

Effect of Mixing Temperature on Characteristics of Thermoplastic Potato Starch Film

N H Zakaria^{1, 2, a *}, N Muhammad^{1, 2, b}, A V Sandu^{2, 4} and M M A B Abdullah^{2, 3, c}

¹School of Manufacturing Engineering, Universiti Malaysia Perlis, Perlis, Malaysia

²Center of Excellence Geopolymer & Green Technology (CEGeoGTech), School of Materials Engineering, Universiti Malaysia Perlis, Perlis, Malaysia

³Faculty of Engineering Technology, Universiti Malaysia Perlis, Perlis, Malaysia

⁴Gheorghe Asachi Technical University of Iasi, Faculty of Materials Science and Engineering, Blvd. D. Mangeron 41, 700050, Iasi, Romania

E-mail: ^anurulhusna.zakaria@gmail.com, ^bnoorhafiza@unimap.edu.my, ^cmustafa_albakri@unimap.edu.my

Abstract. This study present the preparation of potato starch film with glycerol as a plasticizer through a solution casting technique. The effect of mixing temperature (80°C, 85°C, 90°C and 95°C) on the tensile and microstructure properties of potato starch film was investigated. Results shows that the increase of temperature from 80°C to 85°C caused the increase in tensile strength. Nevertheless, as the temperature increase to 95°C, the tensile strength and elongation at break decreased, with the highest value of 2.6MPa and 15.7mm respectively. Both of tensile strength and elongation at break were recorded for starch film prepared at 85°C. Besides, the microstructure of the starch films showed gradual smoother surface, homogenous and grain growth, as the mixing temperature increased. Overall result shows that mixing temperature significantly influenced the properties of the potato starch films.

1. Introduction

Starch is known as one of the potential future green polymer materials that were expected to replace synthetic polymer market. Starch has been considered as the most promising resource for development of biopolymer due to several advantages; which are renewable, biodegradable, non-toxicity, widely available and inexpensive [1, 2].

Hence, starch based biopolymer with these unique properties have become increasingly significant in various applications including plastic packaging, food industry, pharmaceutical and biomedical applications [3, 4]. In addition, starch has already known to have great potential in biomedical fields including tissue engineering scaffolds, bone cements, stents and drug delivery system [5–7].

Several studies have investigated the development and characterization of starch based films including potato starch. Podshivalov et al. [8], reported that potato starch possess several desirable feature such as exhibits good film-forming properties, chemical stability and biodegradable.

Besides, potato starch has demonstrated the possibility to be use in biomedical applications, as it have ability to improves its durability, good tissue integration and did not induce a pathological foreign body reaction [9, 15].



Starch can be process into thermoplastic materials using similar conventional techniques for synthetic polymer materials, such as solution casting, extrusion, injection molding and compression molding [2, 10].

Among of these techniques, solution casting is the most preferable method for the laboratory scale of production starch based films. During solution casting process, the presence of water is very important in order to gelatinize starch granules. Gelatinization occur when starch is heated with certain temperature in the presence of water and shear stress, thus causes the disruption of original starch structure to form thermoplastic starch (TPS) materials [11].

However, TPS products containing only water are sensitive and would lead to poorer mechanical and physical properties, due to their hydrophilic nature. Thus, the incorporation of plasticizer is required to overcome these limitations.

The addition of plasticizer helps to plasticize the starch solution and enhance the film flexibility, extensibility and ductility by reducing intermolecular reactions between starch molecules [12]. Glycerol are the most commonly used plasticizer for starch based films due to low cost and does not exhibit any toxic properties.

This study aims to prepare thermoplastic potato starch film with different mixing temperature, as well as to investigate the tensile and microstructure properties of the film produced.

2. Materials and method

2.1. Materials

Commercially available potato starch, ($C_6H_{10}O_5$)_n (HmbG Chemicals) was used as matrix material. Glycerol, ($C_3H_8O_3$) obtained from (HmbG Chemicals) was used as plasticizer.

2.2. Preparation of the thermoplastic starch films

Starch films were prepared via solution casting technique. About 5g of potato starch was first dispersed in 100 ml deionized water with (30% relative to dry starch) of glycerol content according to the corresponding run of experiments.

The mixture was then heated to different mixing temperature of (80°C, 85°C, 90°C and 95°C) in a water bath for 30 min under constant stirring.

Subsequently, the mixture was poured homogeneously onto petri dish of 14 cm diameter. The mixture were then dried at 45°C in an oven with air force circulation.

The dry films were removed from the petri dish and stored in a dessicator (40% of relative humidity) in a plastic bag for a week prior to testing. Thermoplastic starch films with varies mixing temperature was denoted according to mixing temperature as SF80, SF85, SF90, SF95. Table 1 shows the formulation of thermoplastic starch film.

Table 1. Formulation of thermoplastic starch film.

Material	SF80	SF85	SF90	SF95
Potato starch (g)	5	5	5	5
Distilled water (mL)	100	100	100	100
Glycerol (%)	30	30	30	30
Mixing temperature (°C)	80	85	90	95

2.3. Tensile Test

The tensile test were performed as suggested by Sanyang et al. [4], and the tensile strength and elongation at break were determined according to the ASTM standard (D882-02) by using a 5kN INSTRON tensile machine.

Film strips were cut into 70mm x 10mm sections are subjected to crosshead speed of 2mm/min and initial grip separation of 40mm. The test was conducted with five replication for each sample and the average value was calculated.

2.4. Microstructure Analysis

The microstructure of the film was observed by using scanning electron microscopy (SEM) model (Hitachi TM-3000) operated at acceleration voltage of 15kV.

3. Results and discussion

3.1. Tensile Test

The mechanical properties of thermoplastic starch films were studied through a tensile test. This test was conducted in order to investigate the influence of mixing temperature onto the mechanical behaviour of the starch film. The results of tensile strength and elongation at break are illustrated in Figure 1. As shown in Figure 1(a), the tensile strength of the starch films increased significantly with increasing temperature from 80°C to 85°C. However, as the temperature increase from 85°C to 95°C, the tensile strength decreased from 2.6Mpa to 2.2MPa. The highest tensile strength value of 2.6MPa was recorded for films prepared at 85°C mixing temperature, meanwhile films prepared at 80°C showed the lowest tensile strength value of 2MPa. The decrease in tensile strength as the mixing temperature increased might be caused by the changes in starch structure. This behaviour could be related to the structural modifications of the starch network when heated at high temperature and the matrix of the film become less dense, thus weaken the starch film properties.

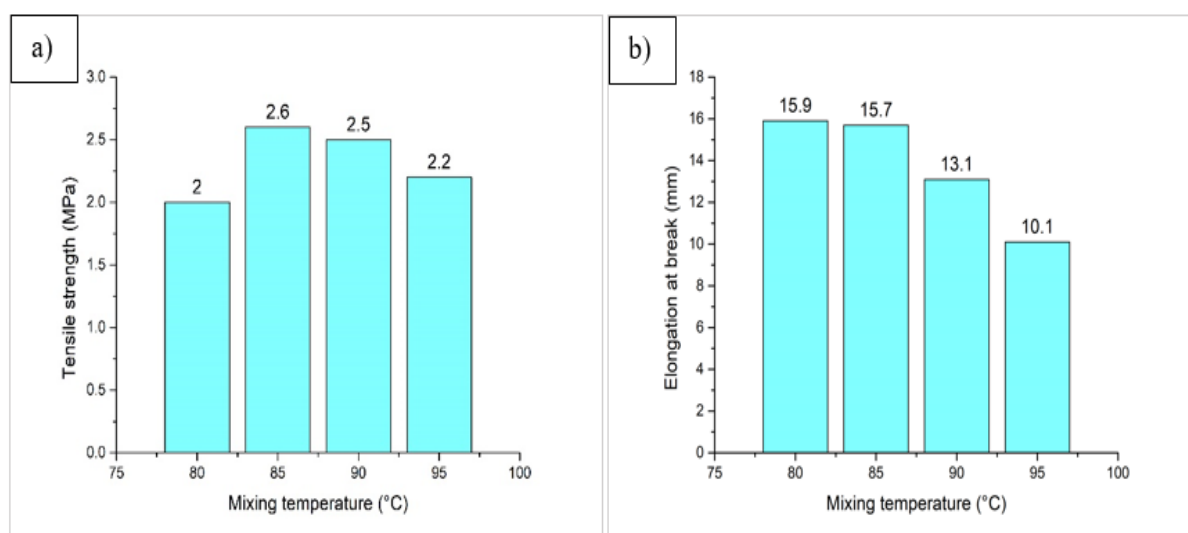


Figure 1. Tensile properties of potato starch film with different mixing temperature, (a) tensile strength and (b) elongation at break.

Figure 1(b) shows the effect of mixing temperature on the elongation at break of the potato starch film. The significant drop in the elongation at break (15.9 mm to 10.1 mm) was observed as the increased in the mixing temperature. This fact is probably due to the hydrogen bonds between the starch and glycerol occur as the temperature is increased, as reported by Vieira et al. [13]. The hydrogen bonds development at higher mixing temperature are associated with stronger interactions between plasticizer and starch molecules that inhibit a macromolecular movement, thus resulting in a decreased in elongation values.

3.2. Microstructure Analysis

Gelatinization process of thermoplastic starch produces measurable changes by microstructures characterization. The changes between grain shape and size, as well as contacts between the phases are commonly observed during gelation process. Figure 2 shows the microstructure of potato starch containing glycerol with different mixing temperature of (80°C, 85°C, 90°C and 95°C) at magnification of 1000x. Observation from SEM image reveal the changes in microstructure

development with increasing mixing temperature during gelatinization process. The surface morphology of thermoplastic potato starch film for all processing temperatures illustrated different sizes of porosity and condition on the surface area.

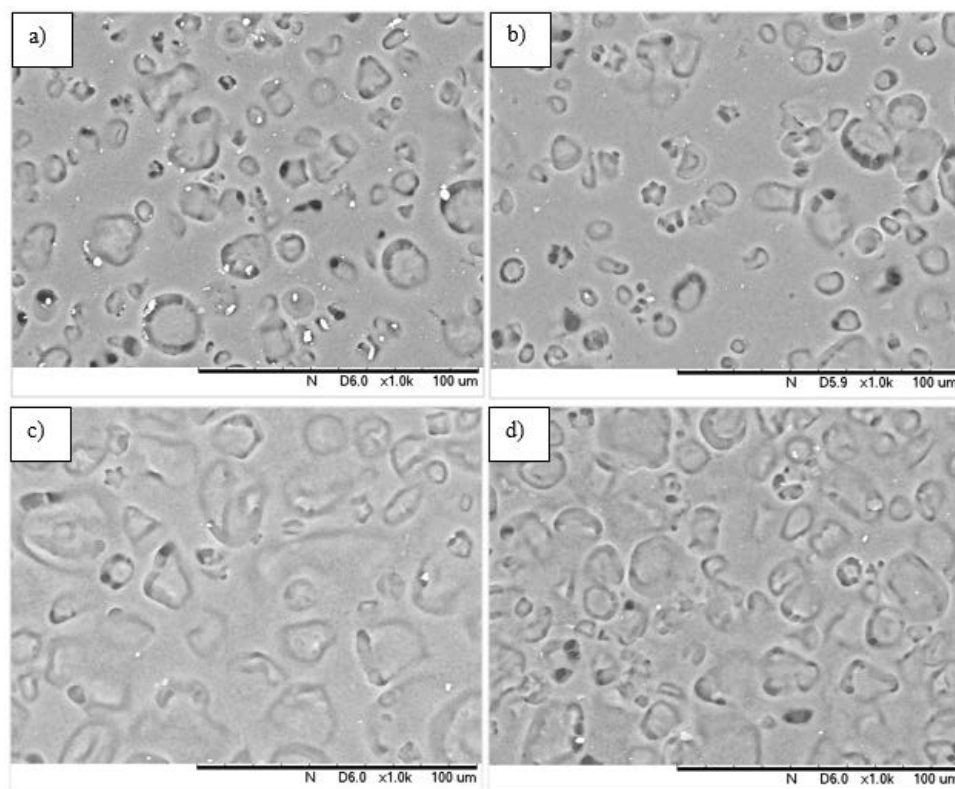


Figure 2. SEM image of potato starch film with different mixing temperature (magnification of 1000x): (a) SF80, (b) SF85, (c) SF90 and (d) SF95.

Figure 2(a) showed rougher surface with more porous and the presence of swollen starch granules which could be due to insufficient mixing temperature to gelatinize the starch. As mixing temperature was further increased, the surface of film showed good dispersion and gradual smoothing with less porosity, but slightly visible agglomerates starch granules which can be observed in Figure 2(c) and Figure 2(d). Similar finding was reported by Mali et al. [14], which stated that the increasing mixing temperature of gelatinization could lead to the smoother surface and homogeneity of thermoplastic starch film. This is because the higher mixing temperature will disrupt the starch molecules interactions and increase the swelling capability of the starch network accordingly, and thereby increase the homogeneity of the film.

4. Conclusions

Potato starch films containing glycerol as a plasticizer with vary mixing temperatures was successfully fabricated through a solution casting technique. The varying mixing temperatures significantly affected the properties of potato starch film by reducing the brittleness and tensile strength. The results displays that thermoplastic potato starch prepared at 85°C of mixing temperature shows the highest tensile strength, and thus identified as desired mixing temperature in this study. This result was supported by microstructure analysis of thermoplastic potato starch, which revealed more smooth and homogeneous surface of the film. These findings presents starch based film as a potential biopolymer for the development of biodegradable materials.

5. References

- [1] Maitz M F 2015 *Biosurface and Biotribology* **1**(3) 161–176
- [2] Maria Guadalupe Lomeli Ramirez T S F-S, Satyanarayana K G, Iwakiri S, Bolzon de Muniz G, Tanobe V 2011 *Carbohydr. Polym.* **86**(4) 1712–1722
- [3] Ochubiojo E and Rodrigues A 2012 *Scientific, Health and Social Aspects of the Food Industry*, 355–380
- [4] Sanyang M L, Sapuan S M, Jawaid M, Ishak M R, and Sahari J 2015 *Polymers (Basel)* **7** 1106–1124
- [5] Chaunier L 2014 *Laryngoscope* **124** 875–881
- [6] Torres F and Arce D 2015 *Biodegrad. Polym. Nanocomposites* 73–94
- [7] Marques A P, Reis R L, and Hunt J A 2002 *Biomaterials* **23**(6) 1471–1478
- [8] Podshivalov A, Zakharova M, Glazacheva E, and Uspenskaya M 2017 *Carbohydr. Polym.* **157** 1162–1172
- [9] Velasquez D, Pavon-djavid G, Chaunier L, Meddahi-pellé A, and Lourdin D 2015 *Carbohydr. Polym.* **124** 180–187
- [10] Majdzadeh-Ardakani K, Navarchian A H and Sadeghi F 2010 *Carbohydr. Polym.* **79**(3) 547–554
- [11] Johech-mo D, Janigová I and Chodák I 2017 *Eur. Polym. J.* **93** 843–849
- [12] Rugchati O, Mahawongwiriya K and Thanacharoenchanaphas K 2013 *Int. J. Biol. Biomol. Agric. Food Biotechnol. Eng.* **7**(9) 491–494
- [13] Gurgel M, Vieira A, Altenhofen M, Oliveira L and Beppu M M 2011 *Eur. Polym. J.* **47**(3) 254–263
- [14] Grossmann E, Garcia M A, Martino M N, Victo M and Zaritzky N E 2002 *Carbohydr. Polym.* **50** 379–386
- [15] Hanganu S C, Armencia A O, Grigoras S, Hanganu L C and Vizureanu P 2010 *Materiale Plastice* **47** 357–378

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