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Performance Evaluation of Natural and Synthetic Fibre Reinforced Polypropylene Composites: Effect of Temperature and Gamma Radiation

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Abstract: *In this research work, three sorts of fabric for example, jute, E-glass and carbon Kevlar were chosen to fabricate composites taking polypropylene (PP) as matrix material. Jute/PP, E-glass/PP, and carbon Kevlar /PP based composites were prepared effectively by a conventional compression molding technique. The goal of this investigation is to look at the analyzed properties, for example, tensile strength (TS), elongation at break percentage (EB%), E-Modulus (EM) of jute, E-glass and carbon Kevlar fabric reinforced polypropylene composite. The properties of produced composite were assessed tentatively utilizing automated UTM machine as indicated by ASTM principles. The composite samples were exposed to different intensities of temperature (-2 degree Celsius and 45 degree Celsius) and changes in mechanical properties were analyzed. The impact of gamma radiation likewise examined. The mechanical properties are found to decrease because of treatment with temperature and gamma radiation into the jute, E-glass and Carbon Kevlar fabric reinforced polypropylene composites. The outcomes uncovered that the tensile strength, elongation at break and E-modulus of jute, E-glass and carbon Kevlar fabric reinforced polypropylene (PP) composites were decreased because of treatment with temperature and gamma radiation yet inverse scenario has observed distinctly for E-modulus of E-glass fabric reinforced polypropylene (PP) composites because of treatment with temperature and gamma radiation.*

Keywords: *Carbon Kevlar Fabric, Composite, E-glass Fabric, Gamma radiation, Jute Fabric, Mechanical Properties, Polypropylene (PP), Temperature.*

INTRODUCTION

Composites are a versatile and valuable family of materials that can solve problems of different applications, improve productivity, lower cost, and facilitate the introduction of new properties in materials. The properties of a composite material are governed by the properties of the fibre used to reinforce it. Nowadays, composites materials are broadly used in different diversified applications area because of their excellent and unique combination of physical and mechanical properties (Islam, et al., 2009; Rahman, et al., 2018).

Synthetic fibre reinforced thermoplastic composites are dominating over natural fibre reinforced composites due to their improved strength, stability, corrosion and moisture resistance properties. The problem of using synthetic fibre reinforced composites is that the fibres are not biodegradable. Due to increasing environmental consciousness, composites made of lingo-cellulosic materials as reinforcing fibre and thermoplastic polymers as matrices are exploring day by day (Varada, et al., 2007; Thiruchitrambalam, et al., 2010).

Natural fibres have several advantages; for example, they have its low cost, low density, stiffness, high specific strength and modulus, recyclable, biodegradable, no health risk, easy and safe handling, light weight, easy availability, renewability, non-abrasiveness, easy processing, non-toxicity, high flexibility, acoustic insulation and much lower energy requirement for processing (Gon, et al., 2012; Zaman, et al., 2010, 2013; Mohanty, et al., 2000).

Jute fibre is a one of the most important natural fibre, after cotton which is mostly used for the industrial applications. Among all the natural fibres, jute has comparatively better properties and appealed worldwide attention as a potential reinforcement of polymer composite because of its inherent properties such as high tensile strength, low density, inexpensive and abundantly available in tropical countries (Repon, et al., 2017; Khan, et al., 1999). Cellulose is the crystalline portion of the jute fibre which is mainly responsible for reinforcement of the composites and another important factor is the low micro-fibril which is the main factor to control the properties of the fibre. Many researchers have investigated the various mechanical, thermal and physical properties of jute fibre reinforced composites. Different matrix materials were used in different research such as polyester resin, natural rubber, polypropylene, polyethylene, polycarbonate, epoxy resin, phenol formaldehyde etc (Ahmed and Vijayarangan, 2007; Khan, et al., 2010; Elbadry, et al., 2012; Saha, et al., 1999; Miah, et al. 2011).

Glass fibres reinforced polymer composites have been prepared by various manufacturing technology and are widely used for various applications. Glass fibres are used as a reinforcing agent for many polymer products; to form a very strong and relatively lightweight fibre-reinforced polymer composite material called glass-reinforced plastic and most common types of used glass fibre is E-glass (Aramide, et al., 2012; López, et al., 2012; Ramzan, et al., 2009). The wide application area including electronics, home and furniture, aviation and aerospace, boats and marine, medical, automobiles etc. of glass fibre reinforced composites has also discussed elaborately (Sathishkumar, et al., 2014). Glass fibres are having excellent properties like high strength, flexibility, stiffness and resistance to chemical harm. It may be in the form of roving's, chopped strand, yarns, fabrics and mats. Each type of glass fibres have unique properties and are used for various applications in the form of polymer composites. The mechanical, tribological, thermal, water absorption and vibrational properties of various glass fibre reinforced polymer composites were reported. Many researchers explored many article regarding matrix comprised and properties of composites (Alam, et al., 2010; Gupta, et al., 2001; Faizal, et al., 2006; Avci, et al., 2004; Ellyin and Maser, 2004; Budai, et al., 2011).

Kevlar fibre, due to its unique properties has become very popular as reinforcement in composite materials and its application has growth considerably. It is mainly popular for its increasing applications in industrial and advanced technologies like ballistic armor, helicopter blades, pneumatic reinforcement, sporting goods, etc. Compared to other synthetic fibres, it possesses significantly lower fibre elongation and higher tensile strength and modulus. Many researchers have been conducted characterization of Kevlar fibre and its composites in recent years (Agarwal, et al., 2017; Matthews and Rawlings, 1999; Mallick, 2007; Pregoretti, et al., 2009; Repon, et al., 2019; Hossain, et al., 2015).

Matrix materials play crucial role in fabricating composite materials. Matrices influences the ultimate thermo-mechanical characteristics of the composite and also have a major influence on the interlaminar shear, and on the in-plane shear properties (Akovali, 2001). Polypropylene (PP) possesses some outstanding properties like low density, high softening point, good flux life, good surface hardness, scratch resistance, very good abrasion resistance, low moisture pickup and high impact strength and it is widely used in thermoplastic composites (Khan, et al., 2001).

The objective of this research work is to study the mechanical properties of jute, E-glass and carbon Kevlar fabric by incorporating them into polypropylene matrix to prepare the composites and compare the properties between natural and synthetic fabric reinforced polypropylene composites. Another goal of this investigation was to investigate the effect of temperature and gamma radiation of jute, E-glass and carbon Kevlar fabric reinforced polypropylene (PP) composites. The composites were tested to evaluate the tensile properties such as tensile modulus, elongation percentage, and E-Modulus.

Figure 1a. Jute fabric

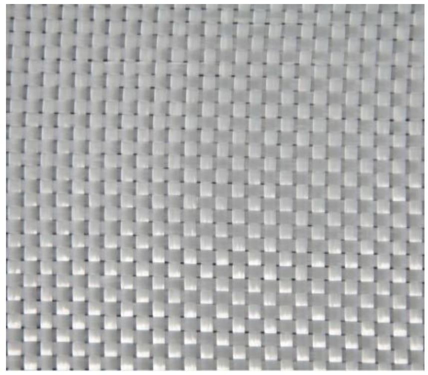

Figure 1b. E-glass fabric

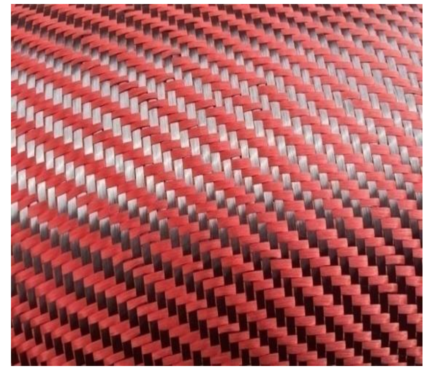

Figure 1c. Carbon Kevlar fabric

Figure 1. Images of reinforcement materials

Materials and Methods

Materials

Three kinds of fabric, for example, jute, E-glass and carbon Kevlar were chosen as the reinforcement in this investigation. Jute fabrics having plain weave structure were collected from Jute Research Institute, Dhaka, Bangladesh. E-glass fabric of plain weave structure and carbon Kevlar fabric of twill weave structure were purchased from CHN Carbon Fiber Technology Co. Ltd., China. Carbon and Kevlar used in this experiment were T 300 (3K) and K 29 (1500D) respectively. **Figure 1** shows the images of fabrics used in this experiment. The ends per inch (EPI), picks per inch (PPI) and areal density (GSM) of the jute, E-glass and carbon Kevlar fabrics are mentioned in the **table 1**. Polypropylene (PP) was utilized as matrix material in this experiment. Polypropylene (trade name: Cosmoplene) was purchased from Polyolefin Company Private Ltd., Singapore. **Figure 2** shows the molecular structure of polypropylene (PP).

Table 1. Fabric specification

Quality parameters	Fabric type & value		
	Jute	E-glass	Carbon Kevlar
Weave structure	Plain	Plain	2×2 twill
Ends Per Inch (EPI)	18	7	14
Picks Per Inch (PPI)	12	6	16
Areal weight(GSM)	340	180	200

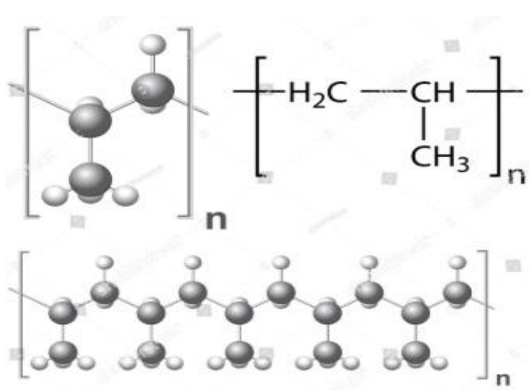

Figure 2. Molecular structure of poly-propylene (PP)

Methods

Fabrication of Composites

Firstly, Polypropylene sheets were made from granules by placing them in between two steel plates in a heat compression molding machine maintaining the temperature 220 degree and pressure 5 ton for 10 minutes. The model of the machine was 3856, Carver Incorporation, USA. Cooling was done another compression molding machine of the same model for 5–7 min at room temperature using 5 metric ton pressure. The resultant polypropylene sheets were cut to the desired size (12 cm × 12 cm) for composite manufacturing. Then, Jute, E-glass and Carbon Kevlar fabric reinforced composites were prepared by using polypropylene sheet in both sides. Here, the temperature and pressure were kept as 220 degree Celsius and 8 ton respectively for 10 minutes. The silicon paper was used for making both polypropylene sheet and composites. Testing specimens were prepared from the composite sheet by cutting with grinding machine carefully. Here, matrix to reinforcement ratio was maintained as 70:30 for preparing all composite samples.

Determination of Tensile Strength, Elongation at Break and E-modulus

The tensile properties such as tensile strength (TS), elongation at break percentage (EB%) and E- modulus (Y) of the prepared composites were evaluated by a universal testing machine (UTM) (Model: H50KS-0404, HOUNSFIELD, series S, UK) at Institute of Radiation and Polymer Technology Laboratory, Bangladesh Atomic Energy Commission, Dhaka, Bangladesh. The specimens were prepared according to ASTM D638 standard. Crosshead speed of 10 mm/min and a gauge length 20 mm were maintained during testing. Equation 1, 2 and 3 were used for measuring the tensile strength, elongation at break percentage and E-modulus respectively (Abdullah-Al-Kafi, et al., 2006; Repon, et al., 2019). Prior to testing all the testing specimens were conditioned at 25°C and 50% R.H for 48 hours. All the mechanical properties of composites were tested under the similar conditions. The average value of five samples was taken as the final value of all tests.

$$\text{Tensile strength, (TS)} = \frac{\text{Fmax}}{\text{A}} \qquad (1)$$

Where, F_{max}= Maximum load applied to the sample and
A= Cross-sectional area of the sample.

Percentage of elongation-at-break was obtained by the following relation:

$$\text{EB (\%)} = \left(\frac{\Delta L_b}{L_0}\right) \times 100 \qquad (2)$$

Where, ΔL_b = Extension at break point and L_0= Original length of the sample.

$$\text{E-modulus, (Y)} = \frac{d\sigma}{d\varepsilon} \qquad (3)$$

Where, $d\sigma$ = Stress at yield point and $d\varepsilon$ = Strain at yield point

Irradiation

The composite samples were exposed to irradiation for dose of 6 krad by using the available gamma source of Cobalt 60 (90 kCi) of the Institute of Radiation and Polymer Technology Laboratory, Bangladesh Atomic Energy Commission, Savar, Dhaka, Bangladesh.

Temperature

The composite samples were exposed to 45degree Celsius temperature for 2 hours and -2degree Celsius temperature for 24 hours separately at the Institute of Radiation and Polymer Technology Laboratory, Bangladesh Atomic Energy Commission, Savar, Dhaka, Bangladesh.

Results and Discussion

Tensile Properties

Tensile Strength

Figures 3, 4 and 5 depicts the tensile strength of jute, E-glass and carbon Kevlar fabric reinforced polypropylene composite. It was observed that the tensile strength of jute, E-glass and carbon Kevlar fabric reinforced polypropylene (PP) composites were decreased due to treatment with temperature and gamma radiation. In case of jute fabric reinforced polypropylene (PP) composites, the tensile strength was decreased as 12.92%, 20.43% and 10.47% for the 45degree temperature treated sample, -2degree temperature treated sample and gamma irradiated treated sample respectively as compared to control sample **(figure 3).** In case of E-glass fabric reinforced polypropylene (PP) composites, the tensile strength was decreased as 9.67%, 23.01% and 7.63% for the 45degree temperature treated sample, -2degree temperature treated sample and gamma irradiated treated sample respectively compared to control sample **(figure 4).** In case of carbon Kevlar fabric reinforced polypropylene (PP) composites, the tensile strength was decreased as 12.38%, 5.51% and 21.61% for the 45degree temperature treated sample, -2degree temperature treated sample and gamma irradiated treated sample respectively compared to control sample **(figure 5).** The tensile strength of composite materials is straightly depending on the strength and modulus of the reinforcing fibres, orientation and length of the fiber, fiber loading, as well as fiber-matrix interfacial adhesion.

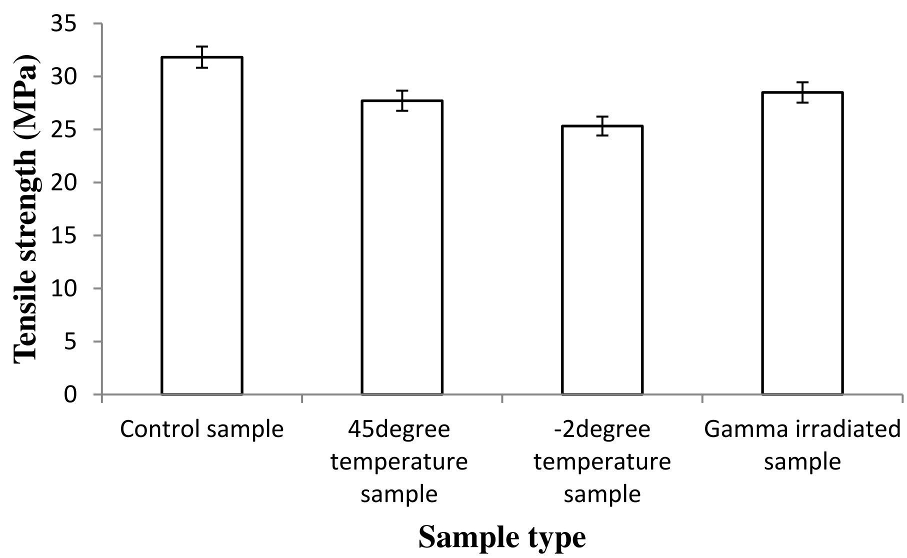

Figure 3. Tensile strength of Jute/PP composite

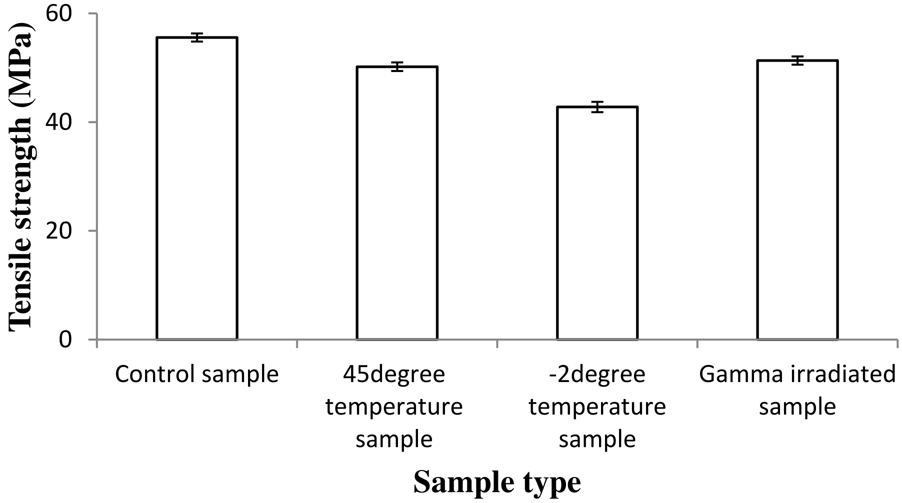

Figure 4. Tensile strength of E-glass/PP composite

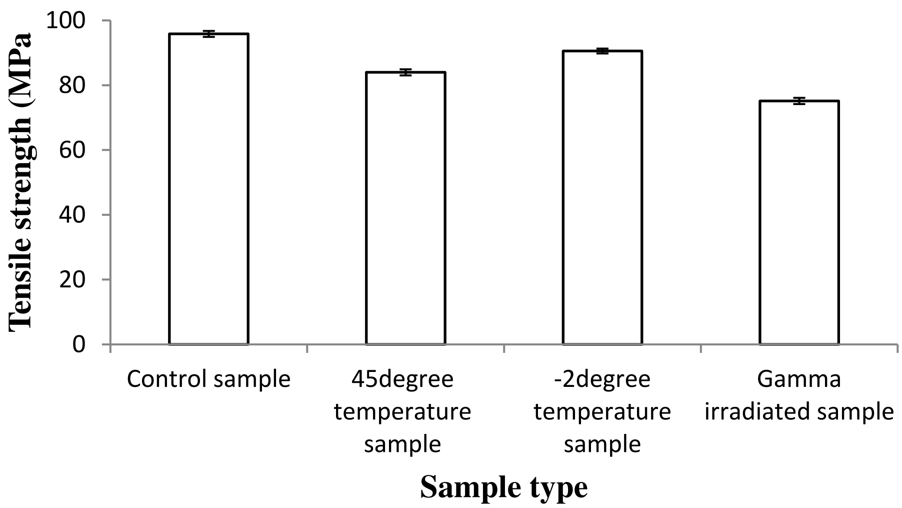

Figure 5. Tensile strength of Carbon Kevlar/PP composite

Elongation at Break

The elongation percentage at break of jute, E-glass and carbon Kevlar fabric reinforced polypropylene composite specimens are presented in figure 6, 7 and 8. It was observed that the elongation percentage at break of jute, E-glass and carbon Kevlar fabric reinforced polypropylene (PP) composites were decreased due to treatment with temperature and gamma radiation. In case of jute fabric reinforced polypropylene (PP) composites, the elongation percentage at break were decreased as 6.18% and 7.87% for the 45degree temperature treated sample and -2degree temperature treated sample but 1.97% increased for the gamma irradiated treated sample as compared to control sample **(figure 6).** In case of E-glass fabric reinforced polypropylene (PP) composites, the elongation percentage at break were decreased as 33.56%, 37.87% and 39.74% for the 45degree temperature treated sample, -2degree temperature treated sample and gamma irradiated treated sample respectively compared to control sample **(figure 7).** In case of carbon Kevlar fabric reinforced polypropylene (PP) composites, the elongation percentage at break were decreased as 45.49%, 38.75% and 41.45% for the 45degree temperature treated sample, -2degree temperature treated sample and gamma irradiated treated sample respectively compared to control sample **(figure 8).**

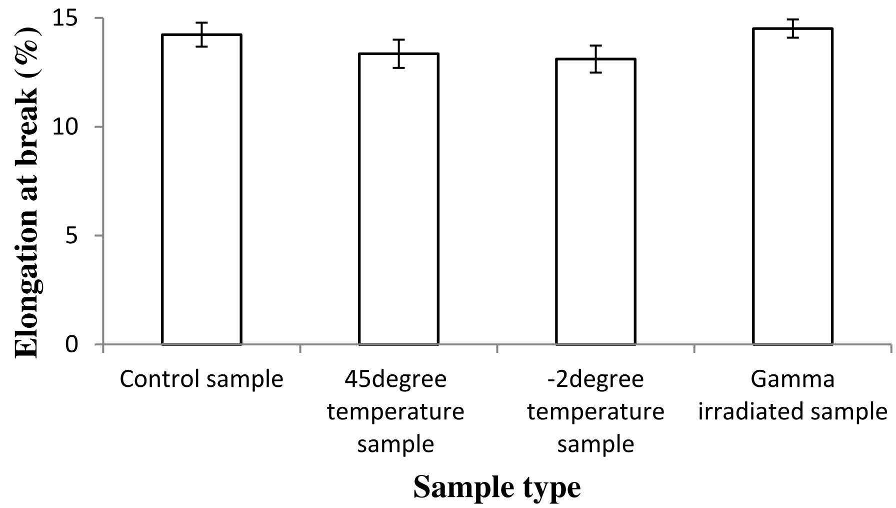

Figure 6. Elongation at break % of Jute/PP composite

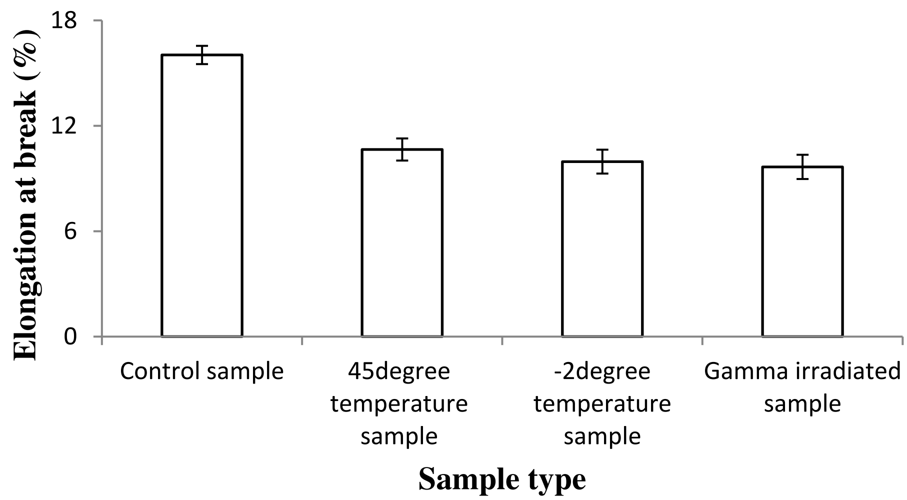

Figure 7. Elongation at break % of E-glass/PP composite

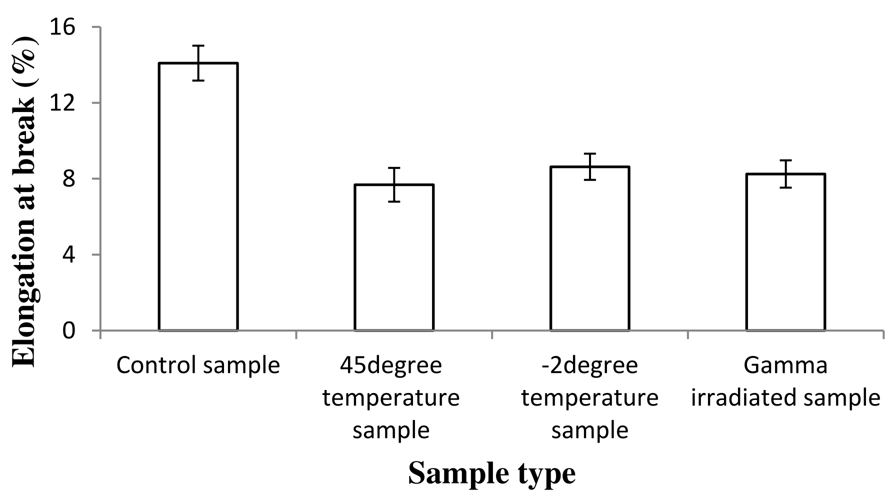

Figure 8. Elongation% of Carbon Kevlar/PP composite

E-Modulus

Figures 9, 10 and 11 illustrates the E-Modulus of jute, E-glass and carbon Kevlar fabric reinforced polypropylene (PP) composites. It was observed that the E-Modulus of jute and carbon Kevlar fabric reinforced polypropylene (PP) composites were decreased due to treatment with temperature and gamma radiation but opposite scenario was observed for E-glass fabric reinforced polypropylene (PP) composites. In case of jute fabric reinforced polypropylene (PP) composites, the E-Modulus were decreased as 22.74%, 15.21% and 2.81% for the 45degree temperature treated sample, -2degree temperature treated sample and gamma irradiated treated sample respectively compared to control sample **(figure 9)**. In case of E-glass fabric reinforced polypropylene (PP) composites, the E-Modulus were increased as 4.99%, 2.69% and 6.14% for the 45degree temperature treated sample, -2degree temperature treated sample and gamma irradiated treated sample respectively compared to control sample **(figure 10).** In case of carbon Kevlar fabric reinforced polypropylene (PP) composites, the E-Modulus were decreased as 24.57%, 30.17% and 29.99% for the 45degree temperature treated sample, -2degree temperature treated sample and gamma irradiated treated sample respectively compared to control sample **(figure 11).**

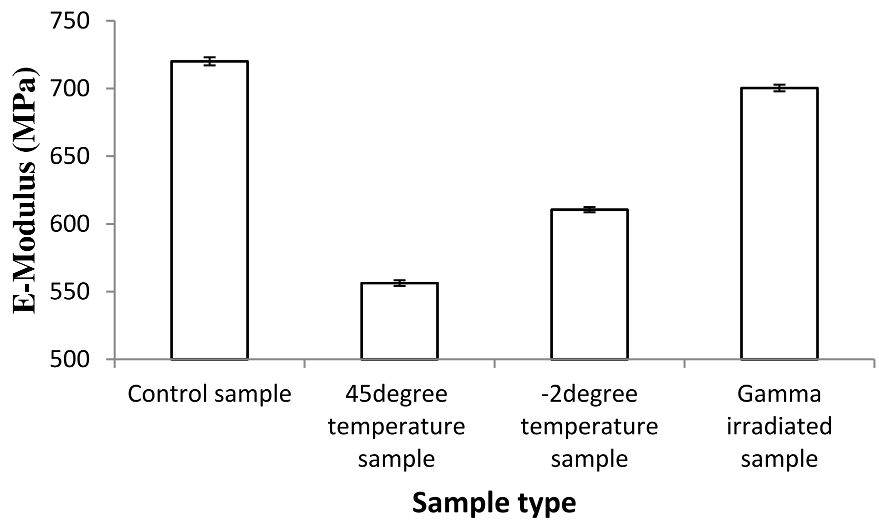

Figure 9. E-modulus of Jute/PP composite

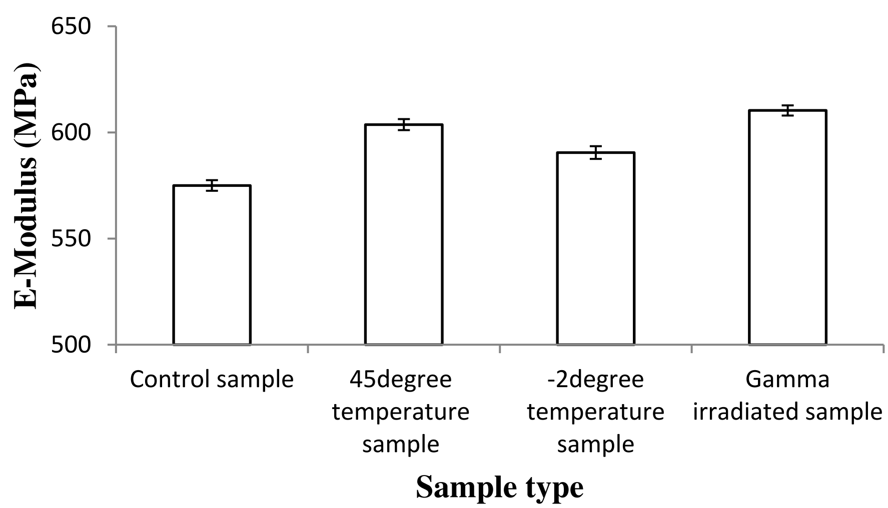

Figure 10. E-modulus of E-glass/PP composite

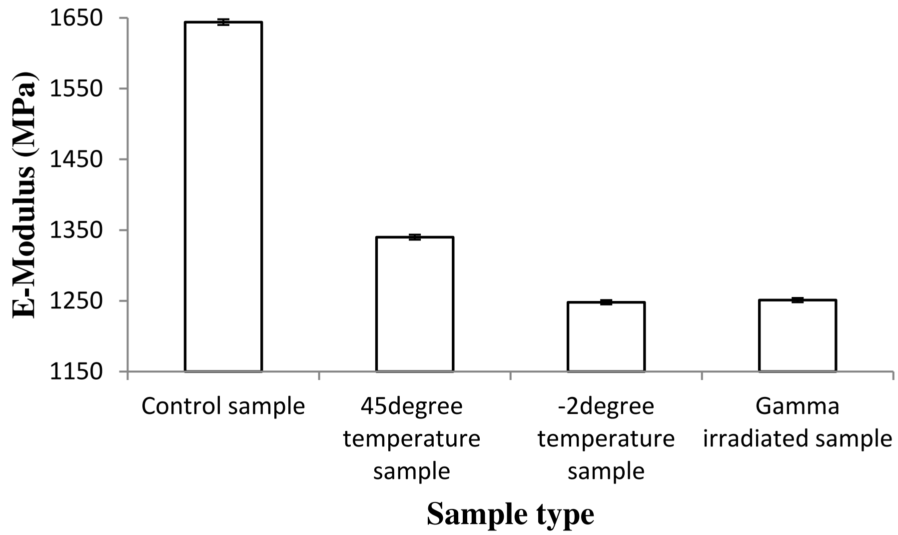

Figure 11. E-modulus of Carbon Kevlar/PP composite

Conclusions

In this work, tensile properties, for example, tensile strength, elongation at break and E-modulus of jute, E-glass and carbon Kevlar fabric reinforced polypropylene composites were explored. It was seen that the tensile strength, elongation at break and E-modulus of jute, E-glass and carbon Kevlar fabric reinforced polypropylene (PP) composites were decreased because of treatment with temperature and gamma radiation but opposite scenario has observed only for E-modulus of E-glass fabric reinforced polypropylene (PP) composites because of treatment with temperature and gamma radiation. Further investigation will be done to improve processing, to expand the application fields for jute, E-glass and carbon Kevlar composites. For improving the composites properties, the fibres may be treated with various chemicals and matrix blend with suitable chemical for making the composites.

Author Contributions

The objectives and methodology of this works were proposed by Md. Reazuddin Repon and Ruhul Amin Khan. The specimen fabrication, characterization and data treatment carried out by Md. Reazuddin Repon, Md. Shariful Islam and S. M. Mehedi Hasan. The article was written by Md. Reazuddin Repon and revised by all authors.

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Conflicts of Interest

The authors declare no conflict of interest.

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