

From agricultural waste to performant coatings

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Exploration for pyrolyzed rice husk as a coating additive

In Europe, the collection and recovery of rice husk are closely linked to the structure of the rice production chain. Rice cultivation is concentrated in a few regions, mainly Italy, Spain, and Greece, where milling facilities process locally harvested paddy rice. These mills act as the primary collection points, because rice husk is generated directly during the de?husking step. In this step, the outer shell is mechanically removed from the grain. Overall, Europe benefits from centralised collection, policy support, and industrial integration of the biomass feedstock, enabling efficient recovery of rice husk as a renewable feedstock.

Unlike many agricultural residues, rice husk is relatively easy to recover: it is produced in a dry, homogeneous stream at industrial scale and is already concentrated at the mill site. This reduces the need for costly transport or separation logistics. In the European Union, rice production reaches around 2.8 million tonnes annually. Kreglinger Europe (°1797 – Antwerp/B) is a distributor of specialty ingredients and chemicals for processing industries and is actively sourcing rice husk and rice bran that are nowadays being upcycled into food applications. The rice husks (originally about 10mm x 3mm) are collected in Spain and Portugal by local cooperative companies that perform drying and basic grinding. As the volumes of this abundant agricultural residual stream are so high,

Kreglinger wants to valorise them into novel industrial applications.

Traditionally, much of this fibrous material is being burned, landfilled, or simply left to decay. Novel recovery pathways have improved in recent years due to circular economy policies. Husk is increasingly valorised for energy, silica extraction, or bio-based materials instead of being landfilled or openly burned. Dedicated value chains are emerging. Rice mills, material producers, and chemical companies collaborate locally to ensure consistent supply and quality.



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- Bio-based anticorrosion additives part 1
- Bio-based anticorrosion additives part 2
- Smarter coating formulation with analytics
- How to select bio-based binders for coatings

Thermal conversion into functional additives

Pyrolysis is a thermochemical process in which rice husk is heated to typically 300–700?°C in the absence of oxygen. This causes it to decompose without combustion. During this process, the biomass is converted into three main products:

- A solid carbon-rich residue (biochar)
- A liquid fraction (bio?oil)
- Combustible gases

Rice husk is unique among agricultural residues because it contains a high amount of silica (up to ~20%), embedded in an organic matrix. The thermal transformation significantly alters the structure of the rice husk. During pyrolysis, the organic fraction decomposes. This results in a hybrid material with a porous carbon framework, a high surface area and presence of functional surface groups. At the same time, the naturally high silica content of rice husks is retained and becomes concentrated. Thus, a unique carbon–silica hybrid material is created.

Before pyrolysis takes place, the rice husk is typically dried to reduce moisture content (usually < 10 %) and cleaned to eliminate impurities such as soil or metal particles. A most important step for the homogeneous conversion is a close control on the particle sizes. These should be uniform for efficient heat transfer and consistent product quality. The prepared husk is then introduced into a pyrolysis reactor (e.g., rotary kiln). There, it is heated in the absence of oxygen to prevent the material from combusting. Instead, the rice husk is stepwise thermally decomposed at temperatures typically ranging from 300 to 700?°C. During the devolatilization (200–400?°C), the hemicellulose and cellulose start to break down together with release of volatile compounds (CO?, CO, light hydrocarbons) and formation of bio?oil vapor. The carbonisation (400–700?°C) results in further lignin decomposition with the formation of an aromatic carbon structure. The material becomes less carbon-rich and more stable while pores develop as volatiles leave.

The composition of the final products and the properties of the pyrolysed rice husk are strongly influenced by the processing conditions:

- **Temperature** determines the porosity and carbon structure of the material
- **Residence time** influences the degree of carbonisation
- **Heating rate** controls the product distribution. Slow pyrolysis generally maximises biochar production, whereas fast pyrolysis favours the production of bio-oil

Preliminary conversion at lab-scale

During initial laboratory trials, the effects of pyrolysis temperature on the properties of the rice husk ashes (RHA) were evaluated (Figure 1). The powders with evolving composition and characteristics were obtained with gradually decreasing organic content and increasing silica content with better developed crystalline structure at increasing temperatures.

- At 350?°C, a carbon-rich and partially decomposed material is formed (dark brown to black colour) with relatively low surface area but partial presence of remaining functional surface groups. This is suitable to serve as a carbon-rich filler (biochar-like properties)

- At 600?°C, an amorphous silica material starts to form (grey colour) with balanced properties of good reactivity and structural stability. This is applicable to serve as adsorbents or additives in cement, concrete, or coatings
- At 800 °C, a more crystalline and stable silica phase has developed (white colour) with complete removal of the organic carbon phases. This, in turn, is suitable to serve as inorganic filler material

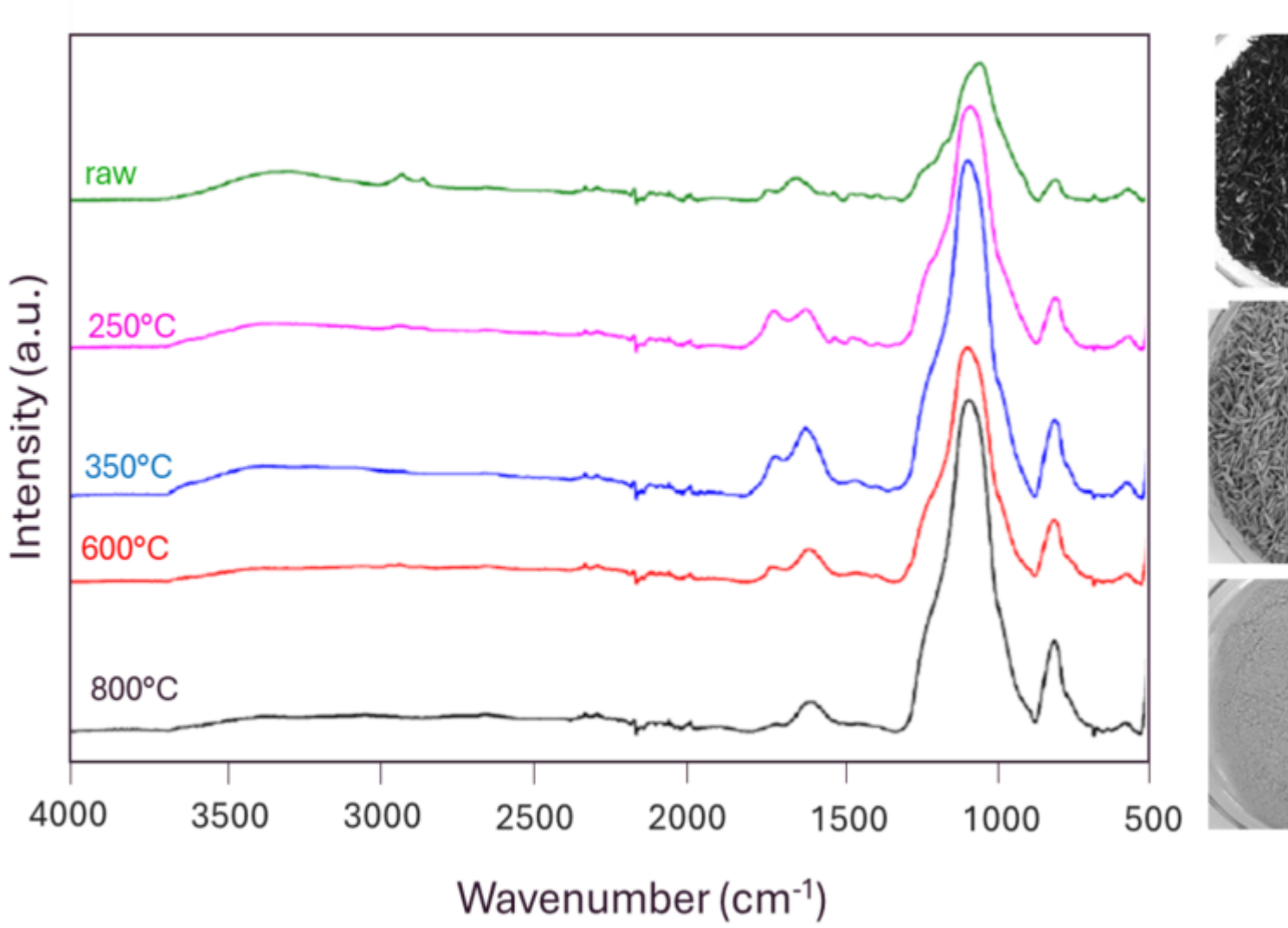


Figure 1. Characteristics of pyrolysed rice husk at laboratory scale under different temperatures, including FTIR analysis, macroscopic pictures and microscopic morphology.

Microwave conversion together with industrial partner

Based on the lab-scale experiments, a cooperation with MEAM (Houthalen, Belgium) was established as a partner in the COOCK+ AddBIO project. An industrial demonstration experiment was performed for conversion of 1 kg rice husk batches through microwave-induced pyrolysis. As an all-in solution provider of microwave technology-based industrial installations, MEAM delivers installations adapted to the needs of the customer. They offer a refined design based on the results of feasibility studies with a set of proprietary instruments and technologies. Biomass conversion is one of the possible examples where microwave technology can help to rethink the processing

industry. It manages the increasing costs and environmental regulations, and it serves the circular economy.

Microwave (MW) heating is a completely different way of heating than classically known. Traditionally, external sources are used to transfer heat to the product to be heated and eventually dried. The greater the ?T between the external source and the product, the faster the heat transfer will generally take place. The heat transfer always takes place via the surface of the product, and this is at the same time the limiting factor. Microwave heating does not require an external source to generate heat in the product to be heated or dried. It is a form of dielectric heating, which simultaneously heats the entire volume of a homogeneous product. Because microwaves can penetrate into the core of a product, the limiting factor is how to manage the surface. Experiments have indicated the role of microwave heating conditions on the formation of rice husk biochar.



Figure 2. Installation for microwave pyrolysis technology at MEAM.

For testing, MEAM Explorer is a multipurpose test device for various microwave applications, such as drying, leaching, combustion, roasting, sintering, and pyrolysis. One of the special features of the used testing unit is its adaptability, based on a unique design with optional entries at various sides of the cavity (Figure 2).

Performance testing in coating applications

The pyrolysed rice husk may offer key benefits as functional fillers in coatings (e.g. epoxy):

- **Mechanical reinforcement:** the high silica content (SiO?) acts as a micro/nano filler that improves hardness, abrasion resistance, or scratch resistance
- **Barrier properties**: the platelet-like and porous particles create a tortuous diffusion path that reduces permeation of water, oxygen or chlorides (e.g. corrosion-resistant coatings)
- **Thermal stability and fire resistance**: the silica-rich structure is inherently thermally stable and acts as a heat barrier with improved flame retardancy and char formation (e.g. intumescent coatings)
- **Conductivity**: the higher carbon content at lower pyrolysis temperatures results in semi-conductive behaviour (e.g. antistatic coatings, EMI shielding)

Internal testing (Figure 3) has demonstrated that the resulting coating properties highly depend on the intrinsic properties of the pyrolysed rice husk when added as an additive at 1 to 7 wt.-% concentrations. After pyrolysis, the fillers were obtained as a fibrous material or further grinded into a controlled powder size. The variations in hardness of the epoxy coating indicate best reinforcing properties for the fibre-like rice husk particles as compared to the powder-like particles.

For both morphologies, the reinforcement is consistently higher for the carbonized materials at low temperatures. This is due to the remaining organic fraction providing good interaction with the epoxy matrix. Alternatively, the pyrolysed rice husk particles at higher temperature are more inert, causing voids at the matrix interface. In parallel, the carbonized rice husk showed wear protection under low loads (lubricating properties), while the crystalline rice husk provides the best wear protection under higher loads (mechanical reinforcement). Summarizing, the complex relationships between coating performance, filler geometries and chemistry are closely observed. This leads to a thorough tuning of the properties of the rice husk as functional additives and an obligatory experimental testing in parallel with the projected application.

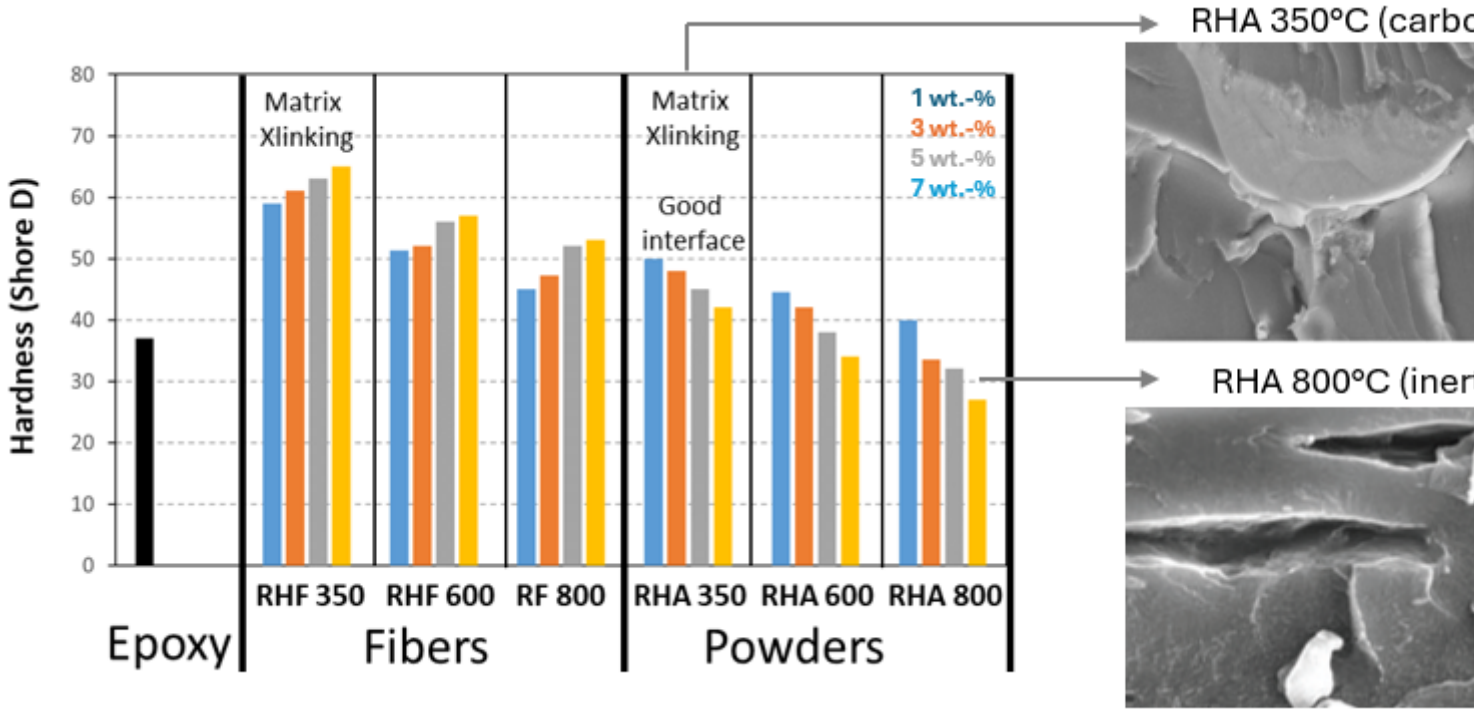


Figure 3. Experimental testing results of coating properties (e.g. hardness as a general measure for mechanical resistance) containing epoxy binder and pyrolyzed rice-husk fibres (RHF) or rice husk powders (RHA) at different temperatures and added at 1 to 7 wt.-% concentration.

Join us in exploring valorisation of biomass as functional additives for coatings?

If this case study is inspiring for you, Sirris is a partner in the COOCK+ AddBIO project, where valorisation routes for residual biomass streams into functional coating additives are demonstrated.

We are always looking to be in contact with industrial partners along the valorisation chain of biomass suppliers, converters, coating formulators and end-users that are interested in further collaboration.

Discover the potential of bio-based additives

Want to discover how residual biomass streams can be used as functional additives for high-performance coatings? Within the COOCK+ AddBIO project, Sirris brings together companies across the entire value chain and supports new valorisation pathways. Discover the AddBIO project and the opportunities for your company.

Discover the AddBIO project

Partners

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