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Mechanical Properties of Porous Polylactic Acid (PLA) Via Salt Leaching Method

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Abstract. The purpose of this research is to evaluate the properties and characterization of porous polylactic acid (PLA). The porous PLA was fabricated via salt leaching method whereas PLA was first dissolved in chloroform under mechanical stirring for 7 minutes. Then, sodium chloride (NaCl) was added into the dissolved PLA. The mixture of PLA and NaCl was then left at room temperature for 24 hours for the chloroform to be evaporated. The solidified films was then been washed under tab water to remove the NaCl content. The removal of NaCl content will lead to porous PLA. The effect of NaCl content on the mechanical and morphological properties of PLA was been studied. The increased of NaCl content shown a reduction trend for tensile properties and elongation at break. Meanwhile, the Young's modulus had been found to increase with increasing NaCl content. The micrograph of the neat PLA showed a smooth surface at the tensile fractured surface. However, the effect of salt leaching method lead to a porous PLA as the NaCl content increased, the pores observed in the micrographs also increased. The higher the content of NaCl increashe amount of pores on the PLA and the number of interconnected pores with uniform pores morphology and well distributed pores.

1. Introduction

Nowadays, plastics wastes become serious environmental issues in our daily life. This is because of the excessive used of plastic synthetically derived plastic from petroleum source [1]. Most type of plastic are not easy biodegrade due to the hydrocarbon and take longer time to decompose causing in waste handling and increase of carbon dioxide (CO^2) emission [2]. According to Malaysian municipal (MSW), plastic pollution is third largest amount of waste in Malaysia. Polylactic acid (PLA) is a new alternative to replace traditional plastic that are produce from the non-renewable source to a renewable source because of its highly versatile and biodegradable while not releasing toxic during production [3, 4]. PLA which belongs to the family of aliphatic polyester is prepared by both ring opening polymerization of the cyclic lactic dimer and through direct condensation of lactic acid that been produced by either a chemical synthesis or carbohydrate fermentation such as starch and corn. PLA getting demand in tissue engineering application because it contain of porous and three dimensional structure which known as scaffold. PLA also has been used for drug delivery system (DSD) especially in medical applications due to its biocompatibility and low toxicity [5]. Usually scaffolding material degrades as the new tissue produce and leaving nothing foreign in the body.

The drawbacks of PLA is the brittleness which cannot fully satisfy the requirement of few application so the limitation. Porous PLA can be produced from salt leaching methods which are one of the physical foaming processes [6]. Salt leaching is the traditional techniques which are still attractive to be used because of the simplicity of its process [7]. Variations of sodium chloride (NaCl) content are preferable for producing pores with good interconnectivity between the pores [8]. PLA have similar properties like polystyrene and it soluble in organic solvent such as chloroform. Besides, chloroform extracted the PLA which give highest porosity for the scaffold and fulfil the requirement on tissue engineering [9]. On other hand, degradation behaviour of PLA depend on stereoregularity and crystalline by the degradation behaviour of crosslinked PLA,were discovered using enzyme as an effective degradation agent. The biodegradability degrades with the presence of microorganism through enzymatic action on time, safely and effectively [10].

The aims of this research is to investigate the effect NaCl content used in salt leaching method on the mechancial and morphological properties of porous PLA.

2. Methodology

Porous PLA was prepared by solvent casting and leaching techniques. First, PLA was stirred by using mechanical stirrer until completely dissolved. Then, NaCl was added into the mixture with continuous stirring. The mixture containing PLA and NaCl was then casted onto a glass mold and left in room temperatures for 24hours to ensure the evaporate of the chloroform. The solidity PLA film was then washed with distilled water for several times to remove embedded NaCl contents. The porous PLA was then dried in the oven at 400 C for 24 hours. Similar procedure was carried out for each formulation as shown in table 1.

Table 1. Formulation of porous PLA

PLA (wt%)	NaCl (wt%)	Chloroform (mL)
100	0	8
80	20	8
60	40	8
40	60	8
20	80	8

3. Result and Discussion

3.1. Tensile Properties

Figure 1 shows the effect of NaCl contents on tensile strength of porous PLA. The results showed that the increasing of NaCl contents used for salt leaching decreased the tensile strength of the porous PLA. The higher amount of NaCl content contributed to more pores formations. According to Bhuvanesh Gupta et al, (2012), in his research of porous polycaprolactone by salt leaching process revealed that, the tensile strength decreased due to the salt leaching technique which introduces the porosity in the surfaces of film. The fractured occurrence mostly happens at porous area because of the low mechanical strength with the present of porous.

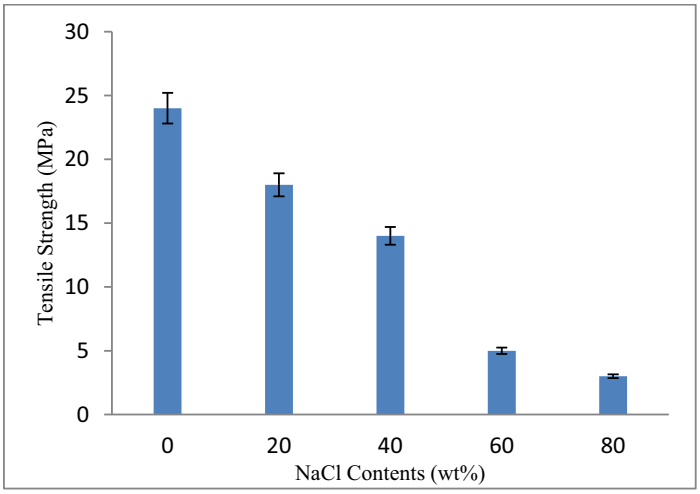


Figure 1. Effect of NaCl contents on tensile strength of porous PLA

Figure 2 reveals the effect of NaCl contents on the elongation at break of porous PLA. It was found that the increasing of NaCl contents decreased the elongation at break of porous PLA. The viscoelasticity of porous PLA reduced significantly because of deformation created on porous PLA. The present of pores created by NaCl on porous PLA gave more ductility and higher deformation that lead to decreasing in elongation at break. According to Liang Ma et al., (2015) in Fabrication of Tissue Engineering Scaffolds in his researches showed the tensile strength before leaching is much higher with the NaCl component intact. Overall, the tensile strength reduced after leaching, as the materials became porous.

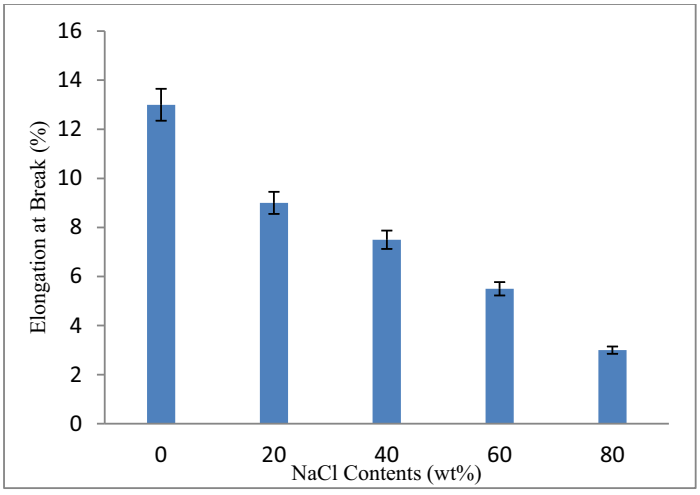


Figure 2. Effect of NaCl contents on elongation at break of porous PLA

Figures 3 indicate the effect of NaCl contents on modulus of elasticity of porous PLA. The modulus of elasticity increased with the increasing of NaCl contents. NaCl contents greatly influenced the amount of pores produced through leaching process. As stated by Yuan H. et al., (2009), in his study on foaming behaviour of PLA revealed that, neat PLA has lower elasticity of modulus due to most porous PLA could not attain high radial expansion ratio (RER). Hence, better elasticity was

produced with the increased of pores and decreased amount of PLA. [14]. Therefore, increased of pores produced weak Van Der Waals forces because of the pores created.

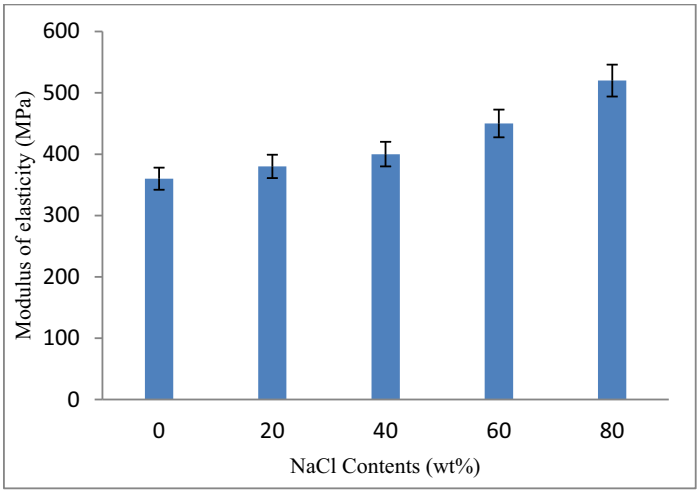


Figure 3. Effect of NaCl content on modulus of elasticity of porous PLA

3.2. Morphology Study

Figure 4 illustrates the micrograph of tensile fractured surfaces of neat at a magnification of 500X PLA. Based on the micrograph, it clearly can be observed that the surface morphology of neat PLA was smooth and a brittle surface. This supported the results that neat PLA has the lowest modulus of elasticity due to it brittleness.

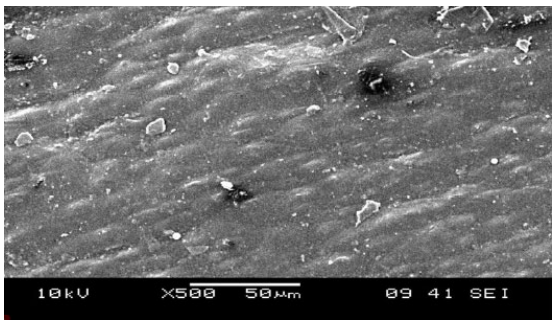
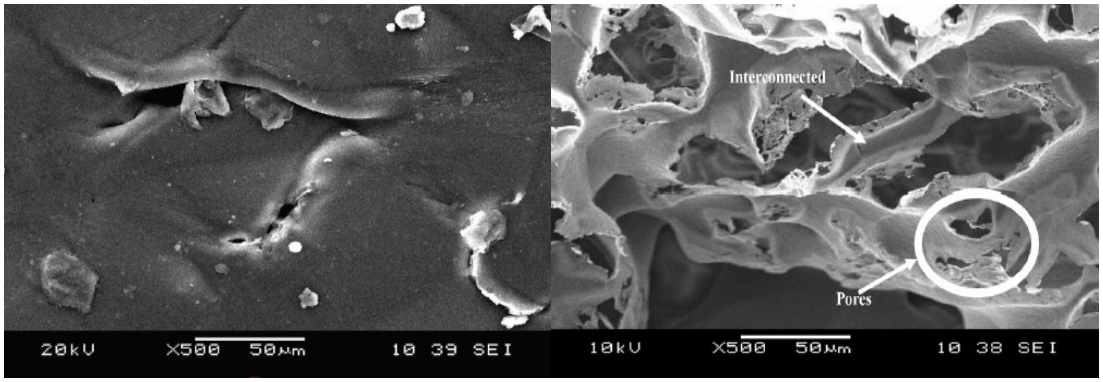


Figure 4. Scanning Elelctron Microscope (SEM) micrograph of tensile fracture surface of neat PLA

Figure 4 (a) and (b) reveal the fractured surfaces of porous PLA produced by 40 and 80wt% of NaCl contents. From the micrographs, NaCl contents were removed out from PLA matrix through leaching process created porous PLA. Porous PLA with higher NaCl contents has higher amount of pores compared to the porous PLA with lower NaCl content. Meanwhile, figure 5 (a) shows porous PLA with lower NaCl content shows very small amount of interconnected pores which far from each other

Porous PLA from 80wt% of NaCl contents pores were well distributed and interconnected as shown in figure 5 (b). The higher amount of NaCl contents produced high number of interconnected pores. Besides, it also had uniform pore morphology and the pores well distributed. From the figure 5 also can be observed no remaining NaCl which can be considered have been leached completely. This

proved that the amount of pores influenced by the NaCl contents which finally produced porous open-cell [16].



(a) 40wt% NaCl content (b) 80wt% NaCl content

Figure 5. Scanning Electron Microscope (SEM) micrograph of tensile fracture surface of porous PLA

4. Conclusion

The NaCl content was found to have a significant effect on the properties of porous PLA. The higher amount of NaCl content will contribute to more pores formation. For tensile strength and elongation at break, the increasing content of NaCl lead to a decreased in the value of tensile strength and elongation at break. On the other hand, the value of young's modulus increased with the increased of NaCl content. Moreover, the morphologies of the neat PLA showed smooth surfaces and with the content of NaCl showed the presence of pores produced by removing NaCl from porous PLA.

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