Journal of Experimental Research

December 2018, Vol 6 No 4

Email: editorinchief.erjournal@gmail.com
editorialsecretary.erjournal@gmail.com

Received: *29th July, 2018*
Accepted for Publication: *20th Nov., 2018*

SHORT COMMUNICATION

Evolution of Bio-degradable Materials in Composite and Developmental Applications: Limitations and Future Prospects.

Adekomaya O.

Department of Mechanical Engineering, College of Engineering and Environmental Studies, Olabisi Onabanjo University, Nigeria

***Author for Correspondence:** adekomaya.oludaisi@oouagoiwoye.edu.ng

Abstract

Bio-degradable materials have been studied in many literature as a potential replacement for metallic and synthetic materials in view of the emerging environmental concerns. Part of its acclaimed advantage is its tendency to evolve cleaner climate and provide safe haven for future generations. The introduction of bio-fibre in many engineering applications is becoming popular as witnessed in the automotive component parts replacement and other useful area of engineering application. With the increasing integration of bio-fibre in composite formation, it is crystal clear that the availability of natural fibre for various engineering application may be hindered as a result of its declining production. In this paper, attempts were made to access the level of production of bio-fibre taking into consideration its competitive demand in climate mitigation. Part of the discussion in this work analysed the existing literature production volume of bio-fibre and the cellulose, lignin content in fibre as it constitutes mechanical and chemical barriers against pathogens. It is expected that this research work will project the broad impact of bio-fibres and proffer its better utilization options. Key of the conclusions drawn in this work reinforces the need to conserve natural fibres in the face of competitive demands.

Keywords: bio-fibres, climate change, green energy, conservation, industrial application

INTRODUCTION

In the last four decades, sustainable engineering materials have evolved in various applications with improved design structure, better mechanical properties and solution miscibility (Ashori, 2008; Adekomaya et al. 2017). In most of the cases, the evolving materials have remained bio-degradable in order to maintain the environmental serenity and cleaner climate (Lai et al. 2008). Bio-fibres have been used and are still being utilized as a result of their environmental friendliness. The sustainable concept of environmental acceptability is central to bio-fibres utilization as shown in Figure 1. The impact of climate change and the evolution of green composite are two revolving concepts in modern literature (Upgupta et al. 2015). In order to curb the impact of fossil fuel utilization, some authors (George et al. 2014) have recommended the integration of bio-fibres into material formation so that the entire products are recyclable. This concept has further put more pressure on natural forest couple with adaptation as fuel in developing countries.

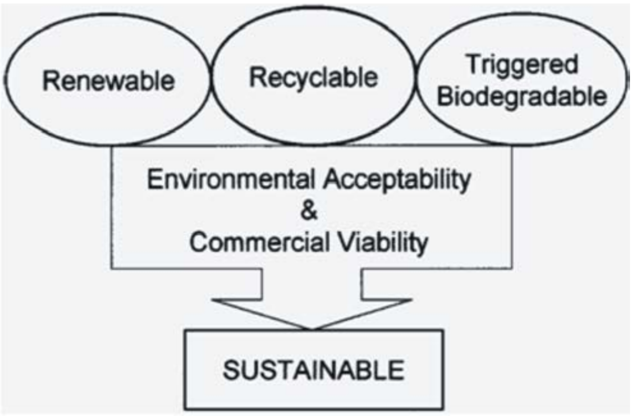

Figure 1: Recyclable concept of Bio-fibres. Adapted from Mohanty et al. (2002)

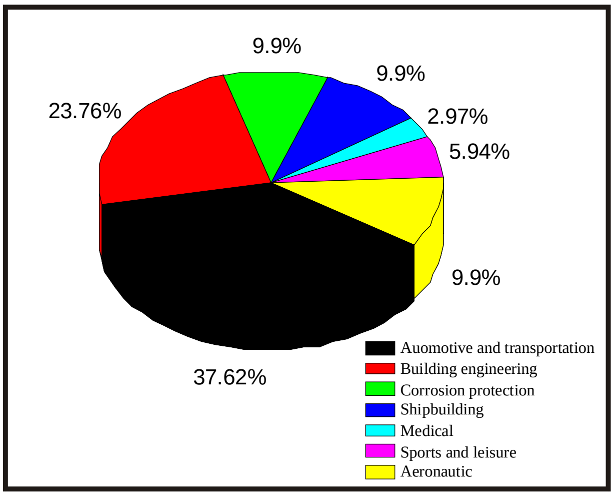

Figure 2: Utilisation of Natural fibres in composite formation. Data were sourced from Biron (2013).

What is most frightening is the level of natural fibre utilization vis-a-vis the biodiversity loss. In automotive industry, natural fibre accounts for large component formation in most vehicle part replacement and this may not be unconnected with payload reduction and weight saving as depicted in Figure 2. Further studies in the work of Faruk et al. (2012) on bio-fibre utilization revealed over-dependence on natural fibres as shown in the diagram. The may further worsen the effect of climate change resulting in desert encroachment and dire climatic weather changes. In order to address this issue, renewable polymeric materials have been projected to bridge the existing gap as contained in the millennium development goal (MDG). Nair and Joseph (2014) highlighted the environmental impact of natural fibre utilization and projected a lighter way of patronising bio-fibres. Part of their recommendation showed that, with the integration of lighter metallic materials in composite formation, comparative weight saving are achieved even with the full content of bio-fibre composite as shown in Figure 3. In another development, these authors (Ramamoorthy et al., 2015, Zaman et al., 2012) x-rayed the performance of bio-fibres especially in key manufacturing areas and concluded that certain deficiencies inhibiting homogeneous matrix are prevalent in bio-fibre composite. This may not be unconnected with property variation and anisotropic tendencies of natural fibres. Some researchers (Galos et al., 2015, Fowler et al., 2006) also corroborated these lapses affirming that key properties of bio-fibres such as strength and stiffness are largely dependent on orientation with properties variation at fibre loading. This anisotropic property is seen a major challenge for engineers who use reinforced composite materials in structures with multidimensional structural members (Thomason and Yang, 2014).

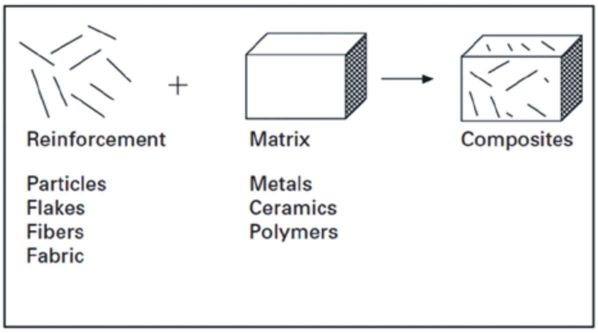

Figure 3: Integration of multi-matrix components in composite formation (Faruk et al., 2012)

In a related development, integration of bio-based materials in construction and other engineering applications is a major contributory factor in global economy and sustainable development goals. This approach has assisted in no small measure to mitigate to heat load in most building as seen in the works of these authors(Çomaklı and Yüksel, 2004, Kayfeci, 2014). This formed part of the communique at the UN Kyoto protocol in 2009 on greenhouse gas reduction and evolving CO2 production where natural fibre was adopted as a sustainable mitigating material on climate change. Part of the lapses identified may not be unconnected with the production of industrial natural fibres in substantially smaller volumes. Key of the discussion in the work of Adekomaya et al. (2017) showcased that the production of natural fibre have not exceeded 6 million tons per annum as at 2015. The study went further to show that these fibre production volumes have stagnated in the last two decades culminating into low availability of bio-fibres for industrial needs.

1.0 Production volume of bio-fibres and improvement in value chain

Evolution of bio-fibre and its associated composite remains the largest raw material globally with cotton accounting for about 25 million tons production per annum (Lau et al., 2018). Table 1 shows the production trends and the geographical dominance of each of the fibre as reported in many workers (George et al., 2014). In a paper published by Biron (2013), the author reported the potential of biodegradable composite materials in 2010 and 2020 as shown in Figure 4. The report indicated that almost 120million tons of biodegradable materials will be sourced in 2020 as against 50 million tons in 2010. It was further shown in his work that the level of production of natural fibre may further decline occasioned by deteriorating weather conditions.

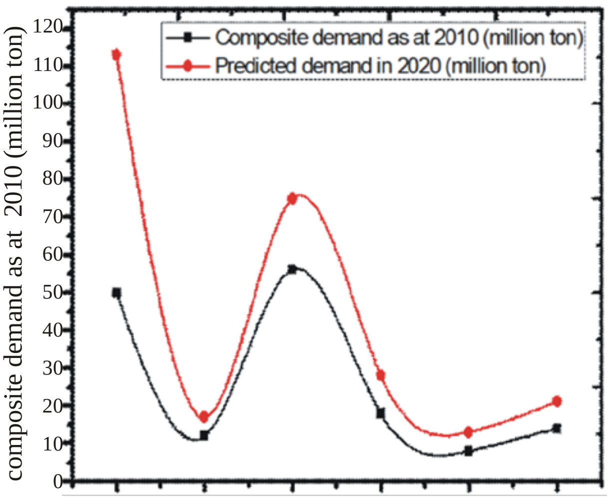

Figure 4: Prediction of composite materials utilization among member countries: Data were sourced from Biron (2013)

The cultivation of cotton appears to be on the high side permeating all the geographical region of the world accounting for almost 40% of total textile fibre in the market. China appears to be the most producing country as its production volume exceed all other producer countries as revealed by findings drawn by Krause et al. (2013). Many developing countries cultivate and produce reasonable quantities of cotton and other biodegradable fibres, but fail to add value to the existing raw fibres which is as a result of lack the technological skill in these countries (Uygunoglu et al., 2015). Recent studies (Semenza et al., 2012, Vincentnathan, 2012) have shown steady growth rate of more than 5% in cotton thereby expanding the market base with improvement in local economy of these countries. In another paper (Reddy and Yang, 2005), findings show that the market base and exports of lesser produced fibres (Sisal, Jute, Kenaf, Flax and Hemp) experienced sharp decline in the last two decades as a result of introduction of cheaper synthetic alternatives. This approach is a major drawback in the wheel of progress of natural fibre composite. The foray of lighter and cheaper synthetic fibre into composite formation has attracted attention in few works (Pihtili, 2009, Dincer, 1998, Ben-Iwo et al., 2016) with no discussion on their recyclability. In another opinion paper published by Samal et al. (2009) , studies have shown the environmental impact of synthetic fibre on other agricultural products in which these fibres fail to meet the minimum weight capacity of the carrying container shipments. The weight imposed on the shipment by these synthetic fibres culminate into additional energy required in transportation. This concern reinforces the need to strengthen the existing innovation on natural fibre by enlarging the scope of its use in line with agro-industrial development.

Table 1: Analysis of different bio-fibres production pattern (estimated in million metric tons per annum over the last two decade). Sourced from Reddy. & Yang (2005)

Bio-fibres	**Millions (tonnes)**	**Main producer countries**
cotton	25	China, USA, India, Pakistan
Kapok	0.03	Indonesia
Jute	2.5	India, Bangladesh
Kenaf	0.45	China, India,Thailand.
Flax	0.50	China, France, Belgium.
Hemp	0.10	China
Ramie	0.15	China
Abaca	0.10	Philippines, Equador
Sisal	0.30	Brazil, China, Tanzania.
Coir	0.45	India, Sri Lanka
Silk	0.10	China, India

An Official Publication of Enugu State University of Science & Technology ISSN: (Print) 2315-9650 ISSN: (Online) 2502-0524

Adaptation of bio-based materials in engineering structures involve the process of substituting the existing fossil based products in order to maintain the global bio-diversity and environmental equilibrium. Part of the beauty of the bio-based materials are based on the concept of recyclability and sustainability. The impact on the environment is largely negligible and only require fundamental change in human attitude to drive home its primary objective. In a relative term, the environmental effect of bio-fibres may also feature in a manner which may indirectly influence the product lifecycle. It is generally believed that natural fibres will be bio-degradable and may be converted in form of carbon which may be suitable for other plants. In another paper (Adekomaya and Adama, 2017), it was established that about 2-4% of biomass from sisal fibre is converted to useful products while their remnant from leaf contains soluble sugars that are further processed for production of biogas.

2.0. Emerging Trend and Prospects for the Future

The major challenges of biodegradable fibres still revolve round its abundance in the face of competitive demand. The work of Zhang (2008) identified storage and the retention lignocellulosic content in natural fibres as a major challenges facing biodegradable fibre. Corn stover as shown in the Figure 5 is available in abundance with cellulose and hemicellulose content stand at 14% and 35% respectively. The Cellulose and hemicellulose provide structural and mechanical strength for biodegradable engineering materials and this will influence the moisture affinity of natural fibre (Kalia et al., 2013, Raghavendra et al., 2013). In another work (Kalia et al., 2013), the amount of cellulose in a natural fibre is a function of the emerging properties of composite, and often time influences the economics of fibre production and their various applications. Some workers (Fernando et al., 2015) suggested the utilization of fibers with higher cellulose content mostly in textile, paper and other fibrous applications as against other findings. The content of cellulose, lignin and hemicellulose in biofibre materials are shown in figure 6. It can be seen in the figure the relative importance of cellulose as its content in biofibre is higher when compared with other. The cellulose primarily gives rigidity to evolving composite and strengthen the mechanical properties against any attacks. Figure 5: Availability of fiber source in million tonnes. Data were adapted from (Reddy and Yang, 2005)Figure 5: Availability of fiber source in million tonnes. Data were adapted from (Reddy and Yang, 2005)

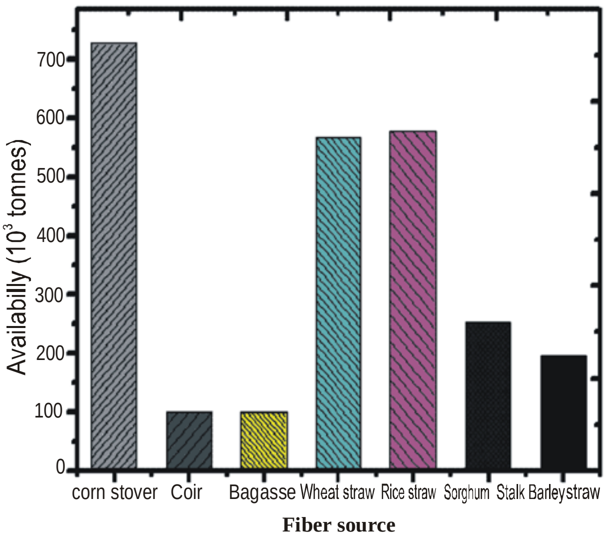

Figure 5: Availability of fiber source in million tonnes. Data were adapted from (Reddy and Yang, 2005)

In another paper (Pihtili, 2009), it was shown that the major limitation is the processing temperature which may degrade the key content of fibres. In many established works (Thomason and Yang, 2014), bio-fibres tends to possess a relatively higher moisture absorption thereby making it difficult for the hydrophobic fibers and hydrophilic polymers to bond together. These concerns is mostly pronounced when these fibres are intended to be used in a moisture related application (Pérez-Pacheco et al., 2013). While various modifications have been employed in different published works, their effects are largely to be felt in real engineering work due to dimensional variability of natural fibres. Despite the shortcoming highlighted, the prospect of bio-fibres in engineering application is overwhelming and still undebatable (Kalia et al., 2013).

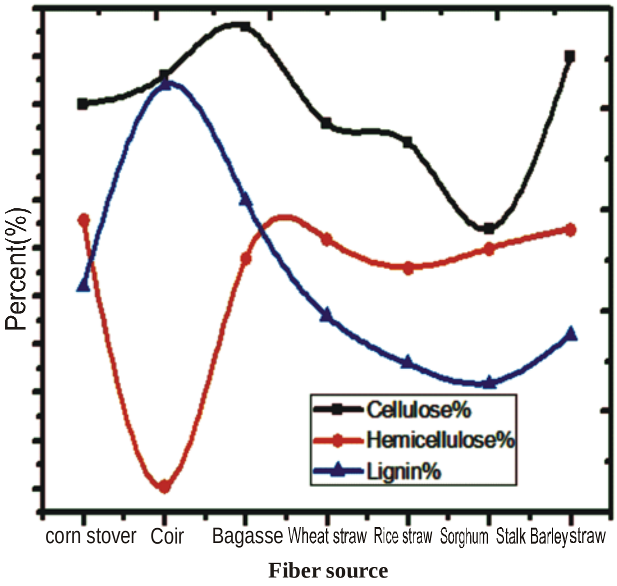

Figure 6: Percent distribution of cellulose, hemicellulose and lignin in bio-fibre source. Data were sourced from (Reddy and Yang, 2005, Biron 2013, Faruk et al., 2012)

In many cases, bio-fibres have been used as a sustainable alternative to aluminium and steel alloys in many structural development and component formation. In another paper (Atuanya et al., 2014) , findings have shown that in the near future, 20-25% of car's weight will comprise of plant fibres. In many vehicular parts, a reasonable weight is saved when the body parts is replaced with glass-fibre reinforced plastic. Further reduction is envisaged with the inclusion of natural fibre in the component part of vehicle (James and James, 2010). Market reports also reinforce the potential and opportunity in biodegradable fibres as against the glass-fibre and metallic materials. In the year 2000 alone, the America market for natural fibre was projected to worth \$160million with astronomical sale of about \$1.4 billion worth of natural fibres in 2006 (Adekomaya et al., 2016). This is an indication of expansive market base for bio-fibres with stricter environmental regulation as reflected in Figure 7.

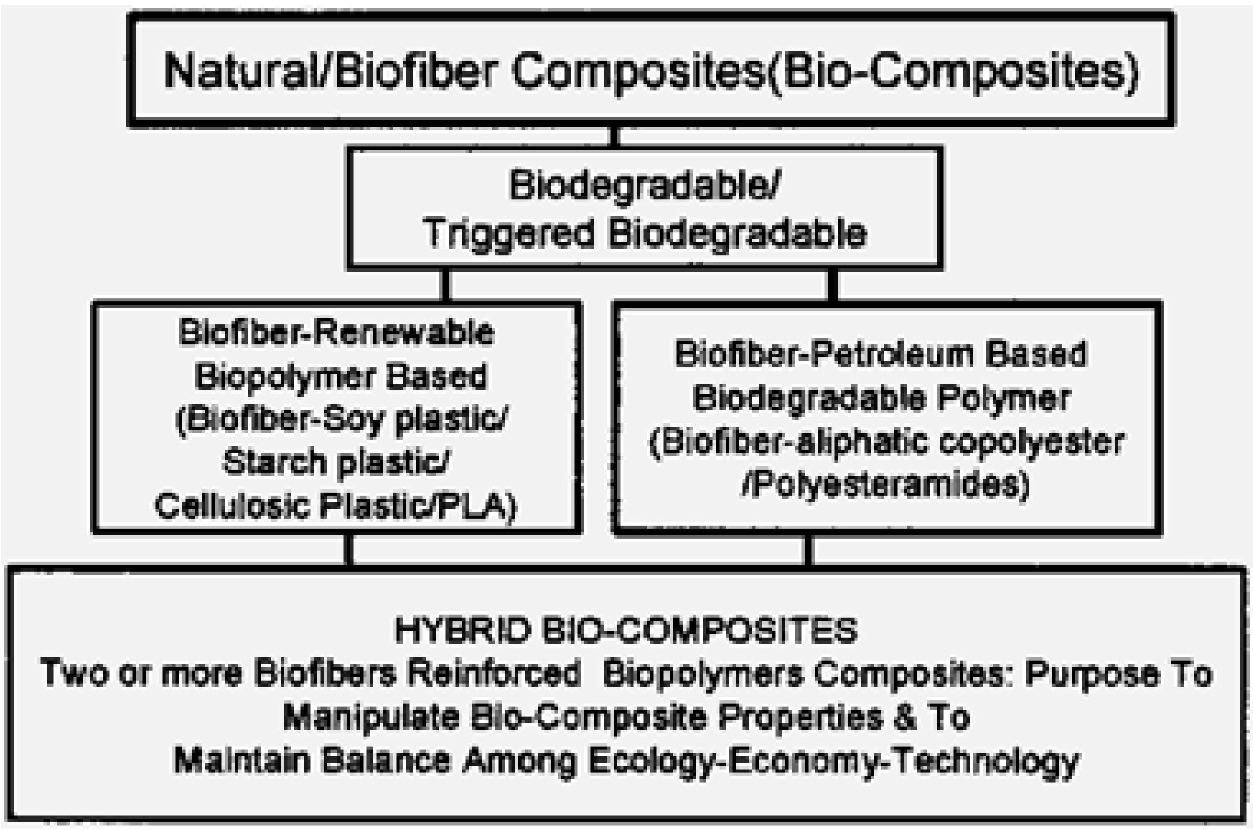

Figure 7: Adaptation of bio-fibres in engineering application. Adapted from James and James, 2010

An Official Publication of Enugu State University of Science & Technology ISSN: (Print) 2315-9650 ISSN: (Online) 2502-0524

CONCLUSIONS

In this paper, it is crystal clear that that the potential and economics of adopting bio-based fibres outweigh their shortcomings. Part of their improvement has been reported in the automotive component formation and other structural application. In the real sense, energy saved from adopting bio-based fibres will significantly impact positively on the environment with huge reduction in emission and severe hot temperature. The only serious problem inhibiting the application of plant fibres is their strong polar character which often creates incompatibility with matrix material. In some published works, significant progress has been recorded in the treatment of bio-fibres and the problem of incompatibility with the matrix may longer reduce the interfacial adhesion in the emerging composite. Based on various researches in the literature, it can be affirmed that the bio-based composites will improve the mechanical strength and acoustic performance of intending application, reduce material weight of various vehicular component part and ultimately reduce energy consumption. The overall production cost of the bio-based composite is expected to reduce with improve market value of the composite. The most significant aspect of encouraging bio-based materials in component formation is to improve biodegradability of most auto interior parts, reduce depletion of bio-diversity and provide safe climate.

REFERENCES

Adekomaya O, Adama K. (2017). Glass-fibre reinforced composites: The effect of fibre loading and orientation on tensile and impact strength. Nigerian Journal of Technology, 36: 782-787.

Adekomaya O, Jamiru T, Sadiku R, Huan Z. (2016). A review on the sustainability of natural fiber in matrix reinforcement–A practical perspective. Journal of Reinforced Plastics and Composites, 35: 3-7.

Adekomaya O, Jamiru T, Sadiku R, Huan Z. (2017). Negative impact from the application of natural fibers. Journal of Cleaner Production, 143: 843-846.

Ashori A. (2008). Wood–plastic composites as promising green-composites for automotive industries! Bioresource Technology, 99: 4661-4667.

Atuanya C, Nwaigbo S, Igbokwe P. (2014). Effects of breadfruit seed hull ash particles on microstructures and properties of recycled low density polyethylene/breadfruit seed hull ash composites. Scientia Iranica. Transaction C, Chemistry, Chemical Engineering, 21: 792-796

Ben-Iwo J, Manovic V, Longhurst P. (2016). Biomass resources and biofuels potential for the production of transportation fuels in Nigeria. Renewable and Sustainable Energy Reviews, 63: 172-192.

Biron M. (2013). Future Prospects for Thermoplastics and Thermoplastic Composites. In: BIRON, M. (ed.) Thermoplastics and Thermoplastic Composites (Second Edition). William Andrew Publishing.

Çomaklı, K, Yüksel B. (2004). Environmental impact of thermal insulation thickness in buildings. Applied Thermal Engineering, 24, 933-940.

Dincer I. (1998). Energy and environmental impacts: present and future perspectives. Energy sources, 20: 427-453.

Faruk O, Bledzki AK, Fink HP, Sain M. (2012). Biocomposites reinforced with natural fibers: 2000–2010. Progress in Polymer Science, 37: 1552-1596.

Fernando AL, Duarte MP, Vatsanidou A, Alexopoulou E. (2015). Environmental aspects of fiber crops cultivation and use. Industrial Crops and Products, 68: 105-115.

Fowler PA, Hughes JM, Elias RM. (2006). Biocomposites: technology, environmental credentials and market forces. Journal of the Science of Food and Agriculture, 86: 1781-1789.

Galos J, Sutcliffe M, Cebon D, Piecyk M, Greening, P. (2015). Reducing the energy consumption of heavy goods vehicles through the application of lightweight trailers: Fleet case studies. Transportation Research Part D: Transport and Environment, 41: 40-49.

George M, Mussone PG, Bressler DC. (2014). Surface and thermal characterization of natural fibres treated with enzymes. Industrial Crops and Products, 53: 365-373.

James SJ, James C. (2010). The food cold-chain and climate change. Food Research International, 43: 1944-1956.

Kalia S, Thakur K, Celli A, Kiechel MA. Schauer CL. (2013). Surface modification of plant fibers using environment friendly methods for their application in polymer composites, textile industry and antimicrobial activities: A review. Journal of Environmental Chemical Engineering, 1: 97-112.

Kayfeci M. (2014). Determination of energy saving and optimum insulation thicknesses of the heating piping systems for different insulation materials. Energy and Buildings, 69, 278-284.

Krause M, Lotze-Campen H, Popp A, Dietrich JP. Bonsch M. (2013). Conservation of undisturbed natural forests and economic impacts on agriculture. Land Use Policy, 30: 344-354.

Lai J, Harjati A, Mcginnis L, Zhou C. Guldberg T. (2008). An economic and environmental framework for analyzing globally sourced auto parts packaging system. Journal of Cleaner Production, 16: 1632-1646.

Lau KT, Hung PY, Zhu MH, Hui D. (2018). Properties of natural fibre composites for structural engineering applications. Composites Part B: Engineering, 136, 222-233.

Mohanty A, Misra M, Drzal L. (2002). Sustainable bio-composites from renewable resources: opportunities and challenges in the green materials world. Journal of Polymers and the Environment, 10: 19-26.

Nair AB, Joseph R. (2014). 9 - Eco-friendly bio-composites using natural rubber (NR) matrices and natural fiber reinforcements. In: Kohjiya, S. and Ikeda, Y. (eds.) Chemistry, Manufacture and Applications of Natural Rubber. Woodhead Publishing.

Pérez-Pacheco E, Cauich-Cupul J, Valadez-González A, Herrera-Franco P. (2013). Effect of moisture absorption on the mechanical behavior of carbon fiber/epoxy matrix composites. Journal of materials science, 48: 1873-1882.

Pihtili H. (2009). An experimental investigation of wear of glass fibre–epoxy resin and glass fibre–polyester resin composite materials. European Polymer Journal, 45: 149-154.

Raghavendra GM, Jayaramudu T, Varaprasad K, Sadiku R, Ray SS, Mohana Raju K. (2013). Cellulose–polymer–Ag nanocomposite fibers for antibacterial fabrics/skin scaffolds. Carbohydrate Polymers, 93: 553-560.

Ramamoorthy SK, Skrifvars M, Persson A. (2015). A review of natural fibers used in biocomposites: plant, animal and regenerated cellulose fibers. Polymer Reviews, 55.

Reddy N, Yang Y. (2005). Biofibers from agricultural byproducts for industrial applications. Trends in Biotechnology, 23: 22-27.

Samal SK, Mohanty S, Nayak SK. (2009). Banana/glass fiber-reinforced polypropylene hybrid composites: Fabrication and performance evaluation. Polymer-Plastics Technology and Engineering, 48: 397-414.

Semenza JC, Herbst S, Rechenburg A, Suk JE, Höser C, Schreiber C, Kistemann T. (2012). Climate change impact assessment of food-and waterborne diseases. Critical reviews in environmental science and technology, 42: 857-890.

Thomason JL, Yang L. (2014). Temperature dependence of the interfacial shear strength in glass–fibre epoxy composites. Composites Science and Technology, 96: 7-12.

Upgupta S, Sharma J, Jayaraman M, Kumar V, Ravindranath NH. (2015). Climate change impact and vulnerability assessment of forests in the Indian Western Himalayan region: A case study of Himachal Pradesh, India. Climate Risk Management, 10: 63-76.

Uygunoglu T, Gunes I, Brostow W. (2015). Physical and Mechanical Properties of Polymer Composites with High Content of Wastes Including Boron. Materials Research, 18: 1188-1196.

Vincentnathan L. (2012). Food Rights, Food Frugality, and Climate Change. Food and Foodways, 20: 76-92.

Zaman HU, Khan MA, Khan RA. (2012). Comparative experimental studies on the mechanical and degradation properties of natural fibers reinforced polypropylene composites. Composite Interfaces, 19: 59-70.

Zhang Z. (2008). Asian energy and environmental policy: Promoting growth while preserving the environment. Energy Policy, 36: 3905-3924.

An Official Publication of Enugu State University of Science & Technology ISSN: (Print) 2315-9650 ISSN: (Online) 2502-0524