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# Quality attributes of map packaged ready-to-eat baby carrots by using chitosan-based coatings

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ABSTRACT

Chitosan-based coatings were developed and their efficacy in maintaining the quality of baby carrots was studied over time. Coatings were applied through the use of spraying and dipping techniques. Baby carrots were packaged under modified atmosphere packaging (MAP) and stored at 4 °C. Different coating types were compared against untreated controls and were evaluated by monitoring parameters such as headspace gas composition, weight loss, pH, colour, texture and microbiological stability. The microbiological status of all stored products were determined through assessment of *Bacillus cereus*, total coliforms, *Pseudomonas* spp., *Staphylococcus aureus*, total viable counts, and yeast and moulds. Additionally, sensory evaluation was performed to study the effects of coatings in relation to customer acceptance. Results showed that chitosan-based coatings delayed microbial spoilage without causing adverse impacts on the quality attributes of baby carrots. Coatings exhibited positive effects on product colour and texture. Sensory analysis showed that overall acceptability of coated baby carrots were similar to uncoated samples. The very positive findings derived from this study could be expanded to investigate and apply other similar bioactive compounds to horticultural-based products in order to maintain product quality over longer shelf life periods.



## 1. Introduction

Attempts to reduce food losses and maintain the quality of fresh food over a longer period of time has been a priority for the food industry (Velickova et al., 2013). The use of edible coatings for food applications has attracted great interest, primarily as sustainable alternative packaging materials and as a means of improving food safety (Lai et al., 2013; Zhong et al., 2014). Edible active coating systems are promising alternative technologies which can be applied to preserve the quality of fresh produce and these coating systems are usually comprised of polysaccharides, proteins and lipids (Fagundes et al., 2014). In the food industry, spraying and dipping are conventional techniques for applying coatings to fruit and vegetable surfaces (Hernandez-Muñoz et al., 2006; Ribeiro et al., 2007; Zhong et al., 2014), and the conditions of the application process have a significant effect on the physical properties of the resulting coating (Skurtys et al., 2010).

Carrots are one of the most popularly consumed vegetables. They are often considered stable products by consumers; however, carrots deteriorate relatively fast during packaged storage, exhibiting very negative physiological changes. They tend to lose their firmness over time and develop off-odours primarily due to possessing high respiration rates and susceptibility to microbial spoilage (Barry-Ryan et al., 2000). Minimally processed carrots usually develop a white appearance on the surface during storage and lose their bright orange colour (Avena-Bustillos et al., 1993; Simões et al., 2010). Both microbial proliferation and white blush on the surface of the product have been shown to be controlled by the application of bio-based edible coatings (Gniewosz et al., 2013).

The greatest losses attributed to food products are due to microbiological alteration and decomposition of foodstuff. A vast array of technologies is available in order to extend the shelf life of minimally processed products (Gonzalez-Aguilar et al., 2010; Pushkala et al., 2013). Temperature and headspace atmosphere are two important parameters that play an important role in maintaining food quality. The use of low temperature, combined with modified atmosphere packaging (MAP), has been studied (Perez and Sanz, 2001; Rocculi et al., 2005; Muriel-Galet et al., 2012) with the purpose of extending horticultural product shelf life. MAP, when combined with the adequate temperature, can extend the shelf life of fresh produce by maintaining the nutritional and sensory qualities of the product (Hancock et al., 2008; Sandhya, 2010; Cantín

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et al., 2012; Tudela et al., 2013). The positive effect of MAP on shelf life can be mainly attributed to the reduction in the respiration rate and metabolic and biochemical activities (Scifo et al., 2009; Muriel-Galet et al., 2012). Therefore, combining a coating treatment with MAP may further extend the shelf life of fresh produce (Yang et al., 2014). The use of an active coating in combination with MAP and chilling represents a way to enhance the quality, safety and shelf life of fruit and vegetable products. Edible antimicrobial coatings have been shown to be efficient alternatives in controlling food contamination. Previous studies have shown the use of an edible coating for extending the shelf life of ready-to-eat carrots (Jagannath et al., 2006; Gniewosz et al., 2013; Lai et al., 2013). However, to date, few studies exist with respect to outcomes generated following combined usage of MAP and chitosan-based coatings on baby carrots under chilled conditions (Simões et al., 2009).

The mechanical and barrier behaviour of coatings are intrinsically linked to physical and chemical characteristics of their constituents (Chiumarelli and Hubinger, 2014). Glycerol is a plasticizer usually employed to enhance edible films and coatings flexibility, modifying the interactions between macromolecules and increasing mobility of polymer chains (Sothornvit and Krochta, 2001; Krotcha, 2002). Among various coatings based on biopolymers, chitosan is one of the most promising coating materials (Janjarasskul and Krochta, 2010). Chitosan, derived from deacetylation of chitin, shows excellent biocompatibility and wide antibacterial spectrum (No et al., 2007; Leceta et al., 2013c; Tezotto-Uliana et al., 2014; Zhong et al., 2014). Moreover, as chitosan is obtained from the processing of industrial shell waste derived from the seafood industry, it represents an example of a value-added processing by-product (Leceta et al., 2013a), which is potentially lucrative owing to its diverse functionality. In this context, the aim of the present work was to evaluate the effects of chitosan-based coatings applied by dipping or spraying on the quality attributes of commercial ready-to-eat baby carrots stored at 4 °C under MAP conditions.

## 2. Experimental

### 2.1. Materials

Low molecular weight chitosan with a degree of deacetylation higher than 75% was provided by Sigma–Aldrich (Spain). Acetic acid was used to adjust the pH of the solution and glycerol as plasticizer. Acetic acid and glycerol were purchased from Panreac (Spain).

### 2.2. Sample preparation and packaging

Commercial ready-to-eat baby carrots (*Daucus carota* L.) were obtained from a local supplier (Cork, Ireland) and selected by quality and uniformity. The carrots were stored at 4 °C prior to the coating treatment. A 1% wt LMw chitosan solution was prepared in 1% wt acetic acid solution. After 15 min under continuous stirring, glycerol was added to prepare a solution with 15% wt glycerol content in order to obtain adequate mechanical properties, as reported previously (Leceta et al., 2013b). Following, stirring continued for 30 min until total homogenization of the mixture was achieved.

Chitosan-based coatings were applied onto baby carrot samples using spraying and dipping techniques. The coating was sprayed onto the surface of the carrots using an aerosol sprayer (Ronseal Power Sprayer, Sheffield, UK). In order to control thickness, coating time was fixed to 30 s. For dipping, samples were immersed in the coating solution for 30 s. Uncoated baby carrots were used as controls. Coated and uncoated samples were allowed to dry in a convection oven (Sumann Drying Oven, Germany) at 20 °C. After drying, sprayed, dipped and control carrots were packed (120 g) under MAP conditions in polystyrene-based laminated trays (PS\EVOH\LDPE) and heat-sealed using a low $O_2$ permeable (3 $cm^3/m^2$/24 h at STP) laminate LDPE\EVOH\LDPE film (Cryovac/WR Grace Europe Inc., Lausanne, Switzerland). A VS 100 BS packaging system (Gustav Muller and Co., Bad Homburg, Germany) was used to perform MAP packaging and the initial internal gas composition was set at 10% $O_2$ and 10% $CO_2$. All samples were stored in the dark under chilled conditions (4 °C) and tested at intervals of 3 days, over a period of 15 days in order to ensure that significant changes in quality attributes could be analyzed.

### 2.3. Physico-chemical analysis

The headspace gas composition (% $O_2$ and % $CO_2$) of packages was determined on each testing day using a gas analyser (PBI Dansensor A/S, DK-4100, Ringsted, Denmark), and the instrument needle was inserted through a rubber septum attached to the lidding material. The test was carried out by duplicate.

Sample mass for weight loss calculation was determined by a digital precision balance (Monobloc Inside B2002-S, Mason Technology, Dublin, Ireland). Results were based on means of three replicates from different packages.

pH values were determined by direct insertion of the probe into the carrots using a digital pH meter (Mettler-Toledo GmbH, Schwerzenbach, Switzerland) with a penetration glass electrode. Six measurements were performed for each treatment.

The colour of baby carrots was determined using a portable Minolta CR-300 colorimeter (Minolta Camera Co. Ltd., Osaka, Japan). The colorimeter was calibrated before each series of measurements using a white ceramic plate and CIELAB colour scale was used to measure colour. $L^*$, $a^*$ and $b^*$ colour parameters were measured employing standard light source D65 and standard observer 2 degrees. Whiteness index (WI*) was calculated and the change of colour with time was evaluated by comparing total colour differences ($\Delta E^*$) between samples. Values were expressed as the means of 10 measurements taken from different areas on 5 carrots for each treatment.

### 2.4. Texture analysis

Texture measurements were carried out using a texture analyser (TA.XT2i Texture Analyser, Stable Micro Systems, UK) with a Warner–Bratzler shear force device. Carrots were equilibrated at room temperature for 3 h prior to texture measurements. Core samples (1.2 cm diameter) were obtained from experimental carrots. The crosshead speed was 3 mm/s and a load cell of 5 kg was employed. Results were expressed as the means of 10 carrots per treatment.

### 2.5. Microbiological analysis

For microbial evaluation, 10 g of sample were transferred aseptically to stomacher bags (Seward, Medical, UK) containing 90 mL of sterile Maximum Recovery Diluent solution (Oxoid, Basinstoke, UK). After 2 min and 30 s homogenization, 10-fold dilution series were carried out for microbiological analyses. Total viable (TVC) and *Staphylococcus aureus* counts were determined by spread plating on plate count agar (PCA) (Merck, Darmstadt, Germany), and Baird Park agar (Merck, Darmstadt, Germany) with egg yolk tellurite emulsion (Sigma–Aldrich, Spain), respectively, after 48 h incubation at 37 °C. *Pseudomonas* spp. and *Bacillus cereus* counts were also spread plated on Pseudomonas agar (Oxoid, Basinstoke, UK) with SR0103E selective supplement (Oxoid, Basinstoke, UK), and Brilliance Bacillus Cereus agar (Oxoid, Basinstoke, UK) with SR0230E selective supplement (Oxoid, Basinstoke, UK), respectively, after incubation at 30 °C for 48 h. Yeast and moulds counts (YMC) were