Iranian Journal of Organic Chemistry Vol. 14, No. 3 (2022) 3373-3377

Mechanical properties of sago starch film incorporated with phycocyanin extract of Spirulina platensis

Fatemeh Sadeghi Erimi[b], Masoumeh Hosseinzadeh[a]*, Sadegh Salmanpour[b]

[a]*Department of Chemistry, Qaemshahr Branch, Islamic Azad University, Qaemshahr, Iran*
[b]*Department of Chemistry, Sari Branch, Islamic Azad University, Sari, Iran*

Received: May 2022; Revised: June 2022; Accepted: July 2022

Abstract: The mechanical and barrier properties of sago starch film incorporated with different percentage of phycocyanin (0.2, 0.4, 0.6, 0.8 and 1.0) were evaluated. With regard to mechanical properties, tensile strength and Youngs modulus decreased when the percentage of extract Elongation at break (%) increased. and increased with increasing percentage of extract from 0.2 to 0.1.

Keywords: Tensile strength, Elongation at break, Youngs modulus.

Introduction

The use of plastics is increasing dramatically in the world and it has an approximately 5% growth annually [1–3]. Some synthetic packaging materials like Polyethylene terphthalate (PET), polyvinylchloride (PVC), etc., have been very popular [4] because of their low cost, good mechanical properties like tensile strength and elongation, good barrier properties to water, oxygen, aroma compounds and carbon dioxide, heat seal ability and so on. In spite of good properties, their use should be restricted due to their non-biodegradability [5]. Increasing use of synthetic packaging films will contribute to environmental problems. In recent years, biodegradable polymers, such as starch, have been studied extensively as a potential packaging film with good physical, mechanical, and barrier properties [6]. Indeed for some foods, for example, fresh foods, biodegradable polymers can be more suitable [7-9].

The popularity of starch is primarily related to it being renewable and abundant [10–12], and relatively low cost.

However, starch alone as a packaging material has many limitations due to its hydrophilic nature and poor mechanical properties (for example brittleness). Therefore, starch is often modified Starch-based films have no color, odor, and taste and in comparison with plastic films that have good barrier properties and have good mechanical and barrier properties [13]. The oxygen barrier property of fresh products such as fruits, meats, and salads has an important role on their preservation. Starch films have a selective permeability to some substances such as oxygen which can make it as a very good modified atmosphere packaging (MAP) [14-15].

The water vapor barrier shows the volume of water vapor that pass from a packaging material. It is very important to prevent dehydration in fresh foods [16]. Mechanical properties of films such as tensile strength and elongation at break are important for proper function of packaging materials and may be influenced by interaction between polymer and chemical compounds [17] Most food contaminations exist on the food surface; therefore packaging has an important role to control food contamination [18-20]. To the best of our

---

*Corresponding author: E-mail: ma_hosseinzadeh@yahoo.com

knowledge, there is no publication in the literature related to mechanical properties of edible films incorporated with phycocyanin. Therefore, the objectives of this research was to characterize the mechanical and barrier properties of sago starch-based film incorporated with, Phycocyanin.

Materials and methods

Purification of phycocyanin

Spirulina platensis were cultured in Caspian Reserch Center and phycocyanin purification by this method [21].

Chemicals and reagents

Sago starch with approximately 12% moisture, glycerol, sorbitol and the other chemicals were supplied by Sigma-Aldrich.

Film preparation

Sago starch –based film was explained [22]. First 4% (w/w) sago starch was added to distilled water and followed by heating to 90 ◦C for gelatinization of starches and stirred continuously for 45 min to complete homogeneity and gelatinization in solution. A mixture of plasticizer (sorbitol: 3/glycerol: 1) that previously reported by as the best heat seal ability at 40%, also added. This mixture was cooled to 40–45 ◦C. Different amount of suspension Phycocyanin dissolve in water (0. 2, 0. 4, 0. 6, 0. 8 and 1 w/V) was added into the mixture Phy1,Phy2,Phy3, Phy4,Phy5 films respectively. Film without the addition of Phy (Phy0) was served as control. Each suspension was cast on Perspex plates and fitted with rims to yield a 16 cm × 16 cm film-forming area. Then the films were dried in the oven at 40 ◦C for 20 h and peeled off after drying, and kept at 23 ± 2 ◦C and the dried and peeled off film was put into a desiccator with 50% relative humidity until further analyses.

Mechanical properties

The mechanical properties of the films was determined using ASTM D882 [22-24] with a slight modification. Film strips cut into 100 mm × 20 mm sections and were kept for 48 h at 23 ◦C and 53% RH to be conditioned. The mechanical properties were then measured using a universal testing machine(SANTAM)in an initial grip separation with crosshead speeds of 50 mm/s and 1 mm/s. Deformation and force were recorded by the software during extension and expressed in graph format. Elongation and tensile strength at breaking as well as Young’s modulus were calculated. At least five replicates were carried out for each sample.

Results and Discussion

Tensile strength, elongation at break and Youngs modulus

Tensile strength (TS) expresses the maximum force per area that the film can tolerance before breaking, while elongation at break (EB), elongation shows flexibility of the film when subjected to mechanical stress and tension and Young's modulus (YM) Films made from high amylose starches showed the highest values of TS and YM. Several studies have reported this behavior [25]. which has been attributed to the capability of linear amylose chains to interact through hydrogen bonds to a higher extent than the branched amylopectin chains Fig. **1** indicates that increasing concentration the phycocyanin extract increased tensile strength from 0.98±0.05 MPa to 41.96±0.125 MPa, probably caused by the phycocyanin coat formed on the surface reinforcing the films and increasing the tensile strength. Furthermore, the changes in the orientation of the helices of starch molecules within the semi-crystalline lamellae could have resulted in a compact structure which also increased TS but decreased to control.

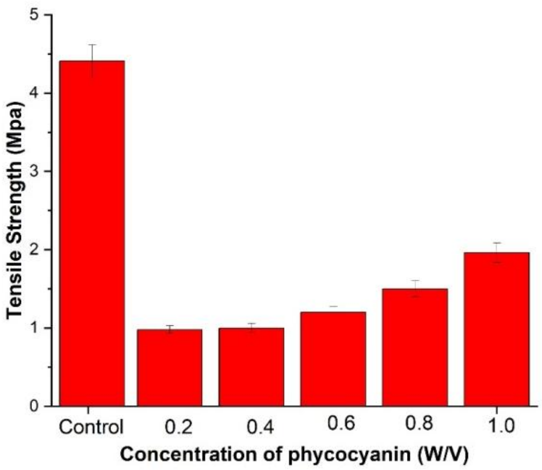

Figure 1. Tensile strength of sago starch films incorporated phycocyanin Bars represent mean (n = 10) ± SD

Elongation at break (%E) showed the opposite behavior of TS and YM in phycocyanin films. %E values increased control when the concentration of phycocyanin and Fig.2 while decreased the percentage of elongation at break from 43.98±0.07 to 25.12±0.705, increased to control increase flexibility of films. This result is consistent with several reports [26].

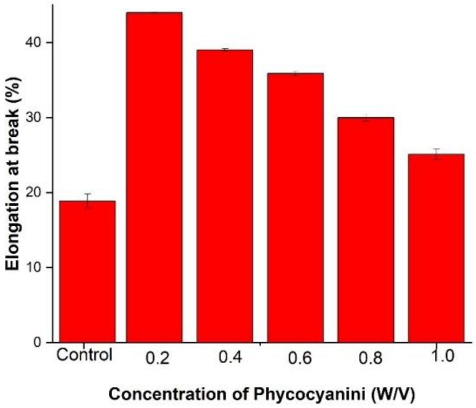

Figure 2. Elongation at break of sago starch films incorporated phycocyanin. Bars represent mean (n = 10) ± SD.

Elongation at break (%E) showed the opposite behavior of TS and YM in phycocyanin films. %E values increased control when the concentration of phycocyanin and Fig.2 while decreased the percentage of elongation at break from 43.98±0.07 to 25.12±0.705, increased to control increase flexibility of films. This result is consistent with several reports [26].

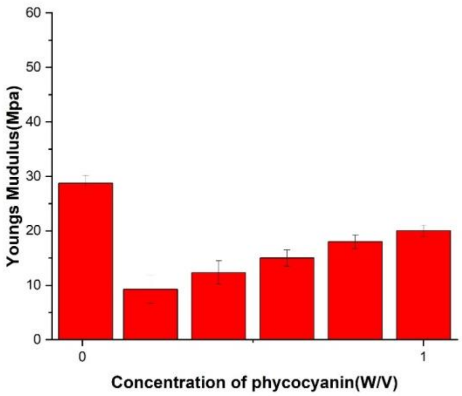

Figure 3. Young's modulus of sago starch films incorporated phycocyanin. Bars represent mean (n = 10) ± SD.

Conclusion

The results demonstrated that films containing phycocyanin (0.2, 0.4, 0.6, 0.8 and 1.0) had a good tensile strength and Youngs modulus decreased and elongation at break increased when percentage of incorporated extract in the film increased.

References

[1] F.E. Ehivet, B. Min, M.K. Park, J.H. Oh, *Journal of Food Science* **2011**, *76,* C178–C184.

[2] V. Siracusa, P. Rocculi, S. Romani, M.D. Rosa, *Trends in Food Science and Tech-nology* **2008**, *19*, 634–643.

[3] G. Robertson, *State-of-the-art biobased food packaging materials*, in: E.Chiellini (Ed.), *Environmentally Compatible Food Packaging*, Woodhead Publishing, Cambridge, UK, **2008**, pp. 3–28.

[4] G. Davis, J.H. Song, *Industrial Crops and Products* **2006**, *23*, 147–161.

[5] A. Sorrentino, G. Gorrasi, V. Vittoria, *Trends in Food Science and Technology* **2007**, *18*, 84–95.

[6] C.N. Cutter, *Meat Science* **2006**, *74*, 131–142.

[7] S. Imam, G. Glenn, B.-S. Chiou, J. Shey, R. Narayan, W. Orts, Types, *Production and Assessment of Biobased Food Packaging Materials*, in: E. Chiellini (Ed.), *Environmentally Compatible Food Packaging*, Woodhead Publishing, Cambridge,UK, **2008**, pp. 29–62.

[8] M. Maizura, A. Fazilah, M.H. Norziah, A.A. Karim, *Journal of Food Science* **2007**, *72*, C324–C330.

[9] J. Lorcks, *Polymer Degradation and Stability* **1998**, *59*, 245–249.

[10] D. Lourdin, G.D. Valle, P. Colonna, *Carbohydrate Polymers* **1995**, 27, 261–270.

[11] Y. Takahashi, T. Kumano, S. Nishikawa, *Macromolecules* **2004**, *37*, 6827–6832.

[12] Y. Zhang, Z. Liu, J. Han, *Starch-based edible films, in*: E. Chiellini (Ed.), *Environmentally Compatible Food Packaging*, Woodhead Publishing, Cambridge, UK,**2008**, pp. 108–136.

[13] M.O. Nisperos-Carriedo, Edible coatings and films based on polysaccharides, in:J.M. Krochta, E.A. Baldwin, M.O. Nisperos-Carriedo (Eds.), *Edible Coatings and Films to Improve Food Quality*, Technomic Publishing Company, Inc., Lancaster,**1994**, pp. 305–335.

[14] J. Rankin, I. Wolff, H. Davis, C. Rist, *Industrial and Engineering Chemistry Chemical and Engineering Data Series 3* **1958**, 120–123.

[15] C. Pagella, G. Spigno, D.M. De Faveri, *Food and Bioproducts Processing* **2002**, *80*, 193–198.

[16] F. Debeaufort, J.-A. Quezada-Gallo, A. Voilley, *Critical Reviews in Food Scienceand Nutrition* **1998**, *38*, 299–313.

[17] S. Quintavalla, L. Vicini, *Meat Science* **2002**, *62*, 373–380.

[18] F.B. Ahmad, P.A. Williams, J.-L. Doublier, S. Durand, A. Buleon, *CarbohydratePolymers* **1999**, *38*, 361–370.

[19] M.N. Abdorreza, M. Robal, L.H. Cheng, A.Y. Tajul, A.A. Karim, LWT – *Food Sciencea and Technology* **2012**, *46*, 135–141.

[20] M. Aminian, A.M. Nafchi, M. Bolandi, A.K. Alias, *Starch/Stärke* **2013**, *65*, 686–693.

[21] R. Bhat, M.-T. Liong, M.N. Abdorreza, A.A. Karim, *International Journal of Food Properties* **2012**, *16*, 1371–1379.
[22] M.N. Abdorreza, L.H. Cheng, A.A. Karim, *Food Hydrocolloids* **2011**, *25*, 56–60.
[23] M. Anker, M. Stading, A.M. Hermansson, *Journal of Agricultural and Food Chemistry* **1999**, *47*, 1878–1886.
[24] *ASTM, Annual book of ASTM standards*, **2010**, Philadelphia, PA.
[25] A. Mohammadi Nafchi, A.A. Karim, *Journal of Nano Research* **2013**,*25*, 90–100.
[26] ASTM, *Annual book of ASTM standards*, **2009**, Philadelphia, PA.
[27] A.M. Nafchi, R. Nassiri, S. Sheibani, F. Ariffin, A.A. Karim, *Carbohydrate Polymers* **2013**, *96*, 2.