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Development and Characterization of Biodegradable Film Using Corn Starch

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A B S T R A C T

Biofilms are prepared from biological materials such as proteins and polysaccharides that act as barriers to outside elements. Biodegradable corn starch-based films were prepared by casting. This work aimed to develop biodegradable films based on corn starch and evaluate the combined effects of various levels of glycerol content, and drying conditions on some of the film properties. The drying conditions and glycerol concentrations were optimized to develop the film. The film thickness, solubility in water, moisture content and degree of swelling were measured to assess the quality of biofilm. The average values of moisture content (%) of the film incorporated with 1.5% glycerol and at drying temperatures of 45^0C, 55^0C and 65^0C are 0.32, 0.28 and 0.17 respectively. The highest film thickness 0.076 was obtained at the glycerol inclusion level 5 per cent.

Introduction

The development of thin transparent barrier films offered new possibilities to the food packaging industry. Polysaccharides and proteins of animal and vegetable origin are natural biodegradable polymers that have traditionally been used to produce environment friendly films (Chandra and Rustgi, 1998). Starch is the most widely employed polysaccharide for film production, because it is naturally abundant and inexpensive (Alves *et al.*, 2007). Starch films present good mechanical and oxygen barrier properties, but their sensitivity to moisture is a major drawback. To improve the characteristics of these materials, films have designed based on starch and protein mixtures (Coughlan *et al.*, 2004).

Corn starch is able to form transparent edible biodegradable film without any previous chemical treatment. On the other hand, in order to increase the workability and flexibility of edible films based on different starches, various plasticizers, usually polyols, have been widely used, glycerol being one of the most preferred and most studied. Glycerol is a hydrophilic plasticizer, and when added at the correct level with respect to the biopolymer content, can interfere with chain to chain hydrogen bonding and the water solubility of the biopolymer (protein/starch mixtures), a process generally used to improve the mechanical properties of edible films (Sobral *et al.,* 2001; Sothornvit & Krotcha, 2001).

Edible plasticized films are usually manufactured by the wet method, which is based on the drying of a film-forming solution or dispersion by casting on a convenient support. Furthermore, the wet process is generally preferred in order to form edible preformed films or to applied coatings directly onto food products (Colla *et al.,* 2006). According to Perez-Gago and Krotcha (2000), the barrier and mechanical properties of edible biodegradable films have been shown to improve when the drying temperatures were increased. Thus the drying conditions used during the drying process of the filmogenic solution can be considered as an important factor in obtaining homogeneous films, and have a great influence on their performance. Thus the aim of this work was to develop biodegradable films based on corn starch and evaluates the combined effects of the glycerol content and drying conditions on some of the film properties.

Materials and Methods

Preparation and conditioning of films

Sodium alginate, corn starch, and gelatin powders were weighed and mixed to get total weight of 5 g (3:1:1), (2:1:2), (2:2:1) ratio and dissolved in 100mL distilled water. After dispersing the dry ingredients uniformly in water, the solution was heated at 50^0 C in hot water bath heated for 2 h and mixed using a magnetic stirrer for 2 h to form a homogeneous film-forming solution. Finally the solution was heated in microwave at power of 300W for 3 minutes. Solutions were finally cooled to 25^0 C and mixed gently for 60min to facilitate removal of air bubbles. Afterwards, 25mL of the film-forming solution was poured onto 16 × 18 cm polyacrylic film casting plates, followed by drying in a drying oven at 65^0 C for 12h. The resulting films were peeled off from the polyacrylic plates and conditioned at 23°C prior to further testing. Among three ratios the best film is selected for further experiment.

Effect of drying temperature and plasticizer on film parameters

The selected film ratio is experimented with different ratios of glycerol (1.5, 2.5, 5.0g) and different drying conditions (45°C, 55°C, 65°C and 75°C). Higher temperature (75°C) leads to browning and tearing of the film. Hence, the samples from lower temperatures were used for further studies.

Characterization of film parameters

Thickness

The thickness of the films was measured using a screw gauge (with an accuracy of 0.01 mm. at five points: one at the centre and four at opposite positions. All measurements were performed in triplicate. The mean thickness of each film was determined from an average of 10 random measurements.

Moisture content

The moisture content of the films was analyzed gravimetrically, in triplicate, according to the standard method D644-99 (ASTM, 1999), by drying the samples at 105°C for 24 h.

Solubility

The solubility was calculated as the percentage of dry matter of the film solubilized after immersion for 24 h in water at 25°C (Colla *et al.*, 2006; Gontard *et al.*, 1994).

Discs of film (2cm diameter) were cut, weighed, immersed in 50mL of distilled water, and slowly and periodically agitated. The amount of dry matter of initial and final samples was determined by drying the samples at 105°C for 24 h. The solubility was calculated using the following formula

$$Solubilty\ in\ water\ (S) = \frac{w_i - w_f}{w_i} x\ 100$$

Where,

S = solubility;

W_i and W_f were the initial and final weight of the disc on dry basis, respectively.

Degree of swelling

The degree of swelling of the films was determined according Turbiani (2007). The total initial mass (mi) of a film sample was determined and the material was immersed in distilled water for different time periods.

At certain periods of time, film was removed from the water and its total mass (mt) was determined, then the sample returned to water, this process was repeated until the weight of the sample film was kept constant.

Excess moisture on the sample surface was removed by placing the film between two sheets of filter paper, before each weighing.

The degree of swelling (DS) was calculated according to equation.

$$Degree\ of\ swelling\ (DS) = \frac{m_t - m_i}{m_i}$$

Results and Discussion

Thickness of the film to variations in the concentration of glycerol and Drying temperatures

The observations with regard to thickness of the film to variations in the concentration of glycerol and Drying temperatures are shown in the figure 1. The average values of thickness of the film incorporated with 1.5% glycerol and at drying temperatures of 45^0C, 55^0C and 65^0C are 0.065, 0.066 and 0.066 respectively. The average values of thickness of the film incorporated with 2.5% glycerol and at drying temperatures of 45^0C, 55^0C and 65^0C are 0.070, 0.072 and 0.075 respectively. The average values of thickness of the film incorporated with 5.0 % glycerol and at drying temperatures of 45^0C, 55^0C and 65^0C are 0.070, 0.074 and 0.076 respectively.

It is clear from Figure 3.1 that the thickness of the film showed the increasing trend that is directionally proportional to increase in glycerol level and increment in drying temperatures. The findings of present study are in accordance with Fernanda *et al.*, (2013) who also observed the thickness of the biofilms Composed of Alginate and Pectin increased steadily with increase in the concentration of crosslinker solution glycerol.

Moisture content (%) of the film to variations in the concentration of glycerol and Drying temperatures

The observations with regard to moisture content (%) of the film to variations in the concentration of glycerol and Drying temperatures are given in Figure 2. The average values of moisture content (%) of the film incorporated with 1.5% glycerol and at drying temperatures of 45^0C, 55^0C and 65^{0}C are 0.32, 0.28 and 0.17 respectively. The average values of moisture content (%) of the film incorporated with 2.5% glycerol and at drying temperatures of 45^{0}C, 55^{0}C and 65^{0}C are 0.40, 0.38 and 0.34 respectively. The average values of moisture content (%) of the film incorporated with 5.0 % glycerol and at drying temperatures of 45^{0}C, 55^{0}C and 65^{0}C are 0.53, 0.35 and 0.33 respectively.

It is seen from Figure 2 that the moisture content (%) is increasing in concurrence with increase in level of incorporation of glycerol whereas it showed vice versa with increment in drying temperatures. It may be justified by the use of plasticizing agent, the inclusion of glycerol molecules between the polymer chains causes the spacing there between increases, facilitating with this diffusion of water vapour through the film (Yang and Paulson, 2000).

Solubility of the film to variations in the concentration of glycerol and Drying temperatures

The observations with regard to solubility of the film to variations in the concentration of glycerol and Drying temperatures are given in Figure 3.

The average values of solubility of the film incorporated with 1.5% glycerol and at drying temperatures of 45^{0}C, 55^{0}C and 65^{0}C are 48.78, 46.55 and 45.48 respectively.

The average values of solubility of the film incorporated with 2.5% glycerol and at drying temperatures of 45^{0}C, 55^{0}C and 65^{0}C are 49.50, 47.16 and 44.35 respectively. The average values of solubility of the film incorporated with 5.0 % glycerol and at drying temperatures of 45^{0}C, 55^{0}C and 65^{0}C are 52.98, 49.14 and 46.00 respectively.

Fig.1 Thickness of the film to variations in the concentration of glycerol and Drying temperatures

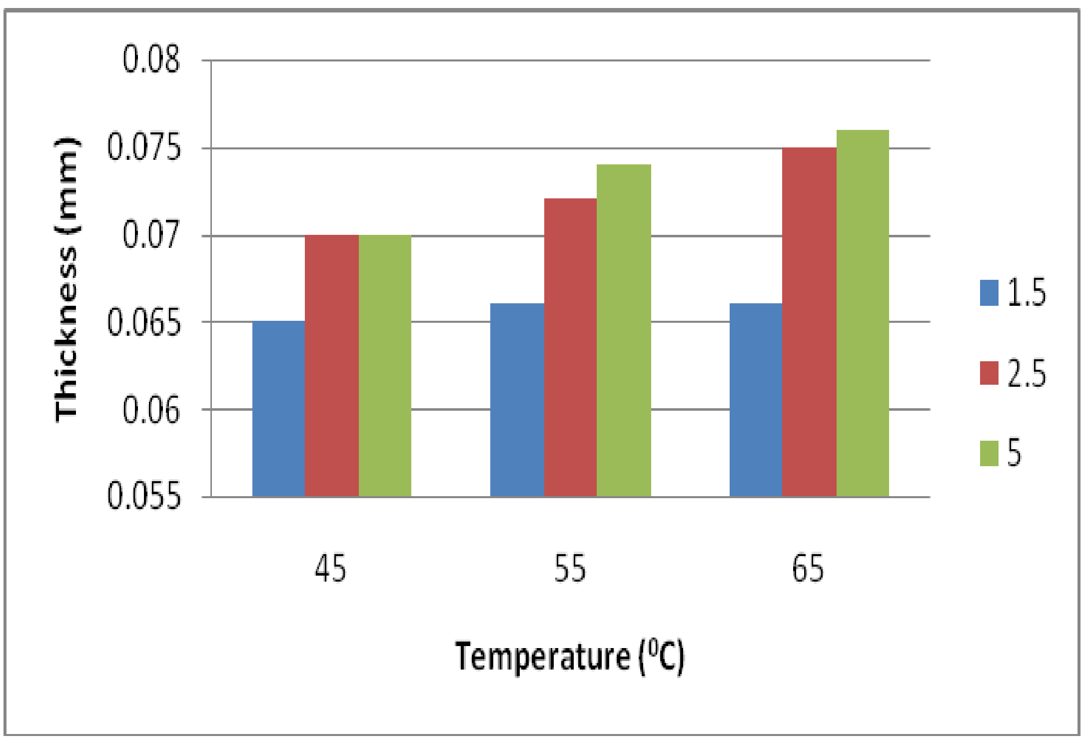


Fig.2 Moisture content (%) of the film to variations in the concentration of glycerol and Drying temperatures

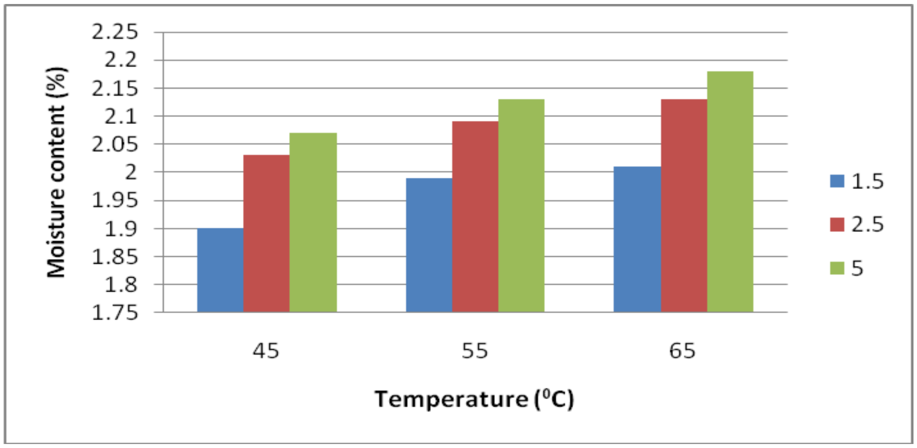


Fig.3 Solubility of the film to variations in the concentration of glycerol and Drying temperatures

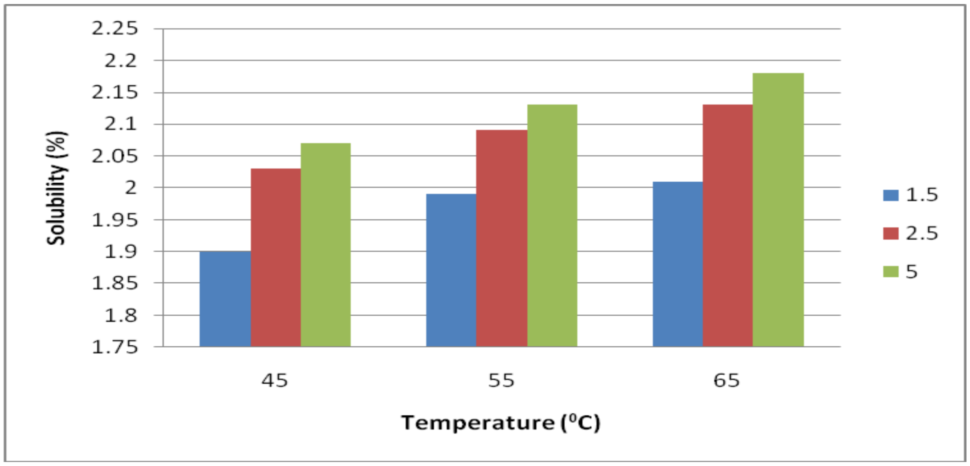
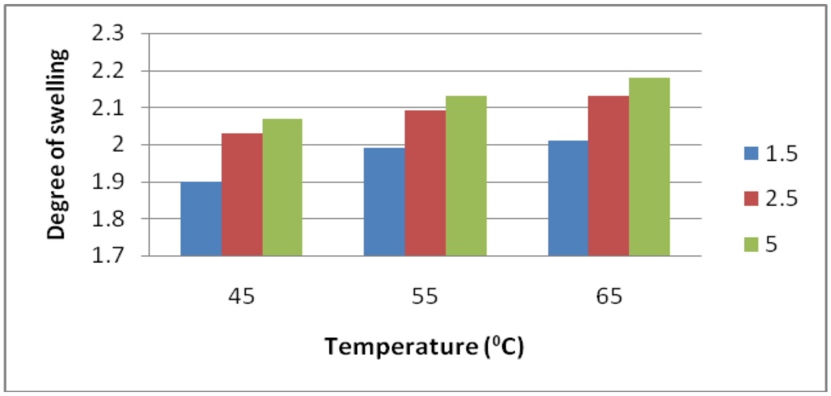


Fig.4 Degree of swelling of the film to variations in the concentration of glycerol and Drying temperatures



Effect of drying temperature and plasticizer on film parameters

Sodium alginate + Corn starch + Gelatin powder

Total weight of 5 g (3:1:1), (2:1:2), (2:2:1) ratio

↓

Dissolve in 100mL distilled water

↓

Addition of glycerol (1.5, 2.5 and 5.0g)

↓

Heating (50^{0}C for 2 h)

↓

Magnetic stirring for 2 h

↓

Microwave heating (300W for 3 minutes)

↓

Cooling (25^{0}C) and gentle mixing for 60 min

↓

Moulding (25mL of the film-forming solution into

16 × 18 cm polyacrylic film casting plates)

↓

Drying (45^{0}C, 55^{0}C, 65^{0}C and 75^{0}C)

↓

Peeling and conditioning at 23^{0}C

↓

Starch based film

It is seen from table 3 that the solubility of the film increased gradually when the level of addition of glycerol increased and it decreased when the drying temperature increased from 45 to 65^{0}C. It can be seen that increasing the concentration of glycerol promotes a slight increase of the solubilization of the films. This may be an indication that the plasticizer used can peel off on the polymer matrix, causing it to gaps in the material, making it more accessible to water molecules Silva *et al.*, (2009).

Degree of swelling of the film to variations in the concentration of glycerol and Drying temperatures

The observations with regard to Degree of swelling of the film to variations in the concentration of glycerol and Drying temperatures are given in figure 4. The average values of Degree of swelling of the film incorporated with 1.5% glycerol and at drying temperatures of 45^{0}C, 55^{0}C and 65^{0}C are 1.90, 1.99 and 2.01 respectively. The average values of Degree of swelling of the film incorporated with 2.5% glycerol and at drying temperatures of 45^0C, 55^0C and 65^0C are 2.03, 2.09 and 2.13 respectively. The average values of Degree of swelling of the film incorporated with 5.0 % glycerol and at drying temperatures of 45^0C, 55^0C and 65^0C are 2.07, 2.13 and 2.18 respectively.

It is clear from figure 4 that the degree of swelling showed increasing trend on both increment variations in the concentration of glycerol and drying temperatures. It might be due to increase in concentration of glycerol is possible to produce more flexible and consequently less resistant to tension, in addition to having greater permeability to water vapor since its display area becomes relatively greater Batista (2004). Another important factor to be considered is the hygroscopic character of glycerol, contributing to the increase in the moisture films (Turbiani, 2007).

Films prepared by the blend of glycerol and corn starch presented good packaging properties. The composite films are translucent and homogeneous. When analyzing the effect of the plasticizer agent glycerol on the characteristics of the films can be concluded that this contributes to increased solubility and permeability to water vapor, addition to providing increased elasticity of the material. The plasticizer used provided to obtain films more malleable in the sense that increased elasticity thereof. The films were considered moderate barrier to water vapor. The use of cross linking agents such as Calcium chloride may extend the water barrier properties.

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