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Effects of coatings on storability of carrot under evaporative coolant system.

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Abstract:

Four different coatings were developed from the mucilage of Cactus and their effectswere investigated on thequality and storability of carrot fruits. The four experimental coatings were: Pure mucilage extracts (ME), Mucilage extract mixed with 5ml glycerol (MEG), Mucilage extract mixed 5ml soy oil (MESO), Mucilage extract mixedwith 5ml olive oil (MEOO) theadditionof oil served as plasticizer. The following parameters were measured: weight loss, ascorbic acid content, pH, firmness and microbial qualities. Four hundred and eighty (480) carrots were arranged randomly into five treatments, the control (untreated) and four coating treatments were stored for seven weeks under Evaporative Coolant System (ECS). Prior to storage, the carrot samples were surface sterilized using 100mg/L sodium hypochlorites. Results showed that Cactus mucilage was effective in extending the shelf-life of carrot when compared to untreated control in the following order: MESO>MEOO>MEG>ME>Control. Results revealed that coatings hindered the growth of microorganisms significantly (P<0. 05).

Keywords: *Daucus carota* L, Evaporative Coolant System (ECS), storability, Cactus mucilage, Plasticizers, Edible coating.

1. Introduction

Carrot (*Daucuscarota*L.*)* belongs to the family *Umbelliferae*. The carrot is believed to have originated in Asia and now under cultivation in many countries. The carrot is an important vegetable because of its large yield per unit area throughout the world and its increasing importance as human food. It is orange-yellow in color, which adds attractiveness to foods on a plate, and makes it rich in carotene, a precursor of vitamin A, it contains appreciable quantities of nutrients such as protein, carbohydrate, fiber, vitamin A, Potassium, Sodium, thiamine and riboflavin, and is also high in sugar content. Its use increases resistance against the blood and eye diseases. It is eaten raw as well as cooked in curries and is used for pickles and sweetmeats [1; 2; 22].

Overall quality and shelf life of fruits and vegetables is reduced by several factors including water loss, enzymatic browning, texture deterioration, senescence processes and microbial growth, among others. In the case of fresh-cut fruits, these events are accelerated due to lesions of tissues inflicted by peeling, slicing and cutting. Edible coatings have been used to reduce the deleterious effect brought about by minimal processing. The semipermeable barrier provided by edible coatings is aimed to extend shelf life by reducing moisture and solutes migration, gas exchange, respiration and oxidative reaction rates, as well as suppress physiological disorders on fresh-cut fruits [56; 6; 41]. Edible coating, acting as a barrier to gases, is expected to generate a sort of modified atmosphere in each coated piece, and along with relative humidity and optimum refrigeration temperature, contributes to achieve a reasonable shelf-life in fresh-cut products. Shelf-life extension may require delay of respiration and physiological process. Thus, the ability of films to modify gas transport has potential for applications in fresh-cut fruit and vegetables that are characterized by active metabolism even during refrigerated storage [21].

Plasticizers like glycerol are required for polysaccharide and protein-based edible films to augment film flexibility and process ability by increasing the free volume or molecular mobility of polymers reducing internal hydrogen bonding between polymer chains while increasing intermolecular spacing. Plasticizers affect the ability

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of the system to bind water and also generally increase film permeability to oxygen [34; 35; 49].

The incorporation of lipids, either in an emulsion or as a layer coating into the films formulations, greatly improves their water vapor barrier properties [20 ; 59].

Edible coatings may also serve as carriers of food additives such as antibrowning and antimicrobials agents, colorants, flavors, nutrients and spices [30; 42; 44; 57]. Sulfur containing amino acids as N-acetylcysteine, have been widely studied in the search for sulfite substitutes and for improving shelf-life of minimally processed apples [36; 48] They can also be incorporated into coatings, and aid in prevention of enzymatic browning, as reported recently by [45].

Polysaccharides capable of forming gels in water are common throughout the plant kingdom. Some of them, such as the pectins in higher plants, carrageenans and agarose in algae, algal and bacterial alginates and xanthan, have been investigated in great detail. A relatively good understanding, of their biochemistry and biophysical properties has already been achieved. By contrast, the composition properties or food applications of mucilages have been much less studied [55]. Mucilages are generally hetero-polysaccharides obtained from plant stems [51]. There are few studies on the composition and properties of *Opuntia ficus-indica* mucilage. McGarvie *et al*. [33] determined that the mucilage extracted from the stems contains residues of D-galactose, D-xylose, L-arabinose, L-rhamnose and D-galacturonic acid. Cactus mucilage may find applications in food, cosmetics, pharmaceutical and other industries. The complex polysaccharide is part of dietary fibre and has the capacity to absorb large amounts of water, dissolving and dispersing itself and forming viscous or gelatinous colloids [13].

Controlled storage conditions are essential for the preservation of vegetables. Modern storage methods for horticultural produce are based on refrigeration and environment control. These include mechanical refrigerated storage, controlled atmosphere and low pressure storage system. These methods are usually too expensive for the local people wholive in remote parts of Nigeria and require simple low-cost cooling systems for the storage of perishable produce. The Nigerian Stored Products Research Institute (NSPRI) developed some passive evaporative cooling system [37].

Plasticizers are additives used to increase the flexibility or plasticity of polymers, and occasionally they are used only to facilitate the polymer processing. Several studies on plasticization of chitosan films revealed that polyethylene glycol (PEG) could improve the elastic properties of chitosan. Caner et al [10], observed that chitosan plasticization using PEG was stable until 9 weeks of storage. On the contrary, [9] found the water barrier and mechanical properties of plasticized chitosan films with glycerol changed during storage. Other authors used plasticizers in chitosan blends. Arvanitoyannis [4] used sorbitol and sucrose to plasticize chitosan/poly(vinyl alcohol) blends.

The present study is aimed at investigating the suitability of prickly pear cactus (*O. ficus indica*) mucilage as an edible coating with additions of hydrophilic plasticizers, namely:-Pure mucilage extract (ME) ; mucilage extract mixed with 5ml glycerol (MEG), mucilage extract mixed with 5ml olive oil (MEOO), mucilage extract mixed with 5ml soy oil (MESO), to extend the shelf-life of carrot.

2. Material and Methods

Cactus stems were peeled and cubed (1 cm^3). Samples were homogenized (20% w/v) in distilled water. The slurry was centrifuged for 10 min at 4500 × g and the supernatant obtained was used to prepare the edible coating [46]. It was then pasteurized to form a pure mucilage extract. Carrots were dipped in coating solution for 30secs, the excess coating was drained and the coated carrot were dried in a forced-air dryer (20 ^oC) for 30 min. Carrots dipped in distilled water were used as a control. After the coating process, the carrots were stored in a basket at ECS temperature of 12 ± 3^oC and 55-65% RH for 7 weeks. For each treatment and storage time, 40 fruits were coated. Firmness, Percentage weight loss and pH were determined from week 1-7 of after coating.

Treatments

T_o (control):-Untreated carrot;

$T_{1:}$-Carrot coated with Pure mucilage extract (ME);

T2:-Carrot coated with mucilage extract mixed with 5ml glycerol (MEG)

T3:-Carrot coated with mucilage extract mixed with 5ml olive oil (MEOO)

T4:-Carrot coated with mucilage extract mixed with 5ml soy oil (MESO)

The treated and untreated fruits were packed in small plastic baskets and each basket contained 20 carrot fruits. The baskets were stored at ECS

temperature and relative humidity (12±3°C and 55-65%).

*2. 1Physiochemical analyses of fruits***:** The following analyses were carried out from week 1-7 after coating.

2. 1. 1 Firmness

Firmness was measured as the maximum penetration force (N) reached during tissue breakage and determined with a 5 mm diameter flat probe. The penetration depth was 5 mm and the cross-head speed was 5 mm s^{-1} using a TA-XT2 Texture Analyzer (Stable Micro Systems, Godalming, UK). Carrots were sliced into halves and each half was measured in the central zone.

2. 1. 2 pH

After firmness analysis, carrots were cut into small pieces and homogenized in a grinder, and 10 g of ground carrot was suspended in 100 ml of distilled water and then filtered. The pH of the samples were assessed using a pH meter (pH-526; WTW Measurement Systems, Wissenschaftlich, Technische Werksta¨tten GmbH, Wellhelm, Germany)

2. 1. 3 Ascorbic acid

Ascorbic acid content was measured using 2, 5-6 dicholorophenol indophenols' method described by [3].

2. 1. 4Weight loss

To evaluate weight loss, separate samples in 3 replicates of each treatment were used. The same samples were evaluated for weight loss each time at weekly intervals until the end of experiment. Weight loss was determined by the following formula:

Weight loss (%) = [(A−B)/A] x 100. Where A indicates the weight at the time of harvest and B indicates the weight after storage intervals [3]

2. 1. 5Microbial analysis

Thirty grams of carrot fruit pulps were removed aseptically from each treatment. The sample was then homogenized in peptone saline solution (8. 5 g l^{-1} NaCl+1 g l^{-1} peptone (Oxoid, L34)) for 1 min in a stomacher (S400, Shanghai Scientific Instrument Co., Ltd., Shanghai, China). After making serial dilutions in peptone water, the samples were plated on different media as follows: (1) plate count agar (PCA), for isolating total aerobic psychrotrophic micro-organisms was incubated at 12^{o}C for 72 hand mesophilic micro-organisms was incubated at 30^{o}C for 72 h; (2) Sabouraud media (Oxoid CM41) for isolating yeasts and moulds was incubated at 25 ^{o}C for 120 h. Colonies were counted and the results expressed as $CFUg^{-1}$ of carrots. Analyses were carried out periodically in randomly sampled pairs of trays within 7 weeks. Two replicate counts were performed for each tray.

2. 1. 6Statistics

The results of this investigation were means of seven measurements. To verify the statistical significance of all parameters the values of means ± S. E. were calculated. SPSS software (version 12. 0, SPSS Inc., US) was used for all statistical analysis for Analysis of variance. The significance level used was 0. 05.

3. Results and Discussion

3. 1 Firmness.

Figure 1 shows the effect of cactus mucilage on firmness of carrot in ECS. The mean ± SE value for the Firmness on cactus mucilage coatings from MESO, MEOO, MEG, ME on carrot were these respectively: 3800.14 ± 339. 68, 3735.17 ± 362.40, 3375.14 ± 439. 96, 3188. 57 ± 439. 96 while the mean ± SE value for the uncoated was 2674. 28 ± 610. 86. Similar results were obtained for carrot with those of [14, 15] where retention of flesh firmness of carrot was achieved by a chitosan coating. Diab et al. [12] also delayed loss of firmness by applying a pullulan-based edible coating. During storage, the texture of the fruits is likely to soften due to several factors, including loss in cell turgidity pressure, loss of extracellular and vascular air and the degradation of the cell wall and consequent loss of water by the cell breakdown [32; 47]. Despite the hydrophilic character of polysaccharides, they can act as a barrier to water transfer, retarding dehydration and, therefore, prolonging the firmness of the coated fruit. Addition of glycerol at 5% to the coating solution had little effect on the firmness of coated carrot, not being statistically significant. Glycerol was added to increase the flexibility of the coating and hence avoided patches on the coated fruit.

3. 2 pH

Figure 2 shows the effect of cactus mucilage on pH. It was observed that, MESO had pH of 3.87 ± 0. 22 which was the highest. The other coatings used were MEOO, MEG, ME and they had the following values on carrotrespectively 3.87 ± 0.22, 3.66 ± 0. 13, 3.67 ± 0.09, 3.67 ± 0.08 and while the mean ± SE value for the uncoated was 3.54 ± 0.16. These results agreed with those reported by [16] and [18] that the decrease of acidity during storage demonstrated fruit senescence. A small change in pH represents a large change in hydrogen ion concentration [8]. The change

in pH was associated with number of reasons; it might be due to the effect of treatment on the biochemical condition of the fruit and slower rate of respiration and metabolic activity [26]. Coatings slowed the changes on pH, effectively delaying fruit senescence. This was probably because the semi-permeable chitosan film formed on the surface of carrot might have modified the internal atmosphere i. e., the endogenous CO_2 and O_2 concentration of the fruit, thus retarding ripening [31; 5] The increase in pH may be due to the breakup of acids with respiration during storage [43].

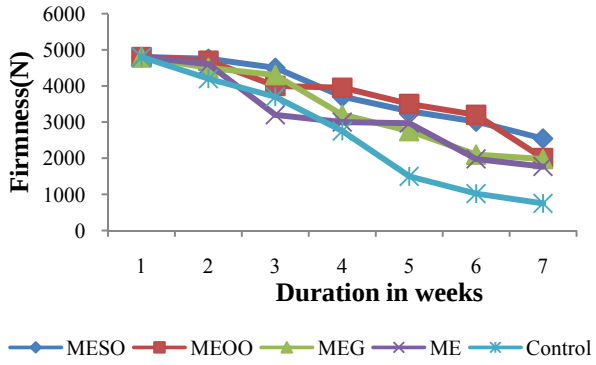

Figure 1: Effect of cactus mucilage on Firmness of carrot in ECS

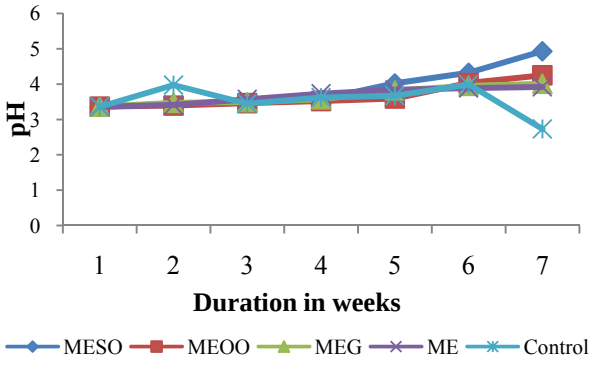

Figure 2: Effect of cactus mucilage on pH of carrotstored inECS

3. 3 Ascorbic acid

Figure 3 shows the effect of cactus mucilage on ascorbic acid. There was a significant decrease in ascorbic acid values of cactus mucilage coated fruits along with storage. However, the rate of decrease in ascorbic acid was significantly higher in untreated control fruits compared with coated fruits Present studies showed that ascorbic acid was mostly high in mature carrots with an indication of decrease in ascorbic acid content as ripening increases. The reason for high ascorbic acid content in coated fruit could be attributed to slow ripening rate of the treated fruit. Oxidation of ascorbic acid may be caused by several factors including exposure to oxygen, metals, light, heat and alkaline pH [51]. Coatings served as a protective layer and control the permeability of O_2 and CO_2 [50]. The results is in line with the findings of [25] who narrated that ascorbic acid content decreased when longan fruit was coated with chitosan at low temperature of 2°C.

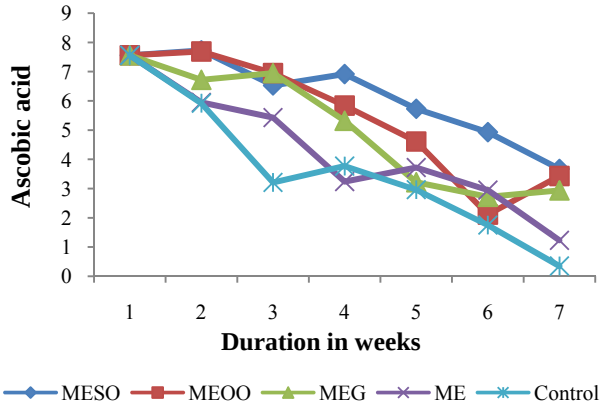

Figure 3: Effect ofcactus mucilage on Ascobic acid on carrot stored in ECS

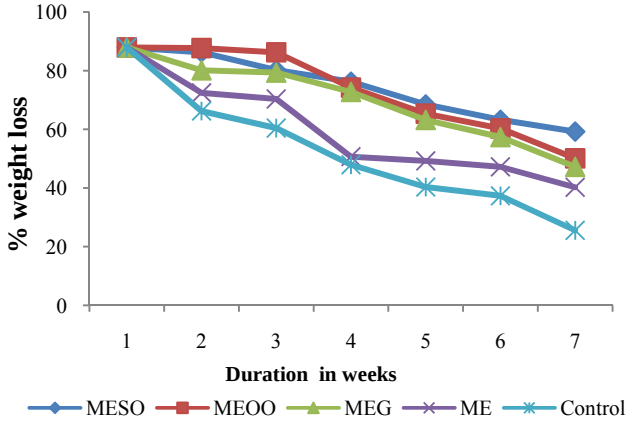

Figure 4: Effect of Cactus mucilage on % Weight loss of carrot stored in ECS

3. 4 Weight loss

Figure 4 shows the effect of cactus mucilage on percentage weight loss of carrot in ECS. Weight loss is an important index of post harvest fresh produce. It is mainly attributed to the loss of water during metabolic processes like respiration and transpiration. Moisture loss and gaseous exchange from the fruits is usually controlled by the epidermal layers provided

with guard cells and stomata. The coating helps to reduce this further because it forms a film on the top of the skin acting as an additional barrier to moisture lossas reported by [53]. The barrier also reduces the oxygen uptake by the fruit which in turn slowed down rate of respiration and associated weightless from the fruit surface. The primary mechanism of moisture loss from fresh fruits and vegetables is by vapor-phase diffusion driven by a gradient of water vapor pressure at different locations [58]. On the other hand, respiration causes a weight reduction because a carbon atom is lost from the fruit in each cycle [28; 40]

This reduction in weight loss was probably due to the effects of these coatings as a semi permeable barrier against oxygen, carbon dioxide, moisture and solute movement, thereby reducing respiration, water loss and oxidation reaction rates [7; 41] The obtained result was similar to the findings of [18, 19] for strawberries coated with starch-based coatings and those of [27], who reported that waxing extended the storage life of avocado both through a reduction in water loss and a modification of the internal atmosphere. Similar data were reported by [5] studying Gala apple, coated with 10% zein (natural corn protein). Sumnu and Bayindirli [52] noted that Semperfresh (10 g L^{-1}) Jonfresh and Fomesa apple wax coatings were efficient in reducing the rate of weight loss of Amasya apples. Chitosan and polyethylene wax (PE) coatings also provided good protection for Hami melon [11].

2. 1. 5 Microbial analysis

Figure 5 shows the effect of cactus mucilage on psychrotrophic organism on carrot in ECS. The predominant microflora which influences the shelf life of fruits and vegetables are psychrotrophicbacteria [23; 17]. The initial physchrotropics microbial load in control samples from MESO, MEOO, MEG, ME were 0. 9, 0.95, 1. 4, 2.3, andlog CFU/g in the first week while that of the control was 1. 9 log CFU/g. Changes in the total aerobic psychrotrophic count, in carrot stored for seven weeks at an average temperature of 12±2°C and relative humidity 55-60% are shown in Figure 5. The value of psychrotrophic microorganisms on cactus mucilage coatings from MESO, MEOO, MEG, ME on carrot were1.57±0.50, 1.88±0.52, 2.97±0.69, 3.24±0.68 log CFU/g respectively and while the uncoated was 3.21±0.69 log CFU/g. During the period of storage coating from MESO, MEOO, MEG, ME significantly hinder the increase in total aerobic psychrotrophic count compared with the control samples ($p<0.05$) (Fig. 5). The coated carrot with MESO, MEOO, MEG, ME

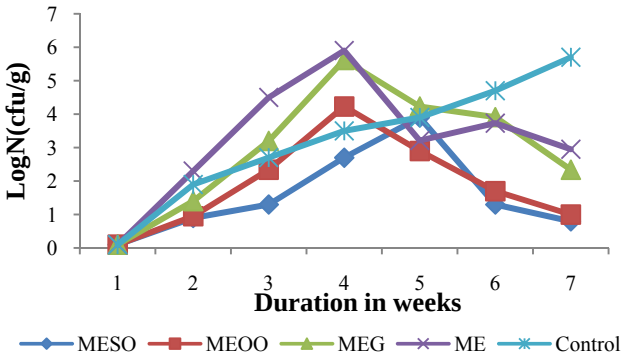

Figure 5: The effect of cactus mucilage on physchrotropics organism on carrot during storage in ECS

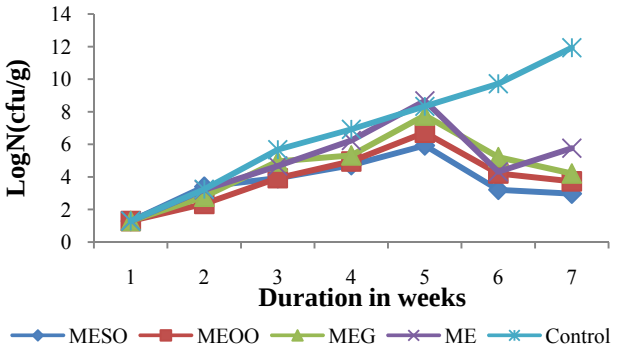

Figure 6: The effect of cactus mucilage on Yeast and mould organisms on carrot during storage in ECS

were able to hindered the microorganisms to lower microbial load of 0.8, 1.0, 2.34, 2.95 log CFU/g respectively while the uncoated carrot had a higher microbial load of 5.7 log CFU/g because of the absence of any substance to inhibit the psychrotrophic microorganisms around the surface area of carrot fruit.

Figure 6 shows the effect of cactus mucilage on yeasts and mould organisms of carrot in ECS. Changes in the total number of yeasts and moulds in cucumber stored for seven weeks at an average temperature of 25°C and relative humidity 50-65% are shown in Figure 6. The initial yeasts and moulds load count from MESO, MEOO, MEG to ME were 3.40, 2.34, 2.78, 3.21 log CFU/g in the first week while that of the control was 3.24 log CFU/g. During the period of storage coating significantly decrease in total aerobic yeasts and moulds count compared with the control samples (Fig. 6). The coated carrot with MESO, MEOO, MEG, ME was able to lower the microbial load to 2.97, 3.73, 4.21, 5.76 log CFU/g respectively while the uncoated carrot had a higher microbial load of 11.93 log CFU/g. This may be because of the absence of any inhibiting substance to the yeast and mould around the surface area of carrot fruit. Lee et al [29] reported very similar results for

minimally processed apples with various types of carbohydrate polymers and whey protein concentrate, using ascorbic acid, citric acid and oxalic acid as antibrowning agents. Howard and Dewi [24] used an edible cellulose-based coating, on minipeeled carrots, Coatings create a modified atmosphere that may change the growth rate of spoilage and pathogenic microorganisms [39].

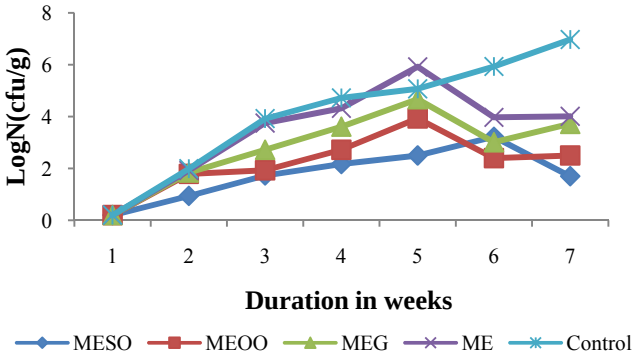

Figure 4: The effect of cactus mucillage on mesophilic organisms on carrot stored in ECS

Figure 7 shows the effect of cactus mucilage on total mesophilic of carrot in ECS. The initial mesophilic microbial load in control samples from MESO, MEOO, MEG, ME were 0. 94, 1.79, 1.84, 1.92 log CFU/g in the first week while that of the control was 1. 99 log CFU/g. This result is consistent with that reported by [38] for broccoli. Results revealed that the application of MESO, MEOO, MEG, ME coating significantly reduced ($p < 0.05$) total microbial counts compared to the uncoated samples. The results of mesophilic aerobic counts showed the effectiveness of MESO, MEOO, MEG, ME as antimicrobial agent. The coated carrot with MESO, MEOO, MEG, ME was able to hinder the microorganisms to lower microbial load of 1.7, 2.5, 3.72, 4.01 log CFU/g respectively while the uncoated carrot had a higher microbial load of 6. 97log CFU/g because of the absence of inhibiting substance on the mesophilic microorganisms around the surface area of carrot.

4. Conclusions

Applications of *Cactus* mucilage coating to carrot were shown to be beneficial in keeping the quality of the carrot fruits in storage. Coating with *Cactus* mucilage slowed down the weight loss, reduced the ascorbic acid content, pH and the growth of microorganisms. Textural analysis showed that prickly pear cactus mucilage could have a protective effect on carrot, reflected by the greater firmness of coated samples during storage, which could reduce economic losses due to spoilage produced from mechanical damage during handling and transportation. The ECS temperature probably acted as a coolant and might have helped the product to maintain its own characteristics. Finally, the overall result showed that Cactus mucilage is effective in extending the shelf-life of carrot fruits when compared to untreated with the addition of plasticizers which helped the coatings to adhere to the surface of the carrot in the following order: MESO>MEOO>MEG>ME>Control.

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