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Heat sealing property of starch based self-supporting edible films

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ABSTRACT

Heat sealing property of self-supporting edible films based on corn starch and a functional polysaccharide, such as amylose (AM), methylcellulose (MC) or hydroxypropylmethylcellulose (HPMC) was evaluated. Films were prepared in the laboratory by casting and heat sealed at 85–166 °C by an impulse heat sealer. Irrespective of film composition, sealing temperature influenced the seal strength. Films sealed at temperature <143 °C showed peeling mode failure attributing to weak seal strength, while that at ≥ 144 °C showed tearing mode failure indicating good seal strength. The highest seal strength was obtained at166 °C, and the value was 0.396, 0.211 and 0.385 N/mm for AM, MC, and HPMC containing film, respectively.

1. Introduction

Heat sealability is one of the paramount criteria of polymer films for their successful industrial application in production of flexible packages. In heat sealing process, two layers of thin films are pressed between two jaws of hot metal bars for sufficient period of time followed by cooling. Polymer melts due to this applied heat and simultaneous interfacial interaction occurs through mass diffusion across the melted layers (Kim & Ustunol, 2001). Upon cooling, a rigid joint develops due to inter-diffusion and entanglement of polymers from both the melted layers at the interface. Seal strength defines the maximum force per unit width of seal required to separate progressively a flexible material from another flexible material that have been pre-sealed, according to ASTM standard method F88-09 (ASTM, 2009). Seal strength is measured to indicate seal quality. According to Mihindukulasuriya (2012), seal strength depends on sealing temperature, applied pressure, and dwell time, the length of time the material remains in heating zone. Theller (1989) and Mueller, Cappacio, Hiltner, and Baer (1998), while working on heat sealing of low density polyethylene (LDPE) film and linear low density polyethylene (LLDPE) film, respectively, observed that dwell time and interface temperature had higher effect on seal strength than that of pressure. Besides seal strength, the knowledge of the failure mode of a heat sealed material is also critical as it evaluates the packaging performance and describes how the sealed surface separates into two layers during the assessment for seal failure. Yuan and Hassan (2007) had presented different modes of seal failure, like delamination, peeling mode failure and tear mode failure.

Development of edible/biodegradable self-supporting flexible films has received considerable attention in different parts of the globe with a common goal to lessen the environmental pollution generated from disposal of synthetic multilayer (laminated films of different polymers, and therefore non-recyclable) non-biodegradable food packaging films. Chowdhury and Das (2015) advocated use of starch based edible films to make pouches or sachets to pack dry food ingredients, spice powders and tea leaf, for maintenance of sensory quality. Additional advantage of edible films is that pouches made from these films would also serve as an effective 'ingredient delivery systems' in food processing where a packed pre-measured quantity of food ingredient(s) could be put directly into the system (Abdorreza, Cheng, & Karim, 2011). However, heat sealability/thermo sealing character of such film is an essential pre-requisite when to be used for making pouches (Abdorreza & Karim, 2013; Ichikawa & Mizokoshi, 2012; Miyata, Noguchi, Nishioka, & Koda, 2013; Thumsorn, Yamada, Pivsa-Art, Miyata, & Hamada, 2013). Seal having sufficient strength should be resorted to withstand impacts during normal handling and storage conditions for practical applications (Debeaufort, Quezada-Gallo, & Voilley, 1998).

A few reports are available on heat sealing property of biodegradable films. These include films based on blends of starch, derived starch, polylactic acid and petroleum based synthetic polymer, in different combinations (Hashimoto et al., 2004; Jagannath, Nadanasabapathi, & Bawa, 2006; Lopez, Lecot, Zaritzky, & Garcia, 2011; Miyata et al., 2013; Otey & Westhoff, 1979; Thumsorn et al., 2013). Tai, Chen, Yang, and Yang (2014) reported

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on films containing soy protein isolate (SPI) and different concentration of polyvinyl alcohol (PVA). Report on films developed from all edible materials is limited. Kim and Ustunol (2001) and Hernandez-Lzquierdo and Krochta (2009) reported the heat sealability and seal strength of films developed from whey protein isolate. Zein (prolamin fraction of corn protein) film exhibits desirable heat sealing property, as quoted by Ghanbarzadeh and Oromiehi (2009). Cho, Lee, and Rhee (2010) opined that the heat sealability of SPI film was improved by laminating the film with an additional layer of zein film. Very recently, Wang, Campanella, Patel, and Lu (2015) developed films from blend of carbohydrates, e.g., sodium alginate and sodium carboxymethyl cellulose, and a protein, e.g., gelatin. They joined the films initially using gelatin solution as an adhesive and subsequently by heat sealing, and indicated seal strength of about 20 N/15 mm. However, reports on starch based edible films are scarce. Pitak and co-workers (Pitak & Rakshit, 2011; Sothornvit & Pitak, 2007) packed some food products in pouches and bags that they made from film containing banana flour and joined by heat sealing. Although they studied the change in quality of the packed food, but no report on strength or peel failure of such seal was available. Abdorreza et al. (2011) reported heat seal strength of several films containing sago starch.

Considering the lacunae in knowledge with biomaterial based films in general and starch based edible film in particular, the present work was aimed to evaluate the heat sealing properties of edible films prepared using optimized blends containing corn starch and a functional polysaccharide (Chowdhury & Das, 2014) as the sources of carbohydrate. The functional polysachharide (FP) taken in this study was amylose (AM), methylcellulose (MC) or hydroxypropylmethylcellulose (HPMC), and added for improvement in mechanical and barrier properties of the film.

2. Materials and methods

2.1. Materials

Commercial grade corn starch was obtained from ANGEL LK18, Angel Starch and Chemicals Pvt. Ltd., Tamil Nadu, India. Through analyses, starch was found to contain moisture, amylose, protein (N × 6.25), fat, and ash (550 °C for 4 h), respectively, as 13.46, 21.70, 0.35, 0.04, and 0.02 g/100 g on wet basis. Potato AM (Sigma, Chemical Company, USA), MC (methoxy content 28–32 g/100 g) and gelatin (Loba Chemie Pvt. Ltd., Mumbai, India), and HPMC (Hi Media Pvt. Ltd., India) were procured from sources as mentioned in the parentheses; on drying, these ingredients were found to contain 12.50, 8.99, 12.01 and 10.12 g moisture/100 g on wet basis, in that order. Glycerol (0.87 w/w, AR, Merck Specialities Pvt. Ltd., Mumbai, India) was used as plasticizer. All these ingredients as received were used for preparation of films. Glass distilled water was used for dispersion of ingredients. Sodium propionate (AR, Loba Chemie Pvt. Ltd., Mumbai, India) was used as antimicrobial agent.

2.2. Preparation of film

Blends were prepared containing optimum amounts of starch and FPs, as arrived at by Chowdhury and Das (2014) to obtain maximum tensile strength and minimum water vapour permeability of films. Three different blends for films thus contained 0.65 g AM + 6.29 g starch; 0.10 g MC + 1.16 g gelatin + 5.68 g starch; and 0.22 g HPMC + 6.72 g starch, all in 100 g total mass. In each blend, total biopolymer was 6.94 g. All the ingredients were dissolved in water. Glycerol was added to maintain a concentration of 2.85 g/100 g blend. Finally, sodium propionate was incorporated into the blend in a weight ratio of 0.185:100. All the blends were gelatinized by heating in a boiling water bath for 10–12 min with continuous manual stirring using a spatula. The gelatinized blend was cast with a 'Thin Layer Chromatography Applicator', and dried. The dried film was stored in open mouth polythene bag at ambient condition (to simulate normal storage condition for commercial plastic film) for minimum 3 months till testing. As the mouth of the bag was open, drying or moisture sorption was possible spontaneously depending on environmental relative humidity (RH) (minimum 20–90% to maximum 70–100%) and temperature (minimum 20–30 °C to maximum 28–45 °C). Sequential steps in details have been described elsewhere (Chowdhury, 2013; Chowdhury & Das, 2010). For each composition, 10–12 numbers of films were cast.

2.3. Heat sealing and seal strength measurement

Heat sealing was carried out by an impulse heat sealer machine (Perfect Impulse Sealer, JTC, Kolkata, India) provided with seal bar of 4 mm width, sealing time setting knob, cooling time setting knob, and foot pedal.

Rectangular shaped strips of film, each measuring 100 mm in length and 25.4 mm in breadth were cut. The strips were conditioned in a chamber maintained at 50% relative humidity (RH) and 25 ± 1 °C at least for 48 h to maintain a uniform water activity level of 0.5 for all the samples during sealing. For sealing (vide Fig. 1), two conditioned strips was placed one over another and then was held in the jaw of machine from the end Z′Z″ and heat sealed with the help of pressure applied by foot pedal. Seal occurred on the shaded area (vide Fig. 1a) with a margin of 11 mm from the end Z′Z″.

A pre-calibrated thermocouple was placed (Aythani, Lockhart, Auras, & Tanprasert, 2006) in between two film strips (dummy runs), and the temperature (within ±1 °C) developed at the sealed area during sealing was noted for several combinations of settings of the sealing and cooling control knobs. The sealing time setting knob controlled temperature by controlling time of the heating impulse. Length of the cooling period was adjusted to allow the film to be hardened under pressure and prevent deformation of the film in the sealed area. The minimum and maximum sealing temperatures were determined based on 'unable to seal' and

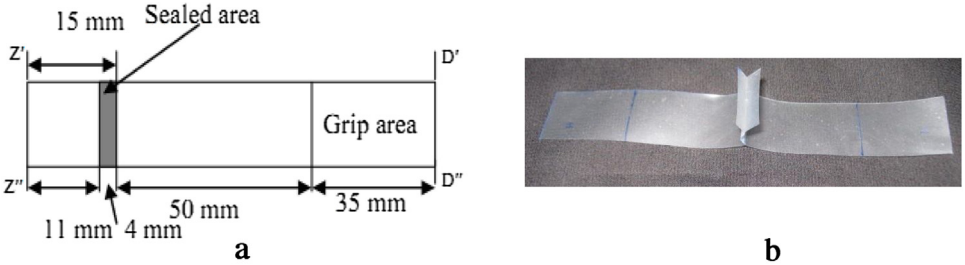

Fig. 1. Sealed sample for seal strength test a) schematic and b) actual.