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Mechanical and Statistical Characteristics of Chicken Feather Fiber Reinforced Polymer Composites

G. Hemath Kumar[1], H. Mohit[2]
[1]*Department of Mechanical Engineering, Madanapalle Institute of Technology and Science, Andhra Pradesh, India*
[2]*Senior Research Scientist, Composite Research Center, Ambattur, Chennai, India*

Abstract: The consumption of chicken meat is increasing day by day because of its popularity in non-vegetarian population. India's total chicken meat consumption for 2017 is forecast at 4.49 million metric tons. The development of poultry production not only increases the valuable products like chicken meats but also the poultry waste. In recent years, around 12.1 million tons of poultry waste produced in India from poultry industries. These wastes produce volatile organic carbon, harmful carbon dioxide and leachates, which is harmful for the humankind as well as environment. The utilization of these waste as valuable products will not only surplus the economy but also protect from human and environmental hazard. In the present work fibre, reinforced composite was developed and their mechanical properties were determined. The poultry wastes like feathers of the chicken was converted into fibers and used as the reinforcing material in the developed polymer based composites. Mechanical properties of waste chicken feather fiber reinforced vinyl ester composites were studied. The microstructure observations indicate the uniform distribution of fibers in vinyl ester matrix. Mechanical properties of pure resins and chicken keratin fiber composites were compared and observed that fiber reinforced composites have better mechanical properties under 10 wt. % of fiber loading than neat resin. Statistical analysis was carried out to determine the mutual relationship among different parameters obtained in this study. The investigation is to convert the poultry wastes into useful products, which can be used in different industrial applications such as automobile, aircraft and building materials.
Keywords: Alkaline Treatment; Chicken keratin fiber; Modulus; Morphological Properties; Strength

I. INTRODUCTION

In recent years, the consumption of chicken meat has increased in India due to rise in population and popularity of chicken meat among non-vegetarian population. The increasing consumption of chicken meat produces large amount of wastes, which is usually dumped at nearby area. The accumulation and degradation of these waste produces dangerous gases such as amines, mercaptans, sulphides etc. and unpleasant odor, which causes health hazard as respiratory problems [1]. These wastes also produce high prospective volatile organic carbon, harmful carbon dioxide and leachates [2, 3].

The quantity is set to rise every year because of continual progress in poultry industry and increase in chicken food products [4]. The chicken feathers could be used as valuable product because of the presence of keratin (90 %wt.) which is highly durable and insoluble protein [5]. Keratin mainly consists of proline, cysteine, serine and lysine are cross-link with each other by forming hydrogen or disulfide bonds resulting in fibers that are strong, light weight, tough and good insulating properties [6]. The chicken feather mainly consists of 60% hydrophobic amino particles and remaining 40% is hydrophilic amino acids [7]. Chicken feathers do not have required length for processing in textile machines. As a result it is not suitable for making woven fabrics and can be spun with yarns in 100% form. It has observed that feathers can be mixed with cotton and converted into spun yarns [8]. The young's modulus and tensile strength of chicken feather fiber was observed 6 GPa and 300 MPa respectively which is better than wool type of fibers [9]. Feathers were used as a secured layer added on the surface of yarns to increase the performance of weaving [10]. It was found that chicken feathers improved abrasion resistance and tensile strength of yarn. The size of feather was decomposed in sludge without releasing the amount of ammonia content. It was recommended that keratin can be substituted with poly vinyl alcohol which is frequently applied in sizing of textile but it is more costly and non-degradable in effluent treatment plants [11]. The fiber extracted from feathers can be applied in various applications such as films, cosmetology, textile, medical, agriculture, composite, hydrogel and other industries. Currently, it was noticed that there are no vast scale industrial application for feathers. On the other hand, feather keratin was developed into protein fibers and scaffold for tissue engineering [12].

Keratin fibers were dissolved in alkali metal hydroxide in the presence of swelling agent and mixed with poly vinyl alcohol before the electro-spun process. It was examined that regeneration of keratin is suitable for producing high resistant keratin fiber due to the absence of cysteine residues in disulphide bonds [13]. In another study, chicken feathers were washed with 5% of non-ionic liquid soap solution followed by rinsing and drying in natural light. Then the feathers were sterilized for 30 min at 21 ºC in 95% of ethanol. After the sterilization process, feathers were rinsed with water and dried in atmospheric condition. It was found that internal barb of feathers have several void which is appeared in SEM [14]. The chicken feather was also extracted by sterilization process with water three times, detergent and 5% of sodium chlorite. It was observed that fibers have potential of spinning and textile applications based on the comfort, touch, liquid permeability, lightness, brightness and its structural properties [15]. Chicken feathers was soaked in alcohol for 24 hours, washed with water soluble organic solvent and then dried in furnace under 60 ºC for 24 hours. The length of fibers were 10 – 30 mm separated from quill using scissors. After the extraction, the fiber was used as reinforcement material in PLA composite which showed the improvement in mechanical and thermal properties [16]. The chicken feather fiber reinforced with vinyl ester and polyester showed that there is decrease in flexural and tensile property due to increase in fiber content [17]. The potential of chicken feather composites for electronic application realizes that there is lower value of dielectric properties compared with other commercial printed circuit boards [18].
From the literature survey, it has shown that washing and sterilization process improves the potential of chicken feather fiber, which can be applied as reinforcement material in polymer materials. The main objective of this paper to study the chemical treatment and effect of fiber reinforcement on mechanical and morphological properties of polymer composites, which can be, applied in automotive parts and air conditioning ducts.

II. MATERIALS AND METHODS

A. Extraction of Chicken Feather Fiber

The chicken feather was collected from various poultry industries in the form of fringe and separated into two forms such as barb and quill, and considered as no treatment process. In water treatment, feathers were cleaned with fresh tap water of 6.5 pH, to remove dirt and blood particles. Then, dried in sunlight for 24 hours in order to reduce the micro-organisms effect and remove moisture content with the help of heat radiation. Finally, fibers were immersed into ethanol solution for 24 hours to sterilize odor and dried in sunlight again for 8 hours to withdraw the residual moisture content is denoted as alcoholic treatment. The average length and diameter of feather fiber used in this study were approximately 250 and 30 µm respectively.

B. Matrix Material

The vinyl ester was procured from Sakthi Fibers Glass Inc., Chennai, India. In vinyl ester, 2 wt.% of promoter, accelerator (Methyl Ethyl Ketone Peroxide) and catalyst (Cobalt octate) were added with the resin during the fabrication process.

C. Fabrication of Polymer Matrix Composites

The waste chicken feather fiber reinforced polymer matrix composite was fabricated by wet layup technique. The resin mixture composite was poured inside the cavity of dimensions 260 x 130 x 5 mm and distributed evenly with brush. The extracted chicken feather was placed on the mixture and load of 50 kN was applied at the top surface. After curing process, the specimen was removed from mould cavity and dried in furnace at 60ºC for 2 hours to remove the residual moisture content.

D. Polymer Composite Characterization

The various tests such as tensile, flexural and compression were carried out in Tinius Olsen (H-15 kN capacity) universal testing machine under room temperature and relative humidity of 65±2%. Tensile properties of chicken feather fiber reinforced vinyl ester composites were measured according to ASTM D 3039/D3039M-14 with the specimen size of 250 x 25 x 5 mm and cross head speed of 2 mm/min. Flexural properties of composite material were determined using three point bending test method as per ASTM D 790. The size of specimen was 100 x 25 x 5 mm and cross head speed of 2 mm/min. The compression test was performed for the specimen size of 15 x 10 x 5 mm with cross head speed of 2 mm/min as per ASTM D695. The impact test was conducted on izod test set up of dimensions 65 x 12.5 x 5 according to ASTM D256.
The fiber and composite were ion sputtered and top surface of the specimen was examined from FE-SEM, Hitachi, Europe under 500 X magnification and 15 kV secondary electrons under vacuum condition.
The chicken feather fiber reinforced polymer composites sample were converted into fine powder of 200 mg was examined in Rigaku Ultima IV X-Ray Diffractometer, Tokyo, Japan with 2θ angle varies from 5° to 60° and step size of 0.05°.

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The FTIR analysis was performed in Perkin Elmer Spectrum 2, USA instrument. The sample was prepared with 95% of KBr and 5% of chicken fiber composite. For each fiber or composite sample, the chemical changes were determined under the frequency of 4000 – 400 cm^{-1} with resolution of 1 cm^{-1}.

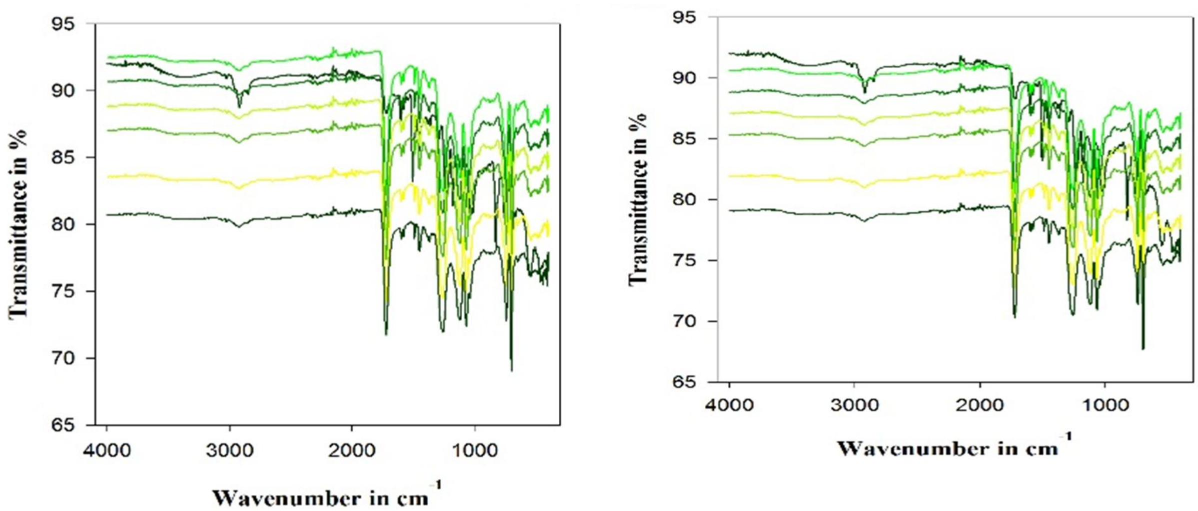
The statistical calculations were performed for chicken feather fiber reinforced vinyl ester composites from SPSS software with confidence level of 95% ($\alpha = 0.05$) using two way ANOVA method.

III. RESULTS AND DISCUSSION

The results obtained in this investigations are explained in details in subsequent sub sections.

A. FTIR Spectra

The chemical nature of individual components regulates the chemical properties of fabricated composites. Fig. 1 (a) and (b) shows the FTIR spectrum of vinyl ester reinforced with chicken feather fibers varying from 0 to 15 wt.%. The sample VERW and VERA determined the three peaks between 1215 and 1165 cm^{-1} are relates to C-O stretching bond, represents the reference to vinyl ester composites due to same wavenumber when compared with pure thermosetting resin. Moreover, the large peaks also found between 1200-1150 cm^{-1} is corresponds to C-O-C with hydrogen bonds for both barb and quill type of fiber reinforced composites. The wavenumber of 1910 cm^{-1} is observed in both the samples of quill and barb samples is tends to peaks of C=O stretch bond. The bands of fresh water and alcohol reinforced vinyl ester composite was found at 1605 and 1565 cm^{-1} respectively shows the plane bending of amino group and small improvement in structures of keratin fiber. The peak at 1235 and 1175 cm^{-1} indicates the carboxylic and cyano-nitrile groups respectively for both the type of composites. Finally, addition of keratin fibers above 10 wt.% showed increase in nitrile bonds and tends to decrease the degree of crystallinity for both epoxy and vinyl ester composites [19- 21].

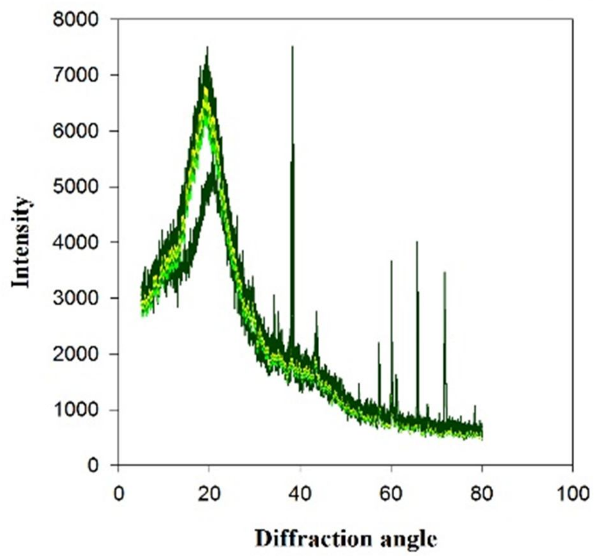


(a) (b)

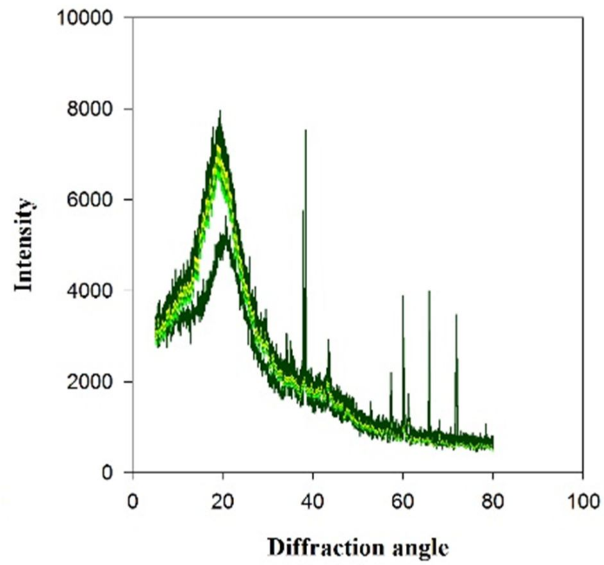
Fig. 1 FTIR spectroscopy of chicken feather fiber reinforced polymer matrix composites (a) VERW and (b) VERA

B. Effect on XRD Pattern

The XRD diffractographs of vinyl ester reinforced with chicken feather fiber by varying from 0 to 15 wt.% are presented in fig. 2 (a) and (b). Most of the composite samples were found to be amorphous in nature and showed larger number of crystalline phases. It is clearly found that the semi-crystalline structure of vinyl ester and epoxy contributed for the peaks nearly at 25º, 28º and 32º. The diffractions were tracked between 45º and 60º to indicate the changes in crystallinity index. The fabricated chicken fiber composites shows diffraction peaks at 44º and 48º signifies the structure of pure vinyl ester and epoxy resin respectively remained same as compared with other fiber reinforced composites. It is also observed that the fiber reinforced composites for VERW and VERA have narrow peaks at 13.5º and 13.9º respectively and d-spacing values ranges from 1.6 x 10-3 to 1.93 x 10-3. The table 1 shows the crystallinity index, particle size and d-spacing values for both epoxy and vinyl ester composites reinforced with chicken feather both barb and quill. The crystallinity index of chicken feather fiber reinforced polymer matrix composite increased upto 10 wt.% and further addition leads to decrease due to increase in d-spacing, particle size and presence of high amino acid content examined from FTIR spectra [22, 23].



(a)



(b)

Fig. 2 XRD of chicken feather fiber reinforced polymer matrix composites (a) VERW and (b) VERA

As a result, quill fiber reinforced vinyl ester composite exhibited highest crystallinity index (35.63%) and improved by 1.06 times than epoxy composite.

Table 1 Crystallinity index, d-spacing and particle size of chicken feather fiber reinforced polymer composites

	Vinyl Ester Resin		
Fiber Content	CI	P_s	d x 10^{-3}
0 wt.%	31.9± 3.22%	12.2±2.59%	1.81±2.45%
Fresh water			
2.5 wt.%	32.60±3.44%	12.58±2.72%	1.77±2.62%
5 wt.%	33.25±3.67%	12.96±2.86%	1.74±2.81%
7.5 wt.%	33.92±3.92%	13.35±2.99%	1.71±3.01%
10 wt.%	34.59±4.19%	13.75±3.14%	1.67±3.23%
12.5 t.%	30.36±3.97%	14.17±3.29%	1.87±3.03%
15 wt.%	30.97±4.24%	14.59±3.45%	1.91±3.12%
Alcohol			
2.5 wt.%	33.58±3.34%	12.84±2.67%	1.71±2.73%
5 wt.%	34.25±3.56%	13.22±2.80%	1.67±2.93%
7.5 wt.%	34.93±3.81%	13.62±2.94%	1.64±3.14%
10 wt.%	35.63±4.07%	14.03±3.08%	1.60±3.36%
12.5 wt.%	31.27±3.85%	14.45±3.23%	1.87±3.03%
15 wt.%	31.89±4.12%	14.88±3.38%	1.91±3.12%

C. Mechanical Properties

Fig. 3 (a) and (b) shows the tensile strength and %elongation of chicken feather fiber reinforced polymer composites. The results shows that the increase in tensile strength and %elongation upto 10% of weight fraction due to strong adhesion between the fiber and resin material. The excess addition of fibers leads to decrease in properties, which indicates the presence of excessive fibers than matrix and poor adhesive strength within the matrix. The tensile properties of quill fiber reinforced composites indicate significantly higher than the barb type fiber for vinyl ester matrix.

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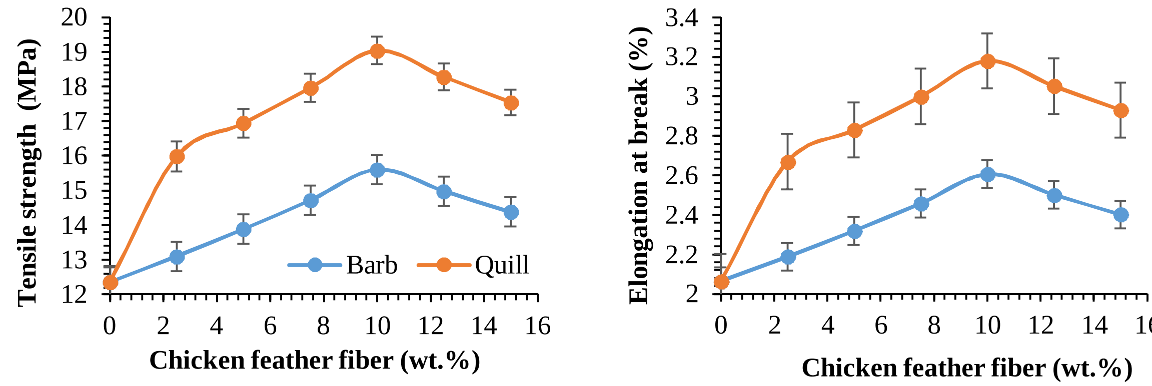


(a) (b)

Fig. 3 Tensile properties of chicken feather fiber vinyl ester composites (a) Tensile strength in MPa and (b) Elongation at break in %

The compression strength for both vinyl ester and epoxy composites reinforced with chicken barb and quill fiber is shown in fig. 4. The compression strength of the composites increases from 2.5 to 10 wt.% as compared with pure resin due to stronger interfacial bonding between the fibers and matrix. Further addition of fibers tends to decrease in property by 0.99 times due to weaker adhesive bonding between the fiber and matrix resin. The chicken barb and quill fiber reinforced vinyl ester composites have considerable larger flexural strength and modulus as compared with pure resin. The flexural strength and modulus of chicken fiber reinforced composites shown in fig. 5 (a) and (b). It is observed that there is an improvement in flexural properties by increasing the fiber loading up to 10 wt.% with the effect of uniform distribution of fiber contents.

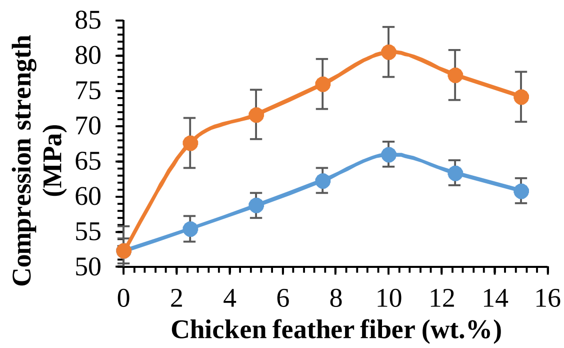
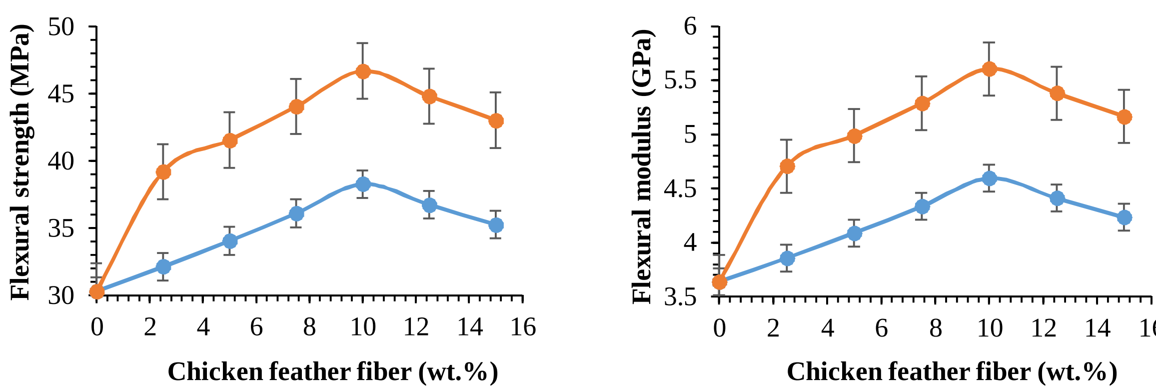


Fig. 4 Compression of chicken feather fiber vinyl ester composites



(a) (b)

Fig. 5 Flexural properties of chicken feather fiber vinyl ester composites (a) flexural strength in MPa and (b) flexural modulus in GPa

The impact property of the material is another supreme characteristic of composite structure, due to its importance in various applications such as aircraft, architecture and automotive applications. Figure 9 shows the results of impact energy of chicken barb and quill fiber reinforced vinyl ester and epoxy composites.

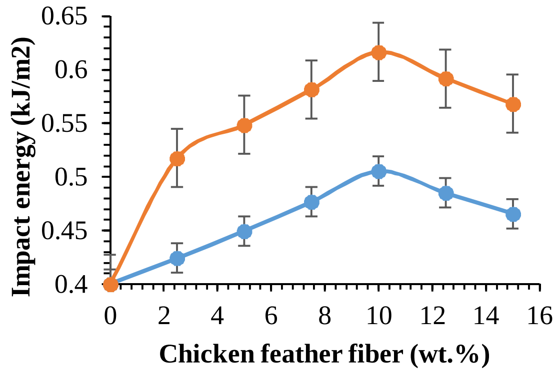


Fig. 6 Impact strength of chicken feather fiber vinyl ester composites

The value of impact energy of quill reinforced composite has better value than barb type for both the resin matrix composites up to 10 wt.% of fiber loading due to short fiber reinforcement natures (Das et al., 2015; Reddy & Yang, 2007; Cheng et al., 2009). Furthermore, vinyl ester composites reinforced with quill fiber improved overall mechanical properties by 1.22 times than neat polymer.

D. Morphological Property

The microstructural of chicken fiber reinforced vinyl ester and epoxy composites were studied by using scanning electron microscope. The micrographs for vinyl ester with different weight fraction of fibers are shown in fig. 7 (a) – (l). Fig. 7 (a), (b) and (c) shows barb fibers were separated from each other and small gaps are present within the resin matrix. The weight proportion of keratin fiber content increased and uniformly distributed within the vinyl ester matrix which is observed in fig. 7 (d). Further addition of fibers tends to formation of voids and loss of network between the barbules is also noticed in fig. 7 (e) and (f). The microstructure of quill fiber vinyl ester composite have uniform distribution of chicken fiber within the polymer matrix is shown in fig. 7 (g), (h) and (i). The network chain is formed by chicken quill fibers as reinforcement in composite is observed in figure 10 (j) and further addition of quill fibers tends to clogging of fibers in network form within the vinyl ester matrix is shown in figure 10 (k) and (l) (Uzun et al., 2011). Table 2 shows the p value for vinyl ester composite is lesser than 0.05. It is observed that result found is very highly significant under the confidence level of 95%.

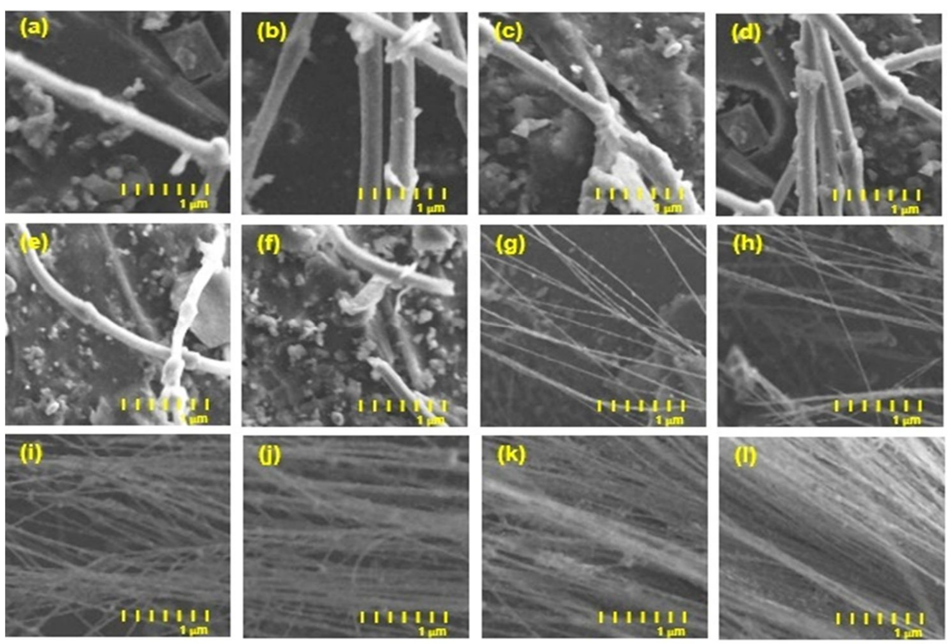


Fig. 7 Morphology of chicken feather vinyl ester composite (a) B2.5, (b) B5, (c) B7.5, (d) B10, (e) B12.5, (f) B15, (g) Q2.5, (h) Q5, (i) Q7.5, (j) Q10, (k) Q12.5 and (l) Q15

Table 2 Statistical analysis of epoxy and vinyl ester composites using two way ANOVA Method

S. No.	Parameters	VER	Remarks
		P value	
1.	Particle size	0.000179	Significant
2.	d spacing	0.00012	
3.	Crystallinity index	4.14×10^{-10}	
4.	Tensile strength	8.75×10^{-6}	
5.	Elongation	0.00441	
6.	Compression strength	4.03×10^{-17}	
7.	Flexural strength	8.21×10^{-12}	
8.	Flexural modulus	6.79×10^{-17}	
9.	Impact Strength	0.00014	

IV. CONCLUSION

The waste chicken feathers collected from poultry industries and treated with water and alcoholic solution. The mechanical and morphological properties of vinyl ester composites reinforced with alcoholic treated chicken fibers were studied. From FTIR spectra, it is found that there is a presence of high amino acid in the composites due to excess addition of fibers and tends to decrease in crystallinity index is also confirmed from X-ray diffraction analysis. In addition, the curves suggest that quill fiber of 10 wt% reinforced in vinyl ester has the best thermal stability as compared with epoxy composites. The quill fibers were found to be uniformly distributed in the vinyl ester and epoxy matrix is noticed from SEM micrographs. From the statistical analysis, it is reveal that there is a significant improvement on mechanical properties of waste chicken feather after the alcoholic treatment. Furthermore, chicken feather fiber reinforced vinyl ester composites are capable to offer favorable mechanical properties for real time applications applied in automobile and aircraft structural parts.

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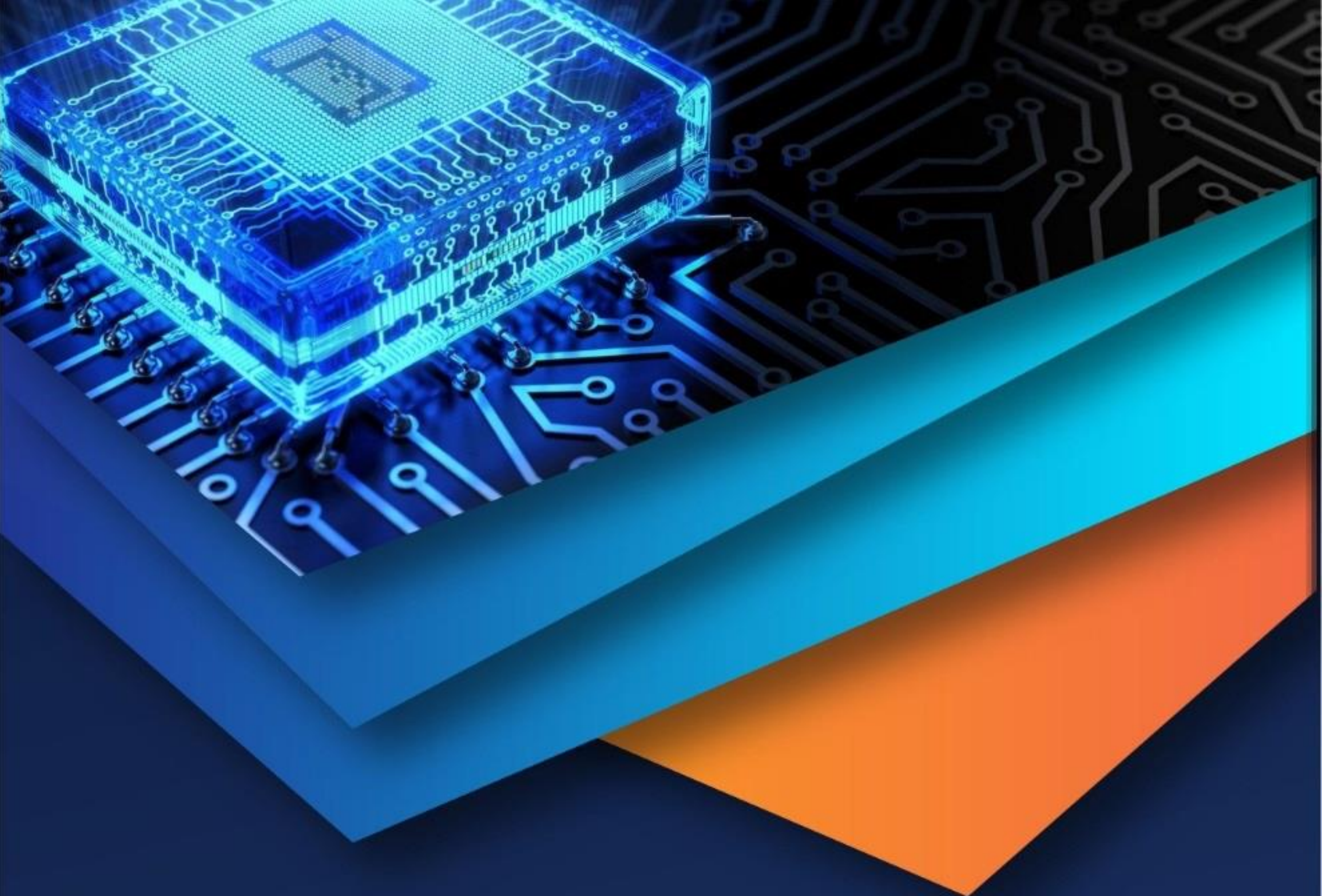

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