The effect of fibre loading on characterization and mechanical properties of polyurethane foam composites derived waste cooking oil, polyol and toluene diisocyanate with adding filler sugar palm (Arenga pinnata) fibre

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Abstract. In the study, sugar palm (Arenga pinnata) fibre reinforced polyurethane foam was prepared by compounding waste cooking oil, polyol and toluene diisocyanate. The composites foam were prepared with different fibre loading: 10%, 20%, 30% and 40% (by weight), with the process conditions: ambient temperature, 1 min stirring and fast stirring. Four samples were cut from polyurethane foam composite and tested according to ASTM standard. Effect of fibre loading on mechanical included tensile strength, FT-IR, and SEM. From the analysis, highest condition of polyurethane foam composites tensile strength was 0.978 MPa.

1. Introduction
The growing global has had many food industries and it has resulted a lot of waste cooking oil especially. That case we need another alternative to reduce it. One of them is using waste cooking oil to make polyurethane foam composites [1]. The polyurethane can be produced through the reaction of hydroxyl group and isocyanate group. Hydroxyl group are found in polyol from vegetable oils such as castor oil [2], soybean oil [3], mahua oil [4] and heavy oil modified [5]. Waste cooking oil contains Poly Ethylene Terephthalate (PET) compounds which can produce polyol [6]. It means oil can use to polyurethane synthesis, like waste cooking oil can be source polyol too. Polyol is an alcohol compound which has more than one -OH groups and is used as a raw material in the production of polyurethane [6]. Polyurethane based wasted cooking oil has been considered as one of the most promising one due to its easy availability and bio degradability [1]. Bio-composite material made from natural fibre-polymer composite became highly attractive material. These fibres have many advantages compared to glass fibre, such as low cost and they are recyclable and biodegradable. Sugar palm (Arenga pinnata) fibre is one of them. Sugar palm (Arenga pinnata) fibre was changed because the character of sugar palm fibre such as hard, durable and difficult or digest organism. Additional isocyanate groups of polyurethane can react with the hydroxyl groups on fibre surface to produce a cross-link, improving the interfacial adhesion between the fibre and the matrix [7].
The polymerisation of polyurethane is made through reaction isocyanate and hydroxyl. The polyaddition reaction is a step-growth process and its individual stages are irreversible. The last step can produce urethane (NHCOO). Addition process is very fast because the effect of group –OH and –NH–COO– (the effects of solvents) [8].

2. Experimental

2.1. Materials
The material that used in this research were waste cooking oil from Giant Fried Chicken at Jalan A. H. Nasution (Medan, Indonesia), polyol FF 7119-2 and toluene diisocyanate from CV. Indo Jaya on Belawan (Medan, Indonesia) and sugar palm fibre from merchant on Binjai (Medan, Indonesia).

2.2. Method

2.2.1. Preparation of Sugar Palm Fibre. Sugar palm fibres were washed from the dust and dried by sunlight for 10 hours. Sugar palm fibre crushed into powder in advance by using a ball mill for 5-7 hours and sieved to produce a particle size of 100 mesh.

2.2.2. Preparation of Source Polyol. Waste cooking oil were filtered from fat and leftovers. Then, Waste cooking oil and polyol were mixed with condition: slowly mixed, 80 °C, 2-3 mins, 3 : 7 (by weight) until unite.

2.2.3. Preparation of Polyurethane Foam Composite. Source polyol and toluene diisocyanate were mixed with condition: ambient temperature, fast stirring, 1min, 1 : 1 (by weight). Adding powder of sugar palm fibre with different fibre loading: 10%, 20%, 30% and 40% (by weight) and mixed fastly. The products were poured into moulds.

2.3. Characterization of Polyurethane Composites

2.3.1. Fourier Transform Infra Red (FTIR). Analysing of FTIR was observed at Research Laboratory, Faculty of Pharmacy, University of Sumatera Utara.

2.3.2. Mechanical Properties. The product composites were cut and tested according to ASTM : D 3039 (tensile strength).

2.3.3. Scanning Electron Microscope (SEM). Analysing of SEM was observed at Physics Laboratory, Faculty of Mathematics and Natural Sciences, University of Negeri Medan.

3. Results and Discussion

3.1. Fourier Transform Infra Red (FTIR)
The FTIR spectrum of sugar palm fibre, polyurethane and polyurethane composite, shown in Figure 1. Sugar palm fibre is typical of lignocellulosic material. A strong and broad absorption band at 3414 cm⁻¹ was assigned to the vibration stretching of the hydroxyl group [7]. The absorption band at 2897 cm⁻¹ can attributed to C–H stretching of methyl and methylene groups. The band at 1712 cm⁻¹ was found the stretching of C═O group and 1604 cm⁻¹ can be ascribed to vibrational stretching of C═C conjugation, mainly due to hemicellulose and lignin, respectively [7] [9]. In addition, absorption at 1246 cm⁻¹ assigned to C–O stretching of acetyl groups in hemicellulose and lignin too [7].
The FTIR analysis results of sugar palm fibre, polyurethane (PU) and polyurethane composite are shown in Figure 1. It reveals a stretching of band at 3402 cm\(^{-1}\), characteristic of the valence vibration of the N–H bond in urethane groups, accompanied with a shift from 3402 to 3378 cm\(^{-1}\) with 30% sugar palm fibre loading. The result of figure 1 indicates the presence of hydrogen bonds between N–H bond of the matrix and O–H groups of cellulose in fibre as well as a reinforcement of the valence vibration band of the C═O bound, located at 1743 cm\(^{-1}\), with fibre loading [9]. Around 1743 cm\(^{-1}\) was assigned to the vibration stretching of amide I band in the urethane pre-polymer. The combination of N–H deformation and C–N stretching vibration of amide II occurred at 1465 and 1469 cm\(^{-1}\) for PU and PU composites, respectively [7] [9]. The absorption band at 2279 cm\(^{-1}\) can be attributed to free isocyanate groups (N═C═O), confirmed that there is excess of NCO- terminated group in the polymer backbone. However, the composite FTIR spectra shows clear signs of bonding between urethane polymer and the sugar palm fibre [7]. This phenomenon suggests an increase in hydrogen bonds between C═O in urethane groups and O–H groups of cellulose in fibre. All these results converge to existence of hydrogen between matrix and reinforcement, as already reported by author [9].

3.2. Tensile Strength
The effect of fibre loading of polyurethane composites on the tensile strength are shown in Figure 2. The result of tensile strength is increasing with increase in fibre loading. In Figure 1, tensile strength is first decrease at 0% to 10% sugar palm fibre loading with 0,403 MPa to 0,298 MPa. These phenomena can be explained that at 10% sugar palm fibre loading, the dissipation energy not enough for participating in the stress transfer [10]. Increase at 20% and maximum at 30% sugar palm fibre loading with 0,423 MPa and 0,978 MPa. This indicates that between fibre and matrix have the good interfacial bonding [7]. Tensile strength increases with increasing fibre loading of sugar palm fibre [11]. The load can be transferred effectively from the matrix to fibres. This requires good interaction as well as adhesion between the matrix and the fibre [12]. And then tensile strength decreases at 40% sugar palm fibre loading with 0,621 MPa. This can be shown the presence of void and agglomeration between the fibres and the matrix [7] [10].
3.3. Scanning Electron Microscope (SEM)

The purpose of the SEM analysis was to observe the morphology of polyurethane composite. The sample test is polyurethane with 30% fibre loading.

![SEM images of fracture pure polyurethane and polyurethane composite with 30% fibre loading](image)

**Figure 3. SEM of fracture pure polyurethane (a) and polyurethane composite with 30% fibre loading of sugar palm fibre (b)**

Scanning electron microscopy of fractured pure polyurethane and polyurethane composites samples using a magnification of 100x are presented in Figure 3. When we compared differences in the structure of fracture pure polyurethane in Figure 3 (a) and in the structure of fracture polyurethane composites in Figure 3 (b), it can be seen that polyurethane composite in Figure 3 (b), filler sugar palm fibre has denser and compact structure because the sugar palm fibre as a filler has been distributed homogeneously and have foam spaces in the polyurethane composite, thus it is increasing the mechanical properties of polyurethane. From Figure 3 (a) could be seen fracture pure polyurethane without filler has also foam and more than polyurethane composite. Figure 3 (b) can be observed that the fibres are adhered to the matrix. It shows SEM for fracture of tensile strength specimen for 30% fibre loading composites. It can be noticed that there is a good fibre matrix/matrix adhesion as no fibre pull outs or gaps appear between fibre and matrix. Homogeneity structure of polyurethane composites is a good interfacial bonding between fibres and matrix, that can indicate improvements in the value of the mechanical properties of the polyurethane composites [7]. Polyurethane is a polymer produced from a mixture of a polyol source with an isocyanate group forming a urethane bond. Isocyanate is highly reactive, so when mixed with polyol will result in spontaneous reaction of polymerization. It is important to remember that the polyurethane reaction can run spontaneously with the help of stirring.
This supports the results of this research that an increase in tensile strength of polyurethane composite caused by the fibre loading which has been distributed homogeneously.

4. Conclusion
Polyurethane composites have showed increasing trend in tensile strength, the highest value is 30% fibre loading. From analysing of FTIR could be seen that functional group of polyurethane and polyurethane composites has similarity with its constituent components. From analysing SEM shows also that there is a good adhesion between fibres and matrix.

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