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EXTRACTION OF POLYSACCHARIDES FROM *OPUNTIA CACTUS* FOR ITS POTENTIAL APPLICATION IN EDIBLE COATING TO IMPROVE THE SHELF LIFE OF CITRUS (KINNOW MANDARIN) FRUIT

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ABSTRACT

Fruits and vegetables are subjected to post-harvest losses due to high moisture contents along with other physiological factors. Among various measure to control loses, development of edible coatings has been an imperative and innovative technique to achieve the desired goal. *Opuntia cactus,* a xerotrophyte, plant contains appreciable amount of polysaccharides thus can be utilized in edible coating formation. The mandate of present study was to extract polysaccharides from cactus for development of edible coatings for their potential applications on citrus fruits. For the purpose, various concentrations of extracted cactus polysaccharides were used to develop edible coatings. These coating were applied on citrus fruits (Kinnow mandarin) which were then stored for period of 35 days. The results indicated that the maximum moisture was observed in T_3 (2% cactus polysaccharides) i.e. 86.94±2.10%. The maximum value for pH of coated citrus was found in T_1 (3.19% cactus polysaccharides) as 3.19±0.02%. Conclusively, as the demand of fresh looking fruits and vegetables is increasing due to the awareness among the masses, edible coatings using cactus polysaccharides can play an imperative role in increasing the shelf life along with retaining the quality of various commodities.

Keywords: Citrus, Edible coating, Cactus, Polysaccharides, Post-harvest losses

INTRODUCTION

Fruits and vegetables are important components of human diet which provide vital nutrients required to boost the health of individuals. Some fruits and vegetables continue their physiological activity even after harvesting thus they are more susceptible to deterioration during storage and transportation resulting in undesirable changes in composition, flavor, appearance and their consumer acceptability (**Hodges *et al*., 2011**). Being perishable commodities, they are more susceptible to post-harvest losses. Currently, these losses are around 25-40% of total produce (**Musasa *et al*., 2013**).
Various techniques to curtail these losses were developed and some of them find potential applications of low temperature, irradiation, and edible coating. Among these, edible coating has gained more importance nowadays. Edible films and coating usually applied to improve the gas & moisture barrier properties. Mechanical features, sensory appraisal, convenience in use and protection against microbial pathogens are its additional benefits. Edible coating is a thin layer of materials applied as a semi-liquid at the outer surface of the commodity by spraying, dipping or brushing. There are different types of coatings based on the material used and amongst polysaccharides based edible coatings are gaining ore popularity. The polysaccharides based edible coatings are hydrophilic in nature thus provide strong hydrogen bonding (**Yahia *et al*., 2004; Abeer*et al*., 2013**).
Citrus being most commonly cultivated tree in the world, with total global production of 72.8 million metric tons in 2005/2006 due to its fruits widely used all around the world. Citrus have a variety of nutrients such as vitamin C, vitamin A (e.g. beta-carotene, zeaxanthin), folate and fiber as well as many non-nutrient phytochemicals such as flavonoids, triterpenes and phenol acids (**Eckert *et al*., 1989**).
Sadly, most of the fruits produced are wasted due to pre/post-harvest damages and the natural ripening enzymes which reduce its shelf-life. Such fruits can be preserved by the use of edible coatings thus maximizing the benefits and minimizing the waste produced. Previously, important polysaccharides used in this type of coatings are starches and celluloses present in plants. However, some of wild plants grown in different parts of the globe contain higher amounts of complex polysaccharides. In Pakistan more than 6000 species of wild plants are reported. One of these is *Opuntia cactus*, a xerotrophyte and native to arid and semi-arid zones. Plants like these can be utilized to protect highly perishable fruits and vegetables, allowing us to extend the shelf-life and availability of fruits like citrus. Thus present research has been designed to investigate the option of extraction of polysaccharides from wild *Opuntia cactus* plant for the preparation of edible coating to improve the shelf life of citrus fruits along with marinating the quality over a longer period of time.

MATERIAL AND METHODS

Extraction of Polysaccharides from Cactus

Sample preparation

Fresh cactus (1000g) was taken and thorns were removed. Samples were washed properly then cut into small pieces and spread on the sheet for some days until sample was ready for grinding purpose. After grinding, sieving of grounded sample was done and powder was further used for polysaccharides extraction.

Extraction procedure

The extraction of polysaccharides from the cactus was done by using hot water as a medium; 100g sample was added in 1000 mL hot water. Firstly, three different buffer solutions (7, 4, and 9) were used for calibration of pH meter. pH of sample was maintained at 10 into half boiled water (500ml) and then placed for 5 h without shaking. Precipitate was separated from supernatant. After that supernatant put into refrigerator overnight then precipitate was separated and dried in hot air oven at temperature 105°C for 12 hrs. This dried extract was called polysaccharide. The final yield of extract at pH 10 was 10g. At pH 9 polysaccharides were extracted by following above procedure but sample weight was 50g in 500 mL half boiled water with final yield of 5g. Same extract was prepared by maintaining pH 8 with final extraction of 5g.

Extraction rate (%) = (polysaccharides weight - raw material weight) × 100

Preparation of Edible Coating

Edible coating was prepared by complete mixing of polysaccharides extract (1g), acetic acid (1g), ascorbic acid (2g), citric acid (1g), glycerol (1.5g), sunflower oil (0.025) and distilled water (1ooml) for treatment 2. Three different concentrations of these edible coatings were prepared.

T**able 1** Different concentration of Polysaccharides based coatings

Chemicals	T0 Control	T1 0.5%polysaccharide	T2 1%polysaccharide	T3 2%polysaccharide
Polysaccharides	-	0.5g	1g	2g
Glycerol	-	1.5g	1.5g	1.5g
Sunflower oil	-	0.025g	0.025g	0.025g
Ascorbic acid	-	2g	2g	2g
Acetic acid	-	1g	1g	1g
Distilled water	-	100mL	100mL	100mL
Citric acid	-	1g	1g	1g

Application of edible coating on citrus

Sample preparation

Citrus from commercial orchards were selected and used in the experiments before any postharvest treatment was applied. Citrus fruits were selected on the basis of size, color and absence of external injuries. The fruits were stored up to 1 week at temperature of 5°C and relative humidity 90% before application of coating. Before each experiment the fruits were randomly washed with fresh water and allowed to air-dry at room temperature.

Surface preparation of citrus

The primary purpose of surface preparation was to remove all contaminants that would hinder proper coating adhesion.

Application of edible coating

Citrus fruits were dipped for the time interval of 1min in the film forming dispersions. Afterwards; they were dried at room temperature for 2-4 h then stored in the cooling environment. The formulation of edible coating for treatment 1, Extract 0.5g, addition of acetic acid, ascorbic acid 2g, citric acid 1g which were act as a antimicrobial. Glycerol 1.5, sunflower oil 0.025g and distilled water 100ml. All above ingredients were mixed thoroughly and applied on fruit. The formulation of edible coating for treatment 2, Extract 1g.1g acetic acid, 2g ascorbic acid, citric acid, glycerol 1.5g, sunflower oil 0.025g and distilled water 100ml. These ingredients were mixed and then applied on citrus. The formulation of edible coating for treatment 3, Extract of polysaccharides 2g, 1g of acetic acid, 2g of ascorbic acid, 1g of citric acid, glycerol1.5, oil 0.025g and distilled water 100 ml were mixed and formed edible coating. For comparing purpose standard of fruits was also taken into the cooling environment analyzed at zero stage and after every 15 days. The storage period was 15, 25 and 35 days for edible coated citrus.

Proximate analysis of citrus

The edible coated citrus samples were analyzed for, moisture, ash content and crude fiber according to their respective methods described in AACC (2000).

Physical parameters of citrus

pH of citrus

The pH of citrus fruit was determined by preparation of required citrus juice quantity in 100 ml beaker. With the help of digital pH meter following the procedure as, pH meter electrodes were standardized with 4, 7 and 9 buffer solution. pH meter device is ready for taking the pH reading of citrus when pH meter gave arrow head signal on slide. pH electrode was put into the beaker as the tip of the electrode was covered and note the pH reading of citrus juice.

Acidity of citrus

The total acidity of citrus was determined by using the method described by Kirk and Sawyer (1999). About 15mL of citrus juice was taken in 3 conical flasks and 1 to 2 drops of phenolphthalein were added in each flask as indicator. Then 20 mL of distilled water was added for dilution purpose and 0.1 N NaOH was used to titrate against it. NaOH volume was noted that was used for titration process. The titratable acidity was determined by following formula:

Total acidity % = (Liter ×Y/ Volume of sample) × 100

Where,
Y = Mol. wt. of citric acid/1000×10

Sensory evaluation

The coated citrus fruits were evaluated for taste, color, flavor, texture and overall acceptability by 9-point hedonic score system (9 = like extremely; 1 = dislike extremely) by panel of judges from Department of Food Science and Technology Bahauddin Zakariya University according to the procedure described by **Meilgaard et al. (2007)**.They also conducted organoleptic analysis which was based on flavor, firmness, overall acceptability and color of commodity after specific interval as compared to control sample.

Statistical analysis

The data of each parameter was obtained by applying completely randomized design (CRD). Levels of significance ($P \leq 0.05$ & $P \leq 0.01$) were determined using 2-factor factorial under CRD by following the principles outlined by **Steel et al. (1997).** Significant ranges were further compared using Duncan Multiple Range (**Steel *et al.*, 1997**).

RESULTS AND DISCUSSION

Moisture content of citrus

The maximum moisture (Table 2)was observed in T_3 (86% cactus polysaccharides) as 86.94±2.10ab followed by T_2 (85.46% cactus polysaccharides) as 85.47±2.12ab .However, the treatments T_1 (84% cactus polysaccharides) and T_0 (control) exhibited the value for moisture as 84.32±1.56bc *and* 83.26±1.43crespectively. Over the storage, decrease in the moisture content was noticed that varied from 89.83±2.78% at 15 days to 85.35±1.40% at 25 days .However, at the termination of 35 days study, moisture was 77.77±0.51%. Likewise, among treatments, a similar decrease in moisture was reported with the course of storage at declined from 87.22±1.72% and 91.49±2.71% at 15 days and 85.95±1.86% and 86.79±1.77% at 25 days in T_2 and T_3, respectively. The maximum decrease in moisture was found in T_0 (control) as 90.01±1.60% at 15 days to 83.93±0.95% and 75.84±1.75% at 25 days and 35 days respectively. Instant research is in accordance with the work of **Mohebbi *et al.* (2012).** In another study, **Al-Juhaimi *et al.* (2012)** worked on coating combination involving polysaccharides to produce edible films and coatings. They deduced that coatings decreased fruit weight & moisture loss, decay incidence.

Table 2 Effects of edible coatings (treatments) and storage intervals on moisture contents of citrus

Treatments	**Storage**			**Means (Treatments)**
	15 days	**25 days**	**35 days**	
T_0	90.01±1.60	83.93±0.95	75.84±1.75	83.26±1.43c
T_1	89.83±2.78	85.35±1.40	77.77±0.51	84.32±1.56bc
T_2	87.22±1.72	85.95±1.86	83.23±2.78	85.47±2.12ab
T_3	91.49±2.71	86.79±1.77	82.55±1.82	86.94±2.10a
Means (Storage)	89.64±2.20a	85.51±1.50b	79.85±1.72c	

T_0: Control, T_1: (84.31% cactus polysaccharides), T_2: (85.46% cactus polysaccharides), T_3: (86.94% cactus polysaccharides)

Crude fiber

The mean values (Table 3) regarding crude fiber depicted non-significant variations among treatments while there was a significant variation with respect to storage. The maximum crude fiber was observed in T_0 (Control) as 4.96±0.16% followed by T_2 (1.0% cactus polysaccharides) and T_3 (2.0% cactus polysaccharides)as 4.83±0.12% and 4.83±0.08%, respectively. However, the lowest value was observed for T_1 (0.5% cactus polysaccharides) as 4.82±0.10%. Over the storage, increase in crude fiber content was noticed that varied from 4.62±0.10% at 15th day to 4.90±0.13 at 25th day. However, at the termination of 35 days study, crude fiber was 5.07±0.12%. Likewise, among treatments, a similar increase in crude fiber was reported with the course of storage that increased from 4.71±0.06% and 4.57±0.11% at 15th day to 4.78±0.12% and 4.90±0.16% at 25th day in T_3 (2.0% cactus polysaccharides) and T_2 (1.0% cactus polysaccharides), respectively. The maximum increase in crude fiber was found in T_0 (Control) as 4.57±0.14% at 15th day to 5.09±0.18% and 5.23±0.17% at 25th and 35th day, respectively. Instant research is in accordance with the work of **Mohebbi *et al.* (2012)and Al-Juhaimi *et al.* (2012).**

Table 3 Effects of edible coatings (treatments) and storage intervals on crude fiber content of citrus

Treatments	**Storage**			**Means (Treatments)**
	15 days	**25 days**	**35 days**	
T_0	4.57±0.14	5.09±0.18	5.23±0.17	4.96±0.16a
T_1	4.64±0.10	4.82±0.06	5.01±0.13	4.82±0.10b
T_2	4.57±0.11	4.90±0.16	5.01±0.09	4.83±0.12b
T_3	4.71±0.06	4.78±0.12	5.01±0.08	4.83±0.08b
Means (Storage)	4.62±0.10c	4.90±0.13b	5.07±0.12a	

T_0: Control, T_1: (4.82% cactus polysaccharides), T_2: (4.82% cactus polysaccharides), T_3: (4.83% cactus polysaccharides)

Ash content of citrus

The maximum value for ash contents of coated citrus (Table 4) was found in T_1 (2.56% cactus polysaccharides) as 2.56±0.07b followed by T_3 (2.51 cactus polysaccharides) as 2.52±0.05b. Moreover, treatments T_2 (2.51 % cactus polysaccharides) and T_0 (Control) showed ash contents values 2.51±0.05b and 2.62±0.05a, respectively. Over the storage, decrease in ash contents was noticed ranging from 2.51±0.05b at initiation to 2.60±0.06a at termination of the trial. Likewise, among treatments a systematic decrease in the ash contents was noticed during storage. Among treatments, T_3 (2.51% cactus polysaccharides) indicated a gradual decrease in the ash contents from 2.48±0.04 to 2.53±0.06and 2.55±0.05 at 25th and 35st day, respectively. Similarly, for treatments T_2 and T_1 variations in ash contents were 2.51±0.06 to 2.49±0.02 and 2.55±0.05 to 2.55±0.08 at 15th to 25st day, respectively. The maximum decrease in ash contents was observed for T_o (Control) as 2.49±0.05 to 2.74±0.03 at initiation to termination, respectively.

The findings of present research work are in agreement with the findings of **Fan *et al.* (2009).** Earlier, **Vargas *et al.* (2009)** worked on chitosan based edible coatings combined with oleic acid to preserve the quality of strawberry. They inferred that physicochemical properties, fungal decay and respiration rates of coated fruit were significantly addressed by coating applications.

Table 4 Effects of edible coatings (treatments) and storage intervals on ash contents (dry matter basis) of citrus

Treatments	**Storage**			**Means (Treatments)**
	15 days	**25 days**	**35 days**	
T_0	2.49±0.05	2.64±0.07	2.74±0.03	2.62±0.05a
T_1	2.55±0.05	2.55±0.08	2.58±0.09	2.56±0.07b
T_2	2.51±0.06	2.49±0.02	2.53±0.06	2.51±0.05b
T_3	2.48±0.04	2.53±0.06	2.55±0.05	2.52±0.05b
Means (Storage)	2.51±0.05b	2.55±0.06a	2.60±0.06a	

T_0: Control, T_1: (2.56 % cactus polysaccharides), T_2: (2.51% cactus polysaccharides), T_3: (2.51% cactus polysaccharides)

pH of citrus

The maximum value for pH of coated citrus (Table 5) was found in T_1 (3.19% cactus polysaccharides) as 3.19±0.02b followed by T_3 (2.95% cactus polysaccharides) as 2.95±0.04c. . Moreover, treatments T_2 (2.98% cactus polysaccharides) and T_0 (Control) showed pH values 2.99±0.05c and3.36±0.03a, respectively. Over the storage of citrus the mean is 2.74±0.02c and 1.60±0.03b at 15 and 25 days .respectively at 35 days the overall mean

The findings of instant research work are in agreement with the findings of **Fan *et al.* (2009).** They concluded that coating application resulted in restricting the rise in pH of coated strawberry. In another attempt **Tapia *et al.* (2008)** concluded that alginate based coatings resulted in improved water vapor resistance, controlled gaseous exchange and maintained overall quality of the fruit.

Table 5 Effects of edible coatings (treatments) and storage intervals on pH of citrus

Treatments	**Storage**			**Means (Treatments)**
	15 days	**25 days**	**35 days**	
T_0	2.78±0.01	3.37±0.03	3.95±0.06	3.36±0.03a
T_1	2.87±0.01	3.11±0.03	3.60±0.03	3.19±0.02b
T_2	2.67±0.04	2.95±0.08	3.34±0.04	2.99±0.05c
T_3	2.64±0.01	3.01±0.06	3.21±0.04	2.95±0.04c
Means (Storage)	2.74±0.02c	3.11±0.05b	3.53±0.04a	

T_0: Control, T_1: (3.19% cactus polysaccharides), T_2: (2.98% cactus polysaccharides), T_3: (2.95% cactus polysaccharides)

Acidity of citrus

It is observed that the maximum value for acidity of edible coated citrus (Table6) was recorded in T_1 (1.59% cactus polysaccharides) as 1.59±0.02b trailed by T_3 (1.69% cactus polysaccharides) and T_2 (1.70% cactus polysaccharides) as 1.69±0.04a and 1.70±0.05a, respectively. However, the lowest values for the trait were observed in T_o (Control) as 1.51±0.03c. During storage, a systematic increase in values for the trait was noticed as 1.83±0.04a at initiation that increased considerably to 1.60±0.03b and 1.43±0.02c at 25th and 35st day, respectively.

Findings of the instant research are in corroboration with the work of **Velickova *et al.* (2013)** who used soy based edible coatings to extend shelf life of strawberries at controlled climate chamber.

Table 6 Effects of edible coatings (treatments) and storage intervals on acidity of citrus

Treatments	Storage			Means (Treatments)
	15 days	25 days	35 days	
T_0	1.76±0.03	1.45±0.04	1.30±0.02	1.51±0.03c
T_1	1.81±0.02	1.59±0.04	1.38±0.01	1.59±0.02b
T_2	1.88±0.06	1.71±0.04	1.52±0.04	1.70±0.05a
T_3	1.89±0.06	1.66±0.02	1.53±0.03	1.69±0.04a
Means (Storage)	1.83±0.04a	1.60±0.03b	1.43±0.02c	

T_0: Control, T_1: (1.59% cactus polysaccharides), T_2: (1.70% cactus polysaccharides), T_3: (1.69% cactus polysaccharides)

Color

Means regarding sensory color of edible coated citrus (Table 7) revealed significant variations among treatments and storage. The maximum panelist scores were assigned to treatment T_3 (2.0% cactus polysaccharides) as 7.80±0.16 trailed by T_2 (1.0% cactus polysaccharides) and T_1 (0.5% cactus polysaccharides) as 7.10±0.21and 6.77±0.25, respectively. Whilst T_0 (Control) was at par with a score of 6.33±0.16. Moreover, there was observed a gradual decline in the scores for the trait with storage with T_0 score declined from from 8.30±0.23 to 5.90±0.12 and 4.80±0.13 at 15th, 25th and 35th day, respectively. Likewise, for T_1 andT_2 panelist ratings for the trait were reported to lower from 7.80±0.26 to 5.80±0.15 and 8.40±0.30 to 5.90±0.18 at 15th to 35th day, respectively. For treatment T_3, panelist ratings lowered from 8.80±0.24 at 15th day to 7.20±0.12 at 35th day.

The findings of instant investigation are in accordance with the work of Baldwinand **Wood (2006).** The sensory attributes were significantly enhanced with improved consumer acceptability. In another trial, **Dang *et al.* (2008)** observed that color changes were considerably controlled by coating application.

Table 7 Effects of edible coatings (treatments) and storage intervals on sensory scores for color of citrus

Treatments	Storage			Means (Treatments)
	15 days	25 Days	35 days	
T_0	8.30±0.23	5.90±0.12	4.80±0.13	6.33±0.16
T_1	7.80±0.26	6.70±0.34	5.80±0.15	6.77±0.25
T_2	8.40±0.30	7.00±0.15	5.90±0.18	7.10±0.21
T_3	8.80±0.24	7.40±0.13	7.20±0.12	7.80±0.16
Means (Storage)	8.33±0.26	6.75±0.18	5.93±0.14	

T_0: Control, T_1: (0.5% cactus polysaccharides), T_2: (1.0% cactus polysaccharides), T_3: (2.0% cactus polysaccharides)

Aroma

It can be seen from (Table 8) regarding aroma of edible coated citrus that there was a systematic decline in the panelist ratings for the trait with the progress in storage. The maximum panelist scores were assigned to treatment T_3 (2.0% cactus polysaccharides) as 7.83±0.19 trailed by T_2 (1.0% cactus polysaccharides) and T_1 (0.5% cactus polysaccharides) as 7.17±0.17and 6.90±0.19, respectively. Whilst T_0 (Control) was assigned a score of 6.30±0.17. Moreover, a gradual decline was observed in the scores for the trait with the developments in storage with T_0 differing from 8.00±0.20 to 6.10±0.14 and 4.80±0.18 at 15th, 25th and 35th day, respectively. Similarly, for T_1 andT_2 panelist ratings for the trait were reported to lower from 8.30±0.11 to 5.60±0.31 and 8.30±0.19 to 5.80±0.09 at 15th to 35th day, respectively. For treatment T_3, panelist ratings declined from 8.70±0.13 at 15th day to 7.10±0.21 at 35th day. The findings are in accordance with the work of **Baldwin (2000**).

Table 8 Effects of edible coatings (treatments) and storage intervals on sensory scores for aroma of citrus

Treatments	Storage			Means (Treatments)
	15 days	25 Days	35 days	
T_0	8.00±0.20	6.10±0.14	4.80±0.18	6.30±0.17 d
T_1	8.30±0.11	6.80±0.16	5.60±0.31	6.90±0.19c
T_2	8.30±0.19	7.40±0.24	5.80±0.09	7.17±0.17b
T_3	8.70±0.13	7.70±0.24	7.10±0.21	7.83±0.19a
Means (Storage)	8.33±0.16a	7.00±0.19b	5.83±0.19c	

T_0: Control, T_1: (0.5% cactus polysaccharides), T_2: (1.0% cactus polysaccharides), T_3: (2.0% cactus polysaccharides

Texture

Mean values regarding texture of edible coated citrus (Table 9) revealed that there was a systematic decline in the panelist ratings with the progress in storage. The maximum panelist scores were assigned to treatment T_3 (2.0% cactus polysaccharides) as 7.83±0.17 trailed by T_2 (1.0% cactus polysaccharides) and T_1 (0.5% cactus polysaccharides) as 7.17±0.19and 6.83±0.19, respectively. Whilst T_0 (Control) was at par with a score of 6.32±0.15. Moreover, there was observed a gradual decline in the scores for the trait with the developments in storage with T_0 differing from 8.30±0.18 to 6.15±0.18 and 4.50±0.10 at 15th, 25th and 35th day, respectively. Likewise, for T_1 andT_2 panelist ratings for the trait were reported to lower from 8.00±0.21 to 5.90±0.19 and 8.50±0.17 to 5.90±0.08 at 15th to 35th day, respectively. For treatment T_3, panelist ratings lowered from 8.60±0.25 at 15th day to 7.20±0.16 at 35th day.

The findings of instant investigation are in accordance with the work of **Shahid and Abbasi (2011).** The sensory attributes were significantly enhanced with improved consumer acceptability.

Table 9 Effects of edible coatings (treatments) and storage intervals on sensory scores for texture of citrus

Treatments	Storage			Means (Treatments)
	15 days	25 Days	35 days	
T_0	8.30±0.18	6.15±0.18	4.50±0.10	6.32±0.15d
T_1	8.00±0.21	6.60±0.16	5.90±0.19	6.83±0.19c
T_2	8.50±0.17	7.10±0.31	5.90±0.08	7.17±0.19b
T_3	8.60±0.25	7.70±0.09	7.20±0.16	7.83±0.17a
Means (Storage)	8.35±0.20a	6.89±0.18b	5.88±0.13c	

T_0: Control, T_1: (0.5% cactus polysaccharides), T_2: (1.0% cactus polysaccharides), T_3: (2.0% cactus polysaccharide)

Taste

Means regarding taste of edible coated citrus (Table 10) showed that maximum hedonic scores were assigned to T_3 (2.0% cactus polysaccharides) as 7.83±0.17 trailed by T_2 (1.0% cactus polysaccharides) and T_1 (0.5% cactus polysaccharides) as 7.17±0.19 and 6.83±0.19, respectively. However, lowest sensory scores was attained by T_0 (control) as 6.32±0.15. With the developments in storage, there was noticed a gradual decline in panelist preferences. It can be noticed that the maximum decline in sensory score was noted for T_0 as scores lowered from 8.30±0.18 and 6.15±0.18 to 4.50±0.10 at 15th, 25th and 35th day, respectively. However, amongst treatments T_3 served as the most effective as it restricted the scores to 7.20±0.16 at the termination of 21 days study. Likewise, for treatments T_1 and T_2, hedonic scores were found to lower from 8.00±0.21 and 6.60±0.16 to 5.90±0.19 and8.50±0.17, 7.10±0.31 to 5.90±0.08 at 15th, 25th and 35th day, respectively.

The findings of instant investigation are in harmony with the work of **Ribeiro *et al.* (2007),** who developed polysaccharide-based coatings to extend the shelf life of citrus. Likewise, **Benítez *et al.* (2013)** deduced that polysaccharides based coatings were instrumental in retaining color, firmness and improved acceptability of fruits.

Table 10 Effects of edible coatings (treatments) and storage intervals on sensory scores for taste of citrus

Treatments	Storage			Means (Treatments)
	15 days	25 days	35 days	
T_0	7.90±0.06	5.90±0.17	4.60±0.14	6.13±0.12
T_1	8.00±0.27	6.60±0.06	5.70±0.23	6.77±0.19
T_2	8.20±0.18	7.10±0.15	5.80±0.30	7.03±0.21
T_3	8.40±0.16	7.40±0.12	6.90±0.28	7.57±0.19
Means (Storage)	8.13±0.17	6.75±0.12	5.75±0.24	

T_0: Control, T_1: (0.5% cactus polysaccharides), T_2: (1.0% cactus polysaccharides), T_3: (2.0% cactus polysaccharides)

Appearance

It is clear from mean values for appearance of coated citrus (Table 11) that a pertinent decline in the panelist ratings for the trait was noticed. The maximum hedonic scores were 7.57±0.19 for T_3 (2.0% cactus polysaccharides) trailed by 7.03±0.21 and 6.77±0.19 for T_2 (1.0% cactus polysaccharides) and T_1 (0.5% cactus polysaccharides), respectively. However, the lowest hedonic ratings were noted for T_0 (Control) as 6.13±0.12. With the development in storage, it was observed that panelist preferences showed a steady decline ranging from 8.00±0.27 to 6.60±0.06 and 5.70±0.23 at 7th, 14th and 21st day for T_1 (0.5% cactus polysaccharides), respectively. Likewise, panelist ratings for treatments T_2 (1.0% cactus polysaccharides) and T_3 (2.0% cactus polysaccharides) lowered from 8.20±0.18 and 8.40±0.16 at initiation to 7.10±0.15 and 7.40±0.12 at 14th day, respectively. Furthermore, at the end of the study sensory scores were recorded as 5.80±0.30 and 6.90±0.28 for respective treatments, respectively. The lowest panelist scores were assigned to T_0 as it differed from 7.90±0.06 and 5.90±0.17 to 4.60±0.14 at 7th to 21st day, respectively.

Our findings are in harmony with the work of **Hassan *et al.*, (2014).** Similarly, **Elizabeth (2006)** concluded that coating application led to increased consumer acceptability due to its natural freshness and shine.

Table11 Effects of edible coatings (treatments) and storage intervals on sensory scores for appearance of citrus

Treatments	Storage			Means (Treatments)
	15 days	25 Days	35 days	
T_0	7.90±0.06	5.90±0.17	4.60±0.14	6.13±0.12
T_1	8.00±0.27	6.60±0.06	5.70±0.23	6.77±0.19
T_2	8.20±0.18	7.10±0.15	5.80±0.30	7.03±0.21
T_3	8.40±0.16	7.40±0.12	6.90±0.28	7.57±0.19
Means (Storage)	8.13±0.17	6.75±0.12	5.75±0.24	

T_0: Control, T_1: (0.5% cactus polysaccharides), T_2: (1.0% cactus polysaccharides), T_3: (2.0% cactus polysaccharides)

Firmness

It can be seen from Table 12 regarding firmness of coated citrus that a pertinent decline in the panelist ratings for the trait was noticed. It can be seen that maximum hedonic scores were 7.57±0.19 for T_3 (2.0% cactus polysaccharides) trailed by 7.03±0.21 and6.77±0.19 for T_2 (1.0% cactus polysaccharides) and T_1 (0.5% cactus polysaccharides), respectively. However, the lowest hedonic ratings were noted for T_0 (Control) as 6.13±0.12. With the development in storage, it was observed that panelist preferences showed a steady decline ranging from 8.00±0.27 to 6.60±0.06 and 5.70±0.23 at 15th, 25th and 35th day for T_1 (0.5% cactus polysaccharides), respectively. Likewise, panelist ratings for treatments T_2 (1.0% cactus polysaccharides) and T_3 (2.0% cactus polysaccharides)at initiation to 25th day were 7.10±0.15 and 7.40±0.12, respectively. Furthermore, at the end of the study sensory scores were recorded as 5.80±0.30 and6.90±0.28 for respective treatments, respectively. The lowest panelist scores were assigned to T_0 as it differed from 7.90±0.06 and 5.90±0.17 to 4.60±0.14 at 15th to 35th day, respectively.

Our findings are in harmony with the work of **Hassan *et al.*, (2014).** They inferred that fruits treated with edible coatings had better firmness and appearance as compared to uncoated fruits.

Table 12 Effects of edible coatings (treatments) and storage intervals on sensory scores for firmness of citrus

Treatments	Storage			Means (Treatments)
	15 days	25 days	35 days	
T_0	8.20±0.19	5.90±0.18	4.50±0.18	6.20±0.18
T_1	7.90±0.19	6.70±0.17	5.90±0.16	6.83±0.18
T_2	8.10±0.21	7.20±0.16	6.80±0.16	7.37±0.18
T_3	8.40±0.17	7.40±0.20	7.10±0.11	7.63±0.16
Means (Storage)	8.15±0.19	6.80±0.18	6.08±0.15	

T_0: Control, T_1: (0.5% cactus polysaccharides), T_2: (1.0% cactus polysaccharides), T_3: (2.0% cactus polysaccharides)

Shininess

The shininess of edible coated citrus (Table 13) showed a systematic increase with increase in polysaccharides application, whilst shown the decreasing trend with increase in storage time. The maximum panelist scores were assigned to treatment T_3 (2.0% cactus polysaccharides) as 7.63±0.16 trailed by T_2 (1.0% cactus polysaccharides) and T_1 (0.5% cactus polysaccharides) as 7.37±0.18and 6.83±0.18, respectively. Whilst T_0 (Control) was at par with a score of 6.20±0.18. Moreover, there was observed a gradual decline in the scores for the trait with the developments in storage with T_0 differing from 8.20±0.19 to 5.90±0.18 and 4.50±0.18 at 15th, 25th and 35th day, respectively. Likewise, for T_1 andT_2 panelist ratings for the trait were reported to lower from 7.90±0.19 to 5.90±0.16 and 8.10±0.21 to 6.80±0.16 at 15th to 35th day, respectively. For treatment T_3, panelist ratings lowered from 8.40±0.17 at 15th day to 7.10±0.11 at 35th day.

The findings of instant investigation are in accordance with the work of **Moreira *et al.* (2011).** The sensory attributes were significantly enhanced with improved consumer acceptability. In another trial, **Hassan *et al.*, (2014)** studied hedonic response of edible coated citrus. They observed that shininess was considerably enhanced by coating application.

Table 13 Effects of edible coatings (treatments) and storage intervals on sensory scores for Shininess of citrus

Treatments	Storage			Means (Treatments)
	15 days	25 Days	35 days	
T_0	8.20±0.19	5.90±0.18	4.50±0.18	6.20±0.18
T_1	7.90±0.19	6.70±0.17	5.90±0.16	6.83±0.18
T_2	8.10±0.21	7.20±0.16	6.80±0.16	7.37±0.18
T_3	8.40±0.17	7.40±0.20	7.10±0.11	7.63±0.16
Means (Storage)	8.15±0.19	6.80±0.18	6.08±0.15	

T_0: Contro, T_1: (0.5% cactus polysaccharides), T_2: (1.0% cactus polysaccharides), T_3: (2.0%cactuspolysaccharides)

Overall acceptability

The overall acceptability of coated citrus (Table 14) showed a pertinent decline in the panelist ratings. The maximum hedonic scores were 7.57±0.17 for T_3 (2.0% cactus polysaccharides) trailed by 7.07±0.16 and 6.70±0.21 for T_2 (1.0% cactus polysaccharides) and T_1 (0.5% cactus polysaccharides), respectively. However, the lowest hedonic ratings were noted for T_0 (Control) as 5.97±0.12. With the development in storage, it was observed that panelist preferences showed a steady decline ranging from 8.00±0.22 to 6.90±0.13 and 5.20±0.27 at 15th, 25th and 35th day for T_1 (0.5% cactus polysaccharides), respectively. Likewise, panelist ratings for treatments T_2 (1.0% cactus polysaccharides) and T_3 (2.0% cactus polysaccharides) lowered from 8.20±0.16 and 8.60±0.26 at initiation to 7.20±0.19 and 7.80±0.14 at 25th day, respectively. Furthermore, at the end of the study sensory scores were recorded as 5.80±0.13 and 6.30±0.09 for respective treatments, respectively. The panelist scores assigned to T_0 differed from 8.10±0.06 and 5.80±0.14 to 4.00±0.17 at 15th to 35th day, respectively.

Our findings are in harmony with the work of **Adetunji *et al.*, (2012).** Likewise, **Shahid (2007)** studied sensory response of various fruits after coatings application. It was concluded that coating application led to increased consumer acceptability.

Table 14 Effects of edible coatings (treatments) and storage intervals on sensory scores for overall acceptability of citrus

Treatments	Storage			Means (Treatments)
	15 days	25 Days	35 days	
T_0	8.10±0.06	5.80±0.14	4.00±0.17	5.97±0.12d
T_1	8.00±0.22	6.90±0.13	5.20±0.27	6.70±0.21c
T_2	8.20±0.16	7.20±0.19	5.80±0.13	7.07±0.16b
T_3	8.60±0.26	7.80±0.14	6.30±0.09	7.57±0.17a
Means (Storage)	8.23±0.18a	6.93±0.15b	5.33±0.16c	

T_0: Control, T_1: (0.5% cactus polysaccharides), T_2: (1.0% cactus polysaccharides), T_3: (2.0% cactus polysaccharides)

CONCLUSION

Citrus fruits are subjected to extensive post-harvest losses due to high moisture content and other physiological factors. These losses can be minimized by adopting various strategies. Among these, application of edible coatings is gaining much popularity owing to their suitability to be utilized with fruit. Polysaccharide extracted from indigenous sources like cactus can be used for the formulation of edible coatings which could play an imperative role in extending the shelf life of citrus. Moreover, the present research broadens the scope for utilization of wild plants with higher polysaccharides contents. The future aspects of the study involve the comparative analysis of edible coatings with commercially applied coatings in the industry.

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