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The Effect of Gamma Irradiation on Quality of Composite from Bagasse, Bamboo, and Polypropylene Coated Resin

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Abstract. Based on data from Direktorat Jenderal Perkebunan the sugarcane production in Indonesia from 2014-2018, sugarcane processing produced bagasse waste with an amount of about 0.825 million tons/year. The data from Badan Pusat Statistik (BPS) showed that national bamboo production in 2014-2018 was above 7 million stems/year. Currently, bagasse waste and bamboo waste are not utilized optimally and have low value. These wastes can be used as composite materials which have a higher economic value. The composite structure can be strengthened by a resin coating and polymerized using gamma irradiation. Gamma irradiation phenomena can also cause degradation which weakens the composite structure, so it is necessary to vary the radiation dose. This research aims to determine the effect of gamma irradiation on composites of bagasse fiber, bamboo fiber, and polypropylene (BBP) on the compressive test, water resistance, and density. BBP composites are made from 10% bagasse fiber, 10% bamboo fiber, and 80% polypropylene with a size of 40 mm x 30 mm x 20 mm. All components were mixed and coated with acrylic resin with a thickness of 2 mm, then irradiated with various doses of 0, 10, 20, 30, 40, and 50 kGy. The results of the BBP composite compressive test for irradiation doses of 0 to 50 kGy were respectively 29.667; 37.167; 50,235; 60,542; 52.537; and 46.545 kg/cm^2. The average result of the water-resistance test of the composite BBP absorbs water as much as 0.524 %. The results of the mean density test of the composite BBP obtained 0.894 gr/ml. The strongest composite structure was obtained at a dose of 30 kGy.

Keywords: Bagasse, bamboo, composite, dosage, gamma irradiation, polypropylene, polymerization.

INTRODUCTION

The issue of environmental pollution has been discussed since then until now. This issue is closely related to industrial activities that produce large amounts of waste (Badan Pusat Statistik 2020). One of the largest waste-producing industries in Indonesia is sugar industry, whose production process use sugarcane as raw material. Sugarcane extraction processing produces waste in the form of bagasse. Bagasse obtained from 35-40% of the amount of milled sugarcane (Rulianah et al. 2017). The amount of bagasse produced in all sugar industries especially Indonesia is estimated 0.825 million tons/year (Ditjen Perkebunan 2016). On the other hand, there is also a large amount of bamboo waste. Based on BPS data for 2013-2017, the national bamboo production reaches 7 million sticks/year which is estimated to produce a large enough bamboo waste (Arsad 2015).

Bagasse and bamboo usage has not been optimal and low economic value (Wulandari 2018). One of the solutions for treating waste and increasing its economic value by making natural-fiber reinforced composite materials (NRCM). NRCM can be used as a raw material in furniture. One of them is used as a substituent for plywood (multiplex). The plywood itself has disadvantages including easy brittle, not moisture-resistant (water), easy to mold, and easy to eat by termites, therefore, So we needed to replace the plywood with other materials that have better quality.

NRCM was chosen from bagasse and bamboo because it does contain high fiber, cellulose, hemicellulose, and lignin (Mokhena et al. 2018; Yunita and Mahyudin 2017). Composites in the polypropylene (pp) matrix, because pp can bind fibers from bagasse and bamboo, is strong, lightweight, and heat resistant (Rizkiansyah and Purnomo 2016).

Composites need to be hybridized for better quality. Composite hybridization is an attempt to improve certain properties of composite materials (Budiman and Sugiman 2016). One of the efforts made by coating polymerized acrylic resins using gamma irradiation. Gamma irradiation will polymerize the material. The presence of polymerized resin will give the composite a quality water resistance with high mechanical strength (El-Rahman et al. 2020).

Gamma irradiation made from unstable energy becomes stable by emitting stored energy in the form of radiation. Gamma rays used in this study came from radioactive Co-60 with energies of 1.17 and 1.33 MeV (Albandar 2019). This energy will break the bond following the addition of monomers from acrylic resin. The monomers formed will form with each other to form increasingly longer bonds, then this process will stop if saturated bonds have been formed or gamma radiation irradiation has changed (Martínez-Barrera et al. 2019).

The resin polymerization process will improve the mechanical properties so that the composite structure becomes strong. This is due to the compressive strength possessed by any composite including BBP composites. The hardening depth is the distance from the surface to the base of the hardened composite resin. Depth of hardening by beam penetration, beam length, beam spread, and irradiation (Harahap 2018). The aim of this research first is to look for the effect of the Co-60 gamma irradiation dose on BBP composites including the compressive test analysis, water resistance, and density. Second to analyse quality comparison of BBP composites with plywood for reviewing the feasibility of BBP composites using plywood.

MATERIALS AND METHODS

Materials and Tools

The materials used were bagasse, bamboo, polypropylene, acrylic resin, and NaOH. The tools used include, hammer, grinder, glassware, stirrers, spoon, furnace, composite molding (size 40 x 30 x 20 mm), analytical scale, oven, compresive test equipment, Ob-servo ignis Co-60 gamma irradiator with energy of 12,000 kCi.

Procedures

Preparation of composite's material

Bagasse and bamboo are chopped, then beaten with hammer so that the fibers separate, then soaked in 1% NaOH, and dried in the sun, after drying the fibers are cut to 10 mm long.

BBP composite making

The tools and materials that have been prepared are then carried out in the process of making fiber-reinforced composites (bagasse, bamboo, polypropylene) with composition of 10% bagasse fiber; 10% bamboo fiber; 80% polypropylene placed in composite molding by a furnace at 180^{o}C until 2 hours. After that, the composite was coated with resin with a thickness of 2 mm, then the samples were irradiated with doses of 0, 10, 20, 30, 40, and 50 kGy.

BBP composite and plywood testing

Compressive strength analysis also uses a compressive testing machine by placing the test sample on a pedestal, then the test sample is loaded vertically, then the maximum load is recorded until the test sample cracks as the Pr value (Yunita and Mahyudin 2017). After that, the calculation use the equation (1).

$$fc = \frac{Pr}{A} \quad (1)$$

fc is the compressive strength (kg/cm^2), Pr is the maximum crack load of the sample (kg), and cross-sectional area or surface being applied force (cm^2).

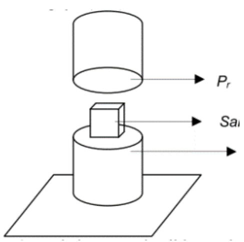

Figure 1. Compressive Test Loading (Yunita and Mahyudin 2017) .

Water resistance analysis is carried out by immersing the sample in a container filled with water at 25^{o}C for 24 hours. After that the test sample is removed and weighed using a digital scale and the results are recorded as mb. After that, calculations are carried out using Equation (2) to obtain the value of water absorption.

$$WA = \frac{mb\text{-}m}{m} \text{ x } 100\ \% \quad (2)$$

WA is water absorption (%), mb is the wet mass of the sample after immersion (g), and m is the mass of the sample in oven-dry conditions (g).

Density analysis of the test sample was carried out under dry conditions. Initially, sample was weighed using an analytical digital scale and the results were recorded as m. Furthermore, the calculation is carried out using Equation (3) to obtain the density value of sample.

$$\rho = \frac{m}{V} \quad (3)$$

ρ is the density (g / cm^3), m is the mass of the sample in dry condition (g) and V is the sample volume (cm^3).

Data analysis

The data were taken from the results of laboratory research including the compressive test, density, and water resistance. Data were taken from primary sources and analyzed using equations 1, 2, and 3. The observation technique used is direct observation through information data shown by the instrument (quantitative). The observations were carried out in several repeated samples. Data processing using statistical analysis. Finally, the data is displayed in graphical form to make it easier to understand and interpreted.

RESULTS AND DISCUSSION

The Effect of Gamma Co-60 Irradiation Dose Variation on BBP Composites with Compressive Test, Density, and Water Resistance Analysis

BBP composites irradiated with gamma will produce chemical interactions, namely polymerization and degradation phenomenon (Girard-Perier et al. 2020; Vujcic et al. 2020). The polymerization occurs when the material forms radical monomers to form an initiator which will bind to other monomers so that the polymerization reaction occurs. The less gamma radiation that is absorbed by the layer, the less copolymerization that occurs (Harahap 2018). Physically, the polymerization process will increase the strength of the material in the BBP composites, but on the other hand, the degradation phenomenon will change the polymer structure into monomers so that its physical strength will be weakened. This happens when the polymerization of the compounds will bond to form a more complex compound, so the strength of the BBP composite also increases.

The aim for this research is looking for optimum phase of gamma radiation dose will be sought which has a polymerization phase more than degradation. One of them is by analyzing the BBP composite with a physical test. The testing process is carried out in accordance with Figure 1, in fact it can be seen in Figure 2.

Figure 2. Compressive Test on BBP Composite

The analysis of the compressive test, density, and water resistance aims to determine the optimal phase of gamma radiation dose. The optimum phase is obtained right when the BBP composite has the highest quality mechanical properties, to facilitate observation and interpretation of the analysis data as shown in Table 1.

Table 1. BBP Composite Analysis Data

Radiation gamma dose (kGy)	Compressive Test on BBP Composites (kg/cm^2)	Density of composite (g/ml)	Water resistance (%)
0	29.667 ± 0.124	0.893 ± 0.023	0.525 ± 0.013
10	37.167 ± 0.129	0.893 ± 0.025	0.532 ± 0.014
20	50.235 ± 0.131	0.895 ± 0.025	0.524 ± 0.014
30	60.542 ± 0.128	0.895 ± 0.024	0.523 ± 0.015
40	52.537 ± 0.127	0.896 ± 0.023	0.519 ± 0.013
50	46.545 ± 0.130	0.894 ± 0.025	0.523 ± 0.015
	Mean	0.894 ± 0.059	0.524 ± 0.034

The results of the compressive test analysis are presented in the form of a graph as in Figure 3. Composite BBP compressive test shows that the compressive strength of the composite will increase with increasing radiation dose, and will stop at the optimal dose. Based on that figure, the relationship between irradiation dose and BBP composite compression test at a dose of 0 to 30 kGy has increased.

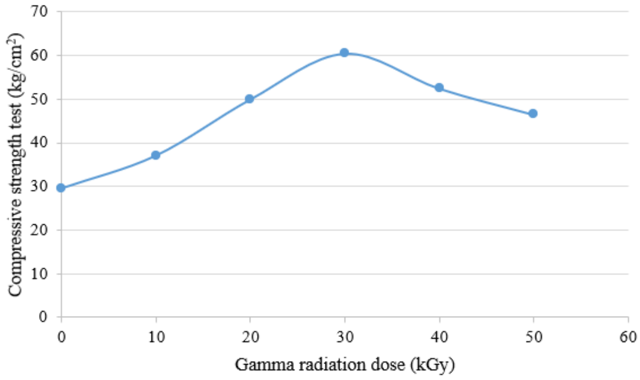

Figure 3. Effect of Gamma Irradiation Dose on Composite BBP Compressive Test.

The gamma irradiation dose at 30 kGy shows the optimum phase, because it has the highest compressive test of the BBP composite. This means that at that time the polymerization phase is dominant. BBP composites when irradiated gamma at dose of 40 to 50 kGy decreased in compressive test. The decrease in composite strength occurs due to the degradation of polymer compounds into monomer. The degradation process produces a compound that is simpler than initial compound, so it has a lower compressive test value. The results show that gamma radiation can effect the compressive test characteristics of the composite (Motaleb et.al. 2019).

The second analysis is density test, from Table 1 made graph which showed in Figure 4. Based on result analysis gamma radiation does not effect to density composites. The density of the composites is influenced by type of material used.

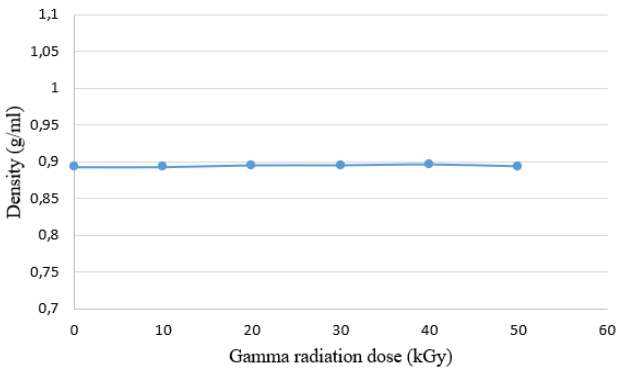

Figure 4. Effect of Gamma Irradiation Dose and BBP Composite Density.

The final test is water resistance of composite. The effect of variations in the dose of gamma Co-60 irradiation that affect the BBP composite. The analysis results are presented in Figure 5.

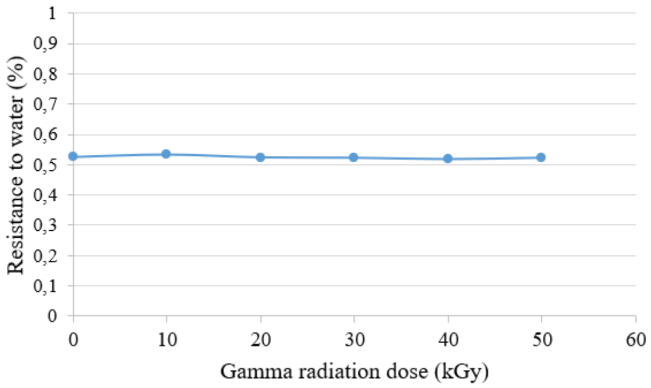

Figure 5. Effect of Gamma Irradiation with BBP Composite Water Resistance.

BBP composites that were made showed good water resistance. The result of composite water resistance was 0.524 ± 0.034 % of the total water absorbed. This shows that the resin-coated fiber composite is resistant to water. Based on Figure 5, it shows that variations in gamma irradiation do not affect the resistance of the composite to water.

Quality Comparison of BBP Composites with Plywood

In order to apply BBP composites as plywood substituent, it is necessary to compare many parameters that affect its quality. The parameters to be compared in this study are compression test, density, and water resistance analysis. Based on the results of analysis, it is can be interpreted that the BBP composite is feasible as a plywood substituent in terms of these three aspects. Comparisons are made with due observance of the SNI established by BSN (National Standardization Agency) regarding plywood with no SNI 8032: 2014 (BSN 2014). The results of the test comparison between BBP composite and plywood are as shown in Table 2.

Table 2. Result Test Comparison of BBP Composite and Plywood Composite.

Testing	BBP Composite	Plywood
Compressive test	60.542 ± 0.128 kg/cm^2	25.342 ± 0.102 kg/cm^2
Water ressistance	0.524 ± 0.034 %	8.573 ± 0.094 %
Density	0.894 ± 0.059 g/ml	0.838 ± 0.044 g/ml

Composite compression test of BBP which had quiet large value of 60,542 ± 0.128 kg/cm^2 was obtained when irradiated gamma Co-60 at a dose of 30 kGy and had a value of 29,667 ± 0.124 kg/cm^2 if the BBP composite was not irradiated with gamma. The results of the compressive test on BBP composites have a higher value compared to plywood which is only 25.342 ± 0.102 kg/cm^2. From the compressive test analysis, it is stated that BBP composites have greater strength than plywood.

The results of the BBP composite's water resistance can look at Table 2 was 0.524 ± 0.034 %, while the plywood obtained was 8.573 ± 0.094 %. It is stated that BBP composites are more resistant to water than plywood. One of the disadvantages of plywood is that it easily absorbs water, causing damage to fibers, which results in easy weathering and mold. The pre-made BBP composites have much better water resistance than plywood.

The analysis results for the density of BBP composites with value of 0.894 ± 0.059 g/ml while plywood density value was 0.838 ± 0.044 g/ml. It shows that plywood has the characteristics of a lighter BBP composite, but the resulting difference is not significant. This means that resulting weight difference between the two materials is not too significant. When compared from the various aspects described above, BBP composites have better quality properties than plywood, by applying BBP composites substituents on plywood it will increase the quality of the products produced.

CONCLUSIONS

Based on the analysis and discussion carried out in the study, it can be concluded the characteristics of resulting BBP composites are compressive strength of 60.542 ± 0.128 kg / cm^2, water resistance of 0.524 ± 0.034%, and density of 0.894 ± 0.059 g / ml with a gamma irradiation dose of Co-60 of 30 kGy. Second the resulting BBP composites have better properties than plywood.

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