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Studies on the post-harvest shelf-life extension of baby corn (*Zea mays*) using edible coating

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Abstract
The study investigated the edible coatings (Chitosan and Carboxyl methyl cellulose) effects on some quality parameters of baby corn during its storage period. Two concentrations (1% and 2%) of chitosan and carboxyl methyl cellulose were applied on baby corn and analysed periodically for 15 days. The results depicted that baby corn treated with 1% carboxyl methyl cellulose (CMC) had most positive and effective results. Baby corn treated with 1% CMC had significantly lower weight loss (3.95%) and spoilage percentage (6.34%) as compared to untreated control with respective values of 7.55% and 11.72%. The same treated had higher values for firmness, ascorbic acid, phenolic content and titratable acidity with respective values of 8.45 N, 5.65 mg/100 g pulp, 40.40 mg/100 g pulp and 0.77%. From the investigation, it was concluded that CMC with 1% concentration was the most effective in preserving and maintaining the physical and physio-chemical attributes of aby corn up to 15 days as compared to untreated control.

Keywords: Baby corn, edible coating, shelf-life, chitosan, CMC

Introduction

Baby corn (*Zea mays*) is an entire young cob and high-value vegetable with Thailand and Taiwan being the largest exporters. Well drained sandy loam to silty loam soils is best suited for baby corn cultivation. It can be grown in well drained black soils as well. The baby corn must be properly harvested, handled, stored and transported as to obtain quality produce in satisfactory conditions. Baby corn comes under highly perishable commodity and has high respiration rate, so it can't be stored for extended duration under ambient conditions and can't be transported to other places (Mehan *et al.*, 2014) [39]. The shelf life may be extended, thereby maintaining quality of the produce by appropriate production and harvesting practices, proper on farm handling, and post harvesting practice such as pre cooling, packaging, storage and transportation. Mechanical stress, at the cut surface, cells and membranes reduces the life of freshly cut produce mainly due to damaged leading to alterations in tissue metabolism such as increase in water loss, CO_2, and ethylene evolution, alterations in flavour, aroma, and volatile profiles, increase in activity of enzymes related to enzymatic browning and development of browning is the major post-harvest loss in baby corn. Various techniques like packaging and low temperature storage need to be adopted to extend its post-harvest life (Mehan *et al.*, 2014) [39]. Baby corn is highly nutritive and its nutritive quality is superior to some of the seasonal vegetables as that of carrot, lettuce, cabbage, and radish. Baby c orn is a good source of protein, vitamins and minerals constitutes about 17.96 g/100 g crude protein and 5.43 mg/100 g vitamin C which is higher than carrots and pumpkin (Hooda and Kawatra., 2013) [34]. Besides these nutrients, it is one of the richest sources of phosphorus. Baby corn is liked by those who are health conscious as it contains less amount of fat that eventually helps in losing weight and for the same cause its demand is increasing day by day within the market. It can be eaten raw as well as cooked and used as garnishing element in different kind of dishes because of its size and appearance.

Post-harvest losses and transportation facility hinders the availability of food stuffs and that's why packaging system is there, it is a process that extends the shelf life of the product and also facilitates distribution and marketing. Use of edible coating is a novel approach to enhance the standard of food for consumer acceptance. Edible coatings are an eco-friendly technique, which slows deterioration of vegetables by controlling gas exchange, moisture transfer, and oxidation (Sharma *et al.*, 2018) [28]. Major advantage of these coatings is that they can be eaten with the food itself and are non-toxic.

Consumers are demanding fresh fruits and vegetables with less use of chemicals and that's why attention has been paid to the natural occurring substance that serve as a barrier between food produce and surroundings and in this regard edible coatings are the most appropriate method and the most important advantage of edible coating is that it is helpful in reducing the use of synthetic packaging as edible coating is made up of biodegradable raw material (polysaccharides, lipids, proteins). It is the thin layer applied to foods that act as a barrier for the parameters that are responsible for the spoilage of food products such as oxygen, moisture and solute movement and in this way helps in prolonging its shelf-life and improves its sensory properties as well and makes the product more appealing for the consumers. Edible coatings have the potential to carry active ingredients such as anti-browning agents, nutrients, antimicrobial compounds that act as a barrier and helps in extending the shelf life (R.K. Dhall., 2013) [40]. As they can be eaten with the food itself, the materials used for edible coatings should be generally recognized as safe (GRAS). It is not a latest technology and had been used by the Chinese in 12th century for fruits and vegetable with use of wax coating but now advances in this technology makes it more efficient than before (Hassan *et al*., 2018) [6].

Materials and Methods

Plant material

Baby Corn were procured from the local market, Phagwara, Punjab and transported to Department of Food Science and Technology, Lovely Professional University, Punjab.

Coating treatments

Experiments were performed using two concentrations Chitosan and Carboxyl methyl cellulose (CMC) at 1% and 2%. The required amount of CMC was dissolved in distilled water and stirred at 60 °C. After complete dissolution 0.3% glycerol (w/v) were added as a plasticizer were added and stirred (Mahna *et al*., 2019). To prepare 500ml of 1%, 2% of chitosan solution, 5gm and 10gm of chitosan were dispersed in 400 ml of distilled water respectively to which 25 ml of acetic acid was added to dissolve the chitosan and the solution made up to 500 ml (Jiang and Li, 2001) [16]. The coating was applied by dipping technique. For CMC coating. Baby corns was dipped for 60 seconds and then dried for 1 hour at room temperature. For Chitosan coating, baby corn was dipped and dried for 4 hours. After coating, baby corn was packed in polyethylene bags and stored for progressive assessments. The uncoated baby corn treated with distilled water were used as control.

Post harvest quality measurements

Weight loss: The physiological loss in weight of fruit was calculated on initial weight basis. At the end of each storage interval the weight of the fruit was evaluated and percent physiological loss in weight (PLW) was considered by recording both final weight (Wf) and initial weight (Wi) of fruits, as per formula given below:

$$Physiological\ loss\ in\ weight\ (\%) = \frac{Initial\ weight - Final\ weight}{Initial\ weight} \times 100$$

Fruit firmness: Fruit firmness was measured with the help of penetrometer. Fruit was firmly held in left hand and firmness was measured on both sides of each fruits using manual penetrometer with 8mm plunger and results were expressed in Newton (N).

Spoilage percentage: Spoilage percentage was calculated by calculating the total number of baby corn and that had been spoiled due to various reasons. It is an important aspect in determining the overall quality. Formula for calculating spoilage (%):

$$Spoilage\ (\%) = \frac{No.\ of\ spoiled\ baby\ corn}{Total\ No.\ of\ baby\ corn} \times 100$$

Organoleptic sensory attributes: Fruits were rated according to the hedonic scale by panels of judges who gave scores (out of 9) based on products overall acceptability.

Total Soluble Solids (TSS): Total Soluble Solid content of baby corn was estimated using Refractometer i.e., Erna Hand Refractometer, Japan. Refractometer with a scale of 0 to 32 °Brix was used at 20 °C (AOAC, 2005).

Vitamin C: Vitamin C content of the fruit flesh was determined by using 2, 6- dichlorophenol indophenols dye (DCPIP) by titration method (AOAC, 2005).

Total phenols: Total phenols were determined by Folin-Ciocalteu (FC) reagent as described by (Mahna *et al.*, 2018) [38]. Briefly, 1gm of freshly part of baby corn was digested with 2ml of 1% HCL-Methanol (1ml HCl in 99 ml methanol) and centrifuged at 12,000 rpm for 10 min and then supernatant was collected and used to quantify total phenolic compound. For this purpose, to the 50 µl extract, 500 µl distilled water and 2.5 ml of 10% by Folin- Ciocalteu solution was added. After 15 minutes, 2 ml of 7.5% sodium bicarbonate was added. Sample was incubated for 30 minutes and absorbance was recorded at 760 nm using spectrophotometer. The absorbance values were converted to total phenolics and were expressed as milligrams of gallic acid per 100 gm fresh weight. Different concentrations of gallic acid in 95% methanol were used as standards.

Titratable acidity: 1 gm sample was dissolved in 9 ml distilled water and 2-3 drops of phenolphthalein indicator was added. Then, it was titrated with 0.1N NaOH solution and noted down the readings of burette.

$$Titratable\ acidity = \frac{Burette\ reading \times N\ of\ NaOH \times 0.064}{Weight\ of\ sample} \text{ x } 100$$

Statistical analysis

The experiment was laid out in Factorial Completely Randomized Block Design with three replications for each treatment. Treatment mean separation was done at p<0.05% using statistical analysis system software version 9.3 (SAS Institute Inc., Cary, NC, USA) at 5% level of probability.

Results and Discussion

Physiological loss in weight (%)

The data obtained from the effect of carboxy methylcellulose (CMC) and chitosan based edible coating on physiological loss in weight (PLW) of baby corn during storage depicted that there was significant difference among the different concentration of CMC and chitosan with context to PLW (Table 1). Initially, there was a reduced weight loss in all the treated baby corn but increased thereafter with expansion in storage period. However, baby corn coated with CMC (1%) showed the minimum mean weight loss (6.34%) followed by CMC (2%) where the mean weight loss was 7.10%. However, the control baby corn recorded the highest mean weight loss (11.72%). The weight loss in CMC (1 and 2%) coated baby corn varied from 3.94 - 9.21% and 4.12 – 10.40% respectively from 5th day to 15th day of storage whereas weight loss in Chitosan (1 and 2%) coated baby corn varied from 5.38 – 12.61% and 4.68 – 13.96% respectively from 5th day to 15th day of storage. On the other side, the control one exhibited weight loss from 7.16% to 16.81% from 5th day to 15th day of storage. According to (Robertson *et al.*, 1990), because of transpiration and respiration, there is an expansion of PLW in fruits and vegetables during storage period which leads in increase in physiological loss of weight. Coatings supplemented with CMC and Chitosan helped in preventing the loss of moisture by acting as a barrier between the product's surface and the outer environment.

Table 1: Effect of CMC (carboxy methyl cellulose) and chitosan on weight loss of baby corn during storage.

Weight loss (%)				
Storage interval (Days)				
Treatment (T)	**5**	**10**	**15**	**Mean (T)**
CMC (1%)	3.94g	5.84f	9.21c	6.34C±0.68
CMC (2%)	4.12g	6.78f	10.40d	7.10D±0.76
Chitosan (1%)	5.38e	8.14f	12.61b	7.57C±0.81
Chitosan (2%)	4.68f	7.25f	13.96b	8.63B±0.86
Control	7.16e	11.21c	16.81a	11.72A±0.72
Mean (SI)	5.05C±0.55	7.84B±0.60	12.59A±0.76	

Data is represented as Mean±S.D.

Firmness

The data obtained from the effect of carboxy methylcellulose (CMC) and Chitosan edible coating on firmness of baby corn during storage showed a reducing trend. The coating treatments were good in firmness preservation. Firmness in CMC (1% and 2%) treated baby corn varied from 10.45N – 8.21N and 12.15N – 8.84N respectively from 5th day to 15th day of storage whereas firmness in Chitosan (1% and 2%) coated baby corn varied from 10.28N – 7.81N and 11.18N – 9.12N respectively from 5th day to 15th day of storage. On the other hand, firmness in control one varied from 12.21N – 9.54N from 5th day to 15th day of storage. During storage, the fruit becomes soften in nature which leads to decline the toughness of cell wall, deprivation of membrane integrity, oxidation of cellulose and hemicelluloses, including gelatin. Coatings of CMC showed the higher firmness in the fruit which might be due to loss of moisture and respiratory activity and thus kept the turgidity of cells (Gill *et al.*, 2016) [41].

Table 2: Effect of CMC (carboxy methyl cellulose) and chitosan on firmness of baby corn during storage.

Firmness (N)				
Storage interval (Days)				
Treatment (T)	**5**	**10**	**15**	**Mean (T)**
CMC (1%)	10.45a	6.71b	8.21c	8.45A±1.88
CMC (2%)	12.15a	8.21b	8.84c	9.73A±2.11
Chitosan (1%)	10.28a	6.95b	7.81c	8.34A±1.72
Chitosan (2%)	11.18a	7.84b	9.12c	9.59A±2.02
Control	12.21a	10.16c	9.54c	10.78B±1.34
Mean (SI)	11.25A±0.91	7.97B±1.36	8.70C±0.69	

Data is represented as Mean±S.D.

Spoilage (%)

All the treated baby corn recorded notable reduction in the mean spoilage per cent than that of control (Table 3). However, the lowest average fruit spoilage (8.33%) was recorded with CMC (1%). On the other hand, highest decay (29.1 %) was noticed in control one. The range of spoilage percentage in CMC (1% and 2%) coated baby corn was observed from 0 to 25% and 0 to 41.66% respectively from 5th day to 15th day during storage whereas Chitosan coated baby corn range from 0 to 44.60% and 0 to 54.16% for 1 and 2% respectively. On the other side, control recorded in the range of 0 to 62.50 per cent from 5th day to 15th day of storage.

Table 3: Effect of CMC (carboxy methyl cellulose) and chitosan on spoilage of baby corn during storage.

Spoilage (%)				
Storage interval (Days)				
Treatment (T)	**5**	**10**	**15**	**Mea n (T)**
CMC (1%)	0.00f	0.00f	25.00d	8.33D±4.17
CMC (2%)	0.00f	12.50e	41.66c	18.05C±6.18
Chitosan (1%)	0.00f	12.50e	44.60e	19.03E±7.24
Chitosan (2%)	0.00f	12.50e	54.16b	22.22B±8.20
Control	0.00f	25.00d	62.50a	29.17A±9.10
Mean (SI)	0.00C±0.00	8.83B±2.67	45.58A±4.30	

Data is represented as Mean±S.D.

Organoleptic sensory attributes (Hedonic Scale 1-9)

Organoleptic sensory attributes depict the consumer suitability, which depends on colour, texture, aroma, taste and appearance of fruit. The observation obtained from the effect of CMC and Chitosan based coating on organoleptic sensory quality (out of 9) of baby corn broadcast an increasing and decreasing trend during storage (Table 4). Baby corn treated with (CMC 1%) showed the maximum average sensory score (7.99) followed by (CMC 2%) (7.63) during the storage and was considered the best coating to maintain the palatability. However, the lowest mean sensory score of 7.04 was observed in the control one during storage. Interestingly, fruit coated with CMC coating indicated a gradual increase in sensory attributes after 10 days of storage; thereby reported the maximum sensory score (8.20); thereafter followed a secured and sharp decrease in sensory score at the end of the storage (7.87). On the other hand, baby corn treated with chitosan (1 and 2%) showed average sensory score of 7.16 and 7.01 respectively during the storage period. However uncoated fruit reported that palatability was reduced at faster rate with extension in storage period. In the current study it was concluded that baby corn coated with CMC (1 and 2%) coating recorded better sensory quality. It is because the coating act as a barrier between product and surrounding that ultimately helps in maintaining the overall quality.

Table 4: Effect of CMC (carboxy methyl cellulose) and chitosan on organoleptic sensory attributes of baby corn during storage.

Organoleptic sensory attributes (Hedonic scale1-9)				
Storage interval (Days)				
Treatment (T)	**5**	**10**	**15**	**Mean (T)**
CMC (1%)	7.90abc	8.20ab	7.87cde	7.99ab±0.18
CMC (2%)	7.70abc	7.90abc	7.30bcd	7.63a±0.17
Chitosan (1%)	7.60ab c	7.10bcd	6.80de	7.16b±0.20
Chitosan (2%)	7.30bc d	7.10bcd	6.60de	7.01b±0.15
Control	7.90ab	7.13bcd	6.10de	7.04b±0.27
Mean (SI)	7.68a±0.10	7.48a±0.17	6.93b±0.15	

Data is represented as Mean±S.D.

Total Soluble Solids (TSS)

The data obtained from the effect of CMC and Chitosan based coating on TSS of baby corn depicted increasing-decreasing trend (Table 5). Baby corn treated with CMC (1%) showed the maximum average total soluble solids (8.65%) followed by Chitosan (1%) with 8.54%. However, the control one showed the lowest average TSS (8.29%) content. The data additionally observed that baby corn coated with CMC (1%) and Chitosan (1%) exhibited a slow enhance in TSS up to 10 days of storage respectively and after 10th day TSS content was decreased at the end of storage. In the current study, the TSS content during the storage showed increasing or decreasing trends might be due to hydrolysis of starch into sugars. On the fulfillment of starch hydrolysis, there was no further increase in TSS occurred, this may be due to its utilization as a substrate during respiration process (Wills *et al.*, 1980) [42].

Table 5: Effect of CMC (carboxy methyl cellulose) and chitosan on Total Soluble Solids (TSS) of baby corn during storage.

Total Soluble Solids (TSS %)				
Storage interval (Days)				
Treatment (T)	**5**	**10**	**15**	**Mean (T)**
CMC (1%)	8.97acd	8.77abc	8.23cde	8.65A±0.38
CMC (2%)	8.85de	8.50abcd	8.10cde	8.48A±0.37
Chitosan (1%)	8.93bd	8.80ab	7.90abcd	8.54A±0.56
Chitosan (2 %)	8.80de	8.60abcd	7.77de	8.39A±0.54
Control	8.06ad	8.90a	7.93e	8.29A±0.52
Mean (SI)	8.72B±0.37	8.71A±0.16	7.98B±0.18	

Data is represented as Mean±S.D.

Vitamin C

The data obtained showed that the Vitamin C values reached maximum at 10th day and then slowly declined. Baby corn coated with 1% CMC had the greatest value (5.65 mg/100 g) and control one had the least value (5.12 mg/100 g) at the end of maintenance. Vitamin C content in baby corn treated with CMC (1 and 2%) ranged from 5.81 to 5.04 mg/100 g and 5.72 to 4.90 mg/100g respectively during the storage period whereas for Chitosan (1 and 2%) it was 5.68 to 4.98 mg/100g and 5.64 to 4.91 mg/100 g respectively. Vitamin C is modified primarily by ascorbic acid oxidase and polyphenol oxidase, the activities of which directly depend on the O2 content of the environment. Thus, a reduction in respiration rate of coated fruit could be a reason for vitamin C preservation (Zhou *et al*., 2008) [43].

Table 6: Effect of CMC (carboxy methyl cellulose) and chitosan on Vitamin C content of baby corn during storage.

Vitamin C (mg/100 g)				
Storage interval (Days)				
Treatment (T)	**5**	**10**	**15**	**Mean (T)**
CMC (1%)	5.81g	6.10c	5.04c	5.65**A**±0.54
CMC (2%)	5.72g	5.78f	4.90a	5.46A±0.49
Chitosan (1%)	5.68e	5.34f	4.98b	5.33A±0.35
Chitosan (2%)	5.64e	5.15f	4.91b	5.23A±0.37
Control	5.76g	5.86c	3.75a	5.12A±0.67
Mean (SI)	5.72B±0.66	5.64B±0.39	4.71A±0.54	

Data is represented as Mean±S.D.

Total phenols

The data obtained witnessed no significant difference in total phenolic content between coated and uncoated baby corn. In case of CMC, average phenolic content was 41.40 mg GAE/ 100g and 40.65 mg GAE/ 100g for 1% and 2% respectively whereas for Chitosan 1 and 2%, it was 40.76 mg GAE/ 100 g and 40.71 mg GAE/ 100 g respectively. On the other hand, for control, it was 40.17 mg GAE/ 100 g.

Table 7: Effect of CMC (carboxy methyl cellulose) and chitosan on phenolic content of baby corn during storage.

Total phenols (mg GAE/100g)				
Storage interval (Days)				
Treatment (T)	**5**	**10**	**15**	**Mea n (T)**
CMC (1%)	42.10f	41.80e	40.30d	41.40D±0.96
CMC (2%)	41.20f	40.65e	40.10c	40.65C±0.55
Chitosan (1%)	41.60f	40.60e	40.10e	40.76B±0.76
Chitosan (2%)	40.20f	40.05f	39.90b	40.71B±0.71
Control	40.80f	39.70e	39.50a	40.17A±0.70
Mean (SI)	41.18C±0.72	40.56B±0.79	39.78A±0.57	

Data is represented as Mean±S.D.

Titratable acidity

The data obtained revealed a slight decrease in titratable acidity at the end of storage. CMC coating with 1% concentration was most effective with 0.77%. Effectiveness of coating treatments could be the result of delay in ripening and maturation that reduces the metabolism involved in TA. The carboxylic acid production resulting from fixation of CO2 could be the main reason for the TA increase (Togrul and Arslan, 2004) [44].

Table 8: Effect of CMC (carboxy methyl cellulose) and chitosan on titratable acidity of baby corn during storage.

Titratable acidity (%)				
Storage interval (Days)				
Treatment (T)	**5**	**10**	**15**	**Mea n (T)**
CMC (1%)	0.81f	0.77f	0.73d	0.77D±0.04
CMC (2%)	0.76f	0.74e	0.71c	0.73C±0.02
Chitosan (1%)	0.79f	0.73e	0.70e	0.74E±0.04
Chitosan (2%)	0.73f	0.69e	0.64b	0.68B±0.03
Control	0.70f	0.65d	0.61a	0.65A±0.04
Mean (SI)	0.75C±0.0004	0.71B±0.0004	0.67A±0.0002	

Data is represented as Mean±S.D.

Conclusion

Overall, the study depicted that baby corn treated with 1% CMC edible coating had most positive and effective results. Baby corn treated with 1% CMC had significantly lower weight loss and spoilage percentage as compared to untreated control. The same treated had higher values for firmness, ascorbic acid, phenolic content and titratable acidity which altogether promoted better qualitative properties in baby corn. It can be concluded that the application of CMC-based edible coatings is a promising method for extending shelf life of baby corn.

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