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Effects of Plasticiser on the Morphology and Swelling Properties of Cellulose-based Hydrogels Derived from Wastepaper

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ABSTRACT: *Cellulose was successfully extracted from wastepaper with a pre-treatment using sodium hydroxide (NaOH) and hydrochloric acid (HCl). The cellulose was then used to fabricate two types of hydrogels: cellulose/carboxymethyl cellulose (CMC)/polyvinyl alcohol (PVA) and cellulose/CMC/glycerol. Epichlorohydrin, an ECH solution was used as a cross-linker for the fabrication of both types of hydrogels. NaOH/urea/ultrapure water (NU) solutions were used to dissolve all the materials needed for the formation of hydrogels. The attenuated total reflectance-Fourier transform infrared (ATR-FTIR) showed the presence of hydroxyl group (O-H), hydrocarbon group (C-H) and carbonyl group (C=O) stretching. Scanning electron microscope (SEM) showed different porosities for both types of hydrogels, while the equilibrium swelling, swelling$_{eq}$ of cellulose/CMC/PVA hydrogels were better compared to the cellulose/CMC/glycerol hydrogels. The highest swelling$_{eq}$ was found for the cellulose/CMC/PVA hydrogel (3/3/4 ratio), CCP334 with 6.33 g/g, while the lowest swelling$_{eq}$ (g/g) was obtained from the cellulose/CMC/glycerol hydrogel (3/2/5 ratio), CCG325 with 1.49 g/g.*

Keywords: cellulose, hydrogels, carboxymethyl cellulose (CMC), polyvinyl alcohol (PVA), glycerol

1. INTRODUCTION

Paper recycling has been one of the main activities in the paper industry where the recycling rates of paper increased yearly. The recovery rates of paper and

paperboard doubled from 1990 to 2018 in the United States where it was estimated almost 53 million tons were recovered in 2018.[1] However, the consciousness of recycling wastes including papers in Malaysia is generally quite low i.e., 4.5% recycling rate in Kuala Lumpur in 2015.[2] As one of the alternatives to recycle the wastepaper, they are used as raw materials to prepare cellulose-based hydrogels in this study.

Hydrogels are composed of copolymers and homopolymers with hydrophilic properties through a cross-linking process that forms water-swollen networks, where even in the swollen state, the stability of their networks is not affected and the hydrogels have a high swelling ratio which is more than 100 indicating that they can absorb a large amount of biological fluids or water.[3,4] The hydrogels are also known to be stimuli-sensitive, which means that environmental stimuli i.e., pH, composition of solvents, light and temperature enable the reversible changes in the properties and shapes of the hydrogels.[5] It was found that the presence of various functional groups including the hydrophilic groups attached to the polymeric chains can also affect the properties of natural polymer-based hydrogels.[6]

The degree of cross-linking affected the level of equilibrium swelling of hydrogels while cross-linking with higher molecular weight elements increased the tendency of the hydrogels to resist mechanical deformation.[7] Mechanical properties of hydrogels were generally found to be increased through chemical cross-linking of cellulose from sodium hydroxide (NaOH)/urea solutions using epichlorohydrin (ECH), which is a common cross-linking agent used for polysaccharides.[8] Cellulose-based hydrogels can be fabricated using ECH cross-linker by different methods including heating the mixtures for 20 h at 50°C followed by freezing for 20 h at –20°C.[9]

However, the fabrication of hydrogels usually involves repeated cycles of the freeze-thawing process.[10] In this study, the time to fabricate the cellulose/carboxymethyl cellulose (CMC)/polyvinyl alcohol (PVA) hydrogels was significantly shortened as the freeze-thawing process was only performed in one cycle. Besides that, the use of reused papers which are abundantly produced, as raw materials to prepare the cellulose can also reduce wastage and increase the efficiency of wastepaper management especially in Malaysia. Two plasticisers namely PVA and glycerol were also used to compare the resultant hydrogels' properties in terms of swelling and morphology.