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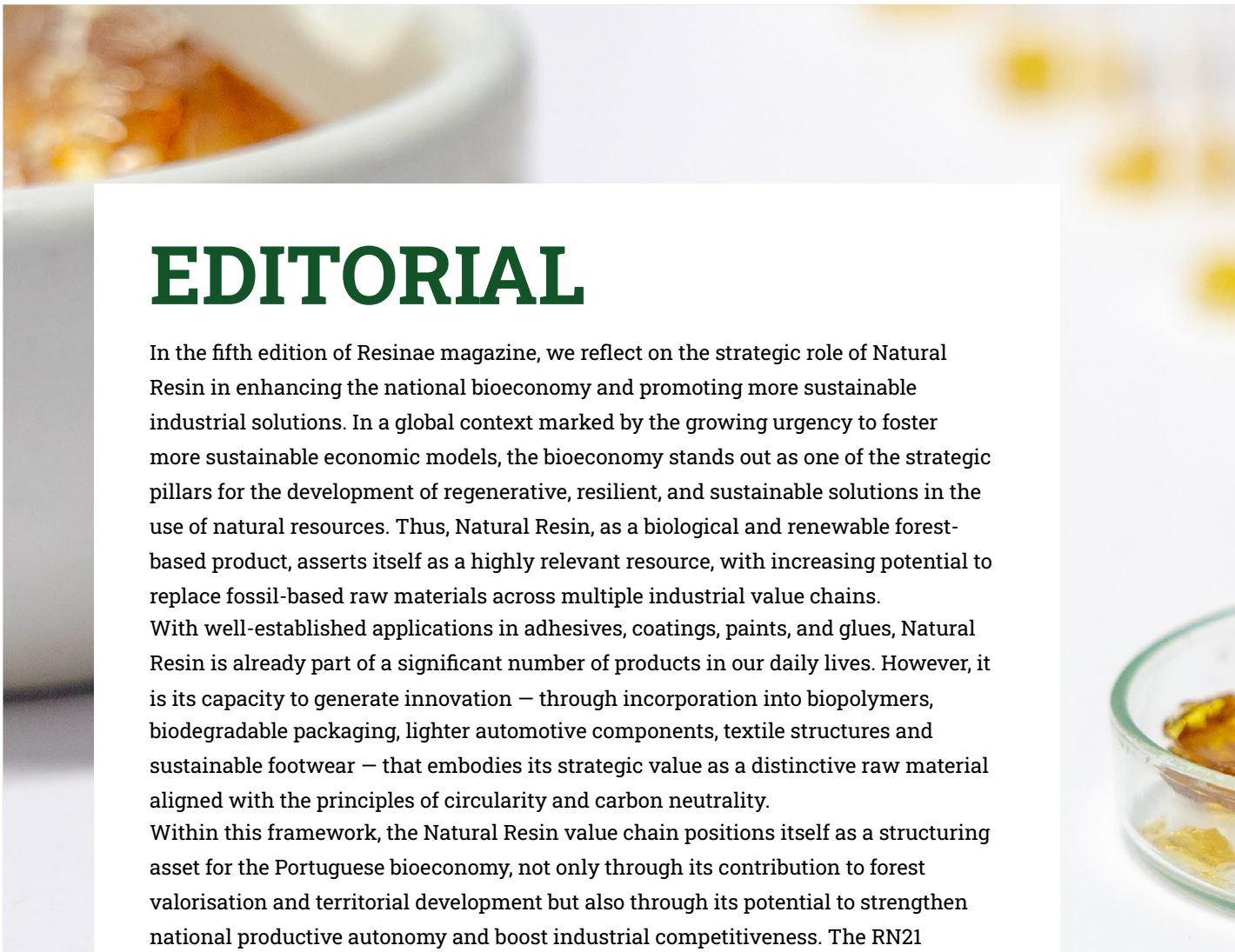

EDITORIAL

In the fifth edition of Resinae magazine, we reflect on the strategic role of Natural Resin in enhancing the national bioeconomy and promoting more sustainable industrial solutions. In a global context marked by the growing urgency to foster more sustainable economic models, the bioeconomy stands out as one of the strategic pillars for the development of regenerative, resilient, and sustainable solutions in the use of natural resources. Thus, Natural Resin, as a biological and renewable forest-based product, asserts itself as a highly relevant resource, with increasing potential to replace fossil-based raw materials across multiple industrial value chains.

With well-established applications in adhesives, coatings, paints, and glues, Natural Resin is already part of a significant number of products in our daily lives. However, it is its capacity to generate innovation — through incorporation into biopolymers, biodegradable packaging, lighter automotive components, textile structures and sustainable footwear — that embodies its strategic value as a distinctive raw material aligned with the principles of circularity and carbon neutrality.

Within this framework, the Natural Resin value chain positions itself as a structuring asset for the Portuguese bioeconomy, not only through its contribution to forest valorisation and territorial development but also through its potential to strengthen national productive autonomy and boost industrial competitiveness. The RN21 Consortium, as an aggregating initiative, reaffirms its commitment to innovation and the development of a more efficient, sustainable, and future-oriented value chain. Innovation, underpinned by the articulation between science, technology, and the business sector, constitutes the main transformative vector of the value chain. Through strategic cooperation between R&D entities, companies, and public institutions, new high-value-added solutions have been emerging, enhancing the use of Natural Resin in highly demanding and sophisticated industrial contexts. Yet innovating requires looking across the entire value chain and, from this perspective, empowering and promoting resin tappers, valuing know-how, and integrating innovative techniques and processes lead to the development of high-value solutions, thereby increasing remuneration throughout the value chain.

José Gaspar
CTO CoLAB ForestWISE

This edition of Resinae highlights some of the necessary pathways to strengthen the objectives of the bioeconomy, through vision, commitment, and the valorisation of endogenous resources and the goods and services provided. Due to its origin, versatility, and cross-cutting impact, Natural Resin positions itself as a key element in this transition, contributing to a more sustainable development model in all its dimensions, anchored in knowledge and territorial cohesion.

MARCO RIBEIRO | INTERVIEW

"THE PROFESSIONALISATION AND VALORISATION OF AN ECONOMIC ACTIVITY CAN ONLY BE ACHIEVED THROUGH THE IMPLEMENTATION OF GOOD PRACTICES."

Resipinus – the Association of Resin Tappers and Distillers, founded in 2013 and based in Leiria, is the only representative entity of the resin tapping sector in Portugal. Its mission focuses on defending and promoting resin tapping activities, covering the entire process from extraction to the primary industrial processing of Natural Resin.

RESIPINUS recently launched the Academia do Resineiro (Resin Tappers' Academy). What was the motivation behind it and what are its main objectives?

With the resurgence of resin tapping activity in recent years, several actions were identified as necessary to improve resin extraction practices. One of the key steps in this process was the creation of a professional training program aimed at enabling resin operators to be as well-qualified as possible, so they can perform their work more efficiently.

It was within this context that the need arose to establish a nationally recognized physical space where such training activities could be developed.

Its main objectives are:

- Qualify resin tappers in good practices and safety;
- Value traditional knowledge and promote the recognition of the profession;
- Encourage social organisation and profitability;
- Foster innovation and sustainable development in the resin tapping sector.

What kind of training and capacity building does the Resin Tappers' Academy offer, and who is it aimed at?

The Resin Tappers' Academy offers a diverse set of training activities that are integrated to complement each other, making the operator as versatile and qualified as possible.

The main modules are directly related to resin tapping and the associated extraction processes, and range from short 4-hour workshops to more comprehensive training modules of 50 or even 300 hours.

To complement this core component, we also offer training on topics such as:

- Seeds, forest nurseries, and plant propagation;
- Silvicultural operations in pine forests;
- Pine forest pests and diseases;
- Tractor driving and handling of forestry machinery;
- Practical operation and technical handling of chainsaws and brushcutters;
- Surveillance and first response to rural fires;
- Occupational health and safety.

These training actions are aimed at all stakeholders in the sector, including resin tappers, operators, technicians, managers, and even forest owners.

What impact do you expect the Academy to have on the professionalization and recognition of resin tapping?

We hope it will have a highly positive impact on the sector's future development.

Professionalization and the recognition of an economic activity can only be achieved through the adoption of best practices, and these can only be guaranteed when operators are properly trained. That's the role we

Marco Ribeiro
President of Resipinus

envision for our resin tappers in the near future — to be well-qualified professionals capable of delivering their work with maximum efficiency.

What are the main challenges currently facing the resin tapping sector? How does the Resin Tappers' Academy help to overcome them?

The challenges are numerous and stem from a variety of sources. However, at the base of the value chain, issues such as the lack of recognition of the profession, limited information about the sector, inefficiencies in several stages of the extraction processes, and the low profitability of the activity, often linked to poor practices, are problems that severely affect the sector's visibility in our country. These challenges end up masking the benefits that this activity can bring to rural territories and to society. From this perspective, we strongly believe that the training activities offered by the Resin Tappers' Academy will result in more skilled and capable operators. This will lead to more efficient processes, improved profitability, and ultimately, a more attractive and respected sector. In the long term, we believe this will contribute to overcoming many of the challenges mentioned above.

How has the RN21 Integrated Project contributed to the promotion of Natural Resin and resin tapping?

This Project is of enormous importance in driving the structural reform the sector needs to establish itself as a truly strategic pillar of the national bioeconomy. Bringing together the various stakeholders in the resin value chain under one Project is, in itself, a highly significant contribution to the promotion of the Natural Resin sector. Historically, the sector has been very fragmented, with individual actors working in isolation and in a closed-off manner. This Project has allowed all parties to come together to think collectively and discuss the sector with a shared goal in mind: increasing the value of Natural Resin from maritime pine.
To achieve this, it's essential to have a deep understanding of the sector's difficulties and invest in research and development that provides improvements across the entire value chain. This is exactly what the Project has enabled, from the development of new extraction techniques and the mechanization of key stages of the process, to the creation of new biological stimulants that induce resin production, and the search for new applications of Natural Resin and its derivatives in other industries, including niche markets that allow for higher added value.

We truly believe that the results of these ongoing efforts will serve as the necessary catalyst for a more prosperous future for resin tapping.

In your opinion, what changes, or new public policies are still needed to boost resin tapping and the Natural Resin sector?

There is certainly still much to be done. As mentioned earlier, this Project is an important stimulus, but all such initiatives need to be part of a national strategy for resin tapping, based on three dimensions that must work in coordination: public administration, industry, and production.

The largest and most promising areas for resin production, either currently productive or with high potential in the near future, are mostly located in public lands (Matas Nacionais) or in areas under co-management with the State (Baldios). These areas represent more than 300,000 hectares and are particularly well-suited for *Pinus pinaster* (maritime pine). From this perspective, we believe the public administration should play a key role in preparing these areas for resin tapping in the coming years. This could be done by implementing a national resin tapping plan with a minimum duration of 20 years, which would address, among other issues, achieving stands with appropriate density for their age and selecting and establishing more productive trees. This preparation could be done directly using existing public resources or indirectly, for example, by assigning silvicultural tasks to resin tappers in co-managed areas, enabling them, especially in northern and central inland regions, to complement their activity during the winter months.

In addition, we believe it is essential to revise and update the legislation governing resin tapping. Without this, it will be impossible to implement more efficient extraction methods. This is a responsibility that should fall to public authorities.

From the industry perspective, we recognize that national companies compete in international markets where Natural Resin is produced at significantly lower costs. However, long transport distances from those sources result in a disproportionately high ecological footprint. For this reason, we firmly believe the creation of effective fiscal and/or economic incentives for the industry to actively favor the use of domestically produced Natural Resin, rather than imported Natural Resin or synthetic alternatives, is of great importance.

"We firmly believe that through the training initiatives developed at the Resin Tappers' Academy, we will achieve more qualified and skilled operators, leading to more efficient and profitable processes, which will ultimately make the sector more attractive."

Finally, we consider it extremely important to implement some medium-long term transversal measures, such as:

- Educating and raising awareness among the public and consumers about Natural Resin — its characteristics, distinctiveness, and advantages.
- Including the topic of Natural Resins in educational curricula and public campaigns on sustainable products.
- Outreach and communication initiatives in co-managed areas in partnership with ICNF and forest perimeter managers.
- Formal recognition by the State of the Resin Tappers' Academy as the leading training institution for resin tapping.
- Establishing comprehensive training protocols and programs between the Academy and vocational schools, polytechnic institutes, and similar institutions, to improve qualifications and increase the number of resin tappers.
- Attracting international workers to the sector through partnerships or agreements involving RESIPINUS, IEFP, embassies, and public authorities.

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HILÁRIO COSTA | INTERVIEW

"THE COMMITMENT TO INNOVATION IS ALSO REFLECTED IN THE CONTINUOUS SEARCH FOR NEW SOLUTIONS."

NARES – Natural Resins is a primary processing industry of Natural Resin, located in Pombal. The company produces rosin and turpentine, combining technology with the valorisation of Portuguese maritime pine forests, with a focus on innovation and the sector's sustainability.

Can you tell us a bit about the history of NARES and its role in the Natural Resin value chain?

NARES emerged as an extension of the activities of Costa & Irmãos, a family-owned company with a long-standing tradition in the Natural Resins industry, founded in 1945. In 2024, Costa & Irmãos shifted its focus to resin extraction, becoming the main supplier of raw material to NARES. Currently, NARES markets Portuguese Rosin and Turpentine, maintaining the Costa & Irmãos brand.

Within the Natural Resin value chain, NARES plays a crucial role by ensuring the transformation and distribution of resin-derived products. Its integration with Costa & Irmãos strengthens the global competitiveness of Portuguese resin.

Costa & Irmãos is a member of RESIPINUS, reinforcing NARES's commitment to the valorization of national resin and to defending the interests of producers and distillers. This partnership enables NARES to align with the goal of preserving and strengthening the reputation of Portuguese Natural Resin, which was once a global market leader.

What are the main challenges faced by NARES and the primary processing industry of Natural Resin?

NARES and the primary processing sector of Natural Resin currently face several key challenges, the five most significant being:

INTERNATIONAL COMPETITION

Increasing competition from producers in other regions has hindered the competitiveness of Portuguese resin. Despite its quality differentiation, price remains a critical factor. Currently, tree yields in Portugal are significantly lower than in other regions, limiting competitiveness by volume and resulting in higher production costs compared to international competitors.

FLUCTUATING DEMAND

Demand for Natural Resin and its derivatives is highly volatile, influenced by fluctuations in hydrocarbons and other substitute products, which significantly affect both pricing and consumption levels.

CLIMATE CHANGE AND SEASONALITY

Extreme weather conditions, such as droughts or excessive rainfall, negatively impact both the quantity and quality of resin extracted, making production stability difficult to maintain.

SUSTAINABILITY AND CERTIFICATIONS

Growing demand for environmental certifications represents a challenge, as most forests in Portugal are owned by smallholders. This fragmentation complicates and increases the cost of aggregating and certifying production areas, which in turn affects the supply of certified resin.

COMMODITY PRICE VOLATILITY

Commodity price volatility, particularly in natural gas, poses a significant challenge to the stability of company profit margins, as it directly impacts production costs.

How has NARES innovated to improve the efficiency and quality of its products?

NARES has been investing heavily in innovation to enhance both efficiency and product quality, ensuring a more modern, secure, and competitive production process. This includes significant investments in automation and strict control of all stages of production, from the reception of raw materials to final dispatch. Additionally, NARES has strengthened its laboratory methods by adopting more rigorous quality control procedures. The company ensures that each batch produced strictly complies with the specifications required by clients and international markets.

These measures guarantee not only the consistency

"Collaboration between the various stakeholders in the value chain is essential for the success of the sector, and encouraging the use of national raw materials could boost both primary processing and resin producers, creating a more balanced and sustainable industry."

Hilário Costa
President of NARES

and purity of the products but also their compliance with the highest standards of quality and sustainability. This commitment to innovation is also reflected in the continuous search for new solutions that optimize the extraction and utilization of Natural Resin, thereby contributing to the long-term sustainability of the sector. Through these proactive initiatives, NARES further reinforces its position as a leading company in the primary processing of resin, combining tradition and innovation to consistently offer products of excellence.

Sustainability is an increasingly relevant topic. How does NARES manage and add value to the waste resulting from primary resin processing?

NARES is actively committed to sustainability, investing in the efficient management and valorisation of waste generated during the primary processing of resin. As part of its PRR (Recovery and Resilience Plan) initiatives, the company has implemented innovative solutions to treat by-products such as pine bark residues and sludge, promoting their reuse and significantly minimising environmental impact.

Are there any resin transformation by-products that are already being reused or have potential for new applications? If so, which applications?

Yes, some by-products from resin processing have significant potential for new applications. NARES has invested in the valorisation of waste materials such as pine bark residues and sludge. Bark, a residue made up mainly of forest residues such as bark, needles and wood, can be used for combustion or transformed into briquettes and activated charcoal, offering both economic and environmental benefits.

Sludge, on the other hand, poses more challenges, as some analyses have indicated that it may be classified as hazardous waste, making it impossible to declassify and subsequently recover it as a by-product.

What impact did the RN21 Project have on NARES?
The Integrated Project RN21 brought several opportunities to NARES, particularly in the valorization of resin by-products, the development of new tapping techniques, and genetic improvement. These advancements have enhanced the efficiency of the production process and reinforced the company's commitment to environmental sustainability, an increasingly valued factor in the market.
Despite this progress, NARES believes there is still room to further strengthen the competitiveness of the sector in Portugal. Collaboration among the various stakeholders in the value chain is essential for the success of the resin industry. Encouraging the use of domestic raw materials could boost both primary transformation and resin producers, creating a more balanced and sustainable sector. In this sense, it would be strategic for incentives to be developed to promote an increase in the consumption of domestic resin, thus enabling the main objective of RN21 to be achieved, which is to promote the production of domestic resin.

Such a measure would reinforce the connection between producers and processors and ensure that the Project's benefits are more equitably distributed across the value chain. The secondary processing industry, which received a significant share of the RN21 incentive, has a unique opportunity to lead this movement. By prioritizing domestic resin, it would also enhance the sustainability of its products. It is essential to emphasize that Portuguese resin should not compromise the competitiveness of secondary processing companies in the global rosin derivatives market. However, creating incentives for its use would help consolidate the primary processing sector and support resin producers, fostering the sustainable growth of the entire industry.
NARES values continued investment in innovation and technology as a key pillar for the future of this industry. Sustaining these efforts, with a stronger focus on competitiveness and on strengthening the value chain, will be crucial to ensure a solid and sustainable future for the Natural Resin sector.

"With these initiatives, NARES reaffirms its position as a benchmark company in the primary processing of resin, combining tradition and innovation to offer products of excellence."

ARTUR BARROS | OPINION

NATURAL RESIN AS A VECTOR FOR SUSTAINABILITY IN THE AUTOMOTIVE INDUSTRY

The integration of sustainability across all stages of the value chain is currently an unavoidable requirement for the automotive industry. In the European context, ambitious targets have been established to reduce the sector's environmental impact and to support the transition toward a circular and climate-neutral economy.
Key objectives set by the European Union include:
- CO_2 Emissions Reduction: a targeted 55% decrease in average CO_2 emissions from new vehicles by 2030, compared to 2021 levels.
- Climate Neutrality: achieving net-zero emissions in the production process by 2040.
- Circular Economy: ensuring that 25% of critical raw materials derive from recycling processes and reaching zero landfill waste.
- Promotion of Electric Mobility: encouraging the widespread adoption of electric vehicles, aiming for a significant market share by the end of the decade.
- Sustainable Supply Chains: reducing reliance on external suppliers and mitigating negative environmental and social impacts.

In response to these challenges, the European automotive industry has been progressively restructuring its processes, placing particular emphasis on the integration of sustainable materials. Priority has been given to the use of polymers from recycled sources, especially post-consumer recycled materials from end-of-life vehicles (PCR-ELV), followed by other post-consumer recycled (PCR) and post-industrial recycled (PIR) materials.
At the same time, there is growing interest in the use of biopolymers, produced from renewable raw materials such as vegetable oils, corn starch, or sugarcane. These materials offer several environmental and functional benefits, including:
- Reduced Carbon Footprint: biopolymers help decrease CO_2 emissions over the product life cycle.
- Energy Efficiency: biopolymers reinforced with natural fibers have lower density, enabling lighter vehicles and reduced energy consumption.
- Renewable Origin: their production is based on non-fossil raw materials, supporting the shift toward a bio-based economy.

Artur Barros
Advanced Materials &
Technologies Unit Manager

1
PCR –ELV
Post-consumer recycling
of end-of-life vehicles

2
PCR
Post-consumer recycling

3
PIR
Post-industrial recycling

However, the use of biopolymers alone does not always meet the strict technical and performance requirements of the automotive sector. In this context, hybrid polymers, a blend of fossil-based and bio-based polymers, have emerged as a promising solution to reconcile sustainability with technical reliability without compromising performance.

One of the main challenges in developing these hybrid materials is achieving compatibility between different polymer types to ensure the preservation of desired properties. This is where Natural Resin may play a distinctive role. Its use as a compatibilizer between fossil and bio-based polymers enhances the cohesion of the polymer matrix, contributing to the structural integrity and performance of the resulting composites.

The application of Natural Resin as a compatibilizer in hybrid composites represents a technically sound and innovative solution. Its integration into automotive materials could significantly contribute to meeting environmental targets without compromising the required standards of quality and safety.

In summary, the valorization of natural resources such as Natural Resin may play a strategic role in the sustainable transformation of the European automotive industry. The future of advanced materials may also be rooted in the forest.

“The use of Natural Resin as a compatibiliser in hybrid composites represents a technical solution with strong innovation potential.“

In 2024, the Portuguese footwear industry exported 68 million pairs of shoes worldwide. Over 90% of its production was shipped to 170 countries across every continent. Key export markets include Germany, France, the Netherlands, the United Kingdom, and the United States. According to data from the National Statistics Institute (INE), footwear exports increased by 3.9% in volume compared to the previous year, reaching 68 million pairs and totaling €1.724 billion in value. Portuguese footwear exports are particularly specialized in leather shoes, which currently account for 83% of the sector's international trade. Portugal is now the 10th largest footwear exporter globally. However, Portuguese footwear exports are also seeing considerable growth in all other segments. The sector contributes over one billion euros annually to Portugal's trade balance.

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MARIA JOSÉ FERREIRA | OPINION

NATURAL RESIN IN THE FOOTWEAR SECTOR: SUSTAINABLE INNOVATION THROUGH INDUSTRIAL COLLABORATION

The competitive strengths of the Portuguese footwear industry lie in the high quality of its products, which combine traditional craftsmanship with innovation, agile production, responsive capabilities, and excellent service. This differentiation has placed Portuguese footwear among the highest globally in export price, ranking second worldwide.

This sustained recognition has been largely driven by the creation and consolidation of a comprehensive Footwear Cluster, led by APICCAPS (Portuguese Footwear, Components, Leather Goods Manufacturers' Association). This cluster brings together footwear and leather goods companies, material and component suppliers, software and production technology developers, and retailers, in cooperation with entities from the scientific and technological system, such as the CTCP – Portuguese Footwear Technology Centre.

"The quality of the products, combining know-how and innovation with production agility, responsiveness, and excellent service, are the main competitive advantages of the Portuguese footwear industry.
The differentiation of Portuguese footwear has led it to achieve the second highest export price in the world."

CTCP is a private, non-profit organization strategically located in the heart of the sector's production hubs, with headquarters in São João da Madeira and a branch in Felgueiras. It provides a broad range of services to cluster companies, mainly SMEs, and their global partners, including laboratory testing, research and innovation (R&D&I), technical and financial consultancy, product and company certification, training, and communication.
CTCP is a national and European reference in industrial innovation and development, driving the technical and technological advancement of the cluster and contributing to its long-term sustainability. This is achieved by fostering collaborative R&D&I and capacity-building projects with companies, universities, and knowledge centers; ensuring best practices are effectively adopted across the industry; integrating environmental, social, and governance (ESG) criteria into processes; and supporting the design and implementation of public and private policies that promote the technological development of the cluster.
Between 1992 and 2022, the world's population increased from around 5 to 8 billion people. Footwear production, however, grew at an even faster pace, nearly tripling to 24 billion pairs per year.

Maria José Ferreira
Director of Research and Sustainability and Quality Control Laboratories of CTCP

This is an astonishing volume of footwear produced annually. Assuming an even global distribution, 3 pairs per person per year could be considered reasonable. Yet, Europe and North America, with only 14% of the global population, account for about 30% of global consumption (2022) — roughly 6 pairs per person per year. These production and consumption levels place the footwear sector under intense scrutiny, particularly due to its heavy use of fossil-based resources and greenhouse gas emissions.

In a rapidly changing world, there are clear indicators that represent opportunities for our industry. Consumers in the countries we export to are increasingly demanding differentiated products that respect the environment, are produced responsibly and locally, and offer a fair price. Within this context, Portugal must strive to lead the development of truly verified sustainable materials, footwear, leather goods, and technologies that help reduce emissions and ecological/carbon footprints. These efforts should prioritize renewable materials such as leather and forest-derived products, as well as timeless, durable, and circular footwear designs.

The Recovery and Resilience Plan (PRR) is a unique opportunity to drive sustained economic growth in Portugal. Under Component 12 – Sustainable Bioeconomy, the BioShoes4All Project, the largest initiative ever undertaken by the Portuguese footwear industry, is a critical investment in the future of the Footwear Cluster. With the involvement of nearly 70 key entities and a €60 million investment, the ambitious project is enabling the development and adoption of new sustaunable materials, technologies, business models, and footwear and leather goods products.

It also offers an opportunity for international projection and dissemination, which will help consolidate the global reputation of Portuguese footwear and open new, high-end markets.

BioShoes4All brings together representative companies from across the value chain and establishes industrial symbioses with projects such as RN21, CoLAB ForestWISE, and forest-based companies to enhance the value of maritime pine (*Pinus pinaster*) bark, its resin, cellulose fibers, and by-products. The guiding principle is to be innovative, inclusive, efficient, and "zero waste." As a result, the next generation of leather,

insoles, and soles will be up to 100% biological, recycled or recyclable, and offer functionalities — flexibility, abrasion resistance, slip resistance, among others.
In terms of footwear and leather goods, the project develops innovative concepts and products, whether fashion, casual, or work-related, for all age groups, from children to seniors. These new products are designed and refined based on studies that measure and aim to reduce their environmental and carbon footprints. This work focuses on material and process development and selection. Ultimately, the goal is to create lightweight, appealing, and durable products made with fewer different materials to enable agile production and recyclability. Manufacturing processes are redesigned to be more human-centered and eco-efficient, minimizing the use of chemicals, energy consumption, and production waste and effluents.
Furthermore, BioShoes4All is investing in cutting-edge technologies to produce bioleathers, bioplastics, biobased rubbers, and bio-components for footwear. The project also supports the implementation of the first production systems in Europe for components and footwear made with expanded, recyclable thermoplastic materials.
Traceability is another core element, ensuring transparency from raw material origin to final footwear production. This will allow customers to know where their products were made, their environmental impact, and how they can be repaired or recycled. Digitalization is also being leveraged to streamline internal processes and improve information management with suppliers and customers.
Everything is being rethought and simplified.

“Customers in the countries to which we export seek differentiated products that respect the environment, are produced locally in a responsible manner, and are offered at a fair price. In this context, Portugal should strive to become a leader in the development of materials, footwear, leather goods, and truly and verifiably sustainable technologies that help reduce the emissions and ecological carbon footprint of products and processes. This includes renewable materials, such as leather and forest-derived products, as well as timeless, durable, and circular footwear.”

Several new solutions are either already developed or in development and are expected to reach the market in 2025. These will be showcased to potential industry clients at upcoming national and international trade shows. We are committed to sharing the results of these innovations with the entire footwear cluster and beyond — particularly with the maritime pine (*Pinus pinaster*) sector — by promoting the application of pine bark extracts and modified rosin resins to stabilize and functionalize leathers, adhesives, soles, and footwear.

SIMOLDES

FROM PINE TREES TO SUSTAINABLE MOBILITY: INNOVATION IN THE AUTOMOTIVE SECTOR

The European automotive industry, a pillar of the global economy, is facing significant challenges as the sector undergoes rapid transformation. The green transition, digitalization, and growing international competition, particularly from China, are creating a highly disruptive environment. In this context, the European Union has implemented various guidelines and regulations to ensure the sustainable use of polymers in the automotive industry. One of the main goals is to reduce the environmental impact of these materials by promoting recycling and reuse.

Directive (EU) 2019/904 aims to reduce the impact of fossil-based polymers on the environment. This directive encourages the replacement of such materials with more sustainable alternatives whenever possible. Furthermore, the European Commission promotes the sustainable use of natural resources to minimize environmental degradation and pollution, including the implementation of practices that enhance material efficiency and reduce waste.

EU Member States are responsible for implementing and enforcing the provisions of this directive, and non-compliance with these obligations can result in significant penalties.

The European Union has established several environmental targets for the automotive sector, aimed at reducing greenhouse gas emissions and promoting sustainability. Key targets include:

1. Reduction of CO_2 Emissions: The goal is to reduce average CO_2 emissions from new cars by 55% by 2030 compared to 2021 levels.
2. Climate Neutrality: Achieving climate neutrality in automotive production by 2040.
3. Circular Economy: Increasing the share of components derived from the circular economy, with a target of sourcing 25% of critical raw materials from recycling and achieving zero landfill waste.
4. Promotion of Electric Vehicles: Encouraging the adoption of electric vehicles, with the goal of representing a significant share of the market by 2030.
5. Sustainable Supply Chains: Reducing dependencies in supply chains to minimize negative environmental and social impacts.

These goals are part of a broader effort to transform the European automotive sector, making it more sustainable and competitive on a global scale. Based on this regulatory framework and these objectives, car manufacturers in the European Union must meet various environmental targets, especially those related to CO_2 emission reductions, which vary according to the average mass of each manufacturer's vehicle fleet.

The major European car manufacturers share several common challenges:

In this context, the future of polymeric materials in the automotive sector is both challenging and promising, with several emerging trends and opportunities.

Trends and Innovations

High-Performance Polymers: The use of high-performance polymers, such as polyamides and polyurethanes, is increasing due to their mechanical, thermal, and chemical resistance.

Weight Reduction: Polymers play a crucial role in reducing vehicle weight, thereby improving energy efficiency and significantly lowering CO_2 emissions.

Sustainability: The use of hybrid biopolymers, combining fossil-based and natural polymers, contributes to greater sustainability without compromising performance.

Flexible Design: Polymers provide greater design freedom, allowing for the creation of complex and highly customized parts.

What Are Hybrid Biopolymers?

A blend of Fossil and Natural Polymers – Combining fossil-based polymers with biopolymers can improve sustainability without compromising performance.

Challenges and Opportunities

Compatibility: One of the main challenges is ensuring effective compatibility between conventional fossil-based polymers and natural products so that the desired material properties are fully preserved.

Cost: Although natural products can reduce environmental impact, production costs may be a limiting factor.

Rosin-Based Resins and Their Potential in the Automotive Sector

The automotive industry is undergoing a transition, driven by the need for more sustainable and efficient solutions. In this context, rosin-derived resins are emerging as an innovative and promising alternative, offering benefits in both material performance and environmental impact. These derivatives, produced from raw materials sourced from natural and renewable sources such as pine trees, are being extensively researched as substitutes for fossil-based synthetic products—representing a significant step toward sustainability.

Rosin resins stand out for their unique properties, including high adhesiveness, thermal resistance, and chemical stability. These characteristics make them particularly attractive for a wide range of applications. Currently, they are widely used in the production of adhesives, paints, coatings, varnishes, cosmetics, and even in the pharmaceutical and food industries. In the development of new materials, combining rosin resins with polymers has shown great potential across various sectors. Their ability to enhance the interaction between polymers and other materials has enabled the creation of lightweight, durable, and high-performance composites. These features are highly valued in automotive applications, allowing for the construction of more efficient and safer vehicles. Furthermore, the use of natural resins enables the production of high-performance coatings and varnishes with superior chemical resistance, enhancing wear protection and significantly extending the lifespan of materials.

Another relevant aspect is the compatibility of these resins with conventional industrial processes, such as extrusion and injection molding. This ease of integration into existing production processes allows the automotive industry to adopt these solutions without requiring drastic changes to manufacturing lines. As such, incorporating natural resins can contribute to reducing dependence on petroleum-derived materials, helping to lower the carbon footprint of the automotive sector.

The future of rosin-based resins in the automotive industry looks promising, with increasing investment

in research and development. The integration of these materials into the industry is a strategic step toward decarbonizing mobility and developing more eco-friendly solutions. The shift toward sustainable materials represents not only an environmental commitment but also an opportunity for innovation and growth for companies in the sector.
With a wide range of applications and benefits, rosin resins have the potential to help redefine the future of automotive materials. The continued development and refinement of these innovative materials will enable significant advances in reducing the environmental impact of vehicles, promoting more efficient, sustainable, and forward-thinking mobility.

Consortium

With a strong focus on innovation, a small multidisciplinary consortium was established, involving one scientific and technological institution and two companies, as presented below.

SIMOLDES PLASTICS

Simoldes Plastics was founded in 1981 in Portugal and is headquartered in Oliveira de Azeméis. The company comprises eight enterprises worldwide and has established three technical and commercial support offices (in Spain, Germany, and France). It is one of the few groups with the capacity to support and manufacture for the automotive industry, serving as an Original Equipment Manufacturer (OEM) supplier for the following groups: Stellantis (Citroën, Peugeot, DS Automobiles, Opel), Renault, Nissan, Mitsubishi, VW Group (Volkswagen, Audi, Porsche, SEAT, Škoda), BMW, Toyota, Scania, and Mercedes-Benz.

UNITED RESINS – RESIN PRODUCTION

With nearly two decades of activity (founded in 2008), United Resins – Resin Production, has established itself as a key player in the transformation of natural raw materials, with a trajectory marked by innovation and sustainability. Based in Figueira da Foz, this Portuguese company began its activity by transforming rosin into resin derivatives, with applications in sectors as diverse as adhesives, depilatory waxes, chewing gum, printing inks, and road marking paints—quickly earning a prominent position in these markets.
More recently, United Resins took a significant step forward by investing in the development of compostable biopolymers produced from bio-based raw materials. These sustainable materials are now used in flexible packaging, paper coatings, and agriculture, responding to the growing demand for environmentally friendly alternatives.
A collaborative and flexible approach is one of United Resins' key strengths. By combining specialized technical knowledge with production capabilities, the company develops tailored solutions for each client, while maintaining a firm commitment to sustainability and the principles of the circular economy.

CeNTItvc – CENTRO DE NANOTECNOLOGIA E MATERIAIS TÉCNICOS, FUNCIONAIS E INTELIGENTES

CeNTI is a leading European Research and Technological Development Centre in the fields of Nanotechnology and Advanced Materials. It conducts applied R&D activities aimed at the industrial uptake of disruptive technologies, innovative product engineering, and technology transfer to companies through a dedicated B2B approach.
CeNTI positions itself as a central technological enabler for a wide range of industrial sectors seeking disruptive innovation through the introduction of advanced materials, nanomaterials, digitization of processes and/or products, resource valorization, among others, to increase their competitiveness and strengthen their international positioning.

Resin-Automotive Synergy

In the current context of the automotive industry's search for more sustainable alternatives, the use of materials derived from natural sources has gained increasing prominence. One of the main focuses of RN21 has been the incorporation of rosin-derived resins as compatibilizers in polymer matrices for structural and decorative components. These derivatives, sourced from natural resins, offer several advantages due to their intrinsic properties, such as excellent thermal stability and compatibility with widely used industrial processes like extrusion and injection molding.

Rosin derivatives show great potential for the automotive sector, especially when incorporated into bio-based polymer matrices. In addition to improving the thermal resistance of formulations, these derivatives play a relevant role in reducing the environmental impact of final products, promoting more sustainable solutions for the industry.

Throughout the development of this initiative, in-depth research was carried out on the incorporation of rosin derivatives into conventional polymers and in combinations with bio-based polymers. This work covered all stages of the process—from formulation and composition to processing and the evaluation of physical, mechanical, thermal, and rheological properties. The broad set of tests proved to be fundamental in validating the performance of the developed materials and ensuring compliance with the strict requirements of the automotive industry.

The results obtained so far show an increase in melt flow index, a factor that could benefit the injection molding process. Additionally, density values remained virtually unchanged, which is particularly relevant for ensuring the lightness of automotive components. In terms of mechanical properties, only minor changes were observed, with impact resistance proving to be the most challenging property to optimize. Overall, the data indicates that the integration of rosin derivatives and bio-based polymers into fossil-based matrices expands their potential use in automotive applications — particularly in interior components. This approach allows for a significant reduction in the use of fossil-based materials by incorporating more sustainable

alternatives without compromising essential mechanical properties. By incorporating up to 40% bio-based content into polymer matrices, manufacturers can significantly reduce dependence on fossil resources while ensuring the quality, strength, and performance required by the market.

Moreover, the study included a detailed environmental impact assessment of the biopolymers with rosin derivatives, using the Life Cycle Assessment (LCA) methodology (Figure 1). This comparative analysis with conventional petroleum-based materials revealed that biopolymers with rosin derivatives have a significantly lower overall environmental impact, especially in terms of carbon footprint and the consumption of non-renewable resources.

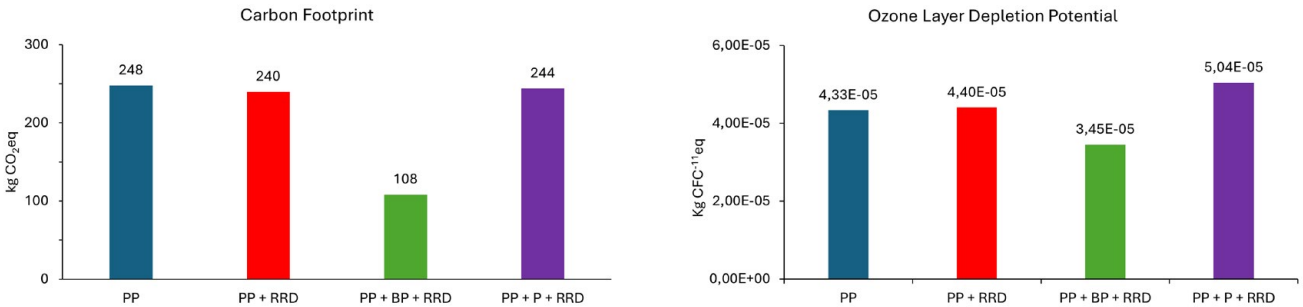

Figure 1. Sustainability analysis of the solutions developed. Caption: PP – Polypropylene; RRD – Rosin Resin Derivative; BP – Biopolymer A; P – Fossil polymer.

This progress represents an important milestone in the development of sustainable materials for the automotive industry, aligning with the market's growing demand for eco-friendly solutions. The use of rosin derivatives not only enhances material properties but also stands out as an effective response to the environmental challenges faced by the sector. The integration of these biopolymers into automotive part manufacturing is undoubtedly taking decisive steps toward a more sustainable and innovative future.

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THE PORTUGUESE FOOTWEAR TECHNOLOGY CENTRE

NATURAL RESIN IN THE FOOTWEAR SECTOR: PAST AND FUTURE

The footwear industry plays a key role in the Portuguese economy, with Portuguese footwear internationally recognized for its high quality, strong focus on design, and commitment to innovation. According to data from APICCAPS – the Portuguese Footwear, Components, Leather Goods Manufacturers' Association – Portugal exported around 67 million pairs of shoes in 2024, accounting for over 90% of its production and reaching more than 170 countries across five continents (Figure 1).

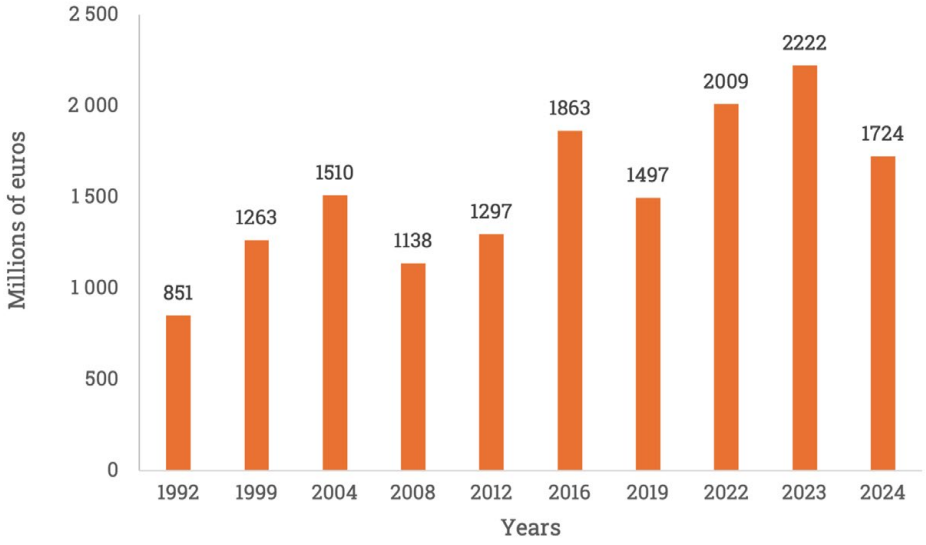

Figure 1 – Evolution of Portuguese Footwear Exports.

The performance of the national footwear value chain is the result of a continuous process of transformation, innovation, capacity building, internationalization, and a commitment to environmental, social, and economic sustainability. **CTCP – the Portuguese Footwear Technology Centre,** with locations in São João da Madeira and Felgueiras – has played a key role in this journey. Acting as a bridge between businesses, the scientific and technological system, and public decision-makers, CTCP fosters increased research capabilities and sectoral competitiveness.

Given the growing demand for sustainable solutions, the Portuguese footwear industry has repositioned itself through projects such as RN21 – Innovation in the Natural Resin Value Chain to Strengthen the National Bioeconomy. This initiative aims to reinforce the sector's resilience and long-term sustainability.

The footwear cluster in Portugal sees the Natural Resin sector from maritime pine (*Pinus pinaster*) as a strategic ally in facing the challenges of ecological transition. The collaboration between Natural Resin and footwear sectors represents a unique opportunity to develop innovative solutions that value renewable raw materials and drive the creation of more sustainable, higher-value products.

In this context, CTCP coordinates two main lines of research: (1) the formulation of new adhesive systems using modified rosin for application in the footwear industry, and (2) the development of sole materials containing rosin derivatives.

The application of rosin derivatives in footwear components, such as adhesives/resins or polymeric matrices, requires the optimization of formulations, assurance of material compatibility, and compliance with pre-established requirements. The objective is to bring these solutions from a laboratory stage to pre-industrial validation, meeting the demands of both national and international markets.

Modified Rosin Adhesive Systems

Historically, natural rosin was widely used in the formulation of industrial adhesives, particularly in the footwear sector. Its adhesive properties and ease of integration into various systems made it a common choice for many applications. However, constraints related to the classification of natural rosin, particularly

in terms of labeling and safety, have led some companies to remove it from their formulations. Against this background, it became essential to identify alternatives that could maintain or enhance adhesive performance without compromising regulatory compliance and sustainability goals.

In this context, **CIPADE – Adhesive Products Industry and Research,** a Portuguese company based in São João da Madeira, stands out. Specializing in the development of adhesive solutions for various industries, with a particular focus on footwear, the company has a strong R&D component and has distinguished itself by creating innovative products that address sustainability, performance, and process efficiency challenges.

Anther strategic partner in this initiative, **United Resins – Resin Production,** based in Figueira da Foz, brings nearly two decades of experience in transforming rosin. The company is committed to sustainable innovation and has been instrumental in producing rosin derivatives for various sectors, including adhesives, depilatory waxes, and printing inks.

The RN21 Integrated Project facilitated the replacement of conventional adhesives/resins in the footwear industry by introducing and evaluating modified rosin resins. These renewable-based resins have an adapted chemical structure that not only addresses classification issues but also holds the potential to maintain the desired technical properties of adhesives. Rosin derivatives, obtained from renewable natural sources, are recognized for their unique tackifier properties and biobased, sustainable character, making them a promising alternative to fossil-based adhesives. These features make them especially suitable for demanding footwear applications, which require strong and durable bonding.

Reformulated adhesives and modified rosin adhesive systems were developed and tested for bonding soles to uppers, stitching, and insole finishing. These innovative systems partially or entirely replaced hydrocarbon (fossil-based) resins. Experimental results generally showed good performance, with adhesion and strength levels comparable to those of conventional formulations. The new biobased alternatives achieved a biological content of up to 18%.

Beyond the advantages already mentioned, the adhesives developed with modified rosin resins proved particularly effective in promoting adhesion and enhancing initial tack—critical aspects for ensuring the efficiency of bonding processes. Product stability over time was also improved, contributing to greater consistency in application results.

It is important to highlight that these resins are biobased and produced in Portugal, enhancing national production. The geographical proximity to raw material suppliers has fostered strategic synergies, facilitating the joint development of innovative solutions tailored to market needs.

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Figure 2 - Adhesive developed with modified rosin resin for use in footwear.

Polymer Matrices with Rosin Derivatives

As part of this joint effort to promote sustainability in the footwear sector, innovative formulations are currently being developed that incorporate different percentages of rosin resin into polymer matrices, specifically as additives to the polymers used in sole manufacturing. This approach aims to create hybrid materials that combine the technical performance of these polymers with the properties of Natural Resin, thereby enhancing the functional and ecological value of the final products.

Within this framework, **CeNTI – Centre for Nanotechnology and Advanced Materials,** based in Vila Nova de Famalicão, is involved in the Project by focusing on the formulation of polymer compounds incorporating rosin derivatives into bio-based polymer matrices. In line with its ongoing sustainable diversification strategy, United Resins has also recently invested in the development of biopolymers produced from bio-based raw materials.

This initiative seeks to create innovative and sustainable solutions for the footwear sector that reconcile technical performance with environmental responsibility, without compromising the quality and functionality standards required by the market.

In partnership, United Resins, CeNTI, and CTCP are studying biopolymer formulations incorporating rosin derivatives, creating high-performance and sustainable composites for industrial processes such as injection molding used in sole manufacturing. This approach enables the development of technically adapted solutions that meet the footwear industry's demands while promoting the valorization of pine resin within a circular economy model.

The various polymer compositions for soles, incorporating between 5% and 20% rosin derivatives,

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have led to materials with a bio-based **content of up to approximately 60%,** demonstrating good processing behavior without compromising the integrity or flow of the material, evidence of compatibility between components and the industrial viability of this solution. These results led to variations in some of the materials' physical and mechanical properties, such as density, which remained comparable to reference materials. Additionally, physical-mechanical properties such as elongation at break, tear resistance, and hardness posed additional challenges, requiring fine-tuning of the formulations. Nevertheless, it was possible to meet the established requirements, ensuring that environmental gains did not compromise the performance of the final product.

Figure 3 - Prototypes developed with soles containing 5 and 15% modified rosin resin.

Figure 4 - Sole with 15% resin in its composition.

Conclusions

Reconciling sustainability with technical performance remains a demanding challenge. The partial and/or total substitution of fossil-based resins and polymers in adhesives and sole materials with bio-based alternatives, such as rosin derivatives, has proven to be a promising solution aligned with increasing environmental demands. It further strengthens their potential as a strategic and sustainable alternative for the footwear industry.

By valorizing renewable resources, this work represents a step toward sustainable innovation in material science and industrial symbiosis, responding to the demands of high-value industrial applications with strong environmental performance.

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TECMEAT

EXPLORING THE POTENTIAL OF ROSIN DERIVATIVES IN ENHANCING QUALITY AND SUSTAINABILITY IN THE MEAT INDUSTRY

Within the scope of the RN21 Project – Integrated Project for Natural Resin, Pillar II2 – New applications and market reinforcement, a group of companies and scientific system entities joined efforts to develop new applications and market niches for rosin in the food and agricultural sectors (materials and packaging) (Pillar II2, Measure 1A). Thus, the RN21 Project aims to drive research and innovation focused on exploring the unique technical properties inherent to Natural Resin extracted from pine trees, extending its application across the entire value chain. To this end, two complementary research lines were defined:

1) Development of protective biopolymeric films with the addition of rosin derivatives;

2) Development of biopolymeric packaging incorporating active ingredients encapsulated with rosin-based materials

Context and challenges of the sector

The agri-food sector, including the meat industry, faces numerous challenges regarding the use of fossil-based packaging and the urgent need to transition to more sustainable and environmentally friendly solutions.
It is a well-known fact that conventional, petroleum-derived packaging generates large amounts of non-biodegradable waste, contributing to soil and ocean pollution. Furthermore, its production and degradation increase the sector's carbon footprint, negatively impacting sustainability targets. In the meat sector, for example, many plastics used (such as laminated or multilayer materials) are extremely difficult to recycle due to their complex composition.

The shift to more ecological and sustainable solutions is inevitable, namely through the development and adoption of advanced bio-based materials such as cellulose films, natural coatings, and biocomposites with improved barrier properties. Additionally, innovative solutions are needed to extend the shelf life of food products, thereby helping to reduce food waste.
Regarding packaging in the agri-food industry, while the European Union and other international bodies are imposing stricter restrictions on the use of single-use plastics and requiring more sustainable alternatives (Regulation (EC) No. 450/2009 and Regulation (EU) 2022/1616), consumers themselves are becoming increasingly attentive and concerned with sustainability. This growing awareness adds additional pressure on companies to adopt more environmentally friendly packaging solutions.
Rosin is a natural product derived from the resin of coniferous trees, primarily maritime pine (*Pinus pinaster*). This age-old material has been gaining prominence due to its potential and eco-friendly nature, responding to the growing demand for sustainable solutions. Its main advantage as a green material lies in its biological and renewable origin. Moreover, rosin extraction is performed sustainably, allowing trees to continue growing and regenerating resin naturally. This process not only supports forest preservation but also promotes responsible forest management and the development of rural communities.
Another key advantage of rosin is its versatility. Thanks to its adhesive, hydrophobic, and film-forming properties—and as a natural alternative to fossil-based

synthetic components—rosin and its derivatives are highly valued in different applications, offering high-quality, high-performance solutions.

In this sense, finding more sustainable, bio-based packaging solutions for the agri-food sector is a fundamental requirement, and this is precisely the challenge addressed by this measure within the RN21 Integrated Project.

The focus on innovation and sustainability drove the formation of a multidisciplinary consortium, involving three entities from the scientific and technological system and two companies. **TECMEAT - the Competence Center for the Agri-Food Sector,** is the lead promoter of this initiative, which aims primarily to foster interaction with the industry and enable pre-industrial validation of the solutions developed in the Project. In this regard, TECMEAT is responsible for conducting tests and trials of the proposed solutions, in accordance with the requirements of the food industry. **KEMI – Pine Rosins Portugal,** is a company specialized in the production of natural rosin and its derivatives. KEMI is involved in developing antioxidant encapsulation solutions using rosin derivatives as encapsulating agents. These capsules are designed for application in food packaging, aiming to extend the shelf life of food products while reducing food waste. **United Resins – Resin Production,** is at the forefront of transforming naturally sourced materials, starting with rosin and, more recently, expanding into compostable polymers based on bio-based raw materials. In this initiative, the company is developing and producing biopolymer films incorporating rosin-based resins for flexible packaging in the meat sector. These materials, which combine the best of the company's two technological domains, are designed to offer innovative and sustainable alternatives to fossil-based solutions, while ensuring strong barrier properties against water vapor and oxygen. **CeNTI – Centre for Nanotechnology and Smart, Functional and Advanced Materials** – is a leading research and technological development centre in Europe in the fields of nanotechnology and advanced materials. CeNTI supports the technical development of both R&D lines in this measure, namely: i) the surface functionalization of biopolymer films incorporating rosin derivatives for packaging applications, using more sustainable and waterless technologies and materials (such as atmospheric plasma, spray coating, and physical vapor deposition) to improve oxygen and water vapor barrier properties; ii) the encapsulation of bioactive agents using rosin derivatives, including the evaluation of loading capacity and controlled release. The developed encapsulated systems will then be incorporated into packaging to promote the extension of food shelf life. Finally, the **Polytechnic Institute of Leiria** is responsible for developing polymer films incorporating antioxidant agents, aimed at application in intelligent meat packaging, specifically designed for processed meat products. These solutions aim to add value and meet the needs of a specific market niche.

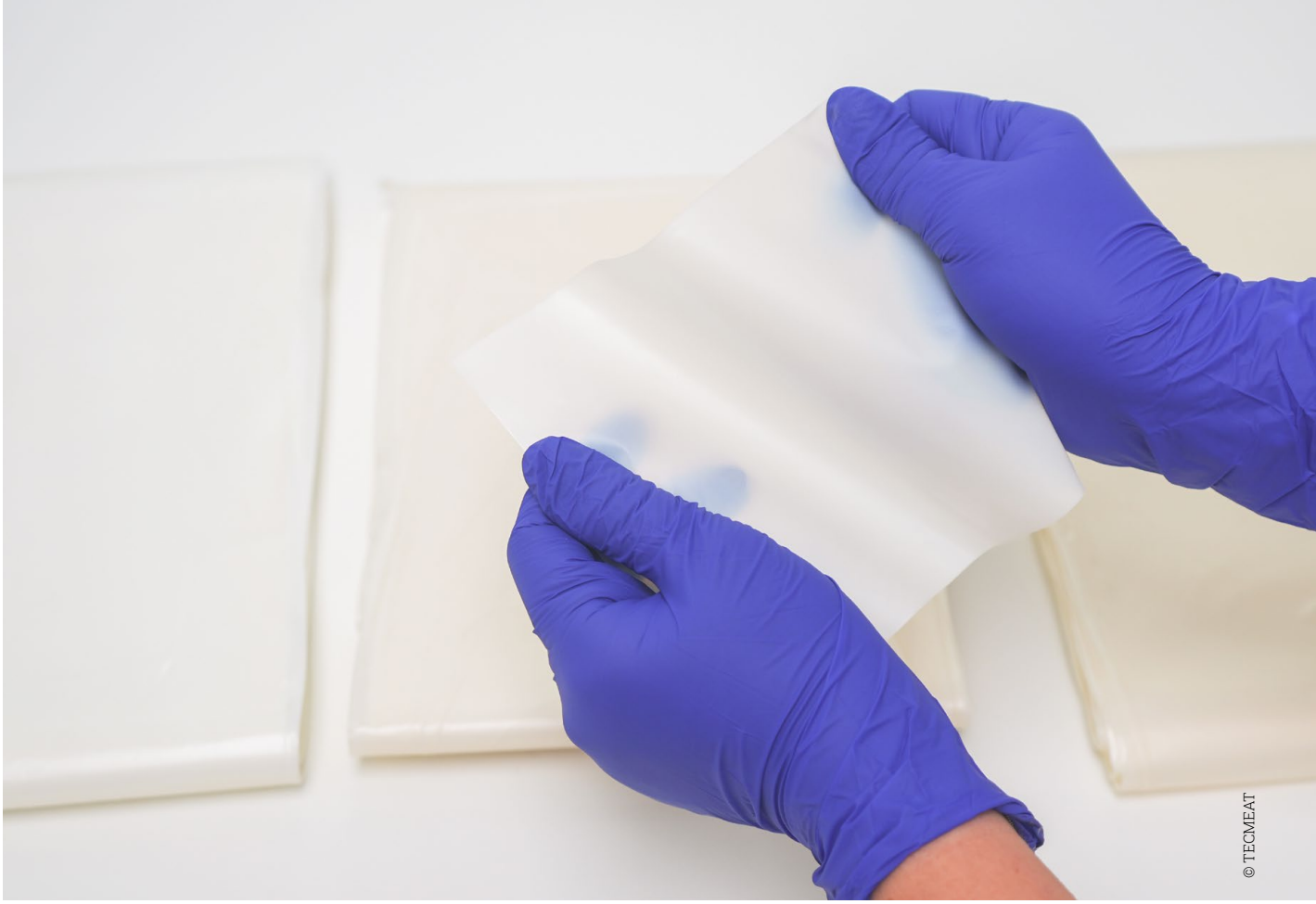

Figure 1. Films produced for food packaging.

Biopolymeric films with improved properties:

Polymeric films and packaging used in food preservation have evolved significantly, not only in terms of aesthetics and design but also in the enhancement of their technical properties. These innovations aim to actively contribute to food preservation by extending shelf life and reducing food waste. As the consumption of packaged food products increases, so does the concern over developing more sustainable solutions to replace fossil-based materials widely used in the market.

In this context, biopolymers have emerged as a promising alternative due to their biodegradability and lower environmental impact. However, to be competitive with conventional films, certain technical properties must be improved to ensure equivalent or superior performance in terms of strength, barrier properties, and food preservation. One approach to achieving this goal involves incorporating functional additives such as rosin derivatives, which have been explored for their film-forming and adhesive properties, as well as their potential to enhance mechanical and barrier characteristics. The addition of these derivatives to biopolymers has proven to be an effective strategy for modifying such properties, resulting in significant changes to the material.

The application of functional coatings to biopolymeric films for food packaging has generated considerable interest due to their potential to improve barrier properties against water vapor and oxygen (WVTR and OTR, respectively). During the developments, these properties—essential for extending the shelf life and preserving the quality of food products—were optimized using different approaches. Water-based formulations and various waterless coating methods were evaluated, including spray coating (SC), physical vapor deposition under vacuum (PVD), and atmospheric pressure plasma-assisted deposition (PC), considering their impact on the structure and performance of the films.

The application of a functional PVD coating resulted in a significant improvement in the films' barrier properties. As illustrated in Figure 3, this approach led to a reduction of around 80% in both WVTR and OTR values when compared to the original control substrate. For the other coating technologies, significant improvements were also observed, namely a reduction in OTR values of over 60% (results for "SC" and "PC" in the figure). These results demonstrate a substantial enhancement of the barrier performance of biopolymeric films, making them more competitive with conventional packaging materials.

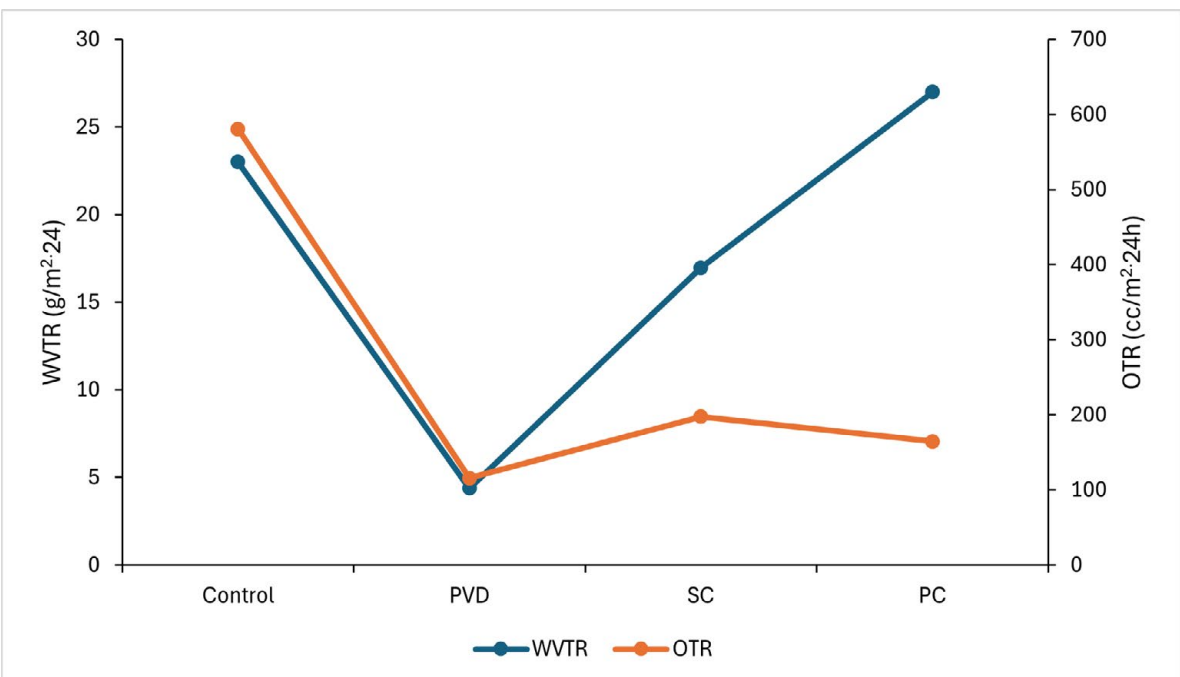

Figure 2. Evaluation of the water vapor transmission rate (WVRT) and the oxygen transmission rate (OTR).

Functional Packaging

In the field of food packaging for meat-based products, particularly premium products, an emerging technology known as Vacuum Skin Packaging (VSP) is gaining traction. This system consists of a rigid tray and a flexible plastic skin that tightly wraps around the packaged product, creating a new way for consumers to interact with packaged meat products.

Within this line of work, significant efforts are being made to incorporate additional functionalities into the films used in such packaging, effectively transforming them into active packaging solutions.

Specifically, a sustainable and innovative technological solution is currently under development: the production of particles based on rosin derivatives that enable the controlled release of natural active agents (antioxidants and antimicrobials) over time, through their incorporation into food packaging. Using an eco-friendly technique, particles made from rosin derivatives are synthesized for the encapsulation of bioactive agents, obtained from the primary transformation of Natural Resin. The goal is not only to develop functional solutions for application in premium meat packaging, but also to promote the value of Natural Resin across its various processing stages.

The functional additive developed is currently being used in the formulation of polymeric films via extrusion processes. At this stage of the Project, the application of polymeric film is undergoing validation for its potential to extend the shelf life of meat products.

Conclusion and potential impact of the solutions on the sector

The transition to more sustainable packaging has faced several challenges. On the one hand, sustainable alternatives such as bioplastics and compostable packaging are increasingly used as viable solutions. On the other hand, these materials still require further technological development to improve their functional properties, such as barrier properties against gases and liquids, which are essential for extending food shelf life and reducing food waste.

The developments being carried out under this project aim to address these challenges by using products from the first and second transformation of Natural Resin to foster innovative solutions. These include biopolymeric films and packaging with improved performance, designed to be both sustainable and functional.

Therefore, while the transition to more sustainable solutions is inevitable, it requires a joint effort by industry, regulators, and consumers to ensure both economic and environmental viability.

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NARES

VALORIZATION OF THE "BARK" WASTE FROM THE FIRST TRANSFORMATION INDUSTRY OF NATURAL RESIN

This article falls under project II1.M3B – Valorization of bark and other residues from the first transformation industry of Natural Resin, part of the Integrated Project RN21, within Pillar II – Strengthening the sustainability of the processing industry. This measure aims to declassify the waste known as "bark", allowing its reclassification as a by-product and, consequently, its use as a raw material in other industries.

Problem Characterization and Motivation

Pine resin extraction is carried out by making incisions in the tree's bark using mechanical tools and applying a stimulant agent (acid), which induces the production of defensive substances — pine resin. Resin is collected using traditional open collector methods, such as the clay pot (*púcaro*) or plastic bag (Figure 1). The project is led by **NARES – Natural Resins** in collaboration with **PRORRESINA – Resin Products.**

Figure 1. Open resin collector types, pot and bag.

Since collectors remain open in the forest for extended periods, they accumulate not only resin but also water and impurities such as pine needles, wood chips and bark, sand, dust, insects, among others. Therefore, before distillation, the resin undergoes a two-step cleaning process: screening and filtration.

Cleaning Process:

- Screening: After being heated and homogenized with turpentine in the malaxator, resin is discharged onto a metal screen (mesh size 7–9 mm), where larger impurities are removed. It is during this stage that the bark waste is generated (Figure 2).

- Filtration: Carried out using plate filters with a filtration aid (dicalite slurry), which removes finer impurities and produces filter sludge as waste.

Figure 2. Metal screen and bark waste.

Quantification and Current Destination

At NARES, the bark waste is stored in a dedicated container and collected by a certified entity approximately every two months. The combined annual production of bark waste by NARES and PRORRESINA is estimated at 103.4 tonnes/year.
The seasonality of waste production is low, as resin collectors remain in the forest for several months and the resin can be stored at the factories before processing, which helps mitigate seasonal effects.
Currently, the waste is classified under the European Waste Catalogue (EWC) code 03 03 01 – Waste bark and wood, and it is sent to landfill by a licensed operator.

Nature of the Waste and Valorization Potential

The bark waste resembles other secondary forest products. A visual inspection allows the following estimated composition:

- 50% pine needles
- 30% pine bark
- 15% wood
- 5% of other materials (resin, insects, sand, dust, paper)

Based on this composition, several potential valorization pathways were considered:

DIRECT COMBUSTION - Use of the waste's calorific value, especially due to resin content. Requires strict emission controls to minimize environmental impact.
PYROLYSIS - Thermochemical conversion into bio-oil, biochar, and gases — with potential for renewable fuel and chemical production.
GASIFICATION - Thermochemical conversion into synthesis gas, which can be used to generate electricity, heat, or for chemical synthesis.
COMPOSITE PRODUCTION - Use in the manufacturing of particleboard, wood panels, or as a filler material in construction.

Waste Declassification Process

Declassifying waste requires a rigorous technical and administrative process. For this purpose, a service contract was established with the Waste Valorization Center (CVR) at the University of Minho, to carry out the necessary steps to qualify the bark waste as an industrial by-product (i.e., no longer classified as waste).

Steps of the process:

1. Physicochemical characterization – To confirm the waste is non-hazardous.
2. Analysis of valorization pathways – Selection of a specific application.
3. Applicability verification – Technical and regulatory validation.
4. Identification of potential users – Obtaining declarations of interest.
5. Submission to APA – Formal initiation of the declassification process in the Portuguese Environment Agency (APA).

Although it is possible to study multiple valorization routes simultaneously, for efficiency reasons, it was decided to focus on a single application.

Physicochemical Characterization

Laboratory tests followed the parameters of Standard NP EN 4486:2016 – Waste-derived fuels. The results are presented in the following tables:

Table 1. Physical parameters

Physical Parameters	
Parameter	**Result**
Moisture content (%)	33,5
Ash content (%)	2,8
Volatile matter content (%)	79,08
LCV – Lower calorific value (MJ/Kg)	21,57
HCV – Higher calorific value (MJ/Kg)	23,21

Table 2. Elemental analysis

Elemental Analysis	
Parameter	**Sample**
Carbon (%)	59,1
Hydrogen (%)	7,59
Nitrogen (%)	0,29
Sulfur (%)	0,01

Table 3. Chemical composition

Chemical composition	
Parameter	**Sample**
Chlorine (mg/kg)	0,04
Arsenic (mg/kg)	<5
Cadmium (mg/kg)	<0,4
Lead (mg/kg)	<5
Copper (mg/kg)	3,6
Chromium (mg/kg)	20,8
Mercury (mg/kg)	<0,3
Nickel (mg/kg)	9,1
Zinc (mg/kg)	54,7

Table 1 shows that the material has a relatively high moisture content, which compromises its calorific value, as part of the energy generated during combustion will be used to evaporate the water. However, the volatile matter content, an indicator of the fraction of the material that volatilizes at high temperatures, combined with an acceptable ash content and good calorific value, suggests a reasonable potential for energy recovery. The results of the elemental analysis (Table 2) revealed a high carbon content, a key element in energy recovery, and a more modest hydrogen content. These two elements, when combined, can form hydrocarbons, which contribute positively to energy production.

On the other hand, the nitrogen and sulfur contents, although they do not contribute to energy recovery and may generate pollutant emissions during combustion, are low in the analyzed sample and do not significantly compromise its energy potential. Table 3, reporting chemical composition, shows that most elements are below critical concentration levels, which is encouraging regarding the use of this residue in energy recovery technologies. Nevertheless, it is important to note that even at seemingly low concentrations, certain elements can have adverse effects, especially in processes such as incineration and gasification, where there is potential for releasing harmful substances to the environment.

Regarding volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs), among the more than 50 substances analyzed, most were below quantification limits. For those that were quantified, such as p-isopropyltoluene (54.9 mg/kg), it is recommended that treatment and monitoring processes be sufficiently robust to mitigate associated risks, even though these compounds are only present in trace amounts.

The comprehensive analyses performed allow the residue to be reliably classified as non-hazardous, thereby opening up the possibility of its safe use as a valuable by-product with potential for energy recovery.

Valorization of the By-product

Considering the potential for recovery identified, the availability in Portugal of entities with experience in the respective processes, the degree of maturity of the technologies involved and the quantities of waste generated annually, it was concluded that the most suitable option for the valorization of bark waste would be burning in biomass boilers or similar.

Research was thus directed toward demonstrating the suitability of the residue as a fuel, in accordance with the Portuguese standard NP 4486:2016, which transposes the European technical specification CEN/TS 15359:2006 into the national context. This standard is based on a classification system according to three parameters, each assessed on a scale from 1 to 5, as shown in Table 4.

Table 4. Reference values for each class of waste-derived fuel.

Parameter	Statistical Measure	Unit	Classes				
			1	2	3	4	5
Chlorine content (Cl)	Mean	% (dry basis)	≤ 0.2	≤ 0.6	≤ 1.0	≤ 1.5	≤ 3
Lower calorific value (PCI)	Mean	MJ/Kg	≥ 25	≥ 20	≥ 15	≥ 10	≥ 3
Mercury content (Hg)	Median	mg/Kg	≤ 0.02	≤ 0.03	≤ 0.08	≤ 0.15	≤ 0.5
	80^{th} percentile		≤ 0.04	≤ 0.06	≤ 0.16	≤ 0.30	≤ 1.00

For the residue under analysis, the following characteristics were considered:

- LHV: 10 MJ/kg (as received basis);
- Cl (dry basis): 0.04%;
- Hg: <0.2 mg/kg (as received basis).

Based on these measured values, the residue would be formally classified as follows:
- LHV – Class 4
- Cl – Class 1
- Hg – Class 4

These results indicate a significant moisture content, which negatively affects combustion efficiency. Therefore, it is recommended to reduce the moisture content to improve energy performance. The low ash content and high concentration of volatile matter, combined with both the higher and lower heating values (Table 1), reinforce the potential of bark waste as a valuable resource for efficient energy generation. However, it is important to consider the emission limits defined by Decree-Law No. 39/2018, which regulates atmospheric emissions from combustion processes. In this context, a combustion test was conducted.

Combustion Test

To demonstrate compliance with the requirements of EN 15259:2007, CEN/TS 15675:2007, and Decree-Law No. 39/2018, Combustion tests were carried out using bark waste, ensuring the quality and reliability of the measurements.

Table 5. Combustion test results

Parameter	Measurements		Treshold values			
	Concentration (mg/Nm^3)	Flow (Kg/h)	Concentration[1] (mg/Nm^3)	Flow[2] (kg/h)		
				Minimum threshold	Average threshold	Minimum threshold
Total Organic Compounds (TOCs)						
Measured value	19					
Value corrected to 6% O2	145	0,002	200	1	2	30
Nitrogen oxides (NOx) (expressed as NO2)						
Measured value	133					
Value corrected to 6% O2	313	0,02	300	0,5	2	30
Carbon monoxide (CO)						
Measured value	526					
Value corrected to 6% O2	1240	0,07	---	1	5	100
Particles						
Measured value	58					
Value corrected to 6% O2	137	0,01	20	0,1	0,5	5

[1] Limit values for concentration according to Decree-Law 39/2018.
[2] Limit values for mass flow rates according to Decree-Law 39/2018, Annex II, Part 1, Table 1.

The main results (Table 5) were:

- **Total Organic Compounds (TOCs):** Concentrations below the established limit values.
- **Nitrogen Oxides (NOx):** Value corrected to 6% O_2 was 313 mg/Nm³, slightly exceeding the limit of 300 mg/Nm³.
- **Carbon Monoxide (CO):** High value, indicating incomplete combustion, possibly due to poor ventilation or low combustion temperature.
- **Suspended Particles (PM):** Concentration well above the permissible limit.

The high CO and particulate concentrations may share a common origin, namely incomplete combustion due to insufficient ventilation (low oxygen availability), inadequate temperatures, and/or high moisture content. The test was carried out in a small-scale boiler (<40kW), typically domestic. It is expected that, in industrial boilers with better ventilation and greater thermal capacity, CO and particulate emissions would be significantly reduced. In addition, the adoption of gas filtration or scrubbing systems (scrubbers) may allow compliance with legal limits. Another solution could be co-combustion with other materials, reducing pollutant concentrations through dilution.

NEXT STEPS

The search for biomass-consuming companies interested in using bark waste as fuel is ongoing. One company with high biomass consumption tested the samples with positive initial results but ultimately chose not to proceed due to concerns that the resin content could cause problematic buildup in the fuel transport systems feeding the boilers.

The prospecting process for potential users continues. Once a company confirms its intention to use the material, we will start the process of waste declassification with the Portuguese Environment Agency (APA), enabling its integration into the circular economy. In this way, the residue will no longer be sent to landfill, contributing to the achievement of waste recovery targets from the first transformation industry of Natural Resin under the RN21 Integrated Project.

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[a]NARES - Natural Resins

OUTREACH

At the forefront of sustainable innovation, RN21 shares knowledge and advancements, connecting stakeholders in the Natural Resin sector towards a greener and more prosperous future.

VISUAL IDENTITY AS A STRATEGIC DEVICE IN CERTIFICATION BRANDS

More than an aesthetic expression, a brand's visual identity constitutes a symbolic architecture with strategic power: it organises symbols, projects values, and visually conveys the brand's commitments. Grounded in branding and semiotics, it structures visual codes that communicate authenticity and reinforce trust, especially in contexts where reliability is determined by both substance and form.

As a perceptual interface between the consumer and the brand's intangible values, visual identity functions as a semiotic system symbolising fundamental identity attributes. In this context, graphic expression is not limited to a purely aesthetic function; it is a device for symbolic representation that translates sustainable values into visual language, providing a clear institutional character and immediate recognition.

A coherent identity strengthens the perception of consistency, becoming the visual extension of the brand's value proposition.

Graphic elements integrated into a robust visual identity act as signals of credibility, projecting a universe of meaning that associates the brand with ethical and environmentally responsible practices.

For biobased product brands, whose value proposition relies on sustainability and guaranteed quality, visual identity serves as a catalyst of meaning, allowing intangible attributes such as traceability, certification, and origin to become tangible and verifiable. By structuring a coherent and codified visual identity, these abstract dimensions gain immediate and verifiable symbolic expression.

Colours, shapes, and symbols with connotative functions are strategically used to evoke connections to nature and circularity, reinforcing the association of the product with an imagery of ecological responsibility. Visual identity thus assumes a narrative synthesis function, translating the brand's value proposition into visual symbols endowed with pregnance and interpretative clarity.

Resinae® – Pinaster Natural Resin emerged as a response to the need to reposition Natural Resin from maritime pine against competition from synthetic and imported products, emphasising differentiating attributes such as sustainable origin, positive impact on forests, and connection to the territory. Developed within the RN21 Integrated Project, Resinae®'s visual identity is based on principles of strategic branding and corporate sustainability, communicating a narrative of innovation, trust, and excellence. Its design results from a value-driven approach, in which each visual element is conceived to translate, amplify, and legitimise the value proposition.

Moreover, Resinae® authenticates products derived from sustainably sourced *Pinus pinaster* Natural Resin, acting as a visual institutional guarantee seal for consumers, producers, and industries in the sector. The logo assumes a metonymic function: it visually and symbolically represents the entire certification system, responsible forest management, and traceability. It is an example of graphic design as a semiotic device with strong indexical weight, capable of condensing practices, standards, and values into a single symbol.

A distinguishing feature of Resinae®'s graphic identity is the labelling system based on the percentage of biobased content: 10%, 40%, 70%, or 100%. This graphic solution reinforces transparency towards the consumer, clearly distinguishing products most aligned with the principles of the circular bioeconomy. Here, design acts as an interpretive mediator between technical data and public perception.

Although traceability is ensured through technical audits, it gains a reliable visual expression through the coherence of the brand's graphic identity.

This coherence becomes a symbolic signature of institutional integrity, functioning as a seal of trust and continuity.

Resinae®'s visual identity exemplifies the strategic, communicative, and symbolic potential of graphic design in legitimising certified biobased brands. This visual system, rooted in disciplines such as branding, semiotics, perception psychology, and systems design, contributes to the construction of a symbolic system in which trust is also manifested through form. By combining technical rigour with visual expressiveness, Resinae® positions itself as a benchmark in sustainability communication, reinforcing responsible practices with institutional legitimacy and market relevance.

Joana Rodrigues[a]

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A POSITIVE DIFFERENTIATION LABEL FOR NATURAL RESIN FROM *PINUS PINASTER*

One of the key goals of the Integrated Project RN21 is the registration and implementation of a distinctive, attractive, and identity-driven brand focused on Natural Resin. In this context, the brand "Resinae® - Pinaster Natural Resin" was created, strongly oriented towards promoting a renewable raw material, with a particular focus on resin extracted from maritime pine (*Pinus pinaster*) of European origin, sourced from well-managed forests that ensure the environmental, social, and economic sustainability of the products bearing the brand.

The guidelines for Brand use are established in a regulation that defines the eligibility criteria required across the entire value chain, from resin tapping in pine forests, through primary and secondary industrial processing, to the incorporation of resin derivatives into different market products.

The development of the Brand aims to revitalize the sector by enhancing the value of Natural Resin from maritime pine in several ways:

Strengthening the Identity of Maritime Pine Natural Resin

Create and promote a brand that ensures consumers of the origin and traceability of Natural Resin throughout the value chain, starting in sustainably managed maritime pine forests, continuing through the production of its derivatives, and up to its incorporation into various final products, through the implementation of a traceability system.

Promoting Sustainability in the Value Chain

By basing the Brand on internationally recognized certification systems for sustainable forest management and chain of custody, the project guarantees that resin extraction takes place in well-managed forest areas. These areas adopt sustainable forestry practices and promote the conservation of natural resources. At the same time, is ensures that all industrial transformation processes meet environmental and social sustainability standards, ensuring that consumers can trust the sustainability principles behind the products.

Improving the Sector's Competitiveness

Boost competitiveness of the Natural Resin sector through product differentiation, by implementing a control, tracking, and labeling system that ensures quality and positions the Brand as a leader in sustainable practices and innovation.

To develop a structured strategic plan aligned with the sector's needs, the implementation methodology followed several steps:

Stakeholder Consultation

Based on the interaction with the stakeholders, it was possible to design the strategy to be adopted in the creation of the Brand, where the European scope of application and the species to be valued were defined, ensuring a competitive position in the international market, focusing on maritime pine due to its importance in Portugal and the Iberian Peninsula.

Use of Recognized Certification Systems

To enhance the Brand's credibility and ensure sustainable certification standards, it was decided to adopt existing and internationally recognized certification systems that cover the entire value chain, both in terms of forest management and chain of custody.

Development of the Regulations

In order to make the system operational, regulations were created for the use of the Brand, which establishes the use of resin extracted in Europe from maritime pine, requires that the areas of provenance are certified by sustainable forest management certification systems and that all operators in the processing chain are

certified by chain of custody certification systems, guaranteeing an environmentally and socially responsible production chain.
Considering that Natural Resin is used in industries as diverse as chemicals, pharmaceuticals, adhesives, glues and paints, among others, in which Natural Resin derivatives are used in formulations with other products, minimum percentages of incorporation of maritime pine resin were considered (10%, 40%, 70% and 100%), to cover the entire value chain.

Trademark Registration

Once the usage criteria were established, the Brand was registered at both national and European levels to legally protect the associated industrial property rights.

Traceability System

Traceability of products will be ensured by external Certification Bodies, which will conduct audits to ensure process compliance throughout the value chain. In this context, technological and procedural solutions are being explored to provide effective and reliable traceability, including options such as Blockchain systems, barcodes or QR codes, and radio-frequency identification (RFID).

Proof of Concept

By the end of the project, a small-scale proof of concept is planned to test and evaluate the effectiveness of the system, identify challenges, and refine procedures, with the goal of scaling up to market level.
From a holistic perspective, by increasing the competitiveness and credibility of Natural Resin from maritime pine, it is expected that its commercial value and production will increase, thereby encouraging more active forest management of this species. The Brand ultimately aims to contribute to the economic development of rural and forest communities, promoting territorial cohesion.

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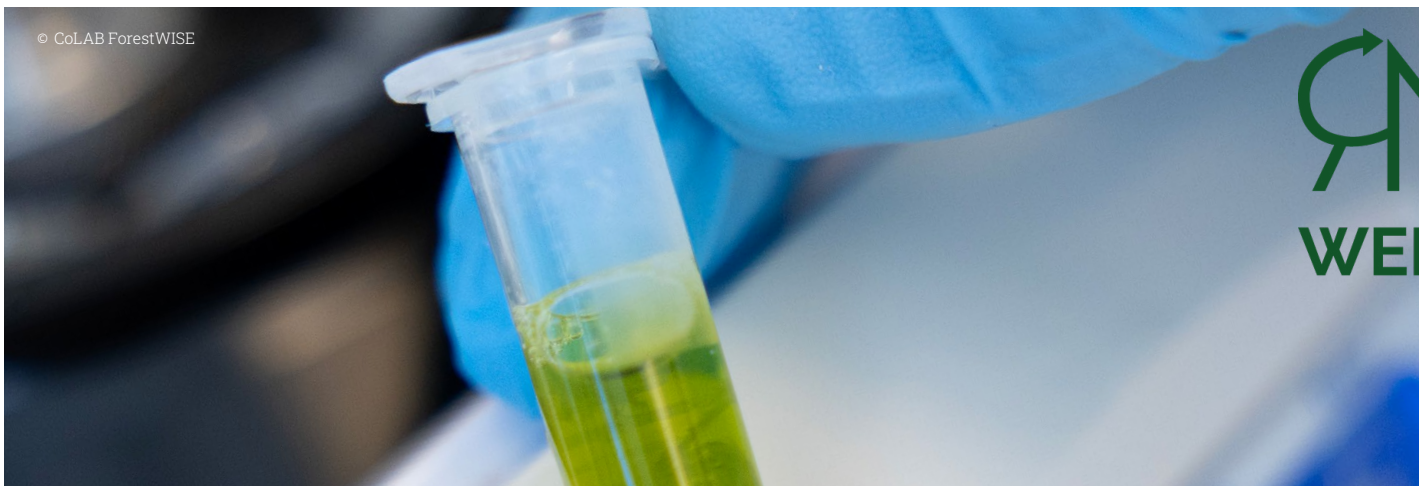
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SOCIAL MEDIA

Our social media channels for the Integrated Project RN21 have the goal of strengthening our relationship with the audience and creating an informal mean of communication. This initiative reflects our commitment to keep all stakeholders updated on the latest developments of the Project, providing a space for closer interactions, sharing valuable information, and creating a community engaged around Natural Resin and our vision for a more sustainable future.

RN 360º PODCAST

Our initiative aims to promote knowledge about Natural Resin and its incredible contribution to a sustainable future. Each episode, approximately five minutes long, is an opportunity to expand your knowledge about this valuable resource. Join us in engaging episodes where we explore the Natural Resin sector and its various applications.

You can find all the episodes at https://rn21.forestwise.pt/podcast

WEBINAR RN21

Each webinar offers insights from experts, researchers, and professionals in the field on the importance of natural resin, its properties and applications, traditional and innovative extraction techniques, among others. Join us on this exciting journey of learning, discovery, and innovation as we unveil the economic potential, forest sustainability, and entrepreneurial opportunities driven by Natural Resin.

You can review all the webinars at https://rn21.forestwise.pt/webinar


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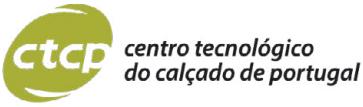
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