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Effect of Fibber Surface Treatment on Mechanical Properties of Bio composites: a Review

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Abstract: Bio composites have become more popular in automotive, aerospace, packaging, and construction sectors because of their wide varieties of advantageous properties like good specific strength as well as modulus, environment friendly, low cost and low density etc. Inspite of their enormous favourable features they also have poor interfacial adhesion, poor wet ability of natural fibbers within the matrix. To overcome these barriers and for efficient utilization of bio composites in structural as well as non structural applications, it is highly required to change fiber surface morphology by removal of various surface impurities like wax, pectin, lignin, and hemicelluloses. Various chemical treatments i.e. alkalization, silane treatment, carination, permanganate, peroxide etc. are widely adopted for this purpose. The mechanical and thermal properties of treated bio composites are higher than the untreated one. It may be attributed to improvement in fiber-matrix interfacial adhesion as well as good wet ability of fibber within the matrix. The main focus of this work is to study the effect of fiber surface treatments on the mechanical properties of biocomposites. Outcomes from most of the cases show that the incorporation of chemical treated fiber compared to untreated fiber in biocomposites leads to increase the tensile and flexural properties but impact strength are reduced.

Key Words: Surface treatment, Biocomposite, Interfacial adhesion, Surface Morphology, Wettability, Mechanical properties

I. INTRODUCTION

Lignocelluloses fibbers attract the engineers to use as reinforcement filler in polymeric resin matrices. The attraction towards them is due to their low cost, low density, acceptable mechanical and thermal properties, recycling, and biodegradation ability. Inspite of their wide varieties of advantages, biofiber also have many drawbacks which create obstacle in effective reinforcement. The main drawback of natural fiber is their hydrophilic nature that causes poor interfacial adhesion with polymeric resin which results development of low strength biocomposite material [8]. To reduce moisture uptake behaviour of natural fiber and to increase the interfacial adhesion with polymeric resin, it is highly required to change the surface topology of natural fiber and make compatible with hydrophobic matrices. Surface modification of biofiber by physical or chemical treatment leads to alleviate their uses in structural applications such as exterior components of automobile, aerospace, building components etc [9]. Surface modification also results in enhancement of aspect ratio, improves the wet ability of fibers, and forms a strong adhesion between polar natural fiber and nonpolar matrix [10].The objective of this paper is to review the effect of fiber surface treatment on mechanical properties of natural fiber reinforced composites.

II. EFFECT OF FIBER SURFACE TREATMENT ON TENSILE PROPERTIES OF BIOCOMPOSITES

A. Effect of fiber surface treatments on tensile properties of Jute fiber/PLA composites

Bhanu K. Goriparthi et al. [1] analyzed the effect of jute fiber surface treatments on tensile properties of Jute/PLA composites. It was observed in fig 1 & 2 that tensile strength and moduli of composites had significantly increased with fiber surface treatment. It may be attributed to better fiber/matrix adhesion of treated composites as compared to untreated composite. The order of tensile properties improvement follows the order: Silane 2 (tri-methoxy methyl silane)> Silane 1(3-amino propyl tri-methoxy silane)>peroxide>permanganate>alkalization>untreated. The maximum improvement in tensile strength and modulus is by 35% and 38% respectively is due to silane 2 treatment.

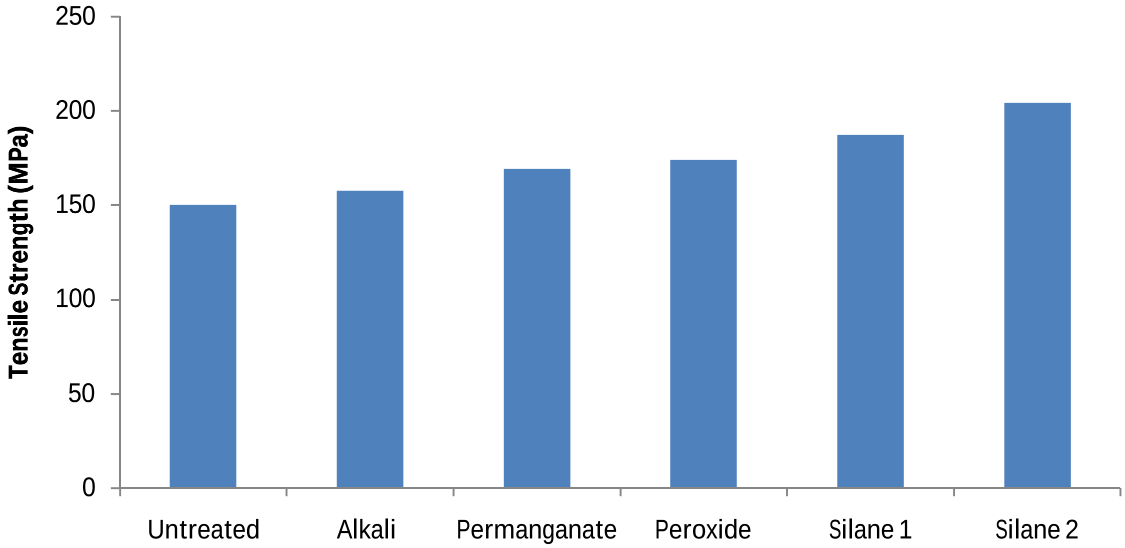

Fig.1. Variations of tensile strength with jute fiber treatments

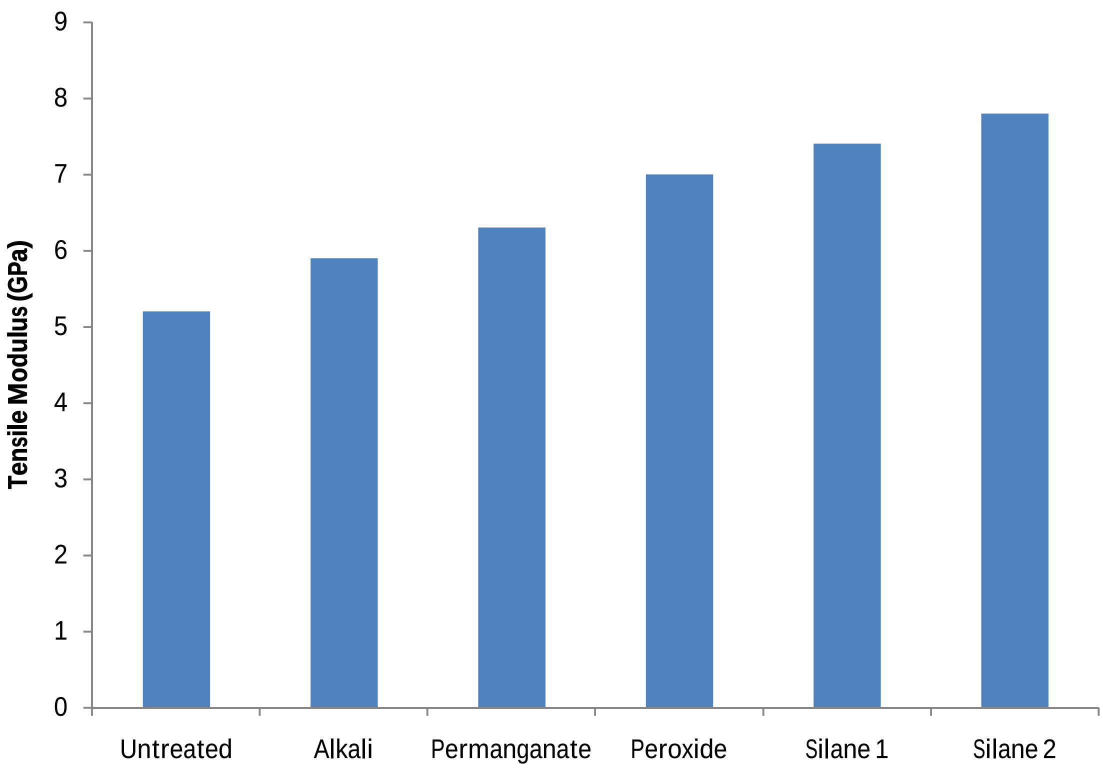

Fig.2. Variations of tensile modulus with jute fiber treatments

B. Effect of fiber surface treatments on tensile strength of Ramie/PLA composites

Hae Young Choi et al. [2] investigated the effect of various surface treatments of fiber on tensile strength of Ramie/PLA composites. Fig 3 clearly reveals that the tensile strength of PLA was decreased by 18.2, 49.82, and 41.08% when PLA was reinforced with FIBNA, FIBNASI, and FIBNAPO composites. It may be attributed to poor dispersion of ramie fiber in the PLA matrix.

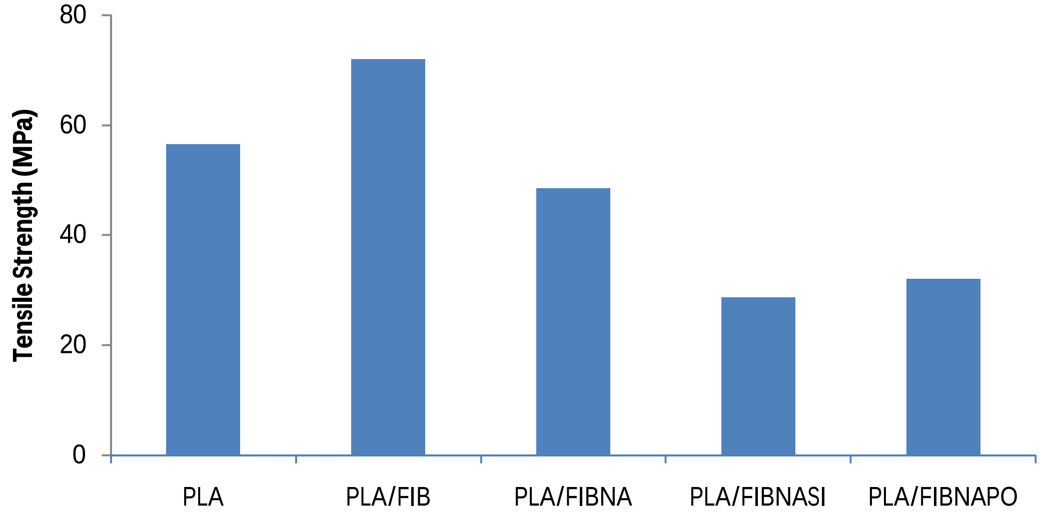

Fig 3. Tensile strength of PLA and chemically treated ramie fiber-reinforced composites

C. Effect of fiber surface treatments on tensile strength of non woven hemp fiber/PLA composites

Geeta Mehta et al. [3] examined the effect of various surface treatments on tensile strength of non woven hemp fiber/PLA composites. Fig 4 clearly shows that the tensile strength of alkaline treated fiber based biocomposite was 34% higher, silane treated biocomposite was 48% higher, UPE-MEKP treated composite was 57% higher, and acrylonitrile treated fiber composite was 80% higher than that of untreated non woven hemp fiber-PLA composites. This increase in tensile strength of the chemically-treated biocomposites is due to the improved adhesion between the fiber and the matrix which results effective stress transfer from matrix to fiber.

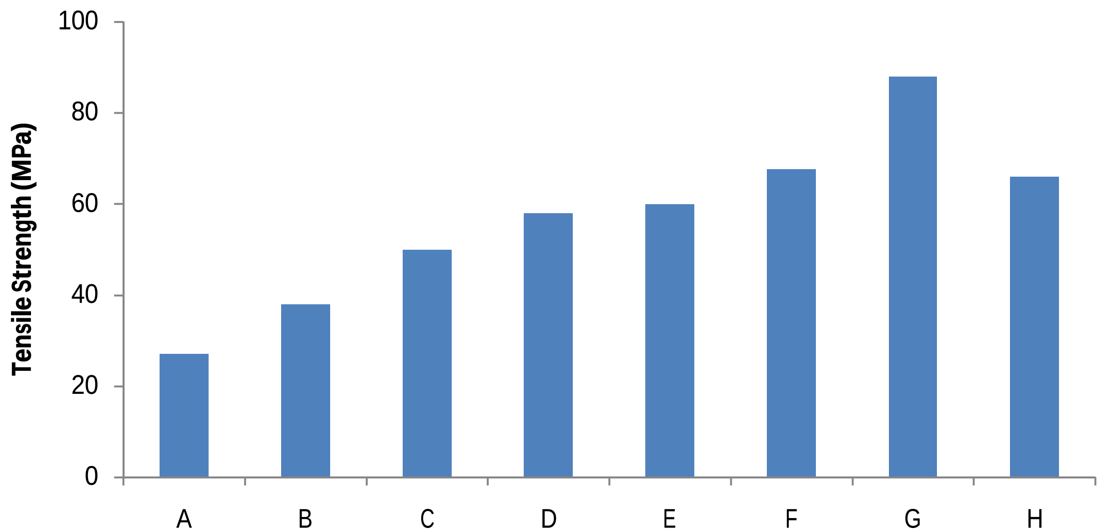

Fig 4. Comparison of tensile strength of surface-treated composites: A, UPE control; B, untreated hemp mat (30% vol.)-UPE; F, acrylonitrile treated hemp mat (30% vol.)-UPE; G, E-glass mat-UPE; H, E-glass mat-hemp mat-UPE.

D. Effect of alkalization on tensile properties of Coir/PBS composites

Tran Huu Nam et al. [4] conduct experiments to analyze the effect of alkalization on tensile properties of Coir/PBS composites. It can be concluded from fig 5 and 6 that the tensile strength and modulus of 5N72 treated Coir fiber/PBS composite at 10, 15, 20, 25, and 30% fiber mass content was 21, 22.1, 22.4, 24.1, and 24.1% and 29.4, 20.5, 40.8, 14.2, and 25.2% respectively higher than untreated Coir fiber/PBS composites. It may be attributed to the greater fiber/matrix interfacial and physical bonding.

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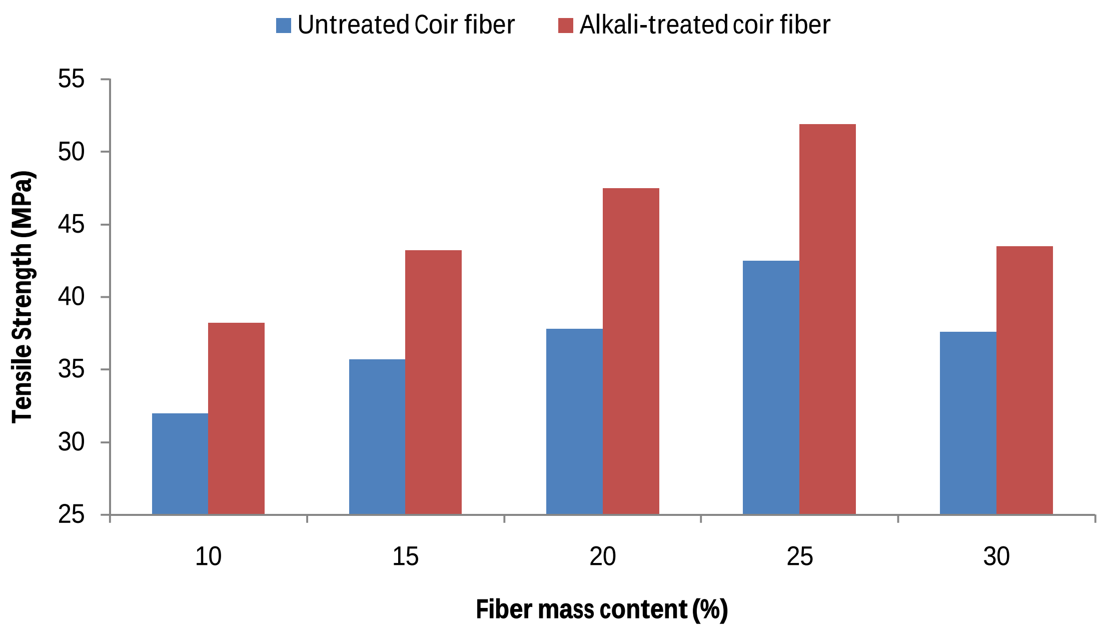

Fig 5. Tensile strength of untreated and 5N72 treated Coir fiber/PBS biocomposites

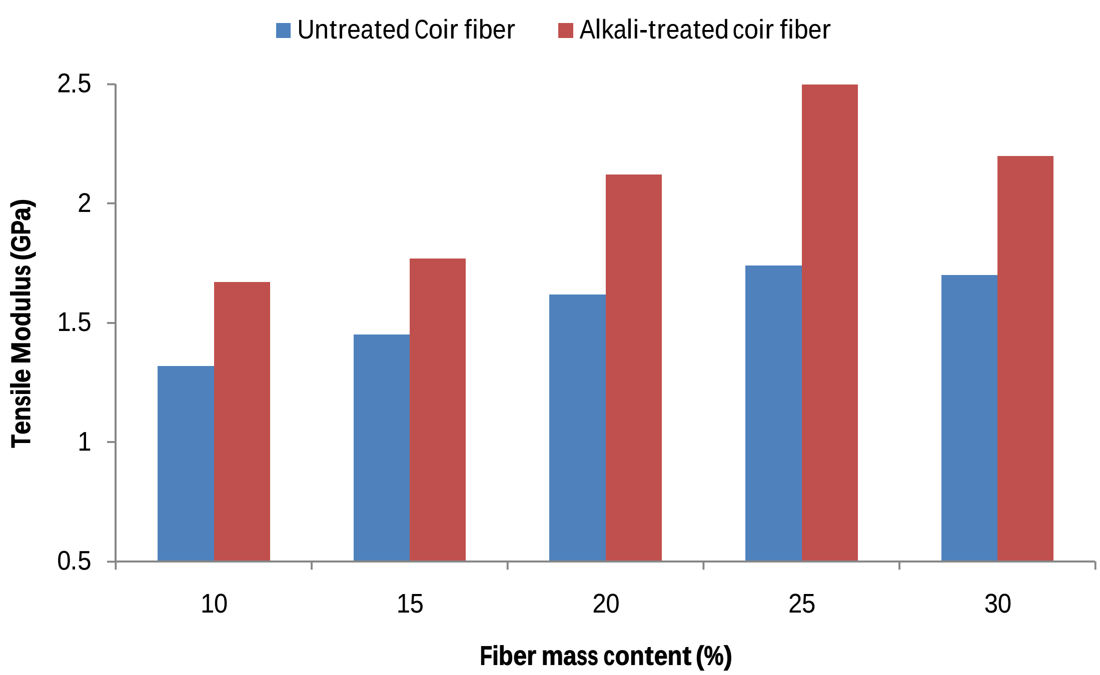

Fig 6. Tensile modulus of untreated and 5N72 treated Coir fiber/PBS biocomposites

E. Effect of fiber surface treatments on tensile strength of Ramie/PLA composites

Tao Yu et al. [5] analyzed the effect of surface treatments on Ramie fiber/PLA composites. It was found that tensile strength and stiffness of PLA was increased with addition of ramie fiber. Table 1 shows that the maximum tensile strength was 66.8 MPa achieved under the NaOH treated fiber condition. It is due to strong adhesion between alkaline treated ramie fiber and PLA matrix which results effective stress transfer between fiber and matrix.

Samples	Tensile Strength (MPa)	Elongation at break (%)
Neat PLA	45.2 ± 1.5	1.2 ± 0.2
Untreated PLA/Ramie composite	52.5 ± 0.8	3.2 ± 0.2
PLA/Ramie composite treated by NaOH	66.8 ± 1.7	4.8 ± 0.2
PLA/Ramie composite treated by 3-aminopropyltriethoxysilane	59.3 ± 1.2	4.1 ± 0.2
PLA/Ramie composite treated by Gamma-glycidoxypropyltrimethoxysilane	64.2 ± 0.7	3.6 ± 0.1

Table 1. Mechanical properties of PLA and PLA-based composites

F. Effect of fiber surface treatments on tensile properties of Jute/PBS composites

Lifang Liu et al. [6] investigate the effect of surface treatments and fiber content on tensile properties of Jute/PBS composites. It was found that fiber surface modification is necessary to develop high strength biocomposites. Fig 7 and 8 represents that the increase of fiber mass content from 0 wt% to 20 wt% will result the increase of tensile strength and modulus but with 30 wt% they are decreased. This positive result up to 20 wt% jute fiber content was due to uniform stress distribution from PBS matrix to dispersed fiber phase and negative is due to agglomeration of fibers within the matrix which result non uniform stress distribution.The biocomposites of jute fiber treated by 2% NaOH, 2 + 5% NaOH, coupling agent with the 20 wt% fiber content exhibit 10%, 16.3%, and 21.7% enhancement in tensile strength, 22.5%, 41.1%, 49.6% in tensile modulus compared to the untreated jute fiber composites respectively.

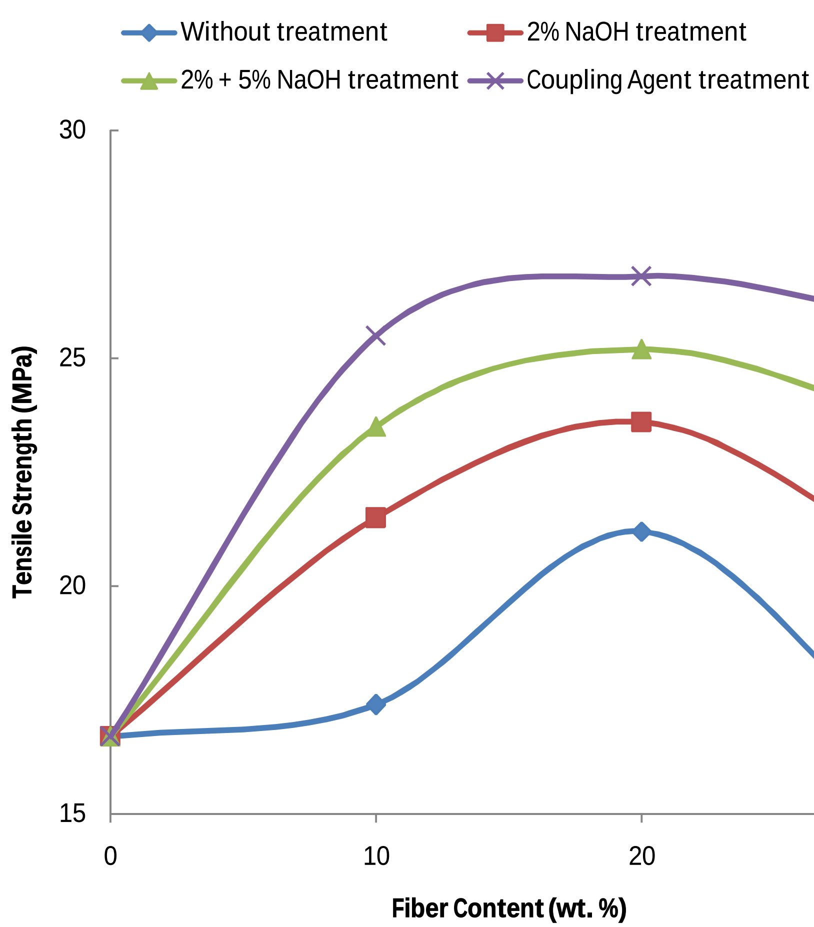

Fig 7. Effect of surface modifications on tensile strength of Jute/PBS biocomposites with different fiber content

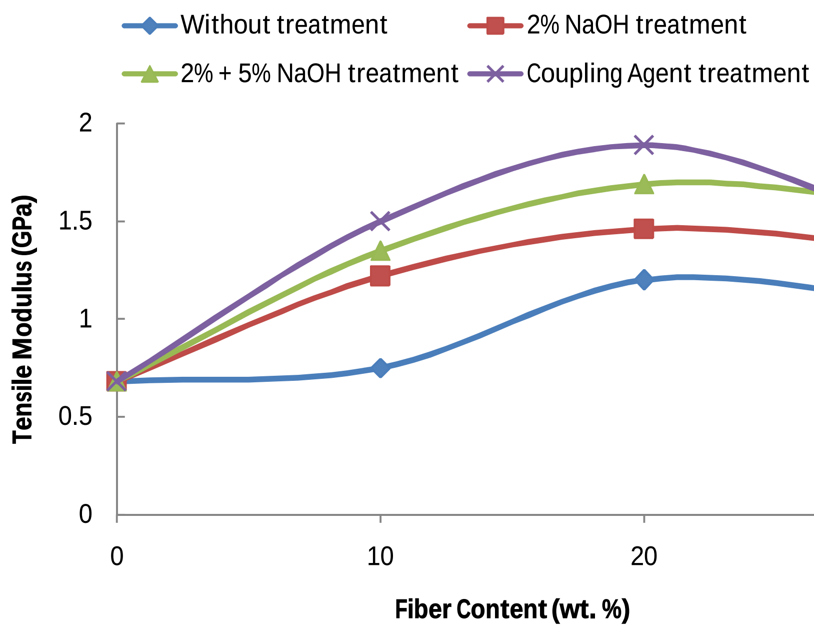

Fig8. Effect of surface modifications on tensile modulus of Jute/PBS biocomposites with different fiber content

III. EFFECT OF FIBER SURFACE TREATMENTS ON FLEXURAL PROPERTIES OF BIOCOMPOSITES

A. Effect of surface treatments on flexural properties of Jute/PLA composites

Bhanu K. Goriparthi et al. [1] investigates the effect of surface treatments on Jute fiber/PLA composites. Fig 9 and 10 shows that the modification of jute fiber surface resulted in enhancement of flexural strength and modulus by 24% and 41% respectively in silane 2(tri-methoxy methyl silane) treated composite due to the strong fiber-matrix adhesion. Out of the two silane, Silane 2 is more effective in fiber-matrix adhesion process which may be due to the strong chemical bonding between organo functional group and PLA matrix compared to the hydrogen bond formed in silane 1 treatment.

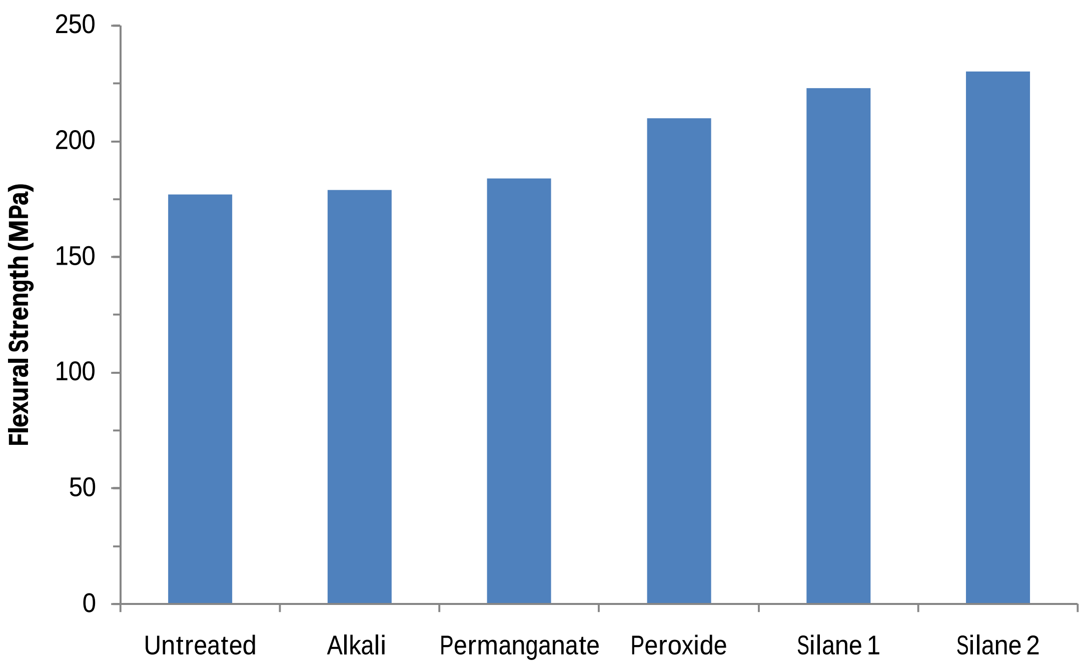

Fig 9. Variations of flexural strength with jute fiber treatments

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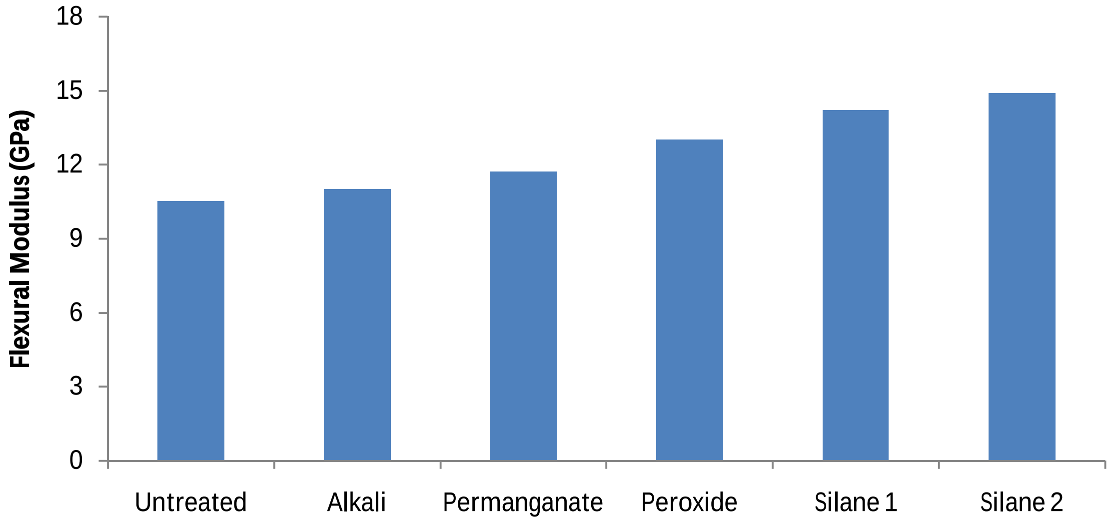

Fig 10. Variations of flexural modulus with jute fiber treatments

B. Effect of alkalization on flexural properties of Coir/PBS composites

Tran Huu Nam et al. [4] studied the effect of alkaline treatment and fiber mass content on flexural properties of Coir/PBS composites. It can be concluded from fig 11 and 12 that flexural properties are gradually increased with increasing fiber mass content from 0% to 25%. But beyond addition of fiber, they are decreased because of improper wetting. The alkali treated Coir/PBS composites with 25% mass content exhibited increase in flexural strength by 6% and flexural modulus by 16.7% compared to untreated composite. This reflects the contribution of sodium hydroxide in terms of change of fiber properties and enhancement of fiber-matrix adhesion.

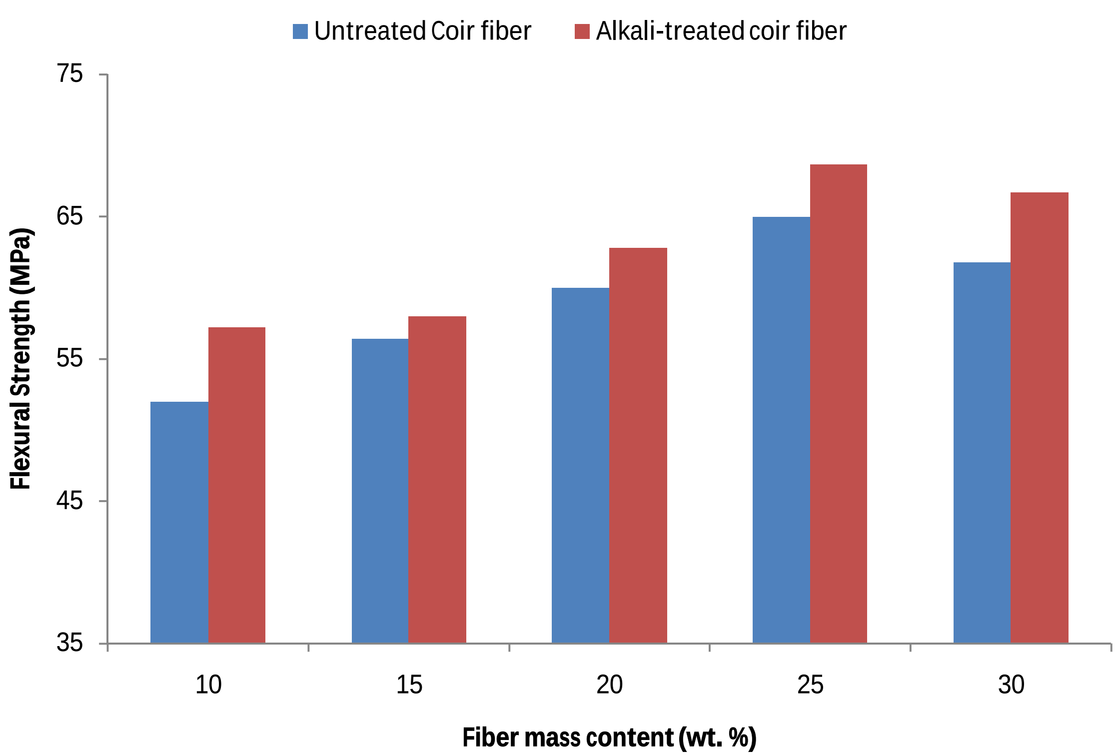

Fig 11. Flexural strength of untreated and 5N72 treated Coir fiber/PBS biocomposites

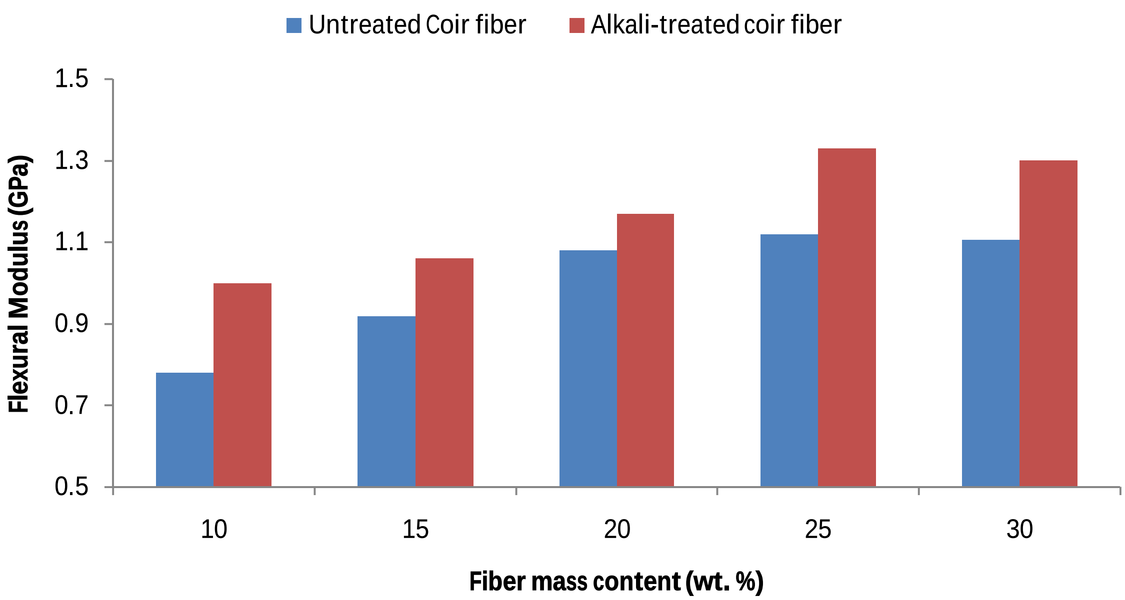

Fig 12. Flexural modulus of untreated and 5N72 treated Coir fiber/PBS biocomposites

C. Effect of surface treatments on flexural properties of Kenaf/PLA composites

Masud S. Huda et al. [7] investigates the effect of kenaf fiber surface treatments on flexural properties of Kenaf/PLA composites. It concluded from fig 13 & 14 that the introduction of kenaf fiber (untreated or treated) in PLA matrix will lead to significantly improvement in flexural modulus but flexural strength was decreases. It may be due to poor adhesion between the kenaf fiber and PLA. The flexural properties of surface-treated kenaf fiber composites show an evident increase compare to untreated fiber composite. It may be attributed to an increase in nucleation density. It was found that FIBNASI composite shows the best flexural modulus (80% improvement) compare to untreated fiber composite. The order of improvement in flexural properties compared to untreated fiber composite is: PLA/FIBNASI> PLA/FIBSI> PLA/FIBNA> PLA/FIB.

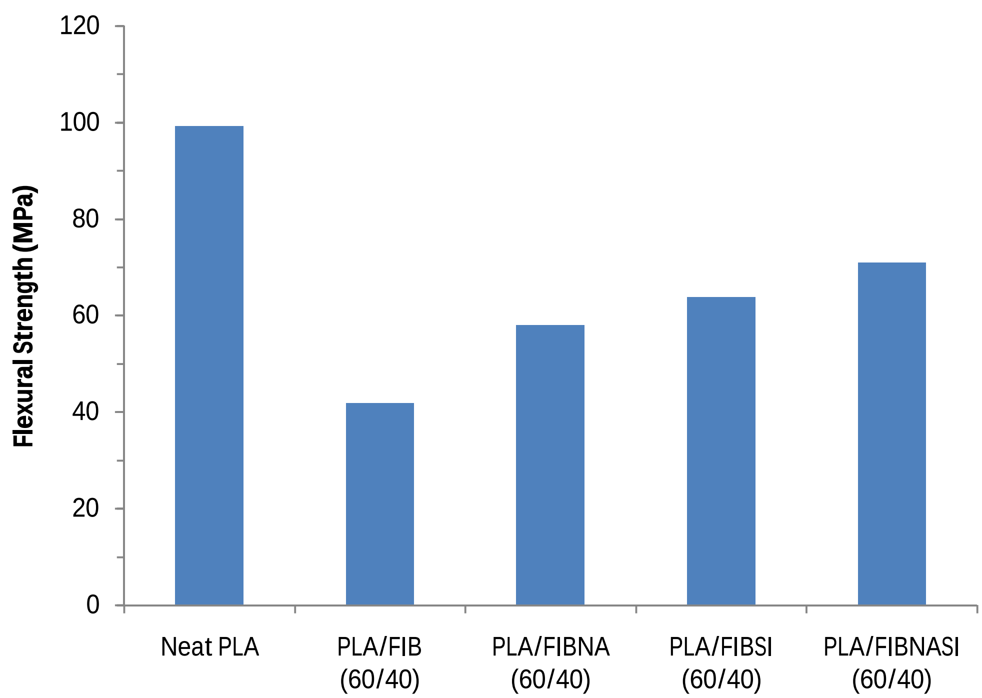

Fig 13. Flexural strength of PLA and surface treated kenaf/PLA biocomposites

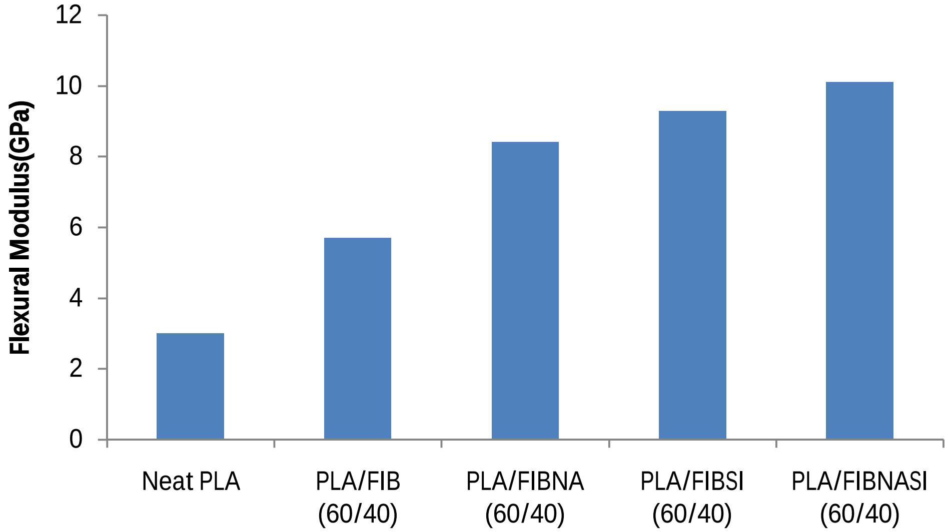

Fig 14. Flexural modulus of PLA and surface treated kenaf/PLA biocomposites

D. Effect of fiber surface treatments on flexural strength of non woven hemp fiber/PLA composites

Geeta Mehta et al. [3] investigate the effect of various surface treatments on flexural strength of non woven hemp fiber/PLA composites. Figure 15 clearly shows that the flexural strength and modulus of elasticity of alkali treated, silane treated, and UPE-MEKP treated biocomposites lie in the same range. The bending strength and modulus of elasticity of acrylonitrile-treated fiber based composites were 7% and 35% higher than those of untreated fiber composite

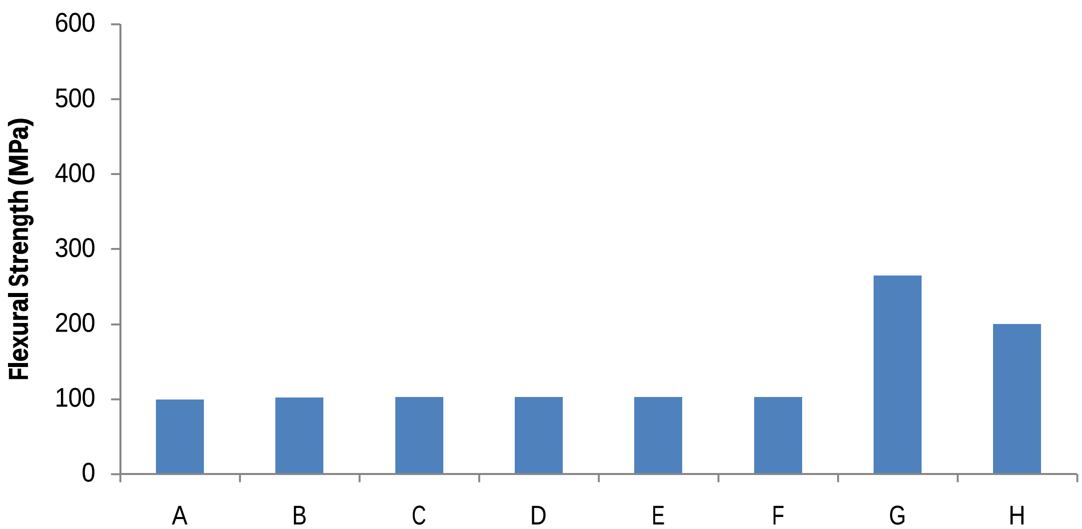

Fig 15. Comparison of flexural strength of surface-treated composites: A, UPE control; B, untreated hemp mat (30% vol.)-UPE; F, acrylonitrile treated hemp mat (30% vol.)-UPE; G, E-glass mat-UPE; H, E-glass mat-hemp mat-UPE.

E. Effect of fiber surface treatments on flexural strength of Ramie/PLA composites

Tao Yu et al. [5] conducted experiment to analyze the effect of fiber surface treatments on flexural strength of Ramie/PLA composites. Figure 16 depicts that the bending strength of composite is increased after surface treatment of ramie fiber. The maximum flexural strength of Ramie/PLA composite was achieved with incorporation of alkaline treated ramie fiber.

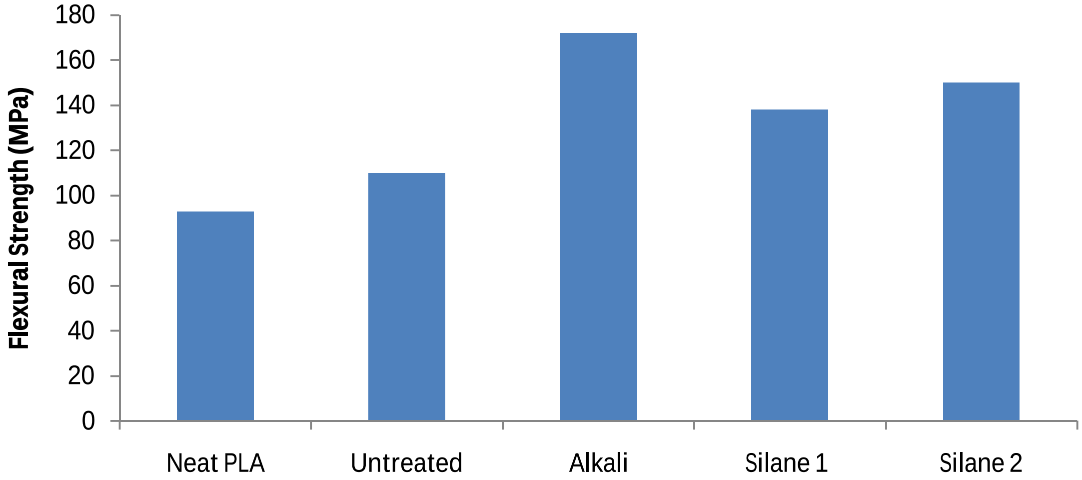

Fig 16. Flexural strength of PLA and PLA based composites

IV. EFFECT OF FIBER SURFACE TREATMENTS ON IMPACT STRENGTH OF BIOCOMPOSITES

A. Effect of surface treatments on impact strength of Jute/PLA composites

Bhanu K. Goriparthi et al. [1] conducted the experiment to analyze the effect of various surface treatments on impact strength of Jute fiber/PLA composite. It was concluded from fig 17 that izod impact strength of treated composites was lower than untreated composite which may be attributed to less fiber pullout due to better adhesion between fiber and the matrix. Debonding, fiber pullout and fracture of fibers are the energy absorption mechanisms during impact. Higher energy required to pull out fibers from matrix than fiber fracture and debonding which results untreated jute fiber composite have better impact strength than treated composites.

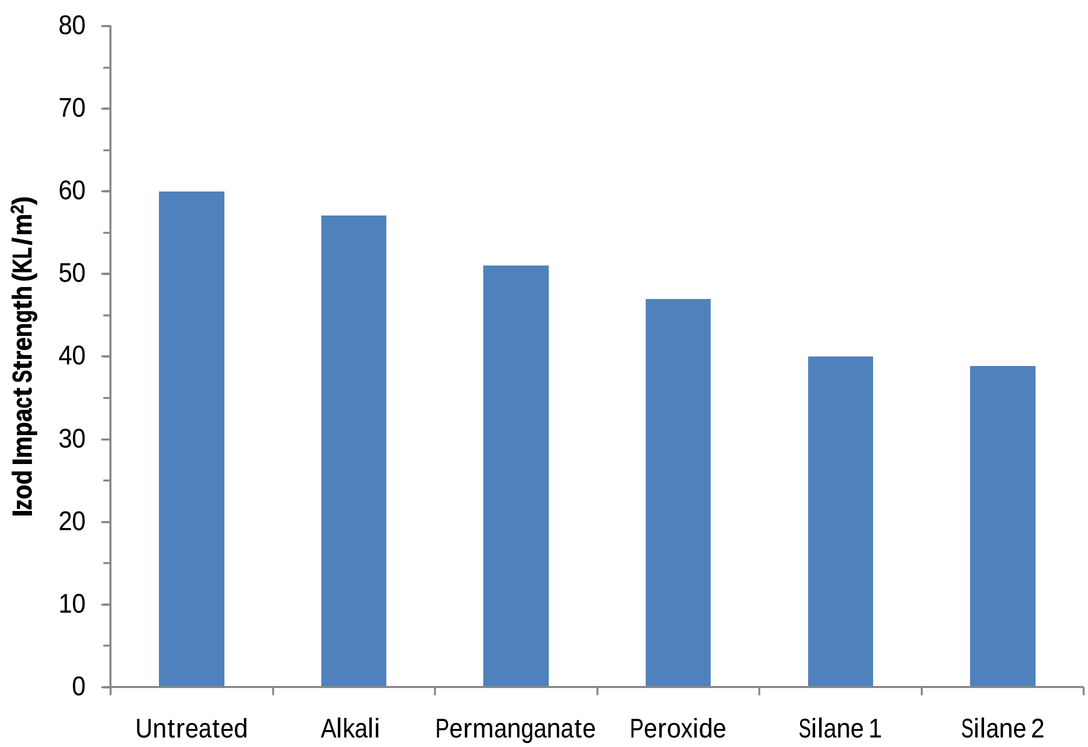

Fig 17. Variation of notched izod impact strength with fiber treatments

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B. Effect of surface treatments on impact strength of Ramie/PLA composites

Hae Young Choi et al. [2] studied the effect of various surface treatments on Ramie/PLA composites. Fig 18 depicts that surface treatments enhanced the impact strength, and FIBNAPO composite perform superior impact performance. For the FIBNA, FIBNASI, and FIBNAPO composites, the impact strength increased by approximately 52, 56, and 65% respectively compared to neat PLA. The excellent behaviour of peroxide treated composite is due to the fact that the stiff behaviour of ramie fiber is changed to flexible nature as well as improvement in surface adhesion characteristics by producing a rough surface morphology.

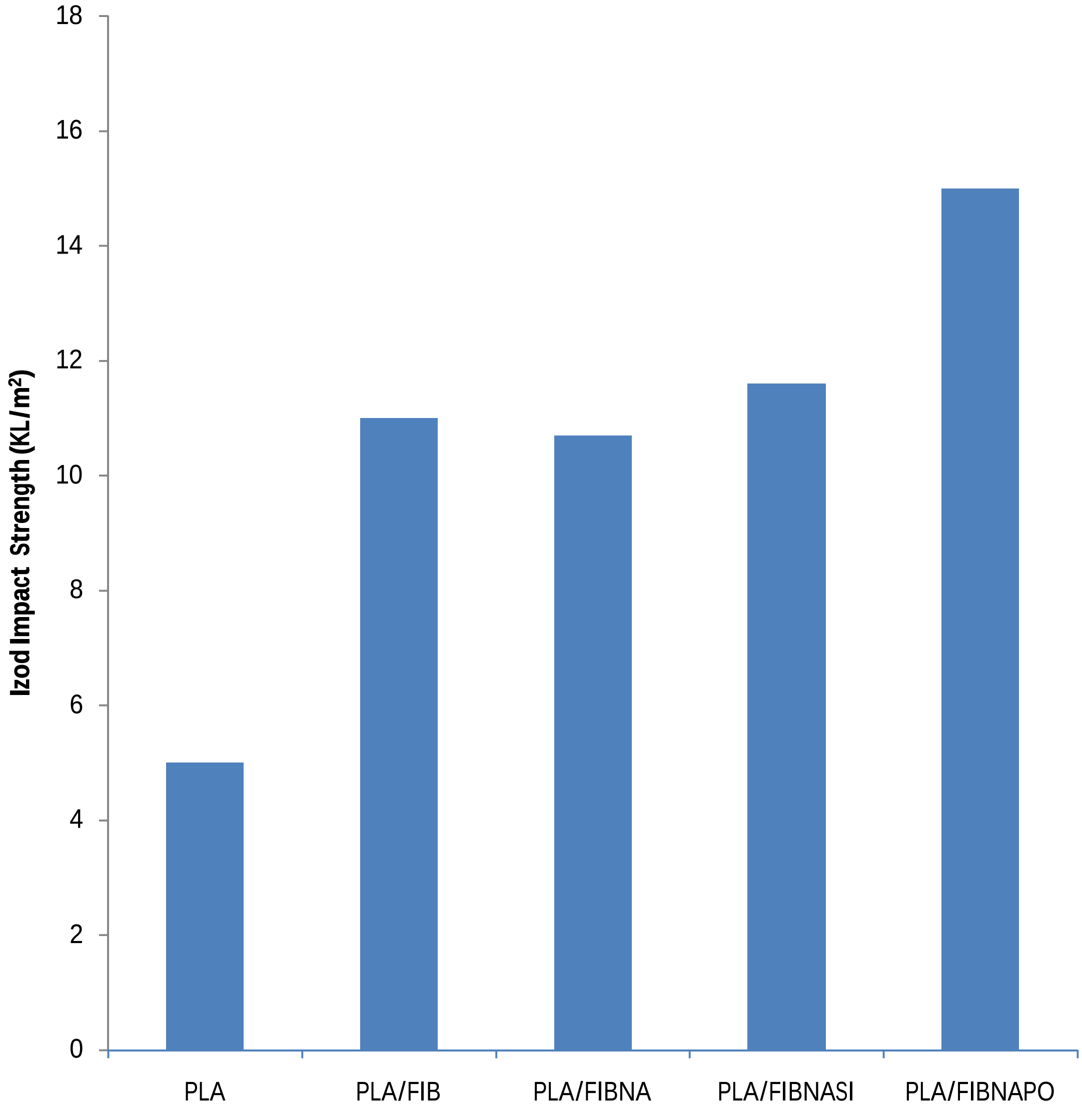

Fig 18. Notched Izod impact strength of the PLA and chemically treated fiber-reinforced composites

C. Effect of surface treatments on impact strength of Kenaf/PLA composites

Masud S. Huda et al. [7] conducted experiments to analyze the effects of various surface treatments on impact strength of Kenaf/PLA composites. Fig 19 reveals that the surface treatment enhanced the impact strength of Kenaf/PLA composite. It was found that FIBNA/PLA composite present an evident increase of 50% impact strength compared to untreated fiber composite. This excellent behaviour of alkaline treated kenaf fiber composite attributed to fact that alkali treatment improves the fiber surface adhesion characteristics by removing natural and artificial impurities, thereby producing a rough surface morphology. In contrast to FIBNA, FIBSI composites possessed decrease in impact strength compared to untreated fiber composite.

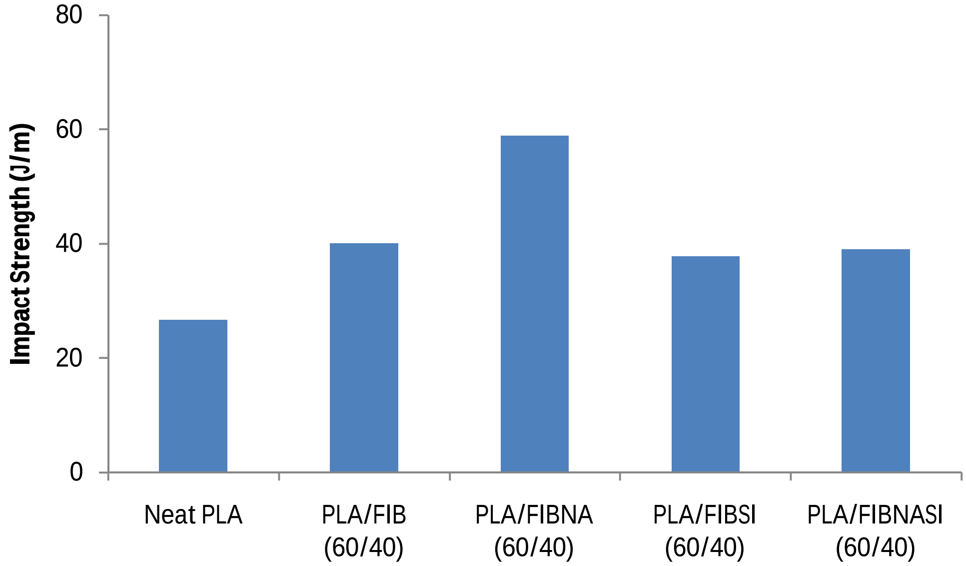

Fig 19. Notched Izod impact properties of PLA and its composites

D. Effect of fiber surface treatments on impact strength of Ramie/PLA composites

Tao Yu et al. [5] investigate the effect of various surface treatments on impact strength of Ramie/PLA composites. It was concluded that incorporation of untreated or treated ramie fibers in PLA matrix will leads to increases the impact strength of resulting composites. The reason behind this significant improvement is the ramie can increase the amount of energy required to pull out fiber from resin. Figure 20 clearly reveals that surface treated ramie fiber/PLA composites have higher impact strength compared to untreated ramie fiber/PLA composites. The maximum impact strength was achieved with alkali treated composites and it is due to strong interfacial adhesion characteristics by removing natural and artificial impurities.

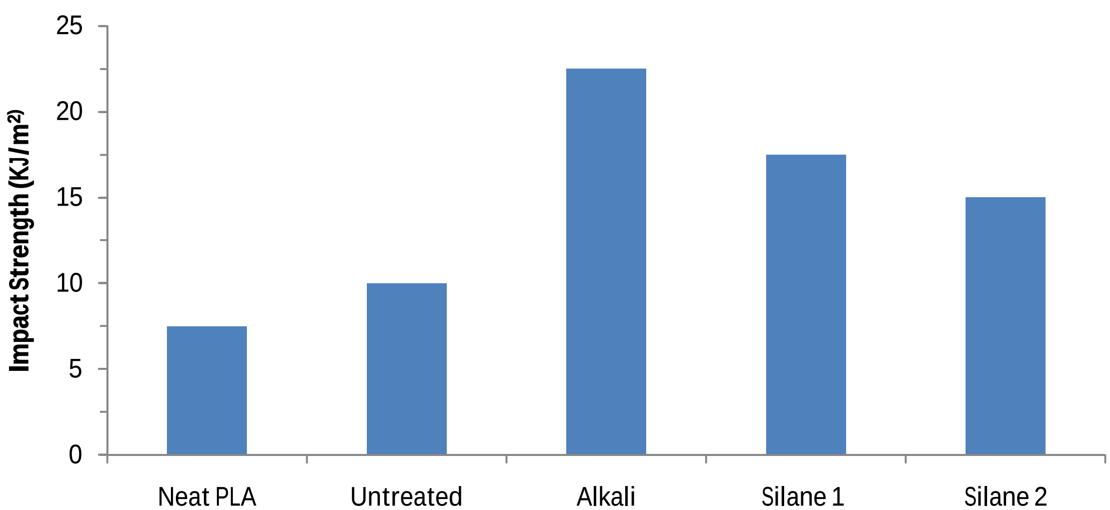

Fig 20. Impact strength of PLA and PLA-based composites

E. Effect of fiber surface treatments on impact strength of non woven hemp fiber/PLA composites

Geeta Mehta et al. [3] performed experiment to analyze the effect of various surface treatments on impact strength of non woven hemp fiber/PLA composites. It was concluded from fig 21 that there was an increment of 82% in impact strength of untreated hemp fiber based composites, 49% for alkali-treated fibers, 94% for silane treated fibers, 120% for UPE-MEKP treated fibers, and 180% for acrylonitrile treated hemp fiber/PLA composites as compared with neat resin.

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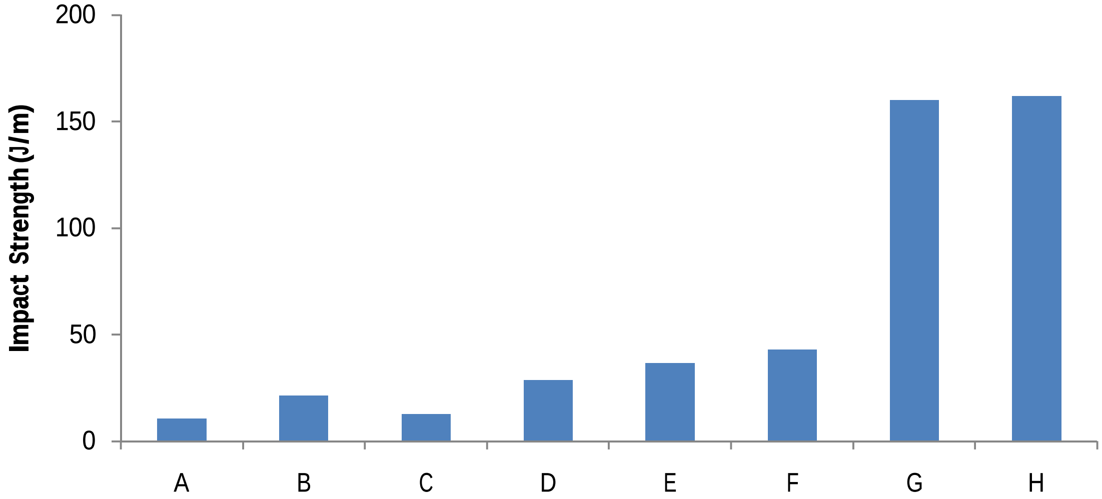

Fig 21. Comparison of impact strength of surface-treated composites: A, UPE control; B, untreated hemp mat (30% vol.)-UPE; F, acrylonitrile treated hemp mat (30% vol.)-UPE; G, E-glass mat-UPE; H, E-glass mat-hemp mat-UPE.

V. CONCLUSIONS

This paper presents the effect of fiber surface treatments on the mechanical properties of biocomposites. The conclusions from this study summarized as follows:

A. Surface treated Jute fiber/PLA biocomposites have better tensile and flexural properties but lower impact strength compared to untreated fiber composites.

B. Silane 2 (tri-methoxy methyl silane) is more effective than Silane 1(3-amino propyl tri-methoxy silane) for improvement in mechanical properties of biocomposites which may be attributed to the strong bond formed between organo functional group of silane 2 and matrix, compared to the hydrogen bond formed by nitrogen to the matrix in case of silane 1.

C. The impact strength of Ramie/PLA composites were increased by peroxide treatment of ramie fibers. This significant improvement is due to the improved interfacial adhesion between ramie fibers and PLA by morphological changes to the fiber surface

D. treatment of coir fibers have increased the mechanical interlocking between the fiber and PBS matrix which results significant improvement in their tensile strength and modulus

E. Fiber mass content in polymer composites positively affects the mechanical properties of the composites up to an optimum limit. In the case of Coir/PBS biocomposites, mean mechanical strength and modulus was increased with increasing fiber mass content up to 25%

F. In the case of Ramie/PLA biocomposites, alkali is an effective surface treatment approach for improvement in flexural strength and impact strength due to the enhanced interfacial adhesion between the PLA matrix and the ramie fibers

G. surface treatment of hemp fibers with alkali, silane, UPE, and acrylonitrile will result strong adhesion between hemp fibers and UPE matrix which leads to comparable performance than glass fiber based composites.

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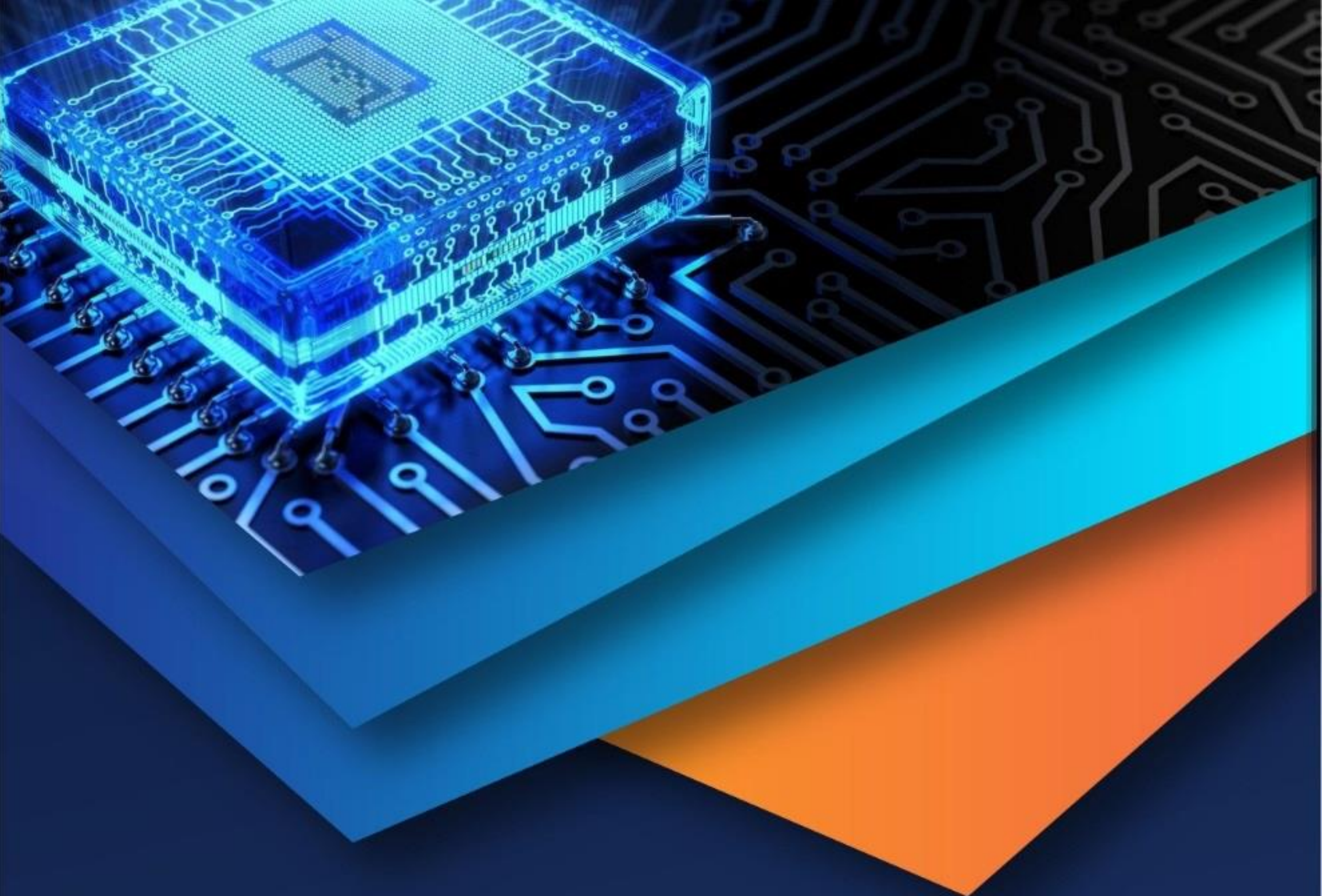

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