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RESEARCH ARTICLE

Utilization of Peanut Shells as Sustainable Fillers for Light Weight and Cost-Effective Composite Material

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Abstract

Objectives: To explore the use of natural composites as environmentally-friendly alternatives to plastic. To investigate the effects of varying ratios of peanut shells and Styrene Diluted Unsaturated Polyester resin (SDUPR) on the mechanical properties of the composites and to assess the biodegradability of the composites. **Method:** Composites were prepared using the manual layup method. Utilized varying ratios of peanut shells and SDUPR as: 50:50, 55:45, 60:40, 65:35 and cured the composites with a curing agent. Performed mechanical tests including Izod Impact test, Flexural test, Rockwell Hardness test using standard test ASTM D256, Flexure strength testing and HR-210MR respectively. Evaluated the biodegradability of the composites. **Findings:** The ratio of peanut shells to SDUPR significantly affects the hardness and biodegradability of the composites. Comparisons of the four sheets provide insights into the mechanical properties of each composite and the impact of the ratio of peanut shells and SDUPR. The observed values of Izod impact test are 1.95 J/cm^2, 1.86 J/cm^2, 1.75 J/cm^2, 1.69 J/cm^2 and Rockwell hardness test are 29 kg.mm, 23 kg.mm, 17 kg.mm, 9 kg.mm. **Novelty:** This study explores the use of natural composites made of SDUPR and peanut shells, contributing to the search for environmentally-friendly materials. It provides valuable insights into the potential of natural composites as a sustainable alternative to conventional materials.

Keywords: Biodegradability; Composites; Peanut Shells; Polyester Resin

1 Introduction

Scientists are now concentrating on renewable resources and other low-impact materials to reduce environmental contamination caused by composites with synthetic fillers. One of the ways in utilizing agricultural waste is to create composite materials with natural fibers, commonly known as fiber-reinforced composites. In the sphere of research and development, interest in such bio composites has gained popularity, recently. Natural fibers can significantly enhance thermoplastics and thermosetting, such as wood fibers, agro-based bast, leaf, seed, and stem. In areas without access to wood supplies or as a result of deforestation, rice husk, cotton, jute, bagasse, straw, cobs, sisal, banana, Alfa, coir, bamboo, peanut shells, etc. can be used as substitute of wood[(1,2)] Unsaturated polyesters, a frequent thermoset due to their diverse variety of properties, are used as a polymer matrix in composites. Unsaturated polyester Resin is curable because of a polymerization reaction that results in crosslinking between different linear polymer chains. Since no by-products are produced during the curing reaction, unlike with other thermosetting resins, resin can be molded, cast, and laminated at moderate pressures and temperatures. The reinforcement of polyesters with cellulosic fibres has been widely reported. Polyester–jute, polyester–sisal, polyester–coir, polyester–banana-cotton, polyester–straw, polyester–pineapple leaf and polyester–cotton-kapok are some of the promising systems[(3,4)]. Although natural fibers have a lot of advantages, they also have certain drawbacks and limitations such as an incompatibility with a hydrophobic polymer matrix. To perform such reactions various chemical treatments such as Silane, acetylation and acid treatment are performed[(5)].

The present work of preparing composites of peanut shells with unsaturated polyester resin can have several benefits and applications like Improved mechanical properties, Waste utilization, Lightweight material, Cost-effectiveness, Environmental benefits (Biodegradability) and Thermal insulation. The findings demonstrated that the filler treatments improved the interfacial adhesion between the fibres and matrix, leading to gain in mechanical qualities as well as a decrease in water absorption. Additionally, it was discovered that the tested composites' flexural strength values are higher than the minimal standards for the flexural strength of panels used for common applications. The produced composites are thus great choices for a variety of potential applications. It's important to note that the specific properties and performance of the composite will depend on factors such as the composition ratio of peanut shells to resin, the manufacturing process, and any additional additives or treatments applied.

2 Methodology

In this study, a natural composite of resin was produced using peanut shells as a sustainable filler raw material. The peanut shells were initially crushed and converted into powder form, after which they were mixed with 1% Benzoyl peroxide as a curing agent in a glass beaker.

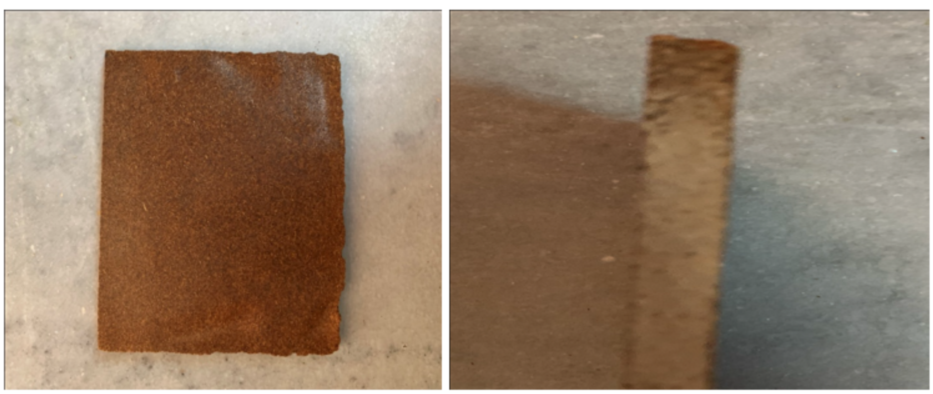

Fig 1. Composite of Peanut Shell and SDUPR

The mixture was thoroughly stirred with a glass rod before adding Styrene Diluted Unsaturated Polyester Resin (SDUPR), and stirring was continued until a homogeneous mixture without any lumps formed. Two iron plates, each measuring 260 mm x 260 mm with a thickness of 12 mm, were chosen. These plates were equipped with four holes at their four corners, and a Teflon sheet measuring 180 mm x 180 mm was placed on each plate. A 9 mm thick laminate was created using the mixture, with a square plate size of 150 mm x 150 mm, which was positioned above the Teflon sheet on one of the iron plates. Another Teflon sheet of the same size was used to cover the laminate, and the second iron plate was placed on top, nuts and bolts were used to tighten all four corners of the plates. The material was then heated in an oven set at a temperature of 100^0C for two and a half hours. Subsequently, the oven was turned off, and the material was left to rest in the oven for 24 hours. After removal from the oven, a natural composite of resin was obtained (Figure 1).

Table 1. Proportion of Peanut Shells and SDUPR

Sr. No.	Particular	PSS-1	PSS-2	PSS-3	PSS-4
1	Amount ofPeanut Shells	100 gm	110 gm	120 gm	130 gm
2	Amount of SDUPR	100 gm	90 gm	80 gm	70 gm
3	Total Weightof Mixture	200 gm	200 gm	200 gm	200 gm
4	Amount ofBenzoyl Peroxide	2 gm	2 gm	2 gm	2 gm
5	Ratio (Peanut Shells: SDUPR)	50: 50	55: 45	60: 40	65: 35

Four different sheets were prepared, with variations in the amount of peanut shells powder and SDUPR (Table 1). However, the proportion of the curing agent (Benzoyl Peroxide) was kept constant, representing 1% of the total weight of the mixture[6–8].

3 Result and Discussion

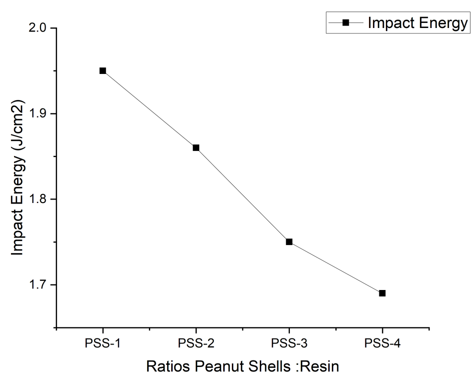

Fig 2. Impact Energy

In the Izod Impact Strength Test, a pivoting arm is raised to a specific height and subsequently released. As the arm moves downwards, it strikes a notched sample causing it to break and the impact angle of the test is fixed at 145°. The impact energy is measured as the energy required to break the sample per unit area and is expressed in J/cm^2. The experimental results show that as the proportion of peanut shells in the sample increases, the impact energy gradually decreases. For instance, the impact energy for the 50:50 mixture is 1.95 J/cm^2, whereas for the mixtures of 55:45, 60:40, and 65:35, the impact energies are 1.86 J/cm^2, 1.75 J/cm^2, and 1.69 J/cm^2, respectively. Figure 2 illustrates the relationship between the proportion of peanut shells and impact energy. The trendline shows a gradual decrease in impact energy as the proportion of peanut shells increases.

The Rockwell scale is a method for quantifying the hardness of a material based on its resistance to indentation. The test involves measuring the depth of penetration of an indenter under a heavy load, compared to the penetration made by a preload. This scale is also applied to measure the hardness of carbides, thin steel, and shallow case-hardened steel. The HrA scale is utilized to determine the hardness of peanut shell sheets, using a preload of 60 kg and unit of hardness is Kg.mm. From Figure 3, it is evident that the hardness of the material gradually decreases as the proportion of peanut shells increases.

The flexural test is a method used to measure the bending strength of a plastic beam and to evaluate the material's stiffness or resistance to bending. The flexural modulus is a measure of the material's ability to bend without undergoing permanent deformation. The key factors that determine a material's flexibility are its Young's modulus of bending and flexural Rigidity. Based on Figure 4, it can be observed that there is a slight decrease in the measured parameter between PSS-1 and PSS-2, a significant decrease between PSS-2 and PSS-3, and a minimal decrease between PSS-3 and PSS-4. According to Figure 5, there is a correlation between the increasing proportion of peanut shells and a continuous decrease in flexural rigidity. This observation suggests that a decrease in resin proportion results in a decrease in both flexibility and flexural rigidity of the material.

In this experiment, a biodegradability test is conducted using four different samples, each with dimensions of 10mm x 15mm. The samples have different ratios of Peanut shells and Resin initiated, which are 50:50, 55:45, 60:40, and 65:35. The samples are pre-weighed before the testing process. To conduct the test, four conical flasks are used, each containing 100 ml of Sabouraud solution. The flasks are inoculated with Aspergillus fungus. Optical Density (O.D.) is measured at 600nm at interval of 24 hours

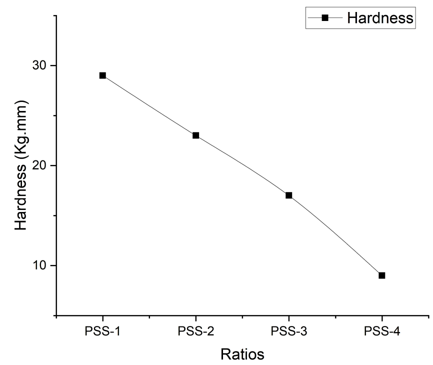

Fig 3. Hardness

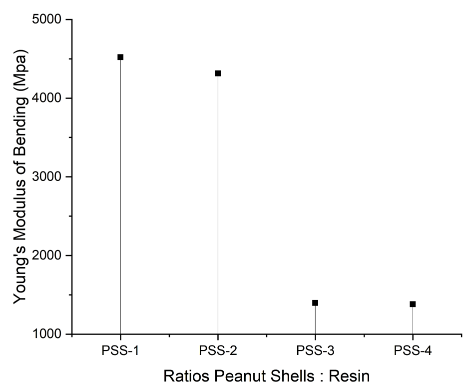

Fig 4. Flexibility

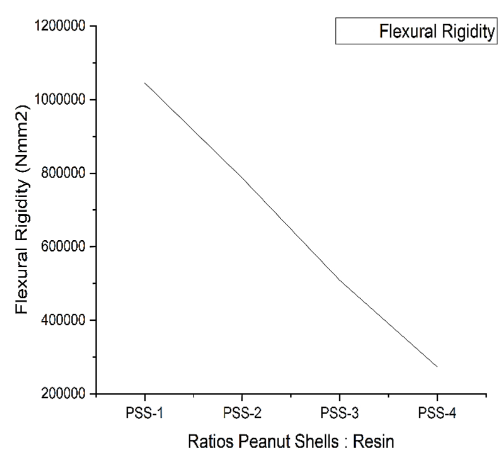

Fig 5. Flexural Rigidity

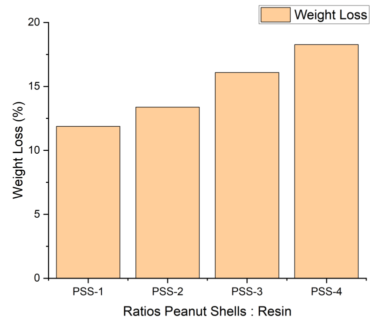

Fig 6. Biodegradability

to track the growth of the fungus and O.D. is measured until the growth of fungus stops. To measure the sugar released, the DNSA method is adopted. After 30 days, all samples are removed and dried properly. Their weights are measured, and the weight loss of each sample is calculated. Figure 6 is used to observe the biodegradability of each sample. The results show that as the proportion of Peanut shells in the samples increases, biodegradability also increases. It is observed that the biodegradability is maximum when the ratio for Peanut shells and Resin is 65:35. This experiment also indicates that when the proportion of Resin is increased, biodegradability decreases.

Fig 7. Izod Impact, Rockwell Hardness, Flexural Strength, Flexural Rigidity, Biodegradability Comparison Test for Rice Husk and Peanut Shells

The provided data presents a comparison between rice husk resin composite and peanut husk resin composite in terms of Izod impact, Rockwell hardness, flexural strength, and biodegradability (Figure 7). Based on the given data, it can be concluded that the peanut husk resin composite performs better than the rice husk resin composite in most aspects, except for biodegradability[6].

4 Conclusion

In the Izod Impact Comparison Test, the impact energy (J/cm^2) of Rice Husk: Resin ratios of 50:50, 55:45, 60:40, and 65:35 was measured and compared with Peanut Shells: Resin ratios. The results showed that the Rice Husk: Resin ratio of 50:50 had an impact energy of 1.75 J/cm^2, while the Peanut Shells: Resin ratio of the same proportion had an impact energy of 1.95 J/cm2, indicating a difference of 11.43%. Similarly, at the ratios of 55:45, 60:40, and 65:35, the Rice Husk: Resin had impact energies of 1.53 J/cm^2, 1.53 J/cm^2, and 1.33 J/cm^2, respectively, while the corresponding Peanut Shells: Resin ratios had impact energies of 1.86 J/cm^2, 1.75 J/cm^2, and 1.69 J/cm^2, representing percentage differences of 21.77%, 14.38%, and 21.05%, respectively. In the Rockwell hardness comparison test, the ratios of rice husk to resin exhibited a hardness range of 24-5 kg/mm, while the ratios of peanut shells to resin showed a range of 29-9 kg/mm. The 50:50 ratio of rice husk to resin resulted in the highest hardness percentage (48%), followed by the 55:45 ratio (36%). The 60:40 ratio yielded a hardness percentage of 20%, while the 65:35 ratio had the lowest hardness percentage (12%). In the flexural strength comparison test, the ratio of rice husk to resin at 50:50 yielded a flexural rigidity of 503,089.76 Nmm^2, while the ratio of peanut shells to resin at the same proportion resulted in a flexural rigidity of 1,045,446.808 Nmm^2. As the ratio shifted to 55:45, the flexural rigidity decreased to 371,191.14 Nmm^2 for rice husk and 786,977.414 Nmm^2 for peanut shells. Further increasing the resin content to 60:40 resulted in a decrease in flexural rigidity to 226,689.9 Nmm^2 for rice husk and 509,118.024 Nmm^2 for peanut shells. Finally, at the ratio of 65:35, the flexural rigidity reduced to 86,135.39 Nmm^2 for rice husk and 273,448.125 Nmm^2 for peanut shells. In the biodegradability comparison test, the weight loss percentages of rice husk-resin composite were observed to be 19.15%, 20.98%, 22.58%, and 23.61% for the ratios of 50:50, 55:45, 60:40, and 65:35, respectively. On the other hand, the weight loss percentages of peanut shell-resin composite were 11.88%, 13.38%, 16.09%, and 18.27% for the same ratios (Figure 7). These results indicate that the rice husk-resin composite exhibited higher biodegradability compared to the peanut shell-resin composite across all ratios tested[6].

Based on the provided data, the peanut shells resin composite outperforms the rice husk resin composite in terms of Izod impact, Rockwell hardness, and flexural strength. The peanut shells composite exhibits higher impact energy, hardness, and flexural strength values, indicating superior mechanical properties. However, the rice husk composite shows better biodegradability with higher weight loss percentages.

Composites made of natural fibers combined with unsaturated polyester resin have gained significant attention in recent years due to their unique properties and environmentally friendly nature[9,10]. Different structures of hybrid polymer composites are used for automobile components, sports, boats, aircraft, office items, equipment, marine and many more industries. In the automobile industry, agro-based thermoset hybrid composites are highly used and composites are also used to prepare doors, windows, different types of furniture, decorative articles etc.[11,12].

Natural fiber composites with unsaturated polyester resin are being increasingly used for manufacturing automotive parts, such as interior trim panels, door panels, seat backs, and parcel shelves. These composites offer excellent mechanical properties, including high strength and stiffness, low weight, and good impact resistance, making them suitable for automotive applications. These composites offer unique properties, such as natural aesthetics, lightweight, and biodegradability, making them attractive for consumer goods applications[13–18].

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