Analysis of Natural fiber constituents: A Review

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Abstract. Natural fibers are being used as reinforcement in polymer based composites to fabricate various high-end application components. Light weight, high strength to weight ratio and bio-degradability are key features of natural fibers. Mechanical properties, as well as thermal properties of the components developed using polymer composites depend on various microconstituent present in natural fiber. Every constituent present in natural fiber has individual characteristic for influencing the properties of the natural fiber reinforced composite. The present paper explores the effects of the different constituent present in natural fibers on thermal and mechanical properties of the fibers.

1. Introduction

Natural fiber reinforced with polymers are being used in many applications from household to aerospace products. The use of natural fiber in polymer matrix composites has increased because of its high specific strength, degradability and no itching problem during its fabrication as compared to synthetic fiber. The properties of natural fiber-based composite are enhancing its use in many applications. Chemical composition present in natural fiber effect its mechanical and thermal properties.The various constituent present in fibers are hemicellulose, cellulose, pectin, wax and lignin [1]. Every constitute has individual influence on properties of natural fiber. Some of those are increase hydrophilic nature and few is responsible for thermal stability of natural fiber. Generally cellulose content is maximum in plant fiber.The hydrocarbons present in cellulose determine the crystallinity of natural fiber, which provide strength, stability and stiffness [2]. Microfibrils made of cellulose molecules act as a reinforced and lignin- hemicellulose act as a matrix for binding the structure of whole fiber yarn [1,3].

The hydrophilic nature of natural fiber depends upon the hemicellulose concentration in fiber. Hemicellulose are generally adhered the cellulose microfibrils and it exist in fiber in form of short branch crudely crystalline chain for embedding the microfibrils [4]. The presence of hemicellulose in fiber also influencing the thermal and biological degradation of natural fiber [5]. Every natural fibers have distinct structure which contain primary and number of secondary cell wall. The different phases of wall present in fiber is shown in figure 1.

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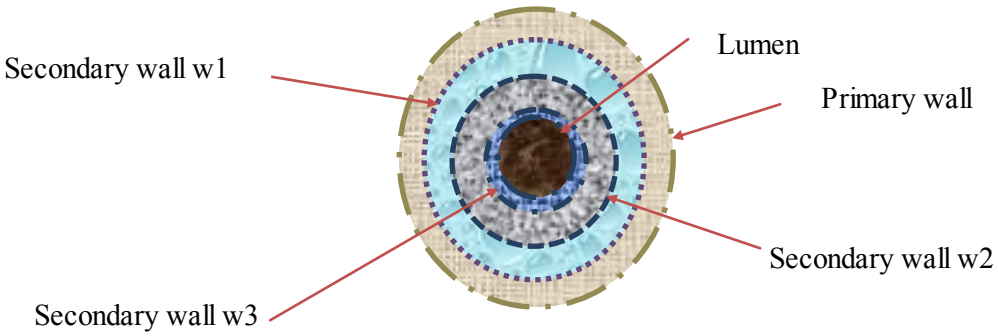


Fig. 1. Structure of biofiber [1]

The different walls of fiber consist of different content such as hemicellulose, lignin, pectin, wax and impurities in varying percentage. The secondary wall made up of three layer, in which wall w2 decided the mechanical strength of fiber. This wall consists of series of wounded cellulose microfibrils and this fibrils bundle adhere due to the presence of hemicellulose and lignin content in wall [1]. Every wall contains some amount of hemicellulose, lignin etc. to bind up the microfibrils. The centre portion of fiber is called as lumen it is a hollow potion of fiber. The properties which are influenced by different chemical composition of natural fibers are shown in figure 2.

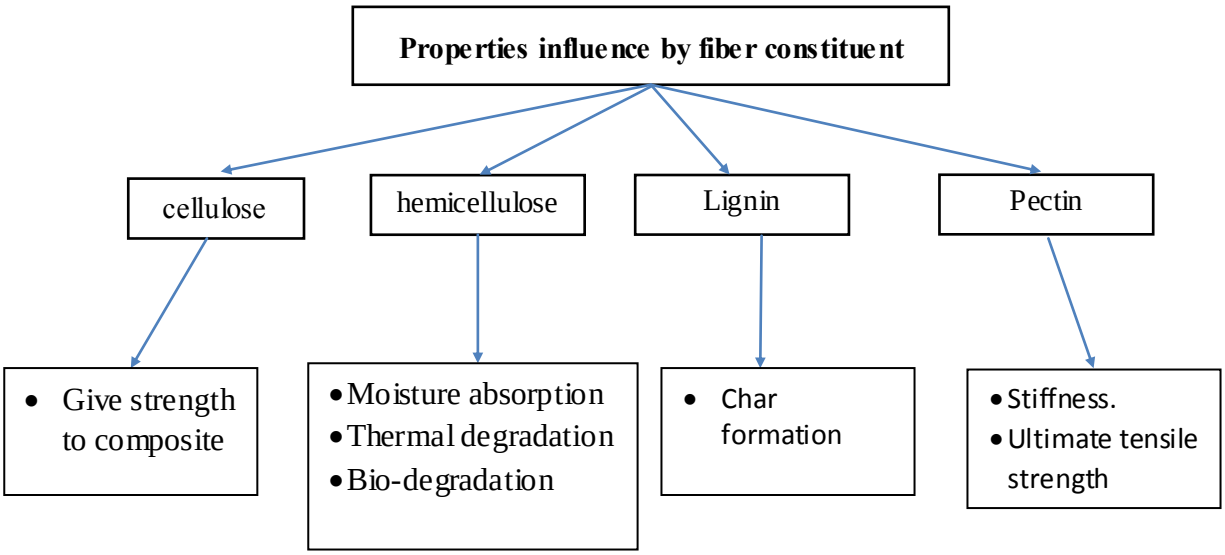


Figure 2. Composites properties influence by fiber constituent [1,6,7,8,9]

2. Fiber Properties influenced by chemical composition of fiber

Mechanical and thermal properties of fibers are influenced by the different chemical composition present in the natural fiber.

2.1 Fiber Properties influenced by cellulose.

Cellulose are the major strength blocks for the plants and in maximum fibers. The quantity of cellulose in fiber around 40-50% in most of the fiber [10]. Cellulose have a crystalline structure as compare to other constituent present in natural fiber. In crystallinity structure of cellulose, cellulose molecule bonded with hydrogen bond. This crystalline structure of cellulose give strength to the fiber during loading condition.

2.2 Fiber Properties influenced by hemicellulose

Hemicellulose is the second highest concentration available in fiber after cellulose . Hemicellulose content attached with cellulose fibrils by hydrogen bond, it binds up the fibrils reinforcement and act as matrix material for binding the cellulose fibrils with lignin [1]. Hemicellulose is the composition of glucose, arabinose, sugar, xylose, galactose and mannose [11]. Presence of hemicellulose content in natural fiber increased the hydrophilic nature of natural fiber.

Hemicellulose also responsible for the thermal stability of natural fiber. The excess amount of hemicellulose content in natural fiber reduce the thermal stability at higher temperature. The beneficial effect of releasing hemicellulose is not only increase the thermal stability but it also reduces the hydrophilic nature of natural fiber. Following are the result shown in table 1. For increasing the thermal stability of natural fiber after treatment by reducing the hemicellulose content.

Table 1. Thermal degradation of natural fiber after treatment

S.no	Natural fiber	Initial Degradation temperature of untreated fiber	Initial Degradation temperature of treated fiber	Treatment process	Reference
1.	Sugar cane bundle	200°C	250°C	Alkali treatment	12
2.	Lady fingure fiber	246.87°C	262.88°C	Alkali treatment	13
3.	Pineapple leaf	333.54°C	363.62°C	Alkali treatment	14
4.	Kraft wood fiber	275–385 °C	308–405 °C	Bleaching	5

2.3 Fiber Properties influenced by Lignin

Ligin is also a binding matrix for cellulose microfibrils it will attached with the cellulose by help of hemicellulose content. Lignin give rigidity to plant fiber by bind up the microfibrils, it also resists microorganism attack and hydrolysis with any acid [6]. Lignin has amorphous structure of crosslinked molecules and act as glue between fibrils. Cellulose and hemicellulose content is degraded by heat before the lignin degrade . The char formation in thermal degradation of natural fiber is due to lignin, this char formation act as coated insulation layer of degradation of lignocellulosic fiber for further degradation [15]. Lignin content increase the thermal stability of natural fiber.

2.4 *Fiber Properties influenced by Pectin*

Pectin is a hetropolysacharide and it is a naturally adhering agent, it presents in primary cell of plant and fiber [16]. The flexibility of plant and fiber is depending upon the pectin content. It holds the hemicellulose and cellulose together in stem by fringe them as shown in figure 4.

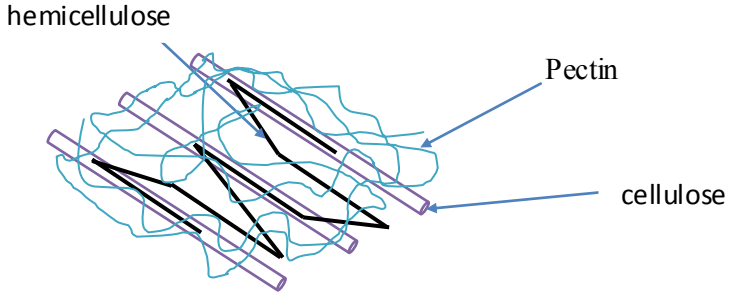


Figure 3. Pectin hold hemicellulose and cellulose

The function of pectin in fiber is to binding up the microfibrils into final fiber. Pectin effect the stiffness and ultimate tensile strength of natural fiber.

3. Conclusion

The effect of different constituent on properties of different natural fibers depends upon the concentration of constitute available in natural fiber. Cellulose is only responsible for the strength of the natural fiber because of its crystalline structure. And for hydrophilic nature of fiber hemicellulose is responsible, higher the concentration of hemicellulose higher the hydrophilic nature of fiber. The stability and geometry of cellulose microfibrils depends upon hemicellulose and lignin concentration. The thermal stability of natural fiber depends upon the lignin concentration, the char formation of lignin before degradation of microfibril it acts as an insulating coating to covered cellulose microfibrils. This review introduces the selection of natural fiber on the basis of its chemical composition for better performance of natural fiber reinforcement composite.

References

[1] John M, Thomas S 2008 Biofibres and biocomposites. Carbohydrate Polymers, 71: 343–64.
[2] Komuraiah A,Kumar NS,2 and Prasad BD 2013 Chemical composition of natural fibers and its influence on their mechanical properties. Mechanics of Composite Materials, 50(3): 359-376.
[3] Dittenber DB and GangaRao HVS 2012 Critical review of recent publications on use of natural composites in infrastructure. Composite: part A, 43: 1419–29.
[4] Banik N, Dey V and Sastry GRK 2017 An overview of lignin & hemicellulose effect upon biodegradable bamboo fiber composites due to moisture. Materials Today: Proceedings ,4: 3222–3232.
[5] Beg MDH and Pickering KL 2008 Accelerated weathering of unbleached and bleached Kraft wood fibre reinforced polypropylene composites. Polymer Degradation and Stability, 93: 1939-1946.
[6] Azwa Z N, Yousif BF, Manalo AC and Karunasena W 2013 A review on the degradability of polymeric composites based on natural fibres. Materials and design, 47: 424–442 .
[7] Silva FDA, Filho RDT, Filho JDAM and Fairbairn EDMR 2010 Physical and mechanical properties of durable sisal fiber–cement composites. Construction building material, 24:777–785.
[8] Methacanon P, Weerawatsophon U, Sumransin N, Prahsarn C and Bergado DT 2010 Properties and potential application of the selected natural fibers as limited life geotextiles. Carbohydrate Polymer, 82:1090–1096.
[9] Suardana NPG, Ku MS amd Lim JK 2011 Effects of diammonium phosphate on the flammability and mechanical properties of bio-composites. Material and design, 32:1990–1999.
[10] Desch, H.E., Dinwoodie, J.M., 1996. Timber: Structure, Properties, Conversion and Use. MacMillan Press Ltd, London.
[11] Reddy N and Yang Y 2005 Biofibers from agricultural by products for industrial applications. Trends in biotechnology, 23(1): 22-27.
[12] Hossaina MK, Karima MR, Chowdhurya MR, Imamb MA, Hosurb M, Jeelanib S, Ramsis Farag R 2014 Comparative mechanical and thermal study of chemically treatedand untreated single sugarcane fiber bundle. Industrial Crops and Products, 58: 78-90.
[13] Hossain SI, Hasan M, Hasan M and Hassan A 2013 Effect of Chemical Treatment on Physical, Mechanical and Thermal Properties of Ladies Finger Natural Fiber. Advances in materials science and engineering, Doi:dx.doi.org/10.1155/2013/824274.
[14] Panyasarta K, Chaiyuta N, Amornsakchaib T and Santawiteec O 2014 Effect of surface treatment on the properties of pineapple leaf fibers reinforced polyamide 6 composites. Energy Procedia, 56:406 – 413.

[15] Mohantya AK, Misra M and Hinrichsen G 2000 Biofibres, biodegradable polymers and biocomposites: An overview. Macromolecular materials and engineering, 276/277: 1-24
[16] Prachayawarakorn J and Pattanasin W 2016 Effect of pectin particles and cotton fibers on properties of thermoplastic cassava starch composites. Journal of science and technology, 38(2): 129-136.