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Research Article

Development of Composite Materials from Phenol Formaldehyde Resins and Evaluation of Their Uses

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***Abstract* –** In this study, the properties, application areas, and use of phenol formaldehyde resins in composite materials have been investigated. The usage areas of phenol formaldehyde resins are getting more and more widespread. Composite materials are being developed by using them together with fibrous biomass sources. Besides, industrial wastes or inorganic fillers are also supplemented with phenol formaldehyde resin. While phenol formaldehyde-based composites are produced, wastes causing environmental pollution are evaluated and some properties of the composites are improved according to the purpose of use. Generally, organic fiber biomass wastes improve the mechanical properties of phenol formaldehyde-based composites. Inorganic industrial wastes also improve both the thermal stability and non-flammability of composites. Reinforcing materials used as fillers interact physically with phenol formaldehyde-based composites. However, biomass sources can also form chemical bonds with some modification processes. To reduce the use of petrochemical components in phenol formaldehyde-based composites, bioraw material syntheses have been carried out. Thus, new generation composites are being developed that are both environmentally friendly and have a low carbon footprint. Moreover, the reinforcement of hard-to-recycle plastics into phenol formaldehyde increases the workability of the composites.

Keywords – Phenol Formaldehyde, Composite Material, Thermal Stability, Mechanical Properties, Biomass Sources

I. INTRODUCTION

Today, phenol formaldehyde resins are widely used in many sectors. Since these resins are petrochemical, they can have negative effects on both the environment and human health. In a study, an environmentally friendly tannin-based phenol formaldehyde resin is used for the production of wood composite. Figure 1 shows the interaction of tannin and phenol formaldehyde. In this study, a new composite is obtained from tannin-based phenol formaldehyde [1].

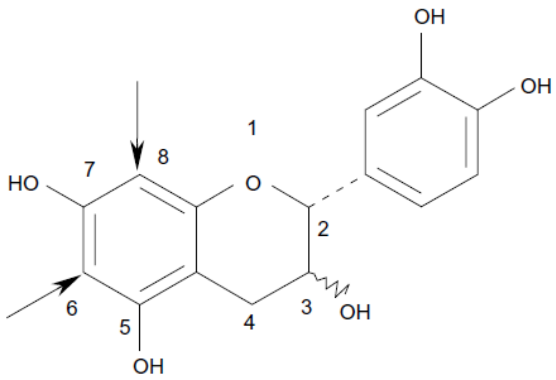

Figure 1. The reaction of tannin and formaldehyde

In another research on biocomposite production, rice husk and reed fiber are used in phenol formaldehyde resin as reinforcement. As a filler, biomass wastes are mixed into phenol formaldehyde after drying and grinding. It has been determined that reed fiber-based biocomposite showed higher mechanical strength than rice husk reinforced composite. In Table 1, the mass ratios of cellulose, hemicellulose, and lignin components in the content of fillers are expressed [2].

Table 1. Components found in reed fiber and rice husk

Components	Reed fiber (%)	Rice husk (%)
Cellulose	50.3	35.6
Hemicellulose	21.7	20.5
Lignin	15.0	16.8

In another study, biocomposite production is carried out from glass fiber reinforced phenol formaldehyde. In this research, glass fiber, phenol formaldehyde, and epoxy resin are used together. According to the results obtained, both the mechanical and electrical properties of three-phase composites are improved. It is envisaged that such composites can be used in complex structural electrical insulation devices and the development of additive manufacturing technology materials [3].

Phenol formaldehyde resins can be used in plywood production, low-temperature coating, and bonding technologies. A study has been conducted on the modification of such resins with various chemical compounds (such as resorcinol, melamine, urea, para-formaldehyde, hydrogen peroxide, dichromate ammonium, potassium, and sodium). For example, in low-temperature pressing, a significant improvement is achieved in high-temperature pressing, without any deterioration in the mechanical properties of the plywood [4].

In addition, silica nanoparticle (SiO_2) reinforced phenol formaldehyde-based nanocomposites are also encountered in the studies. Nanocomposites consisting of SiO2 particles in the resin matrix can easily make a physical interaction. Silica globules can also adhere to the surface of a chemically modified phenol formaldehyde resin substrate containing carboxylic groups in its molecules [5].

Epoxy resin and phenol formaldehyde resin can be used together in different weight ratios. As the epoxy resin ratio in the mixture increases, the mechanical properties of the produced composite improve [6]. Also, phenol formaldehyde can be used as a reinforcement material in carbon fibers in resin. In this way, polymeric wastes that cause environmental pollution are reused and composites with stronger mechanical properties are produced [7].

However, as a result of the widespread use of phenol formaldehyde resin these days, the danger of free phenol has been determined. Free phenol, which is highly toxic, especially in wastewater, is a very dangerous waste for living things. One of the technological solutions for free phenol removal is thermal degradation. However, heat treatment technologies have several disadvantages. For example, such chemicals can negatively affect the atmospheric oxygen and carbon dioxide balance [8].

Especially in recent studies, new biocomposite materials have been developed by reinforcing biomass wastes to phenol formaldehyde resin [9]. Another example is found in lignin-based phenol formaldehyde resins [10].

New industrial needs, environmental requirements, and price fluctuations are driving more research into materials with improved mechanical and thermal properties. Therefore, the use of hybrid composite materials, and organic and inorganic reinforcements provide a better performance of phenol formaldehyde resin [11]. For example, by reinforcing coconut fiber, phenol formaldehyde polymeric resin is strengthened and insulation panels can be developed from multi-layered fibers [12].

Properties such as thermal stability, chemical resistance, non-flammability, and dimensional stability of composites obtained from phenol formaldehyde resins make them suitable material for a wide variety of applications. Phenol formaldehyde-based resins are preferred as adhesives in the wood industry, paint, coatings, aerospace, construction, and building industries to produce composite materials. Phenol formaldehyde resins produced by synthesizing sustainable raw materials are of great importance in the research. The use of renewable resources instead of petrochemical raw materials, both phenol formaldehyde and other resins, may become a necessity in the future. In Figure 2, the lignin structure is given as an example, and such biomass sources can interact both physically and chemically with phenol formaldehyde [13].

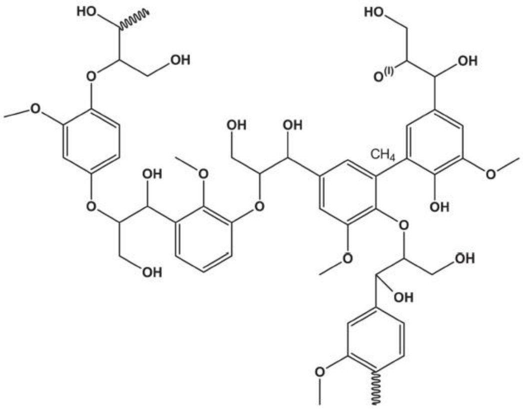

Figure 2. Structure of lignin

Similarly, tannin can form a compound with phenol formaldehyde resin in a compatible form. Figure 3 shows the structure of tannin and Figure 4 shows the structure of hemicellulose. In both, functional hydroxyl structures can give chemical reactions. Such biomass resources will be able to meet the need for alternative renewable raw materials in the future [13].

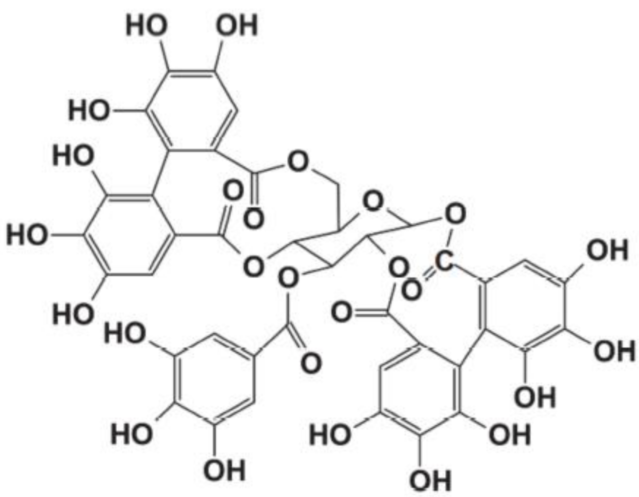

Figure 3. Structure of hydrolyzable tannins

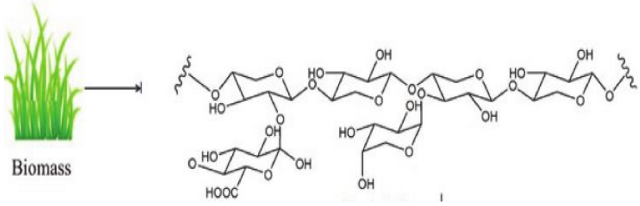

Figure 4. Hemicellulose from biomass

II. MATERIAL AND METHOD

There are many studies on the production of phenol formaldehyde resins. The chemical reaction of phenol and formaldehyde in the appropriate medium (catalyst) and the formation of oligomers are shown in Figure 5. In addition, the chemical bonding of modified cellulose with formaldehyde and polymerization reactions are expressed. The chemical bond structure of the phenol formaldehyde resin after curing is also shown in Figure 6 [14-16].

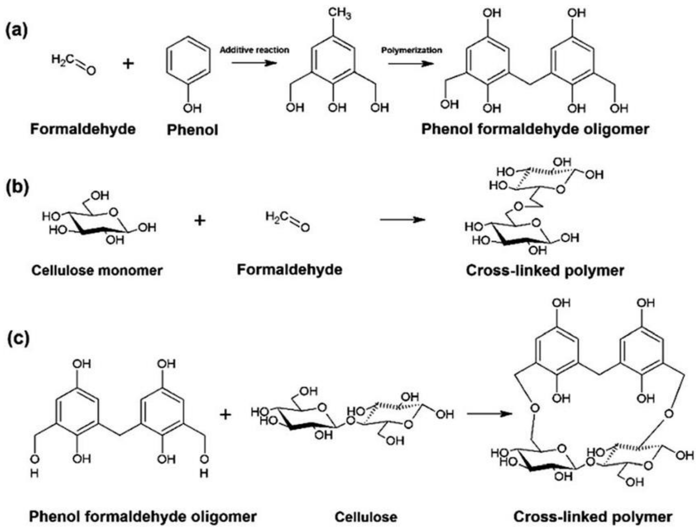

Figure 5. Phenol formaldehyde oligomer

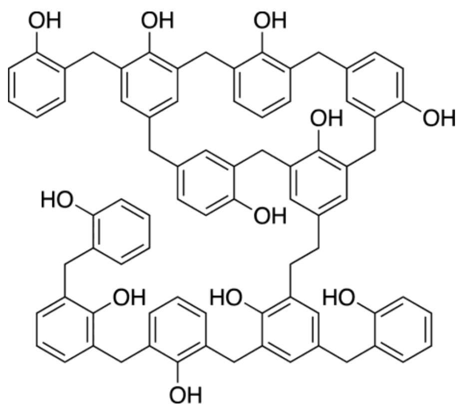

Figure 6. Phenol formaldehyde resin

III. RESULTS AND DISCUSSION

According to the results obtained, biomass supplementation reduces the density of phenol formaldehyde-based composites. Organic wastes can be used as filler in phenol formaldehyde resin to produce economical, easily workable, and flexible biocomposites. The use of cellulosic fibers in phenol formaldehyde resin as a filler increases the mechanical strength of the composite. Density, hardness, and thermal stability of composites obtained by the reinforcement of industrial inorganic fillers to the resin increase. Conductive nanoparticles such as graphene oxide are used to increase the thermal conductivity coefficient of phenol formaldehyde resin [17-20].

IV. CONCLUSIONS

This study has looked into the characteristics, potential uses, and use of phenol formaldehyde resins in composite materials. Phenol formaldehyde resins are being used in a broader range of applications. It is being used in the creation of composite materials along with fibrous biomass sources. Additionally, phenol formaldehyde resin is added as a supplement to industrial wastes or inorganic fillers. When phenol formaldehyde-based composites are created, environmental pollution-causing wastes are assessed, and some composite qualities are enhanced by the intended application. In general, phenol formaldehyde-based composites' mechanical characteristics are improved by organic fiber biomass wastes. Besides, inorganic industrial wastes enhance the thermal stability and inflammability of composite materials. Composites made of phenol formaldehyde interact physically with reinforcing elements used as fillers. On the other hand, certain modification techniques can also help biomass sources create chemical linkages. Bioraw material syntheses have been carried out to lessen the need for petrochemical components in composites based on phenol formaldehyde. This has led to the development of new-generation composites that are low in carbon footprint and favorable to the environment. The composites' workability is also improved by adding reinforcement in the form of difficult-to-recycle polymers to phenol formaldehyde.

REFERENCES

[1] Jahanshaei, S., Tabarsa, T., Asghari, J., *Eco-friendly tannin-phenol formaldehyde resin for producing wood composites*. Pigment and Resin Technology, 2012: 41(5), 296-301.

[2] Hasan, KF, Horváth, PG, Bak, M., Le, DHA, Mucsi, ZM ve Alpar, T., *Rice straw and energy reed fibers reinforced phenol formaldehyde resin polymeric biocomposites*. Cellulose, 2021: 28, 7859-7875.

[3] Li, Z., Zhou, W., Yang, L., Chen, P., Yan, C., Cai, C., Shi, Y., *Glass fiber-reinforced phenol formaldehyde resin-based electrical insulating composites fabricated by selective laser sintering*. Polymers, 2019: 11(1), 135.

[4] Sedliacik, J., Bekhta, P., Potapova, O., *Technology of low-temperature production of plywood bonded with modified phenol-formaldehyde resin*. Wood Research, 2010: 55(4), 123-130.

[5] Hernandez-Padron, G., Rojas, F., Castano, V.M., *Ordered SiO_2–(phenolic-formaldehyde resin) in situ nanocomposites*. Nanotechnology, 2003: 15(1), 98-103.

[6] Rajab, M.A., Kader, E.I., Hammod, A.A., Hameed, A.H.I., *Mechanical properties (Tensile, Hardness and Shock resistance) for the phenol formaldehyde resin with Epoxy resin)*. Diyala Journal of Engineering Sciences, 2019: 12(2), 35-43.

[7] Kulikova, Y., Sliusar, N., Korotaev, V., Babich, O., Larina, V., Ivanova, S., *Recovery and use of recycled carbon fibers from composites based on phenol-formaldehyde resins*. Recycling, 2022: 7(2), 22.

[8] Pervova, I.G., Klepalova, I.A., Lipunov, I.N., *Recycling phenolic wastewater from phenol-formaldehyde resin production*. Earth and Environmental Science, 2021: 666(4), 042032.

[9] Atta-Obeng, E., Via, B., Fasina, O., Auad, M., Jiang, W., *Cellulose reinforcement of phenol formaldehyde: characterization and chemometric elucidation*. Scientific & Academic Publishing, 2013: 1-8.

[10] Ibrahim, M.M., Ghani, A.M., Nen, N., Formulation of lignin phenol formaldehyde resins as a wood adhesive. Malaysian Journal of Analytical Sciences, 2007: 11(1), 213-218.

[11] Dremelj, A., Cerc Korošec, R., Pondelak, A., Mušič, B., *Improved synthetic route of incorporation of nanosilicon species into phenol-formaldehyde resin and preparation of novel ZnAl-layered double-hydroxide hybrid phenol-formaldehyde resin*. Polymers, 2022: 14(21), 4684.

[12] Hasan, K.F., Horváth, P.G., Kóczán, Z., Le, D.H.A., Bak, M., Bejó, L., Alpár, T., *Novel insulation panels development from multilayered coir short and long fiber reinforced phenol formaldehyde polymeric biocomposites*. Journal of Polymer Research, 2021: 467, 1-16.

[13] Sarika, P. R., Nancarrow, P., Khansaheb, A., Ibrahim, T., *Bio-based alternatives to phenol and formaldehyde for the production of resins*. Polymers, 2020: 12(10), 2237.

[14] X. Wang, Y. Deng, Y. Li, K. Kjoller, A. Royd, and S. Wang, *In situ identification of the molecular-scale interactions of phenol-formaldehyde resin and wood cell walls using infrared nanospectroscopy*. RSC Advances, 2016: 6, 76318.

[15] A. H. Suzuki, F. C. Lage, L. S. Oliveira, and A. S. Franca, *Biological Materials as Precursors for the Production of Resins*. Advances in Environmental Research, 2016: 49, 1-39.

[16] M. Purse, B. Holmes, M. Sacchi, and B. Howlin, *Simulating the complete pyrolysis and charring process of*

phenol–formaldehyde resins using reactive molecular dynamics. Journal of Materials Science, 2022: 57, 7600-7620.

[17] Zhao, X., Li, Y., Wang, J., Ouyang, Z., Li, J., Wei, G., Su, Z., *Interactive oxidation–reduction reaction for the in situ synthesis of graphene–phenol formaldehyde composites with enhanced properties*. ACS Applied Materials & Interfaces, 2014: 6(6), 4254-4263.

[18] Savov, V., Valchev, I., Antov, P., Yordanov, I., Popski, Z., *Effect of the adhesive system on the properties of fiberboard panels bonded with hydrolysis lignin and phenol-formaldehyde resin*. Polymers, 2022: 14(9), 1768.

[19] Hüseyin, A.S., İbrahim, K.I., Abdulla, K.M., *Tannin-phenol formaldehyde resins as binders for cellulosic fibers: Natural Resources*, 2011: 2(2), 98-101.

[20] Sanjeevi, S., Shanmugam, V., Kumar, S., et al., *Effects of water absorption on the mechanical properties of hybrid natural fibre/phenol formaldehyde composites*. Scientific Reports, 2021: 11(1), 13385.