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INFLUENCE OF RICE STRAW-BASED POLYOLS ON THE MORPHOLOGY, THERMAL AND SPECTRAL PROPERTIES OF POLYURETHANE FOAMS

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ABSTRACT

The influence of utilizing rice straw-based polyols on the morphology, thermal and spectral properties of polyurethane foam is reported. Utilization of rice straw as raw material was done through liquefaction process using ethylene glycol as solvent. It was found out that 30% replacement of rice straw-based polyols produced closed cell structures suitable for insulation material as revealed in Scanning electron microscope images. Higher percentage of rice straw-based polyols replacement will trigger cell wall structure rapturing that will deteriorate the properties of polyurethane foam.

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Furthermore, Fourier transform infrared spectroscopy confirmed the complete reaction of the hydroxyl and isocyanate groups takes place suggesting that high quality polyurethane foam was formed. Moreover, thermo-gravimetric analysis revealed that hard and soft segments degradation for the 30% rice straw-based polyols replacement is comparable with that of the petroleum-based polyols suggesting that bio-based polyols is a good alternative for the formation of polyurethane foams.

Keywords: Polyurethane; Bio-based polyol; Rice straw; Lignocellulosic biomass

1. INTRODUCTION

Polyurethane foams are known to have a low thermal conductivity and is widely used as insulation materials. The main components in producing polyurethane foams are isocyanate and polyols that are mainly derived from petroleum feedstock [1]. Polyols are the source of the hydroxyl functional groups. Nowadays, renewable resources in the production of polyurethane foams have gained intensive research in polymer industry due to the low cost of polyols source. This led to the development of biomass resources as an alternative replacement to petroleum-based polyols. Many studies demonstrated that the produced polyurethane foams from bio-based polyols are comparable to those petroleum-based polyols in terms of its compressive strength, mechanical and thermal properties [2][3][4].

Previous work fabricated polyurethane foam (PUF) from castor oil using waste glycerol [5]. There was also previous work that utilized coffee grounds as the source of lignocellulosic-based polyols for the production of viscoelastic bio-based polyurethane foams [6]. Moreover, vegetable oil-based polyols were also used to substitute polyols from petroleum feedstock and successfully incorporated in PUF production [7]. On the other hand, there was also a study that utilized corn stover as a raw material in producing bio-based polyols in synthesizing PUF [8]. It was found out that the produced polyurethane foams are comparable to those derived from petroleum-based polyols. The accessibility of utilizing bio-based polyols is better because it is renewable and have low production cost.

There are two major types in biomass. These are vegetable and lignocellulosic biomass. However, the use of vegetable biomass may compete with the industries in food and biodiesel production. This makes lignocellulosic biomass a good candidate for the bio-based polyol resources. Lignocellulosic biomass is composed of cellulose (30-35%), hemicelluloses (15-35%) and lignin (20-35%) [9]. The component of lignocellulosic biomass is highly functionalized with rich in hydroxyl groups that make them a promising material for the production of bio-based polyols for the synthesis of polyurethane foams. However, lignocellulosic biomass needs to be liquefied before it can be used to synthesize PUF. One of the alternative sources of lignocellulosic materials is rice straw. Previous work utilized rice straw as filler material in the production of PUF [10]. There was no reported study that utilized liquefied rice straw as replacement for petroleum-based polyols in the production of PUF. In this work, liquefied rice straw is utilized as replacement to petroleum-based polyols in the production of PUF. Moreover, the influence of rice straw-based polyols in the morphology, thermal and spectral properties of polyurethane foam is investigated.

MATERIALS AND METHODS

Materials. A-side and B-side are the two reaction sides in producing PUF. The A-side material includes the polymeric

isocyanate (NCO) groups. The B-side consists of blowing agent, blowing catalyst, gelation catalyst, surfactant and polyols. The polymeric MDI was purchased from Olympus marketing while VORANOL™490 was used as the source of petroleum-based polyols. While the blowing catalyst (Polycat 5), gelation catalyst (Polycat 8) and surfactant (DABCO DC 3203) were obtained from the Dow chemical. The rice straw-based polyols were produced using liquefaction process. Distilled water was used as the blowing agent.

Preparation of PU foams, PU foaming procedure and Charaterizations.

Rice straw was liquefied via atmospheric liquefaction process using pre-treated rice straw to produce polyols as a replacement to the petroleum-based polyols using ethylene glycol as solvent and sulfuric acid as catalyst. Different amount of rice straw-based polyols was used as replacement to petroleum-based polyols.

Figure 1 shows the PU foaming procedure. The B-side and A-side were weighed and were hand mixed for 10-15 seconds to achieve a homogeneous mixture. The mixture was allowed to rise freely overnight at room temperature. The synthesized PUF was cut for characterization using scanning electron microscope (JEOL JSM-6510LA), Fourier Transform Infrared (Perkin Elmer Spectrum 100) and Thermo-gravimetric analysis (Shimadzu DTG-60H).

2. RESULTS AND DISCUSSION

Figure 2 shows the scanning electron microscope images of the fabricated polyurethane foams with different concentration of rice straw-based polyols. As expected, it is observed that well-defined closed cell structures were formed for the petroleum-based polyols as shown in Fig. 2(a). On the other hand, Fig. 2(b) was formed using 30% rice straw-based polyols as replacement to petroleum-based polyols. It is revealed that closed cell structures were formed in the fabricated polyurethane foam similar to that of petroleum-based polyols. Furthermore, increasing the concentration of rice straw-based polyols replacement to 50% and 100% will eventually rapture the cell wall structures suggesting that deterioration of polyurethane foam properties are expected. This finding on the drastic change in cell wall morphology was similar to the previously reported work using rice straw as reinforcement to the rigid polyurethane foam [11]. This phenomenon may be triggered by the unequal ratio of hydroxyl groups and isocyanate that is necessary to produce a well-defined closed cell structures which will exhibit properties of high quality polyurethane foams. It is expected that isocyanate groups and hydroxyl groups will have a stoichiometry of unity.

In order to determine the effect of rice straw-based polyols on the spectral response of the produced polyurethane foams, FTIR spectroscopy was carried out. Figure 3 shows the FTIR spectra of the petroleum-based polyols as well as the different amount of replacement using rice straw-based polyols in the formation of polyurethane foam. The rice straw-based polyols significantly increases the O-H and N-H vibrational modes around 3300 cm-1. This suggests that an increase in number of hydroxyl groups is expected because of the higher amount of rice straw-based polyols replacement. On the other hand, the isocyanate group (N-C-O) vibrational mode around 2280 cm-1 drastically decreases when the amount of rice straw-based polyols replacement increases. As the replacement of rice straw-based polyols reaches to 100%, the asymmetric stretching coming from isocyanate (around 2280 cm-1) vanishes. This phenomenon leads the stoichiometry ratio of isocyanate groups and hydroxyl groups far from unity [12]. It is believed that stoichiometry ratio far from unity will trigger raptures on the cell wall structure which are observed in Figure 2(c) and 2(d). As a result, deterioration of polyurethane foams properties are also expected.

The TGA spectra of the produced polyurethane foams with petroleum-based polyols and different amount of rice straw-based polyols replacement are shown in Figure 4. It can be observed that the soft and hard segments degradation is present. The hard degradation (200°C-340 °C) corresponds to the urethane bonds. The soft segment (370°C-590°C) corresponds to 30% rice straw-based polyols replacement as well as the petroleum based polyols is comparable suggesting that the quality of the produced polyurethane foams is similar. On the other hand, as the amount of rice straw-based polyols replacement increases, the segments were broken into several stages. Suggesting that deterioration of thermal properties occurred that will influence the properties of the produced polyurethane foams.

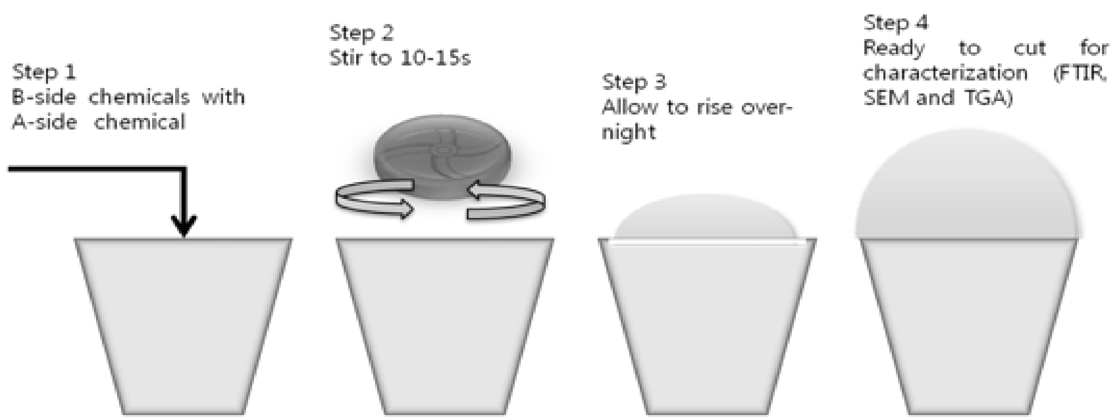

Fig.1. Procedure in synthesizing PU foam

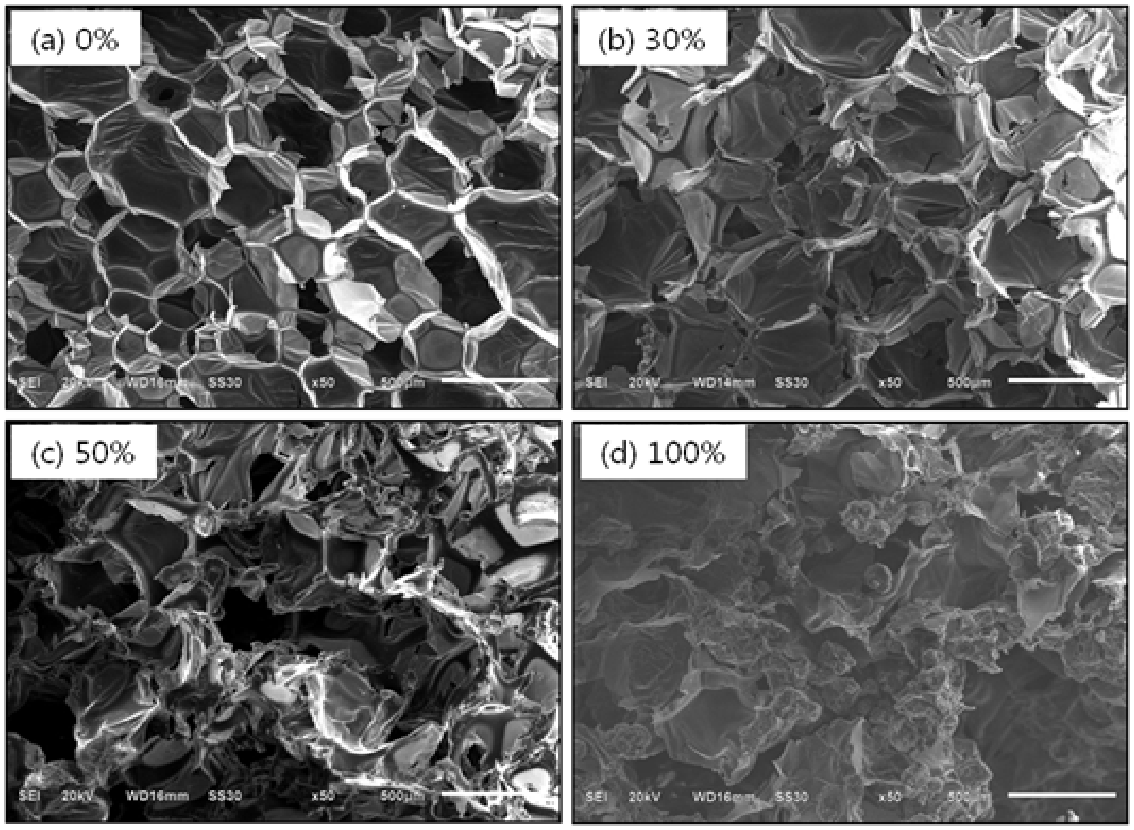

Fig.2. Scanning electron microscopy images of the produced polyurethane foams with a) 0% (petroleum-based polyols), b) 30%, c) 50% and d) 100% rice straw-based polyols replacement

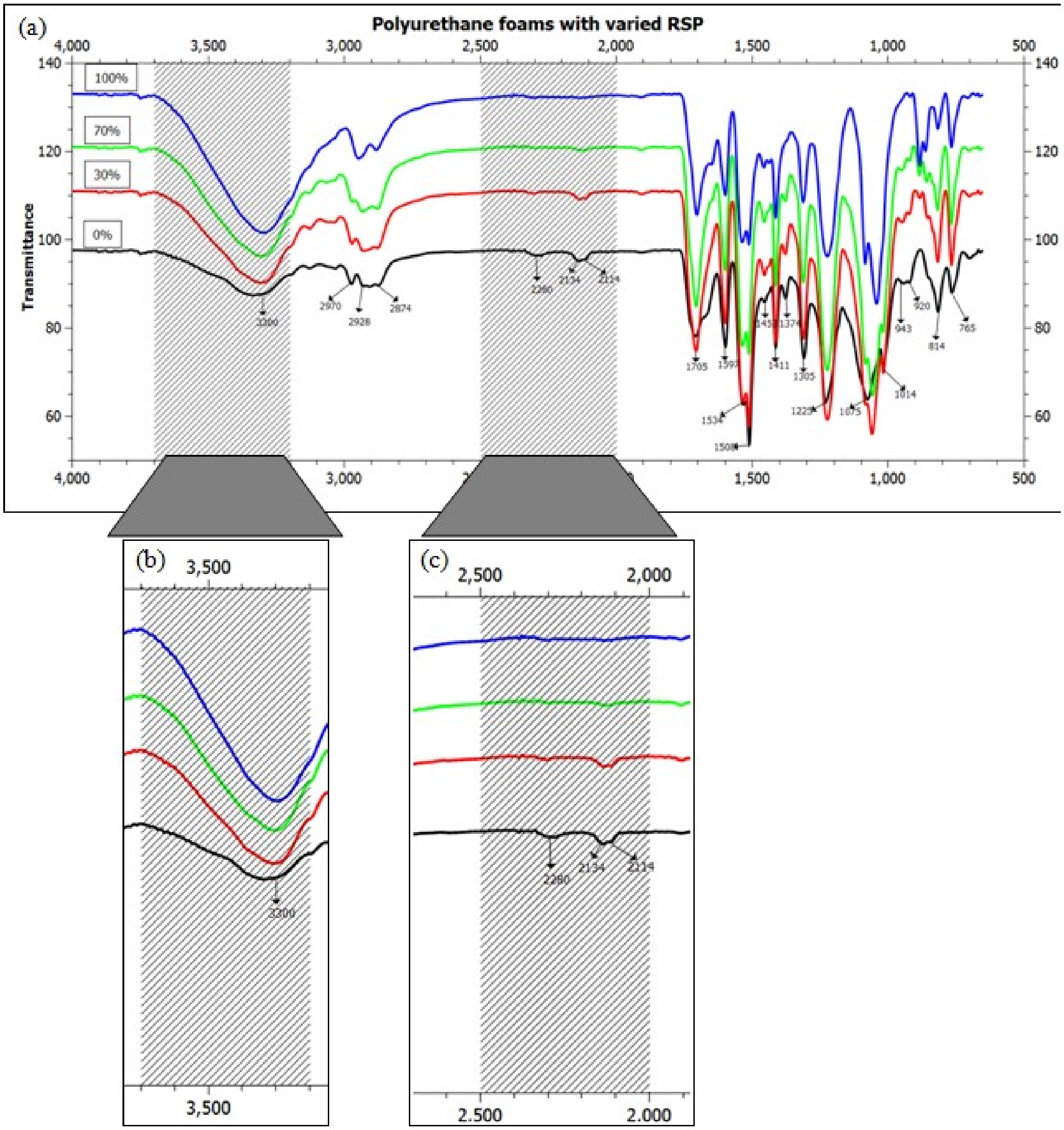

Fig.3. Over-all FTIR spectra of the PUF with varied amount of rice straw-based polyols (0%, 30%, 50% and 100%) replacement (b) in the region between 3100-3700 cm^{-1} and between 2000-2500 cm^{-1} (c).

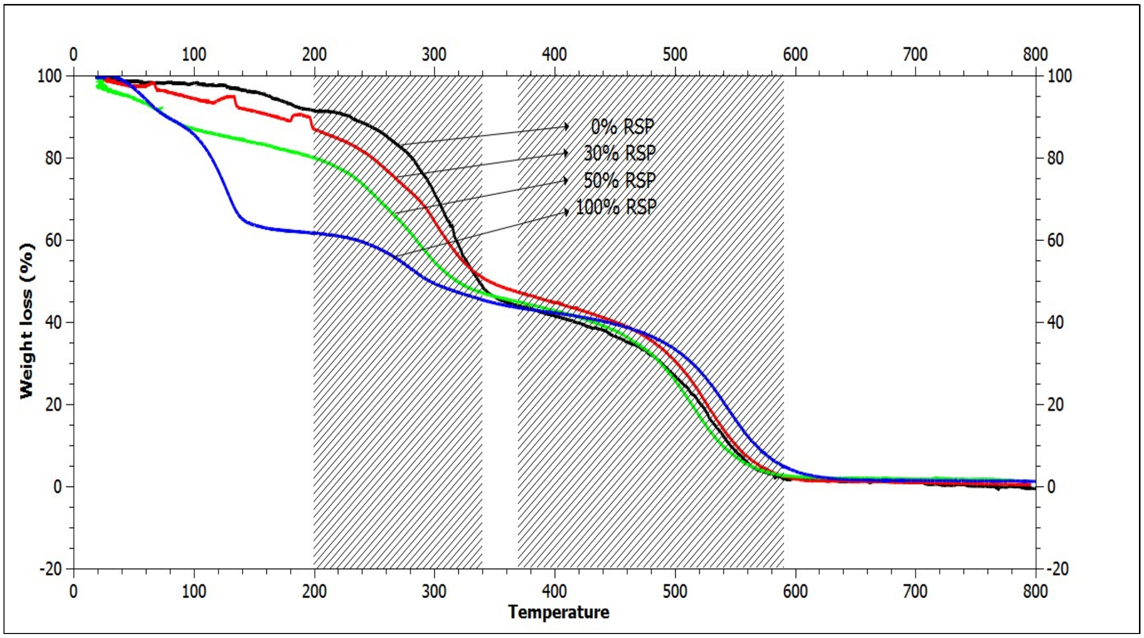

Fig.4. Thermo- gravimetric spectra of the polyurethane foams with varied amount of rice straw-based polyols (0%, 30%, 50% and 100%) replacement

3. CONCLUSION

Polyurethane foams with different amount of rice straw-based polyols replacement as well as the petroleum-based polyols are reported. It was revealed that using 30% rice straw-based polyol replacement exhibit similar morphology, thermal and spectral properties with that polyurethane foam produced using petroleum-based polyols. The utilization of bio-based polyols extracted from rice straw is a promising route towards the realization of renewable source in the production of polyurethane foams.

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