CRITICAL REVIEW OF EFFECT OF VARIOUS PARAMETERS ON NATURAL FIBRE REINFORCED POLYMER MATRIX COMPOSITE

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Abstract

The materials available today are bearing the disadvantages like environmental issues, weight inconvenience, cost parameters and availability. Therefore, the researchers have shifted their focus on experimenting the abundantly available materials in nature so that a new material can be developed which will be an alternative for the existing materials. Natural fibers and the thermoplastics as well as thermosetting plastics are the components are clubbed together and used to make a composite material. To have the complete and partial biodegradability of the composite, the matrix material is chosen accordingly. In this paper the discussion of various natural fibers along with the matrix materials are overviewed. The effect of various parameters such as, chemical treatment of fibers, fiber length variation, fiber volume variation, fiber orientation on mechanical and tribological properties of the composites are studied and mentioned. The morphology of the developed composites is observed by studying the SEM analysis of that composite. The objective of the discussion is to understand the dos and don'ts of the composite development process.

1. Introduction

Due to the awareness of environmental hazards, people have shifted their focus from the conventional materials to the newly developed materials. Composite materials are the part of that development upon which huge research is going on. These are the materials in which the matrix is reinforced with the other material may be in fiber or powder format. The reason for this is that a single material will exhibit its own properties but the composite material will show enhanced properties as it is a blend of two (or more than two) materials. The synthetic fibers like glass, carbon, and aramid can be used to reinforce in the matrix and to make composite material. But seeing its environmental hazards, the usage of natural fibers into the polymer matrix is quite a popular trend **[A8]**. The major advantage of natural fiber composites is they are partially or fully biodegradable. They can be recycled. They are non-toxic and less hazardous to living beings and nature as well. Their recycling is possible and they are less abrasive. Most important is they are lightweight and hence can be a very good alternative to the conventional materials. Another reason for research progress in the area of natural fiber composite is that the material is available in abundant form and in the variety. The agricultural waste also can be the supportive sector in this research as most of the crops generate the huge amount of waste and that can be used for composite making **[1].**

For making natural fiber composite the fibers used are taken from the plants, animals as well as minerals. The fibers which are obtained from plants are extracted from various parts. Depending upon that the categorization is like bast fibers (hemp, flax, kenaf, ramie, mesta, jute, roselle fibres) , seed fibre (kapok, rise husk, cotton fibres), leaf fibre (abaka, banana, sisal, palf fibre), stalk fibre (maize, barley, rice, wheat, oat fibres), grass fibre (corn, bagasse, bamboo, sabai fibres) and fruit fibres (coir or palm fibres) **[3]**.

Various methodologies are available to extract the fibres from plants. Depending upon the fibers and matrix selection, the manufacturing methods also are selected and the composite is manufactured. The manufactured composite is tested as per ASTM standards. Many researchers have investigated the mechanical properties, moisture absorption, the thermal aspects and tribological properties of the composite by varying the thread lengths, volume percentage of the reinforcement, fibre orientation and chemical treatment as well. Applications of these composites can be seen in different areas like aircraft industry, automotive sector, construction industry, for insulation purposes, material replacement for energy saving purposes etc **[16,18,25].**

This is an attempt to overview all the efforts taken in the research area of natural fibre composites and to study the developments and the scope of the further research.

Matrix materials used in composite making:

For the fibre reinforced composite, matrix used plays a vital role as it is responsible for the final strength of the composite. The maximum load of the material is always taken by the matrix material and not by the fibres. Further, if the adhesion between the fibres and matrix is not proper, then the composite formed may lose its strength after some period which may lead it towards failure in action. Hence the fibre and suitable matrix selection is an important step in designing the composite material. Following are the matrix materials which are available for the fibre reinforcement.

Table 1: Natural and biodegradable matrices for natural fibres [A22].

Polymers	Types
Thermoplastic	Ethylene (PE), Polystyrene (PS), Nylons, Polycarbonate (PC), Polyacetals, Polyamide-Imide, Polyether-Ether Ketone (PEEK), Polysulphone Polyphenylene Sulphide And Polyether Imide
Thermosetting	Epoxies, Polyesters And Phenol Formaldehyde.
Rubber	Natural Rubber (NR), Styrene Butadiene Rubber (SBR), Butyl Rubber (IIR), Butadiene Rubber (BR), Nitrile Rubber (NBR), Chloroprene Rubber (CR), Ethylene Propylene Diene Rubber (EPDM), Polyurethane Rubber And Silicon Rubbers

Biodegradable Matrices	**Degradable:** Poly(amides) Poly(anhydrides) Poly(amide-enamines) Poly(vinyl-acetate) Poly(glycolic acid) Poly(lactic acid) Poly(caprolactone) Poly(orthosters) Poly(phsphazines) **Partially degradable:** Poly(vinyl-alcohol) Polyester Poly(ethylene oxide)

2. Effect of various parameters on performance characteristics of NFC

2.1 Effect of chemical treatment:

While making the composite, sometimes the reinforcing fibres and the matrix because of which the composite will fail in application. To avoid this the fibre's surface is treated with various chemical treatments like alkalisation, silane, benzoylation, acrylation, etc. These treatments nt only enhances the fibre matrix adhesion but also helps in reducing the hygroscopic nature of the fibres. The review of some of these chemical treatments is taken and it's effect on the developed composite is overviewed here.

Deshmukh et.al. performed an experimentation in which areca nut fibres were used as a reinforcement. To extract the areca fibres a chemical treatment, in which, KOH solution and water was used. First of all water as well as 2.5% of KOH solution was taken to soak the areca husk. Before soaking, the husk was teased and pressed. In container of 5 litres the water and the chemical solution was prepared and pressed/ teased husk was immersed. After 24 hours the the chemically treated husk was taken out and washed for 15 times with water and the water soaked husk was washed with 3 times with water. The result obtained showed that from the water treated and pressed husk the maximum fibre extraction was 57.34% than the KOH treated which was 52.77%. Therefore KOH treatment is not recommended for fibre treatment **[Deshmukh et.al. 2019].**

To check the effect of chemical treatment on properties of the fibres, Suneel Motru et.al conducted an experimentation in which the Silane treatment was done on flax fibres which were reinforced inside the PLA matrix. The soaking of the fibres in NaOH solution was done for two hours at temperature 80°C. When taken out , fibres were allowed to dry for ten minutes and then washed with distilled water. After testing, the Young's modulus was observed to reduce to 22 GPa from 26 GPa. The surface treatment improved the compressive strength of the material when compared to untreated fibres whereas flexural strength did not get affected by the chemical treatment on fibre surface **[Motru et.al. 2020].**

In another research, the surface treatment was done by using NaOH, taken 2g in 100 ml distilled water. 6 mm to 8 mm length coir fibres were used for surface treatment. These fibres were soaked in the solution for one hour at 70°C and then washed again for removal of the chemical completely. It was found that the tensile modulus and flexural modulus were found improved when compared with the neat PLA material. The fibre content percentage was 5 to 20%. The maximum value for tensile modulus for treated fibres was 1.47 GPa and flexural modulus was 3.07 GPa observed at 5% fibre reinforcement. The reduction in tensile modulus by 45.7% and in flexural modulus was 75.4%. Untreated fibres showed the improvement in flexural modulus by 13.4 and tensile modulus by 25.6. This was observed at 20 and 5 wt% of fibre loading respectively **[Yu Dong et.al. 2014].**

A research was conducted in which the PLA was taken as a matrix and bamboo, vetiever grass and coconut fibres were used as reinforcement. The surface treatment was done on the fibres with flexible epoxy resin. To achieve the viscosity reduction the flexible epoxy resin should be dissolved in acetone. The 200 ml acetone should be used with 1 gm of fibres. After the chemical treatment, the fibres are dried for 24 hours at room temperature followed by the oven drying at 80°C. Impact strength of treated fibres reinforced composites was greater than the untreated fibre reinforced composites. The impact strength of treated Bamboo fibres went on increasing with respect to the reinforcement weight percentage. The maximum was observed at 40 wt%. Untreated coconut fibres showed more drop with respect to the increasing reinforcement volume than the treated one. Untreated and treated both vetiever fibre composite's impact strength remained same and went on decreasing as the reinforcement was increasing **[Wiphawee Nuthong et al 2013].**

In the experimentation done by Amrinder Singh Pannu, banana fibres were reinforced in PLA composite. Before reinforcement , chemical treatment of the fibres was done with the help of NaOH 10% and for two hours. Two types of composite sample were made in the form of rods. They are chemically treated and chemically untreated. Their performance was compared with neat PLA rod. 10,20and 30% of reinforcement of fibres was carried out to make chemically treated as well as untreated composite rods. The tensile test was conducted as per ASTM standard D 7205 and impact test was conducted as per standard D256.

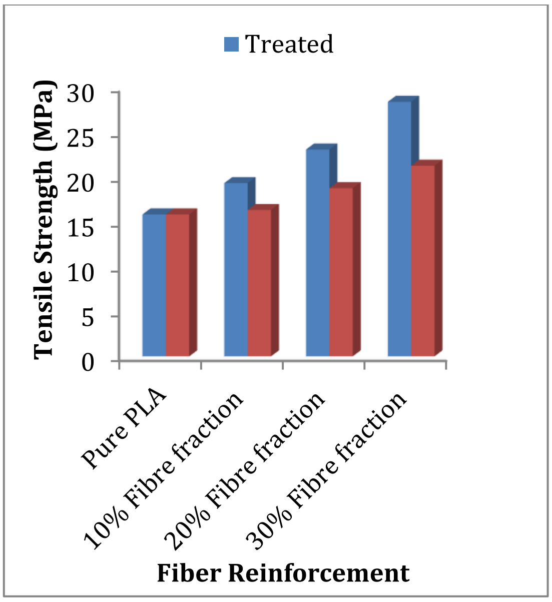

Fig.1 Tensile strength of composite rods [Pannu et.al. 2020]

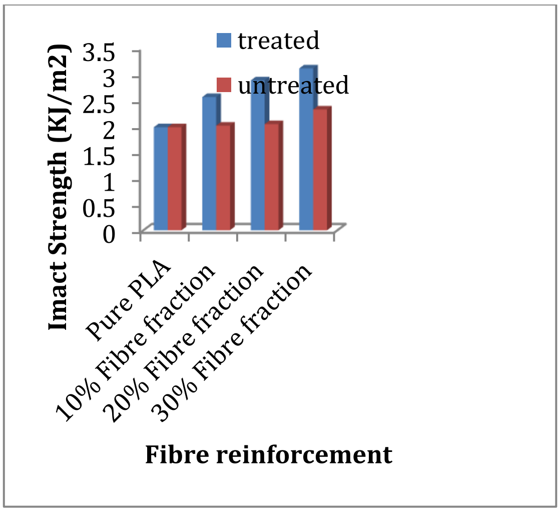

Fig 2: Impact strength of composite rods [Pannu et.al. 2020]

For impact strength of composite rods, chemically treated fibres showed the increase in tensile strength as the fibre reinforcement was increased. Though untreated fibre composite also showed increase in tensile strength but it was not as much as for treated fibre. For 30% reinforcement, it was found maximum. For impact strength, same results were observed in case of treated and untreated fibre composites **[Pannu et.al. 2020].**

Ankit Manral used jute fibres for reinforcement in PLA matrix. The fibres were chemically treated before reinforcement. The chemical used for this is $NaHCO_3$. 10%, 20% and 30% NaHCO3 was used for chemical treatment and the impact strength was checked for these three compositions treated composite materials. Four hours was the time allotted for chemical treatment. Chemical treatment has improved the impact strength of the composite as compared to net PLA and the untreated composite. The maximum value of impact strength was found at 10% of the chemical use for the treatment. When 20% chemical concentration was used to treat the fibres , the storage modulus of the composite was improved and it happened because the interfacial adhesion got better and because of which less migration of the molecules at higher temperatures took place. **[Manral et.al. 2020]**

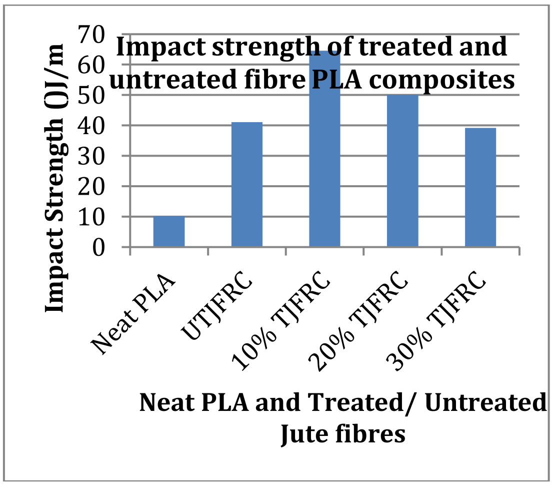

Fig3: Impact strength of treated and untreated jute fibres usage in a composite [Manral et.al. 2020]

Researchers are trying to prove how betel nut fibres can be proved as an alternative to glass fibres as it is having that potential. To improve the surface adhesion , it can be chemically treated. 1% NaOH for one hour was used on fibres and the composite's mechanical properties were observed. The higher value of tensile strength was observed for these chemically treated fibres. The criteria for getting the higher values of tensile strength was reinforcing the fibres from 10 to 30%. Above 40% the tensile strength will decrease. Researchers have tried KOH also for chemical treatment of the fibres. These composites have shown more ductility than the untreated fibres when tested for mechanical properties. There are other chemicals also used for treating the surface of the fibre and they are sodium hydroxide, potassium permanganate, benzoyl chloride and acrylic acid **[Ashok et.al. 2018].**

The investigation was done by researcher Desai et.al in which the composite was prepared with the areca fibres reinforcement in the matrix of PLA. The three materials were experimented. First was neat PLA , second was ultraviolet treated areca fibres in PLA and third was untreated areca fibres in PLA. Further the volume percentage of the reinforcement of fibres were also varied and the composite was tested for its mechanical strength, density , moisture content etc. When chemical treatment is to be done, alkali treatment is widely used. The areca fibres are treated with UV light obtained from LEDs which was having 365 nm wavelength. The treatment was given for one hour and at room temperature. Experimentation proved that there was an enhancement in strength of the composite because of UV treatment as it removes the lignin contain from fibres and allows the cellulose to come on surface. The treatment helps in increasing the hydroxyl group which is responsible for bonding of the fibers with matrix. Moisture absorption was also found lesser in treated fibres than the untreated. Tensile strength and flexural strength was found greater than the untreated one **[Desai et.al 2019].**

2.2 Effect of fibre orientation

One of the parameters which creates the impact on strength of the composite is fibre orientation. Different orientation of fibres reinforced in a composite may give different properties of the composites. Here is an attempt made to review some of those researches in which fibre orientation was taken in to account and experimentation was conducted.

In the experimentation done by kishor dinakaran the areca fibres were reinforced in the epoxy matrix and the composite material was developed. To study the effect of fibre orientation areca fibres were incorporated inside epoxy with angles 0°, 30°, 45°, 60° and 90°. The process used to develop composite was hand layup. The hardener also was used inside the resin with stirring. The fibre's 90° orientation means the fibre axis is parallel to Y axis and fibre's 0° orientation means fibre's axis is parallel to X axis. The composites were made and tested by ASTM standards. The composite (with layers) made by fibre orientation 90°-90°-90° was having the best strength and the obtained Young's modulus value was 1.798 GPa. The elongation recorded 11.6% more than that of the original length. But this best result was obtained when loading was done longitudinally on sample. In case of bidirectional loading the sample having fibre orientation 45°-90°-45° gave the optimum results **[Dinakaran et.al. 2017]**. When Jute and Kevlar fibres were used to make a composite with the help of epoxy resin as a matrix, some results were obtained in the context of fibre orientation and those were discovered by Sunil Manohar Maharana. The making of the composite was done by hand layup method. The fibre reinforcement of Kevlar was kept fixed 20% and jute fibre reinforcement was varied in accordance with the epoxy resin. The fibre orientation was also a variable and 0°,30°, 45° and 60° were the angles considered for reinforcement. When tested for mechanical properties, it was concluded that for 30° fibre orientation and 40% fibre reinforcement sample the tensile strength was found maximum. For same 40% fibre reinforcement, and angle 45° the flexural strength of the composite sample was found maximum **[Maharana et.al.2019].**

To get the better strength of the composite material the hybrid approach was followed by researcher B STANLY et.al for manufacturing of the composite. The glass fibres along with the bamboo fibres were used to reinforce in to the polyester resin. Along with the matrix, cobalt napthanate was used as a oxydiser and methyl ethyl ketone peroxide as a catalyst. Two composite plates were manufactured. One is pure bamboo and polyester and the other is of hybrid bamboo/glass fibre and polyester. Once the composite plates are manufactured, they were cut for the different angular orientation of fibres e.g. 0°/90°and ± 45° and tested as per the ASTM standards for tensile and flexural test. When hybrid composite with fibre angle ±45° was tested for tensile strength it was found 92.26 N/mm2 and its flexural strength was found 387.725 N/mm2. These values were higher when compared with the other composites whose angles were 0°/90°. It is concluded that the composite sample having orientation of fibres with ±45° provided better mechanical strength **[Retnam et.al. 2014].** The investigations were done by author H.Raghavendra Rao et.al. in which natural fibre of hardwika binata and bamboo are used in epoxy matrix along with hardener. Two composites were manufactured, one with hardwika binata and other with bamboo. Three different reinforcement percentage were used in these composites (i.e. 8,16 &24 wt%). Thus in total there were six composite samples in total. From each composite material, four samples were cut with the fibre orientation 0°, 45°,60° and 90°. The effect of tensile strength and impact strength were checked as per the ASTM D638-05 and ASTM D256-06 . The results showed that the tensile stress was maximum at 24 wt% of fibre reinforcement and 0° fibre orientation for bamboo fibres. The value of tensile stress for bamboo fibre is 125 MPa and that for hardwika binata reinforced composite is 105 MPa. At 24 wt% and 90° orientation, minimum tensile stress was detected for bamboo fibre reinforced composite and the value for bamboo was 122 MPa and for hardwika binata it was observed 99 MPa **[H.Raghavendra Rao, 2021].**

False banana and glass fibres were reinforced in epoxy resin (2000 Epoxy) with a hardener (2060 Hardener) and the composite was made. The composite was tested as per ASTM standards for tensile (ASTM-D 3039) , flexural (ASTM-D790M) and compression (ASTM-D3410M) test. The method applied to manufacture the composite was hand layup. Reinforcement volume was also another variable along with the fibre orientation. Banana fibres were oriented in three sets and the three samples were made. The combinations made are (1G,0B,G,0B,0B,G), (G,90B,0B,G,0B,G), (G,G,90B,90B,90B,G). It is concluded that the highest tensile strength 134.38 MPa was obtained for 0° banana fibre orientation and the lowest tensile strength 50.31 MPa was obtained for 90° fibre orientation. On the similar ground , the compressive strength also was found maximum i.e. 47.357 MPa for fibre orientation 0° and was minimum i.e. 13.863 MPa for 90° orientation. For flexural strength experimentation also the 0° orientation have shown its dominance over the other fibre orientation as it gives better strength along the loading direction **[Batu et.al. 2020].**

In a study carried out by Dwiwedi , the fibre orientation effect was studied for tribological behavior on a composite comprising long Jute fibre in a mtrix of unsaturated polyester. While making the composite, the fibres are oriented in three directions and three samples are made. First sample has fibres in the direction of sliding. Second sample was comprising the fibres perpendicular to the direction of sliding and third sample was having fibres normal to the sliding direction (with specific repeating pattern). A composite having fibres normal to sliding direction showed the lowest wear rate and the composite having fibres aligned in a sliding direction showed the highest wear rate. For the composite having the fibres perpendicular to sliding direction, the optimum wear resistance was seen. Operational load capacity for the composites having fibres along the sliding direction, perpendicular to sliding direction and normal to sliding direction was found 70N, 20N and 60N respectively **[Dwiwedi et.al. 2009]**.

2.3 Effect of fibre volume variation

The fibre reinforcement in a matrix can be done up to certain limit only. Many a times maximum up to 40 to 50 % of the fibres reinforcement is allowed in a matrix. It is mandatory to check how the percentage of fibre volume is affecting the properties of the composite manufactured. Therefore the overview of the reinforced fibre volume is taken here.

In the research performed by researcher Borah et al epoxy resin was selected and in that betel nut fibres were reinforced. This composite was tested to see the mechanical strength. As the fibre volume was varied for percentage 0%, 4% , 5% and 8%, the mechanical properties also got influenced. At 5% of the fibre loading the tensile strength value was highest. When the loading was increased for more than 5%, i.e. 8%, the decrement in tensile strength value was observed and it is because of the improper adhesion between the fibre and the matrix. It concludes that to accommodate more fibre volume , it requires more amount of matrix **[Borah et.al. 2018]**.

Areca fibres and the polypropylene matrix was used to make the composite and the mechanical properties as well as the thermal properties were analysed. While making the composites the weight percentage of reinforcement was varied for 5%, 10% & 15% and maleic anhydried was used in 3% amount. From the experimentation it was found that bending strength , tensile strength and elongation was better for the composite having 5% of the reinforcement when compared with 10% and 15%. It was observed that as the reinforcement went on increasing, the mechanical properties got decreasing trend **[R. Christu Paul et al 2020**].

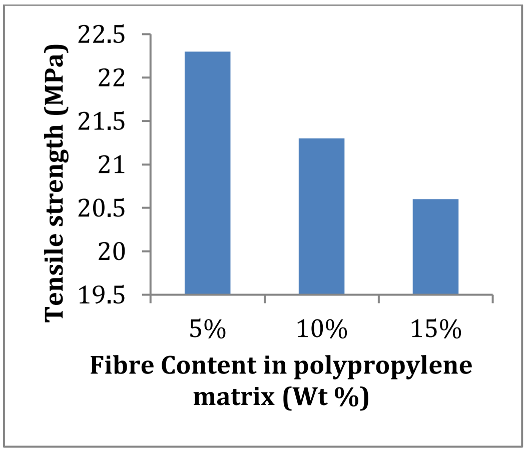

Fig 4: Effect of fibre content on tensile strength [R. Christu Paul et al 2020].

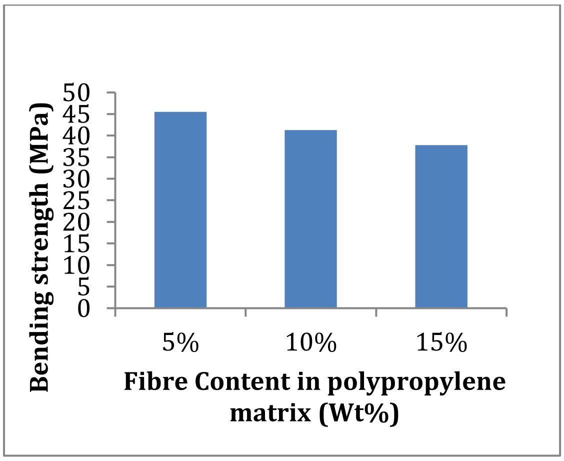

Fig 5: Effect of fibre content on beSnding strength [R. Christu Paul et al 2020].

Three composite samples were manufactured with 7.9%, 13.6% & 17.6 % fibre content. 7.9% and 17.6% were chemically untreated fibres and the fibres with 13.6% were the silane treated. For the untreated (7.9% & 17.6 wt%) fibres elastic modulus was more than the treated one (13.6 wt%). When checked for the compression strength it was found that it is decreased with increase in fibre content in the case of untreated fibres and for treated fibres it was improved. In this experimentation, the flexural strength remains unaffected for fibre content variation as well as fibre treatment variation **[Motru et.al. 2020**]. In an experimentation done by Nuthong three natural fibres named Bamboo,Vetiver grass and Coconut reinforced in the matrix of PLA. The fibre loading was done for 10%, 20%, 30% & 40% by weight. Two sets of this composite were made. In first set the fibres were given no chemical treatment and in another set the fibres were treated with epoxy (EPOLEAD PB 3600). Bamboo fibres showed improved impact strength with respect to the fibre content and maximum improvement for untreated fibres could be seen at 30 wt% of reinforcement and for treated fibres it was observed at 40 wt% when compared with neat PLA. The coconut fibres composite showed decrement in impact strength value with respect to the increase in fibre loading in PLA matrix. The treated fibres showed lesser decrement than the untreated fibres. For vetiver fibres the distinction between the values of impact strength were difficult to make as both treated and untreated fibre composites exhibited the same decrement in impact strength when compared with neat PLA **[Wiphawee Nuthong et al 2013].**

In the findings by Reddy et al Jute fibres were reinforced in PLA matrix and a biocomposite was formed. The jute fibres were loaded with amount 5%,10%,15% and 20% in the matrix. The composite made was tested for mechanical properties with standards ASTMD638M , ASTMD790M. The tensile strength with 15% of jute fibre reinforcement was seen 25% increased compared to neat PLA and the flexural strength of the composite was 116% increased compared to neat PLA. For the same 15% fibre loading , the tensile modulus was 1.55 times higher than the neat PLA and flexural modulus was 1.87 times higher than that of the neat PLA. Up to 15% reinforcement , the mechanical properties showed the increment but after that it decreased. For reinforcement 5%,10%& 15% of jute fibres, the tensile strength of the composite observed as 4%,13% and 25% more than neat PLA **[Reddy et. al. 2020].** In a study reported by the biodegradable matrix Polylactic acid was used in which the bamboo fibres were reinforced. The fibre content and the moulding temperature were varied to check the effect on the composite prepared. Various temperatures were used to heat the matrix i.e. o 120˚C, 140˚C, 160˚C, 180˚C and 200˚C. hot press was used for that. The volume of the reinforced bamboo fibres was varied from 0% to 72%. As the fibre content increases up to 50% the density of the composite sample increase and then decreases. The recorded density at 0% and 50% was 1.20 and 1.35 g/cm3 **[Sinha et.al.2018].**

A research was conducted by Rehman et.al in which the betel nut fibres along with coir fibres were taken and reinforced in a polypropylene mixture to make a hybrid composite. The different volume percentages were selected for reinforcement viz 5%, 10% and 15%. The combination ratio of the fibres were also varied as 1:1, 3:1 and 1:3. When the composite samples were tested as per the ASTM standards, it was found the mechanical properties like impact strength , flexural strength were increased with respect to fibre loading but the tensile strength was decreased. It happened because the increasing fibre loading enhanced the contact area between the fibre and the matrix and as the fibres were moisture absorbing and the matrix was moisture repellent , the bonding took place was weak. Amongst all the combinations, the fibres with alkali treatment were and with combination 1:1 ,when taken with 15 wt% of reinforcement, gave optimum results for mechanical properties **[Rehman et.al. 2018].**

2.4 Effect of fibre length variation

Reinforcing fibres length also plays a vital role in strength of the composite developed. Many researchers have investigated the effects of the fibre length variation on the properties of the developed composites. In this paper the briefing of some of those results is done.

Sajin experimented upon reinforced Jute in polyester for making a composite. The fibres were varied in length and different samples of the composite material was made. The length of the fibres used for reinforcement was 5mm, 10mm, 15mm, 20mm and 25mm. The reinforcement was 30% and the matrix volume was 70% for all the samples. From the fig it is evident that the flexural strength of the composite decreases with respect to the increment in fibre length. The impact strength also goes on decreasing with respect to increment in fibre length. The maximum value for both properties were obtained at 5mm fibre length reinforced composite **[Sajin et.al. 2020]**.

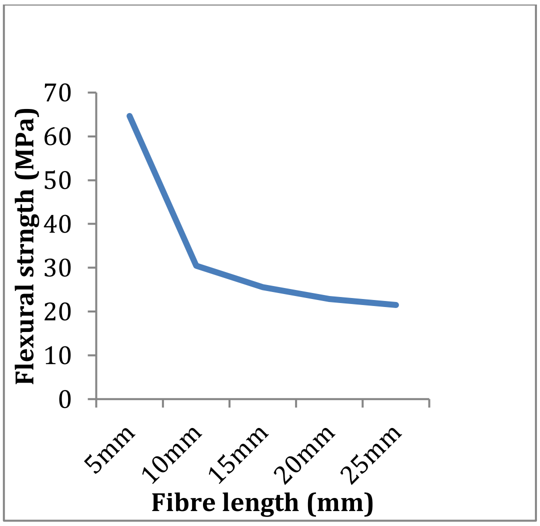

Fig6. Effect of fibre length on flexural strength of the composite [Sajin et.al. 2020]

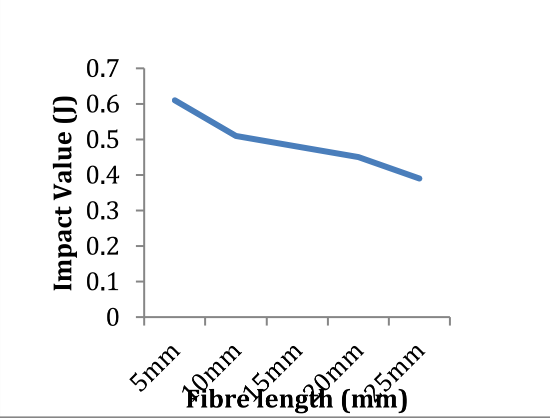

Fig 7: Effect of fibre length on impact strength of the composite [Sajin et.al. 2020]

In the research by Arun kumar the composite was made using date palm, banana and sisal fibres. They are clubbed together the different percentage of the reinforcement was used to make a composite material. Before reinforcement the fibres were cut for lengths 6mm, 8mm and 10mm. Epoxy LY556 with hardener HY951 was the resin used for reinforcement of fibres. First of all 30% of the mixed fibres were added inside the matrix. (Each fibre was with 10% of reinforcement) . For every composition the reinforced fibre's length was varied from 3mm to 8mm. The samples were tested for mechanical properties. It was concluded that when the fibre length was more than 8mm, the elongation of the composite at the breakage found more. With respect to decrease in length (below 8mm) the tensile property decreases. In case of flexural strength the decrease in length improves it and at the shortest length it was found maximum (i.e.132 MPa). The bonding between the matrix and the fibres is responsible for this **[Arun Kumar et al 2020].**

Polypropylene copolymer BJ380MO is a matrix and hemp fibres as a reinforcement were used to make a composite. Kraton 1652G (SEBS) was used for impact modification. Competibiliser also was used. Fibres were cut in three average lengths 1mm, 2.5mm and 4.5mm.In polypropylene matrix the additions of 5% and 15% of MAPP and SEBS respectively are done. In this matrix the 20% and 30% of the fibres are added and extruded in twin extruder followed by injection moulding to get the test samples as per ASTM standard. Generally fibre length increases after mechanical processing but with 20% loading the hemp fibre in PP matrix showed reduction in length. In case of 30% loading, massive fibre breakage was observed in injection mouding. As a result of use of SEBS the fibre length's reduction took place in considerable manner. The increase in tensile strength was obtained in 30 wt% of hemp fibres with different lengths. The composite's stiffness was improved with the increase in fibre length. Thus the fibre length is directly affecting the performance of the hemp fibre reinforced composites **[Panaitescu et.al. 2020].**

In the research performance by Imran Musanif the coconut fibres were used as a reinforcement in the polyster resin (Unsaturated Polyester Resintipe Yucalac BQTN 157) and the composite was made . The orientation of the fibres were chosen as arbitrary. Before the reinforcement the coconut fibres were treated with a chemical solution. The composite was manufactured on the steel plate with printing and tested with ASTM D 256 standard for impact strength and ASTM D 785 for hardness. With changing the fibre length the effect on mechanical properties was checked. The fibres were cut in to pieces 10, 20, 30,40 & 50mm. Loading of the fibres was also the another variable considered for experimentation. 30, 40 & 50 wt% is used with 1% of MEKP. Variation of different fibre lengths with the amount of fibre loading was experimented and the results were concluded. Hardness value will increase when fibre length goes on decreasing. Highest hardness was achieved with composite was having fibre length 10mm and volume percentage 50%. With increased fibre length the impact strength also increases. The highest impact strength was seen at combination 50mm fibre length 50% reinforcement **[Musanif et.al 2018]**. In the experimentation done by Chethana M.R. the areca sheath fibres were used for the reinforcement and the matrix used was Lapox 12 with hardeners. 10mm, 20mm and 30mm were the fibre lengths selected to reinforce inside the matrix. From experimentation it was evident that tensile strength and modulus for 30mm fibre length composite was found higher than the 10mm and 20mm fibre length composite. The value of tensile strength was 13.67 N/mm2 and the value of tensile modulus was 1345.16 N/mm2. **[Chethana M.R. et al.2016].**

Kongkaeu et.al. conducted a research in which the vetiever fibres were reinforced inside the epoxy matrix with varying fibre length (3,5,7,9 and 13mm). The fibre was added with 12 weight percentage of the composite. When the 5 samples were made they were tested

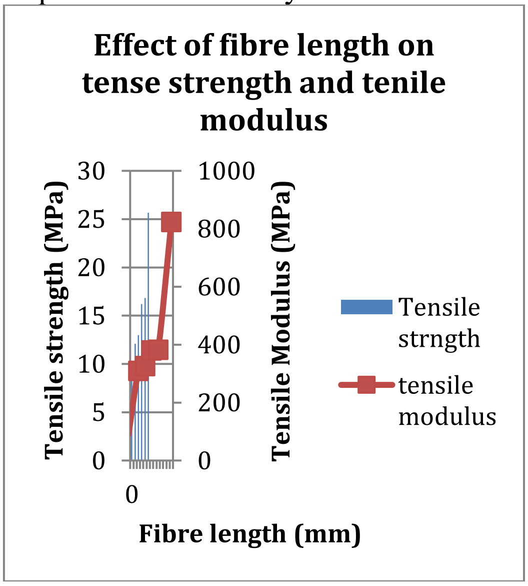

Fig 8: Effect of fire length on tensile strength and tensile modulus [Kongkaeu et.al.2016]

From fig, it is clear that the tensile strength goes on increasing as per the fibre length increases and maxium tensile strength was obtained as 25.65 Mpa and maximum tensile modulus was obtained as 823.17 Mpa at 13mm fibre length.

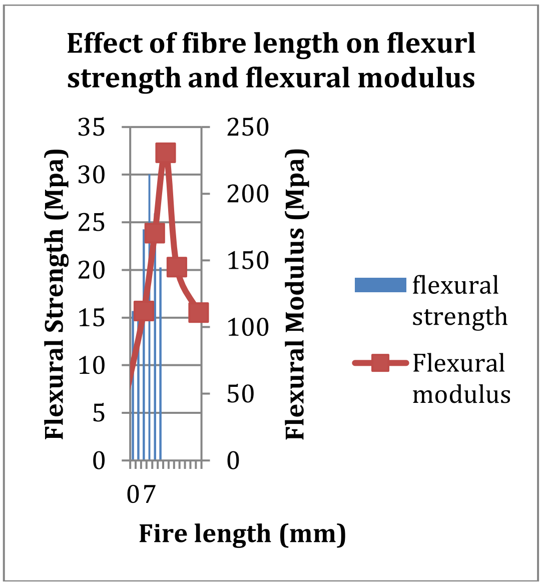

Fig 9: effect of fibre length on flexural strength and flexural modulus [Kongkaeu et.al.2016]

From figure it can be concluded that the flexural strength and flexural modulus increases as fibre length increases. The maximum values for flexural strength and flexural modulus are 30.5 MPa and 250.64 Mpa respectively and those were found at 7mm fibre length **[Kongkaeu et.al.2016].**

The plant *Sansevieria trifasciata* fibres were used to make the composite with the help of matrix polyester. For reinforcement, five different fibre lengths were selected and the composite samples were made accordingly. Chemically treated fibres in the presence of catalyst and accelerator were used to make composite. The fibre length was selected as 2,4,6, 8 and 10mm. While checking the tensile strength, it was seen that as the length of the fibre increases the tensile strength increases. The highest tensile strength was obtained when composite was containing the fibre length 10mm. In a test it was observed that the elongation at the break point of the composite was independent of fibre length. **[Sankar et.al. 2014]**

A study conducted by Sambandamoorty et.al. reveals the sound absorption capacity of the Jute fibres. The fibres were cut in four different lengths of 5mm, 10mm, 15mm and 20mm. The sound absorption was checked with impedence tube meter. The sound absorption capacity went on increasing with respect to fibre length and found maximum at 20mm length. In addition the surface treatment of the 20mm length fibre was carried out with the help of NaOH, NaHCO3 and Cr2SO4. The results revealed that the treatment with alkali on fibre showed the maximum sound absorption property. The fibres without chemical treatment absorbed more sound than the treated fibres. It happened because of presence of voids and cavities in untreated fibres **[Sambandamoorty et.al. 2021].**

3. Tribological properties of natural fibre composite

The composite made with natural fibres has got many applications in various areas like aerospace, automotive, domestic etc. The research is going on whether the tribological properties of the composites can be enhanced or not. Few of the researches have briefed here to get the idea regarding the development of a new composite with the better tribological properties.

Abundantly available three plant fibres sisal, nettle and grewia optiva were selected and reinforced in PLA matrix to make a composite. The compression method with application of heat was used to make a composite. For testing of the wear behavior of the composite, a wear tester of Ducom company was used. Three different types of natural fibers (nettle, grewia optiva and sisal) were incorporated into PLA resin to develop laminated composites using a hot compression technique. There was 10–44% reduction in friction coefficient and more than 70% reduction in specific wear rate of developed composites as compared to neat PLA. The procedure for sliding wear characterization was followed as per the ASTM G99-95 standard. The maximum value of the friction coefficient for the developed composites was reduced as compared to maximum value of friction coefficient for the neat PLA. Wear performance of PLA was significantly improved due to the addition of natural fibers as the specific wear rate of composites was considerably less as compared to specific wear rate of neat PLA, especially at higher loads. The observations from the tribo tester experimentation said that when the sliding speed was increased, the wear rate of PLA/Nettle composite also increases. In case of PLA/Gravia composite, the wear rate was decreased initially and then increased with respect to speed increase. For composite PLA/S, the wear rate decreased with speed increment. Nettle and gravia fibres exhibit good wear resistance for lower values of speed but as it gets softened at higher speeds the wear values enhanced. It is because the fibres breaking or coming out from matrix. Overall observation is specific wear rate of the composite material is lesser than the neat PLA and the wear also is lesser than the neat PLA material **[Bajpai et.al. 2013].**

The study performed by Wei Yin in which the wood samples wenge and tamarisk were taken and their friction behavior against a steel ball was investigated. Being a hard wood wenge was not much affected by friction speed as well as normal load. On the other hand the tamarisk was grealy affected by the same parameters as being the soft wood. For viscoelasticity wenge showed lesser value than the tamarisk. The value of friction force was also observed smaller for tamarisk than wenge. Wenge has higher elastic modulus value than tamarisk **[Wei Yin et al 2015]**. In a research done by E.García et al the high density polyethylene was used in which the peanut shell was used as a reinforcement. The percentage of reinforcement was varied for 2%,4%,6%,8% and 10%. This composite was tested for its tribological properties. Peanut shells were milled in a ball mill to get the fibres. Composite material was extruded and then injection molded as per the ASTM D638 standard. The wear experimentation was done on equipment UMT2 centre tribometer. 10mm spherical pins o Al_2O are used in this. For 10 mm distance and for 10, 20 and 30 N load , the test was conducted . The result concludes that there is no effect on the tribological behavior of HDPE by the reinforcement percentage as the wear volume and wear rate were increased when load applied was increased but it shown similar values for different weight reinforcement percentage **[E.García et.al. 2021]**.

Though there are many advantages of natural fibre composites , some disadvantages like moisture absorption, non durability, matrix property changes are there. To avoid it the hybridization of the composites is to be done. In this study the fibres Flax, Kenaf, Glass and carbon fibres were used in the matrix epoxy with hardner. The composite was tested for a wear and the test is conducted in DUCOM TR-50 as per the ASTM standard. The test was conducted for a sliding distance 1000 m and at constant load 25.5 N. The natural fibres have low wear rate therefore they are suitable to be used in the abrasive applications **[Khandai et.al. 2019].** In the investigations conducted by Nordin et.al. the Kenaf long fibres were selected and reinforced into the matrices. Two matrix materials were selected and two different composite materials were developed. First was Kenaf/Polyster compoite and second was Kenaf/Epoxy composite. The matrix material is used along with the hardener. Both these composites were tested for wear on tester TR-600. Experimentation sliding velocity was 14 m/s which was kept constant. The loads used for the test were from 5 to 30 N. The result of the test was both the composites showed the similar specific wear rate for a considered distance **[Nordin et.al. 2013].** Temesgen et.al. conducted a study related to triological behavior of the neat Polypropylene and natural fibre composite in which the fibres were of woven Jute and the matrix was Polypropylene. A pin on disc tester was used to study the tribological behavior of the composite. A specimen with 40% of fibre loading was used to test on Pin on disc. The applied load variation was 10, 20 & 30 N and the speed was selected 1, 2 & 3 m/s. The covered distance was kept constant i.e. 3000m. As speed of sliding and load applied are increased the coefficient of friction decreased. The specific wear rate was increased with the increase in load applied. This was observed for both neat PP and PP/Jute composite. The friction coefficient observed was reduced in case of the composite when compared to neat PP. The wear resistance property was found increased. The PP/Jute composite's applications thus found promising in the sectors like automotive and biomedical. **[Temesgen et.al 2014].**

4. Morphological study of NFC materials.

When testing of the composite is taken place , some conclusion is drawn. To crosscheck that conclusion the morphological study is done. The microstructure of the composite is studied with the help of SEM. The actual position of the fibres and the matrix can elaborate the situation. Few discussions are enlisted below.

In a study done by Yu Dong coir fibres were reinforced in Poly Lactic Acid matrix and the composite was made. The reinforcement was done in weight percentage 5%,10%,15% and 30%. The coir fibres were treated with chemical NaOH which is taken 2g in 100ml distilled water. The manufacturing method for this composite was compression molding. The stacking of fibres and the resin was taken in moulding machine and thus composite is manufactured. The tensile testing was carried out and the fractured surface morphology was observed using SEM of 15KV(Philips XL20). The adhesion between fibres and matrix can be examined with SEM. In fig a-d it can be observed that the fibre pull out has taken place and because of which the voids got created. These voids created the localized weak areas in composite materials. For treated fibres , the voids were smaller in size when compared with untreated fibres.

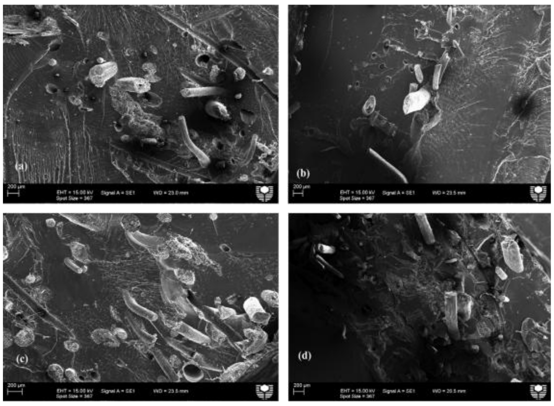

Fig 9: SEM micrographs of PLA based biocomposites reinforced with (a) 5 wt% untreated coir fibres, (b) 5 wt% treated coir fibres, (c) 10 wt% untreated coir fibres, (d) 10 wt% treated coir fibres [Yu Dong et.al. 2014].

If fibres were untreated and with more than 20% of the reinforcement, the gathered fibre bundles (shown in fig e) could be seen at random places which can lead to stress concentration of the composite at that particular place which may lead towards crack formation.

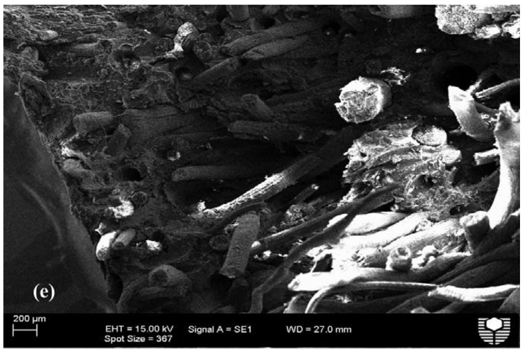

Fig 10: SEM micrographs of PLA based biocomposites reinforced with 20 wt% untreated coir fibres [Yu Dong et.al. 2014].

In this composite the fibres with chemical treatment were fractured along the plane of the matrix. Lesser amount of fibre pulling out was observed **[Yu Dong et.al. 2014]**

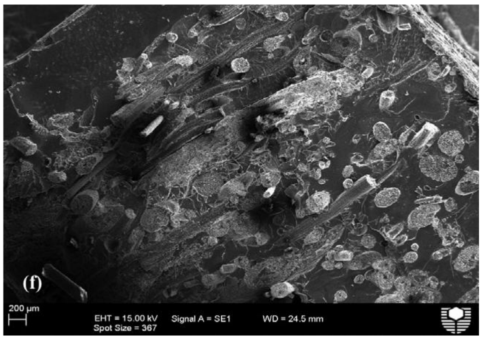

Fig 11: SEM micrographs of PLA based biocomposites reinforced with 20 wt% treated coir fibre [Yu Dong et.al. 2014]

In the study done by Nuthong et al PLA (TE 2000C) and bamboo, vetiver grass and coconut fibres were clubbed together to make a composite. Fibres were treated with Epoxy resin (Epoxidized polybutadiene, EPOLEAD PB 3600) . To check the bonding between the matrix and fibres SEM micrograph was studied. The fibres used in this study were chemically treated as well as untreated.

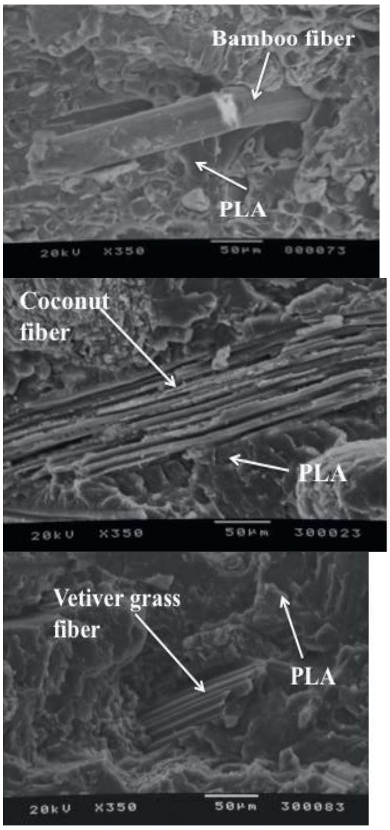

Fig12: SEM micrograph of the fracture surface of untreated composites (a)bamboo fiber/PLA;(b) coconut fiber/PLA;(c) vetiver grass fiber/PLA [Nuthong et.al. 2013].

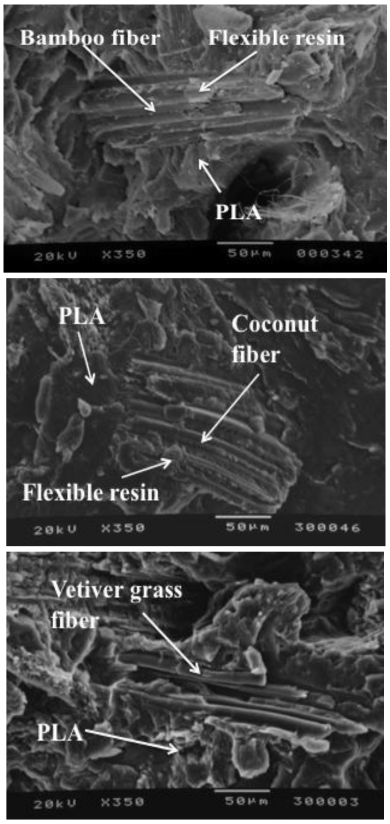

Fig 13 . SEM micrograph of the fracture surface of flexible epoxy treated composites (a) bamboo fiber/PLA;(b) coconut fiber/PLA;(c) vetiver grass fiber/PLA [Nuthong et.al. 2013].

SEM micrograph shows that the interfacial adhesion among the untreated fibres and matrix is improper than the treated fibres and matrix. Because of which the impact strength of untreated fibres and matrix composite was decreased. The best impact strength amongst three fibers was of Bamboo and PLA matrix **[Nuthong et al 2013].**

The study of treated and untreated banana fibres and PLA composite was carried out and tested for its mechanical properties like impact strength and tensile strength. The different amount of fibre reinforcement was done in the matrix. Treated fibre composite's impact strength and tensile strength was found better than the untreated fibre composite as well as better than neat PLA. From SEM morphology it is evident that for 10% of the fibre reinforcement the fracture of the composite can be observed because of the weak bonding between the fibres and matrix. On the other hand the bonding got established well in 30 wt% of the fibre loading inside the matrix. **[Pannu et.al. 2020]**

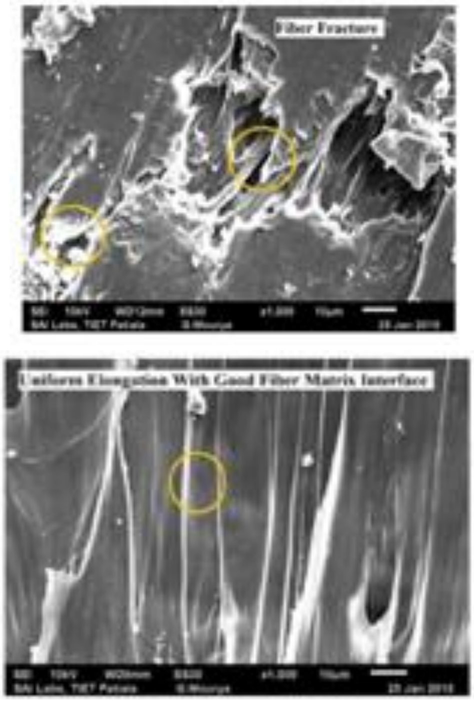

Fig.12 : a) SEM analysis at 10% fiber fraction. b) SEM analysis at 30% fiber fraction. [Pannu et.al. 2020]

In the research conducted by Oksman the Polypropylene and PLA matrix were used in which the reinforcement of flax fibres was done along with plasticizer as it reduces the brittleness of the PLA matrix. The fractured surface of the PLA/Flax composite was observed using SEM. It was seen that the fibres were pulled out and the fibre surfaces were clean. It means that there was poor bonding between the fibres and the matrix. It also can be seen that fibres were separated in the process of extrusion. **[Oksman et.al. 2003]**

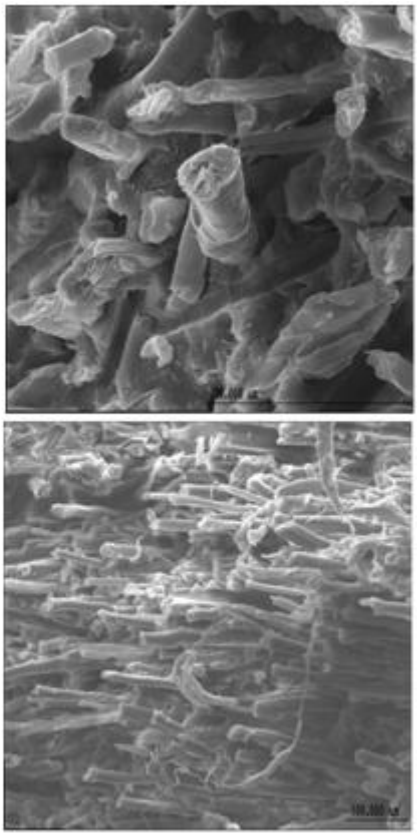

Fig 13: Fractured surface of PLA/flax composites: (a) detailed picture,(b) overview. [Oksman et.al. 2003]

The experimentation was conducted in which the composite samples were made using Jute fibres and unsaturated polyester, kenaf fibres and unsaturated polyester and bamboo fibres with unsaturated polyester. The compression molding technique along with the hand layup method was used to make composite. Tensile test was conducted as per ASTM D3039. The composite when tested, its fracture surface morphology was studied with the help of SEM. The SEM images showed the fibre pull out , fibre breaking and cracks even . These phenomenon certainly will reduce the strength of the composites. But when the tensile strength and tensile mdulus of a single fibres was checked, kenaf fibre's was found greater than the bamboo and jute fibre. That is why the plain areas in composite SEM image of kenaf/PP matrix can be seen which show the better adhesion among the matrix and fibres **[Toshihiko HOJO et al. 2014]**.

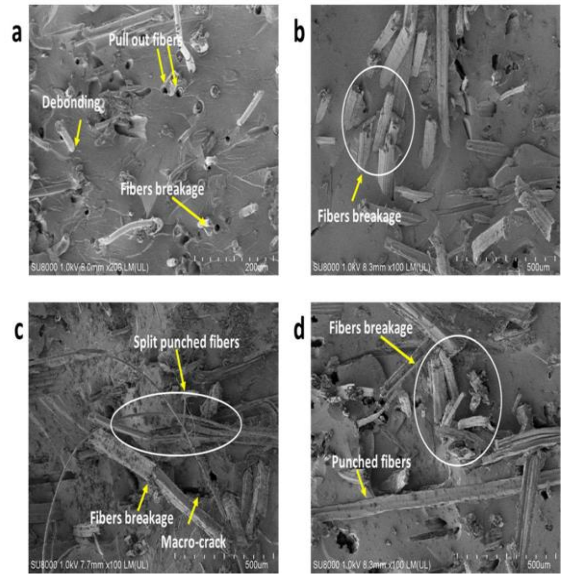

Fig.14. SEM micrographs of fracture cross-section a) Bamboo/UP; (b)Jute/UP; (c)Kenaf/UP; (d)Kenaf/UP after LCF test [Toshihiko HOJO et al. 2014].

Jute fibre is a natural fibre abundantly available in nature and shows very good mechanical properties. In the research performed by Sajin et al the fibre length (5,10,15,20 & 25mm) was the varying element considered and the matrix polyester was loaded with that. For various amount of fibre, the composite performance is seen by testing it as per ASTM standard. It is observed that the 5mm fibre length gives better results of flexural strength and impact strength. It is because for 5mm fibre length the interfacial adhesion was good than the other fibre lengths **[Sajin et.al. 2020]**

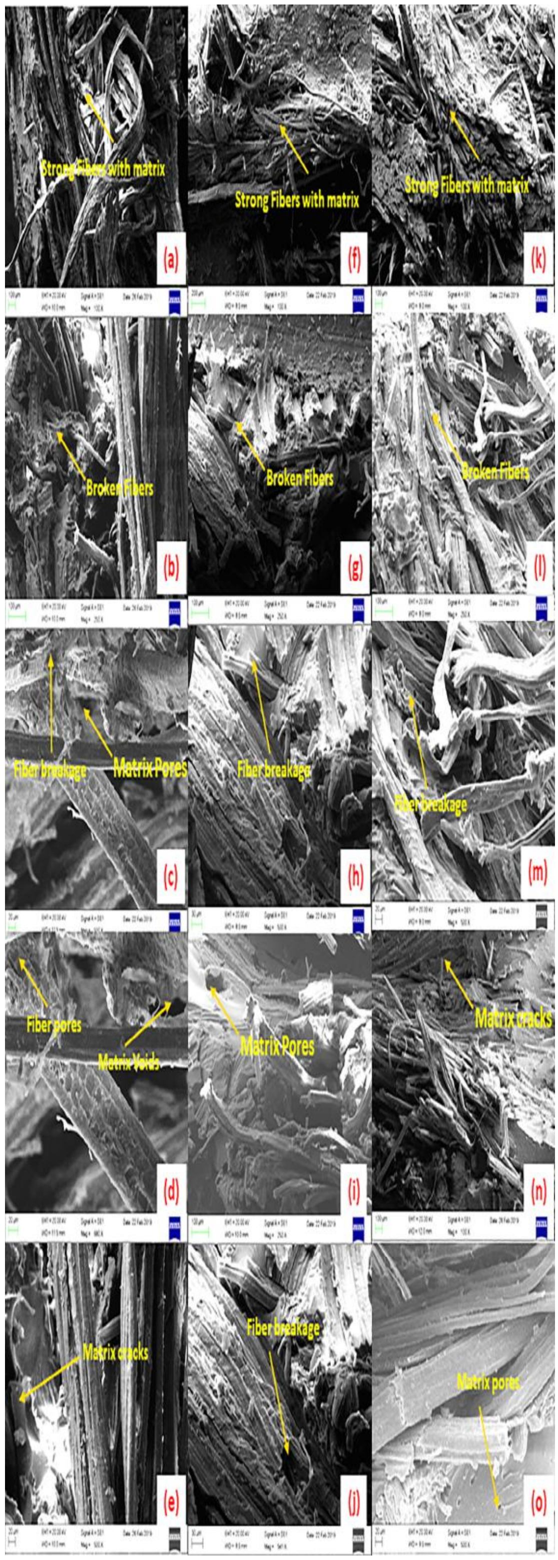

Fig.15: Fractured composite micrograph: Tensile (a-e), Flexural (f-j) and Impact (k-o).

Summary:

Natural fibre composites can be a very good alternative to existing materials in all sectors like domestic, automotive, aerospace, agricultural etc. Its biodegradability also proves it beneficial in the context of environmental issues. The discussion in this paper is about taking overview of the various natural fibre composites and their various properties. The fibres some times are chemically treated before the composite making to have the better adhesion between the matrix and fibres. The alkaline treatment is found used for many fibres because of the better results . Fibre volume variation in a matrix gave different results. The maximum loading of fibres can be done 50% beyond which the mechanical strength usually starts deceasing. Fibre orientation not only affects mechanical properties but also the tribological and wear behavior of the composite. The normal direction fibre's reinforcement gives better results than any other fibre direction. Fibre length also has a significant effect on mechanical/wear properties of the composite depending upon the matrix used.

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