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Active biocomposites of cassava starch: The effect of yerba mate extract and mango pulp as antioxidant additives on the properties and the stability of a packaged product

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ABSTRACT

There is an increasing interest in the utilization of renewable resources for the production of food packaging. Among the biopolymers, starches from several sources are considered promising materials for this purpose, because they are biodegradable, inexpensive and available worldwide. Antioxidant food packaging films were produced by incorporating mango pulp and yerba mate extract into a cassava starch matrix. The bio-based films were used to pack palm oil (maintained for 90 days of storage) under accelerated oxidation conditions (63% RH/30 °C) in order to simulate a storage experiment. Palm oil packaged in these films exhibited a decreased oxidative process rate, which was attributed to the yerba mate and mango pulp in a concentration-dependent fashion. The evolution of the peroxide value contents indicated that, in general, the films with high concentrations of additives improved palm oil stability. Mechanical, physical and barrier properties of the developed film indicated that the addition of these bioactive compounds modified their properties significantly ($p < 0.05$).

Keywords: Mango pulp; Yerba mate extract; Active films; Palm oil; Characterization; Bio-based films

1. Introduction

Traditional food packages are passive barriers designed to delay the adverse effects of the environment on the food product. Active packaging allows packages to interact with food and the environment and plays a dynamic role in food preservation (Brody et al., 2008, 2010).

In recent years, the development of biodegradable packaging materials made from renewable natural resources (e.g., starch) has received increasing attention. Many new food-packaging concepts have been introduced to satisfy consumer demands (Souza et al., 2013). Plastic materials produced from petrochemicals are widely used due to their versatility, mechanical properties andlow cost, but the accumulation of

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large amounts of these conventional synthetic polymers can cause environmental impacts (Brody et al., 2010; Jiménez et al., 2012).

Problems caused by the disposal of these plastics have motivated the development, production and application of biodegradable polymers. Alternatively, there is a growing interest in using biodegradable packaging made from renewable sources, such as films made from starch (Müller et al., 2009).

Oxidation is one of the main mechanisms for the deterioration and reduced shelf life of foods. In addition, oxidation alters the taste (rancidity) and nutritional quality (loss of vitamins and essential fatty acids) of food and generates reactive and toxic compounds that pose a danger to consumers (Lindley, 1998). Antioxidant packaging is an important type of active packaging and represents a very promising food preservation technique for extending food product shelf life (López-de-Dicastillo et al., 2012). The incorporation of antioxidants into biodegradable packaging films has become very studied because oxidation is one of the main causes of food spoilage (Souza et al., 2011; Pereira-de-Abreu et al., 2011).

The incorporation of synthetic antioxidants into packaging materials has recently received increased interest due to toxicological concerns, prompting an increased interest in natural antioxidants (Bonilla et al., 2012). Phenolic acids, terpenes, tocopherols, carotenoids and vitamins are important natural antioxidants that have been proposed for incorporation into packaging to improve the oxidation stability of lipids and to prolong the storage of products (Siripatrawan and Harte, 2010; López-de-Dicastillo et al., 2012; Cavar and Maksimović, 2012). Although many materials with antioxidant activity have been tested, few studies have used natural, edible compounds, and even fewer studies have evaluated how these compounds could be incorporated into bio-based films (Oussalah et al., 2004).

Phytochemical studies of the mango (*Mangifera indica* L.) have shown significant amounts of secondary metabolites that are common components of the human diet. These bioactive constituents, including carotenoids, phenolic compounds and vitamin C, are present in fruits (Ribeiro et al., 2008) and industrialized pulps (Kuskoski et al., 2006) and provide antioxidant protection due to their capacity to scavenge free radicals.

The antioxidants are classified into two types, primary and secondary, depending on the mechanism used to halt the degradation process. The combination of two antioxidants, both primaries or a primary and a secondary, can result in a synergistic effect (Carelli et al., 2005). Studies have showed probable synergistic effect between carotenoids and phenolic compounds (Mertz et al., 2009; Han et al., 2011). However, the understanding of the molecular mechanisms underlying such synergistic effects, as well as the number of the studies, is still limited.

Cassava starch active films containing mango and acerola pulps as additives have already been developed and tested as packaging for palm oil by our research group (Souza et al., 2011). However, acerola pulp exhibited a pro-oxidant effect, likely due to its high concentration of vitamin C. Yerba mate contains high levels of phenolic compounds (Bravo et al., 2007) that can be used as a substitute for acerola pulp, increasing the antioxidant effectiveness of active films. This replacement is important because some of the biological properties of the yerba mate aqueous extract are attributed to the presence of these compounds, including antioxidant properties and protection lipid peroxidation (Murakami et al., 2011).

Yerba mate (*Ilex paraguariensis*, St. Hil.) is a commercially important plant from the subtropical region of South America. It is composed of minerals, vitamins, alkaloids (methylxanthines), phenolic flavonoids (quercetin and rutin) and tannins. The antioxidant properties of yerba mate mainly arise from its phenolic compounds (Bravo et al., 2007).

This study aimed to investigate the antioxidant efficacy and physical, barrier and mechanical property alterations resulting from the incorporation of mango pulp and aqueous yerba mate extract in cassava starch-based edible films using a response surface methodology. The incorporation of these derivatives into packaging produced with cassava starch has great economic importance due to the added value of natural, edible and commercial available raw materials.

2. Materials and methods

2.1. Materials

Cassava starch (Cargill Agrícola SA, Brazil), glycerol (Labsynth, Brazil) and palm oil were obtained from ODELSA SA, Brazil. Mango pulp, yerba mate (*I. paraguariensis*, St. Hil.) and low-density polyethylene (LDPE) films (0.040 mm thickness) were purchased from local markets (Salvador, Bahia, Brazil).

2.2. Characterization of additives

Mango pulp and yerba mate powder were characterized in relation to their chemical composition. Phenolic compounds, flavonoids and carotenoids were measured by UV spectrophotometry according to Roesler et al. (1999), Lee et al. (2003) and Souza et al. (2012a), respectively. Moisture and total solids values were determined by gravimetric measure (AOAC, 2000). The pH values were determined according to the analytical standards (IAL, 1985). The contents of total, soluble and insoluble dietary fiber were analyzed by enzymatic-gravimetric method (AOAC, 2000). Extraction of lipids was performed according to Bligh and Dyer (1959). Fatty acids (FA) profile were separated after hydrolysis and methylation, by gas chromatography (Varian® model 3800), in capillary a column (Elite-WAX 30 m × 0.32 mm × 0.25 mm), and flame ionization detector, the quantification was performed by area normalization (Nascimento et al., 2013). Free sugars of aqueous solution of mango pulp and yerba mate powder were separated by HPLC-IR (PerkinElmer 200 series) using a Polypore Ca pre-column (30 mm × 10 mm × 4.6 mm) followed by a Polypore Ca column (220 mm × 4.6 mm × 10 mm), in an oven at 80 °C. The mobile phase used was chromatographic grade water flowing at 0.1 mL min^{-1}. The quantification was using a standard curve (Assis et al., 2014).

2.3. Preparation of biocomposite films

Preliminary experiments were conducted to evaluate the maximum concentrations of additives that could be incorporated to the films, in order to obtain homogeneous materials, flexible and easy to handle. Therefore, different concentrations of mango pulp (10%, 20% and 30%) and yerba mate (20%, 30% and 40%) were alternately tested. At the end of this stage, the maximum concentrations were fixed in 20% for mango pulp and 30% for the yerba mate. The other concentrations used did not show desirable characteristics in the films obtained.

For films production, film-forming dispersions was prepared by with an aqueous yerba mate extract obtained from