits are mainly consumed as vegetable in a variety of ways, either alone or in combination with other vegetables. It is also used for preparation of pickles, dehydrated products and various confectionaries (Bharathi *et al*., 2013) [3].
Pointed gourd fruit is highly coveted among the cucurbitaceous vegetables due to its rich nutrient composition and generally regarded as ‘king of gourd’ (Yadav *et al.*, 2022) [34]. The fruit contains about 2.5 mg vitamin C, 255 I.U. vitamin A, 4.2 g carbohydrates, 2.0 g protein, 0.3 g fat and 3.0 g fibre (Singh, 1989) [33]. The fruit also contains fair amount of vitamin B-complex (0.5 mg thiamine, 0.6 mg riboflavin, 0.5 mg nicotinic acid) and about 0.5 g minerals like sodium, potassium, copper, sulphur, calcium, magnesium, and iron (Singh, 1989) [33]. It is a rich source of several health-promoting bioactive compounds like vitamins (A, C, B-complex), triterpenes (Cucurbitacin B, euphol, amyrin, taraxerol and betulin), peptides (Trichosanthin and lectin), sterols, steroidal saponin, tannins, flavonoids, etc.

The fruit of pointed gourd is easily digestible and has several therapeutic properties like antidiabetic, hepatoprotective, antipyretic, antioxidant, antitumor, anti-inflammatory, immunomodulatory, antinociceptive, antidiarrheal, cytotoxic, etc. (Ghaisas *et al*., 2008; Bhattacharya and Haldar, 2012) [10, 4].

The fruits of pointed gourd are harvested about 15 – 18 days after pollination, well before they approach physiological maturity. Harvesting of fully grown fruits is usually done once or twice a week. In general, green colour and tenderness (Softness) of pointed gourd fruit are important criteria of its freshness that are directly linked to its cooking quality and palatability. The major problem in the postharvest supply chain of this vegetable is rapid loss of freshness and quality deterioration within 2 – 3 days, at ambient storage condition. The quality alterations that occur in harvested pointed gourd fruit are rapid moisture loss and ripening that is associated with loss of green colour, texture, yellowing, seed hardening, loss of turgidity, lignification and reduction in nutritional value (Siddiqui *et al*., 2020) [32]. However, limited research works have been carried out so far in pointed gourd fruit to preserve its postharvest quality at ambient storage condition. Application of edible coatings has emerged as a promising eco-friendly method to reduce moisture loss, gaseous exchange thereby preserving quality and extend storability of fruits and vegetables (Pranoto *et al*., 2005) [27]. In the present study, we have investigated the effects of surface coating with sodium alginate, chitosan and carboxymethyl cellulose (CMC) on postharvest quality of pointed gourd fruits during storage at ambient condition.

Chitosan is a polysaccharide made up of (1, 4)-linked 2-amino-deoxy-β-D-glucan, and is a deacetylated derivative of chitin (Kumar *et al*., 2013) [18]. It has been reported to be non-toxic, biodegradable, biofunctional, biocompatible, and has potent antibacterial and antifungal properties (Yu *et al*., 2013) [35]. Likewise, alginates are natural linear polysaccharide composed of D-mannuronic and L-guluronic acid monomers and are salts of alginic acid, obtained from brown sea algae (Dhall, 2013) [9]. Similarly, another edible coating material carboxymethyl cellulose is a derivative of cellulose, prepared by the reaction of cellulose with sodium hydroxide and chloroacetic acid (Biswal and Singh, 2004) [5]. Many research reports indicated the beneficial effects of chitosan, sodium alginate and CMC coating on preserving quality of harvested fruit and vegetables.

2. Materials and Methods

The fruits pointed gourd (*Trichosanthes dioica* Roxb.) were harvested at commercial maturity stage during early morning. Immediately after harvest, fruits were transported to Postharvest Laboratory of the Department of Horticulture, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. Thereafter, those were sorted to obtain healthy, uniform fruits and randomly divided into seven groups. Fruits were then treated (Surface coated) with sodium alginate, chitosan and carboxymethyl cellulose (1% and 2%) while, control fruits were treated with distilled water. The surface moisture of the treated fruits was air-dried, packed in corrugated fibre board boxes and stored at ambient condition. At 2 days interval, fruits were randomly selected and observation were recorded on different physico-chemical quality attributes for a period of 6 days.

2.1. Weight loss

Weight loss of fruit was measured by weighing the pointed gourd fruit at regular interval during storage with an electronic weighing balance. Finally, the weight loss of pointed gourd fruit was calculated using the following formula and results were expressed in percent.

$$\text{Weight loss (\%)} = \frac{\text{Initial weight (g)} - \text{Weight onthe day of sampling (g)}}{\text{Initial weight (g)}} \times 100$$

2.2. Total chlorophyll content

The total chlorophyll content was determined following the method described by Arnon (1949) [2]. For this, 1.0 g of fruit skin was taken and crushed with 80% acetone to extract the chlorophyll pigment, the volume of which was adjusted up to 10 ml with 80% acetone. Later, the crushed sample was centrifuged at 10,000 rpm for 10 minutes. Subsequently, the supernatant was extracted and absorbance was recorded in spectrophotometer at 645 and 663 nm with reference to the blank prepared with 80% acetone. Finally, the total chlorophyll content was calculated and results were expressed as mg/g fresh weight (FW).

2.3. Total carotenoids content

The total carotenoids content was estimated following the method referred by Roy (1973) [30]. For this, 1.0 g of fruit sample was crushed in acetone (80%) for extraction of carotenoid pigments, till the tissue became colourless. Afterwards, the sample extract was taken in a separating funnel, and then petroleum ether and 5% sodium sulphate solution were added in the extract. When the carotenoid pigments were transferred from acetone to petroleum ether layer, then it was transferred to 50 ml volumetric flask and the volume was made up with petroleum ether. Finally, absorbance was recorded at 452 nm in a spectrophotometer using petroleum ether as blank. The results of total carotenoids were expressed as mg/g FW.

2.4. Soluble solids content

The estimation of soluble solids content (SSC) content of pointed gourd fruit during storage was done using digital refractometer (Atago, Tokyo, Japan) and the results were expressed in percent (%).

2.5. Total flavonoids content

The aluminum chloride method of Zhishen *et al*. (1999) [38] was used to estimate the total flavonoids content of pointed gourd fruit. In this method, 1.0 g of the pointed gourd fruit sample was mixed with 10 ml of methanol. After that, the mixture was centrifuged at 10,000 rpm for 10 minutes. One ml of supernatant was taken from this in a test tube containing 4 ml of distilled water and 0.3 ml of 5% sodium nitrite solution. After 5 minutes, 0.3 ml of 10% aluminum chloride solution was added to the test tube. The solution was then stored at room temperature for 6 minutes and 2 ml of 1.0 N sodium hydroxide solution was added. Finally, volume of the sample was made up to 10 ml with distilled water. Then, the absorbance of the sample was recorded at 510 nm in a spectrophotometer alongside a reagent blank. A standard calibration curve was produced using rutin. The total flavonoids content of pointed gourd fruit was expressed as milligram of quercetin equivalent per 100 g of fresh weight (mg QE/100 g FW).

3. Results and Discussion
3.1. Weight loss
In this study, postharvest application of sodium alginate, chitosan, and CMC was found effective in reducing the weight loss of pointed gourd fruit during storage (Figure 1). Weight loss increased over time in all treatments, but the control and 2% chitosan-treated fruits showed a faster increase in weight loss. After 2 days of storage, the control fruit exhibited the highest weight loss (16.79%), while the fruit treated with 1% chitosan showed the lowest weight loss (8.75%). After 4 and 6 days of storage, the control fruit again displayed the maximum weight loss of 26.69% and 40.25%, respectively. However, these weight losses were statistically at par with the treated fruits. The 1% chitosan treatment exhibited the lowest weight loss (28.25%) on the final day of the experiment. The results indicated that postharvest application of sodium alginate, chitosan, and CMC can effectively reduce the weight loss of pointed gourd fruit during ambient storage. Hong *et al.* (2012) [12] reported that coating of guava fruit with chitosan was highly effective in conferring a physical barrier to moisture loss, therefore, a decreased weight loss in the chitosan coated fruit was observed. Chitosan has been reported to be effective in delaying weight loss in banana, mango (Kittur *et al*., 2001) [16] and strawberries (Ribeiro *et al.*, 2007). Chitosan coating was beneficial in lowering weight loss by acting as a barrier and protecting against gases and water vapor diffusion (Sharma *et al.*, 2021) [31]. Sodium alginate also, has been specifically recognized for its exceptional barrier properties against water vapor and gases. This characteristic reduces both respiration and transpiration rates, consequently minimizing the weight loss experienced by the treated fruits (Poverenov *et al.*, 2014; Brasil *et al.*, 2012) [26, 6].

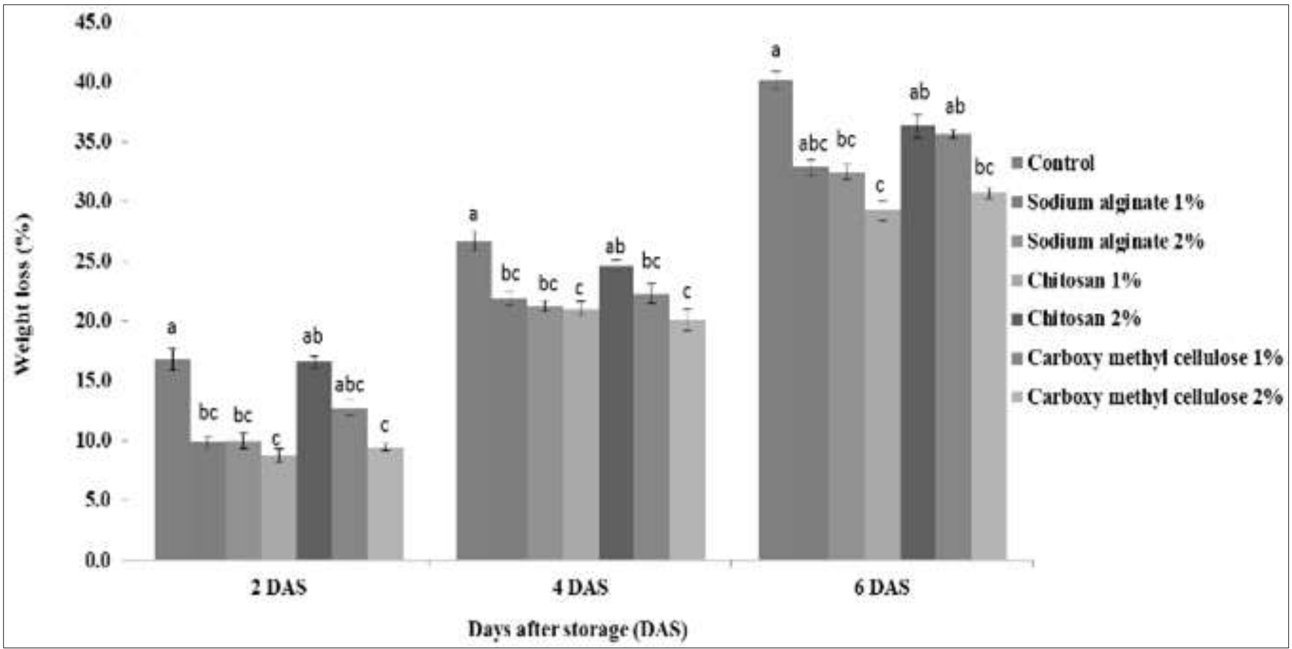

Fig 1: Effect of different edible coatings on weight loss of pointed gourd fruit during storage at ambient condition

3.2. Total chlorophyll content
The study revealed that total chlorophyll in pointed gourd fruit decreased during storage (Figure 2). The maximum loss of total chlorophyll was recorded in control fruit from 3.35 mg/g to 0.73 mg/g. However, chitosan (1%) treatment significantly delayed chlorophyll degradation, retaining 1.30 mg/g total chlorophyll on the final day of storage. Chitosan (1%) showed the greatest potential in preserving chlorophyll content during postharvest storage, while a higher CMC concentration (2%) proved more effective than the control and other CMC treatments in reducing chlorophyll degradation. These findings emphasized the significance of using natural edible coating treatments like chitosan and CMC in maintaining the visual appeal (green colour) of fruits during storage. These results are consistent with the findings of Olawuyi *et al.* (2019) [22], where chitosan coatings were found to effectively reduce chlorophyll degradation in cucumber during storage. Additionally, the higher CMC concentration (2%) exhibited a positive impact on reducing chlorophyll degradation, supporting previous studies highlighting CMC's potential in maintaining chlorophyll content in fruits during storage (Jafarzadeh *et al.* 2021) [14].

3.3. Total carotenoids content
In this study, data presented in Table 1 showed the effect of edible coating treatments on total carotenoids content of pointed gourd fruit. The study showed that during postharvest storage, total carotenoid content in pointed gourd fruit increased progressively. On the 2nd day of storage, fruits treated with 1.0% and 2.0% sodium alginate and 1.0% chitosan showed lower carotenoids levels compared to untreated fruit. The highest carotenoid content (1.16 mg/g) was recorded in untreated fruit. After 4 days, control fruit displayed the highest carotenoid content (1.34 mg/g), compared to treated fruits. On the 6th day, treatment with 1% chitosan and 2% CMC exhibited the slowest carotenoid accumulation rate (1.32 mg/g) compared to other treatments. The control fruits exhibited the maximum carotenoids content (1.61 mg/g). Overall, the treatment with 1% chitosan and 2% CMC consistently showed superior results in delaying carotenoid accumulation. The change in colour in pointed gourd is known to occur due to the transformation of chloroplasts into chromoplasts (Chitravathi *et al*., 2016) [7]. The application of chitosan decreased the degradation of chlorophyll pigments by suppressing chlorophyll degrading enzymes such as

chlorophyllase; as a result, rate of carotenoid synthesis was also decreased. On the other hand, application of surface coating might have created a modified atmosphere surrounding the fruit, which thereby increased carbon dioxide level around the produce, thus helping to reduce chlorophyll degradation and delaying carotenoid synthesis in fruit.

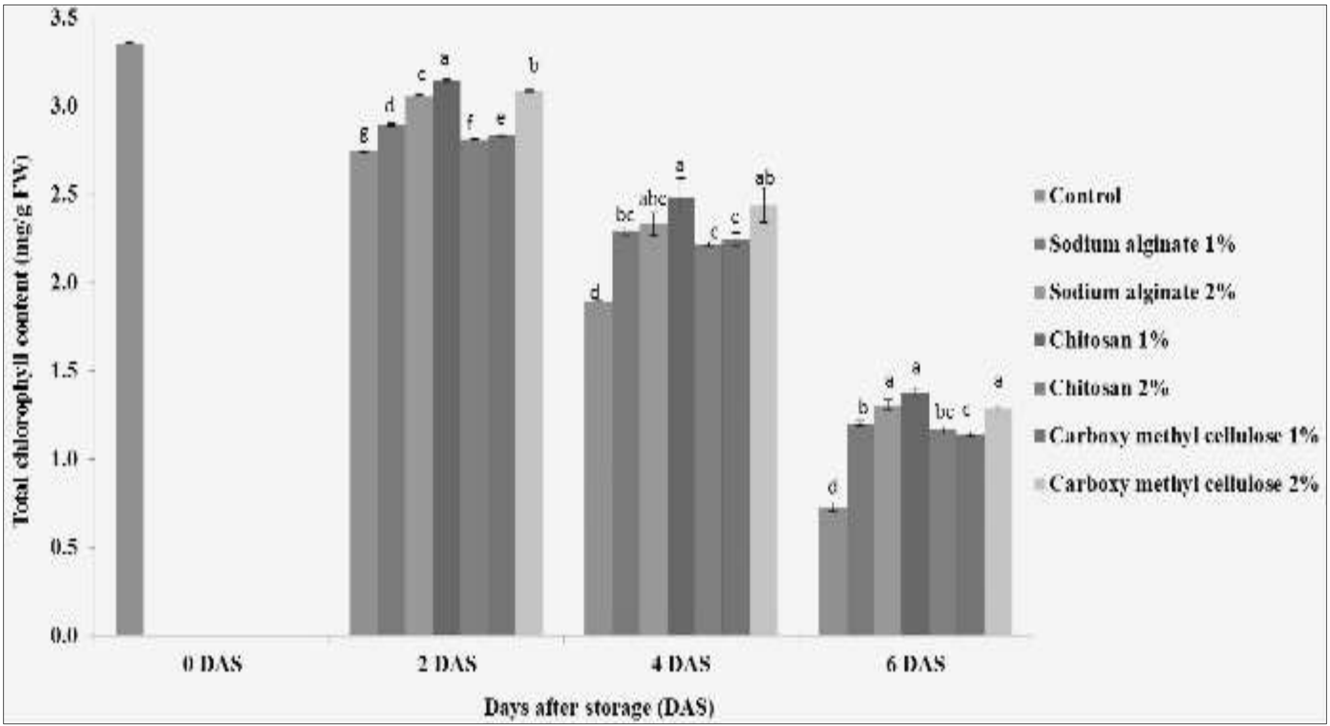

Fig 2: Effect of different edible coatings on total chlorophyll content of pointed gourd fruit during storage at ambient condition.

Table 1: Effect of different edible coatings on total carotenoids content of pointed gourd fruit during storage at ambient condition.

Treatments	**Total carotenoids content (mg/g FW)**		
	Days after storage (DAS)		
	2 DAS	**4 DAS**	**6 DAS**
Control	1.16±0.04 a	1.34±0.011 a	1.61±0.03 a
Sodium alginate 1%	0.90±0.01 cd	1.10±0.02 b	1.43±0.04 bc
Sodium alginate 2%	0.90±0.01 cd	1.09±0.03 b	1.39±0.04 cd
Chitosan 1%	0.83±0.01 d	1.05±0.02 b	1.32±0.02 d
Chitosan 2%	1.00±0.03 b	1.15±0.05 b	1.52±0.04 ab
Carboxy methyl cellulose 1%	0.91±0.04 c	1.15±0.02 b	1.42±0.02 c
Carboxy methyl cellulose 2%	0.85±0.01 cd	1.08±0.05 b	1.32±0.02 d
Initial value: 0.80 ± 0.01 mg/g FW			

Values are mean ± standard error of four replicate determinations (n=4). In each sampling day, treatment values followed by the same letters are not significantly different ($p<0.05$).

3.4. Soluble solids content

In this study, at the initial stage there was no significant difference in soluble solids content (SSC) between treated fruits after two days (Table 2). On this day, 1% chitosan coating retained the highest soluble solids (4.0%), while the control fruits had the lowest (3.35%) soluble solids content. From the fourth day onward, untreated fruits showed a higher degradation rate of soluble solids compared to treated fruits. Chitosan at 1% had the slowest degradation rate, maintaining the highest retention of soluble solids (3.37%) after six days, which was at par with sodium alginate (2%) and CMC (2%) treatments. By the end of the experiment, control fruits experienced the most significant loss of soluble solids, dropping to 2.72%. Soluble solids in fruit include sugars, organic acids, vitamins, pigments, and other soluble salts. The study showed that SSC in pointed gourd decreased gradually over the storage period. The faster decline in control fruit was likely due to higher respiration rates where sugars were used as respiratory substrates. This reduction in soluble solids during respiration was due to the breakdown of carbohydrates and pectin materials, protein hydrolysis, and the disintegration of glycosides (Lara *et al.*, 2004) [19]. Factors such as moisture loss, increased metabolic activity, and natural aging also contribute to the decrease in SSC during storage (Chouksey *et al.*, 2013) [8]. Chitosan as an edible coating maintained fruit quality and extended storage life by creating a protective barrier that mitigates water loss and slows down the degradation of soluble solids. Previous research has also showed chitosan's effectiveness in delaying the loss of soluble solids in strawberry (Martinez *et al.*, 2018) [20]. Likewise, CMC coating helped in retaining soluble solids content by minimizing moisture loss and metabolic activity, as observed in sweet pepper (Rao *et al.*, 2011) [28] and cucumber (Zhang *et al.*, 2015) [37]. Sodium alginate coating also delayed ripening, impacting the conversion of starch to soluble sugar and preserving soluble solids (Moalemiyan *et al.*, 2012) [21].

Table 2: Effect of different edible coatings on soluble solids content of pointed gourd fruit during storage at ambient condition.

Treatments	Soluble solids content (%) Days after storage (DAS)		
	2 DAS	4 DAS	6 DAS
Control	3.35±0.12 b	3.12±0.05 d	2.72±0.06 d
Sodium alginate 1%	3.87±0.05 a	3.42±0.03 c	3.07±0.06 bc
Sodium alginate 2%	3.85±0.10 a	3.52±0.03 bc	3.22±0.05 ab
Chitosan 1%	4.00±0.07 a	3.67±0.03 a	3.37±0.05 a
Chitosan 2%	3.80±0.04 a	3.40±0.06 c	2.95±0.06 c
Carboxy methyl cellulose 1%	3.82±0.05 a	3.45±0.06 bc	3.00±0.07 c
Carboxy methyl cellulose 2%	3.97±0.05 a	3.57±0.08 ab	3.25±0.13 ab
Initial value: 4.12 ± 0.03%			

Values are mean ± standard error of four replicate determinations (n=4). In each sampling day, treatment values followed by the same letters are not significantly different ($p<0.05$).

3.5. Total flavanoids content

In this this study, the effect of different edible coatings (sodium alginate, chitosan, and carboxymethyl cellulose) on total flavonoids content in pointed gourd fruit during storage was evaluated (Figure 3). The data indicated significant variation among the treatments, with a general reduction in flavonoids content over the storage period. Initially, the application of surface coatings helped to maintain higher flavonoids content compared to control. After two days, chitosan 1% and CMC 2% were most effective than other treatments. The control fruit's flavonoids content dropped from 5.81 mg QE/100 g FW to 2.90 mg QE/100 g FW after six days, showing a two-fold reduction. On the sixth day, chitosan 2% treatment maintained flavonoids content similar to the control. However, 1% chitosan-treated fruits had the highest flavonoids content (3.09 mg QE/100 g FW), which was closely followed by 2% CMC-treated fruits (3.08 mg QE/100 g FW). Flavonoids are secondary metabolites with numerous health benefits, including antioxidant properties (Panche *et al*., 2016; Pietta, 2000) [23, 24]. The observed reduction in flavonoids during storage is linked to their conversion to secondary phenolic compounds or enzymatic activity (Howard *et al*., 2003; Pinelo *et al*., 2004) [13, 25]. Chitosan and CMC coatings helped to limit these changes by reducing polyphenol oxidase activity (Zhang and Quantick, 1997) [36]. Similar effects have also been noted in strawberry (Jiang *et al*., 2020) [15] and fig. Sodium alginate coating slowed down flavonoid degradation by creating a modified atmosphere (Gonzalez-Aguilar, 2010) [11]. This helped in preserving flavonoids during postharvest storage.

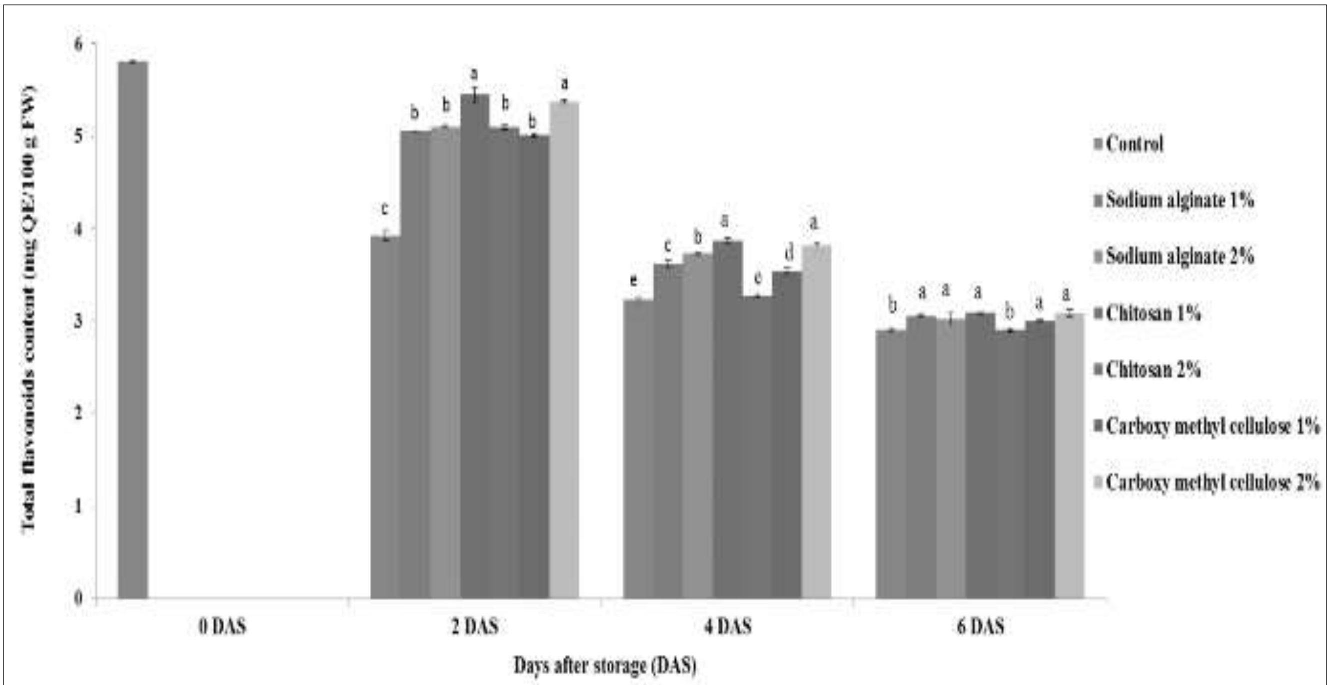

Fig 3: Effect of different edible coatings on total flavonoids content of pointed gourd fruit during storage at ambient condition.

4. Conclusion

The findings demonstrated that surface coating of pointed gourd fruit with sodium alginate, chitosan and carboxymethyl cellulose enhanced shelf life and maintained postharvest quality of pointed gourd during ambient storage, compared to control. However, chitosan 1% was most effective in minimizing weight loss, preserving chlorophyll content, reducing carotenoid accumulation, and retaining higher levels of soluble solids and total flavonoids. This suggested that 1% chitosan coating can be used to prolong freshness and marketability of pointed gourd fruit in the postharvest supply chain.

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