

FIBER INSULATION MATERIALS FROM EUCALYPTUS BARK FIBERS – FIRST RESULTS

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Abstract:

*When focusing on the production of insulation materials from forest biomass, it has to be considered that the typical wood assortments used for their production are limited and expensive. Moreover, this forest biomass is increasingly demanded by an expanding search for renewable raw materials. Increasing the market share of sustainably produced insulation materials by decreasing their costs is possible with the utilization of alternative cheap raw materials with high availability in combination with a simpler production technology. In this context, the high fiber content and unique fiber morphology of the bark of *Eucalyptus globulus* is an interesting raw material. In this paper, a new processing technology for *Eucalyptus* bark fibers is presented, which allows the production of competitive and high-performance fiber insulation materials. Due to a less expensive raw material, less thermal and electric energy consumption in the production, less investment costs due to a simpler production technology and less bonding agent content the production costs are reduced significantly. In addition, insulation materials made of *Eucalyptus* bark fibers offer partly better properties compared to common insulation materials. They can also be adapted to various requirements for sound and thermal insulation in buildings.*

Key words: *Eucalyptus globulus* bark; bark fibers; insulation materials; processing technology.

INTRODUCTION

In comparison to common solid wood products and wood-based panels, the production of high-performance insulation materials based on wood fibers or other sustainably available fibrous materials is quite young and limited. Aside from the fact that thermal building insulation has become increasingly important over the recent years, the market share of insulation materials made of renewable raw materials is about 7%, including wood fiber insulation mats and boards with about 3.5% market share in Germany (Dorsch et al. 2014). Insulation materials from natural fibers such as hemp or wool are not competitive because of their high price, low availability and difficult processing. Even wood fiber insulation materials suffer from comparatively high manufacturing costs, which are caused by high raw material costs, high thermal and electrical energy consumption, investment intensive production technology and expensive bonding agents.

Modern wood fiber insulation materials are manufactured from coniferous species in two different processes. One is the wet process, which is based on mat formation from a fiber in water suspension. In this process, fiber insulation boards are produced with a thickness of up to 20mm and a raw density of up to 280kg/m³. For insulation boards with a higher thickness several layers are glued together. The other process is the dry process, which is based on medium density fiberboard (MDF) technology and is characterized by the use of thermoset and thermoplastic adhesives. This process substituted the wet process in the

production of wood fiber insulation materials largely. In the dry process, it is possible to produce flexible insulation mats with raw densities between 50-80kg/m³ and rigid insulation boards with raw densities of 80-240kg/m³. In the dry process, it is possible to produce insulation materials with a thickness of up to 300mm continuously. Flexible insulation mats are bonded with thermoplastic bicomponent (bico) fibers with an adhesive content of 5-8%. These adhesive fibers have a high melting core that serves as a support to prevent the mat from collapsing during consolidation, and a low melting sheath, that binds with the wood fibers. Rigid insulation boards are mainly produced with polymeric methylene diphenyl diisocyanate (PMDI) an adhesive content of 4-8%. Air-injected wood fiber insulation without adhesives is also available.

State-of-the-art in fiber production for wood fiber insulation materials are pressurized single-disc MDF refiners. This technology is based on a thermomechanical pulping process that uses steam pressure to soften the lignin in the wood matrix to ease defibration. Refiner plates defibrate the wood chips into single fibers and fiber bundles. Common digestion conditions provide temperatures about 180°C respectively 10 bar with retention times of 3-4 minutes depending on wood species. This amounts to a thermal energy consumption of 220-300kWh/t for the refining process. The specific electric energy consumption for defibration is about 90-120kWh/t. Another 500-850kWh/t is needed to dry the fibers to 6-12% moisture content after defibration. For more competitive wood fiber insulation materials, it is necessary to cut down the electric and thermal energy consumption together with the complex and expensive machinery (Figures according to own measurements).

The raw material for the processing technology presented in this paper is bark of *Eucalyptus globulus*. This material is generally seen as a problematic byproduct. Due to a lack of economic usage, a large amount of the bark already remains in the plantations. This increases the risk of devastating forest fires. The main difficulties with the processing of Eucalyptus bark are difficult handling in mechanical systems and a high ash content. These difficulties can be overcome by the processing technology presented in this paper.

PROCESSING TECHNOLOGY FOR EUCALYPTUS BARK FIBER INSULATION MATERIALS

Eucalyptus bark as a raw material

Eucalyptus species represent the second most important industrial forest plantations worldwide, with a total area of 14.1 million ha (Forest Stewardship Council - FSC 2012). The suitable species for insulation material production is *Eucalyptus globulus*, because of its bark (see Fig. 1) with a high content of long fibers. *Eucalyptus globulus* is cultivated worldwide as a raw material for pulp production. The largest cultivated areas are situated in Europe, followed by Asia and Latin America (Forest Stewardship Council (FSC) 2012). On the Iberian Peninsula, about 1.3 million ha are planted with *Eucalyptus globulus* trees. In Chile, *Eucalyptus globulus* covers 34% of the total forest plantations, with as much as 0.8 million ha (Instituto Forestal 2016). In *Eucalyptus globulus* trees, bark represents 11–15% of the mass at the maximum cutting age of 15 years for pulping (Miranda et al. 2013).

Eucalyptus bark makes up a large residual stream of pulp and saw mills. This accounts for roughly 1.2 million cubic meters of Eucalyptus bark annually on the Iberian Peninsula (García-Villabrille et al. 2014). Discussions and negotiations with potential suppliers show that this raw material is available in sufficient quantities for industrial production at different wood industry locations in Europe, as well as in South America. The price for Eucalyptus bark can be calculated with less than 15 Euro per ton (dry calculated).

For the results presented in this paper, the *Eucalyptus globulus* bark was imported from the Atlantic coast of Galicia in Spain. The logs were between 12 and 15 years old with a diameter of up to 25cm. They were debarked in an industrial drum debarker. Before defibration, the bark was air-dried to a moisture content of 20% and then chipped with a drum chipper (Bruks Klöckner GmbH, Alpenrod, Germany). Another possibility for size reduction is offered by a hammer mill. A hammer mill generates a fibrous material in one step and is another well suited processing technology for eucalyptus bark besides the following refining process (Vega 2017).



Fig. 1.

Stem of a Eucalyptus globulus tree with typical bark stripes coming off (left). Bark of Eucalyptus globulus after debarking with a drum debarker. The fibrous structure is visible (right).

Refining process

The defibration of the Eucalyptus bark was developed at a 12-1CP refiner (Andritz AG, Wien, Austria). This 12" laboratory scale refiner plant is designed for pressurized as well as for unpressurized refining. The plant includes a S7 control system (Siemens AG, München, Germany) with trend analysis of the power consumption of the refiner motor. Pressurized refining generates wet bark fibers, that tend to stick together and form firm chunks, presumably because of their high amount of phenolic extractives (compare Lima 2018). Unpressurized refining, on the other hand, works very well. So far, defibration with the plate design 12XA803 (Andritz AG, Wien, Austria) worked well. The plate gap was adjusted to 2.5mm. Therefore, the electric energy consumption of the refiner motor was found to be just above idle load. This is due to drastically reduced friction between the refiner plates. For pressurized refining a plate gap of 0.1-0.5mm is typical. Nevertheless, one side effect of unpressurized refining of dry material is the generation of dust. This dust has to be collected, but can be utilized for energy generation. Another side effect is the drying of the fibers during refining, because of the friction heat between the refiner plates.

These results open possibilities to use simply designed, unpressurized refiner systems. By this energy- and investment-intensive steam generation, pre-heaters, digesters as well as drying by means of tube dryers could be avoided. The total thermal energy consumption in an industrial process could thus be reduced by at least 60%. Furthermore, no waste water is produced during fiber production, which must be treated at high cost and expense. But most of all, the purely mechanical defibration generates a fiber, which possesses an excellent morphology to produce insulation materials. Compared to wood fibers generated in a thermomechanical process, the bark fibers have numerous branches and hooks, which leads to an improved web formation and therefore lowers the adhesive requirement (see Fig. 2. Comparison of the morphology of spruce fibers (left and right: top) and Eucalyptus bark fibers (left and right: bottom). The unique fiber morphology with a lot of fibrillated branches and hooks is visible. Laboratory refiner plant Andritz 12-1 CP, refiner plate 12XA803. Digestion conditions: spruce: retention time 6min., 6bar, refiner plate gap 0.15mm; Eucalyptus bark: unpressurized 20°C, refiner plate gap 2.5mm. Images taken with Zeiss Smartzoom 5, left: 72x, right 50x.).

Fiber analysis

So far, the fiber morphology has been analyzed with the digital microscope Smartzoom 5 (Carl Zeiss AG, Oberkochen, Germany). Gravimetric fiber size distribution was analyzed using the air jet sieve e200LS (Hosokawa-Alpine, Augsburg, Germany), but no satisfying results were achieved, because of agglomerates. In addition, it was not possible to apply an automated optic fiber size measurement device, because of the fiber length and agglomerates. Unpressurized refining of Eucalyptus bark generates a unique fiber morphology, different to common pressurized wood fiber geometries (see Fig. 2). This branch- and hook-rich fiber morphology provides a "Velcro" effect with a self-adhesive characteristic that leads to improved web formation and therefore lowers the adhesive content. On the other hand, blending with adhesives, mat forming and fiber analysis is more difficult.

Another aspect that must be considered when processing Eucalyptus bark is the ash content. It was found to be at 7.6%(Vega 2017). Other studies observed also a high content of ash, for example a reported ash content of 4.7% (Vázquez 2008) and of 1.6 – 3.5% (Pereira 1988). The high ash content may be due to the accumulation of sand and minerals during logging and outdoor storage. A direct consequence of this is a high wear of mechanical processing elements that must be taken into account.

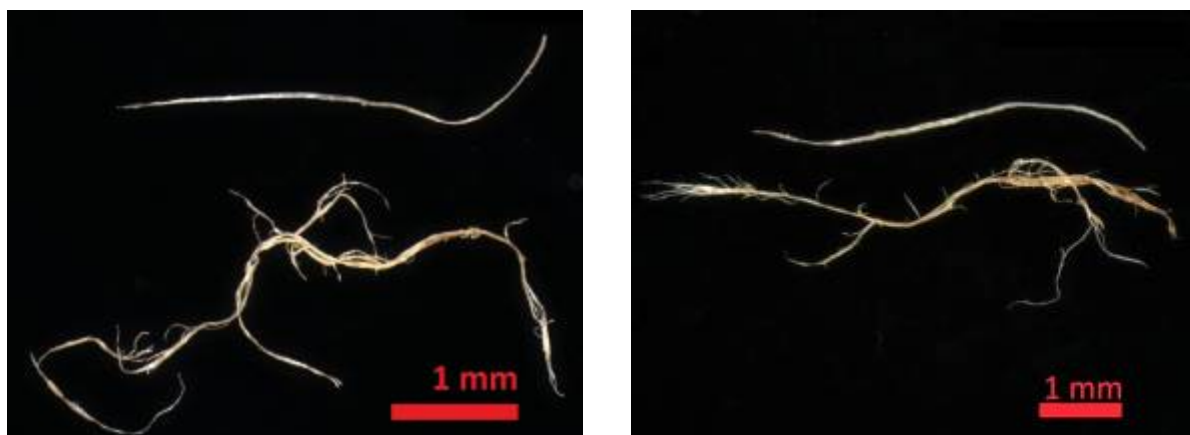


Fig. 2.

Comparison of the morphology of spruce fibers (left and right: top) and Eucalyptus bark fibers (left and right: bottom). The unique fiber morphology with a lot of fibrillated branches and hooks is visible. Laboratory refiner plant Andritz 12-1 CP, refiner plate 12XA803. Digestion conditions: spruce: retention time 6min., 6bar, refiner plate gap 0.15mm; Eucalyptus bark: unpressurized 20°C, refiner plate gap 2.5mm. Images taken with Zeiss Smartzoom 5, left: 72x, right 50x.

Bicomponent (bico) fibers

In addition to raw material costs, energy- and investment-intensive pressurized refining and the necessary drying technology, the adhesives used in wood fiber insulation production contribute to the high manufacturing costs. It is necessary to optimize the use of binders in terms of process technology and adhesive content. For flexible mats production, the distribution of bico fibers in insulation materials is insufficient (see Fig. 3). On the other side, the use of PMDI as an adhesive in the production of insulation boards is problematic because it is hazardous and the systems have a relative low availability.

Crucial in the production of Eucalyptus bark fiber insulation materials is the optimal binding fiber. Bico fibers must be chosen from the parameters of fineness, length, strength, elongation, crimping and preparation. Different bico fibers with contents of 1-6% have been tested initially. With an optimal bico fiber and blending respective mat forming process it is possible to reduce the bico fiber content to 2% in insulation mats.

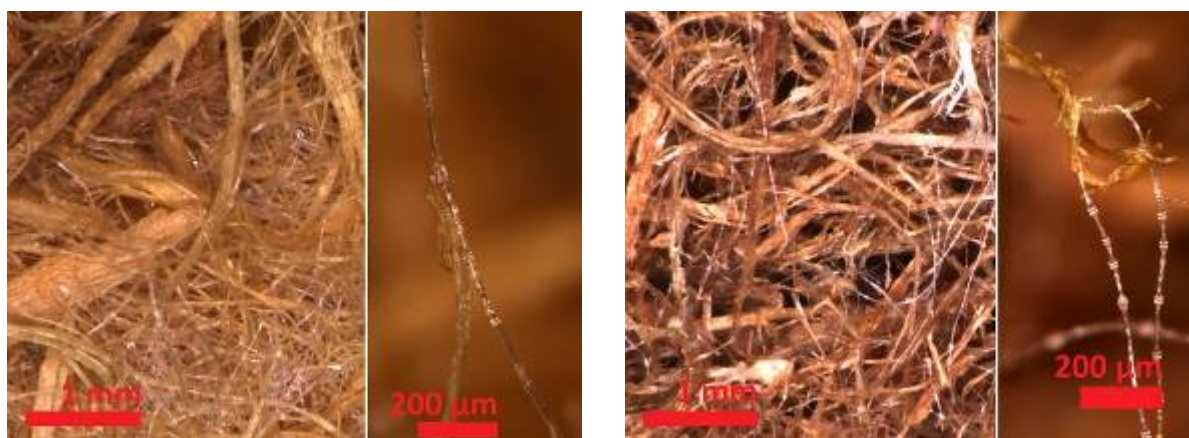


Fig. 3.

Common bico fibers and their distribution in a wood fiber insulation mat. Visible is an inhomogeneous fiber size distribution and blending of bico fibers (left). A Eucalyptus bark insulation mat shows a more homogenous distribution and blending (right). Also, the bico fiber functionality could be improved. Images taken with Zeiss Smartzoom 5, 70x magnification (left) and 200x magnification (right).

Mat forming and consolidation

A manufacturing process for fiber insulation mats and boards was developed that starts with the blending of Eucalyptus bark fibers and bico fibers. Here, a two-step process delivers good results. At first, bark fibers and bico fibers are blended in a ploughshare batch mixer (Gebrüder Lödige Maschinenbau GmbH, Paderborn, Germany). After that, the fiber mixture is homogenized in an air stream fluffer. Mat

forming takes place in an aerodynamic mat-forming device. In this device, the fiber blend is fed into an air stream and then distributed evenly into a press frame. Further, this press frame is transferred into a steam injection press (Dieffenbacher GmbH, Eppingen, Germany). Subsequent bonding was realized using super-heated steam for 30s heating up the mat to approximately 108°C. Further heating over the melting point of the bico fibers of 127°C was done using hot plates for additional 10 to 20 minutes depending on the raw density, respectively heat conductivity of the mat. As a result, fiber mat and board samples with a size of 700x700mm and with a thickness of 50mm were produced. To avoid influence of the edges, the samples were trimmed to 600x600mm.

In addition to the manufacturing of fiber insulation mats and boards in the laboratory of the university, initial trials were conducted on an aerodynamic web-forming pilot plant (Autefa Solutions GmbH, Friedberg, Germany). This pilot plant combines aerodynamic mat forming with carding technology (Airlay Card). Here also, Eucalyptus bark fibers were blended with bico fibers using fiber opening and blending technology of Autefa. By using a special carding set adapted to the bark and bico fibers, the bark fibers are further opened. Compared to the state-of-the-art, a considerably improved blending of the bico fibers and a significantly more homogeneous distribution of the bico fibers is achieved. Emerging dust from the mat can be efficiently and easily extracted and fed into the energy generation process. This result could also be useful for the production of conventional wood fiber insulation materials.

First results of material properties

The first results show that fiber insulation materials made of Eucalyptus feel and look like conventional wood fiber insulation materials. Fig. 4 shows examples of a Eucalyptus bark fiber mat and a Eucalyptus bark fiberboard. They can be adapted to many requirements in the sound and thermal insulation of buildings. The fiber mat and the fiberboard have a low heat conductivity (see Table 1), although this needs to be improved. Despite the low bico fiber content the strength properties are comparable to conventional wood fiber insulation materials (see Table 2).

Table 1

Thermal properties of Eucalyptus bark fiber insulation materials		
Type	Thermal conductivity*	Specific heat value
1 Fiber mat, 51 kg/m ³ , 4 % bico	0.042 W/(m*K)	2254.9 J/(kg*K)
2 Fiberboard, 160 kg/m ³ , 4 % bico	0.044 W/(m*K)	

*Measurements were made with a not calibrated heat flow meter at a moisture content of 7%.

Table 2

Mechanical properties of Eucalyptus bark fiber insulation materials		
Type	Tensile strength perpendicular to the surface	Compressive stress at 10 % compression
1 Fiber mat, 53 kg/m ³ , 2 % bico	1.8 kPa	0.6 kPa
2 Fiberboard, 200 kg/m ³ , 3 % bico	2.5 kPa	42.9 kPa



Fig. 4.

Eucalyptus bark fiber mat with a density of 53kg/m³ (left) and a wood fiber insulation board with a density of 200kg/m³ (right). Both are bonded with 2% respectively 3% bico fibers.

CONCLUSION

With the use of Eucalyptus bark for manufacturing fiber insulation materials, a resource that has so far been regarded as a problematic residue rather than a raw material, would be put to value. The often-criticized Eucalyptus cultivation in Europe would possibly appear in a different picture. The use of Eucalyptus bark would relieve the raw material source wood, as well as, fossil raw material sources for the production of synthetic insulation materials. The proportion of renewable raw materials and the cost structure of building construction would be improved by using this inexpensive insulation material. Regarding social sustainability, existing jobs would be secured and new jobs would be created especially in structurally weak parts of southern Europe, in the wood fiber insulation industry, in the associated machinery and plant construction, in forestry and at the suppliers.

Eucalyptus bark fiber insulation materials can be produced cheaper than conventional wood fiber insulation materials and are, therefore, competitive with synthetic or mineral insulation materials. The national and international market share of insulation materials made from renewable raw materials could therefore grow significantly. The production of insulation materials from a mixture of wood fibers and bark fibers is also possible without quality restrictions. The possible fungicidal effect of Eucalyptus bark ingredients (durability) and the possibly lower flammability caused by the high silicate content are still under investigation.

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