*Fibers and Polymers* 2015, Vol.16, No.1, 196-200
DOI 10.1007/s12221-015-0196-5

ISSN 1229-9197 (print version)
ISSN 1875-0052 (electronic version)

# Composites from Water Hyacinth (*Eichhornea Crassipe*) and Polyester Resin

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(Received May 30, 2014; Revised July 21, 2014; Accepted July 28, 2014)

**Abstract:** Fibrous plants are available in abundance in nature and are a renewable resource. The development of high performance composites from a cheap natural fiber, such as water hyacinth (*Eichhornea crassipes*) is particularly beneficial from an economic point of view. Remarkable, thermosetting resins such as polyester are used widely as a composite matrix due to polyester resins present a good dimensional stability, thermal stability, and good mechanical properties. For this study, some composites from water hyacinth fiber and polyester resin were prepared by using solution impregnation and hot curing methods. The composites were prepared by varying fiber percentages (5, 10, 15, and 20 wt%). These were characterized by FTIR and DSC analysis. Additionally, the elastic modules (MOE) from static test according to ASTM (D143-94) and by dynamic test from Sylvates Duo were obtained. Mechanical properties such as flexural strain and compression strength parallel of the different composites were analyzed. Thus, composites which had a concentration of water hyacinth in the range of 5 to 10 wt% yielded the best results. Additionally, the analysis showed no evidence of a negative effect on mechanical and thermal properties of the composite by addition of water hyacinth to the polyester resin. Furthermore, the results showed that water hyacinths fibres presented a competitive reinforcement quality when they were compared with other natural fibers, as such jute, abaca, and rice straw.

**Keywords:** Polyester, Composite, Water hyacinth, FTIR, DSC

## Introduction

Recent research focused to produce lignocellulose-polymer composites of good quality performance, showed that the composite's substrate type as well as its weight fraction were important factors in determining properties of the composites [1-3]. Natural fibers are a useful class of materials; because of their natural origin, they are environmentally clean, renewable, and biodegradable resources [4]. Fibers can be readily obtained by recycling agro-based products such as waste paper, wood, and rice hulls from a rice-processing plant, and sunflower and sunflower seed hulls from an oil processing unit.

The most successful application of the water Hyacinth (*Eichhornea crassipes*) has been in the sewage water treatments for nutrient removal and retention of particles [5,6]. In contrast, water Hyacinth presents environmental and economic problems; in natural water sources such as rivers and canals have serious water pollution problems due to widespread growth of the water hyacinth plant which is a wild plant absorbs more than 60 % of water [7].

In relation to other fibers, the water hyacinth has a high percentage of holocellulose that is an advantage in its applications as a reinforcing material [8]. Thus synthetic polymers could be reinforced with various natural fillers, such as water hyacinth in order to improve the physico-mechanical properties, and obtain the characteristics demanded in definite applications [9,10].

Therefore, from the date mentioned above, the purpose of this research is to find an alternative application of water hyacinths. Thus, the ground water hyacinth was used together with unsaturated polyester to produce lignocellulose-polymer composites. The effect of the water hyacinth fiber in the composites on their thermal and mechanical properties was investigated using differential scanning calorimetry (DSC). Furthermore, a structural analysis was carried out by fourier transform infrared spectroscopy (FTIR).

## Experimental

### Composite Specimen Preparation

Water Hyacinth fiber was collecting from local Patzcuaro Lake, Mich. Mexico. The collected plants were cut and the segments were separated into stems, leave and root; although only stems were used as raw materials.

The stems segments were cut into small pieces about of 3 cm long and dried at 70 °C into a programed oven until constant weight was obtained. Dried stems were ground with a Willey mill with 40 mesh (with a particle size of 425 $\mu$m), to produce the sawdust. Afterward the sawdust was dried at 60 °C for 24 h. Then, the sawdust was blended with a polyester resin (Sigma Aldrich Inc.) and a catalyst (Fivipol), which was carried out by a mechanical stirrer at constant speed of 120 rpm for 2 h. Four percentages of fiber loadings were used to prepare the composites (5, 10, 15, and 20 wt%), where there were 10 replicates for each concentration.

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The mixtures were poured into molds (30×2×2 cm) and dried at 22 °C for 20 days. After that, they were released from their molds.

**Structural Analysis**

Structural analyses of the composites were performed using a Nicolet 5ZDA spectrometer in the 4000 to 400 $cm^{-1}$ range at a resolution of 4 $cm^{-1}$ in transmission mode. All samples were prepared in FTIR-grade KBr (Aldrich) to form pellets of 12.8 mm in diameter.

**Thermal Behavior**

DSC analyses were carried out in a thermal analyzer DSC822 Mettler, USA from 0 °C to 500 °C at a heating rate of 1.0 °C/min under $N_2$ atmosphere.

**Transmission Speed of Ultrasound**

The transmission speed of ultrasound was determined by using ultrasound technology Sylvatest duo equipment.

**Flexural Strength and Flexural Modulus**

Dynamic modulus was calculated from board density and measured wave propagation velocity in timber using Sylvatest Duo.

The recent trend in machine grading focuses on acoustic principles (ultrasound, vibration). The important feature of acoustic method is sound velocity "c". It can be related to grading characteristics:

$$C = \sqrt{\frac{E}{\rho}}\ (\mathrm{m \cdot s^{-1}}) \quad (1)$$

where $E$ is dynamic modulus (MPa) and $\rho$ is wood density ($kg.m^{-3}$).

Modulus and flexure static strength of the composites were obtained complying with ASTM (D143-94) [11], using a Shimadzu RH-10 Universal Testing Machine.

## Results and Discussion

**Structural Analysis**

Spectra of the polyester resin and composites by FTIR are showed in the Figure 1. The spectrum of polyester resin showed characteristic absorption bands of due to aliphatic ethers/esters -COO- at 1123 $cm^{-1}$, aliphatic hydrocarbon C-H stretching between 2974 $cm^{-1}$ and 2886 $cm^{-1}$. The presence of C=O stretching vibration at 1725 $cm^{-1}$ was observed and aromatic groups were revealed by the signal of phenyl group at 1449 $cm^{-1}$, unsaturated in plane deformation at 1070 $cm^{-1}$, unsaturated aromatic out-of-plane bending deformation at 744 $cm^{-1}$ and 705 $cm^{-1}$; with these characteristics bands were possible to determine the structure of an unsaturated polyester resin [12-14]. Additionally, important observation is that, between the spectrum of the composite at 95 and 100 wt% of polyester resin had no significant difference. For the polyester resin, there was a light reduction in intensity of some characteristics picks. Furthermore, the spectra showed no measurable interactions between the water hyacinth and the polyester resin. This reveals that the polyester resin and water hyacinth not react chemically each other by the solution impregnation and hot curing methods.

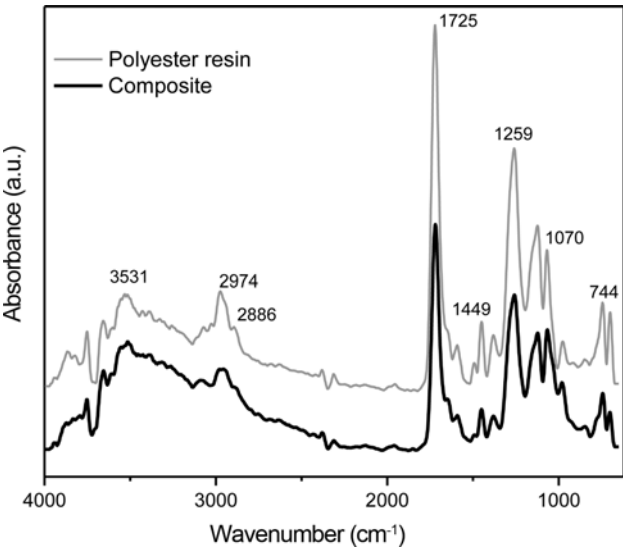


**Figure 1.** FTIR spectra for polyester resin and composite with 5 wt% of water hyacinth.

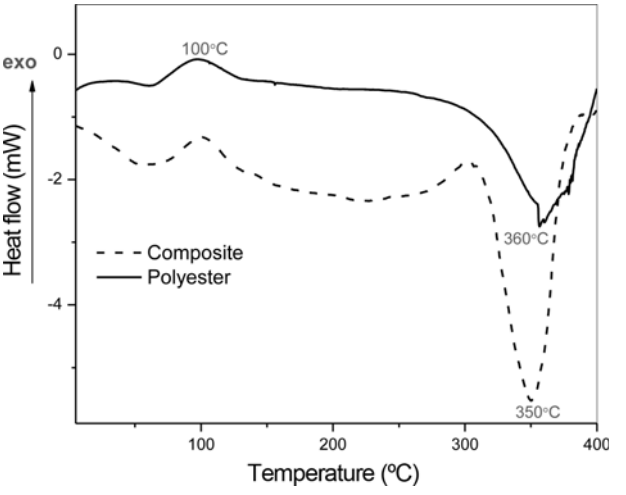


**Figure 2.** DSC curves for polyester resin and composite with 5 wt% of water hyacinth.

Figure 2 illustrates the thermal transitions in the range of 0 to 400 °C of a pure polyester resin and a composite having 5 wt% of water hyacinth analyzed by DSC. Initially, pure polyester resin showed an exothermic peak at 100 °C which was associated with the cross-linking reaction and water molecules released, furthermore an endothermic peak at 360 °C was observed due to the melting temperature. No further changes were observed when thermograms of pure

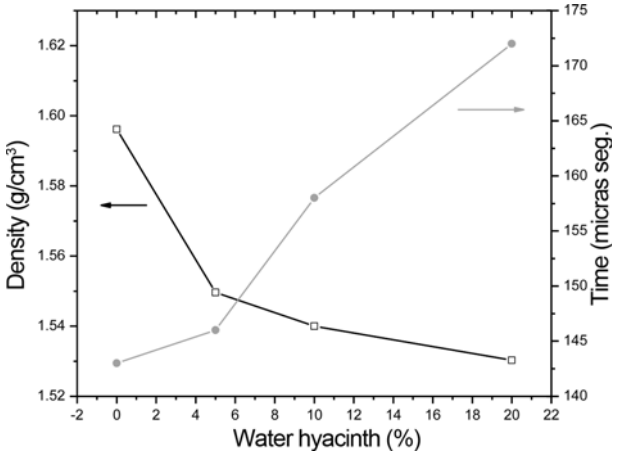


**Figure 3.** Density (□) and the transmission speed (●) of ultrasound in function of time at different concentrations of water hyacinth.

polyester and composite were compared. These results are consistent with those previously indicated by FTIR. However, it is possible to notice that water hyacinth incorporation slightly altered the melting temperature of polyester (from 360 to 350 °C) [15-18].

Figure 3 shows the results of the density and transmission speed of ultrasound as function of time. These results showed an inverse relationship between density and the speed of ultrasound through the composite.

According to equation (1), the velocity of propagation of an ultrasonic wave is expressed as:

$$c = \sqrt{1/\rho k} \quad (2)$$

where $k$=compressibility, $\rho$=density of material (g/cm$^3$) and $c$=speed of sound.

The polyester resin has a high density therefore a low propagation velocity of ultrasound; because of this, polymeric materials generally attenuate the ultrasonic waves. Consequently, a composite containing a low polyester resin concentration will allow a faster propagation of ultrasound. Additionally, the speed of ultrasound increases as function of moisture content, as result the composite with the higher percentage of water hyacinth (20 wt%) showed a faster ultrasound speed.

**Dynamic Flexural Modulus**

Figure 4 shows that MOE values were significantly increased as consequence of water hyacinth percentage. This effect is due to propagation of ultrasound waves through the composite which depends on the density and stiffness of the material. In these analyses (Sylvatest Duo method) the density of the sample value was considerate; in order to be closer of real results Similar result was obtained on different set of samples [20].

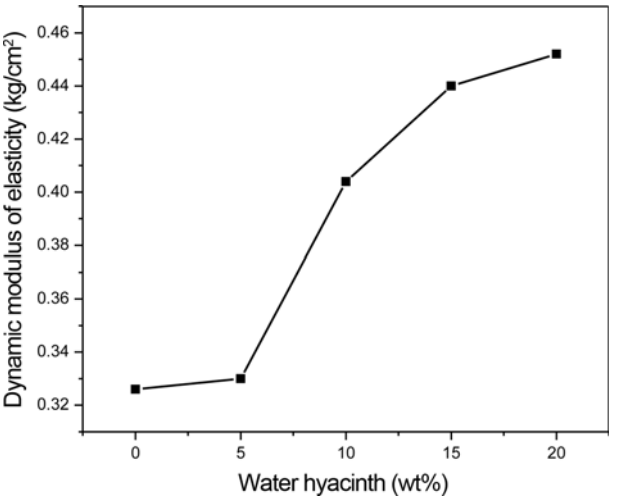


**Figure 4.** Dynamic modulus of elasticity of polyester resin-water hyacinth composites.

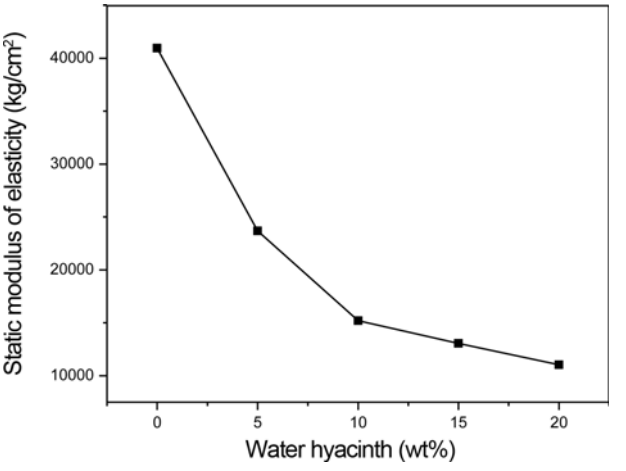


**Figure 5.** Static modulus of elasticity of composites.

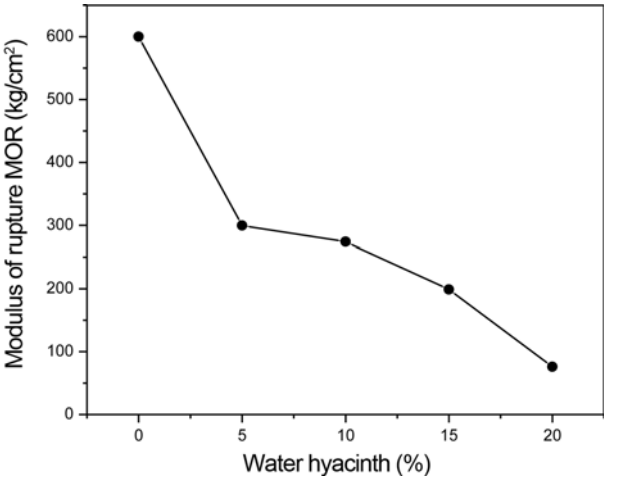


**Figure 6.** Modulus of rupture of composites with water hyacinth fiber in various proportions.

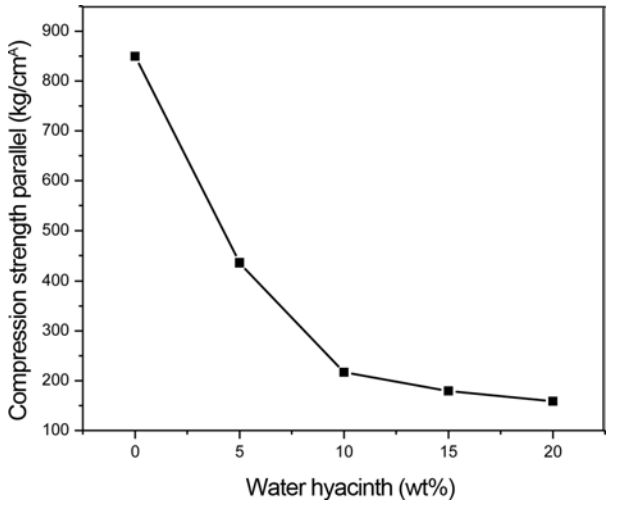


**Figure 7.** Compression strength parallel of polyester resin-water hyacinth composites.

**Static Flexural Modulus**

The flexural moduli were used to determine the static modulus of elasticity, MOE (stiffness) and modulus of rupture, MOR (flexural strength). Both moduli decreased markedly as fiber content was increased.

Figure 5 shows the results of static MOE for composites with 5, 10, 15 and 20 wt% of water hyacinth fiber. It was observed an increase of the MOE's values as well as a decrease of the elastic modulus when the density of the composite was rose, which could be generated by an interfacial separation (water hyacinth-polyester) attributed to the low interaction of the fiber with the polyester matrix.

Figure 6 shows the MOR. From it, a composite with a water hyacinth fiber concentration of 20 wt% exhibited the lowest values of MOR. Evidently, the deficiency of compatibility between fiber and polyester resin produced a more brittle material.

**Compression Strength Parallel**

Figure 7 presents the compression strength parallel efforts values which dropped off by an increase water hyacinth concentration. These results are analogous with those which are presented by composites made from wood-epoxy resin (238-496 kg/cm$^2$) and pure wood (325-700 kg/cm$^2$) [20].

## Conclusion

The integration of water hyacinth fibers into a polyester resin allowed generates composites of lower weight with superior acoustic insulation in relation to the polyester resin. In contrast, in all cases, mechanical properties such as modulus of rupture, static modulus of elasticity and compression strength parallel decreased as consequence of water hyacinth addition. However, the decreases of these mechanical values are similar to those obtained by the addition of other natural fibers. Moreover, according the present results, water hyacinth can be used to replace conventional materials such as glass, carbon and plastic fibers. Consequently, the potential application and use of this natural fiber carry as result a reduction of the water pollution.

## Acknowledgements

Financial support from the National Council of Science and Technology (CONACyT-Mexico) under the projects approved #61414 and 104257, PROMEP Collaborative Thematic Networks. Coordination of Scientific Research (UMSNH) and CIC-UMSNH are gratefully acknowledged.

## References

1. K. K. Chawla and J. R. M. D'Almeida, "Proc. of ICCM-IV IVth Int. Conf. Composite Materials", p.1195, Tokyo, Japan, 1982.
2. K. G. Satyanarayana, K. Sukumaran, A. G. Kulkarni, S. G. K. Pillai, and P. K. Rohatgi, *Composites*, **17**, 329 (1986).
3. T. Rials, M. P. Wolcott, and J. M. Nassar, *J. Appl. Polym. Sci.*, **80**, 546 (2001).
4. J. R. M. D'Almeida, *Polymer Plast. Tech. Eng.,* **40**, 205 (2000).
5. Q. Mahmood, M. R. Siddiqi, E. Islam, M. R. Azim, P. Zheng, and Y. Hayat, *J. Zhejiang Univ. Sci. B*. **10**, 991 (2005).
6. M. Meerhoff, N. Mazzeo, B. Moss, and L. Rodríguez-Gallego, *Aquat Ecol.*, **37**, 377 (2003).
7. P. Pranut, P. Prakaipech, and C. Saowaroj, *J. Sci. Res. Chula. Univ.*, **26**, 1 (2001).
8. O. Mansour, B. Abdel-Hady, S. K. Ibrahem, and M. Goda, *Polymer Plast. Tech. Eng.*, **40**, 311 (2001).
9. H. U. Zaman, M. A. Khan, R. A. Khan, M. A. Rahman, L. R. Das, and M. Al-Mamun, *Fiber. Polym*., **11**, 455 (2010).
10. A. K. Rana, A. Mandal, and S. Bandyopadhyay, *Compos. Sci. Technol*., **63**, 801 (2003).
11. ASTM D143-14, Standard Test Methods for Small Clear Specimens of Timber, ASTM International, West Conshohocken, PA, 2014.
12. D. H. Williams and I. Fleming, "Spectroscopy Methods in Organic Chemistry", 5th ed., pp.35-42, McGraw Hill, Maidenhead, England, 1995.
13. G. A. L. Verleye, N. P. G. Roeges, and M. O. De Moor, "Easy Identification of Plastic and Rubbers", pp.115-134, Rapra Technology Ltd., Shrewsbury, UK, 2001.
14. U. Knuutinnen and P. Kyllonen, *e-Preserv. Sci*., **3**, 11 (2006).
15. N. Shukry and B. S. Girgis, *Polymer Plast. Tech. Eng.*, **31**, 541 (1992).
16. M. R. Huang and X. G. Li, *J. Appl. Polym. Sci*., **68**, 293 (1998).

17. S. Montserrat, C. Flaque, P. Pages, and J. Maek, *J. Appl. Polym. Sci*., **56**, 1413 (1995).
18. M. I. Aranguren, N. E. Marcovich, and M. M. Reboredo, *Mol. Cryst. Liquid Cryst*., **353**, 95 (2000).
19. A. Rohanová, R. Lagaňa, and V. Vacek, *Annals of Warsaw University of Life Sciences-SGGW For. and Wood Technol.*, **72**, 229 (2010).
20. H. Toker, E. Baysal, A. Özçifçi, M. Altınok, A. Sönmez, F. Yapıcı, and S. Altun, *Wood Res.*, **53**, 59 (2008).