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Synthesis and characterization of chicken feather derived rachis fiber-bamboo particulate hybrid reinforced epoxy composites for sustainable structural applications

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Abstract

Purpose – This paper aims to reduce waste management and generate wealth by investigating the novelty of combining chicken feather fiber and bamboo particles to produce hybrid biocomposites. This is part of responsible production and sustainability techniques for sustainable development goals. This study aims to broaden animal and plant fiber utilization in the sustainable production of epoxy resins for engineering applications.

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Design/methodology/approach – This research used two reinforcing materials [chicken feather fiber (CFF) and bamboo particles (BP)] to reinforce epoxy resin. The BPs were kept constant at 6 Wt.%, while the CFF was varied within 3–15 Wt.% in the composites to make CFF-BP polymer-reinforced composite (CFF-BP PRC). The mechanical experiment showed a 21% reduction in densities, making the CFF-BP PRC an excellent choice for lightweight applications.

Findings – It was discovered that fabricated composites with 10 mm CFF length had improved properties compared with the 15 mm CFF length and pristine samples, which confirmed that short fibers are better at enhancing randomly dispersed fibers in the epoxy matrix. However, the ballistic properties of both samples matched. There is a 40% increase in tensile strength and a 54% increase in flexural strength of the CFF-BP PRC compared to the pristine sample.

Originality/value – According to the literature review, to the best of the authors' knowledge, this is a novel study of chicken fiber and bamboo particles in reinforcing epoxy composite.

Keywords Green composite, Sustainability, Rachis fiber, Bamboo particles, Clean environment

Paper type Research paper

Introduction

In engineering, composite materials are constantly gaining attention because of the improved mechanical properties obtained from the combination of two materials better than that of the individual components. The improved specific strength and durability of composites is a key feature that makes them useful and adaptable for use in engineering applications (Sultan *et al.*, 2011). Composites consist of the matrix (continuous) and reinforcement (discontinuous) phases and of the three broad classes of materials: metals, ceramics and polymers; polymers are the most widely used matrix materials for composite production. This is due to the lightweight, durability, adhesive nature, moldability, corrosion resistance and ease of production of complex parts (Hsissou *et al.*, 2021; Shahar *et al.*, 2019). The mechanical property of composites depends on the type and arrangement of the reinforcement in the matrix, resulting in high stiffness, directional strength and alternatives in lightweight applications. The arrangement can be multidirectional or bidirectional, while multidirectional alignment is known for higher water absorption, the bidirectional arrangement has higher mechanical qualities (ultimate tensile strength and Young's modulus) (Aeyzarq and Siti, 2013). Polymers used in composite production are divided into thermoplastics and thermosets.

An important class of thermosets is epoxy polymers; although they are brittle, with low fracture energy and higher curing time, they are preferred for high-strength applications because of their high ultimate tensile strength and corrosion resistance with corresponding lower shrinkage and creep. The handicapped properties of polymers, such as limited strength, service temperature and flammability, are generally improved by reinforcing the polymer matrix using either short, continuous or particulate fibers (Oladele *et al.*, 2020). Epoxy is an excellent matrix in the production of polymer composites because it has been proven to be an effective adhesive and laminating resin for many industrial applications owing to its excellent moisture barrier, adhesion, binding strength and mechanical strength (Jeyapragash *et al.*, 2020; Oladele *et al.*, 2022).

In recent years, there has been an increased need to abide by the envisioned goals of the United Nations Sustainable Development Goals (SDGs). The engineering field is more focused on sustainable consumption and production (Goal 12), thereby driving the expansion of new materials towards biodegradable materials as sustainable alternatives for synthetic materials (Bichang'a, *et al.*, 2023; Gasper *et al.*, 2019). Sustainable biobased (natural) reinforcements are preferred because it is eco-friendly, cost-efficient, with low-carbon footprint, have a low weight-to-strength ratio and are readily available (Kurien *et al.*, 2022; Salman *et al.*, 2016). Natural reinforcements are beneficial in enhancing sustainable consumption and reducing environmental pollution from plant and animal waste (Khan *et al.*, 2022).

Plant waste is generated seasonally from plant parts left behind after the harvest, such as the stem, roots and leaves, while animal wastes results from the non-consumed part of animals, such as wool, silk, hides, feathers and eggshells. All plants and animals have a specific waste index; a high waste index value corresponds to a high amount of waste (Jayathilakan *et al.*, 2012). The contribution of chicken feathers (CF) to the overall specific waste index of chicken is about 10%, significantly contributing to global animal waste, with about 12.7-kilo metric tons per annum. Most of the traditional techniques for waste disposal result in either atmospheric, water or land pollution. Similarly, the world's increasing population generates more waste from plant parts and plastic consumption (Formela *et al.*, 2022). Industries can transition to more environmentally friendly methods, lessening their influence on the environment and fostering a more sustainable economy, by adopting natural reinforcements like bamboo and chicken feather fibers which provide biodegradable renewable resources, efficient energy utilization, low environmental footprint, promotes biodiversity, local economic development and waste utilization (Moshood *et al.*, 2022).

Of all animal fibers, only chicken feather fibers (CFFs) possess a honeycomb structure with an excellent combination of 91%, 8% and 1% β-keratin protein, water and lipids, respectively. The keratin structure of chicken fibers contains high amounts of glycine, alanine, serine, cysteine and valine but low amounts of lysine, methionine and tryptophan that form helically twisted micro-fibrils (Oladele *et al.*, 2018; Vijayan *et al.*, 2021). This gives them higher tensile strength, impact strength, flexural strength, lightweight and thermal insulation (Kurien *et al.*, 2022). As a bio-composite reinforcement, CFF displays excellent properties such as dimensional stability, wear resistance, hydrophobicity, oil repellence and hardness. Similarly, in plants, bamboo is a choice material for reinforcement because it possesses high strength, lightweight, good weathering ability and good mechanical properties (Chand and Fahim, 2021). The chemical constituents of bamboo are cellulose, hemicellulose, lignin and water. The main cross-section is filled with micro-gaps and micro-holes, resulting in better absorption and ventilation (Das, 2010). The chemical constituents are 50%, 40% and 10% parenchyma, fiber, vessels and sieve tubes.

CFF has been used extensively as reinforcement for polymer-based composites. Researchers such as (Kurien *et al.*, 2022) described the challenges to the complete utilization of CFF, which include non-standardized extraction procedures and difficulty in quantitatively analyzing the extent of treatment required. Using fibers from chicken feathers in composite materials presents several obstacles, such as large-scale production, cost-effectiveness, adhesion enhancement, adequate cleaning and consistent sizing. Developing sophisticated processing methods and hybrid composite technologies are used to assuage the challenges (Mishra and Bhattacharyya, 2023). The CFF was uniformly dispersed in the matrix, providing corrosion resistance and improved interfacial adhesion between the fiber and the epoxy matrix. Similarly, Khan *et al.* (Khan *et al.*, 2022) discussed the excellent interlinking, hygroscopic, hydrophilic and acoustic properties of CFF. Also, the CFF has the least density of all the investigated natural fibers, ensuring its utilization for lightweight applications. Uzun *et al.* (Uzun *et al.*, 2011) and Oladele *et al.* (Oladele *et al.*, 2018) showed that CFF improved the tensile, flexural, and impact strength of the resulting composite materials, while Farhad Ali *et al.* (2021) showed through thermogravimetry analysis that the helix structure of the peptide bridges degrades into CO_2, H_2S and HCN at elevated temperatures of about 600°C.

Conversely, researchers have used bamboo fibers in fibrous and particulate forms. Bamboo's elasticity, toughness, ability to sequester carbon and adaptability make it a useful material for reinforcing structures; because bamboo possesses nodes, which increase its bending and tensile capabilities, it has great potential for use in the construction industries (Emamverdian *et al.*, 2020). Bamboo contains chemical elements such as lignin, holocellulose and ash content. The amount of lignin in bamboo affects its mechanical qualities. Also, bamboo's tensile strength is positively impacted by the elongated bond structure of α-cellulose, which has an inverse relationship with hemicellulose (Hartono *et al.*, 2022).

Particulate reinforcements are discontinuous phases with uniform dimensions in all directions, while fibrous reinforcements are discontinuous phases with a high length-to-diameter ratio in the matrix. Although fibrous reinforcement is generally preferred because of the improved stiffness compared to the particulate counterpart, particulate reinforcement provides improved strength, wear resistance, hardness, friction coefficient and toughness of composites (Katiyar *et al.*, 2021; Tanzi *et al.*, 2019). Research (Martijanti *et al.*, 2021) showed that bamboo particles improved the flexural and tensile strength of polymer composites with excellent homogeneity and reduced porosity. Also, Tan *et al.* (2019) investigated the mechanical properties, creep-recovery and dynamic viscoelasticity of biocomposites reinforced with different bamboo parts. Generally, all the parts improved the properties of the composite, but bamboo green has the highest crystallinity, modulus and creep resistance, while bamboo culm showed the best processability and mechanical properties of all the investigated bamboo parts.

Importantly, Adediran *et al.* (2021) investigated the hybrid effect of combining bamboo reinforcement with coconut fibers. The result showed that the thermal, electrical, hardness, flexural, yield strength, modulus of elasticity and rupture were all improved. The increasing improvement trend encountered a depreciation trend at 8 Wt.% of the particulate reinforcement, which is an important consideration in composite production. Similarly, Malsawmkima and Rajaprakash (2021) showed that combining bamboo fibers with chicken fiber enhances tensile and flexural strength better than many natural fiber alternatives. The review of Rajak *et al.* (Rajak *et al.*, 2019) showed that improving strength, stiffness and chemical resistance can be achieved by fiber reinforcement, while wear resistance is mainly improved by particle reinforcement. Many works have been carried out using the chicken feather barbs fibers; however, little work has been done on using the chicken feather rachis fibers. Therefore, this research investigated the synergistic effect of rachis fiber from chicken feathers and bamboo particles from bamboo stems on the mechanical properties of epoxy resin. Varying amounts of the rachis fibers and a constant amount of bamboo particles were used as reinforcements to improve properties. Fiber lengths were varied to investigate their influence on the fabricated composites (Oladele *et al.*, 2021). This becomes necessary because, recently, interest in green materials encourages the use of polymer-based materials in structural applications, and the suitability of a material for any selected application is necessitated by structural and environmental compatibility which has been the areas of research focus for product development in recent times (Oladele *et al.*, 2024).

Materials and method

This research used epoxy resin matrix LY556 (bisphenol A) mixed with epoxy hardener/curing agent/catalyst (HY951) manufactured by East Coast Resin, Unipol Inc, 316 Brighton Beach Ave, Brooklyn, New York, USA, and purchased from IRIS Epoxy Resins and Hardner Nationwide Distributor in Lagos State, Nigeria. The mixture reacts to form the epoxy resin used as the matrix material for the experiments. The reinforcement materials are; chicken feathers that were sourced locally from a poultry farm in Akure, Ondo State, Nigeria, while the bamboo stalks were sourced from a farmland in Ife, Osun State, Nigeria. The chicken feather fiber was extracted according to the methodology of Oladele *et al.* (Oladele *et al.*, 2018) by sorting, washing and sun-drying. The feathers were trimmed to separate the barbs from the rachis. Hence, the rachises from the CFF were further prepared by cutting into two sets, 10-mm length (CFF10) and 15-mm length (CFF15) for the experiment. The bamboo fibers were extracted according to the methodology of Bahari and Krause (Bahari and Krause, 2016) by cutting the stalk into straight, physically homogenous forms before chipping them into small forms. The chips were then dried to remove moisture and impurities capable of causing degradation. The particles were then milled to obtain fine particles and sieved to obtain homogenous particles of $<150\ \mu$m.

Composite preparation

The composites were produced by hand layup technique keeping an average ratio of 2:1 for the epoxy resin and hardener, while the Wt.% of the bamboo particles was kept constant at 6 Wt.% and the Wt.% of the rachis fibers was varied between 3 and 15 Wt.% for two fiber lengths – 10 mm (CFF10) and 15 mm (CFF15), respectively. The particulate and the fiber reinforcements were randomly dispersed in the matrix through homogeneous mixing and molded to form hybrid chicken feather fiber-bamboo particulate polymer-reinforced composites (CFF-BP PRC) according to ASTM-standardized test samples for experimental analysis. Three composite samples were made for each experimental test which are tensile, flexural and impact. In this research, three samples were used in the preliminary investigations to evaluate the viability of novel composite compositions and spot possible hitches before expanding the research. A sample size of three can nonetheless provide insightful results, especially for our chosen statistical techniques for estimating mechanical properties.

Numerous conventional mechanical tests are available for composite materials, such as impact, flexural, shear, compression and high-force tension (tensile) (Saba *et al.*, 2019). The tensile and flexural properties of the samples were investigated using a universal tensile testing machine (Model: Instron series 3369) at the Center for Energy Research and Development, Obafemi Awolowo University of Technology, Ile-Ife, Osun, Nigeria. The tensile experiment was performed according to the ASTM C1557 standard, cutting dumbbell-shaped (90 × 10 × 3 mm) samples for the test at a speed of 5 mm/min with a 100 kN load cell to obtain the ultimate tensile strength of the sample specimen. The flexural experiments were performed using a three-point bending setting according to the ASTM D790 standard at a crosshead speed of 3 mm/min until fracture, and the fracture load was recorded. Impact-related damage to composite structures usually entails the emergence of many failure modes near the impact site. Because several damage mechanisms occur simultaneously, composite structures respond complexly to impact shock (Sultan *et al.*, 2012). The impact test was performed using a Charpy V-Notch impact testing machine (Instron CEAST 9050) at the Center for Energy Research and Development, Obafemi Awolowo University of Technology, Ile-Ife, Osun, Nigeria. The dimensions used are 64 × 11 × 3 mm in accordance with the ISO 179 standards to obtain the energy absorbed, which is then translated to the impact energy. The hardness test was performed using the Shore D hardness tester at the Department of Metallurgical and Materials Engineering, Federal University of Technology, Akure, Ondo, Nigeria. The first step in the hardness was mounting the samples, and the indenter was brought to the surface of the sample with a load of 15 kgf applied at five different points to obtain five different values whose average was used as the hardness value.

The density of the CFF-BF PRC samples was estimated by calculating the volume of water displaced when immersed in water. Equation (1) was used in estimating the density of the composites. The water absorption test was carried out according to the ISO 175 standard. The initial weight of the samples was determined using a chemical weighing balance at the Department of Metallurgical and Materials Engineering, Federal University of Technology, Akure, Ondo, Nigeria. The samples were immersed for 24 h, removed and wiped clean. The final weights were measured and then returned to the immersion medium. This was repeated for seven consecutive days. The initial weights (w_i) and final weights (w_f) after each period of all the samples were measured and recorded. The % moisture content was calculated using equation (2). The morphology of the fractured tensile samples was investigated using SEM (Model: EVO MA 15, Carl Zeiss SMT) at NLNG Multi-User Laboratories, Faculty of Engineering, Amadu Bello University, Zaria, Nigeria. The fractured sample surface was imaged by cutting the samples into required sizes that fit into the microscope's stage. The samples were made electrically conductive by sputter coating with platinum using low-vacuum sputter coating or high-vacuum evaporation. The SEM images were taken at an accelerating voltage of 20 KV and a working distance of 10.6 mm:

$$Density = \frac{mass}{volume} \tag{1}$$

$$\%\ moisture\ content = \frac{w_f - w_i}{w_i} \times 100\% \tag{2}$$

Results and discussion

The density for the CFF-BF PRC is shown in Figure 1, where it was discovered that the densities of the CFF10-BP PRC and CFF15-BP PRC fiber lengths based fabricated composites were lower than that of the pristine epoxy resin, which was 1.161 kg/m^3. It was discovered that the densities in both samples reduced as the reinforcement content increased from 3 to 15 Wt.%, with 10-mm fiber length samples having the least values in each of the fiber content considered. The highest density of CFF-BP PRC is from 3 Wt.% samples with 0.924 and 0.992 kg/m^3, while the least are from 15 Wt.% samples with 0.920and 0.932 kg/m^3 for CFF10 and CFF15 mm samples, respectively. When compared with the control, the samples with the respective least densities have been able to cause 21% and 20% reduction in density. The weight reduction is attributed to the fiber and particulate having a lower density compared to the epoxy resin. The research of Aranberri *et al.* (Aranberri *et al.*, 2017) shows a reduction in the density of CFF PRFC attributed to the presence of hollowed structures in CFFs for lightweight applications.

The water absorption experiment evaluated the dimensional stability of both sample sets daily for 7 days in a moist environment. The water absorption value of the pristine epoxy resin was 0.035% which was of lower absorption values than CFF10-BP PRC (0.099%) and CFF15-BP PRC (0.477%). This value is comparable to the lowest water absorption values obtained by (Munde *et al.*, 2023) for glass/epoxy composites (1.51%). The low absorption values resulting from the CFF10-BP PRFC and CFF15-BP PRC are expected because CFF is hydrophobic. As the days proceeded, the increasing absorption level was attributed to the presence of BP and the presence of a hydrophilic polymer backbone in CFF that increased as the Wt.% increased. Increased length of CFF results in increased absorption observed between CFF10-BP PRC and CFF15-BP PRC-based composites. The results of the water absorption experiment are shown in Figure 2.

The hardness of CFF-BP PRC was estimated for both CFF10-BP PRC and CFF15-BP PRC and the pristine samples. Although the results showed an increasing trend of hardness for both CFF10-BP PRC and CFF15-BP PRC as the Wt.% of reinforcement increases. However, the maximum hardness at 15 wt.% of CFF10-BP PRC (64.5 HS) was lower than that of

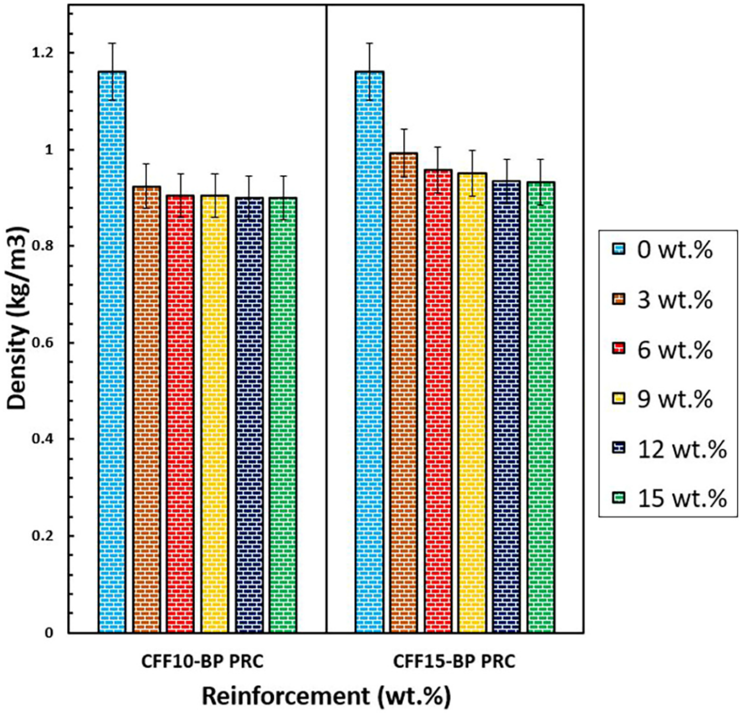

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Figure 1.
Density of the different CFF-BP PRC composites and pristine sample

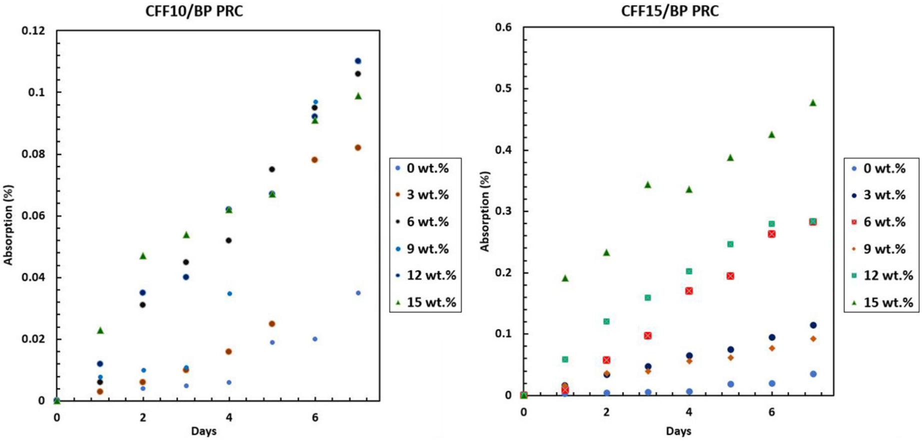

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Figure 2.
Water absorptivity of different CFF-BP PRC composites and pristine sample

CFF15-BP PRC (64.8 HS). Nevertheless, the maximum specific hardness (SH) values for CFF10-BP PRC (70.1 HS) were higher than that of CFF15-BP PRC (69.52 HS). For both CFF10-BP PRC and CFF15-BP PRC, the estimated specific hardness property was higher than the normal hardness. The results of the hardness tests are shown in Figure 3.

The loading conditions determined the mechanical properties of CFF-BP PRC. Tensile loading conditions were used to estimate the ultimate tensile strength and modulus of elasticity of CFF-BP PRC, while flexural and impact tests were used in estimating the impact and flexural strengths. The specific mechanical strength of each of the samples was also determined. The specific strength (SS) was obtained by dividing the strength by the material density. Specific strength provides an important criterion for evaluating the strength of materials, especially lightweight materials with high strength. Obtaining the specific strength is important for natural fiber/particulate reinforced polymer composites (NF/PPRC).

Figure 4 shows the results from the unidirectional tensile samples on the universal testing machine tested to fracture. The typical stress-strain (σ–ε) curves represented the specimen's behavior. All these samples showed a complicated shape (jagged shape), and the final values for each of the sample's mechanical behavior was an average of three steps. Prior researchers also showed this phenomenon (Naito, 2022; Naito *et al.*, 2012). Most of the samples showed an intermediate modulus in the initial stages of tensile loading, with the average values of maximum stress taken as the ultimate tensile strength. Notably, while some of the samples showed considerable ductility, others fractured after low strains.

The tensile properties of the samples are shown in Figures 5 and 6. The ultimate tensile strength for the varying composition of the CFF-BP PRC was shown in Figure 4, while the elastic modulus of the samples was shown in Figure 5. As shown in the plots for CFF10-BP PRC, the ultimate tensile strength reduced with increasing Wt.% of reinforcement but increased with increasing Wt.% of reinforcement in CFF15-BP PRC. The optimum value for tensile strength was obtained at 3 Wt.% for CFF10-BP PRC (16.65 MPa) and 15 Wt.% for

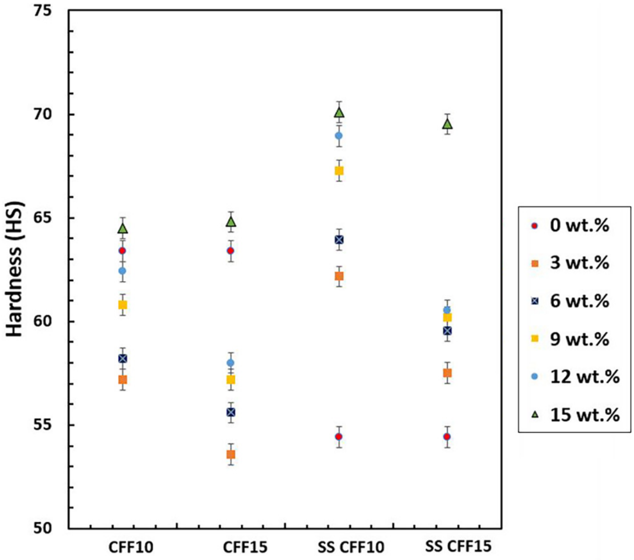

Figure 3.
Hardness of different CFF-BP PRC composites and pristine sample

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CFF15-BP PRC (15.27 MPa). Similarly, the overall maximum specific tensile strength was recorded for the 3 Wt.% CFF10-BP PRC (18.02 MPa) compared to the highest specific tensile strength at 15 Wt.% for CFF15-BP PRC (16.39 MPa). This implies that for tensile applications where lightweight is required, CFF10-BP PRC is preferred because its highest specific tensile strength is about 10% higher than CFF15-BP PRC.

Figure 7 demonstrates a significant amount of nonlinearity before hitting the breaking stress, i.e. the maximum flexural stress indicates the flexural strength of the material. The

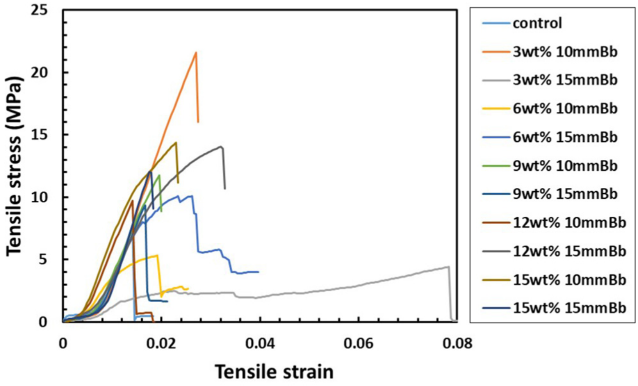

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Figure 4. Tensile stress-strain curves of different CFF-BP PRC composites and pristine sample

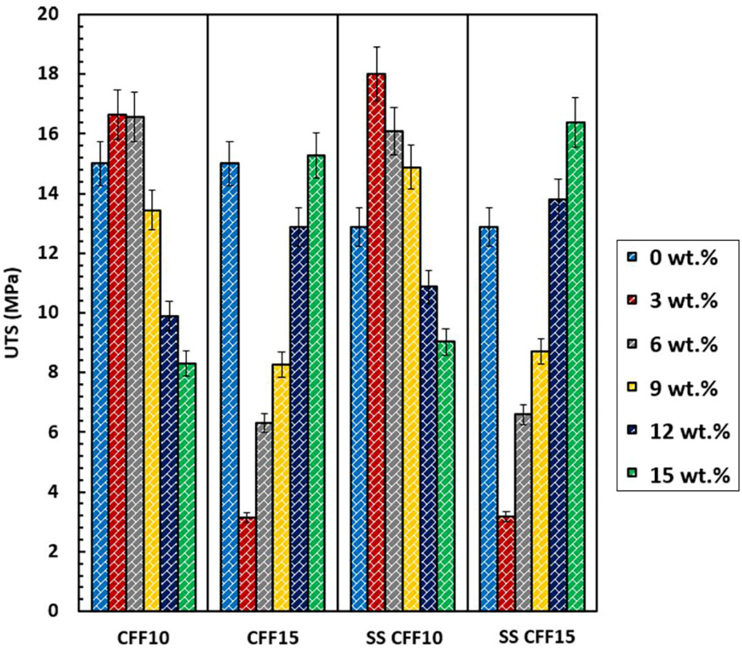

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Figure 5. Ultimate tensile strength of different CFF-BP PRC composites and pristine sample

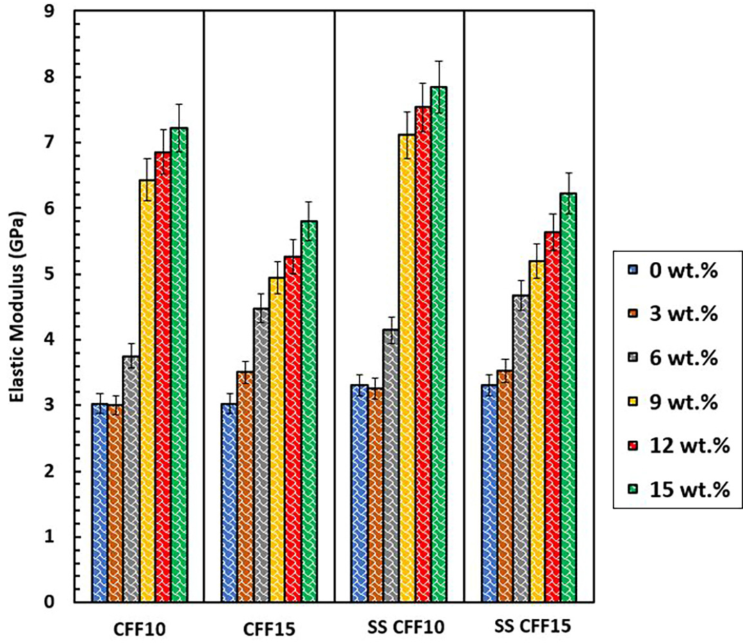

Figure 6.
The elastic modulus of different CFF-BP PRC composites and pristine sample

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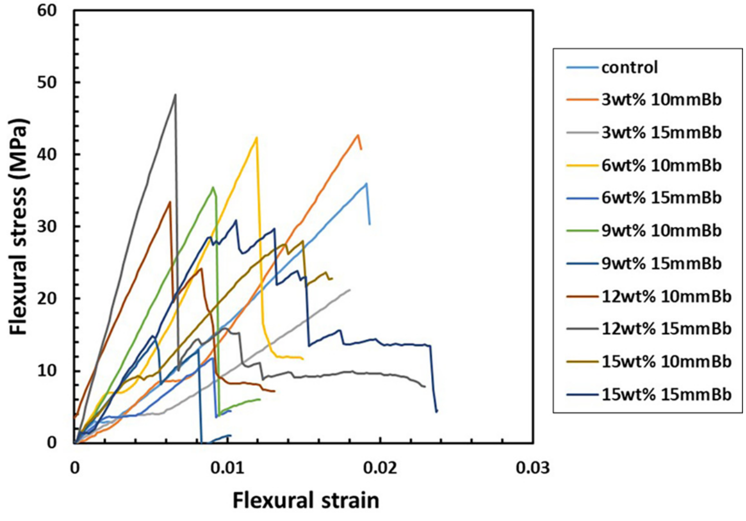

Figure 7.
Flexural stress-strain curves of different CFF-BP PRC composites and pristine sample

Source: Authors' own creation

adhesive force between the fiber/particulate reinforced epoxy is strong, resulting in apparently similar fracture mode with tensile plots shown in Figure 4. It can be determined that the increase in flexural strength provides bonding sites to the polymer matrix so that the full weight can be distributed among the fibers and particles, preventing the polymer surfaces and matrix from separating.

A similar trend to tensile results was obtained in the flexural strength results where the flexural strength rescinded for CFF10-BP PRC, making the highest flexural strength to be observed in 3 Wt.% (40.05 MPa), but increased in CFF15-BP PRC results as the Wt.% reinforcement increased making 15 Wt.% (32.41 MPa) the highest. The specific flexural strength was also the highest for 3 Wt.% CFF10-BP PRC (43.34 MPa) as compared to 15 Wt.% CFF15-BP PRC (34.77 MPa), indicating a higher specific flexural strength (24.64%) for lightweight application. The variation in flexural strength is shown in Figure 6.

This anomalous behavior for tensile and flexural properties was reported by Alam and Chowdhury (Alam and Chowdhury, 2020) for reinforced epoxy composites, where such behavior was attributed to irregular adhesion, poor coupling, interfacing and curing between laminates. However, the elastic and flexural modulus of the CFF-BP PRC, as shown in Figure 8 and Figure 9, respectively, gave the expected trend in elastic modulus of the CFF-BP PRFC as the Wt.% increases. The sample with the highest modulus was the 15 Wt.% from both CFF10-BP PRC (7.22 GPa) and CFF15-BP PRC (15.27 GPa) for the elastic modulus and CFF10-BP PRC (0.54 GPa) and CFF15-BP PRC (0.477 GPa) for the flexural modulus. The increased modulus is attributed to the higher modulus of the reinforcements compared to the epoxy, which increases as the Wt.% increases. The specific elastic modulus and flexural modulus were also found to be higher by 15 Wt.% CFF10-BP PRC (7.85 GPa) and (0.59 GPa), respectively, compared to 15 Wt.% for CFF15-BP PRC (6.22 GPa) and (0.51 GPa). This

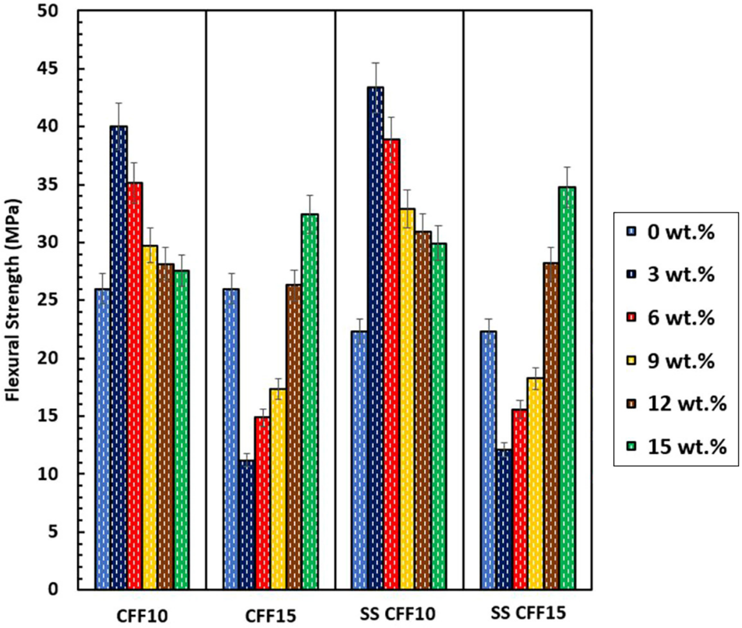

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Figure 8.
Flexural strength of different CFF-BP PRC composites and pristine sample

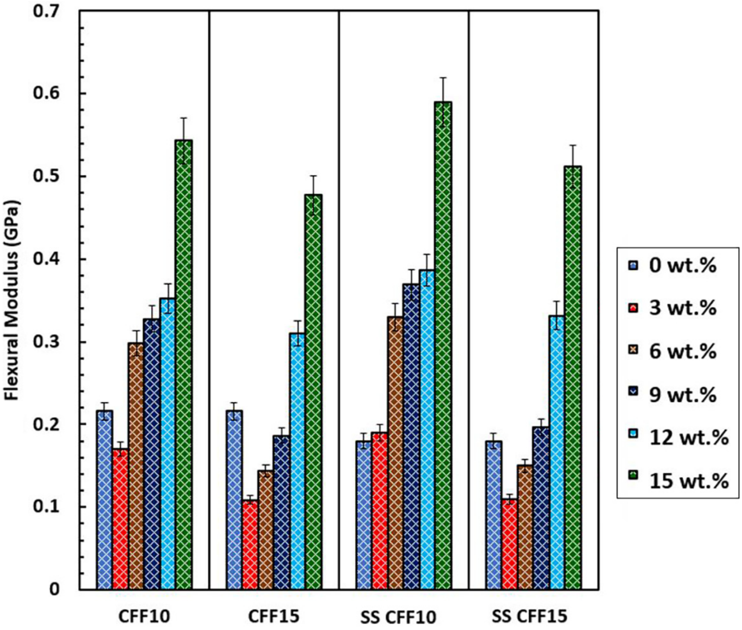

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Figure 9.
Flexural modulus of different CFF-BP PRC composites and pristine sample

implies that CFF10-BP PRC has a better specific elastic modulus (26.21%) and specific flexural modulus (15.68%) than CFF15-BP PRC.

The impact results showed an increasing trend as the wt.% increases for CFF-BP PRC, and both CFF-BP PRC fiber lengths-based samples at 15 Wt.% had almost the same maximum impact strength value (5.91 J/m^2), as shown in Figure 8. The results of this experiment show that CFF-BP is a good reinforcing material for epoxy resin composites because it reduces the density and enhances lightweight. The CFF-BP reinforcement increased the hardness, tensile, impact and flexural strengths. The elastic and flexural moduli were also improved with low water absorptivity, which makes CFF-BP PRC a good engineering material. Similarly, the specific impact strength of both samples at the 15 Wt.% matches (6.39 J/m^2). This means that both CFF-BP PRC samples have competitive properties and applicability for ballistic applications (Figure 10).

The produced CFF-BP PRC morphology was examined using SEM analysis to evaluate the dispersion efficiency of CFF-BP in epoxy resin, as shown in Figure 9. The two extreme end fiber content-based composites, 3 Wt.%, and 15 Wt.% samples, were each investigated for both CFF10-BP PRC and CFF15-BP PRC. Figure 11 shows significant differences in the structural profile of the samples, showing even dispersal and continuity of the CFFs in the CFF-BP PRC matrix. The 3 Wt.% CFF10-BP PRC showed significant surface adhesion with reduced entrapped air at the fractured surface examined. This feature implies that the composite was properly blended even at the least weak surface. It was also observed that the 3 Wt.% CFF15-BP PRC and 15 Wt.% CFF10-BP PRC showed significant entrapped air within their structure. Additionally, 15 Wt.% CFF15-BP PRC had micro-cracks. Hence, it was established that CFF-BP PFC had good adhesion, compatibility and miscibility within the matrix, which is responsible for the improved mechanical strength.

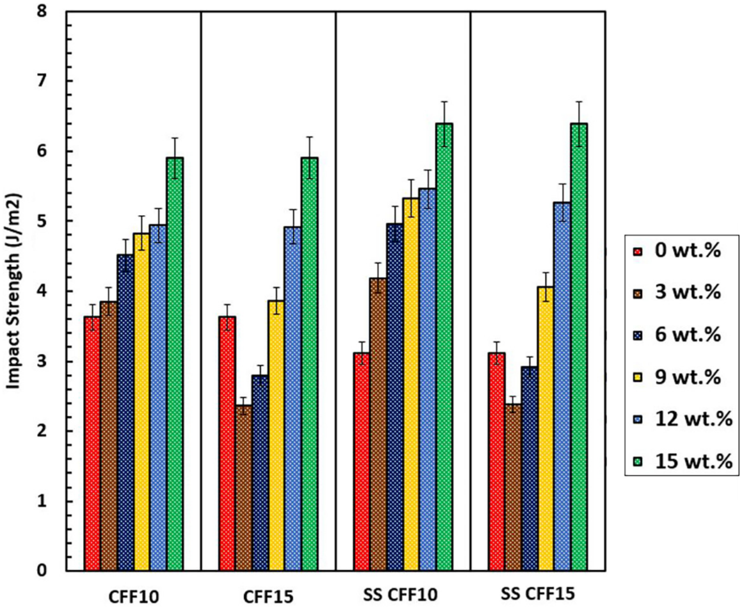

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Figure 10.
The impact strength of different CFF-BP PRC composites and pristine sample

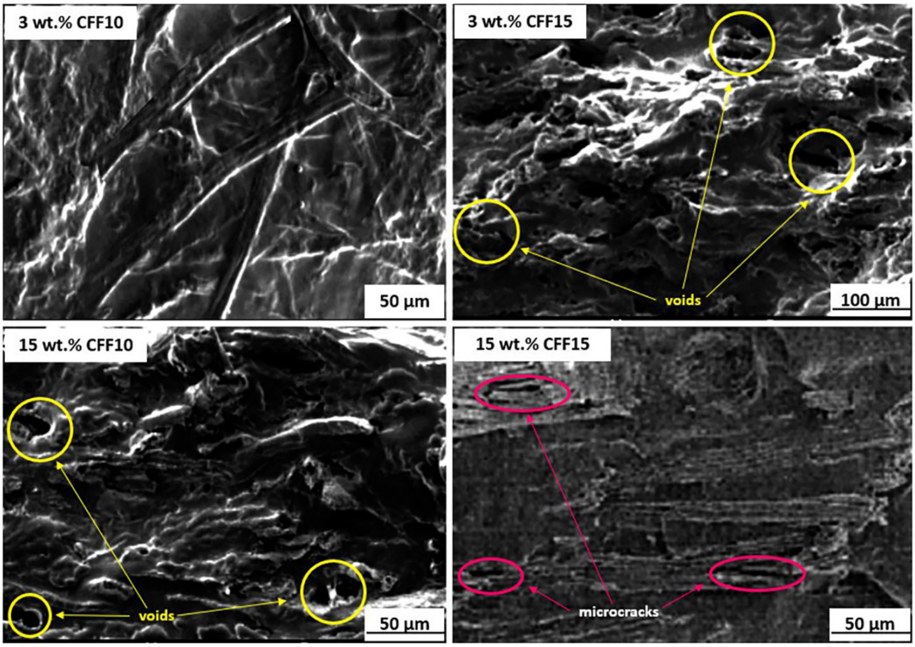

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Figure 11.
SEM image of different CFF-BP PRC composites and pristine sample

Conclusion

This research successfully used chicken feather-derived rachis fiber and bamboo particulate as reinforcements in epoxy resins with significant enhancements in the evaluated properties. It was determined that the existence of BP and a hydrophilic polymer backbone in CFF was responsible for the rising water absorption level with absorption time. The density was reduced by 21% in CFF10-BP PRC and 20% in CFF15-BP PRC. Fabricated composites from CFF10-BP PRC showed better overall mechanical properties compared with the CFF15-BP PRC, which confirmed that short fibers are better in the enhancement of randomly dispersed fibers in the epoxy matrix. The specific tensile strength, flexural strength, elastic modulus and flexural modulus for CFF10-BP PRC were 10%, 24.64%, 26.21% and 15.68%, respectively, which were higher than the values from CFF15-BP PRC. However, the ballistic properties of both samples matched. It was discovered that there is a 40% increase in tensile strength and a 54% increase in flexural strength in the CFF-BP PRFC as compared to the pristine sample. Also, there was an overall increase in hardness, elastic modulus, flexural modulus and impact strength by 11%, 139%, 151% and 63%, respectively. Hence, adding these blends of plant and animal-based reinforcements in epoxy with improved performance will further advance the development of green and biodegradable materials for several engineering applications. This innovative material can be used in automotive, aircraft, construction, sports, marine, electronics, renewable energy, medical, consumer goods and environmental sectors – all of which demand materials that are strong, lightweight, resilient and water-resistant. These composites lessen dependency on non-renewable materials and encourage a sustainable economy by using renewable resources and cutting waste. Based on biodegradability and reduced processing energy needs, these agro-based materials support environmentally friendly agricultural techniques and reduce carbon emissions. This research encourages a more ecologically sensitive approach to material science and engineering practices by stimulating innovation and market transformation.

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