

---

---

Preparation and Characterization of Crushed Sponge Gourd (*Luffa Cylindrica*) Fibre Reinforced Polystyrene Composites

By

**Abdulrahman Musa, Muhammad Abubakar Lawal, and Hamza Abba**

Department of Chemistry,  
Ahmadu Bello University, Zaria-Nigeria

Email: [absudaisu@yahoo.com](mailto:absudaisu@yahoo.com)

---

---

**ABSTRACT**

*In this study, crushed luffa cylindrica fibres were used to modify polystyrene matrix PS using compression moulding system. The fibres were alkaline treated with (5% conc.) NaOH. The treated and untreated fibres were characterised by Fourier Transform Infrared spectroscopy FTIR. Different weight fractions of the matrix to the treated fibre; 50:50, 60:40, 70:30, 80:20 and 90:10 were prepared respectively. The water absorption behaviour was observed and recorded for the composites. The morphological changes on the surface of the fibre before and after the chemical treated was investigated, using Scanning Electron Microscopy (SEM). Finally, the effect of fibre reinforcements on the flexural strength of the different weight ratio of the composites was found to be within the ranges of 4.25 to 1.37 N/mm<sup>2</sup>, with the material having a weight percentage of 80:20 showing the optimum strength value with the magnitude of 4.25 N/mm<sup>2</sup>. The successful enhancement of the flexural strength of this thermoplastic can be employed in the production of environmentally disposable high strength packing material.*

**Keywords:** Luffa Fibre, Polystyrene, Flexural Strength, FTIR, SEM

**INTRODUCTION**

Natural fibres are now attracting attention as good reinforcements for polymer matrices for many applications, a lot of work have been published in this regard (Ahankari, Mohanty, & Misra, 2011; Arrakhiz et al., 2012; El Mechtali et al., 2015). This observation is because of developments in science and technology in search for materials with excellent properties, eco-friendliness, light weight and low cost. Researches on fibre modified polymer composites as well as their production have served as one of the most promising approaches to meet up with this demand (Arpitha & Yogesha, 2017; Hao, Sapuan, Hassan, & Sheltami, 2018; Kim, Dutta, & Bhattacharyya, 2018). The use of natural fibres such as sisal, bamboo, hemp, kenaf, flax, palm, and jute, as reinforcements for both engineering and commodity plastics in certain applications, is particularly attractive. This is attributed to their; biodegradable, non-toxic, low densities, and cost effectiveness characteristics (El Mechtali et al., 2015; Panthapulakkal, Zereshkian, & Sain, 2006; Satyanarayana, Guimarães, & Wypych, 2007).

Similarly, thermoplastics are in high demand for both engineering and commodity plastics. For instance, polystyrene PS has excellent transparency, high electrical insulation ability as well as fluidity (Ching, Chuah, Ching, Abdullah, & Rahman, 2017). Further, this polymer has been reinforced with natural fibres to enhance and increase its applicability (Poletto, 2016; Singha & Rana, 2012). Polystyrene polymers are hydrophobic in nature; hence lack compatibility with natural fibres, which are hydrophilic. One way to improve the fibre association with polymer matrix is to subject it to chemical treatment. This increases the fibre-

surface roughness as a result of the removal of some waxy and gummy hydrophilic cells (Marques, Melo, Araujo, Lunz, & Aguiar, 2015). Good interaction between the polymer and the fibre can also be achieved by graft-copolymerising of hydrophobic polymer to the surface of the fibre. This approach gives the best fibre-polymer adhesion (Singha & Rana, 2010).

Luffa cylindrica (LC) also known as sponge gourd, is a plant from the cucumber family grown for its multipurpose use. It has an architectural structure that is highly complex with compositions such as; cellulose (60%), hemicelluloses (30%) and lignin (10%) (Mazali & Alves, 2005). Recently, many reports (Lai, Kao, Liu, & Chiu, 2016; Mohana krishnudu, Sreeramulu, & Ramesh, 2018; Patel & Dhanola, 2016) have shown the use of luffa fibre as a reinforcement for different polymer matrices. Its complex microstructure confers excellent mechanical performance with potential in vibration and shock isolation, as well as thermal insulation, and acoustic absorption (Shen, Xie, Huang, Zhou, & Ruan, 2013).

In this work, the treated luffa fibre was used to reinforce PS matrix and the water absorption behaviour of the obtained material was observed. The characterization of the sponge fibre was accomplished using FTIR and its surface modification was examined with SEM. Finally, the flexural strength for different weight fractions of the prepared composites were analysed accordingly.

## MATERIALS AND METHOD

The luffa sponges used for this work were collected locally in Zaria, Kaduna State, Nigeria. The fibres were peeled, cut, washed with distilled water severally, and dried in an oven for 72 hours before size reduction. Then, the obtained fibre particles were alkaline treated according to the procedure described by Mohanta et al. (Mohanta & Acharya, 2016). The PS used was purchased from a chemical vendor within Zaria and used as supplied.

### *Preparation of Composite*

10 g Luffa cylindrica (LC) and 90 g of PS were weighed to give a 90:10 weight fraction of the composite. The two roll mills of the moulding machine are subjected to a temperature of 200 °C for 10 minutes and the mixture was placed in the machine, while melting, the crushed luffa fibre were introduced to the polymer for compounding. The mixture was then transferred to the compressing machine where it was subjected to a temperature of 180 °C for 5 minutes, after this, it was allowed to cool for 5 minutes before usage. The same procedure was adopted for the preparation of samples with weight fractions of; 80:20, 70:30, 60:40, and 50:50 respectively.

## CHARACTERIZATION

### *FTIR Analysis*

FTIR spectra of both treated and untreated LC fibres were recorded on Agilent Cary 630 FTIR Spectrophotometer using KBr pellets over a range of 4000-500 cm<sup>-1</sup>.

### *Water Absorption Behaviour*

The water absorption test was carried out according to the standard method described by ASTM D5229. The given weights of the composites were measured and immersed in a beaker containing distilled water and was allowed to stand for a period of 12, 24 and 48 hours. They were then removed and wiped with a tissue paper and reweighed to obtain the new constant weight. The new weight was subtracted from the original weight and the difference

in weight is the extent to which the composites can absorb water. This absorption capacity is expressed in percentage calculated using the expression below

$$H_2O (\%) = \frac{W_2 - W_1}{W_1} \times 100 \quad \dots\dots\dots \text{Equation 1}$$

Where:

W<sub>1</sub> = Weight of dry sample

W<sub>2</sub> = Weight of saturated sample

**SEM Analysis**

The SEM analysis of the composite materials reinforced with treated and untreated, was carried out to study the morphological changes that occurred on the surface of the treated fibre. The SEM measurements were recorded on Leo Electron Microscopy Machine (435-VP).

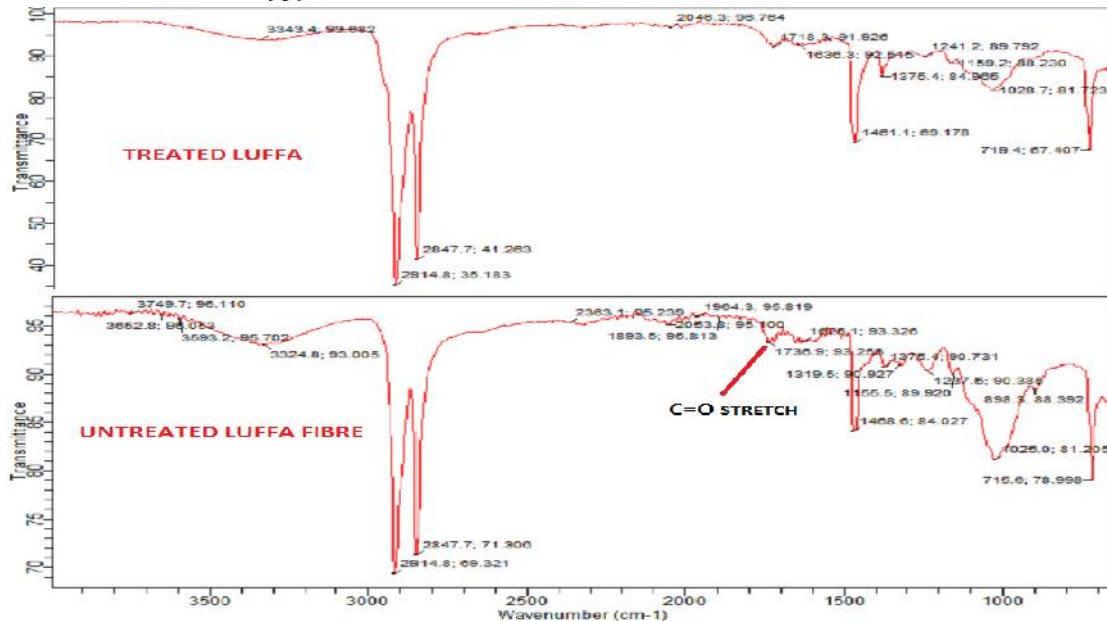
**FLEXURAL / BENDING STRENGTH TEST**

The flexural tensile strength was carried out on the UTM machine (100 KN 2007) in accordance with ASTM D 3039-76 standard to examine the strength of the composites with different proportion of the fibre.

**RESULTS AND DISCUSSION**

**FTIR Result**

Fig. 1, Shows the FTIR spectra of treated and untreated luffa cylindrica fibre (*Momordica cylindrica L.*). From the spectra, the result obtained after the treatment of the fibre shows a shift in the frequency of the carbonyl functional group carbonyl (C=O) from 1732 to 1724 cm<sup>-1</sup>, and a reduction in the peak intensity as well, this may be due to the removal of acetyl group present in the hemiacetal of the fibre. Also, a decrease in the intensity of the band at 1160cm<sup>-1</sup> associated with C-O stretching of the acetal group of the untreated fiber can serve as evidence for the successful removal of acetal as well (Sinha & Rout, 2009). The result also shows that, the intensity of the -OH band present in untreated luffa fibre is obviously reduced in the treated luffa indicating that some free hydroxyl group were removed in the treated fibre (Tsuboi, 1957).



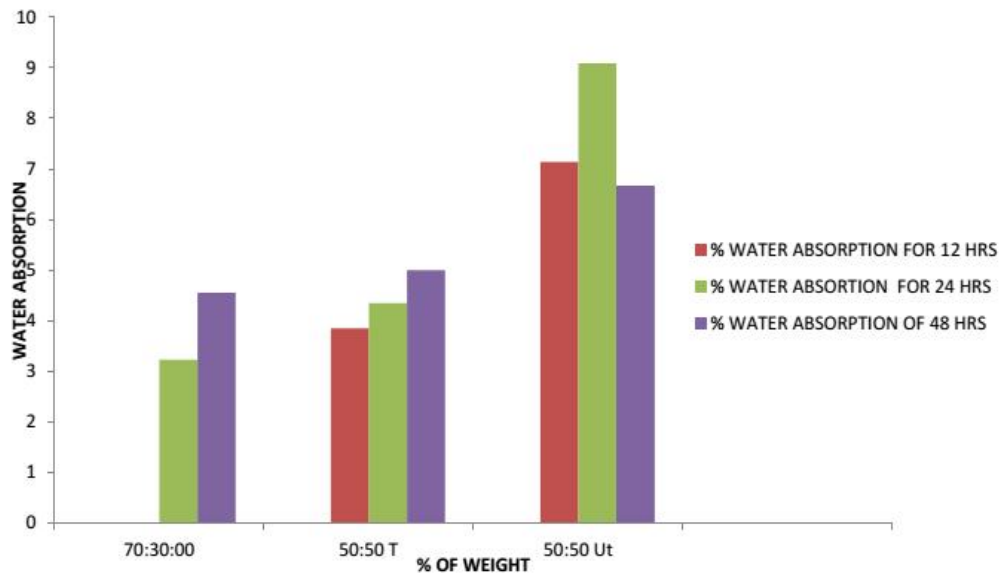
**Figure 1:** FTIR Spectrum of treated and untreated Luffa Cylindrica Fibre

**Water Absorption Behaviour.**

Table 1. shows the values of the calculated weights of water absorption for composites with weight fractions of; 70:30, 50:50 T for which the treated fibre was used, while 50:50 U.t represent the weight fraction of the composite for which untreated fibre was employed. Fig. 2, shows the water absorption characteristic of this composites. It was observed that, the percentage of water absorption was higher for the untreated 50:50 U.t composite as compared to that of the treated counterpart 50:50 T. This could be due to the treatment reaction that removes the hydrophilic hemicellulose and lignocellulosic cells of the fibre hence lowering interaction with water (Tsuboi, 1957). In addition, as the matrix percentage is increased, the water absorption behaviour is expected to reduce since the matrix is hydrophobic in nature (Bujjibabu, Das, Ramakrishna, & Nagarjuna, 2018).

**Table 1:** Water Absorption Capacity Result

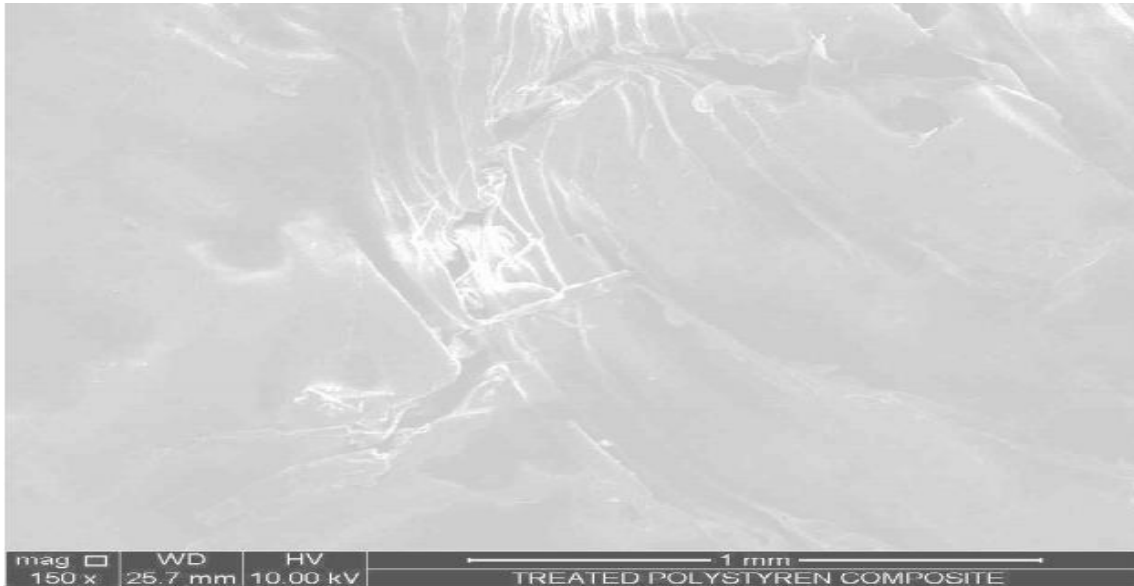
Composite	Initial Weight (g)	Final weight (g)	% of H <sub>2</sub> O Absorption	Time (hrs)
70:30	1.90	1.90	0.00	12
	3.10	3.20	3.23	24
	2.20	2.30	4.55	48
50:50 T.	2.60	2.70	3.85	12
	2.30	2.40	4.35	24
	2.00	2.10	5.00	48
50:50 U.t	1.40	1.50	7.14	12
	2.20	2.40	9.09	24
	3.00	3.20	6.67	48



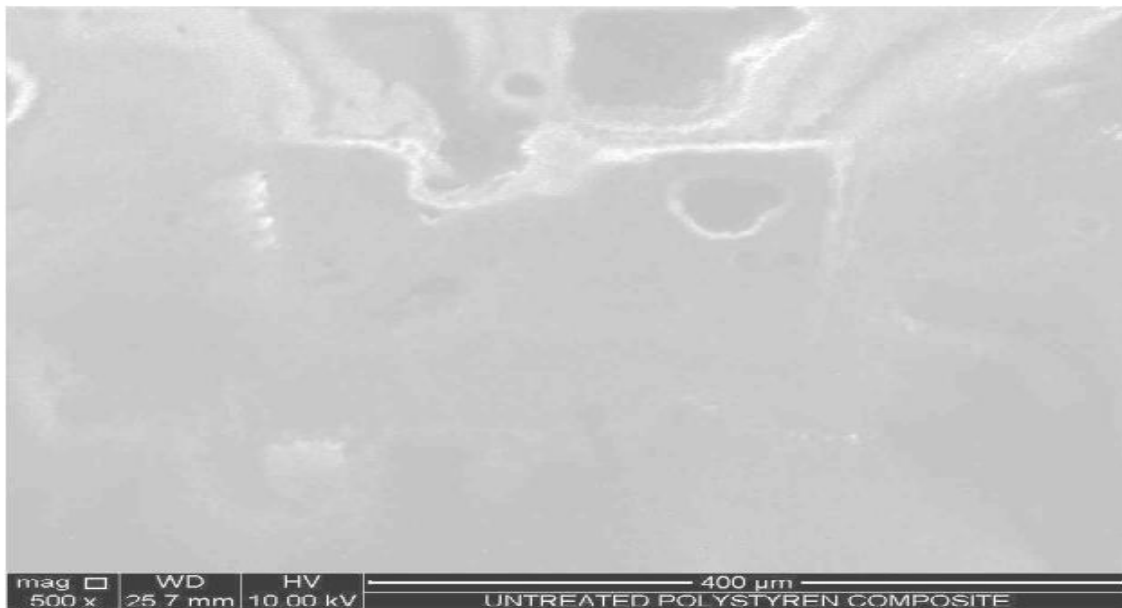
**Figure 2:** Result of Water Absorption Studies

**Morphological Analysis**

Fig. 3(a) and 3(b) are the SEM micrographs for both treated and untreated luffa fibre reinforced composites (50:50). It can be seen from the images that the interfaces are fully immersed in fibrous polymer phase especially for the treated sample. This is an indication of effective fibre-polymer interaction. The untreated fibre composite microstructure shows a surface, containing a waxy, amorphous fibre structure, which are packed together. Such gummy substance contributes to poor fibre-matrix adhesion (Mishra et al., 2003). While for treated fibre composite, the result indicates the absence of waxy and gummy components hence resulting in a clean and smooth surface.



**Figure 3(a): SEM Micrograph of Treated Fibre Reinforced Composite**



**Figure 3(b): SEM Micrograph of Untreated Fibre Reinforced Composite**

### Flexural Test

Table 2, shows the values for the flexural strength for the different weight fractions of the composite material, while Fig. 4, shows the plot of the values given in Table 2. The test was carried-out for the composite materials fabricated with matrix to fibre weight fractions of; 90:10, 80:20, 70:30, 60:40 and 50:50 respectively, of which the fibre was treated. Also, 50:50 weight ratio of matrix to untreated fibre was separately conducted. It is worth mentioning that, flexural strength does not depend only on the weight fraction of the reinforcement alone, its orientation and relative distribution within the matrix also influence the experimentally measured value (Melo, Panzera, Freire, & Scarpa, 2018; Nohrström, Vallittu, & Yli-Urpo, 2000). This is reflected on the test values for each of the compositions used in this work.

The results showed an optimum flexural Strength of 4.25 N/mm<sup>2</sup> for the composite with 80:20 weight fraction, which is 92.3 % increment when compared with that of 90:10 weight fraction sample, with flexural strength of 2.21 N/mm<sup>2</sup>. This can be attributed to better inclusion of the fibre particles within the polymer matrix allowing for effective transfer of stress from the matrix to the fibre before failure (Rana, Mitra, & Banerjee, 1999). However, as the fibre content is increased, the flexural strength diminishes as a result of fibre-fibre agglomeration resulting in material that is brittle. This brittleness can be associated with the presence of voids within the composites that obstruct stress propagation when load is applied (Yang et al., 2004). But, the flexural modulus gets improved upon even with higher particulate composition possibly due to the analysis of the sample at a point on the material where there is relative dispersal of the reinforcement particles within the matrix, hence, the increased result for composite sample with 60:40 weight compositions (Fu, Feng, Lauke, & Mai, 2008).

Treatment of the fibre enhances better stacking with polymer matrix, hence, the improved flexural strength in the absence of particle agglomeration. However, at fibre content of 50%, the flexural strength of the untreated is found to be higher than that of the treated sample with the same percentage weight. The reason for this reversed behaviour is unclear. Probably, it might be related to the diffusion of the polystyrene inside the large particles of the luffa sponge fibre at early stages of the extraction process due to presence of lignocellulosic cells, thereby increasing the mechanical interlocking between the matrix and the reinforcement which is reflected as the high test result for this composition (Gironès et al., 2011).

**Table 2:** Flexural Strength Result of the Composites.

Composite	Flexural strength (N/mm <sup>2</sup> )
90:10	2.21
80:20	4.25
70:30	2.32
60:40	3.95
50:50 treated	1.37
50:50 untreated	3.71

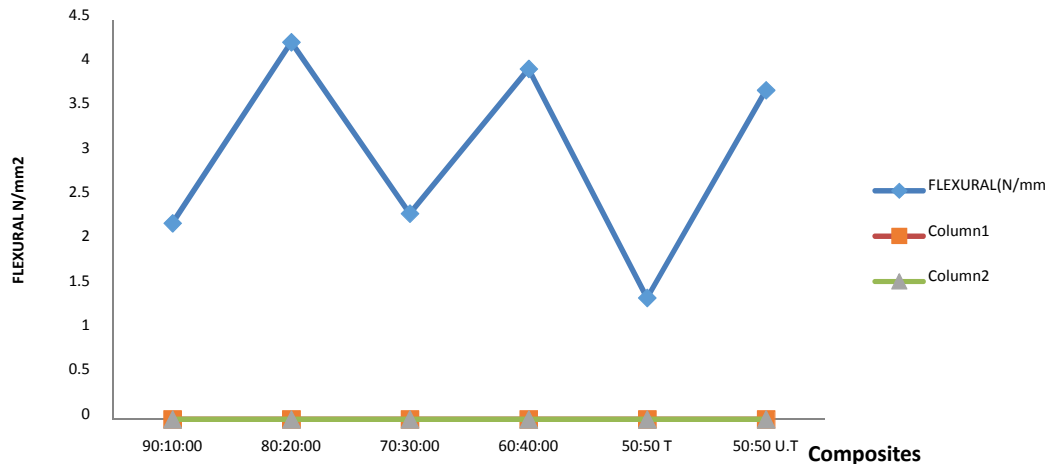


Figure 4: The Flexural strength pattern for the Composites

## CONCLUSION

The characterisation analysis of this study shows that, the alkaline chemical treatment of the sponge gourd was successfully as well as its incorporated into the polystyrene matrix. The flexural strength of the resulting composite was greatly enhanced, even though, excess of the fibre particles in the matrix can cause decrease in this mechanical property due to their agglomeration.

## REFERENCES

- Ahankari, S. S., Mohanty, A. K., & Misra, M. (2011). Mechanical behaviour of agro-residue reinforced poly(3-hydroxybutyrate-co-3-hydroxyvalerate), (PHBV) green composites: A comparison with traditional polypropylene composites. *Composites Science and Technology*, 71(5), 653-657. doi:<https://doi.org/10.1016/j.compscitech.2011.01.007>
- Arpitha, G. R., & Yogesha, B. (2017). An Overview on Mechanical Property Evaluation of Natural Fiber Reinforced Polymers. *Materials Today: Proceedings*, 4(2, Part A), 2755-2760. doi:<https://doi.org/10.1016/j.matpr.2017.02.153>
- Arrakhiz, F. Z., El Achaby, M., Kakou, A. C., Vaudreuil, S., Benmoussa, K., Bouhfid, R., . . . Qaiss, A. (2012). Mechanical properties of high density polyethylene reinforced with chemically modified coir fibers: Impact of chemical treatments. *Materials & Design*, 37, 379-383. doi:<https://doi.org/10.1016/j.matdes.2012.01.020>
- Bujjibabu, G., Das, V. C., Ramakrishna, M., & Nagarjuna, K. (2018). Mechanical And Water Absorption Behavior Of Natural Fibers Reinforced Polypropylene Hybrid Composites. *Materials Today: Proceedings*, 5(5, Part 2), 12249-12256. doi:<https://doi.org/10.1016/j.matpr.2018.02.202>
- Ching, Y. C., Chuah, C. H., Ching, K. Y., Abdullah, L. C., & Rahman, A. (2017). 5 - Applications of thermoplastic-based blends. In P. M. Visakh, G. Markovic, & D. Pasquini (Eds.), *Recent Developments in Polymer Macro, Micro and Nano Blends* (pp. 111-129): Woodhead Publishing.
- El Mechtali, F. Z., Essabir, H., Nekhlaoui, S., Bensalah, M. O., Jawaid, M., Bouhfid, R., & Qaiss, A. (2015). Mechanical and thermal properties of polypropylene reinforced with almond

- shells particles: Impact of chemical treatments. *Journal of Bionic Engineering*, 12(3), 483-494. doi:10.1016/s1672-6529(14)60139-6
- Fu, S.-Y., Feng, X.-Q., Lauke, B., & Mai, Y.-W. (2008). Effects of particle size, particle/matrix interface adhesion and particle loading on mechanical properties of particulate-polymer composites. *Composites Part B: Engineering*, 39(6), 933-961. doi:<https://doi.org/10.1016/j.compositesb.2008.01.002>
- Gironès, J., Lopez, J. P., Vilaseca, F., Bayer R, J., Herrera-Franco, P. J., & Mutjé, P. (2011). Biocomposites from *Musa textilis* and polypropylene: Evaluation of flexural properties and impact strength. *Composites Science and Technology*, 71(2), 122-128. doi:<https://doi.org/10.1016/j.compscitech.2010.10.012>
- Hao, L. C., Sapuan, S. M., Hassan, M. R., & Sheltami, R. M. (2018). 2 - Natural fiber reinforced vinyl polymer composites. In S. M. Sapuan, H. Ismail, & E. S. Zainudin (Eds.), *Natural Fibre Reinforced Vinyl Ester and Vinyl Polymer Composites* (pp. 27-70): Woodhead Publishing.
- Kim, N. K., Dutta, S., & Bhattacharyya, D. (2018). A review of flammability of natural fibre reinforced polymeric composites. *Composites Science and Technology*, 162, 64-78. doi:<https://doi.org/10.1016/j.compscitech.2018.04.016>
- Lai, S.-M., Kao, Y.-H., Liu, Y.-K., & Chiu, F.-C. (2016). Preparation and properties of luffa fiber- and kenaf fiber-filled poly(butylene succinate-co-lactate)/starch blend-based biocomposites. *Polymer Testing*, 50, 191-199. doi:<https://doi.org/10.1016/j.polymertesting.2016.01.015>
- Marques, M. d. F. V., Melo, R. P., Araujo, R. d. S., Lunz, J. d. N., & Aguiar, V. d. O. (2015). Improvement of mechanical properties of natural fiber-polypropylene composites using successive alkaline treatments. *Journal of Applied Polymer Science*, 132(12). doi:10.1002/app.41710
- Mazali, I. O., & Alves, O. L. (2005). Morphosynthesis: high fidelity inorganic replica of the fibrous network of loofa sponge (*Luffa cylindrica*). *Anais da Academia Brasileira de Ciências*, 77, 25-31.
- Melo, A. B. L., Panzera, T. H., Freire, R. T. S., & Scarpa, F. (2018). The effect of Portland cement inclusions in hybrid glass fibre reinforced composites based on a full factorial design. *Composite Structures*. doi:<https://doi.org/10.1016/j.compstruct.2018.01.069>
- Mishra, S., Mohanty, A. K., Drzal, L. T., Misra, M., Parija, S., Nayak, S. K., & Tripathy, S. S. (2003). Studies on mechanical performance of biofibre/glass reinforced polyester hybrid composites. *Composites Science and Technology*, 63(10), 1377-1385. doi:[https://doi.org/10.1016/S0266-3538\(03\)00084-8](https://doi.org/10.1016/S0266-3538(03)00084-8)
- Mohana krishnu, D., Sreeramulu, D., & Ramesh, N. (2018). Synthesis, Characterization, and Properties of Epoxy Filled *Luffa cylindrica* reinforced composites. *Materials Today: Proceedings*, 5(2, Part 1), 3835-3841. doi:<https://doi.org/10.1016/j.matpr.2017.11.637>
- Mohanta, N., & Acharya, S. (2016). Fiber surface treatment: Its effect on structural, thermal, and mechanical properties of *Luffa cylindrica* fiber and its composite. *Journal of Composite Materials*, 50(22), 3117-3131. doi:10.1177/0021998315615654
- Nohrström, T. J., Vallittu, P. K., & Yli-Urpo, A. (2000). The Effect of Placement and Quantity of Glass Fibers on the Fracture Resistance of Interim Fixed Partial Dentures. *International Journal of Prosthodontics*, 13(1), 72-78.



- Panthapulakkal, S., Zereshkian, A., & Sain, M. (2006). Preparation and characterization of wheat straw fibers for reinforcing application in injection molded thermoplastic composites. *Bioresource Technology*, 97(2), 265-272. doi:<https://doi.org/10.1016/j.biortech.2005.02.043>
- Patel, V. K., & Dhanola, A. (2016). Influence of CaCO<sub>3</sub>, Al<sub>2</sub>O<sub>3</sub>, and TiO<sub>2</sub> microfillers on physico-mechanical properties of Luffa cylindrica/polyester composites. *Engineering Science and Technology, an International Journal*, 19(2), 676-683. doi:<https://doi.org/10.1016/j.jestch.2015.10.005>
- Poletto, M. (2016). Polystyrene cellulose fiber composites: effect of the processing conditions on mechanical and dynamic mechanical properties. *Matéria (Rio de Janeiro)*, 21, 552-559.
- Rana, A. K., Mitra, B. C., & Banerjee, A. N. (1999). Short jute fiber-reinforced polypropylene composites: Dynamic mechanical study. *Journal of Applied Polymer Science*, 71(4), 531-539. doi:doi:10.1002/(SICI)1097-4628(19990124)71:4<531::AID-APP2>3.0.CO;2-I
- Satyanarayana, K. G., Guimarães, J. L., & Wypych, F. (2007). Studies on lignocellulosic fibers of Brazil. Part I: Source, production, morphology, properties and applications. *Composites Part A: Applied Science and Manufacturing*, 38(7), 1694-1709. doi:<https://doi.org/10.1016/j.compositesa.2007.02.006>
- Shen, J., Xie, Y. M., Huang, X., Zhou, S., & Ruan, D. (2013). Behaviour of luffa sponge material under dynamic loading. *International Journal of Impact Engineering*, 57, 17-26. doi:<https://doi.org/10.1016/j.ijimpeng.2013.01.004>
- Singha, A. S., & Rana, R. K. (2010). Enhancement of hydrophobic character of lignocellulosic fibers through graft-copolymerization. *Advanced Materials Letters*, 1(2), 156-163. doi:10.5185/amlett.2010.6134
- Singha, A. S., & Rana, R. K. (2012). Natural fiber reinforced polystyrene composites: Effect of fiber loading, fiber dimensions and surface modification on mechanical properties. *Materials & Design*, 41, 289-297. doi:<https://doi.org/10.1016/j.matdes.2012.05.001>
- Sinha, E., & Rout, S. K. (2009). Influence of fibre-surface treatment on structural, thermal and mechanical properties of jute fibre and its composite. *Bulletin of Materials Science*, 32(1), 65. doi:10.1007/s12034-009-0010-3
- Tsuboi, M. (1957). Infrared spectrum and crystal structure of cellulose. *Journal of Polymer Science*, 25(109), 159-171. doi:doi:10.1002/pol.1957.1202510904
- Yang, H.-S., Kim, H.-J., Son, J., Park, H.-J., Lee, B.-J., & Hwang, T.-S. (2004). Rice-husk flour filled polypropylene composites; mechanical and morphological study. *Composite Structures*, 63(3), 305-312. doi:[https://doi.org/10.1016/S0263-8223\(03\)00179-X](https://doi.org/10.1016/S0263-8223(03)00179-X)