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Active biodegradable packaging for fresh pasta

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The objective of this study was to produce an active biodegradable packaging for fresh pasta. The biodegradable film was produced by blown extrusion using thermoplastic starch, poly(butylene adipate-co-terephthalate) (PBAT) and potassium sorbate as an antimicrobial agent. Fresh pasta sheets were intercalated with biodegradable films (i.e., film/pasta/film/pasta/film), sealed in LDPE bags, and stored at 10 °C; the microbiological analyses and the characterisation of the films were performed before and during storage. The migration of the antimicrobial agent to the pasta was also evaluated. The films had mechanical properties suitable for use as active packaging for fresh pasta. The active films controlled the microbial growth, thus increasing the shelf-life of fresh pasta. Moreover, the amounts of potassium sorbate that migrated to the product were much lower than the concentrations allowed by the Brazilian legislation for fresh pasta. The film with 4.5% potassium sorbate was the best at controlling the microbial growth in the product; this film is suitable for use as an active packaging for fresh pasta.

1. Introduction

Most food packaging material is manufactured using petroleum-based non-biodegradable polymers, and their disposal is becoming a serious environmental issue. The partial replacement of these materials with biodegradable polymers from renewable sources (i.e., biopolymers) can reduce the impact that packaging materials have on the environment.

Among the biopolymers, starch is considered a promising raw material due to its price, availability and ability as a thermoplastic starch (TPS) to produce biodegradable films. However, pure TPS films are hydrophilic and have poor mechanical properties. Thus, TPS blended with biodegradable synthetic polymers such as poly(butylene adipate-co-terephthalate) (PBAT) are being studied to improve the mechanical performance, and reduce the hydrophilicity of the blends (Brandelero, Grossmann & Yamashita, 2011, 2012; Müller, Laurindo & Yamashita, 2012; Olivato, Grossmann, Bilck & Yamashita, 2012; Olivato, Grossmann, Yamashita, Eiras & Pessan, 2012; Raquéz et al., 2008; Reddy & Yang, 2010).

Antimicrobial agents that migrate from the active packaging material to the food product are very attractive because of their potential to control microorganism growth, and thus extend the shelf-life of the product (Han, 2000). In this type of packaging, antimicrobial agents migrate from the packaging material in small quantities and in a controlled manner instead of being added directly to the food (Silveira et al., 2007; Soares, Rutishauser, Melo, Cruz & Andrade, 2002).

Several studies have shown that antimicrobial agents such as organic acids, potassium sorbate, bacteriocins, thiosulfinates, enzymes, proteins, antibiotics, fungicides, chelating agents and metals may be added to edible films to reduce the growth of microorganisms (Cha & Chinnan, 2004; Devlieghere, Vermeiren, Bockstal & Debevere, 2000; Han, 2000; Kechichian, Ditchfield, Veiga-Santos & Tadini, 2010).

Cellulose acetate films containing 3–6% of sorbic acid were used for the preservation of pastry dough and were effective in inhibiting the growth of microorganisms during 40 days of storage at 8 °C (Silveira et al., 2007). Degirmencioglu et al. (2011) investigated the effects of a modified atmosphere packaging (i.e., containing CO_2 and N_2) with and without the addition of potassium sorbate (0, 0.15 and 0.3%) on bread slices. After 7 days of storage, the mould and yeast count in the bread slices that had been packaged with potassium sorbate was lower than 3 log CFU/g. Similar study were also done by Souza et al. (2012).

The objective of this study was to produce, by blown extrusion, an active biodegradable packaging for fresh pasta sheets using TPS/PBAT blends, and potassium sorbate as an antimicrobial agent The mechanical and barrier characterization of the films and microbial analyses of the pasta were performed before and during

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refrigerated storage with the main objective to observe the efficiency of the produced material.

2. Materials and methods

2.1. Materials

The active packaging was formulated with cassava starch (Indemil, Brazil), glycerol (Dinamica, Brazil), poly(butylene adipate-co-terephthalate) (PBAT) (BASF, Germany), which is under the commercial brand Ecoflex®-F, and potassium sorbate (Chemco, Brazil).

2.2. Biodegradable film production

The films were produced by blow extrusion using a single-screw extruder (BGM, model EL-25, Brazil) with a screw diameter (D) of 25 mm and a length of 28D and a film-blowing die of 50 mm. The process conditions consisted of a screw speed of 35 rpm and a temperature extrusion profile of 100, 120, 120, 130 and 130 °C. The formulations of the biodegradable films are shown in Table 1.

2.3. Fresh pasta production

The fresh pasta was produced by Massaria Artigianale Comércio Ltda (Brazil) without any preservatives. One hundred kilograms of dough contained 47 kg of flour, 15 kg of semolina, 16 kg of pasteurised whole eggs, 18.5 kg of pasteurised egg yolks and 3 kg of salt. These ingredients were homogenised in an industrial mixer until a smooth and firm dough was obtained. The dough was laminated to a thickness of 0.5 mm and cut into sheets of 150 mm × 150 mm.

2.4. Fresh pasta packaging

Fresh pasta sheets (150 mm × 150 mm) were intercalated with the biodegradable films (i.e., film/pasta/film/pasta/film) and sealed in low-density polyethylene (LDPE) bags. The packaged pasta was stored in a climatic chamber (Freeztec, Brazil) at 10 ± 1 °C; microbiological analyses and film characterisation were performed before and during storage.

2.5. Biodegradable film characterisation

2.5.1. Mechanical properties

Tensile strength tests were performed using a TA XTplus texture analyser (Stable Micro Systems, England) according to the American Society for Testing and Material Standards (ASTM D882-02, 2002). The properties measured were tensile strength (MPa), elongation at break (%), and Young's modulus (MPa).

2.5.2. Apparent opacity

The apparent opacity (Y_{ap}) of the films was determined using a colorimeter (BYK Gardner, USA) and was calculated based on the ratio between the luminosity (L^*) of the system (CIELab), which was measured with a black background (L^*_B) and a white background (L^*_W), and the thickness of the film (φ). The results were expressed on an arbitrary scale (0–100% μm^{-1}) according to Equation (1):

$$Y_{ap} = \left[\left(L^*_B/L^*_W\right)/\varphi\right] \times 100 \tag{1}$$

The opacity of the films intercalated with fresh pasta was determined after 2 and 37 days of storage at 10 °C.

2.5.3. Water vapour permeability (WVP)

Water vapour permeability (WVP) was determined gravimetrically, according to the ASTM E96-00 (1996) and under a relative humidity gradient of 33–75%. The tests were conducted in duplicate.

2.6. Fresh pasta characterisation

2.6.1. Microbiological analyses

The yeast and mould counts in fresh pasta were taken in Dichloran Rose Bengal Chloramphenicol (DRBC) agar incubated at 24 °C for 5–7 days; coliform bacteria, which were grown at 45 °C, were counted using the most probable number method (MPN) (APHA, 2001, p. 676).

2.6.2. Physicochemical analyses

2.6.2.1. Water activity and moisture content. The water activity of the fresh pasta was determined using an Aqualab CX2T equipment (Decagon Devices, USA) at 25 ± 2 °C, and the moisture content (on a wet basis) was determined according to the procedure described in the AOAC 925.04 (1995). Analyses were performed in duplicate.

2.6.2.2. Colour. The colour parameters L^*, a^* and b^* (CIELab system) of the fresh pasta were determined using a colorimeter (BYK Gardner, Germany) with an illuminant D_{65} (daylight) and a visual angle of 10°. The ΔE values (i.e., the colour difference between two spectrophotometric measurements) were calculated according to Equation (2):

$$\Delta E = \sqrt{\left(L^*_t - L^*_0\right)^2 + \left(a^*_t - a^*_0\right)^2 + \left(b^*_t - b^*_0\right)^2} \tag{2}$$

where 't' represents a specific storage period and '0' is the beginning of storage. The reference sample was the pasta in the beginning of storage ($t = 0$).

2.6.2.3. Pasta/film interaction. The sorbic acid content in the fresh pasta was assessed by ultraviolet absorption spectrometry (UV) at 530 nm AOAC 975.31 (1995).

2.7. Statistical analysis

The results of mechanical properties, colour parameters, opacity and water vapour permeability were analysed using analysis of variance (ANOVA); treatment means were compared using Tukey's test and Student's t-test at a 5% significance level ($p < 0.05$) using a Statistica 8.0 software (Stat-Soft, Tulsa, OK, USA).

3. Results and discussion

3.1. Film characterisation

3.1.1. Apparent opacity

The opacity of all films containing potassium sorbate (Fig. 1) was lower than that of the control films (CF), most likely due to the

Table 1
Formulations of the active biodegradable packaging containing potassium sorbate.

Formulation	Starch (kg/100 kg)	Glycerol (kg/100 kg)	PBAT (kg/100 kg)	Potassium sorbate (kg/100 kg)
CF	62.0	18.0	20.0	0.0
FS1.5	60.5	18.0	20.0	1.5
FS3.0	59.0	18.0	20.0	3.0
FS4.5	57.5	18.0	20.0	4.5

CF = control film; FS1.5 = film containing 1.5% of sorbate; FS3.0 = film containing 3.0% of sorbate; FS4.5 = film containing 4.5% of sorbate.