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Influence of glycerol and chitosan on tapioca starch-based edible film properties

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Abstract

The individual and interactive effects of glycerol and chitosan on tapioca starch-based edible film properties were investigated using response surface methodology. Tests were run on the polymeric matrices to determine film forming solution apparent viscosity, mechanical and dynamic-mechanical properties, water vapour permeability (WVP) and color. All film forming solutions exhibited pseudoplastic behaviour. It was observed from the mechanical characteristics point of view, that the chitosan had a positive effect while the glycerol had a negative effect. The tan δ values were affected more by glycerol than the chitosan. With regards to WVP data, the chitosan addition had a negative effect, whereas the glycerol one had a positive influence. Moreover, both the chitosan and glycerol influenced the color indices. It can be concluded that the concentrations of chitosan and glycerol led to changes in tapioca starch edible film properties, potentially affecting film performances.

Keywords: Chitosan; Tapioca starch; Glycerol; Edible films; Response surface methodology

1. Introduction

Edible films and coatings have been particularly considered in food preservation, because of their capability in improving global food quality (Franssen and Krochta, 2003; Franssen et al., 2002; Guilbert and Biquet, 1996; Greener Donhowe and Fennema, 1994). The films can be used to cover food surfaces, separate incompatible zones and ingredients, form a barrier against oxygen, aroma, oil and moisture or perform as pouches or wraps. Among other important features, they can be used as carriers of functional agents, as antioxidants or antimicrobials, and to improve appearance and handling (Kester and Fennema, 1986). Film production by natural and abundant biodegradable polymeric materials as cellulose, gums, starches or proteins, is also convenient due to the lower environmental consequences compared with common synthetic plastic materials (Cutter, 2006).

Tapioca is a significant crop in South America, and it is an economical source of starch (FAO, 2004). Tapioca starch-based edible films exhibit appropriate physical characteristics, since these film are odourless, tasteless, colorless and impermeable to oxygen. However, films show

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brittleness with inadequate mechanical properties. The physical properties of sorbate-containing tapioca starch–glycerol edible films as affected by gelatinization and drying process were studied by Flores et al., (2007a). They found that the gelatinization technique and drying method used to obtain edible films affected network characteristics determining changes in physical properties. Moreover, the release of potassium sorbate from tapioca starch-based edible films with glycerol as plasticizer was studied and modelled by Flores et al. (2007b) who inferred that the proposed model satisfactorily fits the experimental data. Therefore, concluding that casting technique which produces films with high amorphous degree contributes greatly to the matrix relaxation for sorbate release.

The addition of plasticizer agents is necessary to improve the film flexibility. Glycerol is one of the most popular plasticizers used in film-making techniques, due to stability and compatibility with hydrophilic bio-polymeric packaging chain (Fernández Cervera et al., 2004). The application of hydrophilic films, as starch-based films, is limited by the water solubility and the poor water vapour permeability. To solve this shortcoming, the blending of starch with different bio-polymers (Xu et al., 2005) or the addition of hydrophobic materials such as oils or waxes (García et al., 2000; Anker et al., 2001; Ayranci and Tunc, 2003) have been proposed.

The reasons for chitosan addition in edible films are the good film forming and mechanical properties, no toxicity, biodegradability, relative more hydrophobic nature that could provide higher moisture barrier and water resistance (Bangyekan et al., 2006; Mathew and Abraham, 2008). The effects of acid (acetic, formic, lactic, propionic) concentrations, plasticizers concentration and storage time on the properties of solution-cast chitosan films have been widely studied. Wong et al. (1992) investigated the water vapour permeability of chitosan films using formic acid aqueous solution. Caner et al. (1998) found that the tensile strength was not time dependent, but elongation decrease with storage time. The films formed with 7.5% lactic acid solution had uniquely high values for the elongation at break and the amount of added plasticizer affected the film properties. Park et al. (2002) evaluated the characteristics of different molecular weight chitosan observing that the mechanical properties increased with chitosan molecular weight. Moreover, Hoagland and Parris (1996) prepared chitosan and pectin laminated films with either the glycerol or lactic acid as plasticizer. The films with chitosan and pectin had storage and loss modulus significantly greater than the respective moduli of chitosan films alone. The water vapour permeation of pectin or chitosan films, made with lactic acid, was unchanged by lamination. The rheological and surface tension properties of the filmogenic suspension and water solubility, color, mechanical properties and water vapour permeability of the composite film of chitosan and methyl cellulose were determined by García et al. (2004). They found that the chitosan films showed rigid characteristics (high elastic modulus and small elongation). Bangyekan et al. (2006) evaluated film properties including mechanical and physical properties of chitosan-coated cassava starch film observing that an increase in chitosan coating led to a significant increase in tensile strength and tensile modulus and a decrease in percentage elongation.

The study of properties of tapioca starch edible films in relation to different concentrations of chitosan and glycerol is a subject of great importance as it provides the knowledge of the advantages and disadvantages of its possible applications on the future of food shelf life.

The objective of this study was to determine the influence of chitosan and glycerol on the properties of tapioca starch-based edible films, using an experimental design and a response surface methodology analysis.

2. Material and methods

2.1. Preparation of edible films forming solutions

Chitosan solutions: chitosan of high molecular weight (Sigma–Aldrich, St. Louis, MO) was dispersed in acetic acid (J.T. Baker, Phillipsburg, NJ, USA) (1% v/v) to prepare solutions of proper concentrations. The dispersions were heated (80 °C) on a hotplate for 60 min under continous stirring to dissolve chitosan completely.

Tapioca starch solutions: Tapioca starch (Berasa S.A., Argentina) was dispersed in water–glycerol solutions in order to obtain 4% (w/w) suspensions. The quantities of glycerol were previously established. All dispersions were heated (125 °C) on a hotplate for 30 min under continous stirring to gelatinize starch completely.

Blend solutions: film-forming solutions were obtained by mixing chitosan and starch/glycerol solutions in similar proportions (50 g of each one) under gently stirring for 20 min. The chitosan and glycerol final contents of solutions varied according to Table 1. Tapioca starch concentration was maintained at 2% w/w in all blend solutions. Finally, a vacuum was applied to remove air from the systems.

2.2. Edible film preparation

Edible films were obtained by casting technique: 18 g of film forming solutions were dispensed on the surface of Petri dishes (9 cm diameter) and dried in a controlled temperature chamber (32 °C) for 48 h. After film constitution,

Table 1
Variables and their levels for the CCD

Variable levels	Independent variables	
	Chitosan (%)	Glycerol (%)
−2	0.1	0.5
−1	0.325	0.688
0	0.55	0.875
+1	0.775	1.063
+2	1	1.25