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Effect of Additional Natural Filler Waste on The Mechanical Properties of Polyurethane Polymer

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ABSTRACT

The mechanical properties of polyurethane/conocarpus leaf composites were studied. The conocarpus leaf powder was mixed with 0-55% of polyurethane. The best ratio was obtained when using 45-55%. The obvious improvement in the mechanical parameters was recorded when adding conocarpus leaf powder with 55% of polyurethane. The properties of polyurethane/conocarpus leaf composites were analyzed as a function of the additional ash amount. All prepared composites showed improved ash dispersion in the polyurethane matrix. The highest value of the compressive strength was when the ratio of 45%, reaching 9.82 MPa. This is because of this homogeneity rate between conocarpus leaf powder and chains of the polymer. The lowest value was obtained, reaching 3.3 MPa when using 30%.

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1. INTRODUCTION

The mechanical characteristics of polymeric materials are crucial for almost all industrial, technological, and domestic uses. In many applications, stiffness, strength, and toughness are particularly important qualities. The chemical composition and the supermolecular structure of the polymeric material both have a significant impact on mechanical qualities. The linear region, the yield region, and the elongation region up to the break make up the first two regions of the stress-strain curve for the polymeric material. Hook's law, which describes the immediate and recoverable deformation associated with the bending and stretching of the interatomic bonds between the polymer atoms, was obeyed in the first region, a linear region where the deformation was not particularly great. Additionally, molecules are not consistently displaced concerning one another. The linear zone can serve as a representation of the polymer's elastic limit region, where uniform extension results from the stress that is growing at a consistent pace. While some fundamental features like rigidity, thermal softening, and melting behavior are defined by the chemical molecular structure, the final mechanical properties are established by the supermolecular structures or morphology. Depending on variables such as orientation owing to manufacture, various cooling rates, variations in thermal history, and secondary crystallization, the same molecular structure can produce a wide range of morphologies. The interface attraction between the filler and the polymer is typically used to predict how well-filled polymers behave. Including fillers made of inorganic minerals (Sreekanth *et al*., 2009). Solids called fillers are added to polymers to enhance their qualities and lower the price. They reduce the softer polymer, which has the opposite effect of plasticizers. They are referred to as organic or inorganic additives added to the polymer with the intention of either increasing material volume, which lowers cost, or maybe improving certain mechanical qualities (Hamadi *et al*., 2011; Said & Companion, 2011). The properties of the base materials can be changed quickly and affordably by adding fillers to polymers. Because of this, both industry and research are becoming increasingly interested in particulate-filled polymers. This allows for the customization of a variety of qualities, including strength, stiffness, electrical and thermal conductivity, hardness, and dimensional stability (Luyt & Geethamma, 2007). Some researchers focused on polyurethane (PU) that had been modified utilizing cheap local fillers. The findings show that the mechanical characteristics of polyurethane are significantly changed by the addition of ash powder. The mixture's estimated hardness, which is 3.78 MPa, was best measured at a ratio of 60% of the powder additive, while the elasticity of the polymer was best measured at a ratio of 0%. Furthermore, at a ratio of 60%, the highest value of Young's modulus (1.71) MPa) was discovered. In addition to being utilized for pipes, tubes, window frames, and packaging film, HDPE composites are also used as materials in the automotive sector (Mičušík *et al*., 2006; Mareri *et al*., 1998; Osman *et al*., 2004; Pukánszky & Vörös, 1996). According to the findings of this study by Atiqah *et al.* (2018) the composites now have better mechanical and thermal properties. The optimal tensile strength, flexural strength, and impact strength values for the composite formulation with 40% of sugar palm fiber loading were 17.22 MPa, 13.96 MPa, and 15.47 kJ/m2, respectively. The purpose of this investigation is to determine how adding conocarpus leaf ash affects the mechanical characteristics of polyurethane.

2. EXPERIMENTAL METHOD

2.1. Material basis in this study

This investigation's base substance was polyurethane. The reaction between the two substances (polyol and isocyanate) occurs when they are both liquids. As a result, a gas called

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carbon dioxide is generated. This gas helps to create cellular gaps inside the bulk of the combination. A so-called frothy liquid emulsion is created as a result of the mixing process, and it reacts to the gas. The chemical reaction depicted in **Figure 1** produces polyurethane, which is then used to create insulating materials.

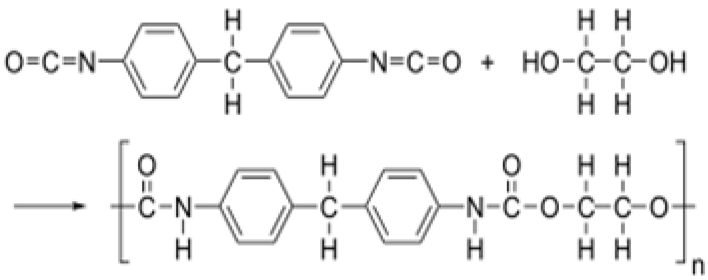

Figure 1. Chemical composition of polyurethane (Akindoyo *et al*., 2016).

2.2. Fillers

In this research, Conocarpus leaf waste was used as filler, with polyurethane as a natural organic filler (Atiqah *et al*., 2018). The Conocarpus leaf was cut into little pieces, and then ground by grinding machine electrical to powder, and then treated the Conocarpus leaf powder by using the analyzer and sieve from the type (Allen-Bradley Sonic Sifter Model L3P), provided by the (ATM Corp. American company) equal to (150) µm. The conocarpus leaf powder is shown in **Figure 2**.

Figure 2. Photograph of the Conocarpus leaf powder waste.

2.3. The preparation of composites

By adding several weight ratios (i.e. 30, 35, 45, and 55%) of Conocarpus leaf powder to the polyurethane mixture during the polymerization procedures, the samples of polyurethane with Conocarpus leaf powder were created. Until the mixture was homogeneous, the mixing operation was maintained. The finished product was then put into a slab mold with a cylindrical shape. The measurements of the cylindrical form samples for stress are 3 cm in

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length and 1 cm in diameter, and the dimensions of the rectangle form samples for tensile and bending strength are 11 cm in length, 1 cm in width, and 2.4 mm in thickness (see **Figure 3**). **Table 1** shows the weight ratio of the Conocarpus leaf powder and polyurethane.

Table 1. The weight ratio of the Conocarpus leaf powder and polyurethane.

Note	Sample				
	1	**2**	**3**	**4**	**5**
Conocarpus leaf powder (%)	0	30	35	45	55
Polyurethane (%)	100	70	65	55	45

2.4. Mechanical testing

The following resources were used to evaluate the samples produced for this study. The models' tensile strength, bending resistance, and compression resistance were tested using (Zwick Rell (2.5 KN)) machine that was made in Germany. **Figure 4** shows the machine used to measure the mechanical specimens, and equation (1) is utilized to determine the tensile strength (Ghali *et al*., 2011; Patnaik *et al*., 2010).

$$Q = F / A \ (N / mm^2) \quad (1)$$

where A is the cross-sectional area (mm^2), and F is the cutting force (N).

The Young modulus was calculated using the stress-strain graphs and the following equation (2):

$$Y = (Ơ\mu / \varepsilon\mu) \ (Mpa) \quad (2)$$

where *Y* is the Young modulus (MPa), *Ơμ* is the max stress (MPa), and *εμ* is the max elongation (%).

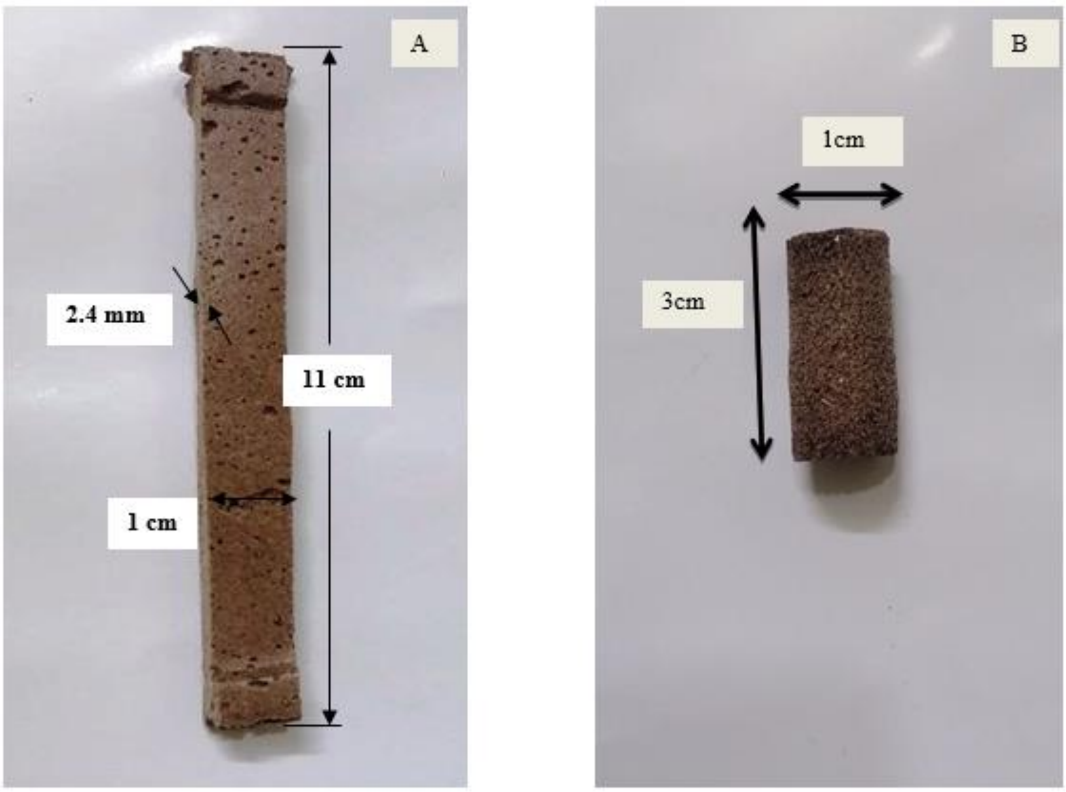

Figure 3. (a) the rectangular sample, (b) the cylindrical slab sample.

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3. RESULTS AND DISCUSSION

Figure 4 indicates the relationship between stress and filler content. The behavior of the mixture begins with a high effect at the ratio of 0% which is 2.86 MPa. Then, the behavior of the mixture decreases when the weight percentages of the fillers are added, especially at the ratio of 35% with a strength of 1.04 MPa. The polymer at this ratio has high flexibility and low strength, which is due to the fillers that weaken the chains of polymeric as a result of the inhomogeneity limiting the strength. Therefore, the mixture at this ratio is fragile. The maximum strength of the mixture was recorded. It is 2.73 MPa at 45%. Fillings at this ratio fill the polymer chains and limit their movement. Thus, the mixture is homogeneous and strong (Hamadi *et al*., 2012).

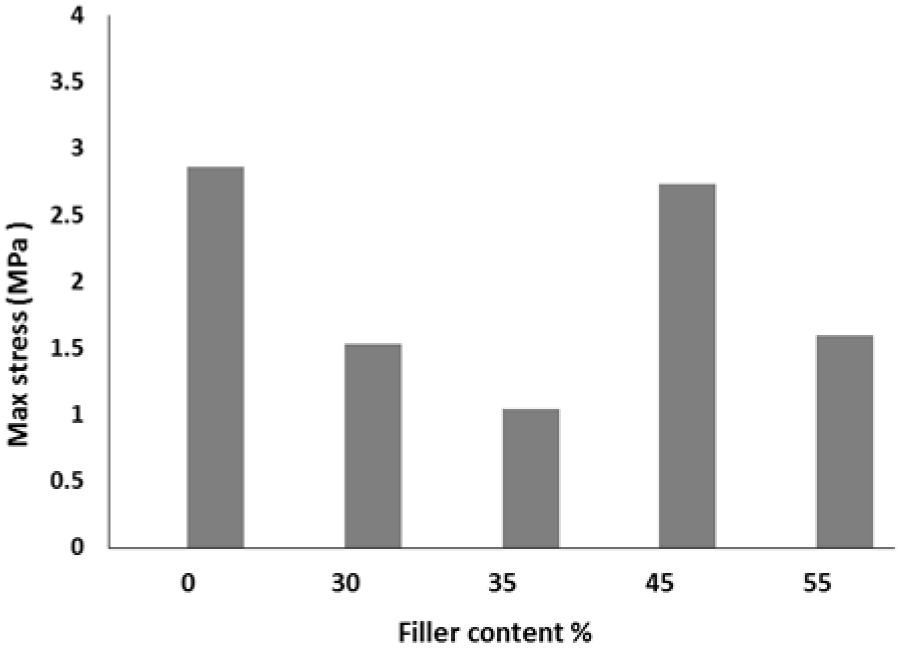

Figure 4. The relation between stress and the filler content.

Figure 5 indicates the relationship between compressive strength and filler content. The behavior of the polymer with fillers begins with a very weak effect at the ratio of 0%, reaching a value of 1.08 MPa, then the polymer behavior increases when adding the weight percentages of the fillers, especially at the ratio of 45%, which is 9.82 MPa. The polymer at this ratio has weak elasticity and high strength, due to the fillers that fill the chains of polymer, as a result of the high homogeneity between the polymer and the fillers, which limits the movement of the polymeric chains. After that, the behavior of the mixture decreases when the weight ratios of the fillers are increased to arrive at the strength of 8.99 MPa at a ratio of 55%. The fillers weaken the polymer at this percentage.

Figure 6 shows the relationship between the bending resistance and filler content, where the ratio (0%) shows resistance to bending of 12.6 MPa, i.e., the polymer at this ratio has weak elasticity and high hardness, compared to the ratios of 30, 35, and 45%. As the ratios of additives increased (especially at the ratio of 55%), the maximum bending resistance was 9.04 MPa. At the ratio of 55%, the presence of fillers between the chains of polymer restricts chain movements, in which high harmony between the polymer chains with filler occurs, which results in lower flexibility - higher strength (Karaman, 2021).

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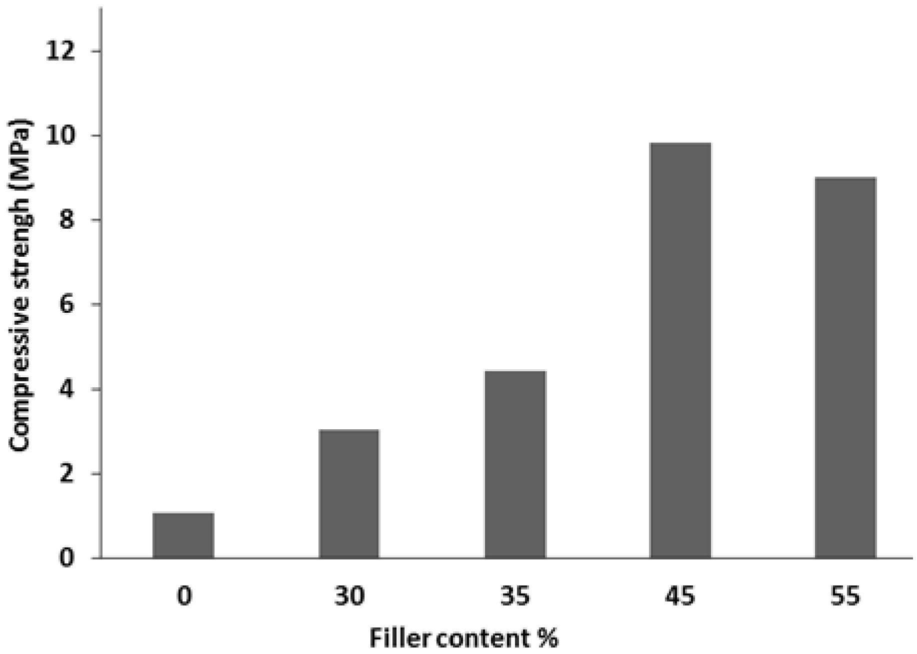

Figure 5. The relation between compressive strength and filler content.

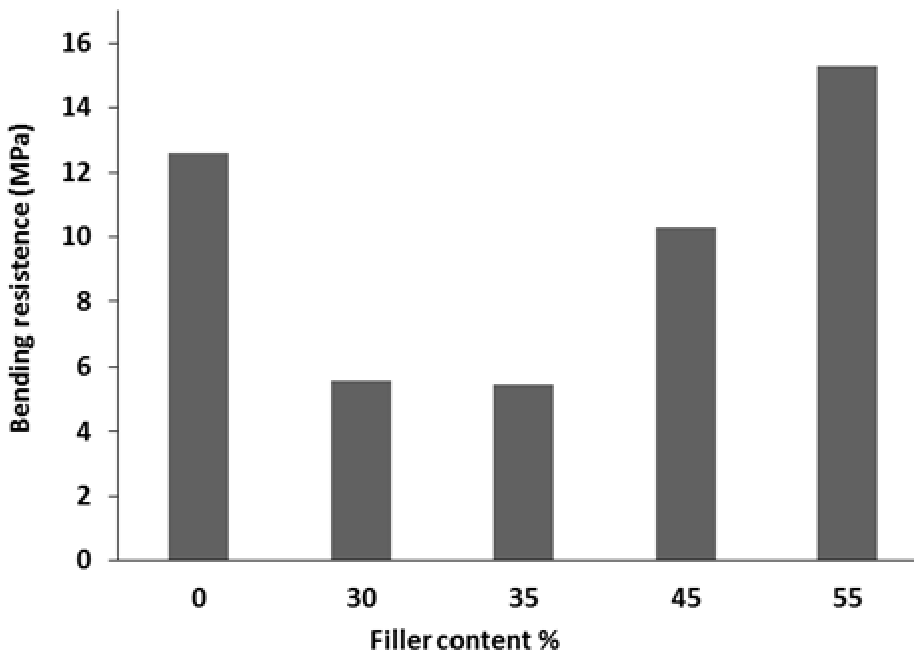

Figure 6. The relation between the bending resistance and the filler content.

4. CONCLUSION

Natural fillers, such as waste conocarpus leaf powder, can be incorporated in the form of fillers whose concentration affects the mechanical qualities. The functional groups have an impact on the mechanical characteristics, and Conocarpus leaf powder can enhance the mechanical properties and boost strength by tightening the bond between the functional filler groups and the polymer. With a concentration of 45–55%, the filler utilized in this study produces the greatest results in terms of mechanical qualities (stress-strain). Due to the type of interaction between the polymer chains, modifying the ratio of conocarpus leaf powder

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addition undoubtedly had a significant impact on mechanical parameters such stress-strain, toughness, and elongation.

5. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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