Innovative Food Science and Emerging Technologies xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Innovative Food Science and Emerging Technologies

journal homepage: www.elsevier.com/locate/ifset

Application of edible coatings to improve global quality of fortified pumpkin

Carolina E. Genevois, Marina F. de Escalada Pla, Silvia K. Flores *

Departamento de Industrias, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, Ciudad Universitaria, (1428), CABA, Argentina
Member of the National Scientific and Technical Research Council (CONICET), Argentina

ARTICLE INFO

Article history:
Received 11 May 2015
Received in revised form 1 November 2015
Accepted 2 November 2015
Available online xxxx

Keywords:
Fortified foods
Cucurbita moschata Duchesne ex Poiret
Edible coating
Color
Texture
Iron bioaccessibility

ABSTRACT

A refrigerated ready-to-eat food fortified with iron (Fe) and ascorbic acid (AA) was produced using pumpkin (*Cucurbita moschata* Duchesne ex Poiret) and applying a dry infusion process. It was observed that the presence of both Fe and AA in the vegetable matrix (control system) produced the browning of the product. The edible coatings application based on k-carrageenan or tapioca starch was proposed in order to improve the product stability. The AA degradation in the tissue was significantly reduced in the pumpkin with a starch-based coating. The result of an "in vitro" gastric and intestinal digestion assay indicated that when Fe was in the coating, Fe solubility at pH 2 was lower than control and tended to improve at pH 8. It was interpreted as a better accessibility of Fe at intestinal lumen level, and moreover, it could avoid gastric side effects. The products obtained were safe from microbiological view point and presented a satisfactory color and texture.

Industrial relevance: The formulation of food fortified with iron (Fe) represents a challenge from nutritional as well as technological view point because the reactivity of this mineral with other food matrix nutrients. This work proposes the elaboration of a vegetal refrigerated food, ready to eat, fortified with Fe and ascorbic acid (AA). The pumpkin was selected as raw material due its high consume and availability, proper nutritional characteristics and low cost. The dry infusion technique applied is sustainable, economic and with a minimal use of drinking water. In addition, biopolymer-based edible coatings were applied as an emerging technology for the carrying of micronutrients. It was demonstrated that when an edible coating was performed, the color and AA retention were improved and the Fe accessibility at pH of lumen intestinal trended to be higher. This study shows that the production of fortified pumpkin is simple and transferable to the food industry, and constituting a contribution from the food technology to the innovation of processes and formulation of a functional food fortified with Fe.

1. Introduction

The use of edible films and coatings in the food industry is a new topic of great interest due to their potential to increase the shelf life of foods. The possible action modes of edible coatings include delay of the moisture migration, slowing of the solutes or gas transport (O_2, CO_2), reduction of the migration of oils and fats, improvement of the mechanical properties, retention of volatile compounds, support of food additives (Flores, Famá, Rojas, Goyanes, & Gerschenson, 2007). Edible films can act additionally or cooperatively with other factors (Ramos, Miller, Brandão, Teixeira, & Silva, 2013) in improving the overall quality of the food, providing protection to the external microbial contamination, extending the shelf life of food and possibly improving the efficiency of packing materials. Besides presenting advantages such as biodegradability, ability to be ingested and low oxygen permeability (Han, 2000), these films can act as a barrier against external factors or as a carrier for the incorporation of food additives as antimicrobials, antioxidants, flavors, colors, which can improve the antimicrobial protection, appearance, texture and taste during storage (Cuppett, 1994). It has been reported that the application of edible coatings in fruits and vegetables improved retention of color and flavor components during storage, extended product life, retarded moisture and firmness loss, and product senescence (Ciolacu, Nicolau, & Hoorfar, 2014; Dhall, 2013; Rojas-Graü, Soliva-Fortuny, & Martin-Belloso, 2009). Tamer and Çopur (2010) applied a chitosan-based coating on the surface of strawberries, carrot, mango, cantaloupe, pineapple and mushroom and reported a growth inhibitory effect of microorganisms and an improved stability. Garcia et al. (2008) reported that the application of a cassava starch-based films containing potassium sorbate reduced significantly the activity of microorganisms in samples of pumpkin (*Curcumis moschata*, Duchesne). Recently, progress has been made in the use of films and coatings to incorporate edible nutrients or bioactive compounds. Mei and Zhao (2003) evaluated the feasibility of applying edible films based on milk proteins to incorporate high concentrations of calcium and vitamin

---

* Corresponding author at: Departamento de Industrias, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, Ciudad Universitaria, (1428), CABA, Argentina. Tel./fax: +54 11 45 76 33 66.
E-mail address: sflores@di.fcen.uba.ar (S.K. Flores).

http://dx.doi.org/10.1016/j.ifset.2015.11.001

Please cite this article as: Genevois, C.E., et al., Application of edible coatings to improve global quality of fortified pumpkin, *Innovative Food Science and Emerging Technologies* (2015), http://dx.doi.org/10.1016/j.ifset.2015.11.001

E, concluding that the functionality of the film forming matrix was affected by high concentrations of nutrients.

Commonly available fortified foods include non-structured and formulated foods. In contrast, impregnation or vacuum impregnation allows the introduction of physiologically active compounds to vegetal tissues without disrupting their cellular structure, but inducing changes in their behavior during further processing. In this sense, some authors (Alzamora et al., 2005; Barrera, Betoret, & Fito, 2004; Fito et al., 2001; Martín-Diana et al., 2007; Oms-Oliu et al., 2010) analyzed the feasibility of vacuum impregnation treatment in the development of products fortified with calcium and iron (Fe) from fresh fruits and vegetables. Recently, a pumpkin fortification process was optimized minimizing the color detriment due to the combined addition of AA and Fe into vegetal matrix. The pumpkin impregnated with 0.216 g/kg of Fe and 0.80 g/kg of AA resulted with a final color more similar to the control (pumpkin without fortification). In that opportunity, authors reported that, in general, air drying produced color detriment on pumpkin fortified with AA and Fe. It was also established that edible tapioca starch coating exerted a protective effect in terms of the color of pumpkin pieces during drying. The color variation due to drying process applied (ΔE) was 9.05 ± 0.07, while when product was coated, (ΔE) was 1.5 ± 0.4 (Genevois, Flores, & de Escalada Pla, 2014). From these results, it would be also interesting to evaluate different coatings strategies, such as using low gelation temperature polysaccharides, in order to diminish rate of detriment reactions like browning or AA lost. In this sense, k-carrageenan can constitute edible films by lowering the temperature and, on the other hand, pregelatinized tapioca starch results useful to formulate coatings at low temperatures.

The objective of the present work was to formulate a refrigerated ready-to-eat food based on *Cucurbita moschata* Duchesne ex Poiret fortified with Fe and AA. Application of edible coatings was also proposed in order to improve the product stability during processing and storage.

2. Material and methods

2.1. Chemicals

Food grade sucrose, glucose (Anedra, Argentina) and k-carrageenan (Degussa, Argentina) or pregelatinized tapioca starch (Lorenz Companhía, Brazil) were employed. The additives: $FeSO_4.7H_2O$ (Merck, Argentina), potassium sorbate (Sigma, USA), L-(+)-ascorbic acid (Merck, Argentina), citric acid and glycerol (Sintorgan, Argentina) and other chemicals used were of analytical grade.

2.2. Preparation of the pumpkin fortified with Fe and AA

2.2.1. Dry infusion process of pumpkin cylinders

Pumpkin (*Cucurbita moschata* Duchesne ex Poiret) obtained in a local supermarket was carefully washed and rinsed with distilled water. Then, 120 cylinders (≈960 g) of 29 mm diameter and 15 mm thickness were cut from the mesocarp using a stainless steel cork borer. The cylinders were blanched with water vapor for 8 min, rapidly cooled for 1 min by immersion in water at 0 °C and then submitted to a dry infusion (Alzamora, Guerrero, Nieto, & Vidales, 2004) according to Genevois et al. (2014) with some modifications. Briefly, pumpkin cylinders were placed in a plastic bowl and sprinkled with powdered glucose (33 g/100 g pumpkin) and sucrose (23 g/100 g pumpkin). Water from vegetal tissue began to flow from the pumpkin cylinder to the surrounding. In that moment, citric acid (0.15 g/100 g pumpkin), potassium sorbate (0.104 g/100 g pumpkin) and AA (2.21 g/100 g pumpkin) were added to the liquid solution and the orbital agitation started up. Citric acid was added in order to decrease pH values below 5, since sorbate is more effective, as an antimicrobial, in this range of pH (Damodaran, Parkin, & Fennema, 2008). The dry infusion was carried out at 20 °C up to equilibrium on an orbital shaker (Vicking S.A., Argentina) at 35 rpm.The described conditions of infusion were selected taking into account previous assays. Equilibrium was reached at 72 h when pumpkin cylinders and the surrounding solution achieved the same a_w and pH values. Once the dry infusion was concluded, the cylinders were drained through a stainless steel strainer. The pumpkin cylinders obtained by the previous described dry infusion methodology were named F0 (80 cylinders).

It must be remarked that a control system (F3, 40 cylinders) was performed in similar conditions used for F0 but fortified with Fe by adding $FeSO_4\ 7H_2O$ (0.17 g/100 g pumpkin, equivalent to 34 mg Fe/100 g pumpkin) to the dry infusion media.

2.2.2. Coating process of pumpkin cylinders

Pumpkins without Fe in the infusion medium (F0) were divided into two batches (40 cylinders each one), one of them was coated by dipping in a solution based on pregelatinized tapioca starch (F1), and the other one was coated with a k-carrageenan solution (F2). The methodology used in the preparation of edible coatings was as follows: pregelatinized tapioca starch (6% *w/w*) or k-carrageenan (2% *w/w*) was dissolved in distilled water. Glycerol (1.5% *w/w*) as a plasticizer, potassium sorbate (0.025% *w/w*) as antimicrobial agent and $FeSO_4.7H_2O$ (0.5% *w/w*) were added to each biopolymer aqueous solution. The preparations were stirred at room temperature (20 °C) on a magnetic stirrer for 20 min until a proper homogenization. For starch-based coating, pumpkin pieces were immersed for 5 min, removed from the solution and dried in a convection chamber at 35 °C for 4 h. In the case of k-carrageenan, the coating solution was placed on a hot plate until a temperature of 67 °C was reached; then pumpkin cylinders were coated with gel of k-carrageenan and allowed to cool for coating constitution. The dry infusion process and the coating were performed at least twice.

2.2.3. Packaging and storage

Finally, each pumpkin system (F1, F2 and F3) was introduced into low-density polyethylene bags of 80 μm thickness, provided with an easy-to-close Ziploc® closing. The bags were filled with the corresponding 5 pieces (40 g) and stored in a chamber at 8 °C.

2.3. Product characterization

In order to analyze the changes during the processing and storage, the samples were taken from blanched pumpkin, equilibrated pumpkin after dry infusion or final coated product. In addition, samples throughout storage at 8 °C were characterized.

2.3.1. pH and a_w

Pumpkin cylinders were reduced to a puree with the aid of a homogenizer UltraTurrax (IKA, USA) at 6500 rpm for 20 s. The pH was determined with a pHmeter (Cole-Parmer, USA). Water activity (a_w) was measured with a hygrometer (Aqualab, USA) at 20 °C. Determinations were performed at least in duplicate on the samples from blanched pumpkin, equilibrated pumpkin after dry infusion or final coated product.

2.3.2. Moisture and soluble solids contents

Pumpkin samples were frozen and freeze dried (Christ, Germany) for 48 h at 1.1 Pa and 25 °C, to determine the water content. The percentage of soluble solids (°Brix) was determined with a refractometer with automatic temperature compensation (Atago, USA) in the juice extracted from pumpkin cylinders by pressing the sample with a spatula. Water loss (WL) and solid gain (SG) in the different systems were calculated according to the following equations (de Escalada Pla, Campos, & Gerchenson, 2009):

$$WL = \frac{M_t \times m_t - M_0 \times m_0}{M_0} \times 100,$$

Please cite this article as: Genevois, C.E., et al., Application of edible coatings to improve global quality of fortified pumpkin, *Innovative Food Science and Emerging Technologies* (2015), http://dx.doi.org/10.1016/j.ifset.2015.11.001