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Influence of Processing Variables on Tensile Strength and Water Absorption of Natural Fibers Hybrid Composites

K. Saravanan[a], S. Kubera Sampath Kumar[b], C. Prakash[c], S. Sivamani[d], J. Prakash Maran[e], and G. Rajeshkumar[f]

[a]Department of Fashion Technology, Bannari Amman Institute of Technology, Erode, India; [b]Department of Chemical Engineering (Textile Technology), Vignan's Foundation for Science, Technology & Research (Deemed to Be University), Guntur, India; [c]Department of Handloom and Textiles, Indian Institute of Handloom Technology, Ministry of Textiles, Govt. Of India, Shantipur, India; [d]Engineering Department, University of Technology and Applied Sciences (Salalah College of Technology), Salalah, Oman; [e]Department of Food Science and Nutrition, Periyar University, Salem, India; [f]Department of Mechanical Engineering, Psg Institute of Technology and Applied Research, Coimbatore, India

ABSTRACT

Natural fibers are gaining popularity among researchers and academics for use in polymer composites due to their environmental friendliness and long-term viability.A new series of green composites using chicken feather fiber (CFF) and jute as reinforcing materials in a polypropylene resin-based polymer matrix-were used to fabricate the hybrid composites. This paper examines the impact of molding pressure, temperature, and time on the tensile strength and water absorption characteristics of compression molded hybrid composites. The findings of experiments undertaken to evaluate hybrid composites produced with different fiber fractions and processing parameters are discussed in this paper.When the composites' overall tensile strength was compared, the 100% Jute fiber composite had the highest tensile strength when the maximum pressure, temperature, and time were kept constant. Temperature and pressure have a considerable impact on composite sample tensile strength, whereas time has little influence.As predicted, raising the jute weight percentage in composites increases water absorption.

摘要

天然纤维因其环境友好性和长期生存能力而越来越受到研究人员和学者的欢迎, 用于聚合物复合材料. 以鸡毛纤维 (CFF) 和黄麻为增强材料, 在聚丙烯树脂基聚合物基体中制备了一系列新型绿色复合材料, 用于制备混杂复合材料. 本文研究了模压压力、温度和时间对模压混杂复合材料拉伸强度和吸水性能的影响. 本文讨论了用不同纤维组分和工艺参数制备的混杂复合材料的实验结果. 当最大压力、温度和时间保持不变时, 100%黄麻纤维复合材料的总拉伸强度最高. 温度和压力对复合材料的拉伸强度有很大的影响, 而时间的影响很小. 正如预测的那样, 提高黄麻在复合材料中的重量百分比会增加吸水率.

KEYWORDS
Chicken feather fiber; hybrid composites; jute fiber; polypropylene; tensile strength; water absorption

关键词
鸡毛纤维; 混合复合材料; 黄麻纤维; 聚丙烯; 抗拉强度; 吸水率

Introduction

Natural fibers, such as chicken feathers, and resins, such as polypropylene, offer several benefits. They have a good calorific value and low density, are ecologically friendly, have great acoustic and thermal insulation characteristics, and function as a toughening agent (Gholampour and Ozbakkaloglu, 2020). All of these benefits encouraged scientists to look into the mechanical characteristics of a chicken feather reinforced polypropylene hybrid composite. In addition, as a by-product, approximately 15 million tons of chicken feathers are gathered globally each year.Burying and burning are the most

CONTACT C. Prakash ✉ dearcprakash@gmail.com Department of Handloom and Textile Technology, Indian Institute of Handloom Technology, Fulia, Ministry of Textiles, Govt. Of India, Shantipur, Nadia, West Bengal, India

common ways for disposing of unwanted chicken feathers, and both have negative environmental consequences since they emit greenhouse gases. As a result, chicken feather fiber (CFF) is being used to fabricate composites to solve this problem. It offers a number of features that make it an excellent natural fiber substitute that will not harm the environment when utilized. Chicken feathers comprise 91% keratin, a protein, 8% water, and 1% lipid. Chicken feathers contain amino acids that aid in the formation of hydrogen bonds, resulting in fibers that are both strong and lightweight, with good thermal characteristics. Feathers are hierarchically branching, highly organized structures that are among the most complex keratin structures seen in vertebrates. Feathers make about 5–7% of a chicken's body weight and are an important by-product of the poultry business (Flores-Hernández et al. 2014; Yu et al. 2004).

Additionally, natural fibers are viewed as a viable alternative to synthetic fibers due to their tailored properties such as biodegradability, renewability, non-toxicity, low energy consumption, and lower cost (Sumesh, Kanthavel, and Kavimani 2020).Natural fibers are derived from plants, animals, and minerals. Animal fibers are a viable alternative for fabricating bio-composites (Keya et al. 2019). Keratin provides excellent elasticity and mechanical strength (Gogoi, Chowdhury, and Maji 2021; Bansal et al. Bansal, et al., 2021a, Bansal, et al., 2021b).

Polypropylene (PP) resin is a relatively inexpensive general-purpose resin with excellent mechanical properties, thermal stability, corrosion resistance, and low water absorption rate (Dang et al. 2019; Lila et al. 2018). Additionally, PP is a semi-crystalline polymer that is used in textiles, packaging, construction materials, and automobile components (Hufenbach et al. 2011; Pak et al. 2018). While PP has some desirable properties, they are insufficient to withstand the dynamic loads encountered in real-time applications. To that end, this PP is reinforced with a variety of natural fibers, including flax (Zhong, Kureemun, and Lee 2017), sisal (Jarukumjorn and Suppakarn 2009), kenaf(Zampaloni et al. 2007),jute (Gassan and Bledzki 2000), ramie (He et al. 2015), coir (Zaman and Beg 2014), and sugarcane (Leão et al. 2015).

Chicken feathers may be utilized as a matrix with characteristics comparable to composites made of polypropylene (PP) and jute fiber as reinforcement, resulting in a totally biodegradable composite, according to Reddy et al. A 50/50 fiber/jute composite had a flexural strength of 68 MPa, whereas a 40/60 PP/Jute composite had a flexural strength of 42.7 MPa. It was also discovered that raising the fiber fraction reduced stiffness. At 60 wtpercent of fiber, the modulus of elasticity also decreased (Reddy, Jiang, and Yang 2014).

Huda and Yang (2008) evaluated the mechanical and acoustic characteristics of composites made from powdered chicken quill and polypropylene (PP) to composites made from jute and PP. Quill was thought to have a higher compatibility with PP than jute. The tensile strength of the optimized ground quill composite was lower than that of the pure PP composite, while the flexural strength was comparable. Quill-PP composite's noise reduction coefficient was enhanced by 71%.

Due to the synergistic effect, hybrid composites composed of two natural fibers exhibit superior overall properties to single fiber composites (Ravikumar, Suresh, and Rajeshkumar 2020). As a result, the current work aims to fabricate hybrid composites from CFF and jute fibers and to investigate the effect of processing conditions on the composites' tensile strength and water absorption behavior. Additionally, CFF and jute fiber composites were fabricated separately and compared. Also, SEM and statistical analysis were performed in this work.

Materials and methods

Materials

Feathers of chicken

The feathers of chicken were kindly provided by Suguna Poultry Industry, Tamilnadu, India. To minimize feather fiber variability, feathers were collected from chickens grown under the same conditions. After cleaning the chicken feathers with hot water and sterilizing them with 95% ethanol, they were rinsed with water and air-dried. To maintain fiber length uniformity, the tip and base were cut and removed. Surgical blades were used to cut the barb portions from the chicken feather. The obtained chicken feather fibers have a length of 25–32 mm, a strength of 2.65 g/den, a moisture regain of 12%, and a breaking extension of 1–6% with a density of 1.12 g/cc.

Jute fiber

The long staple fiber of jute was kindly provided by M/s Jothi Jute Textiles Industry, Tamilnadu, India. It was cut into 30 mm length to maintain length compatibility with CFF. Jute fibers have a strength of 36 g/Tex, a moisture recovery of 13.5%, a breaking extension of 1.6%, and a density of 1.48 g/cc.

Polypropylene

The staple fibers of polypropylene (APOLON®) was kindly supplied by M/s Zenith Fibers Ltd., Baroda, India. Polypropylene has a denier of 2.5, a tenacity of 6 g/denier, a melting point of 1600 degrees Celsius, and a density of 0.91 grams per cubic centimeter.This polypropylene is used as a matrix material in composite fabrication.

Methods

Composite board manufacturing

The designation, composition, and percentage of fiber volume fractions (V_f) of the composites used in this study are listed in Table 1.Five different loadings of CFF and jute fibers (50 wt. percent, 37.50 wt. percent, 25 wt. percent, and 12.50 wt. percent) were used in the composite samples, along with a constant polypropylene content (i.e., 50 wt.percent).Variations in the process conditions were used to prepare the samples.Fabrication and properties of fiber composites are strongly influenced by the matrix and fiber proportions.The proportions can be expressed in either weight fractions, which are useful for fabrication, or volume fractions, which are frequently used in property calculations.After the fibers (CFF, jute, and polypropylene) were mixed, they were fed into a carding machine approximately four times to ensure homogeneous blending, and finally the webs were produced.The webs were dried at 115°C for 24 h to remove any remaining moisture.

The levels of variables like temperature (165,175,185 Degree Celsius), pressure (5, 10, 15 Bar) and time (3, 6, 9 Minutes) are chosen based on the melting point of the resin used, final thickness (minimum of 5 mm) expected in the composite board.

Tensile strength test

All specimens for tensile testing were cut into dog-bone shapes.Tensile tests were conducted in accordance with ASTM 1882 L using an INSTRON (Model 4301) Universal Testing Machine equipped with a 1 kN load cell and a 5 mm/min crosshead speed.Tensile tests were conducted until

Table 1. Formulation of composites and fiber volume fraction (V_f).

Designation of Samples	Composition	(V_f) % Reinforcement	(V_f) % Matrix
100% CFF	CFF (50. wt%) + Polypropylene (50 wt.%)	40.54	59.46
75:25 CFF/Jute	CFF (37.50 wt.%) + Jute (12.50 wt.%) + Polypropylene (50 wt.%)	42.1	57.9
50:50 CFF/Jute	CFF (25 wt.%) + Jute (25 wt.%) + Polypropylene (50 wt.%)	39.25	60.75
25:75 CFF/Jute	CFF (12.50 wt.%) + Jute (37.50 wt.%) + Polypropylene (50 wt.%)	40.72	59.28
100% Jute	Jute (50 wt.%) + Polypropylene (50 wt.%)	37.82	62.18

tensile failure was achieved.Seven specimens were tested, and an average of the tested specimens was presented using at least five imitate specimens.

Analysis using a scanning electron microscope (SEM)

A JEOL JSM 6510 high-resolution scanning electron microscope was used to examine the morphology and microscopy of composite materials. To avoid charging under the electron beam, the specimens were placed on a stub and sputter coated with a thin coating of gold prior to examination.

Statistical analysis

An analysis of variance (ANOVA) was performed on experimental data at a 95% confidence level to evaluate the relative impact of process conditions to the tensile strength and water absorption behavior of produced composites, which displays F observed vs. F crucial. A 0.05 *p*-value was chosen.

Results and discussion

Tensile strength and response surface regression equations of CFF and its hybridcomposites

The tensile strength of the CFF and its hybrid fiber reinforced polypropylene composites under various processing conditions is shown in Table 2, and all of the respective composites exhibit superior tensile strength properties at run order 8 compared to other run orders. As shown in Table 1, adding 12.50, 25, 37.50, and 50% jute fiber increases the composite's tensile strength. The tensile strength values for 100% CFF composites obtained from all run orders are compared to those for other fiber loading weight percent composites and presented herein. The 75:25 CFF/Jute composite exhibits a tensile strength increase of 0% to 27%. The 50:50 CFF/Jute composite exhibits a 6% increase in tensile strength to 94%. Tensile strength is increased by 11% to 145% in the 25:75 CFF/Jute composite. The greatest increase in tensile strength was observed in a Jute composite composed entirely of Jute. Tensile strength increases by approximately 45 to 185%. This investigation established that using 50% jute fiber in the manufacturing of composites results in the highest tensile strength properties when compared to 50% CFF composites. The tensile strength of the composite material was determined, and

Table 2. Tensile strength of CFF and its hybrid composites.

	Input factors			Responses				
Run	A: Temperature °C	B: Pressure bar	C: Time min	Tensile strength (100% CFF) GPa	Tensile strength (75% CFF) GPa	Tensile strength (50% CFF) GPa	Tensile strength (25% CFF) GPa	Tensile strength (0% CFF) GPa
1	185	5	6	1.9	1.9	2.1	2.4	2.7
2	175	15	3	1.8	1.9	3.1	4.3	5.3
3	175	10	6	1.7	1.8	2.2	2.9	3.2
4	175	15	9	1.8	1.9	2	3.8	4.8
5	165	10	9	1.6	1.7	1.8	1.9	2.7
6	175	10	6	1.7	1.9	2.1	2.8	3.2
7	165	10	3	1.1	1.6	2.1	3.9	4.2
8	185	15	6	2	2.4	4.4	4.9	5.7
9	185	10	3	1.8	2.3	3.5	3.9	4.4
10	165	5	6	1.3	1.4	1.4	1.7	2.8
11	175	10	6	1.7	1.9	2.3	2.9	3.1
12	175	5	3	1.7	1.9	2.6	2.9	3.8
13	185	10	9	1.8	2	2.1	2.3	2.5
14	165	15	6	1.5	1.7	2.7	2.9	3.9
15	175	5	9	1.8	1.9	1.9	2	2.3

the actual results were used to generate the regression equations. The tensile strength of the composite material was determined after varying the temperature, pressure, and time. Table 3 contains the equations with Y denoting the predicted tensile strength.

Effect of processing conditions on tensile strength of CFF and its hybrid composites

The contour plot depicted in Figure 1 effectively interprets and explains the effects of process variables on mechanical properties. The information provided by the contour plot diagram regarding the interaction of parameters with tensile strength properties is extremely useful when fabricating CFF and its hybrid composites for a variety of applications.

Figure 1 shows the effect of processing conditions on the tensile strength of CFF and hybrid composites samples by keeping the intermediate values of time (6 min), temperature (175°C), and pressure (10 bar). The addition of jute fibers to CFF enhanced the tensile strength of the composites. The tensile strength of the composites rose when the quantity of jute fiber in the composites was increased.

Figure 1(a) illustrates the effect of processing conditions on the tensile strength of a 100% CFF composite and confirms that increasing the temperature directly increases the tensile strength of 100% CFF. However, the maximum tensile strength (1.80 N) was observed as the temperature was increased at the minimum pressure. It was discovered that when pressure was increased, the rate of increase in tensile strength was the smallest, whereas when temperature was increased, the rate of increase in tensile strength was the greatest. This is because polypropylene melts readily at high temperatures and the interface between the fiber surface and resin becomes strong because of the carding process's homogeneous mixing of reinforced fiber and polypropylene in the fiber stage.

The influence of time and pressure on the tensile strength of 100% CFF revealed that the highest tensile strength was attained in the shortest amount of time at moderate pressure. Furthermore, the tensile strength did not diminish or increase over time. As a result, the amount of heat given to the composite appears to be the only determining factor.

The time-temperature relationship for 100% CFF composite samples followed the same pattern as in the previous case. Tensile strength increased as the temperature increased. Maximum tensile strength was observed at the highest temperature in the shortest amount of time. Melting occurs when polymer chains detach from their crystal structures and transform into an amorphous liquid. As a result, good binding between the reinforcement fibers occurs, increasing the tensile strength. According to the ANOVA results for the 100% CFF composite (Table 4), the F observed > F critical values are 7.88 and 89.76 (P 0.05) for pressure and temperature, respectively. F observed F critical values are 2 and 1.04 for pressure and time, respectively ($P > .05$). For temperature, F observed > F critical is 8.41 (P0.05), while F observed F critical is 1.16 ($P > .05$). The analysis revealed that temperature is the most important factor, followed by pressure and time.

Table 3. Response surface regression equations for tensile strength of the CFF and its hybrid composites.

Sample	Regression Equation	R^2%
100% CFF	$Y = -42.43 + 0.45*(x_1)+0.04*(x_2)+ 0.79*(x_3) -0.0005*(x_1x_2) - 0.004*(x_1x_3) -0.002*(x_2x_3) - 0.001*(x_1^2) + 0.035*(x_2^2) - 0.001*(x_3^2)$	95.97
75:25 CFF / Jute	$Y = -7.26 + 0.07*(x_1) - 0.15*(x_2)+ 0.52*(x_3) + 0.001*(x_1x_2) - 0.003*(x_1x_3) + 3.2*10^{-18}*(x_2x_3) - 0.0001*(x_1^2) - 0.0003*(x_2^2) + 0.005*(x_3^2)$	88.55
50:50 CFF / Jute	$Y = 57.66-0.69*(x_1) - 0.92*(x_2)+ 1.58*(x_3) + 0.005*(x_1x_2) - 0.009*(x_1x_3) - 0.007*(x_2x_3) + 0.002*(x_1^2) + 0.0095*(x_2^2) - 0.004*(x_3^2)$	84.91
25:75 CFF / Jute	$Y = -9.27 + 0.20*(x_1) - 1.15*(x_2) - 1.13*(x_3) + 0.0065*(x_1x_2) + 0.003*(x_1x_3) + 0.007*(x_2x_3) - 0.0007*(x_1^2) + 0.007*(x_2^2) + 0.023*(x_3^2)$	89.46
100% Jute	$Y = 17.71-0.07*(x_1) - 2.04*(x_2) - 0.18*(x_3) + 0.009*(x_1x_2) - 0.003*(x_1x_3) + 0.017*(x_2x_3) + 0.00004*(x_1^2) + 0.024*(x_2^2) + 0.031*(x_3^2)$	96.06

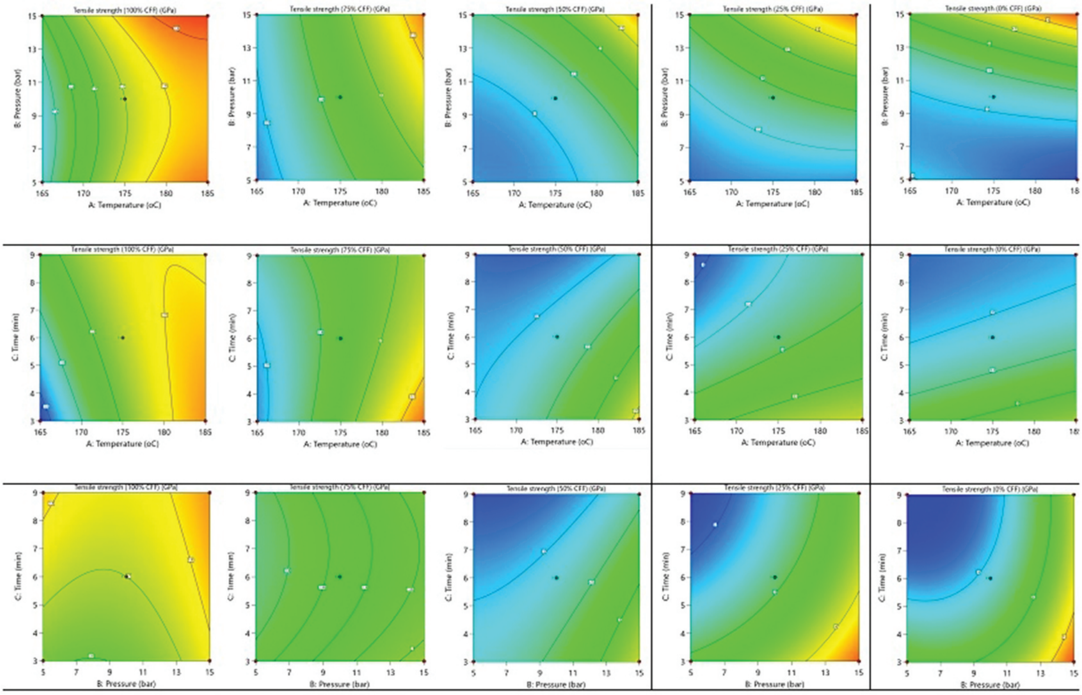

Figure 1. Contour plots of process conditions vs. tensile strength of CFF and its hybrid composites a) 100% CFF b) 75:25 CFF/Jute c) 50:50 CFF/Jute d) 25:75 CFF/Jute and e) 100% Jute.

The influence of processing conditions on the tensile strength of a 75:25 CFF/Jute composite is shown in Figure 1 (b). In reaction to the rising temperature, it progressively increased. The tensile strength was unaffected by pressure. At the highest temperature and lowest pressure, tensile strength is greatest.

The effects of time and pressure on the tensile strength of a 75:25 CFF/Jute composite were not significant. Time and pressure have a detrimental effect on tensile strength, i.e., it decreases with increasing time and pressure. Increased processing pressure may result in fiber damage and matrix starvation. Temperature has a significant effect on tensile strength when compared to time for a 75:25 CFF/Jute composite. The greatest tensile strength was observed at higher temperatures and shorter time periods. According to the ANOVA results for the 75:25 CFF/Jute composite (Table 4), the F observed > F critical value for pressure is 0.66 ($P > .05$), and for temperature, the F observed > F critical value is 6.97 (P 0.05). F observed F critical values are 0.23 and 0.28 ($P > .05$), respectively, for pressure and time. F observed F critical values are 0.17 and 0.48 ($P > .05$), respectively, for temperature and time. The processing temperature was found to have a greater effect than the other conditions, as it had the highest F value.

Figure 1 (c) illustrates the effect of processing conditions on the tensile strength of a 50:50 CFF/Jute composite. The tensile strength of 50:50 CFF/Jute samples increased linearly with temperature and pressure increases. Maximum tensile strength was observed at pressures ranging from 12.5 to 15 bar and temperatures ranging from 180 to 185o C. Time and pressure, as well as time and temperature, had the same effect on the 50:50 CFF/Jute composite as in the previous case. At maximum pressure, temperature, and time, the maximum tensile strength was observed. Time demonstrated a detrimental effect on tensile strength (i.e., tensile strength decreased with time despite an increase in pressure and temperature). According to the ANOVA results for the 50:50 CFF/Jute composite (Table 4), the F observed F critical values were 5.09 and 3.56 for pressure and temperature, respectively. F observed F critical values were 2.17 and 6.18 for pressure and time, respectively ($P = .05$). F observed was 5.19 and

Table 4. Effect of pressure*temperature, pressure*time, and temperature*time on tensile strength of CFF/Jute composite.

100% CFF composite						
Source of Variation	SS	df	MS	F	P-value	F crit
Pressure	0.037222	2	0.018611	7.882353	0.040955	6.944272
Temperature	0.423889	2	0.211944	89.764713	0.000475	6.944272
Pressure	0.041667	2	0.020833	2	0.25	6.944272
Time	0.021667	2	0.010833	1.04	0.432825	6.944272
Temperature	0.390556	2	0.195278	8.419162	0.036846	6.944272
Time	0.053889	2	0.026944	1.161677	0.400152	6.944272
75:25 CFF/Jute composite						
Pressure	0.048022	2	0.024011	0.669869	0.561151	6.944272
Temperature	0.464022	2	0.232011	6.972721	0.05572	6.944272
Pressure	0.043356	2	0.021678	0.282406	0.767846	6.944272
Time	0.035356	2	0.017678	0.230296	0.804146	6.944272
Temperature	0.067223	2	0.0336	0.175365	0.84527	6.944272
Time	0.186324	2	0.0931	0.485908	0.647276	6.944272
50:50 CFF/Jute composite						
Pressure	2.661432	2	1.330321	5.099042	0.079370	6.944272
Temperature	1.861667	2	0.930833	3.56869	0.128989	6.944272
Pressure	0.548889	2	0.274444	2.1762115	0.229348	6.944272
Time	1.560556	2	0.780278	6.1872247	0.059674	6.944272
Temperature	2.020556	2	1.010278	5.195714	0.077252	6.944272
Time	1.287222	2	0.643611	3.304521	0.141864	6.944272
25:75 CFF/Jute composite						
Pressure	4.790556	2	2.395278	4.121893	0.106730	6.944272
Temperature	0.602222	2	0.301111	0.518164	0.630800	6.944272
Pressure	4.323889	2	2.161944	18.1	0.009901	6.944272
Time	1.800556	2	0.900277	7.537209	0.043976	6.944272
Temperature	0.538422	2	0.2692111	1.129347	0.408463	6.944272
Time	3.130755	2	1.5653778	6.566794	0.054503	6.944272
100% Jute composite						
Pressure	5.966489	2	2.983244	7.389552	0.045370	6.944272
Temperature	0.584422	2	0.292211	0.723812	0.539145	6.944272
Pressure	6.802222	2	3.401111	30.015689	0.003902	6.944272
Time	2.431089	2	1.215544	10.727496	0.024693	6.944272
Temperature	0.349489	2	0.174744	0.376352	0.708335	6.944272
Time	3.229356	2	1.614678	3.477577	0.133316	6.944272

F critical was 3.30 for temperature and time, respectively. For the remaining processing conditions, $P > .05$ was observed. Except for the time, other processing conditions had no statistically significant effect on the tensile strength of a 50:50 CFF/Jute composite.

Figure 1(d) illustrates the effect of processing conditions on the tensile strength of a 25:75 CFF/Jute composite). The tensile strength of 25:75 CFF/Jute samples remained constant up to a moderate level of pressure despite the temperature increase. Tensile strength increased with increasing pressure and reached its maximum value at maximum temperature and pressure. While increasing the pressure resulted in a gradual increase in tensile strength, increasing the time resulted in a decrease in tensile strength. The duration of heating had an effect on the wetting of the fiber and matrix and also resulted in a more complete impregnation of the fiber and matrix. Contrary to expectations, tensile strength decreased as processing time increased. This could be due to the jute fiber degrading thermally when subjected to a longer processing time. Maximum tensile strength was determined at maximum pressure in the shortest amount of time. As time passed, it was observed that the tensile strength of the 25:75 CFF/Jute composite gradually decreased. The greatest tensile strength was observed at the shortest time and highest temperature. According to the ANOVA results for the 25:75 CFF/Jute composite (Table 4), the F observed F critical values were 4.12 and 0.51 for pressure and temperature, respectively ($P > .05$). F observed > F critical was 18.1 and 7.53 (P 0.05), respectively, for pressure and time. F observed

F critical values were 1.12 ($P > .05$) for temperature and 6.56 (P0.05) for time, respectively. The results indicate that pressure played a significant role, and that time had a detrimental effect. Temperature was found to have no effect on the processing parameter.

The effect of processing conditions on the tensile strength of a 100% Jute composite is shown in Figure 1 (e). As temperature and pressure increased, the tensile strength of a 100% Jute composite increased. Even when the temperature was raised, there was no significant increase in tensile strength at moderate pressure. When the effect of time and pressure on the tensile strength of 100% Jute was investigated, the trend was similar to that described above: as pressure increased, the tensile strength increased, and as time passed, the trend decreased.The effect of time and temperature on the tensile strength of a 100% Jute composite revealed that the tensile strength increased as time and temperature decreased. Jute fiber tensile strength is reduced as a result of increased exposure to thermal conditions during composite processing, which may result in thermal degradation. Jute fibers are primarily made up of rigid, crystalline cellulose micro fibrils that are surrounded by an amorphous lignin and hemicelluloses matrix. The cellulose morphology of jute fiber was the main determinant of its tensile strength. Lignin, pectin, and hemicelluloses with a high degree of cross-linking or branching provide structural integrity and rigidity, contributing to the stiffness of the material.Thermal degradation processes in natural fibers typically begin at temperatures as low as 120oC, resulting in the decomposition of waxes present in the fibers.Around 180°C results in the decomposition of pectin. Temperatures of approximately 230°C have the effect of decomposition of cellulose. Additionally, short cellulose-based fibers will agglomerate.According to the ANOVA results for 100% Jute composite (Table 4), the F observed > F critical value was 7.38 and the F observed F critical value was 0.72 for pressure (P 0.05) and temperature ($P > .05$), respectively.F observed > F critical values were 30.01 and 10.72 for time and pressure, respectively (P 0.05).F observed > F critical values were 0.37 and 3.47 for temperature and time, respectively ($P > .05$).The ANOVA analysis revealed that pressure had a significant effect, followed by time, which had a negative effect, and temperature, which had a negligible effect.

Tensile fracture surface analysis of CFF and its hybrid composites

Scanning Electron Microscopy (SEM) was used to investigate the interfacial properties of CFF and its hybrid fiber reinforced polypropylene matrix-based composites. Figure 2(a) depicts the SEM image of the tensile fracture surface of a 100% CFF composite. SEM analysis revealed a significant difference in the fiber-matrix interaction between the composites depending on the processing variables. As indicated by the gap between the CFF and PP resins in the figure, the interfacial bonding between them was insufficient. This could be explained by the low adhesion of the fiber surfaces to the PP resin. As a result, this composite's tensile strength was low.

Gaps between CFF and matrix might be seen in composite boards made at low pressure and temperature, as well as in this sample, contributing to the sample's low tensile strength. The tensile fracture surface of a 75:25 CFF/Jute composite is shown in Figure 2(b). Cracks and holes between reinforcement and matrix were plainly visible in composite boards created at low temperatures, including this sample, contributing to the sample's low tensile strength qualities. Weak interfacial adhesions at the tensile fracture surface can quickly lead to matrix debonding. There was fiber pull-out visible.Figure 2 (c) illustrates the tensile fracture surface of a 50:50 CFF/Jute composite. For composite boards manufactured at low pressure and temperature, the presence of pulled-out traces and numerous holes between reinforcement and matrix is clearly visible, indicating a lack of interfacial adhesion at the interface, which is primarily responsible for the reduced tensile strength. Figure 2 (d) illustrates the tensile fracture surface of a 25:75 CFF/Jute composite. The SEM image revealed a greater proportion of fibers than polymer matrix, and the large number of poorly bonded interface areas between reinforcement and matrix contributed to the deformation of the composite board manufactured under low pressure and temperature. The tensile fracture surface of a board composed entirely of Jute is depicted in Figure 2(e). There were instances of fiber breakage and pull-out. For composite

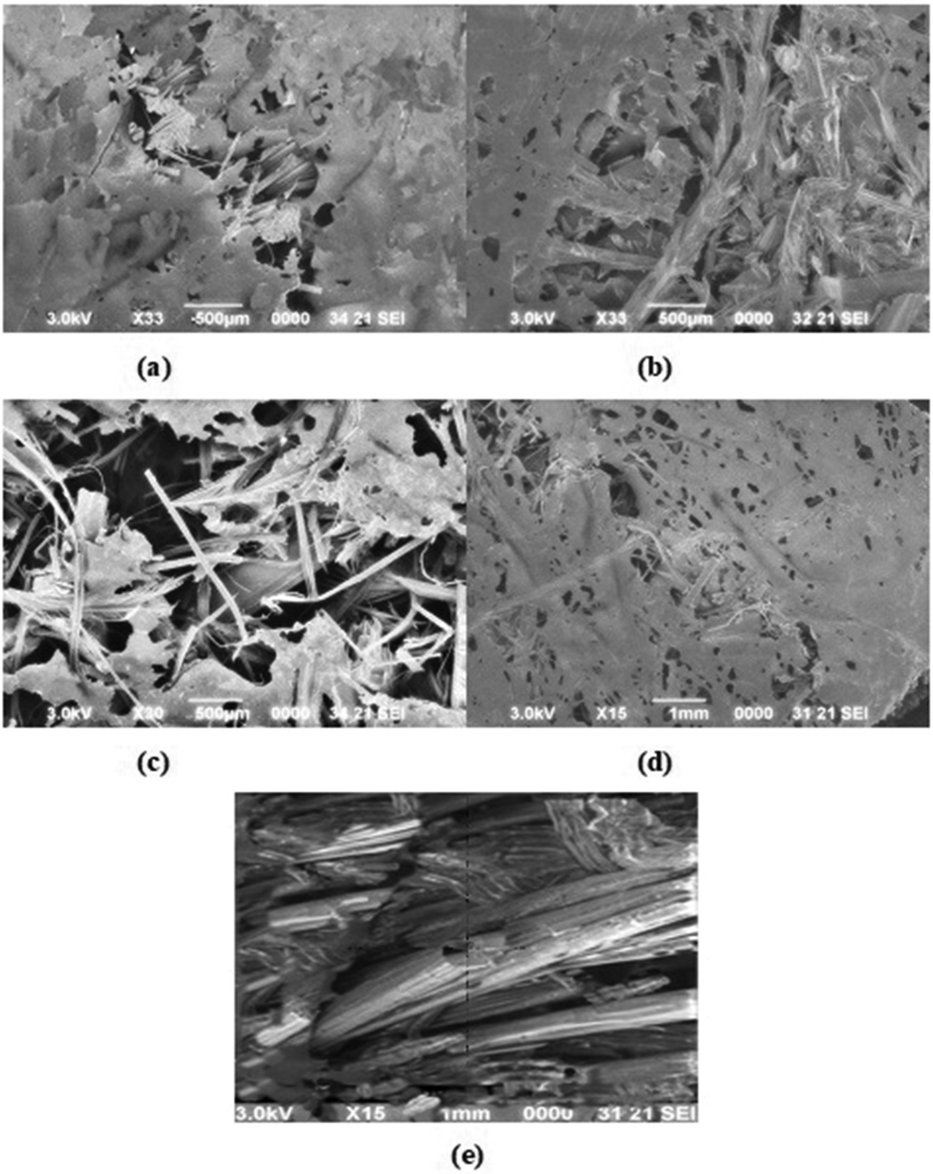

Figure 2. Tensile fracture surfaces of CFF and its hybrid composites a) 100% CFF b) 75:25 CFF/Jute c) 50:50 CFF/Jute d) 25:75 CFF/Jute e) 100% Jute.

boards manufactured under low pressure and high temperature, gaps between the jute fiber and matrix were clearly visible, and these samples are responsible for the low tensile strength properties. This could be as a result of matrix fracture or fiber pull-out.

Water ABSORPTION CHAracter of CFF and its hybrid composites

Figure 3 illustrates the water absorption characteristics of manufactured composites as a function of run order (processing conditions). Given the critical role of fiber absorption in reinforcement, the hydrophilic properties of CFF and its hybrid fiber composite were investigated. Water absorption

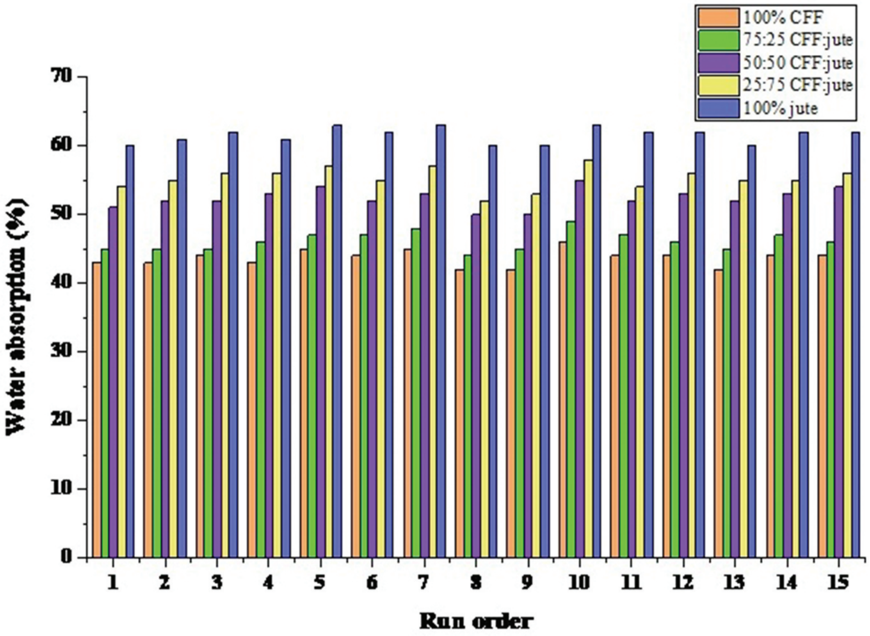

Figure 3. Water absorption of composites.

(percentage) increased as jute fiber loading increased. This could be a result of the functional group's polarity. The fibers swell laterally as a result of the water absorption, and apparently the water molecules that mediate between the chains form the fiber, weakening the secondary valence forces and assisting the chain's slippage. This results in changes to the fibber's and composites' physical properties (Pak et al. 2018).

Water absorption by a fiber bunch occurs in three phases: the first involves diffusion from the water vapor to the fiber surface through the air; the second phase involves diffusion from the bundle's surface to the surface of a single fiber through the air in the spaces between the fibers; and the third phase involves diffusion from the fiber surface to the surface of another fiber through the air in the spaces between the fibers. As predicted, raising the jute weight percentage in composites increases water absorption. This is owing to the hydrophilic characteristic of jute fiber.Water absorption is lower in CFF composites than in jute composites, as the amino acid content of CFF has already demonstrated that the fiber is both hydrophilic and hydrophobic. Water absorption is a concern that may complicate application and necessitates additional research.A low absorption value is desirable for application; this can be achieved through fiber surface modification or an improved interface.

Conclusion

The characteristics of tensile strength and water absorbtion were studied and presented in this study work on chicken feather fiber and jute fiber reinforced with polypropylene. Following are the results of the experiment. Hand lay-up approach may be used to successfully fabricate CFF, Jute filled polypropylene hybrid composites. When comparing the composites' overall tensile strength, the 100% Jute fiber composite demonstrated the highest tensile strength when the process variables were maintained at 185°C temperature, 15 bar pressure, and 6 min time. On a 100% CFF composite, the lowest tensile strength was observed when the process variables were maintained at 165°C temperature, 10 bar pressure, and 3 min time. Temperature and pressure had a significant effect on the tensile strength of 100% CFF samples, while time had no effect. Pressure and time have no effect on the tensile strength of

75:25 CFF/Jute samplesbut temperature has a significant effect. The effect of temperature, pressure, and time on the tensile strength of 50:50 CFF/Jute samples were not significant. At maximum temperature and pressure, the maximum tensile strength (4.4 N) was observed. Pressure and time have a significant effect on the tensile strength of 25:75 CFF/Jute and 100% Jute samples, respectively, whereas time has a detrimental effect on the tensile strength. Temperature had no effect on tensile strength. SEM analysis of tensile fractures reveals the presence of pulled out traces, cracks, and numerous holes between reinforcement and matrix for composite boards manufactured under low pressure and temperature. This research also confirms that increasing the jute weight % in composites improves water absorption, as expected.

Disclosure statement

No potential conflict of interest was reported by the author(s).

ORCID

C. Prakash http://orcid.org/0000-0003-2472-6765
S. Sivamani http://orcid.org/0000-0002-8986-9866
G. Rajeshkumar http://orcid.org/0000-0003-1190-2838

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