International Journal of Current Engineering and Technology
ISSN 2277 - 4106

Available at http://inpressco.com/category/ijcet

Research Article

Investigation of Impact Strength Properties of Oil and Date Palm Frond Fiber Reinforced Polyester Composites

Anthony N. Anyakora[a*]

[a]National Institute for Pharmaceutical Research and Development, Abuja, Nigeria.

Accepted 25 April 2013, Available online 1June 2013, **Vol.3, No.2 (June 2013)**

Abstract

The impact properties of composite panels made from polyester matrix reinforced with untreated (as raw) and silane-treated oil and date palm frond fibres have been studied. Theses fibres were used in two distinct tangled mass; untreated (as raw) and treated forms. Composites of these fibre wastes up to 70% by weight in polyester matrix were fabricated by hand lay-up technique and analyzed. The results obtained indicate that fibre content and surface treatment cannot lead to improved impact strength of fibre composite panels. The scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDX) showed presence of higher ash content in the treated oil and date palm frond fibre composite panels. The results revealed a correlation between ash content and impact properties, thus it can be inferred that the use of oil, and more stable date palm frond fibres in the development of composite materials for some low-to-medium structural load applications is promising, especially in the production of low cost housing products. The use of this composite will assist in achieving better economic value with the use of agricultural waste and saving on foreign exchange will be achieved.

Keywords: *Oil and date palm frond fibres, polyester, izod impact strength, and silane.*

1. Introduction

With the prosperity of our economy and the improvement of our living conditions, people are asking for better living environment. Various kinds of materials have emerged and are being developed for use in engineering and in various aspects of the economy. The development of fibre reinforced composite-based products to substitute traditional engineering materials is becoming a trend in engineering application. Particularly attractive are the new materials in which the biomass resources like the oil and date palm fibre. Although, oil palm (*Elaeis guineensis)* and date palm (*Phoenix dactylifera)* fronds from pruning that are generated in plantations are presently under-utilized in interrow mulching, their good potentials for exploitation can serve as replacements for glass fibre in composite application and in solving associated environmental problems (H. Rozman *et al*, 2005). The general drawback of high moisture absorption that result in swelling of the oil and date palm frond fibres and concerns on the dimensional stability of natural plant fibre composites affect their use as reinforcements in polymer matrix. In oil palm for example, the moisture update is high (12.5%) at 65% relative humidity and 20%, by dry fibre and 14.6% by wet fibre (A. Sanadi *et al*, 1985). Studies show that oil and date palm frond fibres are very porous and have lacuna-like cross-section with varying diameters, and contain large amount of lignin. These factors affect their mechanical properties, such as high ductility, but have lower tensile strength than most other natural plant fibres (M. Sreekala *et al*, 1997). Additionally, studies show that good fibre- matrix bonding decrease the rate and amount of water absorbed by the composite, including the employment of effective surface treatment that reduces feathering. The consequent encasing of the cellulose fibres from feathering protects the fibres from breakdown due to oxidation and increased strength of the reinforced composite (A. Bismarck *et al*, 2001).

Generally, most natural fibres exhibit moderate degrees of elasticity and plasticity, for which, during the fibre preparation, the fibre against fibre friction is evident by the spreading of the batching lubricant, and the spreading of fibre dust (Brydson, 2001). The metallic surfaces of the handling chambers that often experience wear with time shows that fibre surfaces is responsible. It also infers that appreciable damage is done to the fibre during the processing. To withstand destruction, the material must be capable of absorbing energy imparted to it during stress application, and releasing this energy upon removal of the stress, without occurrence of failure. Therefore, the oil and date palm frond fibres proposed for use as alternative reinforcing material in polyester composites should be processed such as becoming tough to absorb great amount

*Corresponding author: Anthony N. Anyakora

of energy to resist early fracture as needed in most engineering application.

2.0 Materials and methods

2.1 Materials

The oil and date palm frond fibres were obtained from fronds of mature and fruited plants with known age, and used within two weeks of felling. These extracts were processed at the Pulp and Paper section of Federal Institute for Industrial Research, (FIIRO) Oshodi, Lagos, Nigeria into tangled mass of varying diameters of 0.45 - 0.81mm and lengths of 12.00 - 36.90mm.

The Polymer used was Siropol 7440 un-saturated polyester resin purchased from Dickson Chemicals Ltd, Lagos, Nigeria with specific gravity of 1.04, viscosity of 0.24 Pa.s at 25^{o}C. Other chemicals used were; cobalt in styrene, diglycidylethers and phenylsilane procured from Zayo - Sigma Chemicals Limited, Jos, Nigeria.

A two-part mould facility - of 150mm x 150mm made from 4mm flat mild steel sheet with active surfaces ground, pre-designed cavity of 5mm depth, with clamping bolts in place fabricated at the Dantata & Sawoe Mechanical Workshop, Abuja, was adopted in the production of test specimen plates.

Other equipment used were impact testing machine: Amsler - Nominal energy 850J, Maximum Impact velocity –7.5m/s, continuous adjustable pendulum angle up to 150^{o}C; carbolite muffle furnace: 2330 watts, 1100^{o}C, working size - 150 x 150 x 250mm; Compact Scale/Balance : Model – FEJ, Capacity – 1500g, 1500A and EVO/MA 10 Scanning Electron Microscope, controlled by JPEG SmartSEM software, of 5 nanometer resolution installed at Science and Technology Complex (SHETSCO), Gwagwalada, Abuja, Nigeria.

2.2 *Methods*

2.2.1 *Fibre extraction*

The fibres of oil and date palm fronds were extracted by chemico-mechanical process. The process involved the impregnation of sample with 'white liquor' and conversion of the softened sample into fibre by mechanical action, followed by thorough washing, screening and drying. The extracted fibres were separated, re-washed and dried in the forced-air circulation type oven. The fibres were subsequently weighed and percentage yield determined. The fibres were fluffed and separated into two tangle-mass bulks, one for surface-treated fibre composite while the other for the untreated ('as raw') fibre composite production.

2.2.2 *Surface treatment of the extracted fibre*

The process adopted in this work was the silane treatment preceded by the sodium hydroxide treatment. Known weights of extracted date and oil palm fibres were soaked in prepared known volume of 0.5 mol/litre of NaOH for 2 hours. The products were removed and washed with distilled water before air-drying. Subsequent processes included soaking the surface-treated fibres in 2% phenlysilane solution for 24 hours. Subsequently, the product was removed, dried at 60^{o}C and stored in specimen bag ready for use.

2.2.3 *Production of test specimen*

The test specimen panels of 10-70wt. % oil and date palm frond fibres content were produced by hand lay-up process. Curing was assisted by placing the composite in an oven operated at 110^{o}C. The mouldings were removed from the oven after 30 minutes and conditioned following the BS ISO 1268-3:2000 Instructions and Guidelines. Five (5) test samples each was cut from seven (7) stocks of 10-70wt. % fibre contents of the surface-treated oil and date palm frond fibre reinforced composites and untreated (as raw) oil and date palm fibre reinforced composites.

2.2.4 *Composite characterization*

The Izod Impact test was conducted according to BS2782-3: Method 352F:1996. During the test, the notched specimens cut into dimensions of 200mm×200mm×5mm, for which the support displacement of machine was 240mm, were mounted in-between machine supports and the pendulum was allowed to strike the specimen after swinging from a fixed height. Since the machine scale is graduated on '0' to '10' (kg-m), the first hammer was lifted and locked at the top and then gauge adjusted on 10 (kg-m), then the number on the scaled part was then read as presenting the impact strength of the specimens after dropping hammer.

2.2.5 *The scanning electron microscopy of fractured surfaces*

The impact fractured surfaces of both surface-treated fiber composite and 'as natural' fiber composites with fiber content of 40% were quantitatively analyzed using EVO/MA 10 Scanning Electron Microscope.

3.0 Results and discussion

Table 1: Izod impact strength of polyester reinforced with oil and date palm frond fibre.

Fibre (wt. %)		Composite impact strength (J/m)	
		Oil palm frond	Date palm frond
10	Untreated	143.82	150.20
	Treated	248.32	168.65
20	Untreated	135.64	151.87
	Treated	206.56	175.88
30	Untreated	122.87	157.54
	Treated	172.21	171.96
40	Untreated	115.15	144.61

	Treated	130.74	165.66
50	Untreated	97.43	138.16
	Treated	104.76	161.88
60	Untreated	82.11	135.98
	Treated	89.42	156.82
70	Untreated	63.14	127.89
	Treated	64.33	147.72
Correlation Coefficient		0.959025	0.948659

Table 2: Comparison of impact strength of oil and date palm frond fibre reinforced polyester composites with some agro fibre reinforced polyester composites.

Property	Unit	Test	Oil Palm Frond	Date Palm Frond	*Treated Kenaf	*Talc
Fiber (wt. %)	-	-	40	40	40	40
Izod Impact Strength (notched)	J/m	BS2782-3: Method 352F: 1996	130.74	165.66	204.32	320

*Source: (Brydson (2001), Nielsen (1994).

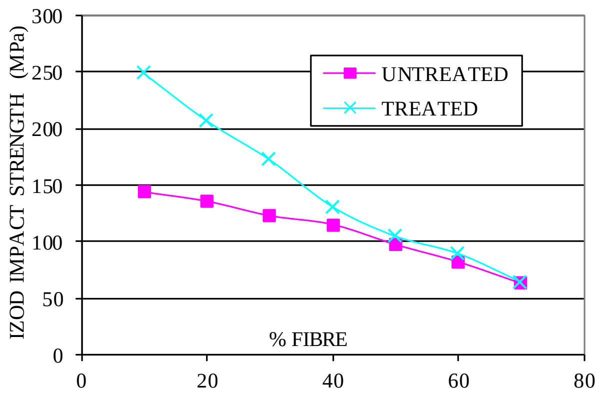

Fig. 1: Izod impact strength of untreated and treated oil palm frond fibre – reinforced polyester composites

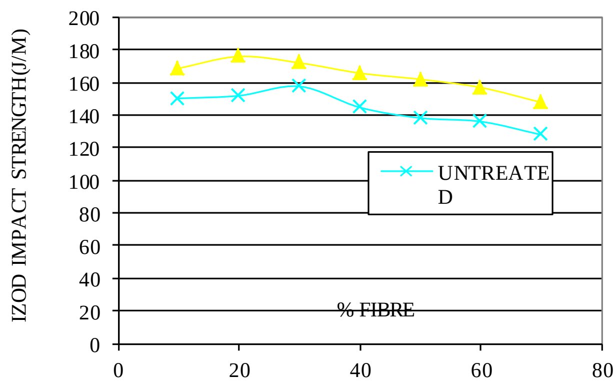

Fig. 2: Izod impact strength of untreated and treated date palm frond fibre - reinforced polyester compsites

Table 3: Elemental analysis (Energy Dispersive Spectroscopy- EDS) of oil and date palm frond fiber polyester composites.

	Composition of Element (%wt.) in the Composite													
Specimen	C	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Fe	Co	Zn
Untreated oil palm frond composite	59.2	39.4	-	-	0.82	0.35	-	-	0.22	-	-	-	-	-
Treated oil palm frond composite	65.7	31.9	0.42	-	1.21	0.45	-	-	0.09	-	0.12	-	0	-
Untreated date palm frond	54	43.9	-	-	-	0.81	-	-	-	-	1.31	-	-	-
Treated date palm frond composite	57.3	39.2	-	-	1.98	0.85	-	-	-	-	0.31	-	0	-

3.1 *Effect of fibre content and surface treatment*

Oil and date palm frond fibres are known to elongate substantially when a tensile stress is applied to them and this leads to a high strain value. This coupled with the high load bearing ability as compared with other plant fibres makes these palm frond fibres tougher. Essentially, these properties seem to have a strong bearing on the impact properties. The absorption of moisture by the fibres is minimized in the composite due to encapsulation by the polymer. Although it is difficult to entirely eliminate the absorption of moisture without using surface barriers on the composite surface, this is generally reduced through chemical modification of some of the hydroxyl groups in the fibre but with some increased costs (M. Rowell *et al*, 2001).

From the results of effect of fibre treatment on the izod impact properties of oil and date palm fronds fibre-reinforced polyester composites in Figures. 1and 2; it is evident that the surface treated fibre composites of oil palm frond showed outstanding decrement in impact strength, while the date palm frond showed a virtual non-significant change between the untreated and treated fibre.

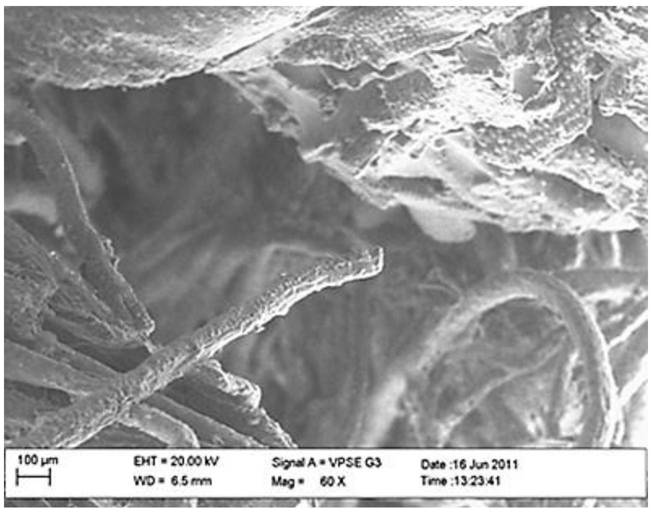

Fig. 3: SEM of fractured surface of untreated oil palm frond 40wt. % fibre polyester composite.

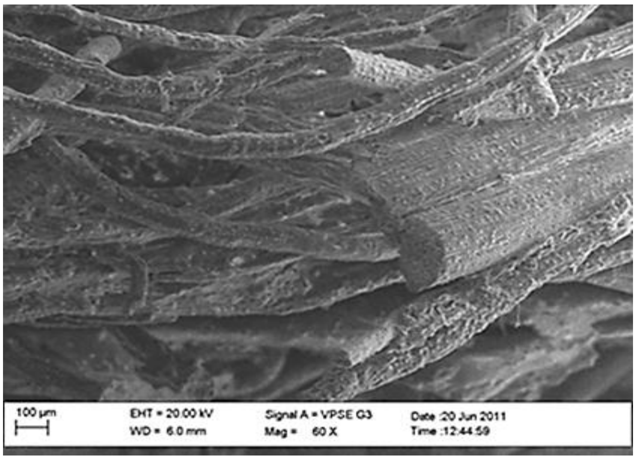

Fig. 4: SEM of fractured surface of treated oil palm frond 40wt. % fibre polyester composite.

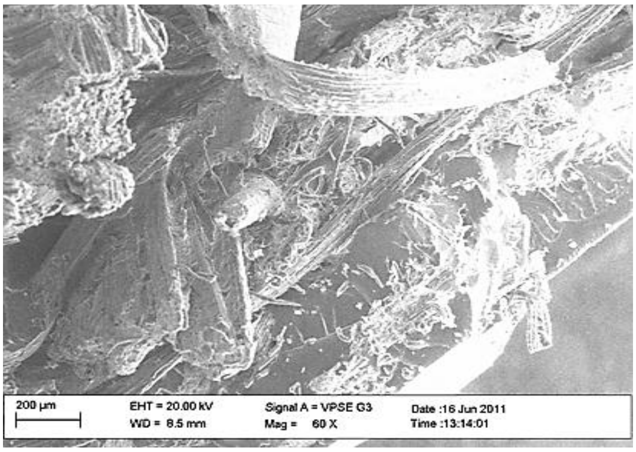

Fig. 5: SEM of fractured surface of untreated date palm frond 40wt. % fibre polyester composite.

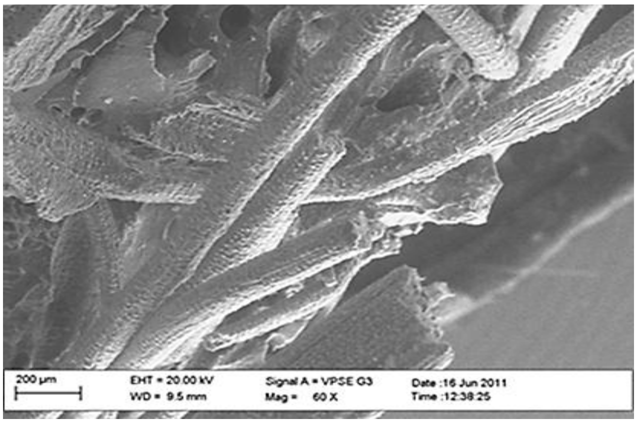

Fig. 6: SEM of fractured surface of treated date palm frond 40wt. % fibre polyester composite.

The impact strength properties of both composite panels of oil and date palm frond fibres decreased with increasing fibre content which agrees with literature (M. Keramat *et al*, 2008). Although, the results show that this part of palm tree exhibit unstable properties when compared with the impact strength properties of treated kenaf and talc in Table 2, it is inferred however that the application of oil and date palm frond fibre composites can be adopted without fibre surface treatment, as good fibre-matrix bonding will still be achieved.

With the high correlation values of impact strength of untreated and treated oil and date palm frond fibre composite panels showing that surface treatment may not be desirable in achieving improved impact properties, the continuous decrement in the impact strength of treated oil palm frond fibre composite up to 70 wt. % fibre content could be ascribed to manufacturing defect or the unstable morphology of oil and date palm frond fibres (Schuh and Gayer, 2007). As noted by some findings (M. Rowell *et al*, 1998), there are three main factors affecting the strength of a fibre reinforced composite, namely, fibre modulus, fibre loading and fibre aspect ratio. It can be inferred from the result that, the presence of silane could not guarantee the increased energy absorption efficiency of stress transfer from the matrix to the fibre for a significant improvement in the fibre-matrix interfacial bonding, thus the application of surface treatment may not be necessary for improved impact strength properties.

3.2 Scanning electron microscopy (SEM)

Most metals and polymeric materials exhibit ductile or brittle fracture under impact loading conditions depending on the temperature, specimen size, strain rate, and mode of loading (D. William, 1997), from the failure characteristics of SEM Figures 3-6, it is observed that the fibre surfaces were covered with protrusions and small voids in both untreated and treated fibre reinforced composites. Although the untreated fibre composites showed fibre peeling and resin ‘craze’ which suggests poor fibre-resin bonding, the treated fibre composites showed different failure characteristics where fibre damage showed that transfer of load was gradual till the interface failed before the fibre failure, thus explaining the incompatibility of the interfacial region due to hydrophilicity of natural fibres. This requires that natural fibre surfaces be treated to block the hydroxyl groups so as to make them more hydrophobic. These failure modes have direct consequence on the impact strength characteristics of the composites.

Similarly, the morphology of fractured surface of treated natural fibre composites showed that the composites failed by a combination of fibre fracture and fibre pull-out indicating that the amount of energy absorbed before fibre fracture was a major mechanism in the impact strength of the composite. The expected positive effect of surface treatment was not reflected in the non-significant improvement of the impact strength properties which agrees with literature (M. Keramat *et al*, 2008). It is also noted that the impact strength properties of natural fibre composites decrease with increasing fibre content in composites. This behavior is observed with both natural and synthetic fibres as suitable reinforcements in composite production (M. Sreekala *et al*, 1997).

Generally, the toughness property of fibres improve with surface treatment especially with the notched samples necessitating that the fibres bridged the cracks while increasing the resistance of the propagation of the crack and further limiting fibre pull-out. The non-significant effect of fibre surface treatment on the impact strength properties of the oil and date palm frond fibre composite suggests outstanding property which is consistent with the literature, thus, it may not be desirable to surface-treat these fibres for reinforcement in areas not requiring high impact properties (Zhang, 2001); (B. Singh *et al*, 1995).

Since the impact behavior of some materials such as polymers, in which a material is subjected to high rates of strain, resulting in complex multi-axial stressing, which often gives rise to brittle type fracture, and that at lower rates of strain, the state of the material may appear to be tough and non-brittle, the tendency therefore, for brittle fracture under impact conditions is thus increased to where an incidental notch (in essence being a crack) or some form of stress concentrator is present (Totov and Lanham,1979).

The results shown from the SEM analysis tend to suggest that the composites of oil and date palm frond fibres exhibited the normal material behavior necessary for failure predictions which is often lacking in most natural composite materials that preclude their application in engineering.

3.3 Energy dispersive spectroscopy (EDX)

From the energy-dispersive X-ray spectroscopy (EDX) result (see Table 3), the composition of elements in the randomly oriented fibre composites, showed improvement in carbon content and reduction in oxygen content as ash content increases. This can be associated with the protrusions in treated fibre composites as opposed to the peeling of fibres in the untreated fibre composites. The ash content has correlation with the impact strength properties of oil and date palm frond composite panels, although with little or no significant effect can be inferred.

4.0 Conclusion

This study showed that:

1. It is possible to produce low-to-medium impact strength composite panels from oil and date palm frond fibres.
2. Increase in oil and date palm frond fibre content and fibre surface treatment will not induce improved impact properties of polyester composites suitable for use in some low-to-medium structural load applications.
3. Date palm frond fibre is more stable than the oil palm frond fibres in composite application of production of good impact strength composite panels.
4. The high ash content of treated oil and date palm frond fibres and loading have no significant effect and correlation with impact strength properties of polyester composites.

It is deduced that the oil and date palm frond fibres can be regarded as valid alternatives to replace some conventional synthetic fibres as reinforcement in polyester matrix. In spite of the lower impact strength exhibition of these agro fibre composites, they are impervious to moisture and still support deformation which is an advantage over the use of kenaf and talc in polyester composite.

Acknowledgement

The staffs of the following organisations are acknowledged for their useful assistance in carrying-out this study:

- National Institute for Pharmaceutical Research and Development (NIPRD) Idu, Abuja.
- Federal University of Technology, Minna, Niger State, Nigeria.
- Science and Technology Complex (SHEESCO) Gwagwalada, Abuja, Nigeria.
- Federal Institute for Industrial Research (FIIRO) Oshodi, Lagos, Nigeria.

References

Bismarck, A., Mohanty, A. K., and Aranberri-Askagorta, I., Czapla, S., Misra, M., Hinrichsen, G., and Springer, J., (2001) Surface Characterization of Natural Fibers, Surface Properties and the Water Uptake Behaviour of Modified Sisal and Coir Fibers, *Journal of Green Chemicals.*, 3, p.100.

Brydson, J. A. (2001) *Plastics Materials*, 8th Ed., Newness-Butterworth, London,p.94.

Keramat, M., Jahromi, A., Jafari, S., Mohtasebi, S. and Rafiee, S.,(2008) Engineering Properties of Date Palm Trunk Applicable in Designing a Climber Machine. *Agricultural Engineering International*: The CIGR E-Journal. Manuscript FP 08 002. March, vol.X.

Nielsen, L. E., (1994) *Mechanical Properties of Polymers and Composites*, Vol. 6, Marcel Decker Press, New York. pp.45 - 78.

Rowell, M. R., Han, J. S., and Rowell, J. S., (2001) Natural Polymers and Agrofibers Composites Fibers. *Journal of Plastic Composites*, 31.pp.21-23.

Rowell, M. R., Sanadi, A. R., Cauldfield, D. F. and Rodney, E. J., (1998) Utilization of Natural Fibers in Plastic Composites: Problems and Opportunities, *Journal of Plastic Composites*, 22 .pp.18-29.

Rozman, H. D,; Mohd-shak, Z. A; and Ishiaku, U. S. (2005) *Oil Palm Fiber-Thermoplastic Composites in Natural Fibers, Biopolymers, and Biocomposites* Edited by Mohanty, A. K.; Misra, M and Drzal, L. T. Taylor & Francis Group Publishers, London.pp.408-409.

Sanadi, A.R., Prasad, S.V., and Rohatgi, H, (1985) Natural Fibers and Agro-Wastes as Fillers and Reinforcements in Polymer Composites. *J. Science and Ind. Res.* 44; pp.437-442.

Schuh, T. G. and Gayer, U., (2007) *Utilization of Natural Fibers in Plastic Composites, Lignocellulose Plastic Composites,* UBESP Publisher, Botucatu, S P, Brazil. pp.181 – 195.

Singh, B., Jones, R. W., and Graber, J. H.,(1995) *Construction Building Materials*, 9. p.39.

Sreekala, M. S., Kumaran, M.G., and Thomas, S., (1997) Utilization of Short Oil Palm Empty Fruit Bunch (OPEFB) as reinforcement in Phenol-Formaldehyde Resins: Studies on Mechanical Properties, *Journal of Polymer Engineering. 16*, 265.

Totov, W. V. and Lanham, B. J., (1979) *Reinforced Thermoplastics*. Applied Science Publishers, London. pp.130-138.

William D. Callister. Jr (1997) *Materials Science and Engineering, An Introduction*. John Wilel & Sons, Inc. New York. pp484.

Zhang, Qinli,(2001) Bamboo Flooring Industry in China; *The International Symposium on Utilization of Agricultural and Forestry Residues.* Peking, China. p.136