BRALECOMP

1st Brazilian-German Workshop on Composite Products from Alternative Lignocellulosic Resources

Workshop report

Editors
Christian Gauss
Goran Schmidt

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What? 1st Brazilian-German Workshop on Composite Products from Alternative Lignocellulosic Resources

When? March 5 – March 9, 2018

Where? Faculty of Animal Science and Food Engineering
University São Paulo - USP
Pirassununga, SP, Brazil

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KEYNOTE

Dear participants of the Brazilian-German workshop BRALECOMP.

Let me first express my gratitude to the organizers for arranging this important step for the better utilization of our natural resources, as bamboo, and also congratulate the participants to learn, discuss and meet for further cooperation.

Working since 1958 on the utilization of bamboo, I am fascinated about the great achievements for its processing and use. I remember with gratitude my visits to a number of your countries, for Technical Projects and International Conferences, like on Guadua 2004 in Pereira. So, I greet my colleagues from these times and later visits, as Antonio Beraldo, Khosrow Ghavami, Jorge Montoya and others.

I will read later with great interest the presentations of this conference and wish you lively discussions for strengthening the international cooperation to achieve wider utilization of alternative lignocellulosic resources.

Yours sincerely,

Professor Dr. Dr. h.c. mult. Walter Liese

INTRODUCTION

In Brazil, enormous quantities of renewable raw materials such as sugar cane, soybeans or wood are grown. Brazil's many years of experience in producing and using ethanol as a biofuel is important to Germany.

A workshop on "Creating value from bioresources" in São Paulo and a fact-finding mission funded by the International Bureau (IB) were the starting points for a German-Brazilian initiative in the bioeconomy field. The IB supported the BMBF in identifying topics and partners for the internationalization of the "Bioeconomy 2030" strategy in Brazil. Since 2014, the Federal Ministry of Research has been funding four projects with Brazil as part of the "BioEconomy International" funding program. Both countries want to further expand cooperation in this area. BRALECOMP shall lay the fundament for a bilateral BMBF project

The Brazilian bioeconomy depends on high-quality products from lignocellulosic raw materials (wood, bamboo, palm, sugar cane). The production of engineered high value products and high-performance composites in Brazil is emerging but needs a strong push.

One well known example is the industrial bamboo sector in Brazil. Only a few manufacturers process bamboo to toothpicks, chopsticks, curtains, pulp and charcoal. Most of these products are of low value and exports are relatively rare. University of Hamburg, Fraunhofer WKI as well as the University of São Paulo showed that bamboo is suitable for industrial panel materials such as fibre boards (MDF), particleboard (PB) oriented strand boards (OSB) and long-strand bamboo composites (also known as scrimber) as well as fibre matrix composites. Technical, economic and ecological feasibility are proven but not yet applied to a broad extent.

The obstacles to a successful implementation and the great opportunities of such raw materials requires investigation and action. BRALECOMP, the “1st Brazilian-German Workshop on Composite Products from Alternative Lignocellulosic Resources” shall promote a vertically and horizontally integrated R&D network. We are willing to form long term consortium of industrial, academic and public partners from Brazil and Germany and seek motivated contributors, creative participants and experienced partners.

As a result, we are seeking a bilateral research consortium of research institutes and industrial partners. The development, characterization and application of composite materials based on alternative lignocellulose and biogenic binders will be the focus of this collaboration. The combination of South American semi-finished products from agricultural sources and European processing technology shall lead to a prototype production plant in a later stage.

SCHEDULE

Monday, March 5

8:00 – 9:00 a.m.	Registration
9:00 – 9:150 a.m.	*"Welcome speech"* (FZEA-USP Director & Prof. Dr. Holmer Savastano J., USP, Brazil)
	Session 1
9:150 – 10:45 a.m.	*"Novel composite materials with vegetable fibres as sustainable engineering solutions"* (Prof. Dr. Holmer Savastano J., USP, Brazil) *"The state of the art of WPC from alternative resources"* (Prof. Dr. Andreas Krause, UHH, Germany)
10:45 – 11:00 a.m.	Coffee break
11:15 – 12:155 p.m.	*"Hardwood processing in Germany-Challenges and opportunities for the WBP industry"* (Dr. Dirk Berthold, Fraunhofer, Germany)
12:155 – 2:15 p.m.	Lunch
2:30 – 4:15 p.m.:	*"Preparation and characterization of aligned and non-aligned fibers based on the main constituents of lignocellulosic biomass and recycled polymer"* (Dr. Rachel Passos, USP, Brazil) "*Application potentials of industrial cellulose*" (Dr. Elaine C. Ramires, Fibria, Brazil) "*The wood panel industry in Brazil: Looking for alternative and secondary resources*" (Johannes Ohlsson, Dieffenbacher, Germany)
4:15 – 4:30 p.m.	Coffee break
4:30 – 5:30 p.m.	Panel discussion / Wrap-up

Tuesday, March 6

	Session 2
9:00 – 10:30 a.m.:	*"Situation of the use of bamboo as construction material in Brazil: past, present and future"* (Prof. Dr. Antonio L. Beraldo, Unicamp, Brazil) Presented by Dr. Elson Montagno.

	"Improvement of the physical-mechanical properties of Bamboo, with an adequate cellular diffusion treatment in the industrials processes of the preservation and mechanical drying" (Prof. Dr. Jorge A. Montoya Arango, UTP, Colombia)
10:30 – 10:45 a.m.	Coffee break
10:45 – 12:15 p.m.:	*"Engineered bamboo: Sustainable Composites for Construction"* (Dr. Bhavna Sharma, U. Bath, UK) → Cancelled due to illness *"Bamboo Project: Species, Characterization and Applications for laminated bamboo lumber (BLC/LBL)"* (Prof. Dr. Marco A. R. Pereira, Unesp, Brazil) *"Application of bamboo in architecture"* (MSc. Sven Mouton, KU Leuven, Belgium)
12:30 – 2:00 p.m.:	Lunch
2:00 – 2:45 p.m.:	*"Alternatives for bamboo treatment and chemical modification"* (MSc. Christian Gauss, USP, Brazil) *"Brazilian perspective for bamboo business: Yesterday, today and tomorrow - industrial, agricultural and commercial view"* (Guilherme Korte, Aprobambu, Brazil)
2:45 – 3:30 p.m.	Panel discussion / Wrap-up
3:30 – 3:45 p.m.	Coffee break
	Session 3
3:45 – 5:00 p.m.:	"*Research and application potentials of geopolymer as binder and matrix material in composites with lignocellulosics"* (Dr. Johannes Welling, Thünen Institute, Germany) "*The potentials of castor oil polyurethane for composites and impermeabilization*" (Donizetti C. Luciano, Imperveg, Brazil)
5:00 – 5:30 p.m.	Panel discussion / Wrap-up
	Wednesday, March 7
	Session 4
9:00 – 10:45 a.m.:	*"Use of fibers and residues from palm plants: Bionic inspiration for composites"* (Prof. Dr. Ing. Jörg Müssig, Hochschule Bremen, Germany)

	"Particleboards of agroindustrial wastes and castor oil polyurethane adhesive: performance evaluation in rural building" (Prof. Dr. Juliano Fiorelli, USP, Brasil) *"Morphological characterization of cactus wood Cereus Jamacaru"* (Mariana N. L. da Silveira, UFLA, Brazil)
10:45 – 11:00 a.m.	Coffee break
11:00 – 12:30 p.m.:	*"Lignocellulosic materials reinforced with bamboo sheets"* (Prof. Dr. Juliana Cortez Barbosa, Unesp, Brazil) *"Technological characterization of bamboo culms by non-destructive methods (NDM): microCT/X-ray densitometry"* (Prof. Dr. Mario Tommasiello Filho, USP, Brazil)
12:45 – 2:15 p.m.	Lunch
2:15 – 3:00 p.m.	Poster block
3:30 – 4:15 p.m.:	*"Vegetable fiber reinforced composites: Elaboration and properties"* (Prof. Dr. Marie-Ange Arsene, UAG, Département Français d'Amérique) *"Non-conventional materials & technologies for the 21st century"* (Prof. Dr. Khosrow Ghavami, PUC-Rio, Brazil)
4:15 – 5:00 p.m.	Panel discussion / Wrap-up
5:00 p.m.	Closing remarks and farewell coffee
	Thursday, March 08
8:30 – 11:00 a.m.	Visit to Infibra
11:00 – 01:30 p.m.	Transfer to São Carlos / Lunch
1:30 – 3:00 p.m.	Visit to USP-Lamem, São Carlos
3:00 – 5:30 p.m.	Visit to TSCtech
5:30 p.m.	Return to Pirassununga
	Friday, March 09
8:30 – 12:30 p.m.	Visit to ESALQ-USP
12:30 – 3:00 p.m.	Lunch and Follow-up session | Cooperation, future activities
3:30 – 5:30 p.m.	Cultural event | Visit of historical sugar cane processing site
5:30 p.m.	Return to Pirassununga or transfer to São Paulo

Session 1 | The state of the art of lignocellulosic composites from different perspectives

Session 1 introduced the auditorium to the current situation and challenges in the processing of alternative lignocellulosics. “Alternative” hereby means not only usage of non-wood materials (bamboo, palm), but alternatives to typical eucalypt and pine. Furthermore, alternative applications for existing products were presented. The contents and discussion of this session shall answer the question: Which strategies and developments have led to research, industry involvement and established industrial scale production?

Novel composite materials with vegetable fibres as sustainable engineering solutions

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Hardwood processing in Germany – challenges and opportunities for the wood-based panel industry

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For the last 40 years the German (and European) timber industry concentrated its investments and technological developments on the processing of softwood, whereas forestry developed silvicultural strategies that lead to enhancing the share of hardwood species. Consequently, efficiency of hardwood forest management is not sufficient compared to softwood forest management, therefore the growing stock of hardwood forests is increasing (almost 50% of German forests, in some regions up to about 85%) and this development will be significantly amplified within the next tree generation (100-150 years). On the other hand, hardwood species are hardly used for high added value products. Due to different physical and chemical properties, an immediate substitution of softwood by hardwood into existing processing technologies and final products is impossible. Thus, there is need for new ways to use hardwood for high added value products, to serve the requirements of a changing hardwood working industry. Furthermore, procurement of on-demand hardwood assortments, new products, process and service innovations, as well as new application fields are necessary to push the substantial utilization of hardwood timber.

To address these aspects several projects focusing on the hardwood processing, the development and the optimization of hardwood-based composites as well as technologies have been conducted at WKI. Results from following projects were presented:

- Substitution of Softwood by Hardwood in the Wood Based Panel Industry: This aspect has been addressed in projects like “Beech OSB” (BMBF Project: Management and Use of Beech and Grand Fir Forests), “Beech MDF and HDF” (BMBF Project: Management and Use of Hardwoods from Forests and Plantations) or “Utilization of low quality hardwoods” (FNR Project)
- Hardwood Veneer Based Products (LVL, Plywood) for New Applications in Cars, Train Wagons and Tram Doors: This topic has been focused in the BMBF Project “HAMMER” (Combination of Beech Veneers with Steel and Aramid for Car Doors) and

will be worked at in the BMWI Project “For(s)tschritt” (Use of beech LVL for Car and Wagon Roofs and Tram Doors)

- Optimization of the wood peeling process for the production of multilayer boards made of beech veneer with improved impregnability in a densified CO2-atmosphere (Project “OptiPro”)

The state of the art of WPC from alternative resources

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Preparation and characterization of aligned and non-aligned fibers based on the main constituents of lignocellulosic biomass and recycled polymer

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The aim of the present investigation was to add value to two of the major components of lignocellulosic sisal fibers (cellulose and lignin) and recycled poly (ethylene terephthalate) (PET) via preparation of materials with high added value. In this context, the properties of electrospun mats of aligned and non-aligned fibers were investigated, via electrospinning of solutions containing those raw materials, combined or not (PET/cellulose and/or lignin), in trifluoroacetic acid (TFA). The DMA results indicated the positive influence of fiber alignment on the higher storage modulus – E’ for mats

of PET/cellulose and/or lignin (values up to approximately 330 MPa) and it was also possible to observe no significant influence of fiber alignment on the Tg of PET for these materials. The Tg values for electrospun PET combined with cellulose and/or lignin were higher (values up to approximately 112 oC) than that of the reference mat composed only of PET (PETref, 92.5 ± 0.1 oC), and the tensile strength increased with the cellulose and/or lignin loading. It was observed that the main influences of the presence of lignin were

on the flat fibers morphology and on the increase of the elongation at break of the materials of approximately 90% compared to PETref. The presence of cellulose resulted mainly in a high elastic modulus of the materials (values up to approximately 360 MPa) compared to the ones presented by mats containing PET and by this polymer combined with lignin. Therefore, the goals of the present study were reached with the preparation of aligned and non-aligned fiber mats based on two of the main constituents of lignocellulosic sisal fibers (cellulose and lignin). To the best of our knowledge, this approach is unprecedented, and the prepared materials have a wide range of possible applications, such as air filtration systems, for example.

Potential application of industrial cellulose pulp

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Industrial cellulose pulp is an important commodity available worldwide that can be use used as reinforcement in bio-based composites. Fibria, a Brazilian company and one of the leaders in the cellulose pulp production and market, is committed with the diversification through the development of birefinery strategy and within this strategy biocomposites development is noteworthy. Besides biocomposites, the biorefinery strategy at Fibria includes: pyrolysis, lignin, nanocellulose and textile.

Biocomposites strategy is focused on the use of cellulose kraft pulp as reinforcement in polymeric matrices and it is in initial state of development with the identification of potential technology partners. The main drivers for biocomposites, besides sustainability, are the diversified areas of application, ranging from low volume high-tech products to high volume commodity products; the high consistent quality of cellulose kraft pulp; and diverse business models, ranging from business-to-business to business-to-consumers strategies. Despite the accelerated development of the biocomposite area, it is possible to identify several opportunities and R&D development needs, such as the clear identification and evaluation of feasible and profitable value chains and technologies; development of cost effective methods adaptable to production and product needs; and evaluation of recycling feasibility for bio-based composites. All these developments are important and will be faster and well succeeded

with the establishment of partnership and collaborations between universities, private companies and research centers. Fibria is committed within this initiative for developing biocomposites business strategy with their eucalyptus cellulose kraft pulp.

Alternative and secondary resources for the wood panel industry: Focus on Brazil

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Presentation annexed.

Session 2 | Markets, Performance and Availability of bamboo and bamboo-based products

Session 2 focused on products and materials based on bamboo. The presentations addressed technological aspects and potentiality of this plant. At the end of the session the panel discussion was held to answer the question: How can research projects, industry and public service overcome the challenges and improve the conditions for such products?

Bamboo as a construction material in Brazil: past, present and future

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Bamboo has not yet received sufficient attention in Brazilian society. Known in other countries as the “plant of thousand uses”, investigations about bamboo are still scarce and awaken little appeal in the scientific community. However, with the recent filiation of Brazil to INBAR (International Network of Bamboo And Rattan) it is expected that the applications of bamboo should be leveraged. In this presentation/work, one can glimpse a panorama of the studies developed at Unicamp since the 1980s, evidencing the large range of applications that can use this vegetal.

Improvement of the physical-mechanical properties of bamboo, with an adequate cellular diffusion treatment in the industrials processes of the preservation and mechanical drying

J. A. Montoya Arango[1]

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It is essential for a good quality bamboo, to have a good preservation treatment in order to avoid possible biotic and abiotic attacks, that can occur to the material in different stages of the life cycle of the product. There are different types of preservation treatments, among the best known we have: dip treatment in cold borax salts,

treatment in borax salts by hot immersion, treatment by the boucherie and modified boucherie method, etc. For this presentation we are going to use the treatment by dip in hot borax salts 4%. Subsequently and in order to complement the treatment, the drying process is done in automatic chamber, with temperatures ranging from 42°C to 53°C; the relative humidity starts with 85% - 90% up to 35% - 40%, determining the Humidity of Hygroscopic Equilibrium for each of these values of Relative Humidity, managing to decrease the moisture content, from 60% - 70% up to 12% - 15%. With the previous procedure, in the drying chamber it is possible to complement the dip treatment of the Xylem and post-xylem vessels of the vascular bundles or bundles fibers, accelerating the treatment by cell diffusion and the passive transport by osmosis to parenchymal cells until complete treatment 100%.

Bamboo project: Species, characterization and applications for laminated bamboo lumber (BLC/LBL)

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The bamboo project started in 1994 with the introduction of several bamboo species in the local campus of Unesp University aiming the supply of raw materials for future studies. In a continuous process, the project has been developing technically by means of several activities related to the production chain of this plant, involving the monitoring of different species development, harvesting, seedlings production, treatment, drying, processing, characterization and applications.

The Glued Laminated Bamboo (GLB) was developed and characterized for use on the development of new products, initially using the bamboo species *Dendrocalamus asper*, *Guadua angustifolia* and *Guadua chacoensis*, in which all of them were planted and harvested locally. The project naturally got closer to the areas of Design and Architecture, establishing a relation with under-graduate and graduate students. As a multidisciplinary approach, the project also started to act in extension activities and in the social insertion, seeking to transfer the acquired knowledge to the society.

Alternatives for bamboo treatment and chemical modification

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Bamboo is a plant of the Poaceae family characterized by its excellent specific mechanical strength in comparison with traditional building materials such as steel, cement and wood. Brazil presents immense potential for the use of bamboo as an engineering material due to the favorable weather for its cultivation and for the possibility of industrialization or for handcraft use. However, without a suitable treatment, bamboo is prone to biological degradation in a brief period of time, reducing its use as a structural material. Conventional treatment solutions for wood used in Brazil have good performance but are normally based on heavy metals and other toxic elements, such as CCA and creosote. The use of boron salts for the preservative treatment of bamboo as structural element, specifically disodium octaborate tetrahydrated (DOT), has been widely applied due to low cost, effectiveness, flame retardant action and low toxicity for humans and for the environment. Nevertheless, its use presents restrictions for the treated material because of the excessive leaching of boron in the presence of water and therefore, makes it impossible to use it in external applications. In the present work several alternatives for bamboo treatment are explored using low toxicity solutions aiming a broad-spectrum functionality, such as boron solutions combined with tannin extract and citric acid. As an example, a study using citric acid in association with DOT for bamboo treatment has been evaluated in order to improve the bamboo dimensional stability in contact with water, induce a chemical modification and diminish boron leaching. The performed treatment with a 20% w/w citric acid solution followed by drying at 120°C caused a reduction in water absorption of 25.2 % in comparison with reference samples, even after 87 h of immersion in a leaching test. Besides the reduction in water absorption, it was possible to observe a swelling reduction efficiency of 31.1 %. Samples treated with lower concentration of citric acid solution (10 % w/w) presented a reduction of 16 % in water absorption. Similar behavior was observed in the samples treated with citric acid combined with DOT, achieving up to 38.5 % in swelling reduction efficiency. FT-IR analyzes suggest that these changes are related with the chemical modification of bamboo by the citric acid through a process of esterification, with the increase of C=O bonds. Although chemical modification occurred, no considerable changes were observed in the dynamic MOE (obtained by NDT) of the treated samples, showing an average of 22.0 ± 3.2 GPa.

Additionally, through boron penetration analysis it was possible to infer that citric acid helps to decrease boron leaching process.

Brazilian perspective for bamboo business: Yesterday, today and tomorrow - industrial, agricultural and commercial view

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Session 3 | Biogenic and non-conventional binders and matrices

In session 3 alternative binders for lignocelullosic composites were focused, aiming a discussion around the following questions: Which traditional and novel binders and matrices will help to overcome current challenges? Is there a future for phenolic resin? Thermoplastic polymers? Inorganic binders? Geopolymer? Polyurethane?

Research and application potentials of geopolymer as binder and matrix material in composites with lignocellulosics

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Worldwide millions of cubic meters of wood composites are produced annually. For the major part formaldehyde-based binder systems are used (UF, MUF, PF, etc.). Due to the health risks of formaldehyde and its emission into indoor air the allowable emission rates for wood composites have been reduced stepwise over the last decades. Even though the emissions have reached very low levels many researchers are looking for alternative formaldehyde-free binder systems. Geopolymer binders might become a solution in the near future. The application of geopolymer has been tested for particle board and plywood with good results. The mixture of fine aluminosilicate powder materials (e.g. metacaolin and flyash) in combination with an alkaline activator solution can be used instead of conventional glues forming a water proof and thermally stable wood composite material. Other than in conventional mineral bonded particle board (Portland cement, gypsum, etc.) the geopolymer binder is less affected by sugar-like wood constituents which retard the hardening process. The curing of Geopolymer binders can be accelerated by temperature. Production parameters similar to the conventional binder pressing processes can be used resulting in short pressing cycles. There exists a wide range of possible applications for geopolymer binders in the wood working industry. Research in this field has just started.

The potentials of castor oil polyurethane for composites and impermeabilization

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Session 4 | Products, processes, characterization and applications of materials inspired by nature

In session 4, the lead questions are on products and applications close to nature. The priority of the research focus was defined, and a multi-product approach was discussed. The panel discussed these questions: Where must future research go to? Technology? Standardization? Performance? Costs? Market? Raw material accessibility? Which are our priority sectors?

Use of fibers and residues from palm plants: Bionic inspiration for composites

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Load-bearing biological structures often need to combine sufficient tensile and bending stiffness with resistances against fracture and may thus be a valuable source of inspiration for the improvement of man-made composites. Motivated by the almost ubiquitous presence of structural and mechanical gradients in biological composites, we designed simple, graded, fibre-reinforced composites which were used as a model system to investigate the functional significance of these gradients in detail. Our results suggest that graded composites can combine desirable properties of different fibre types, suggesting promising new routes for the development of technical composites, and improving our understanding of the structure-function relationship of load-bearing plant structures. We quantified mechanical variations in the drupes of coconut palm trees, and the babassu nut and found systematic changes in stiffness, strength, critical elongation and orientation of reinforcing, fibrelike elements. Schematic models of the biological structure were developed and compression moulded. Bio-inspired and bio-based composites with similar structural and mechanical gradients were used as simple model systems. The bio-inspired and bio-based composites illustrated that a systematic variation in the properties and distribution of reinforcing fibres can significantly enhance impact performance, while tensile and flexural properties remain largely unaffected. Hence, gradations may play a similar functional role in the biological composites. Besides using drupes of palms trees as bio-inspiration for composite structure we used the fibres and residues from palm plants to produce PLA-based

injection moulded composites. Based on the evaluation of the compounded and injection moulded composites we are able to turn agricultural waste into sustainable and biodegradable products.

Particleboards of agroindustrial wastes and castor oil polyurethane adhesive: Performance evaluation in rural building

Juliano Fiorelli[1]

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Morphological characterization of cactus wood *Cereus jamacaru* DC.

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The anatomical description of the wood is of the utmost importance to help in the knowledge of the properties, characteristics and ideal using of the different secondary xylems. The study of characteristics and anatomical description of wood must be realized, comprising the constituent elements of the wood, as well as its functions, organization and peculiarities. The objective of this study was to characterize the anatomical structures of the *Cereus jamacaru* wood, popularly known as Mandacaru, from Cactaceae family. Microscopic characteristics were described according to IAWA (1989) recommendations. For the microscopic analyzes, histological sections were obtained obtaining permanent slides, and then photomicrographs in the transverse, longitudinal radial and tangential longitudinal planes. With the analysis of the three planes of the secondary xylem was possible to identify the microscopic characteristics. Growth rings boundaries are indistinct. Diffuse porosity, multiple vessels (2-3) mostly, but with the presence of solitary vessels. Average pore diameter - 65,456 µm. Absence of tyloses or any deposit in the vessels. Presence of simple perforation plates. Alternative intervessel to opposite pits. Axial parenchyma scanty, more than three cells wide. Nonlignified parenchyma observed between the axial elements in bands. Multisseries rays with width less than ten cells. Heterogeneous rays with erect cells in the marginal and square in the center. Septate fibers. The wood presents characteristics that indicate water security because it has many tissues with function of storage being until its septate fibers to store substances and possessing many parenchyma tissues. This gives

a certain veracity when we analyze the environment and climate that the plant normally develops for long periods without water availability.

Lignocellulosic materials reinforced with bamboo strips

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Several bamboo species present high mechanical strength and modulus of elasticity in tensile tests parallel to fibers, in which represents a potential use for materials reinforcement. Thus, this work presents the influence of bamboo strips inclusion in the mechanical properties of different lignocellulosic composites. The bamboo species *Dendrocalamus asper*, *Guadua angustifolia*, *Guadua tagoara* and *Phyllostachys pubescens* Mazelex H. de Lehaie were used as well as Pinus taeda wood, comercial wood panels (EGP – Edge Glued Panel, MDF – Medium Density Fiberboard and MDP – Medium Density Particleboard) and the adhesives EPI 1911 and PVA (polyvinyl acetate). The bamboo strips were glued as reinforcement of the lignocellulosic materials and the modulus of rupture (MOR) and modulus of elasticity (MOE) in bending were determined. In all the studied cases, the use of bamboo strips provided an increase of MOR and MOE in static bending. Therefore, the use of bamboo strips as reinforcement for lignocellulosic materials shows an alternative to increase the range of applications of those materials, especially for structural use.

Technological characterization of bamboo culms by nondestructive methods (NDM) - microCT and X-ray densitometry

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INBAR states that of the 1,300 bamboo species occurring in the world, 19 species are a priority, including the genus *Bambusa*, *Guadua*, *Dendrocalamus*, *Phyllostachys*, among others. These bamboo species present significant variations in the anatomical, physical, chemical and mechanical properties of their culms, being influenced by genetic factors, age, silvicultural management, soil and climatic conditions, etc. The non-destructive

method (NDM) was, initially, applied to extract the culm samples of bamboo species by using the increment borer, such as hardwoods and conifers, as an alternative of their cutting. Also, in laboratory the precision automatic diamond-cutters and polishing equipment (used for cutting and polishing rocks, metals, etc.) were applied with advantages in the culm sample preparation of bamboo species in relation to the traditional sliding microtome, sanders, etc. For the culm bamboo technological characterization of bamboo by NDM were used X-ray equipment (collimated beams and digital) and X-ray microtomography (microCT), complemented by the culm analysis under stereoscopic microscope. These NDM methodologies allowed, initially, the characterization of the culm anatomical structure indicating marked differences between bamboo species; in the same way, showed significant variation of the anatomical structure along the culm thickness, with greater contrast in their internal-intermediate layers in relation to the external. The microdensity profiles of the bamboo culm (internal to outer culm thickness) indicate a significant increase and the anatomical distinctness of three layers; a correlation of culm microdensity and the anatomical structure of the bamboo species was also observed. The results indicate the potential of NDM for genetic improvement and management of the bamboo species. Likewise, the importance of NDM is discussed concerned the culm technological characterization and assessing their quality.

Vegetable fibre reinforced composites: Elaboration and properties

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Non-conventional materials and technologies (NOCMAT) for the 21st century

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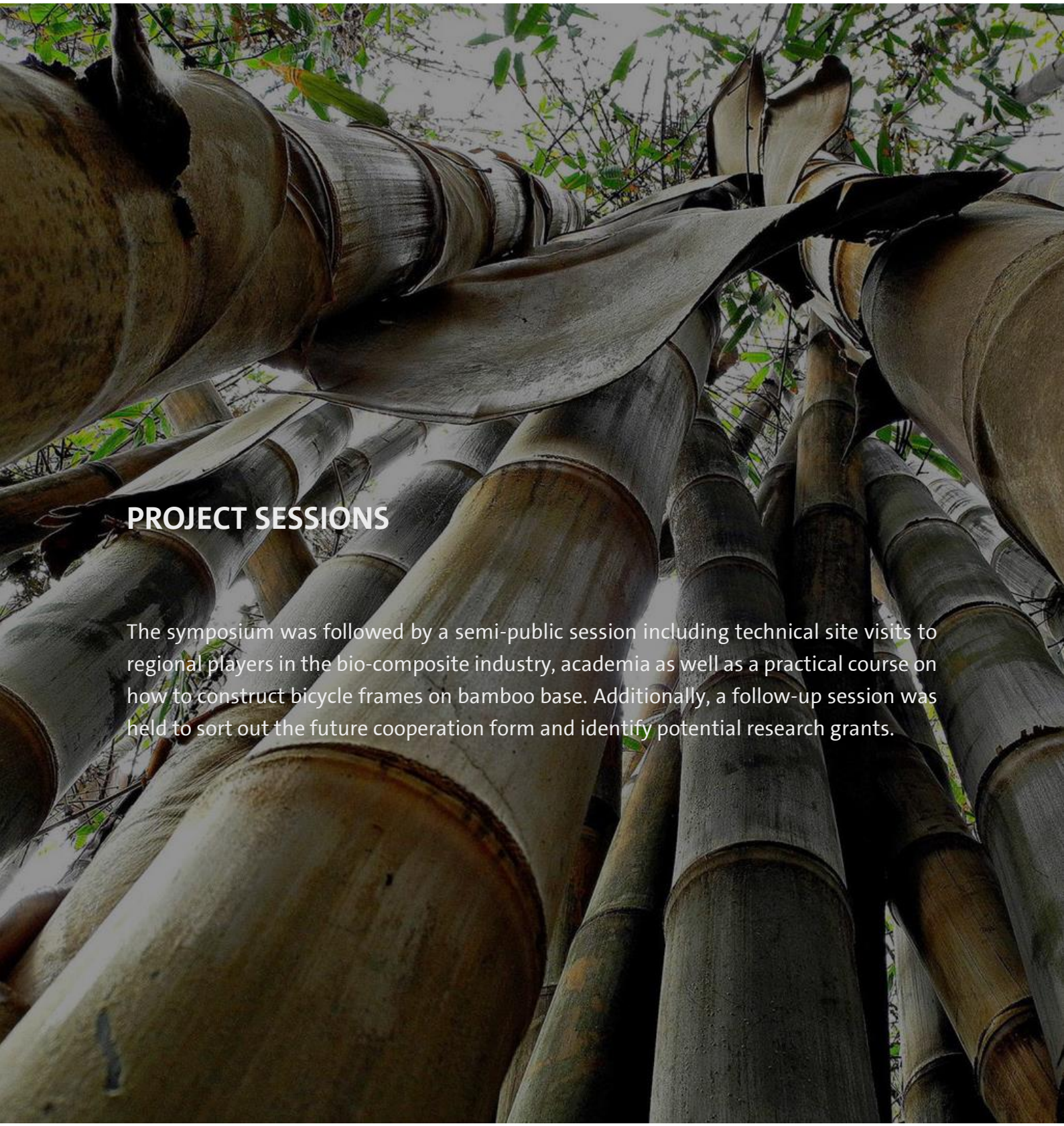
This paper addresses scientists, researchers and especially young engineers, architects, designers and planners to get acquainted with non-conventional materials and

technologies (NOCMAT) which certainly will influence their future choices, to make use of traditional sustainable materials such as soil, natural fibres, bamboo and agricultural residues besides discussing the climatic construction which was the basic tradition in Persia. During the last 40 years of research and development into NOCMAT, many materials and technologies have shown viable to contribute towards the sustainability and ecological development. However, large industries are not interested to solve the many problems of our time in a humane way without a big and immediate financial return. Profit and economic growth is still the focus of governments and industries. They invest in armament and construction. New constructions erected, scraping the skies with nearly 1000m high buildings. Desserts turned into paradise with immense costs. Medicine advanced, prolonging life. Food production increased with the help of science and technological advances. Outer space explored, searching for possible earth like planets. Just in case if earth is not livable anymore that a few special people get away. Still in spite and partly due to all these advances, a great majority of people live in misery, hungry, without clean drinking water and decent housing and suffer from the degradation of the land by pollution. Very few benefit from those amazing advances, not by hard working but through abuse of power. Industries are demanding more and more raw materials, which exist now mainly in developing countries, and creating havoc on earth in search and exploration of those materials. The question arises: is it a blessing to have natural resources in the ground, exploited and many times are being the cause of conflicts, and bring absolutely no benefit for the local population? How about the environment? Nature is responding with climate changes, freak storms and other natural disasters. Now, the application of NOCMAT goes together with moderation, meeting basic needs and a general well-being of the population. NOCMAT makes possible that a greater part of the population can follow up a life's dream or at least can have a decent meaningful life. NOCMAT means as well that remaining natural resources should be preserved for the future generations. The modern science being studied and thought in schools and universities only the industrial nonrenewable materials such as cement and steel A new research line of research has been started at PUC-Rio in 1979, to investigate, local renewable materials such as bamboo, vegetable fibres, soil composite and recycled materials such as rice husk ash, sugar cane ash among others. The main objective is to present the recent results of the research in the field of nonconventional materials and technologies (NOCMAT).



PROJECT SESSIONS

The symposium was followed by a semi-public session including technical site visits to regional players in the bio-composite industry, academia as well as a practical course on how to construct bicycle frames on bamboo base. Additionally, a follow-up session was held to sort out the future cooperation form and identify potential research grants.

Bamboo bicycle frames

For those who are interested in handicraft and bamboo culture, we offered a complementary session together with a bamboo bicycle expert who introduced materials and techniques. A technical, hands-on course showed the participants how to build a bamboo-based bicycle frame out of natural fibre composite materials and bamboo and simple handicraft methods.

In the mini-course we went through the steps to build a personalized bamboo bike frame, from taking the rider's measurements to doing the BikeCad project, through the treatment and preparation of the bamboo and other materials, until the frame acquires its final shape with gluing and finishing. With the frame ready we set up the bike for a test ride on the campus.

The course was done by LABambu, a union of professionals from different areas developing projects to promote social inclusion from open technologies and natural materials in a bamboo lab. The responsible instructor, Lucas Elias de Abreu, has been working with bamboo since 2011, when he joined the Bamboo group of Unesp-Bauru, where he continues as a volunteer collaborator. He has participated in several bamboo courses, among them the Design and Architecture in Bamboo of the post-graduation at Unesp-Bauru. LABambu ministered dozens of lectures and workshops such as Geodesic workshop, Bamboo bikes, bamboo green roof courses and workshops of general bioconstruction, harvest, planting and handling of bamboo. More information can be found here: https://labambusite.wordpress.com/bicicletas-labambu/

Fibre cement at INFIBRA

Approximately 15 people of the Workshop joined the technical visit at fibre cement company Infibra, located in the city of Leme, São Paulo. The visit was organized and conducted by the company's R&D team. Firstly, a general introduction about the company was presented, followed by a guided visit through the manufacturing facilities,

from the raw-materials reception up to the final products. The fibre cement tiles are produced with a combination of synthetic fibres (PP and PLA) and cellulose pulp, in an adequate proportion for optimal production process, mechanical strength and durability.

Wood structures laboratory at USP

At the University of São Paulo campus of São Carlos, we visited the Laboratory of wood and wood structures (Lamem), moderated by the Professors Francisco Antonio Rocco Lahr and Carlito Carlil Junior. During the visit, all the laboratory facilities were presented (mechanical test lab, sample production, wood characterization, fire test infrastructure and so on). Lamem is known by its excellence in wood research and it is one of the oldest laboratories for wood structures research in Brazil.

Natural fibre mats at TSTech

After the visit at Lamem, the Bralecomp group went to TSTech (Tapetes São Carlos division), a company with old expertise in using vegetable fibres for carpet production and more recently for the production of composites for the automotive industry. The company's Director and other employees responsible for the production lines warmly received our group. After a quick presentation and discussion about the company, the

group was guided through the production facilities, with a special focus on the production of automotive panels using vegetable and synthetic fibre fabrics.

Follow-up at Esalq/USP in Piracicaba

The follow-up session was planned to be done during a visit at ESALQ - USP laboratories and while socializing on the last day of the workshop week. At the wood anatomy laboratory, the participants were introduced to x-ray microscopy methods which serve to analyze basic anatomical characteristics of alternative lignocelluloses, such as bamboo.

After the visit at ESALQ-USP, the group headed to the "Engenho Central", one of the most beautiful architectural settings in the state of São Paulo and perhaps Brazil, known for inspiring poets, artists, architects, journalists, scientific researchers, tourists, lovers of history and culture.

Imbedded inside a park with more than 85.000 m^2, a couple of imposing buildings dating from the 19th and 20th centuries that once housed mills, boilers and warehouses for the production and storage of sugar and alcohol, has been carefully and gradually regained and revitalized. Its preservation, in all instances, represents unconditional respect for the past generations and keeps alive much of the history of Piracicaba, sugar and alcohol in São Paulo and Brazil. The story of the sugar cane value-chain in Brazil is a splendid example of how a monocultural commodity-based agricultural systems could shift into multi-product value-webs.

One of the main workshop outcomes was to form an extended bilateral consortium and write a mutual research project. We identified at least three potential open calls[A]. At the follow-up session, all potential open calls were discussed and a match-making between research demands and potential partners was made. The BraleComp workshop shall develop a long-term project matching with the political framework of the German "National Bioeceonomy Research Strategy 2030".

[A] https://www.zim-bmwi.de/internationale-fue-kooperationen/download/ausschreibung-de-bra
https://www.bmbf.de/foerderungen/bekanntmachung-1612.html
https://www.bioeconomy-international.de/lw_resource/datapool/_items/item_154/bekanntmachung_b-i2017_en.pdf

The “Bioeconomy International 2017” Call offered a three-years bilateral cooperation funded partly by FAPESP[B], the São Paulo Research Foundation, and the German Federal Research and Education Ministry, BMBF.

A balanced consortium was formed out of institutions from São Paulo state and Northern Germany. The consortium consists of universities, applied research institutions, industrial research partners and resort research entities and submitted a joint application on April 16, 2018 to PtJ/BMBF[C] and FAPESP:

- Prof. Dr. Andreas Krause, Institute for Wood Sciences, Biology Department, Universität Hamburg, Germany
- Prof. Dr. Jörg Müssig, The Biological Materials Group, Hochschule Bremen - City University of Applied Sciences, Germany
- Dr. Johannes Welling, Thünen Institute of Wood Research, Germany

[B] FAPESP, Portuguese: Fundação de Amparo à Pesquisa do Estado de São Paulo
[C] PtJ, German: Projektträger Forschungszentrum Jülich

- Dr. Dirk Berthold, Department of Wood Based Panels, Fraunhofer Institute for Wood Research, Germany
- Dr. Holmer Savastano Junior, Department of Biosystems Engineering, University of São Paulo, Brazil
- Dr. Elson de Araújo Montagno, EduLab, InOver ltda, Brazil
- Dr. Maria Teresa Pedrosa Silva Clerici, Food Technology, University of Campinas, Brazil
- Dr. Juliana Cortez Barbosa, Industrial Wood Engineering Faculty, São Paulo State University, Brazil

The results of this first act are expected to be published IV/2018.

MISCELLANEOUS

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The first approaches of this project happened in September 2016, when we (Christian and Goran) started developing ideas and raising funds. The project consortium has been growing since then. Especially in the starting phase many little helpers supported us and kept our motivation up. Thanks for your important contribution in the early stage Emilin Joma, Luisa Pischtschan, Juliana Becker.

Our thanks of course go to Holmer Savastano Jr. and the local organization team, Mariana Pavesi and Josiane Gonçalves Borges, for the pragmatic and straightforward handling of the event and their kind hospitality in Pirassununga.

Also, we are particularly grateful to all our excellent speakers: Dirk Berthold, Andreas Krause, Marie-Ange Arsene, Elaine Ramires, Johannes Ohlsson, Elson Montagno, Marco Pereira, Jorge Montoya, Guilherme Korte, Donizetti Luciano, Jörg Müssig, Juliano Fiorelli, Mariana Silveira, Juliana Cortez, Mario Tomasiello, Johannes Welling and Khosrow Ghavami for their kind acceptance of our invitation. This made it a worth experience for all participants.

Our helping hands during the workshops days as well as the kind hosts during our technical visits. Thank you, Gustavo Rocha (Infibra), Francisco Antonio Rocco Lahr (Lamem), Giusepe Lombardo (TSTech) and Luiz Gustavo Nussio (Esalq-USP).

Thank you all for your significant efforts!

About our host

The Construction and Ambience (C&A) Group at USP is coordinated by Prof. Dr. Holmer Savastano Junior and is located at the city of Pirassununga – São Paulo, Brazil. The C&A group is part of the Biosystems Engineering department in the Faculty of Animal Science and Food Engineering (FZEA/USP, Brazil) and integrates the BioSMat group which is composed of several national and international research institutions with experience on the development, production and characterization of composites and nanocomposites materials with organic and inorganic matrix reinforced with natural fibers and based on agro-industrial wastes, and of non-conventional materials in general.

The group develops sustainable products for rural, industrial and urban buildings, with a special interest in non-conventional materials based on inorganic and organic matrix, cements reinforced with natural fibers and composites based on agro-industrial residues. The laboratory carries out the characterization of building elements analyzing the mechanical, physical and microstructural properties and the durability of materials and composites.

The C&A Group is composed of undergraduate and graduate students, researchers with doctor degree from various areas of expertise under the guidance of the faculty members, in collaboration with several institutions in Brazil and abroad.

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Online resources

All presentations, posters and lesser relevant documents are part of the online annex. The access is password-restricted (password: growBR2018). Please find the data room here http://www.growme.de/report.html

Presentations on MONDAY, March 5, 2018	**day_1_05-03-2018.zip** Download File
Presentations on TUESDAY, March 6, 2018	**day_2_06-03-2018.zip** Download File
Presentations on WEDNESDAY, March 7, 2018	**day_3_07-03-2018.zip** Download File
Poster presentations	**posters_07-03-2018.zip** Download File
Science Slam (Fund BMBF)	**20170322_wkiuhh_bmbf_brtag_gs.pdf** Download File

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