Cars from Jute and Other Bio-Fibers

DR. Omar Faruk
Visiting Research Associate
Department of Forestry
126 Natural Resources Building
Michigan State University
East Lansing, Michigan-48824
USA
Em@ail: ofaruk@msu.edu

Biographical Note

DR. Omar Faruk was born in Bangladesh. He completed his B.Sc.(Hons) and M.Sc. in Chemistry from University of Chittagong, Bangladesh. Then he was doing M.Phil. in Chemistry at Bangladesh University of Engineering & Technology (BUET) and acted as teaching assistant also. With the DAAD (German Academic Exchange Service) scholarship, he went at 1999 to Institute for Materials Science, Polymer & Recycling Technology, Department of Mechanical Engineering, University of Kassel, Germany under a research project (Natural Fiber and Wood Reinforced Composites). After completion the scholarship (2001), he continued to work there as a "Research Assistant" to pursue his Ph.D. research. In 2005 he achieved his Ph.D degree (Doctor of Engineering) and till February 2006 he has done his Post Doctorate research there. He joined as "Visiting Research Associate" at Department of Forestry, Michigan State University, East Lansing Michigan USA on 1st March 2006. He has 45 publications (including a book) to his credit which has published/accepted/submitted in different international journals and conferences.

Introduction

Bio-fibers are fashionable and not just in the wardrobe: it is a long time now since compostable automotive components and computer casings were utopian pipe dreams. Jute, hemp, flax and other bio fibers that once fell into neglect are enjoying a comeback in the high-tech development. Above all, the automotive industry is interested in the new biomaterials, because cars should be partially decomposable or recyclable by 2006. Furthermore, light-fibrous materials are also replacing conventional glass-fiber-reinforced plastics in other sectors–from construction to the computer industry–so benefiting the environment [1].

Lightweight, strong, and low-cost, bio-fibers are poised to replace glass and mineral fillers in numerous interior parts. For centuries they have been made into baskets, clothing, sacks, ropes, and rugs. They have even been smoked. Now plant-derived bio-fibers; jute, kenaf, hemp, flax, banana, sisal and also wood fiber are making their way into the components of cars.

The field of bio-fiber research has experienced an explosion of interest, particularly with regard to its comparable properties to glass fibers within composites materials. The main area of increasing usage of these composites materials is the automotive industry, predominantly in interior applications, due to the need is greatest here [2]. The growth outlook for bio-fibers in automotive components is expected to increase by 54 percent per annum [3].

In the last decade, bio-fiber reinforced polymer composites have been embraced by European car makers for door panels, seat backs, headliners, package trays, dashboards, and trunk liners. Now the trend has reached North America. Bio-fiber composites gain widespread acceptance in US automotive industry. Nowadays, in the USA more than 1.5 million vehicles are the substrate of choice of bio-fibers such as kenaf, jute, flax, hemp and sisal and thermoplastic polymers such as polypropylene and polyester [4]. Bio-fibers have benefited from the perception that they are "green" or eco-friendly. What is proving more important is their ability to provide stiffness enhancement and sound damping at lower cost and density than glass fibers and mineral fillers.

The automotive industries throughout the world are continuously optimizing the cost verses quality in order to remain competitive in the market. Moreover increased importance of renewable resources for raw materials and recyclability or biodegradability of the product at the end of the useful life is demanding a shift from petroleum-based synthetics to agro based bio-fibers in automotive applications.

Due to the modernization of the transport system and economic developments in the last century, the number of automobiles produced in USA, Europe, and Asia crossed 69 million in the year 2004. It is a fact that automotive textiles are the growing markets in terms of quantity, quality and product variety [5-7]. On an average each automobile utilizes fibers or fabrics, woven or non-woven based composites to the tune of 20 square meters. This is in the increasing trend due to the advantages of lightweight, high strength and day by day lowering cost of textile products. As many as 40 automotive components such as trunk and hood liners, floor mats, carpets and padding, speakers, package trays, door panels, and oil and air filters contain fabrics made of synthetic fibers [8-10]. Furthermore, these fiber-based composites can contribute greatly to the automotive manufacturer’s final goal constituting 30% weight reduction and cost reduction of 20% [11].

Increased social awareness of environmental problems posed by the non-degradable, non-recyclable contents of the salvaged automobiles is forcing automotive manufacturers to enhance the biodegradable content which is in favor of switching to bio-fibers. If biodegradable fibers were chosen to substitute many of the existing composites, the finished products do not pose difficulty in disposing [12, 13]. To accelerate this process of switching to recyclable and biodegradable constituents, the legislations in USA & Europe have issued a specific directive on the end-of-life vehicles [14] that promotes the use of environmentally safe products and reduces the landfills. The directive, which came into effect at the turn of this century, predetermines the deposition fraction of a vehicle to 15% for the year 2005, and then gradually reduced to 5% for the year 2015 [14].

The European and North American market for bio-fibers reinforced plastic composites reached 685,000 tones, valued at 775 million US dollar in 2002 [15]. Wood-polymer composites accounted for 590,000 tones while the rest amount represents the other bio-fiber composites. Germany occupies a totally dominant market position in terms of product innovation, research, and commercially available products. Two-thirds of all bio-fibers consumed in the automotive industry with Europe take place in Germany. In Germany, car manufacturers are aiming to make every component of their vehicles either recyclable or biodegradable [16].

Indeed, the use of bio-fibers has risen dramatically in recent years. The German automotive industry has increased its usage, from 4000 tons in 1996 to 18,000 tons in 2003. For Europe, it accordingly amounts to almost 70,000 tons of these new natural fiber materials.

Projections for 2005 and 2010 suggest that the total application of bio-fibers in the European automotive sector could rise to between 50,000 and 70,000 tons in 2005 and to more than 100,000 tons by 2010 as shown in figure 1.

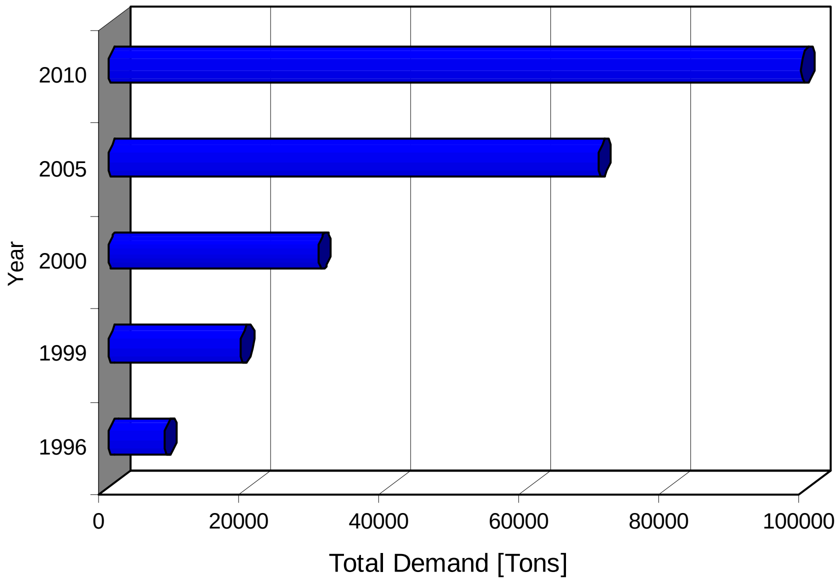


Figure 1: Total consumption of bio-fibers within Western Europe, 2005 and 2010 are predictions [17]

On the other side, European consumer is concerned about environmental issues. As a result, the environmental driving force stems partly from European regulations. The effect is two fold. Bio-fiber composites in the automotive industry both reduce material waste and increase fuel efficiency. A major question for the automotive industry is what to do with the glass fibers of a glass fiber-plastic composite after its life cycle. This leads to a clear advantage for using bio-fiber composites, which can be recycled. The second environmental benefit is to reduce fuel emissions. Europe is committed to follow the Kyoto protocol. By 2005 there is a commitment to reduce fuel consumption in Europe by 50 percent [18]. If lighter materials are used in the automotive industry, fuel efficiencies rise, making it easier to meet this goal. In the current situation, it is estimated that no more than 50 kg of natural fibers can be used in a car. This corresponds to a reduction of about 10 kg if glass fiber composites are replaced with bio-fiber composites in an automobile. If the weight of a car can be reduced by 10 to 20 kg, the effect on the environment will be significant.

Fiber Resources

The use of bio-fiber composites for automotive components is a phenomenon that has appeared and developed only during the last few years. The principal fibers now being used for this purpose belong to flax and hemp, grown in the temperate climates of Western Europe, and the sub-tropical fibers, jute and kenaf, mainly imported from Bangladesh and India, banana fiber from Philippines, sisal from Florida, USA, South Africa and Brazil and wood fiber from all over the world.

Table 1 shows the commercially important fiber sources of agricultural bio-fiber that could be utilized for composites [17].

Table 1: Commercially important fiber sources

Fiber	Species	World Production (10^3 t)	Origin
Wood	(>10,000 species)	1,750,000	Stem
Bamboo	(>1250 species)	10,000	Stem
Cotton lint	Gossypium sp	18,450	Fruit
Jute	Corchorus sp	2,300	Stem
Kenaf	Hibiscus cannadbinus	970	Stem
Flax	Linum usitatissimum	830	Stem
Sisal	Agave sisilana	378	Leaf
Hemp	Cannabis sativa	214	Stem
Coir	Cocos nucifera	100	Fruit
Ramie	Boehmeria nivea	100	Stem
Abaca	Musa textiles	70	Leaf

The data for this table was extracted from several sources using estimates and extrapolations for some of the numbers. For this reason, the data should only be considered to be a rough relative estimate of world fiber resources. The traditional source of agro-based composites has been wood and for many countries, this will continue to be the major source.

Fiber properties

The bio-fiber world is full of examples where cells or groups of cells are 'designed' for strength and stiffness. A sparing use of resources has resulted in optimization of the cell functions. Cellulose is a natural polymer with high strength and stiffness per weight, and it is the building material of long fibrous cells. These cells can be found in the stem, the leaves or the seeds of plants. In general, the fiber consists of a wood core surrounded by a stem. Within the stem there are a number of fiber bundles, which contain individual fiber cells or filaments. The filaments are made of cellulose and hemicellulose, bonded together by a matrix, which can be lignin or pectin. The pectin surrounds the bundle thus holding them on to the stem. The principal differences between the individual fibers are: fiber qualities, lignin content, odor and so on.

Applications

The automotive industry requires composite materials that meet performance criteria as determined in a wide range of tests. Typical market specification includes the following criteria: Ultimate breaking force and elongation, flexural properties, impact strength, fogging characteristics, flammability, odor, acoustic absorption, suitability for processing temperature and dwell time, dimensional stability, water absorption and crash behavior.

Most of the composites currently used by industry are designed with long-term durability in mind. Generally, bio-fiber can be used as both fillers and reinforcement for automotive interior components. Current applications, with typical weights of used natural fibers are presented in table 2.

Table 2: Typical weight of natural fibers using in automotive component [2]

Automotive Component	Typical Weight of Fibers (kg)
Front door liners	1.2 – 1.8
Rear door liners	0.8 – 1.5
Boot liners	1.5 - 2.5
Parcel shelves up to	2.0
Seat backs	1.6 – 2.0
Sunroof sliders up to	0.4
NVH material min	0.5
Headliners average	2.5

Bio-fiber reinforcement in blended thermoplastic or resinated thermoset compression moldings is now generally accepted for applications as door liners/panels, parcel shelves and boot liners.

The manufacturers and models are known to incorporate natural fibers for such components to a greater or lesser extent [2, 23], are presented in table 3.

Table 3: Automotive manufacturers, models, and components using bio-fibers

Automotive Manufacturer	Model and Application
Audi	A2,A3,A4,A4 Avant,A6,A8,Roadstar,Coupe: Seat back, side and back door panel, boot lining, hat rack, spare tire lining
BMW	3,5 and 7 series and others: Door panels, headliner panel, boot lining, Seat back
Daimler-Chrysler	A, C, E, S class: Door panels, windshield/dashboard, business table, piller cover panel A class, Travego bus: exterior under body protection trim M class: Instrumental panel (Now in S class: 27 parts manufactured from bio fibers, weight 43 kg)
Fiat	Punto,Brava, Marea,Alfa Romeo 146, 156
Ford	Mondeo CD 162, Focus: Door panels, B-piller, boot liner
Opel	Astra, Vectra, Zafira: Headliner panel, door panels, pillar cover panel, instrumental panel
Peugeot	New model 406
Renault	Clio
Rover	Rover 2000 and others: Insulation, rear storage shelf/panel
Saab	Door panels
SEAT	Door panels, seat back
Volkswagen	Golf A4, Passat Variant, Bora: Door panel, seat back, boot lid finish panel, boot liner
Volvo	C70, V70
Mitsubishi	Space star: Door panels Colt: Instrumental panels

The automotive components with bio-fiber reinforced composites can be expected to increase steadily with increased model penetration. The following figures will show some automotive components manufactured by different bio-fiber reinforced polymer composites.

Figure 2: Automotive door in-liner, instrumental panel made from wood fiber reinforced composites

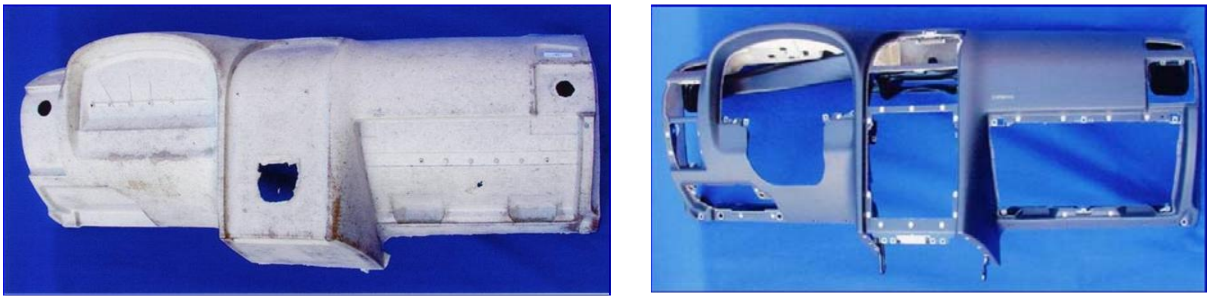


Figure 3: Automotive instrumental panel made from wood fiber reinforced composites

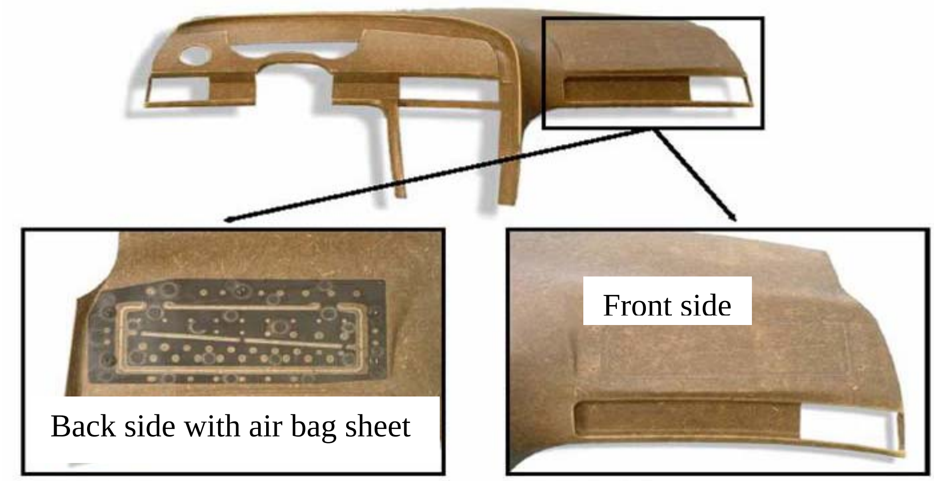


Figure 4: Automotive instrumental panel with integrated airbag flap made from bio-fiber reinforced composites

Figure 5: Automotive interior components made from wood fiber reinforced composites

Figure 6: Automotive door-inliner made from jute, flax, hemp, sisal fiber reinforced composites

The automotive industries are using bio fibers for interior components for certain years. But the new invention is, nowadays bio fibers composites are using also in the exterior components of an automotive. DaimlerChrysler's innovative application of abaca fiber in exterior under floor protection for passenger cars has been recognized [25, 26].

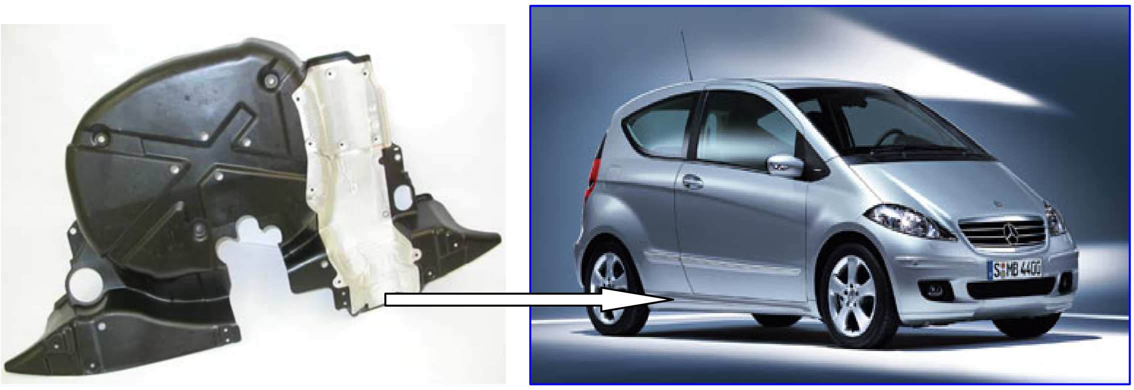
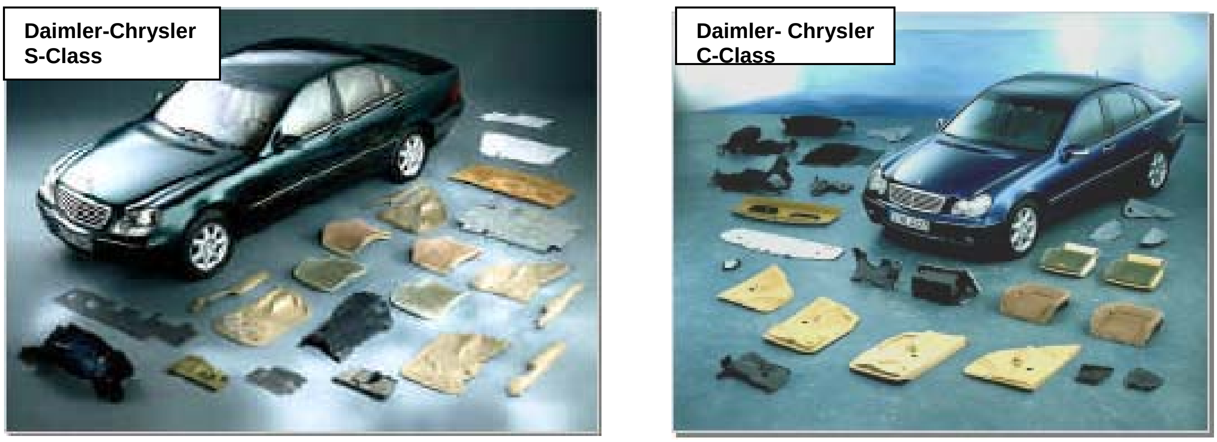


Figure 7: Under floor protection trim of Mercedes A class made from banana fiber reinforced composites

The other exterior parts (front bumper, under floor trim of bus) from flax fiber reinforced composites are coming also within a short time [27].

Figure 8: Automotive exterior components made from flax fiber reinforced composites

The automotive company Ford (In Germany) is using kenaf fiber in their model "Ford Mondeo" which is importing from Bangladesh [28] and the door panels of Ford Mondeo are manufactured by kenaf reinforced polypropylene composites. Daimler-Chrysler are using bio-fiber reinforced composites in their different models which are 20-25 components weighted 12-25 kg.



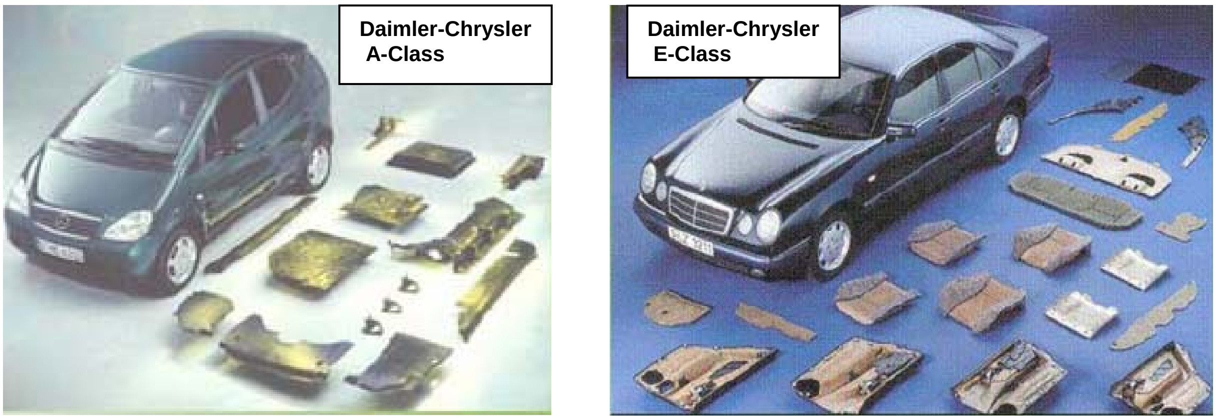


Figure 9: Daimler-Chrysler's different models with components made from different bio-fiber reinforced composites

Nowadays, 27 components of a car are manufactured from bio-fiber reinforced composites which weighted 43 kg (73% more than previous weight), used in newest Mercedes S class [29].

Figure 10: Newest Mercedes S class automotive components made from different bio fiber reinforced composites

6. Conclusions

The use of bio-fibers within composite applications is being investigated throughout the world. Many automotive components (interior and exterior) are now made from bio-fiber reinforced composites materials which are mainly based on polypropylene with reinforcing bio fibers jute, flax, hemp, kenaf and wood.

The primary importance to the automotive industry is weight reduction of the component which is possible up to 30 percent with the using of bio-fiber. Cost savings is another important factor. Therefore the future opportunities of using bio-fibers as replacements for glass fibers in automotive applications are enormous.

Engineers who previously worked for large automotive companies but felt they could be doing more toward helping the environment have developed a concept car. It is called the

EcoCar and is advertised as a sustainable vehicle for the future, running on biofuels. It is built from bio fiber composite panels that incorporate biodegradable resins as the matrix material.

7. References

[1] L.M. Sherman, Plastics Technology Online, **1999**, issue 10
[2] B.C.Suddel,W.J.Evans, Seventh International Conference on Woodfiber-Plastic Composites, May 19-20, **2003**, Madison, Wisconsin USA p. 7-14
[3] Annual report,Department of Environment, Food and Rural Affairs Publications, EU, August **2002**
[4] http://www.nutiva.com/about/media/2005_03_18.php
[5] P. Böttcher, Vliesstoffe & Technische Textilien,**2002**,2,35
[6] M.Karus, S. Ortmann, D.Vogt, 2004,www.nova-institut.de
[7] M. Kaup, M. Karus, M., Source: Nova Institute, **2002**, http://www.nova-institut.de
[8] W. Kinkel, Presentation, Symposium „Marktinnovation Hanf - Verbundwerkstoffe mit Hanffasern, Märkte und Ökonomie“, Wolfsburg/Germany, May 26th, **1999**
[9] D. Jensen, Energie Pflanzen III, **2001**,13
[10] J. Knothe, Th. Schlösser, 3rd International Wood and Natural Fibre Composites Symposium, Kassel, September 19-20th, **2000**
[11] W. Fung, M. Hardcastle, Woodhead Publishing Ltd, Cambridge, England, **2001**
[12] D. H. Mueller, A. Krobjilowski, H. Schachtschneider, J. Muessig, G. Cescutti, Proceedings of the INTC-International Nonwovens Technical Conference, Atlanta, GA/USA, 24-26. September **2002**
[13] J. Muessig, Proceedings, 4th International Wood and Natural Fiber Composites Symposium Kassel/Germany, April 10-11, **2002**
[14] N.N., Directive 2000/53/EC of the European Parliament and the Council of end-of-life vehicles, Office Journal of the European Communities, October 21st, 2000, ABl. EG Nr. L 269 S. 34L 269/34
[15] J.Morton, J. Quarmley, L.Rossi, Seventh International Conference on Woodfiber-Plastic Composites, May 19-20, 2003, Madison, Wisconsin USA p. 3-6
[16] J.C.M. Brujin, Applied Composite Materials, **2000**, 7, 415
[17] B.C. Suddell, W.J. Evans, Chapter 7 in book Natural Fibers, biopolymers and biocomposites edited by A.K.Mohanty, M.Misra, L.T.Drzal, USA ,**2005**
[18] D.Puglia, J.Biagiotti,L.M.Kenny, Journal of Natural Fibers, **2004**,1,23
[19] G.C. Ellison,R. McNaught,E.P. Eddleston, www.maff.gov.uk/farm/acu/acu.htm, **2002**
[20] W.D. Brouwer, http://www.fao.org/documents/show_cdr.asp?url_file=/DOCREP/004/Y1873E/y1873e0a.htm
[21] Natural Fibre-Reinforced composites are light and strong, Modern Plastics International, **1994**, 23, 69
[22] U.Riedel, 8th International AVK-TV Conference for Reinforced Plastics and Thermoset Moulding Compounds, 27-28th September, **2005** Baden-baden Germany
[23] E.Proemper, 7th International AVK-TV Conference for Reinforced Plastics and Thermoset Moulding Compounds, 28-29th September, **2004** Baden-baden Germany
[24] A. Maguro,Die Angewandte Makromolekulare Chemie,**1999**, 272,99
[25] N.N., http://www.netcomposites.com/news.asp?2888, **2004**
[26] M.Hintermann, Conference RIKO-2005, 10th November **2005**, Hannover Germany
[27] H.B. Buttlar, Conference RIKO-2005, 10th November **2005**, Hannover Germany
[28] http://www.presseportal.de/story.htx?nr=650074
[29] S. Schlott, Kunststoffe, **2005**, 11, 96