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Chitosan powder coating, a novel simple technique for enhancement of shelf life quality of carrot shreds stored in macro perforated LDPE packs

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ABSTRACT

Efficacy of an innovative powder coating technique based on chitosan, a biopolymer, with and without citric acid pretreatment (CACH and CH, respectively) was evaluated for quality maintenance of shredded carrots. Chitosan coating alone and in combination with citric acid pretreatment were found to be beneficial in reducing weight loss and resulted in minimal changes in pH, titrable acidity and total soluble solid content and exhibited lower respiration rate on storage. Total phenolic content and reducing power of chitosan coated samples were higher compared to control, indicating antioxidant activity of chitosan. β-carotene was found to be better retained in CACH treated samples, whereas, CH treated samples showed better retention of vitamin C. Chitosan treated samples were also characterized by better colour retention, superior sensory and microbial quality after 10 days of storage compared to control which was acceptable only till the 5th day of storage at 10 °C.

Industrial relevance: Minimally processed carrots are a growing segment in the food retail industry. However, their high perishable nature necessitates a good preservation strategy. The study has demonstrated the viability of using powder coating in combination with macro perforation as a simpler, quicker and cost-effective technique, as against the conventional coating techniques for extending shelf life of carrot shreds. The study further confirms the ability of chitosan, an environmental friendly biopolymer produced largely from industry waste, for improving the shelf life quality and health potential of fresh cut produce. The above preservation strategy also has high commercial feasibility.

1. Introduction

Production of minimally processed fruits and vegetables is emerging as one of the major growth segments in the food retail industry. A number of advantages are offered by fresh cut produce over whole produce, which includes reduction in cost, minimal waste, wide variety combined with consistency in quality (James & Ngarmsak, 2010). However, the highly perishable nature of these minimally processed produce poses several challenges to the fresh cut industry. The processing operations such as peeling, shredding, cutting and slicing lead to tissue damage, thereby causing adverse reactions in the produce. The various detrimental changes include browning, off flavor, loss of texture and higher microbial load. Increased research efforts are now being focused on various means to minimize these changes and deliver quality product to the consumers.

Diverse technologies have been developed in order to meet this requirement. Preservation techniques like refrigeration, controlled and modified atmospheric storage currently exist, but the high capital and maintenance cost associated with these techniques limit their application. Other techniques used to minimize deleterious effects of minimal processing include controlling the relative humidity, use of chemical sanitizers and preservatives or a combination of methods (Zhang & Quantick, 1997).

Among the sanitizing agents used, chlorine is the most widely used for fresh produce. However, the reaction of chlorine with organic residues is reported to result in the formation of potentially mutagenic or carcinogenic reaction products. The commercially available chemical alternatives to chlorine are reported to have limited ability to reduce microbial load to desired levels (Sapers, 2001). The use of chemical preservatives such as sulphites and hydrogen peroxide has been also discouraged due to several drawbacks associated with their use. Other chemical preservatives like citric acid and hydrogen peroxide are known to impart off flavor and undesirable textural changes (Amanatidou, Slump, Gorris, & Smid, 2000). The disadvantages of the above approaches and the increasing environmental concerns have created a need to explore safer and natural alternative treatments to extend the shelf life of fresh cut fruits and vegetables.

Search for naturally occurring substances having ability to act as alternative antimicrobials have, therefore, increased. One such naturally occurring compound is chitosan, obtained from the partial deacetylation of chitin which is the second most abundant polysaccharide and

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a major waste in the marine food industry. It has emerged as one of the most promising coating material for fresh produce owing to its excellent coating ability, broad antimicrobial activity, and compatibility with other substances (Shahidi, Arachchi, & Jeon, 1999).

Among the wide variety of minimally processed vegetables available, the consumption of fresh cut carrots as ready to eat carrot snacks or as salad vegetables are increasing in popularity (Barry-Ryan, Pacussi, & O'Beirne, 2000). However, sales are hindered because of rapid deterioration during storage and shelf life is usually limited to 7 to 8 days even upon refrigerated storage at 5 °C (Ahvenainen, 2000). High respiration rate, development of off-flavors, acidification, loss of firmness, discolouration and microbial spoilage are some of the major problems associated with minimally processed carrots (Barry-Ryan et al., 2000).

Chitosan has been studied as a successful edible coating material for whole fruits and vegetables but application in fresh cut produce has been explored only in the past decade. Evaluation of chitosan to extend the shelf life quality of shredded carrots is largely unexplored, though there are studies on the beneficial effects of chitosan coating on carrot slices (Vargas, Chiralt, Albors, & Gonzalez-Martinez, 2009) and sticks (Simoes, Tudela, Allende, Puschmann, & Gil, 2009) using dip technique.

Several disadvantages are associated with dip technique. One is the requirement of large amount of coating solution for complete immersion of the commodity leading to longer preparation time. Reuse of the coating is not possible due to quality alteration of the solution. The above problems can be avoided in spray coating, which is more suitable for whole produce. But, for fresh cut fruits and vegetables, leaching of pigments and nutrients into the dip and spray solution is generally encountered, which would in turn result in reduced nutritional quality. In order to overcome this, in the present study, powder coating technique was explored as an innovative alternative to spray and dip coating methods. It is a simple technique and offers several advantages over the other methods. It is less time consuming as the time for coating preparation and drying can be effectively reduced, apart from reduction in amount of coating material used.

To our knowledge, this study is probably the first wherein powder coating technology utilizing chitosan has been evaluated on fresh cut fruits and vegetables.

The present study also employs suitable packaging technique in conjunction with coating to achieve optimum results. The type of packaging suggested for fresh cut produce is LDPE (Robertson, 2006). For preserving the quality of minimally processed produce, modified atmosphere packaging (MAP), along with low temperature storage has been recommended. It uses the natural process of respiration of vegetables in conjunction with the restricted gas exchange through a barrier to modify in-pack O_2 and CO_2 (Hirata, Nakatani, Ishikawa, Yamada, & Katsuura, 1995). Non-perforated MAP has been found to be unsuitable for highly respiring vegetables such as fresh cut produce, since it causes development of anaerobic environment in the packages leading to fermentation. Micro perforated MAP is an alternative option. However, the low availability and high cost of micro perforated packaging materials limit their applicability only to high value commodities. A simpler alternative is macro perforation, which involves only the punching of macro perforations in the film package (Rai & Singh, 2012) to achieve desirable gaseous diffusion across the packages. Seljasen, Hoftun, Selliseth, and Bengtsson (2004) have reported the suitability of perforated packing for extending the shelf life of whole carrots. Use of such packing has not been reported for carrot shreds.

The objective of the present study was, thus, to study the effect of chitosan powder coating, with and without citric acid pretreatment on the physicochemical parameters, bioactive compounds, microbial and sensory quality of carrot shreds stored in macro perforated LDPE packages.

2. Materials and methods

2.1. Experimental materials

2.1.1. Carrots

Medium sized carrots (*Daucus carota*) were procured from the local market. Carrots were initially washed under running tap water to remove surface dirt and soil contamination. Root tips and leaf ends were removed and carrots free from damage were selected for processing.

2.1.2. Chitosan

Chitosan flakes (source—crab shells, degree of deacetylation—80–85% and molecular weight—160 kDa) were procured from Panvo Organics, Chennai, India. Purification of chitosan was carried out by the method given by El Ghaouth, Arul, Grenier, and Asselin (1992). Chitosan flakes were dissolved in 0.25 N HCl. The solution was centrifuged at 3000 rpm for 15 min. The supernatants were collected and neutralized with 2.5 N NaOH. The precipitate was filtered, washed with distilled water and dried in oven at 60 °C. The purified chitosan flakes were ground to mesh size 20 to obtain a fine powder.

2.2. Preliminary experiment

A preliminary experiment was conducted to determine the optimum concentration of chitosan to be used. Chitosan powder was applied to the carrot shreds at various concentrations of 0, 0.1, 0.2, 0.3 and 0.4% and stored in macro perforated LDPE pouches at 10 °C for 10 days. The carrot shreds were periodically analyzed for key quality parameters such as moisture content, weight loss and vitamin C (Table 1).

2.3. Pretreatment and application of chitosan powder coating

For the actual experiment, the carrots were divided into two batches, I and II, prior to peeling. Carrots in batch I were not subjected to any pretreatment. Batch II carrots were pretreated by dipping in 0.1% citric acid solution for 2–3 min followed by peeling operation. The peeled carrots from both the batches were then subjected to shredding to obtain shreds of 35–40 mm length and 2–3 mm thickness.

The experimental design of the main experiment is depicted in Fig. 1. One set of both batches I and II carrot shreds were kept aside. The untreated batch I carrot shreds were control (C), whereas, citric acid pretreated carrot shreds (batch II) served as positive control (CA). Finely powdered chitosan was applied at a concentration of 0.2% to the other set of carrot shreds (from batches I and II) which were spread as a thin layer in trays.

Uniform contact of the coating material with the shreds was achieved by thorough mixing. The samples were coded as CH (chitosan powder coated) and CACH (combination of citric acid pretreatment and chitosan coating).

2.4. Packaging and storage

For studying the shelf life of control and treated carrot shreds, the samples were distributed into sets of 100 g × 7 each in macro perforated LDPE resealable pouches (15 × 13 cm; 6 mm thickness). Ventilation area of 8 cm^2 was provided, dispersed over the whole pouch by sixteen holes each of 0.5 cm diameter. The packages were stored at 10 °C for 10 days and sampling was carried out at periodic intervals.

2.5. Analysis

Periodic analysis of the samples was carried out on the initial day, and the fifth and tenth days of storage. The microbial load of the samples was assessed on the initial and seventh day of storage.