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Effect of Glycerol on The Water Barrier Properties and Biodegradability of Lotus Root Starch Bioplastic Films

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Abstract

Numerous starch-based bioplastic films have been developed by researchers due to the negative effects of synthetic plastics on the environment. Thus, lotus root starch is a great alternative natural polymer due to its biodegradability and ease at processing. In this work, bioplastic films were prepared with 0.5, 1.0, 1.5, and 2.0 mL of glycerol aiming to observe the effect of glycerol to water solubility, water absorption, water permeability, and biodegradability property of lotus root starch bioplastic films. The result revealed the water solubility increased, the water vapour permeability and biodegradability decreased with the increase in glycerol content. While water absorption was inconsistent in results. The results showed the suitability of lotus root starch-based bioplastic films for food packaging materials.

Keyword: Starch bioplastic film; water absorption; water solubility; water vapour permeability; biodegradability.

INTRODUCTION

Nelumbo nucifera, the scientific name for lotus, is an edible aquatic palatable herb with nutritional value that belongs to the monogeneric family *Nelumbonaceae,* which has been widely domesticated around the world (Shad et al., 2011)(Pal & Dey, 2013). The lotus plant's blooms, leaves, seeds, and rhizomes can all be used for a variety of things (C. Chen et al., 2021). Starch derived from lotus also has a significant medical and economic benefits.

The primary raw materials that make up the global starch market are maize, wheat, potatoes, sweet potatoes, and cassava (Luchese et al., 2018). The usage of biopolymers derived from renewable sources as packaging raw materials has expanded; starch is one such material and is thought to be the second most abundant biopolymer in the world, right after cellulose. A biopolymer that is abundant, affordable, and renewable called starch has an unusual mix of features. Therefore, the use of lotus root starch as bioplastic films is encouraging to be explored.

Additionally, starch is now produced on an industrial scale, which is significant for introducing its usage in packaging production (Luchese et al., 2018). Starches are frequently employed in the food industry. Therefore, starch can be altered chemically or physically to suit particular industrial needs (Nurulain Syuhada et al., 2018). However, starch-based bioplastic films are sensitive to humidity. Bioplastic films have low physical and mechanical strength (Abotbina et al., 2021)(Vinod et al., 2020).

This research was carried out to develop bioplastic films as an alternative for food packages by using organic material from lotus root starch with considered the effect of glycerol on bioplastic films. These bioplastic films are expected to has higher physical properties and more rapid decomposition.

Materials and Methods

Materials

The pure lotus root starch (XIHUOUFEN) from West Lake Sanjia Village was purchased from SUSUSHOU (China). There were no contaminants in the pure lotus root starch, and its purity was over 95%. While, analytical grade glycerol anhydrous was supplied from R&M (Malaysia) and is used to make the films more flexible.

Bioplastic Films Preparations

15 g of lotus root starch, 2.3mL of distilled water and 1mL of glycerol was mixed in the beaker. Then, mixture solution of glycerol, water and lotus root starch in a beaker was whisked until it attained a uniform solution. Then, the mixture solution was poured onto the glass Petri dish and steamed in a home steamer for 40 min to cause the starch to gelatinize. When it was cold, the biofilm had developed and was ready to peel off. The glycerol was added at 0.5, 1.0, 1.5 and 2.0 mL.

Bioplastic Films Characterizations

Water Absorption Test

Sample bioplastic films for water absorption tests were conducted in consonance with ASTM 570-98 (2010) (Wan Zarina et al., 2018). First, the dry samples mass was weighed precisely. Then, the samples were immersed in 100 mL of distilled water for 12 h. After being immersed in water for 12 h, the samples were then weighed. The water absorption can be determined by calculating the percentage of swelling of the sample bioplastic films, which is formulated in the eq. (1):

$$Swelling\ (\%) = \frac{[\mathrm{W}_i - \mathrm{W}_o]}{\mathrm{W}_o} \mathrm{x}\ 100 \tag{1}$$

Where, W_0 = the weight at the beginning of the dry bio plastic films
W_i = the final weight of the bio plastics films

Water Solubility Test

The procedure described by (Marichelvam et al., 2019) was used to prepare samples for the water solubility test. The samples were cut with a 2.0 cm^2 dimension. The samples were agitated at 180 rpm for 6 h at room temperature while immersed in 100 mL of distilled water. The samples were then dried in an oven at 105ºC until a final fixed weight was established. Eq. (2) was used to determine the percentage of all soluble materials (% solubility):

$$W_s\ (\%) = \frac{[W_0 - W_f]}{W_0} \mathrm{x}100 \tag{2}$$

Where, W_s = solubility in water
W_o = the weight at the beginning of the bioplastic films
W_f = the final weight of the bioplastic films

Water Vapour Permeability Test

According to the modified technique of ASTM standard E96-05, the water vapour permeability (WVP) of lotus root starch bioplastic films was investigated. Samples were put onto glass cups that were 1.5 cm below the sample and filled with deionized water. The glass weighing cups were set within a silica gel-filled desiccator. For a total of 14 h, the glass cups were weighed every 120 min (Marvizadeh et al., 2021). The measured WVP of the bioplastic films was determined using the following eq. (3).

$$\mathrm{WVP} = (WVTR \times L)/\ (\Delta \mathrm{P} \times \mathrm{A}) \tag{3}$$

Where, $WVTR$ is the water vapour transmission rate (g), L is the average film thickness (m), ΔP is the partial water vapor pressure variance (Pa) through two sides of the film, and A is the area of the cup.

Biodegradability (soil burial test)

A container was filled with 500 g of soil with a high concentration of nitrogenous bacteria (with a negligible moisture content). The samples were weighed and buried in the ground for 14 days at a depth of 2 cm at room temperature. Afterwards, the samples were weighted and recorded. For visual assessment, the picture of the samples was taken. The biodegradability test was measured by eq. (4).

$$\text{Weight Loss (\%)} = \frac{(wo-w)}{wo}\ x\ 100 \tag{4}$$

Where, wo and w are the weights of samples before and after the test.

Results and Discussion

Water Absorption

Fig 1. shows the result of the effect of glycerol on the water absorption test of lotus root starch bioplastic film samples. The result shows after 12 h, lotus root starch bioplastic films with addition 0.5 mL of glycerol absorbs approximately 163% of its weight. While, the lowest water absorption was at 1.0 mL. However, at 1.5 mL and 2.0 mL the water absorption increased by 95% and 111% respectively. Overall result shows that when the amount of glycerol increases, the water absorption decreased. While glycerol and water fight for the polar sites on amylose and amylopectin, the absorption of water by glycerol causes an increase in film hygroscopicity at higher relative humidity (Müller et al., 2008).

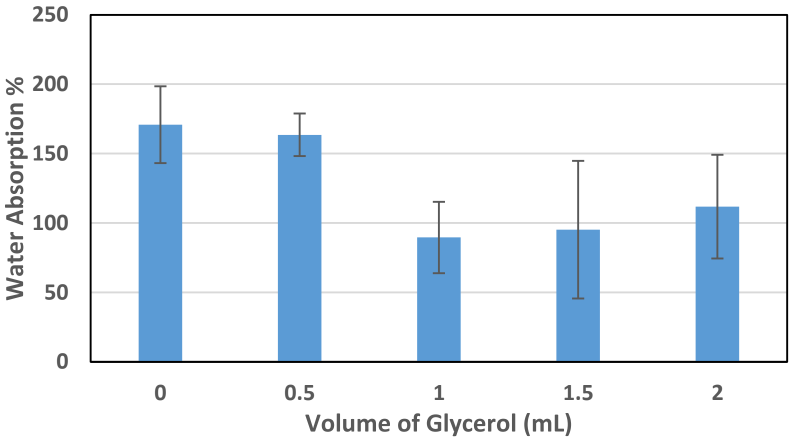

Figure 1: The effect of glycerol on water absorption of lotus root starch bioplastic films

Water Solubility

Fig 2. shows the effect of glycerol on water solubility test of lotus root starch bioplastic films. The results demonstrated that the addition of 0.5, 1.0, 1.5 and 2.0 mL of glycerol increased the water solubility from 18% to 86%. This due to higher content of amylose in films may account for a higher solubility index (C. Chen et al., 2021) (Datta & Halder, 2019). The addition of plasticizers to biopolymers altered the three-dimensional molecular structure of the polymer, decreased the intermolecular attraction forces, and increased the free volume of the system. Furthermore, the structure of the polymer became less dense allowing water to enter its structure and dissolve it. Plasticizers act to minimise polymer intermolecular tensions, improve the mechanical properties of the film, such as its extensibility, and increase the mobility of the polymeric chains (Müller et al., 2008).

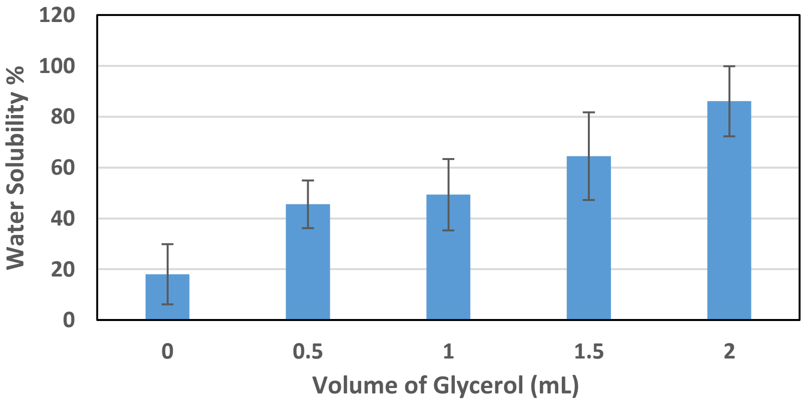

Figure 2: The effect of glycerol on water solubility of lotus root starch bioplastic films

Water Vapour Permeability

Water vapour passage through things is measured using water vapour permeability (WVP). Effect of glycerol content upon water vapour permeability of bioplastic films can be seen in Fig 3. As predicted that the film less water vapour permeability with the addition of glycerol on the bioplastic films. Results demonstrated that water vapor permeability decreases with increasing of glycerol from 0 to 2 mL for every 120 min over the course of 14 h. The highest WVP showed by the sample of lotus root starch without glycerol, compared to the addition of 0.5 mL, 1.0 mL, 1.5 mL and 2.0 mL of glycerol. This may be explained by the good biopolymer interactions that result in lower glycerol concentrations and a dense, highly compact starch network and structure (Tarique et al., 2021). Similar results of WVP are also reported by (J. Chen et al., 2021).

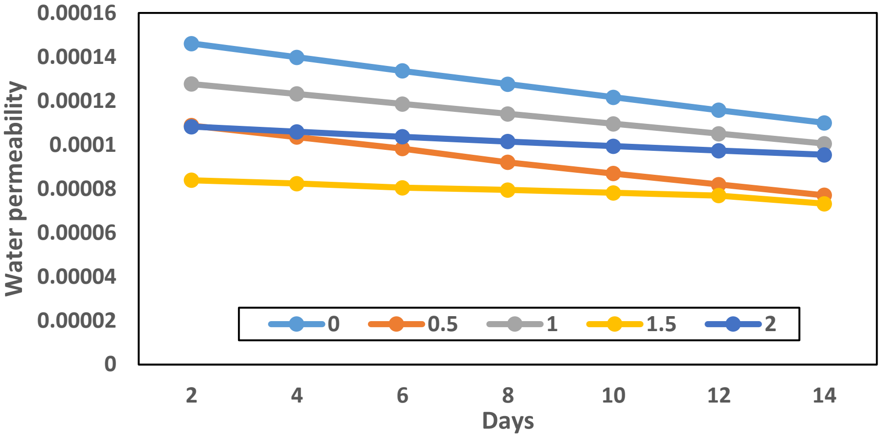

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Figure 3: The effect of glycerol on water vapour permeability of lotus root starch bioplastic films

Biodegradability (soil burial test)

Fig 4. shows a soil burial degradation test for lotus root starch bioplastic films with 0, 0.5, 1.0, 1.5- and 2.0-mL glycerol performed for 14 days. The breakdown of materials involves a variety of factors, including fungi, bacteria, microorganisms, and other biological agents. The biodegradable polymer immediately starts to degrade as these tiny organisms interact with it. These microbial species transformed the polymer by an enzymatic or metabolic process, resulting in the breakdown of the polymer into smaller molecules with lower average molecular weights. As shown Fig.4, the weight loss of bioplastic film samples gradually decreased on the second day and then started to slow down for the following days as the bioplastic film samples degraded. At the end of 14 days, the weight loss of bioplastic film samples 0-, 0.5- and 1.0-mL glycerol were found at 75.17%, 72.75 % and 66.75% respectively. While the bioplastic film samples at 1.5 mL and 2.0 mL had lost 62.48% and 61.79%. This phenomenon can be attributed to the strong connection between soil microbial activity and the rate of film deterioration consistently higher was influenced by the moisture content. In other words, the amount of water in the films grew simultaneously with the pace of deterioration. The results of a recent investigation into water absorption also supported by (Tarique et al., 2021).

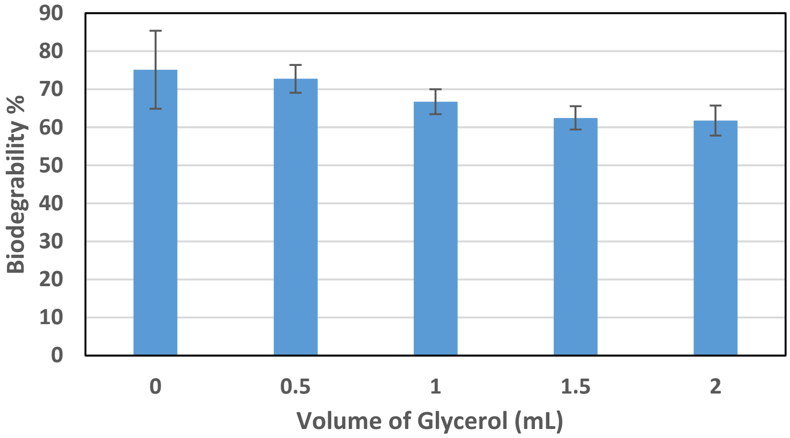

Figure 4: The effect of glycerol on biodegradability of lotus root starch bioplastic films

CONCLUSION

Preparation of lotus root starch biofilms with incorporation of glycerol has been successfully prepared. Results demonstrated the bioplastic films without glycerol were frail, brittle, and impossible to remove from the Petri dish. Hence, the incorporation of glycerol as a plasticizer to mixture solution in the process led to a decrease in the brittleness, fragility, increase flexibility and peel ability as films as well. These findings demonstrate that the increasing of the glycerol to the lotus root starch bioplastic films was increased its water solubility properties, decreased water vapor permeability and biodegradability behaviour. While, the water absorption inconsistent with the increasing of the glycerol concentration. Further research for lotus root starch bioplastic films should be done focused on mechanical properties and thermal behaviour for the application of food packaging.

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