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december **2025**

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Print Run
750 copies

Frequency
Biannual

ISSN
2975-9595

The RN21 Integrated Project - Innovation in the Natural Resin Sector for the Reinforcement of the National Bioeconomy, is co-financed by the Environmental Fund through Component 12 - Promotion of Sustainable Bioeconomy (Investment TC-C12-i01 - Sustainable Bioeconomy No. N.º 01/C12-i01/2021 e N.º 02/C12-i01/2021), European funds allocated to Portugal by the Recovery and Resilience Plan (PRR), under the European Union's (EU) Recovery and Resilience Mechanism (MRR), framed within the Next Generation EU, for the period from 2021 to 2026.

EDITORIAL

In the sixth edition of the Resinae magazine, we reaffirm the importance of Natural Resin as an endogenous and strategic resource for the Portuguese bioeconomy, capable of reconciling economic growth, sustainability and territorial cohesion. In a context where the transition to more sustainable production models is imperative, Natural Resin stands out as a key raw material, responding to the demand for ecological solutions and replacing fossil-based raw materials.

The established presence in adhesives, coatings, paints and glues proves its industrial relevance. The transformation of rosin and turpentine derivatives into higher value-added products demonstrates the versatility of Natural Resin. However, it is in the potential for new markets — from biopolymers to functional solutions for advanced materials — that its strategic value is affirmed, combining technical performance, versatility and biological origin.

In this context, the resin value chain is a structuring asset: it enhances the value of forests and territories, stimulates national production and drives innovation throughout the entire value chain.

The aim is clear: to increase resin production through sustainable forest practices, promote transformation with greater technological intensity and strengthen Natural Resin presence in markets where it replaces fossil-based materials, contributing to the national bioeconomy.

Collaborative innovation is the driving force of this path. When science, technology and industry converge, solutions with higher added value emerge, capable of responding to demanding technical requirements and boosting a greener economy.

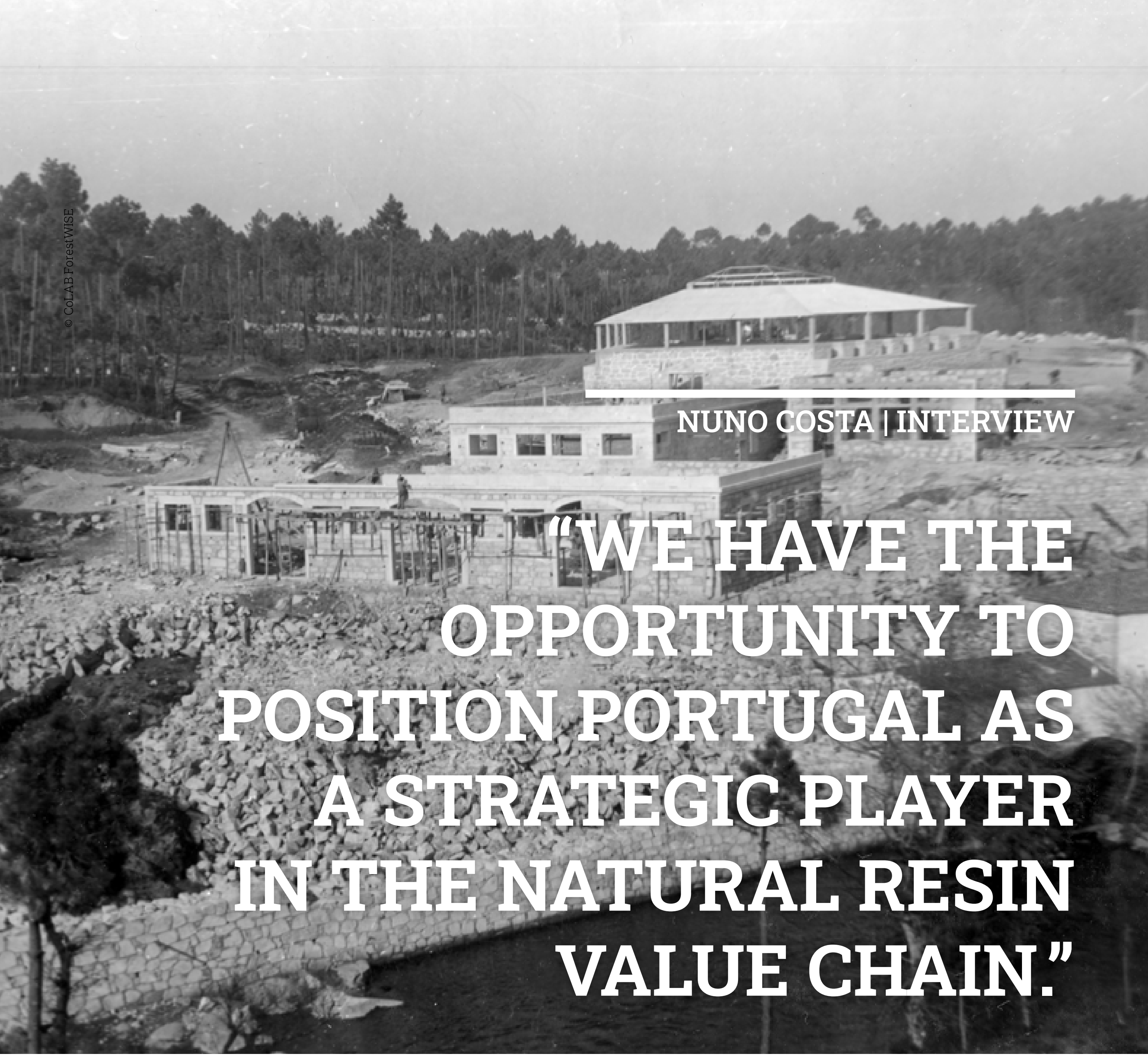
Portugal has, in Natural Resin, a strategic option to build greater resilience and value in forests, generate wealth in the territory and upgrade its industrial base, contributing to decarbonisation targets in Portugal and in the EU.

The advances of RN21 reveal the potential to diversify the uses of this resource, increase scale and integrate new markets, stimulating investment, employment and talent.

The Resinae magazine has helped to reaffirm this value chain, from forest to industry, from science to market, showing that sustainability is now expressed through solutions tailored to new demands, developed in greener industries.

Rogério Rodrigues
Executive board CoLAB ForestWISE

The future of Natural Resin is built on knowledge, cooperation and vision. Over six editions, a shared vision has been consolidated, supported by a wide-reaching communication campaign. The next step is to create a sectoral platform capable of sustaining this dynamic and projecting it forward: a Natural Resin Cluster that brings together companies, research centres and territorial entities, amplifies the impact of knowledge and promotes the production and transformation of Natural Resin for diversified markets. The RN21 consortium will continue to work so that this strategic value chain can assert itself as a European reference in bioeconomy, applied innovation and forest valorisation.



"WE HAVE THE OPPORTUNITY TO POSITION PORTUGAL AS A STRATEGIC PLAYER IN THE NATURAL RESIN VALUE CHAIN."

Nuno Costa, Industrial Director at Eurochemicals, holds a PhD in Chemical Engineering and a postgraduate degree in Operations Management. With nearly two decades of professional experience, he combines a solid industrial background with a close connection to the academic and scientific community.

Eurochemicals operates in the secondary transformation of Natural Resin. Could you share with us what types of products you develop from rosin and how you position yourselves in the market?

Eurochemicals - Pine Rosins Portugal S.A. is dedicated to the production of rosin derivatives and offers product alternatives for different market segments, including adhesives, rubber, compounds, paints and varnishes, road marking, and cosmetics. We provide high-performance, state-of-the-art formulated blends and rosin-based resins. Our mission is to transform rosin into high value-added solutions for diverse industries, guided by a continuous pursuit of excellence in the development of customized products and solutions that meet the needs of our clients and the market.

Our market positioning relies on a unique combination of accumulated experience, specialized knowledge, and a culture of continuous innovation. We strongly invest in R&D, collaborating with clients and partners to develop tailored, sustainable, and technologically advanced solutions.

Eurochemicals stands out not only for the quality and versatility of its products but also for its ability to anticipate trends and follow the evolution of global markets. We are a customer- and future-oriented company, with an agile structure, a collaborative spirit, and a permanent commitment to excellence and sustainability, actively contributing to the strengthening and modernization of the Natural Resin industry.

Founded in 1971, Eurochemicals is one of the oldest secondary transformation companies still operating in Portugal. In your opinion, what are the main changes the sector has experienced over the past decades?

Eurochemicals traces its origins to the *Sociedade Portuguesa de Resina Dismutada, S.A.*, founded in 1970 by the International Synthetic Rubber Company Ltd (UK), which began industrial activity in 1971. In 1983, it became part of the Italian ENI group until 2011, when it transitioned to Portuguese ownership and adopted the name Eurochemicals Portugal S.A. After a restructuring and diversification of its portfolio, Pine Rosins was established in 2016, a joint venture between Eurochemicals and Kemi, the result of a true business symbiosis.

In the 1970s and 1980s, Portugal was one of the world's largest producers and exporters of resin, reaching 140.000 tons and ranking as the second-largest exporter globally. Initially, Eurochemicals was also engaged in resin tapping and distillation activities. However, due to the gradual decline of the national resin tapping industry in the 1990s, the company redirected its investment towards secondary processing, specializing in the production of rosin derivatives.

The early 2000s were marked by increasing environmental concerns, and Eurochemicals responded by installing and operating an innovative Regenerative Thermal Oxidation system for the combustion of volatile organic compounds from its operations.

In recent years, the industrial sector has faced a highly volatile environment shaped by global economic crises, geopolitical instability, and significant disruptions in supply chains, which have exerted strong pressure on prices. These factors have tested the resilience of companies, demanding constant adaptability, innovation, and enhanced competitiveness, particularly in a market increasingly driven by environmental, regulatory, and sustainability requirements.

The modernization of production processes and the qualification of personnel, supported by a balance between practical experience and scientific knowledge, along with the growing digitalization of operations, have brought new challenges, requiring companies to strengthen their capacity for adaptation and rapid response in a more agile, dynamic, and uncertain market.

More recently, sustainability and bioeconomy have become the key drivers of innovation, and Natural Resin has assumed a prominent role in the transition toward a bio-based economy, proving to be a real alternative to fossil-based raw materials in multiple industrial applications.

Eurochemicals is a clear example of how the Portuguese Natural Resin industry has remained resilient, continuously reinventing itself over the decades.
Today, more than ever, we have the opportunity to position Portugal as a strategic player in the international Natural Resin value chain, built on technical expertise, environmental responsibility, and innovation.

Within the RN21 Integrated Project, Eurochemicals is participating in the development of new rosin-based biopolymers for materials and packaging. What future applications do you foresee for these solutions?
The rosin-based biopolymers developed within the RN21 Integrated Project show great potential to partially or fully replace fossil-based polymers, serving as a direct alternative to conventional polymers such as EVA (Ethylene-Vinyl Acetate), EBA (Ethylene-Butyl Acrylate), SIS (Styrene-Isoprene-Styrene) and SBS (Styrene-Butadiene-Styrene).
These biopolymers offer a wide range of applications, including coatings, hot-melt adhesives for packaging, and modifiers for other materials. Their excellent mechanical properties, high flexibility, elasticity, and elongation, combined with good tensile strength and resistance to rupture, as well as the possibility to tailor adhesion levels to specific end-use requirements, open the door to new applications for these biopolymers, overcoming the current technological limitations.

In your view, what are the main barriers to market entry for new materials based on Natural Resin?
The main challenges to enter new markets lie in both cost and the intrinsic properties of resin itself, particularly its high rigidity and low toughness, which limit its use in applications subject to impact or deformation. However, the market is showing increasing concern for sustainability and a greater willingness to adopt solutions that promote circular economy principles. There is a growing readiness to assume an additional cost in exchange for reducing environmental impact. From a technical standpoint, the excellent mechanical properties of the biopolymers developed under the Integrated Project RN21 leave us optimistic about their potential to open new markets and applications.

How do you envision the future of the Natural Resin value chain, and what role can companies like Eurochemicals play in strengthening this market?
The future of the Natural Resin value chain holds enormous potential, driven by increasing environmental awareness and the global transition towards a more sustainable economy.
This future is already being built today, through greater integration among the various actors across the chain,

Nuno Alves da Costa
Industrial Director at Eurochemicals

from sustainable forest production to the primary and secondary transformation industries, downstream sectors, and the vital contribution of universities and research centers, which have been key to generate knowledge and prosperity within this sector.
The collaborative network that has been established gives us confidence that Portugal has all the potential to stand out internationally in this field. Our capacity for innovation, research, and development is constantly being challenged. We know that to thrive in a demanding and rapidly evolving market, it is essential to strengthen strategic and collaborative partnerships. These partnerships will be crucial for expanding and growing in the market, reinforcing Portugal's position as an international reference in this sector and creating value for all stakeholders.

More recently, sustainability and bioeconomy have become the key drivers of innovation, and Natural Resin has assumed a prominent role in the transition toward a bio-based economy, proving to be a real alternative to fossil-based raw materials in multiple industrial applications.

Finally, what legacy do you believe the RN21 project will leave for the modernization and valorization of the Natural Resin value chain?

The RN21 Project represents a milestone in the modernization and promotion of sustainability within the Natural Resin value chain in Portugal. By integrating the entire value chain, from the forest to the end consumer, and bringing together 36 entities from across all segments of the sector, it has fostered an unprecedented spirit of collaboration. By overcoming competitive barriers and promoting partnerships among organizations, the RN21 Project has demonstrated that strategic cooperation creates synergies that enhance the entire value chain. This alignment of efforts and objectives has established a solid foundation for a more competitive, innovative, and sustainable ecosystem, benefiting all stakeholders. The true legacy of the RN21 Project lies in the collaborative culture it has cultivated and the partnerships it has helped to strengthen. These will continue to generate positive impacts well beyond the project's lifetime, contributing decisively to reinforcing and valorizing Natural Resin as a strategic resource for the country.

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PAULO NOVO | INTERVIEW

"THESE INNOVATIONS AIM TO MAKE RESIN TAPPING MORE SUSTAINABLE AND APPEALING TO NEW GENERATIONS OF FORESTRY PROFESSIONALS."

Paulo Novo, Professor at ESTG (School of Technology and Management) and researcher at CDRSP (Centre for Rapid and Sustainable Product Development), Politécnico de Leiria,.

How did the geographical proximity to the Leiria Pine Forest and the region's resin-tapping tradition motivate IPLeiria's participation in the Integrated Project RN21?

The location of the Politécnico de Leiria,, in Portugal's central region and in close proximity to the historic Leiria Pine Forest (Pinhal de Leiria), was a decisive factor in our integration into the Integrated Project RN21. This area is well known for its strong resin-tapping tradition, with roots that go back several generations of forest workers. Even today, the Leiria Pine Forest represents one of the largest pine areas in Portugal with productive potential for the extraction of Natural Resin. This geographical proximity allows us not only to directly observe the challenges faced by resin tappers but also to collaborate actively and continuously with local stakeholders. The connection to the territory facilitates the implementation of innovative solutions adapted to the concrete realities of Portuguese forests and promotes a more integrated approach between scientific research and field practice.

How is IPLeiria contributing to innovation in resin tapping within the scope of the Integrated Project RN21?

Our contribution to the RN21 project focuses on two main projects, particularly project I2.M2, dedicated to the research and development of new resin-tapping techniques. We are working on the development of a closed resin collection system, which represents a significant advancement compared to traditional methods. This system prevents contamination by external particles such as leaves or insects and reduces the evaporation of volatile components with high economic value, such as turpentine. In parallel, we are contributing to the improvement of the *descarrasque* process — the removal of bark before resin extraction using the traditional method. In collaboration with the association Resipinus, we are involved in developing a mechanized cutting head that will replace the manual tool. This equipment will enable a better attachment of the closed resin collection system to the tree, making the process faster, safer, and more ergonomic. These innovations aim not only to increase the efficiency of the activity but also to make it more sustainable and attractive to new generations of forestry professionals.

Beyond the forestry component, IPLeiria is also involved in the project dedicated to the valorization of Natural Resin for food and agricultural applications. What solutions are being explored for its use in food packaging?

Yes, IPLeiria is also participating in project II2.M1A, in partnership with CENTI and KEMI, which aims to explore new applications for Natural Resin beyond the forestry sector. One of the most promising solutions involves incorporating rosin — a resin derivative — into films for food packaging, particularly for meat products. These films are designed to release, in a controlled manner, a molecule with antioxidant

The closed resin collection system we are developing not only improves the quality of the final product but will also allow the recycling of collection bags through a dedicated cleaning system currently under development.


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Paulo Novo
Professor at ESTG – Polytechnic of Leiria and researcher at CDRSP.

properties, thereby contributing to food preservation and extending shelf life. This approach represents a significant innovation by combining the valorization of an endogenous natural resource with a concrete response to a specific need in the food industry. Moreover, it promotes the replacement of conventional materials with biodegradable solutions aligned with the principles of the circular economy and environmental sustainability.

Sustainability is a cross-cutting concern within the Integrated Project RN21. How do the products under development aim to address this challenge?

Sustainability is one of the fundamental pillars of the Integrated Project RN21, present at every stage of product and process development. The closed resin collection system we are developing not only improves the quality of the final product but will also allow the recycling of collection bags through a dedicated cleaning system currently under development. This solution promotes the circular economy and significantly reduces material waste. In addition, by encouraging national resin production, we help reduce dependence on imports, which directly impacts the carbon footprint associated with international transport. Another important aspect is the continuous presence of resin tappers in the forest, who play a key role in monitoring forest areas, assisting in the early detection of fires and the preservation of ecosystems. Thus, the products and technologies developed under RN21 seek to balance innovation, efficiency, and environmental responsibility.

In your opinion, is the Natural Resin sector receptive to technological innovation? What still needs to be done to bring scientific knowledge closer to field practice?
The Natural Resin sector has shown an increasing openness to technological innovation, as demonstrated by the creation of the RN21 consortium, which brings together companies, higher education institutions, and research centers in a collaborative effort. The results already achieved, such as the innovative resin collection system, the mechanized cutting head, and the development of new applications incorporating Natural Resin components for food packaging, are concrete examples of this progress.
However, there are still challenges to overcome. It is necessary to strengthen the technical training of field professionals to ensure they are prepared to use the new tools and processes. Furthermore, effective technology transfer mechanisms must be established to enable smooth communication between researchers, industry, and resin tappers. Scientific solutions must be economically viable, easy to implement, and adapted to the real conditions of Portuguese forests. Conducting practical demonstrations and pilot projects can be an effective strategy to accelerate the connection between science and practice.

Finally, looking to the future, what impact would you like these developments to have on the Natural Resin sector?
Our goal is for the developments promoted by the Integrated Project RN21 to contribute to the genuine revitalization of the Natural Resin sector in Portugal. We hope they will significantly increase national production, create qualified jobs in rural areas, and help retain populations in low-density territories.
The modernization of the value chain, through the introduction of innovative technologies and sustainable practices, could make the sector more competitive at an international level. Furthermore, we would like Portugal to establish itself as an example of forest-based bioeconomy, capable of generating high value-added products from renewable natural resources. Above all, we want the knowledge generated within the project to effectively reach the field — transforming the lives of sector professionals and contributing to the valorization of Portuguese forests as a strategic national asset.

This approach represents a significant innovation by combining the valorization of an endogenous natural resource with a concrete response to a specific need in the food industry.

ISABEL LIMA | OPINION

ROSIN: A NATURAL RESIN LEADING THE GREEN TRANSITION IN THE ADHESIVES INDUSTRY

The incorporation of renewable, rosin-derived products into adhesives marks a decisive step toward more sustainable chemical processes, reducing dependence on fossil-based raw materials and promoting production cycles aligned with the circular economy.

The global adhesives industry is currently undergoing a profound transformation, facing a dual challenge that demands both balance and foresight: on one hand, ensuring that products maintain the high technical performance required by different industrial sectors; on the other, reducing dependence on fossil-based raw materials, in line with growing regulatory and social pressure for more sustainable solutions. In this changing context, rosin, a subproduct of Natural Resin derived from pine trees, stands out as a promising and strategic resource, one capable of combining performance, innovation, and environmental responsibility.

Derived from pine resin, rosin perfectly aligns with CIPADE's core values and principles: environmental responsibility, continuous innovation, and the pursuit of excellence. This renewable and widely available natural resource represents a real and viable alternative to fossil-based derivatives traditionally used in the chemical industry. Its use not only reduces the environmental footprint but is also fully consistent with the principles of the circular economy, promoting more responsible and sustainable production cycles. By incorporating rosin into its adhesive formulations, CIPADE materializes its commitment to green, efficient, and competitive solutions, strengthening its position as a benchmark in the sector.


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Isabel Lima
Administrator at CIPADE Industry and Research of Adhesive Products, S.A.

A Green Alternative

Of renewable origin, rosin stands out for its low environmental impact, fitting perfectly within decarbonization targets and circular economy principles. It also offers competitive advantages: abundance, cost-effectiveness, and ease of processing.

Functionality with Performance

Thanks to the resin acids in its composition, rosin provides tackiness, viscosity, and compatibility with various polymers, including biopolymers. This enables the development of high-performance adhesives for sectors such as footwear and leather goods.
CIPADE's focus on rigorous research and development has resulted in high-quality products where rosin contributes to adhesion, stability, and versatility.

Challenges and Innovation

Through participation in collaborative initiatives such as the Integrated Project RN21, CIPADE is leading the search for new rosin applications through research and product customization. Its commitment to innovation and technical support after sales reinforces client trust and ensures the continuous evolution of its solutions.
However, some limitations still exist in rosin-based adhesive formulations, namely price (when compared to fossil-based resins), yellowish color, characteristic odor, and lower thermal stability. Nevertheless, research and chemical modification have already demonstrated the potential to overcome these challenges, broadening rosin's range of applications.

Market Trends

With consumers and regulators increasingly demanding greener solutions, the use of rosin can now be positioned as a competitive strategy. Its adoption represents not only a responsible choice but also a strategic move toward leadership in the sustainable adhesives market.

Vision for the Future

In a context shaped by increasingly stringent environmental regulations and a global market that values low-impact solutions, investing in rosin represents a solid and consistent path forward. The sustained use of this raw material is expected to grant companies both technical and commercial leadership while contributing to a more responsible, resilient, and innovative economic model.
The incorporation of renewable, rosin-derived products into adhesives marks a decisive step toward more sustainable chemical processes, reducing dependence on fossil-based raw materials and promoting production cycles aligned with the circular economy. However, this is only the first of many steps that CIPADE intends to take over time, reinforcing a continuous journey of sustainable innovation that extends well beyond rosin itself. For CIPADE, working with this type of resin means standing at the forefront of the industry's ecological transition, committed not only to developing sustainable solutions but also to positively influencing the entire value chain. Thus, rosin should not be seen merely as an ecological alternative, it is a strategic, intelligent, and effective choice that reflects CIPADE's forward-looking vision and the national chemical sector's contribution to a more balanced and sustainable economy.

JORGE SOUSA | OPINION

THE FUTURE OF MARITIME PINE: CERTIFICATION, INTEGRATED MANAGEMENT, AND SUPPORT MEASURES

The maritime pine (*Pinus pinaster*) is one of Portugal's most emblematic forest species and plays an irreplaceable role in the rural economy, particularly in sustaining populations in low-density territories, protecting soils, and mitigating climate change. For decades, it was the tree that provided timber, resin, and income to thousands of families, serving as one of the silent drivers of Portugal's forest and rural economy.

However, its management has long faced numerous challenges: the pine wood nematode, fragmented land ownership, increased vulnerability to more intense and frequent wildfires, lack of coordination across the value chain, and the difficulty of ensuring a stable and competitive economic return from timber and Natural Resin[1].

At a time when forests are called upon to respond to the major challenges of sustainability and bioeconomy, it has become urgent to rethink the role of the maritime pine. It is not enough to lament the past or the decline in prominence of this species, we must look to the future and mobilize concrete tools that can restore vitality and profitability to these forest areas.

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Forest Certification: Credibility and Value Creation

Among the mechanisms available to enhance the value of forest products, certification of sustainable forest management (SFM) stands out for its growing impact. In a globalized market where consumers are increasingly attentive to product origin and environmental practices, certification acts as a genuine seal of trust. It ensures that forests are managed in a sustainable, transparent, and responsible way, thereby increasing the credibility of the entire value chain.

In the case of maritime pine and Natural Resin, investing in certification can mark a turning point. By opening access to more demanding, higher-value markets, certification can position Portugal as a preferred supplier of raw materials and strengthen the link between forests and industry. Forest certification contributes significantly to reduce both economic and environmental losses, while promoting sustainability, efficiency, and resilience in Portuguese forest management[2]. For forest owners and managers, it is also a clear incentive to align management practices with international standards, benefiting from the economic value that results from such recognition. This approach can help integrate maritime pine into the bioeconomy value chains of Europe, strengthening the competitiveness of products such as wood and resin.

In parallel with the certification of sustainable forest management, product valorization can also be achieved through the creation of brands such as Resinae®, officially launched in January 2024 during the *Resinae Ignite* event under the Integrated Project RN21. Created to promote the value of Natural Resin from *P. pinaster*, Resinae® represents quality, traceability, and environmental commitment, reinforced by international FSC® and/or PEFC® certification[4].

Collective Management: Overcoming Fragmentation

One of the greatest barriers to effective forest management is fragmented land ownership, particularly in the central and northern regions of Portugal. Small plots, often abandoned or lacking technical supervision, make forest profitability unfeasible and leave landscapes more vulnerable to wildfire.

The 6th National Forest Inventory (IFN6) by ICNF reveals that only 11% of the maritime pine area consists of stands larger than 50 hectares, while 69% is divided into stands smaller than 10 hectares — a level of territorial fragmentation that seriously hinders effective management and forest sustainability[5].

Collective management emerges as a clear response to this problem. By bringing together landowners under shared technical coordination, it becomes possible to achieve economies of scale, reduce costs, share resources, and attract investment. More than an option, it should be regarded as an essential condition for the long-term sustainability of the sector.

Ongoing initiatives led by Forest Associations — such as the Joint Management Units (UGC) promoted by the Organização Florestal Atlantis (OFA) and the Grouped Forest Areas (AFA) project promoted by the Associação Florestal do Baixo Vouga (AFBV) — demonstrate that, when leadership and trust are in place, results translate into more fire-resilient areas, higher productivity, and a greater capacity to access public funding.

Public Support as a Lever for Transformation

Execution reports from the PDR2020 program up to 2023 show that the Alentejo and Ribatejo regions, including Lezíria and Médio Tejo, accounted for 47% of the contracted funding, while much of the small-scale forest area north of the Tagus received only residual support[6]. Although this paradigm has started to shift in recent years, it is essential to reinforce this trend through stronger and better-targeted investment in the most vulnerable territories.

Public support, both from EU and national sources, has played a crucial role as a true lever for transformation, enabling the financing of structural interventions such as fuel management, pest and disease prevention and control, rehabilitation of degraded areas, and the introduction of innovative techniques, such as genetic improvement, to enhance productivity and the quality of products and by-products derived from maritime pine.

However, it is important to stress that financial incentives alone are not enough. Support measures must be designed with continuity, stability, and simplification in mind. Forest owners and producers need predictability to plan in the medium term, not sporadic incentives that trigger temporary investment peaks without ensuring sustainable management. In this context, the creation of framework agreements or program contracts could represent an innovative and structuring solution, allowing the combination of public and private resources in a long-term commitment to the valorization of maritime pine and its by-products, especially Natural Resin[7].

Capitalizing on Skilled Labor and Dignifying the Profession

One of the sector's most critical challenges is the shortage of qualified labor. The aging of the workforce, combined with the difficulty in recruiting new forest operators and technicians, due to the low economic and social recognition of the profession, has had a significant impact on both the business fabric and day-to-day forest management.

Jorge Sousa
Technical coordinator at OFA
Organização Floresta Atlantis

Generational renewal in the forestry sector remains a major concern. For the 2025/2026 academic year, 60 openings were offered in Forestry Engineering programs across three Portuguese higher education institutions, but only 13 were filled, corresponding to an occupancy rate of 22%[8]. These figures confirm the low attractiveness of forestry careers among young people in Portugal and underscore the urgent need to rethink communication and outreach strategies to enhance the social, economic, and environmental value of forestry professions.

It is crucial to invest in training, requalification, and, above all, in the dignification of these professions. A robust and innovative forestry sector can only be consolidated if young people are encouraged to build strong, respected careers in forestry. This calls for national campaigns that highlight the essential contribution of forestry professionals, programs that connect schools and universities to the sector, and concrete incentives for new generations to establish themselves in forestry.

Without skilled people to design, plan, implement, and execute, it will be impossible to achieve the ultimate goal: a resilient, productive, biodiverse, and socially attractive forest.

“The forest must become appealing not only as a natural and economic system but also as a professional life project, a space for technological innovation, green entrepreneurship, and personal and collective fulfillment.”

A Strong Sector for New Challenges

In a world undergoing rapid climate, energy, and economic transition, forests are expected to play multiple roles: storing carbon, providing clean energy, preserving biodiversity, creating jobs, and revitalizing rural territories. Maritime pine, due to its adaptability and the value of its by-products, can and should be part of this equation. However, this will only be possible if there is a clear strategic vision, strong cooperation among stakeholders, and a firm commitment to innovation.

The combination of public support, sustainable forest management certification, and integrated management is not merely a collection of measures, it represents a pathway to restoring dignity and a future to a species that has shaped Portugal’s landscape and can once again become a reference in the European bioeconomy. This requires coordination among landowners, technicians, and public and private entities but presents a unique opportunity to turn challenges into solutions, ensuring that maritime pine is not a relic of the past but a vital resource for the future.

To truly strengthen maritime pine, we must view the forest as a living, multifunctional, and strategic system. Support schemes, certification, and integrated management are only tools, the essential element is the collective ability to use them to transform vision into reality, creating a more sustainable, innovative and competitive forest that serves society and the bioeconomy.

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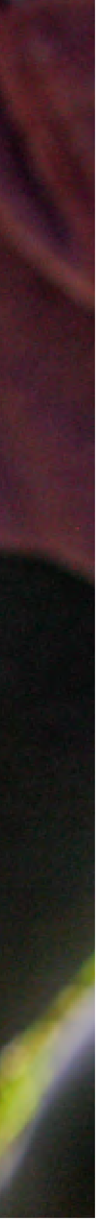
GENETIC BREEDING FOR A MORE PRODUCTIVE AND SUSTAINABLE FOREST

Forest trees play a central role in ecosystems, ensuring, among other functions, the maintenance of biodiversity, soil protection, regulation of the hydrological cycle, and carbon sequestration. At the same time, they are an essential source of raw materials such as wood, cork, resin, and other non-wood forest products that have made a significant contribution to the economy and job creation. In addition to the environmental challenges that these organisms naturally face throughout their often extremely long life cycles, such as extreme weather events, pests, and diseases, forests are currently under increasing pressure. Climate change, often associated with the introduction of exotic pathogens and invasive species, disrupts ecosystem balance and threatens biodiversity. These pressures affect tree growth dynamics and interactions with other organisms, making forest systems more vulnerable to different types of stress, both biotic and abiotic. Such changes often result in a decline in the productivity and quality of raw materials used by the industry. In this context, there is growing interest in improving specific traits associated with productivity and resilience to stress factors.



What is Genetic Improvement?

For thousands of years, humans have sought to obtain plants and animals that are more productive, resilient, or exhibit other desirable traits for human use, from food production to various other applications. This process began through the selection of individuals showing favorable performance among populations with natural variability in the traits of interest, particularly in species of agronomic importance. Crossing selected individuals, followed by successive cycles of selection and crossing, made it possible to combine in the offspring the most valued parental traits. This process remains the foundation of genetic improvement programs today (Figure 1). However, advances in several scientific fields over recent decades have made it possible to carry out this process in a more informed, rapid, and efficient way.

Quantitative genetics has provided tools to estimate the heritability of traits and predict the expected gains in each selection cycle. By determining the proportion of variation observed in each trait that is explained by genetic factors, and can therefore be passed on to offspring, it is possible to distinguish variation due to the environment from truly heritable variation, thus guiding the choice of individuals to be used as parents. The prediction of expected gains in each selection cycle, based on appropriate statistical models, enables the planning of crossings in a more efficient and precise way, maximizing phenotypic improvements over generations.

A more detailed understanding of the genetic heritage of target species for breeding has made it possible to identify and use DNA markers, specific locations in the

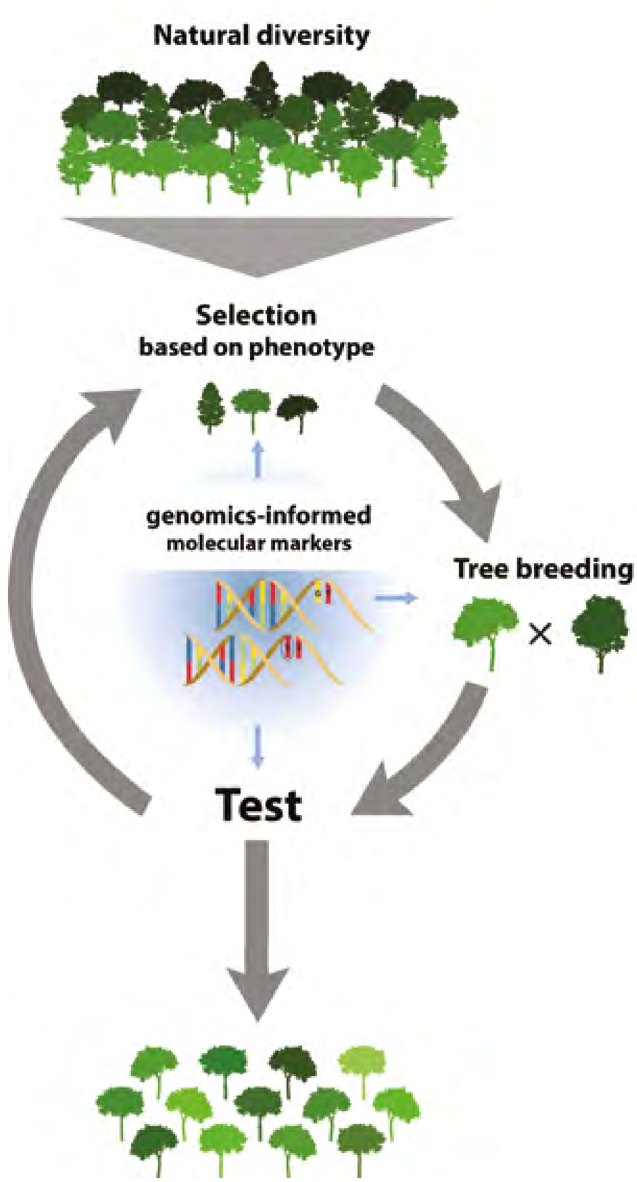


Figure 1 - Illustrative diagram of genetic improvement.

DNA that vary between individuals and can be easily detected in the laboratory. Today, with advances in genomics and the ability to sequence entire genomes, combined with precise large-scale quantification of phenotypic traits, it is possible to identify DNA markers associated with traits of interest and their performance. Thanks to this approach, and since each individual has a unique set of DNA markers, it has become feasible to evaluate the genetic potential of a tree while still in its juvenile phase. This can be achieved through molecular analysis of small tissue samples, such as leaves, drastically reducing the time required to complete selection cycles, which has traditionally been one of the main constraints in forest breeding due to the longevity of tree species.

Genomics has paved the way not only for marker-assisted selection but also for genomic selection, which uses thousands of markers distributed across the genome to build highly accurate predictive models, thereby increasing selection efficiency, even for traits with low heritability or strong environmental influence. In practice, genomic tools have the potential to anticipate breeding decisions, optimize crossings, and accelerate the availability of improved materials in species that traditionally require decades of field evaluation before the best genotypes can be selected.

At the same time, molecular biology tools such as genetic editing, already implemented in some forest species, open new perspectives for the direct modification of specific genes related, for example, to wood quality or disease resistance, although this approach still faces regulatory and public acceptance barriers.

In the field, integration with modern silvicultural practices ensures that these innovations go beyond the laboratory. Through networks of clonal trials established in multiple locations, genotypes are tested under different environmental conditions. Vegetative propagation and, in some cases, tissue culture facilitate large-scale multiplication of superior individuals, ensuring that the genetic gains achieved are effectively transferred to plantations.

The Example of Resin Production

If we consider the specific case of resin production in conifers, a raw material used across a wide range of industries, there is evidence that both resin yield and composition are under genetic control in several pine species. In *Pinus pinaster*, recent work in quantitative genetics also points to a strong genetic control of resin production[1], supporting the implementation of a breeding program aimed at optimizing this trait, alongside other characteristics of interest, based on existing natural variability.

The availability of genomic resources in *Pinus pinaster*, particularly knowledge of thousands of DNA markers consisting of single nucleotide polymorphisms (SNPs), also enables the use of genomic tools that take advantage of all the benefits this approach offers. In a first step, it is desirable to ensure the existence of genetic variability within the set of trees that will constitute the base breeding population. This can be rapidly assessed using existing DNA marker sets that characterize each individual. In a second step, when quantitative measures of phenotypic parameters associated with resin production are available, it becomes possible to associate specific markers with individuals exhibiting a characteristic production profile, that is, to determine whether the specific pattern of markers distributed across an individual's genome correlates with its productivity or even with the chemical composition of its resin. This approach is known as a Genome-Wide Association Study (GWAS). If statistically significant associations are obtained, these markers can, after validation, be used to identify individuals with desirable traits through the analysis of a small tissue sample (e.g., needles) from young plants that have not yet reached the productive phase (Figure 2).

Challenges in Forest Tree Breeding

Despite recent advances and multidisciplinary approaches to forest tree breeding, this field still faces limitations related to the biology of these species and the complexity of the ecosystems in which they grow. Among the main challenges is the long duration of life cycles. Even with genomic tools that enable early prediction of genetic potential, there remains a mismatch between the moment of selection and the environmental conditions prevailing when those trees reach maturity. This temporal gap is particularly critical in the context of rapid climate change, where environmental conditions 20 or 30 years from now may differ substantially from those of today.

The maintenance and management of genetic

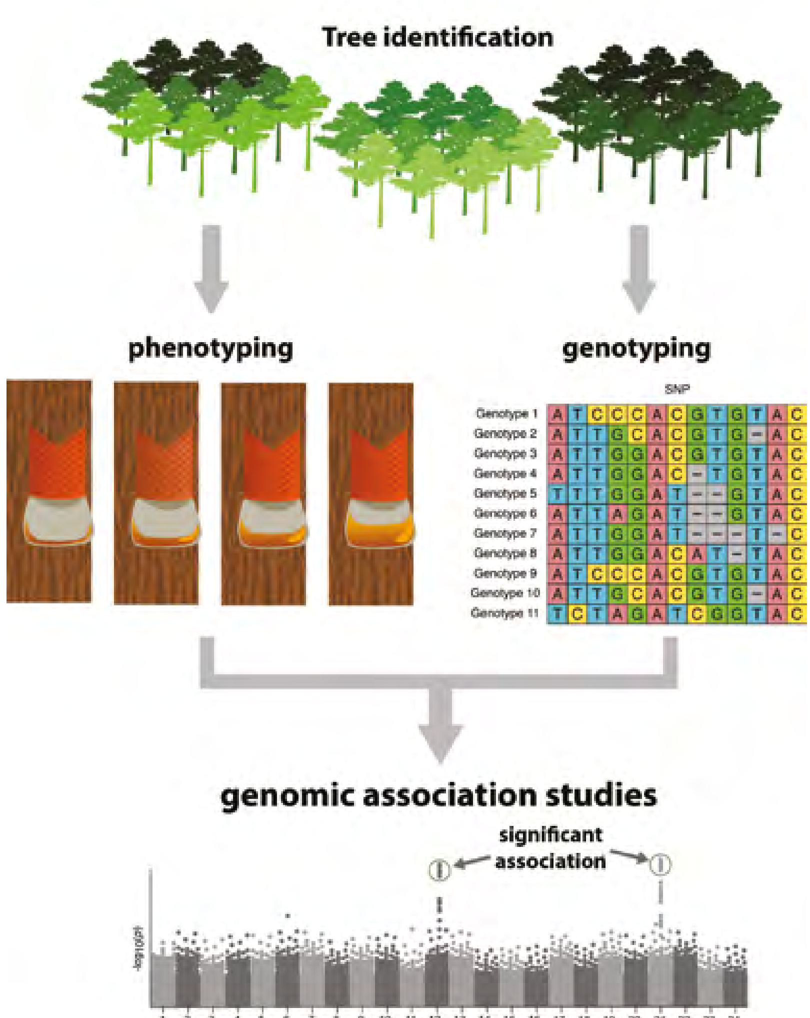


Figure 2 - Potential application of genomics in breeding for resin production.

variability constitutes another key challenge.

A broad genetic base is essential to ensure population resilience to future diseases, pests, and environmental changes. However, repeated selection of a few superior individuals may lead to genetic erosion, reducing diversity and increasing plantation vulnerability.
To mitigate this risk, investment is needed in germplasm banks, in situ and ex situ conservation networks, and breeding strategies that maintain diversity within improvement programs.
It is also crucial to integrate breeding with responsible forest management practices, including appropriate site selection, respect for ecological limits, and preservation of areas with high biodiversity.
Thus, the success of breeding programs also depends on aligning these aspects with land-use planning policies and sustainability goals.
Despite the challenges, the combination of classical knowledge with recent advances in genetics, genomics, and biotechnology has enabled the implementation of increasingly sophisticated forest tree breeding programs. These programs not only contribute to increasing the productivity and quality of forest raw materials but also address global challenges such as climate change, pest and disease pressure, and the need to make forest production more sustainable and competitive.

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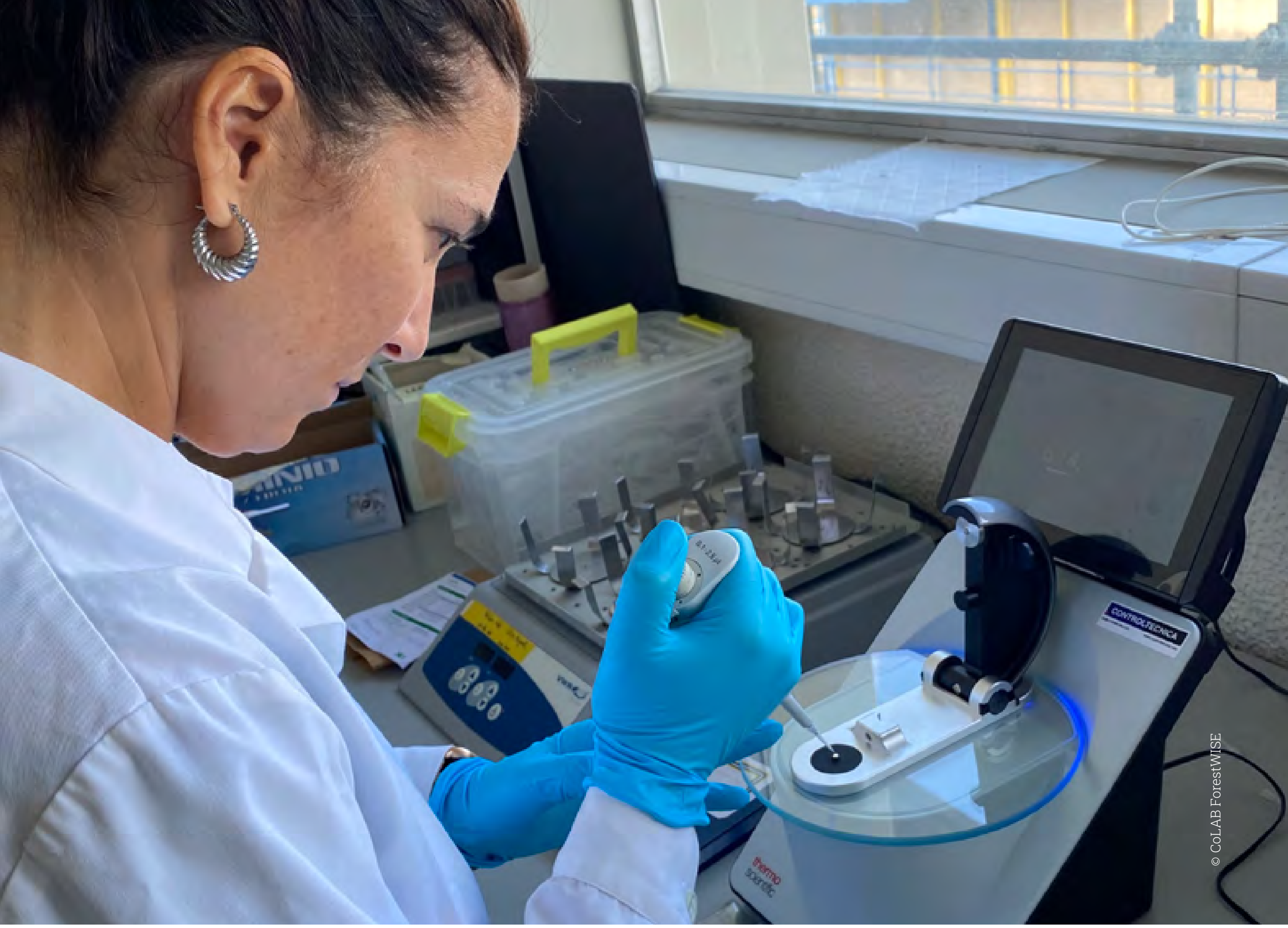

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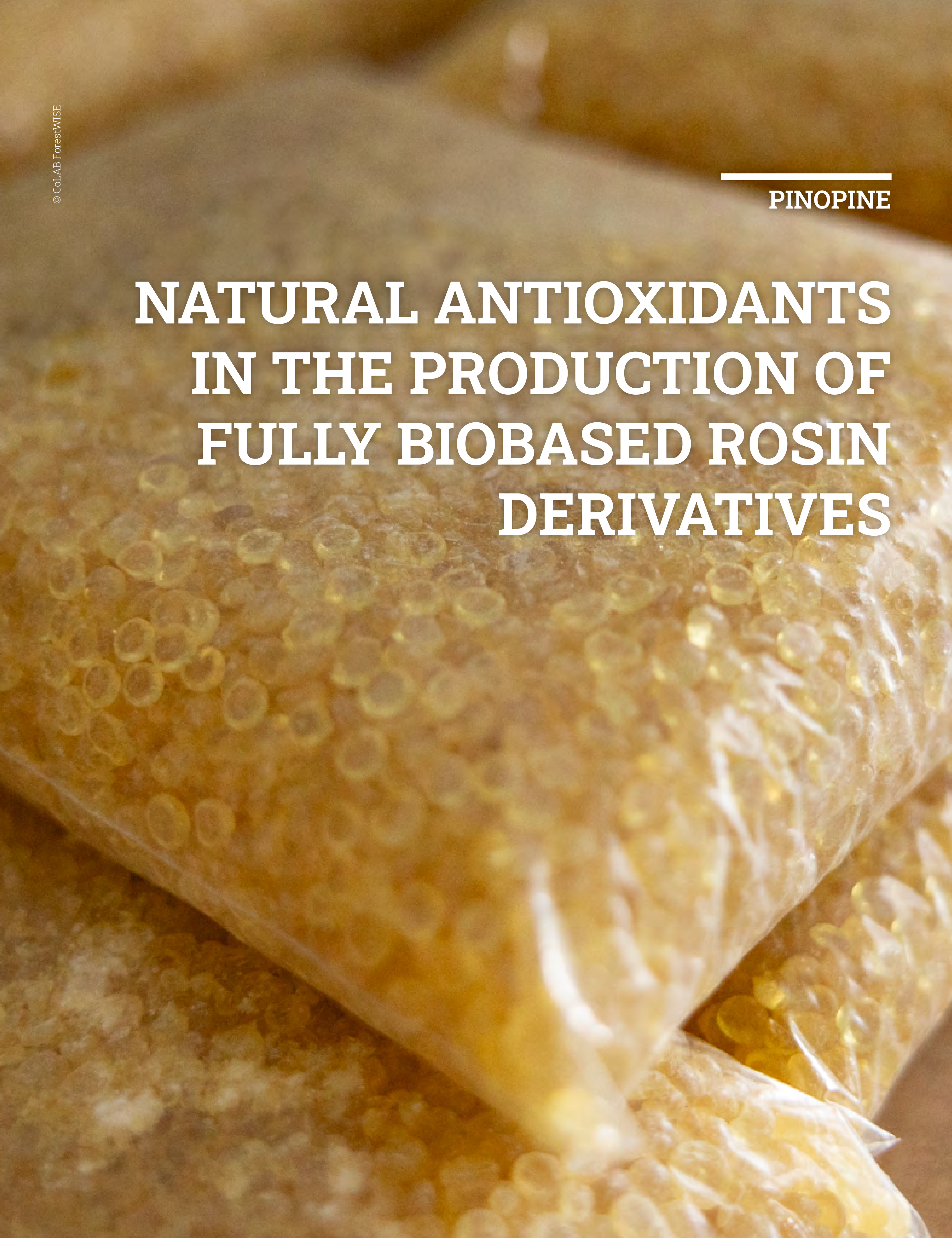
[1] Almeida, P.A.C. Produção de resina no ensaio clonal de pinheiro-bravo na Mata Nacional de Escaroupim. Lisboa: ISA-Universidade de Lisboa, 2023. Dissertação de Mestrado



PINOPINE

NATURAL ANTIOXIDANTS IN THE PRODUCTION OF FULLY BIOBASED ROSIN DERIVATIVES

Rosin, also known as colophony or gum rosin, is a natural product obtained as a solid resinous constituent exuded from the oleoresin of several pine species, with the main sources being *Pinus elliottii*, *Pinus pinaster*, and *Pinus massoniana*. Rosin can have three different designations depending on its origin. Gum rosin is obtained by the distillation of crude gum (collected directly from living resinous trees through vertical incisions in the trunk); wood rosin results from the extraction of resin from the stumps of resinous trees using an organic solvent, followed by distillation; and tall oil rosin, that comes from the distillation of crude tall oil (CTO), which is a by-product of pulp production using the Kraft process.

Although the composition of these three types of rosin differs, all are primarily composed of monocarboxylic diterpenic resin acids, fatty acids, and non-volatile neutral unsaponifiable compounds. The resin acids commonly found include abietic, dehydroabietic, pimaric, isopimaric, communic, palustric, neoabietic, and levopimaric acids (Fig. 1). Among the neutral substances present in rosin, diterpenic alcohols, hydrocarbons, and aldehydes are the most prominent.

Rosin is widely used in various industrial applications, including adhesives, coatings, printing inks, chewing gum, and cosmetics. However, rosin is prone to oxidation, which can lead to material degradation and reduced product performance. The susceptibility of rosin to oxidation, often resulting in yellowing and/or darkening, is one of the main limitations of its use. This limitation is primarily related to the reactivity of the conjugated double-bond system present in abietic-type resin acids, as this molecular structure is highly vulnerable to oxidation reactions in the presence of free radicals, light, and high temperatures (Fig. 1).

To prevent or minimize oxidation and improve rosin stability, various compounds, particularly antioxidants, can be added to the resin. In addition, rosin esterification with other compounds can also be used to enhance its stability. Esterification involves the reaction of rosin with an alcohol to form an ester, reducing its acidity and making it less susceptible to oxidation.

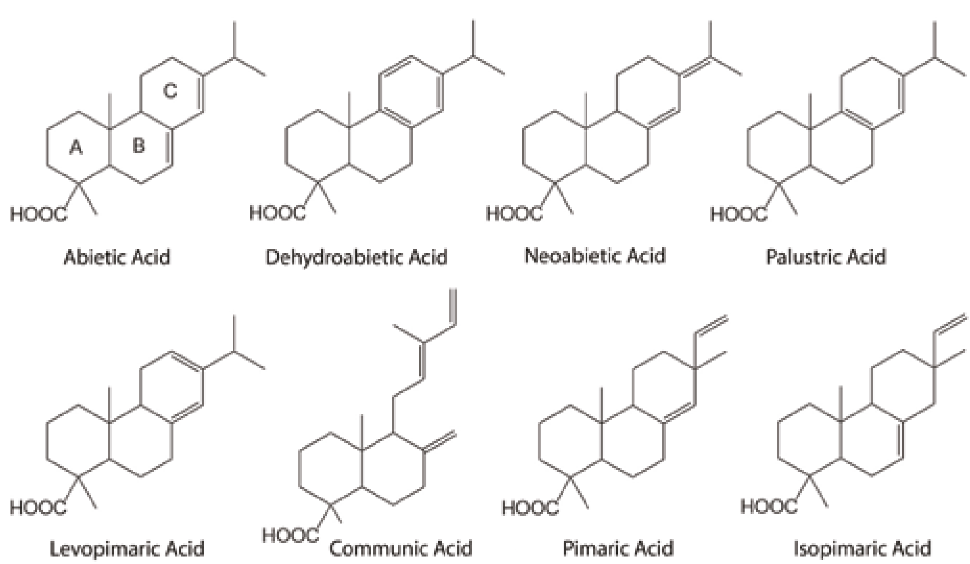


Figure 1 - Resin acids and conjugated double-bond systems susceptible to oxidation.

1. Antioxidants

An antioxidant is a substance capable of preventing or minimizing the oxidative degradation of a material. Oxidation is a chemical process that occurs when a material is exposed to oxygen, UV light, and/or high temperatures, leading to the degradation of its physical and chemical properties. Antioxidants can prevent or slow down this process by inhibiting the formation of free radicals or eliminating free radicals before they can react with the material.

There are two main groups of antioxidants, differentiated by their mechanism of oxidation inhibition: primary and secondary antioxidants.

Primary antioxidants, also known as free-radical scavengers, are generally stereochemically impeded phenolic compounds (Fig. 2), i.e., each hydroxyl (-OH) functional group attached to the phenolic ring is stereochemically hindered by the other groups attached to the neighboring carbons of the same ring. These antioxidants inhibit the formation of free radicals such as peroxy (ROO) or alkoxy (RO) radicals very rapidly, preventing material degradation. Inhibition occurs through the donation of a hydrogen atom from the antioxidant's hydroxyl group to the free radical, resulting in the formation of a stable molecule and preventing further reactions with other molecules. These antioxidants are highly efficient and typically required only in small quantities to neutralize a large number of free radicals.

Examples of synthetic primary antioxidants (Fig. 4) include butylated hydroxytoluene (BHT), butylated hydroxyanisole (BHA), tert-butylhydroquinone (TBHQ),

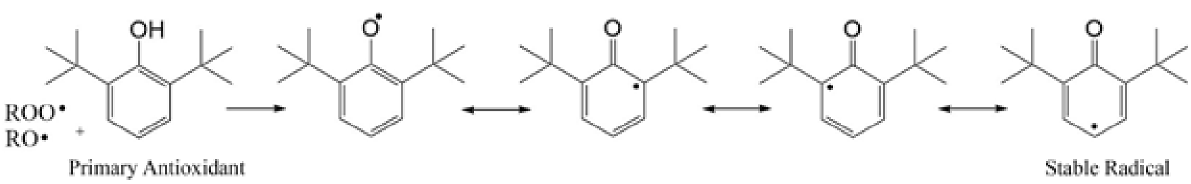


Figure 2 - Free radical deactivation reaction using a primary antioxidant (BHT).

and pentaerythritol tetrakis(3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate) (Irganox 1010).

Secondary antioxidants, also known as peroxide decomposers, act by neutralizing pro-oxidant catalysts. These antioxidants inhibit the formation of peroxides and the decomposition of hydroperoxides into free radicals by donating hydrogen atoms to the radicals, converting them into alcohols or other stable molecules (Fig. 3). Secondary antioxidants are highly effective when used together with primary antioxidants, forming a synergistic relationship that maximizes the oxidative stability of materials. Secondary antioxidants are typically phosphites, such as tris(nonylphenyl) phosphite (TNPP), and thioethers, such as dilauryl thiodipropionate (Fig. 4).

In recent years, numerous synthetic antioxidants have been developed with enhanced stabilization efficiency and multifunctionality. A significant advance has been the design of dual-function molecules—both primary and secondary. Examples include calcium

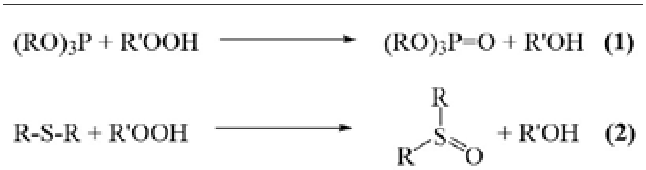


Figure 3 - Peroxide decomposition reactions by two types of secondary antioxidants: (1) phosphites; (2) thioethers.

bis[monoethyl(3,5-di-tert-butyl-4-hydroxybenzyl) phosphonate] (Irganox 1425) and 4,4'-thiobis(2-tert-butyl-5-methylphenol) (Lowinox TBM-6) (Fig. 4). These antioxidants combine the ability to deactivate free radicals with the decomposition of oxidation products, providing more robust protection. Additionally, some antioxidants can chelate pro-oxidant metal ions such as iron and copper, which may catalyze oxidation reactions.

The synthetic antioxidants mentioned above (Fig. 4) are extensively used in the rosin derivatives industry. However, although they play a crucial role in protecting rosin against oxidative degradation, helping to extend its shelf life and preserve desired properties, they are

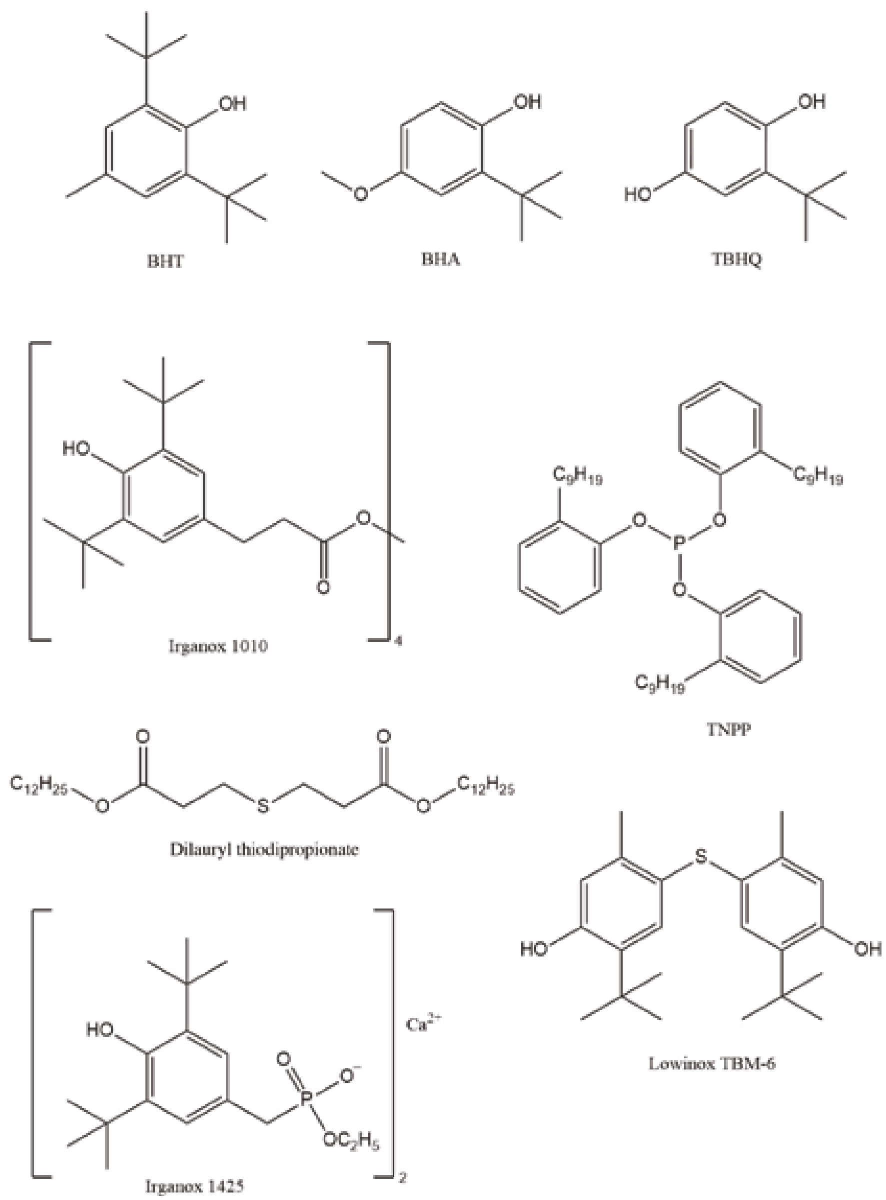


Figure 4 - Examples of common synthetic antioxidants.

often considered carcinogenic or toxic. Therefore, the search for natural compounds with antioxidant properties is of great importance. Examples of natural compounds with antioxidant activity used in various formulations (e.g., foods, cosmetics, pharmaceuticals, polymers, etc.) and potentially applicable to rosin modification include ascorbic acid, vitamin E, and carotenoids, among others. Nevertheless, a major challenge in using these natural antioxidants in rosin modification lies in their low thermal stability, as they tend to degrade at the high temperatures typically employed in the production of rosin derivatives for subsequent applications.

2. Natural Antioxidants

The transition toward natural antioxidants instead of synthetic ones has been a growing trend in many industries and should also be incorporated into those working with rosin processing. The choice of natural antioxidants must ensure that they meet the required thermal stability and performance standards necessary for rosin modification. In addition, natural antioxidants should not interfere with the physical and chemical properties of rosin, nor alter the color or odor of the final product. The price and availability of materials are also extremely important factors. Below are some examples of natural antioxidants with potential for use as antioxidants or stabilizers in rosin modification (Fig. 5).

2.1 Tocopherols

Due to their high concentration in vegetable oils, such as soybean or sunflower oil, tocopherols are among the most common antioxidants found in nature, especially α-tocopherol (vitamin E). As with most phenolic antioxidants, the main mechanism of action of tocopherols is free radical scavenging. It has also been reported that tocopherols can neutralize singlet oxygen through a charge-transfer mechanism.

Two studies comparing α-tocopherol with commercial synthetic antioxidants, Irganox 1076 and BHT, demonstrated that the antioxidant capacity and thermal stability of α-tocopherol were superior to those of Irganox or BHT. However, for long-term stabilization, the efficiency of α-tocopherol was lower than that of Irganox 1076.

2.2 Ascorbic Acid

Ascorbic acid (vitamin C) is commonly used to stabilize beverages, fruits, and vegetables. However, its application is limited by its temperature sensitivity. Ascorbic acid contains four hydroxyl groups capable of donating hydrogen to oxidative systems, scavenging free radicals, neutralizing singlet oxygen, and acting as a reducing agent.

2.3 Gallic Acid

Gallic acid is a polyphenol commonly found in a variety of fruits and vegetables such as grapes, green tea, and tomatoes. As a phenolic compound, gallic acid acts as an antioxidant by neutralizing free radicals and interrupting oxidation reactions that lead to product degradation. Moreover, gallic acid can chelate pro-oxidant metal ions, such as iron, further enhancing its antioxidant performance.

2.4 Caffeic Acid

Caffeic acid contains a catechol unit, which gives it antioxidant activity due to its ability to neutralize free radicals. For example, studies have shown that caffeic acid can improve the stability of pecan nut oil. Moreover, compared with synthetic antioxidants, caffeic acid exhibited better antioxidant performance than BHT and BHA, though weaker than TBHQ.

2.5 Citric Acid

Citric acid is a natural metal chelator found in a wide range of fruits and vegetables. It has been studied as an antioxidant in the production of butter, vegetable oils, and solid fats. Its use in combination with primary antioxidants, such as tocopherols and BHA, has shown synergistic antioxidant activity, mainly due to its metal-chelating potential, which prevents metal-catalyzed oxidation.

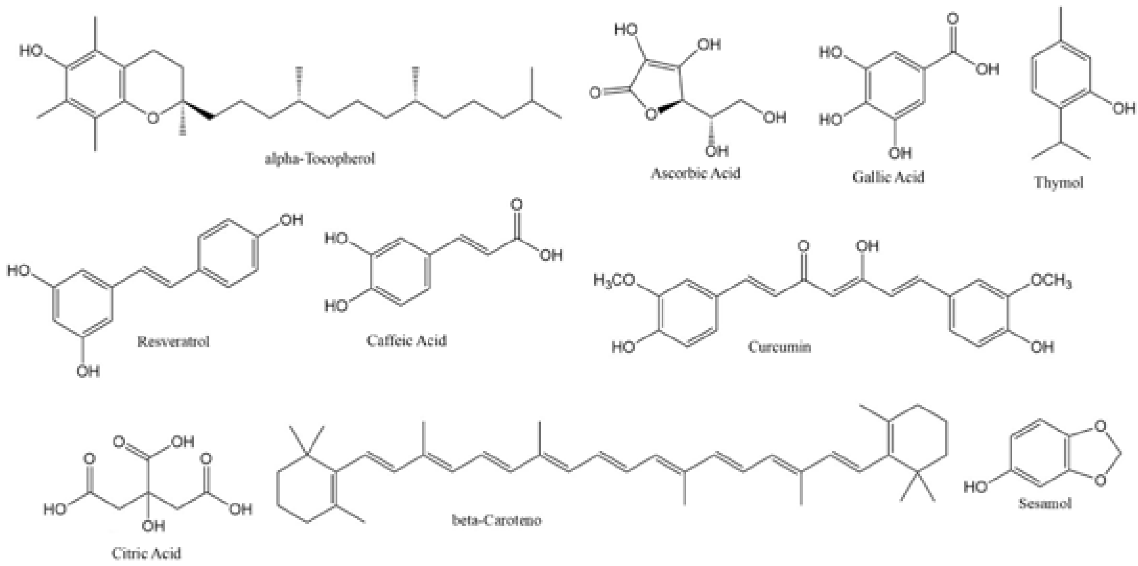


Figure 5 - Examples of natural antioxidants.

2.6 Carotenoids

Carotenoids are naturally occurring yellow, orange, and red pigments found in several fruits and vegetables. Examples include β-carotene, lutein, lycopene, astaxanthin, and canthaxanthin. These compounds are considered secondary antioxidants due to the presence of a long chain of conjugated double bonds, which enables them to scavenge free radicals and neutralize singlet oxygen and peroxyl radicals. For example, studies have shown that astaxanthin is 54 times more potent than β-carotene, 65 times stronger than vitamin C, and 500 times more active than vitamin E or coenzyme Q10 in radical scavenging activity.

2.7 Curcumin

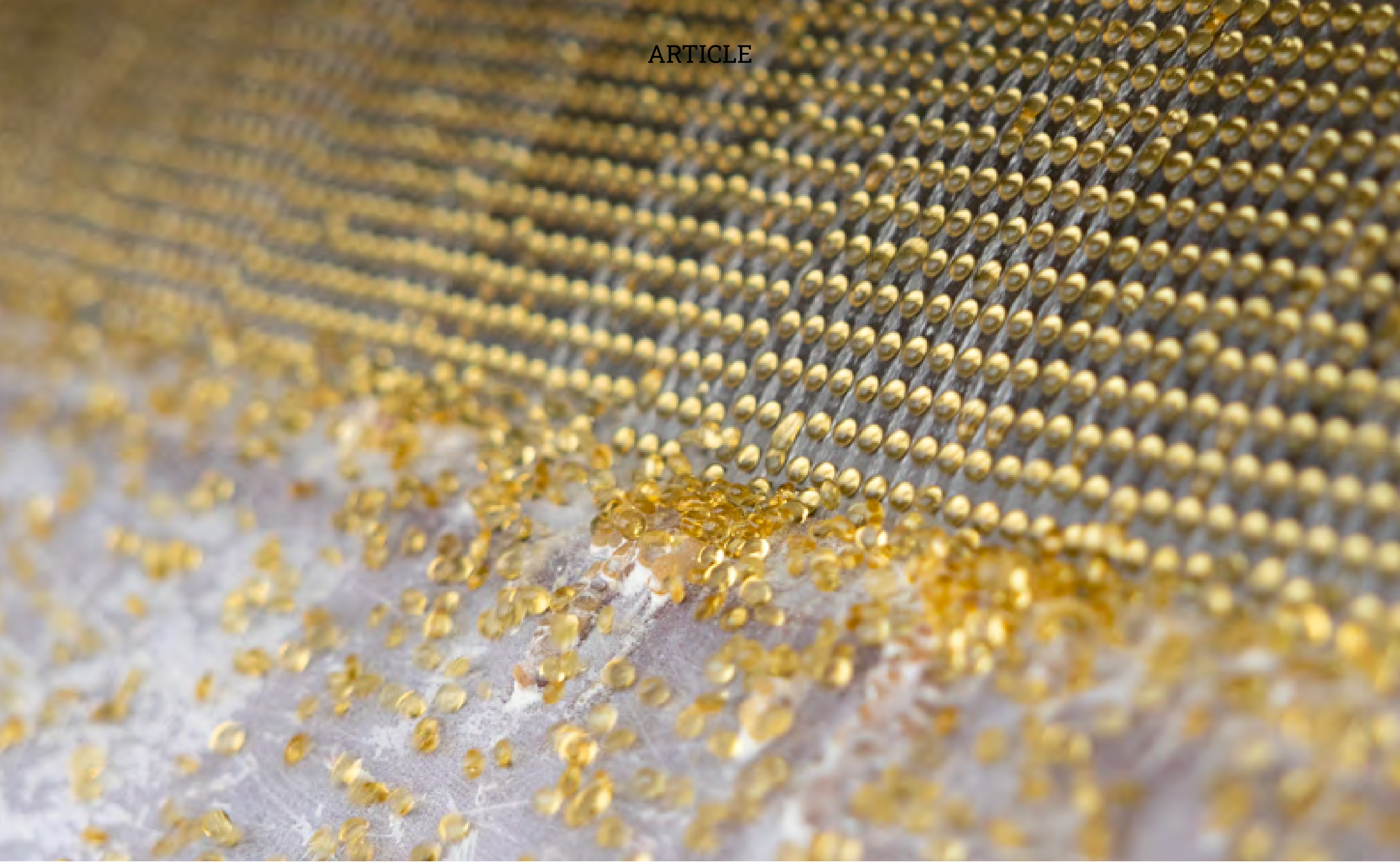
Curcumin is a yellow, liposoluble active compound and the principal pigment of turmeric. Its unique conjugated structure includes two methoxylated phenols and an enolic β-diketone form, conferring strong free radical scavenging capacity. At equivalent concentrations, curcumin exhibits approximately twice the antioxidant activity of the polyphenol resveratrol, and its free radical scavenging capacity is comparable to vitamin E and BHT.

2.8 Resveratrol

Resveratrol is a phenolic compound belonging to the stilbene family, found in grape seeds, grape skins, and red wine. It exhibits strong antioxidant activity that surpasses both BHT and α-tocopherol. This may be attributed to its two phenolic rings (compared to one in BHT) and a higher number of hydroxyl groups (three compared to one in α-tocopherol).

2.9 Sesamol

Sesamol is an important aromatic compound in sesame oil, serving as a key quality stabilizer. It possesses very strong antioxidant activity and is frequently used as an antioxidant in food and pharmaceutical formulations. Recent studies suggest that sesamol's antioxidant effect is primarily due to its singlet oxygen quenching ability. Sesamol is commercially available in pure form and is relatively inexpensive compared with other natural antioxidants. Additionally, one study demonstrated that sesamol has a higher free radical scavenging capacity than TBHQ at room temperature. However, under high-temperature conditions, its antioxidant performance was less effective than TBHQ.



2.10 Thymol and Carvacrol

Thymol and its isomer carvacrol are two monoterpenic phenolic compounds found in various aromatic plants, especially species of the genera Thymus (thyme) and Origanum (oregano). Both exhibit excellent antioxidant properties due to the presence of a hydroxyl group capable of absorbing and neutralizing free radicals. For example, Quiroga et al. reported that thymol provided antioxidant protection to roasted sunflower seeds comparable to that of BHT.

Conclusions

The use of antioxidants in rosin processing can improve the stability and performance of the material for various industrial applications. The selection of the antioxidant type depends on the specific application requirements and the desired properties of the final product. However, the incorporation of natural antioxidants in rosin modification faces several challenges, including compatibility with rosin, potential color changes, and issues related to thermal stability. Other limiting factors in the use of natural antioxidants are their availability and cost, since obtaining high-quality natural antioxidants can be more expensive or technically challenging compared with synthetic antioxidants that are widely available on the market.

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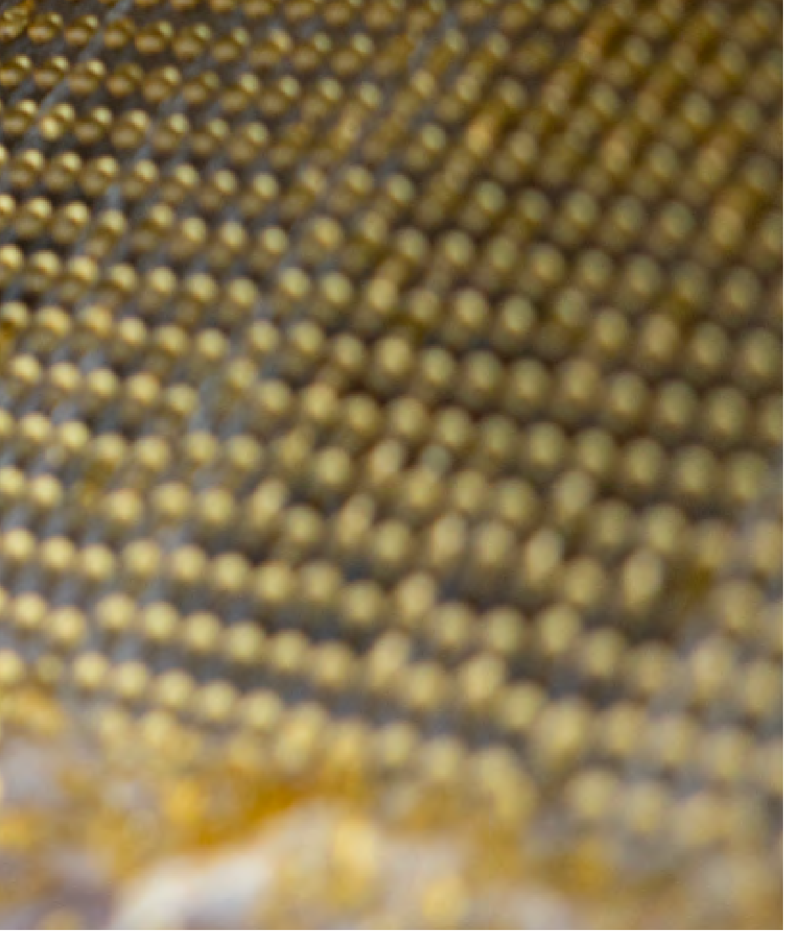

[1] Quiroga, P.R., Asensio, C.M., Nepote, V., 2015. Antioxidant effects of the monoterpenes carvacrol, thymol and sabinene hydrate on chemical and sensory stability of roasted sunflower seeds. J. Sci. Food Agric. 95, 471–479. https://doi.org/10.1002/jsfa.6744.

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GUM CHEMICAL

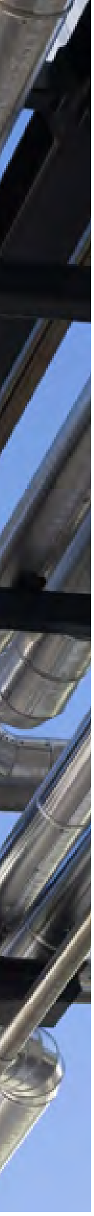
HYDROGENATED ROSIN PRODUCTION: INNOVATION IN THE BIOECONOMY

The growing demand for sustainable alternatives to fossil-based resources has driven the development of renewable materials; in this context, rosin, a natural by-product of pine resin, stands out as a strategic raw material for multiple industrial applications, namely adhesives, paints, varnishes, food products, and cosmetics.

With the advancement of the bioeconomy and the support of programs such as the PRR, this project aims to enhance the value of national rosin for high-performance applications, promoting sustainability through greater integration of local resources into the industrial value chain.

Rosin is a solid, yellowish, renewable material obtained from the distillation of pine gum resin. Chemically, it is composed of resin acids (around 90%), such as abietic and pimaric acids, and esters, alcohols, and aldehydes (approximately 10%).

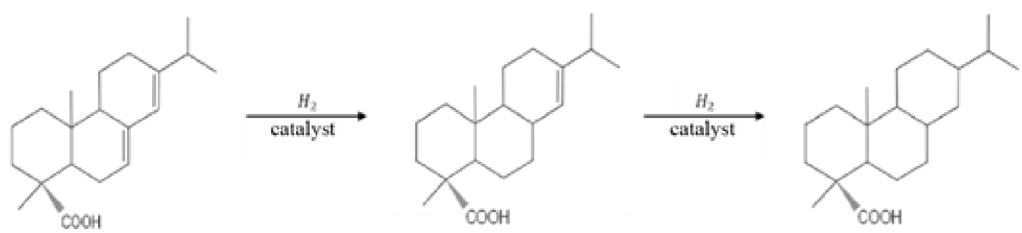
The resin acids contain highly reactive carbon–carbon double bonds, which make rosin susceptible to oxidative degradation and darkening over time, limiting its use in applications that require high thermal stability and durability. To overcome this limitation, hydrogenation is applied, a process that significantly increases the thermal resistance of rosin, reducing the oxidation of the final product.



Process

Hydrogenation consists of breaking the double bonds present in the resin acids by adding molecular hydrogen (H_2) in the presence of catalysts such as noble metals. It is an exothermic reaction, generally carried out in the liquid phase, with hydrogen in the gas phase, under high pressure and temperature.

As a catalytic reaction, it can be conducted either partially—by breaking the first double bond to form dihydroabietic acid—or fully—by breaking both double bonds to form tetrahydroabietic acid, which requires more severe operating conditions.



Abietic Acid Dihydroabietic Acid Tetrahydroabietic Acid

Figure 1 – Hydrogenation Process of Abietic Acid.

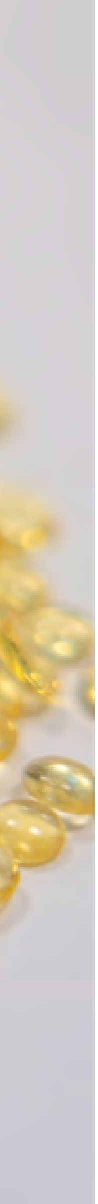
The hydrogenation process of rosin has been studied in batch and tubular reactors, testing different conditions of pressure, temperature, residence time, and catalytic composition, to optimize selectivity, conversion, and material stability.

To analyze the degree of hydrogenation, advanced analytical techniques were used, such as gas chromatography (GC), infrared spectroscopy (FTIR), and nuclear magnetic resonance (NMR). These methods allowed monitoring of the hydrogenation level and evaluation of the physicochemical properties of the modified rosin, being essential not only to validate process efficiency but also to ensure that the final products meet strict requirements of stability, purity, and industrial performance.

Hydrogenated resins are particularly valued in the adhesives industry (hot-melt and pressure-sensitive), precisely for their combination of thermal-oxidative stability, lighter color, low odor, excellent polymer compatibility, and good adhesion, cohesion, and tack properties. They also have relevant applications in the electronics industry (soldering fluxes), food industry (including resins for packaging and flavors), cosmetics, paints and coatings, medical devices, paper, as well as in textiles and footwear industries. However, some disadvantages remain, such as the need for post-reaction filtration to remove the catalyst, the energy and technology-intensive nature of the hydrogenation process, requiring pressure-resistant reactors, and the operational risks associated with hydrogen use.

Within the project, new types of hydrogenated rosin were developed with properties tailored to specific requirements, particularly the formulation Hydrosin 5202 E, a high-purity, partially hydrogenated rosin with light color and high thermal stability, ideal for industrial adhesives that demand resistance and long-term performance.

Figure 2 – Hydrogenated Rosin.



Industrial Scale-up

The implementation of one of the lines of the Industrial Scale-Up Unit, according to the previously identified specifications and characteristics, is currently in the installation phase, in line with the approved project. All necessary equipment and support infrastructure for its operation will be integrated. At this stage, the construction of one of the lines is well advanced, while the civil infrastructure supporting the larger unit is under development.

This phase of the project is particularly strategic, as it ensures the transition between experimental development and industrialization, allowing the validation of the technical and economic feasibility of the process at full scale.

The industrial development of hydrogenated rosin and its derivatives, through controlled hydrogenation and esterification processes, fits perfectly within the PRR strategies for a sustainable economy based on renewable resources and high value-added products.

The technical and commercial viability of this project is supported by growing global demand, as well as by the unique properties of hydrogenated resins that meet the needs of modern industry, particularly in the production of adhesives and food products.

The use of hydrogenated rosin as a substitute for conventional petrochemical products offers clear environmental advantages, particularly in terms of reducing the carbon footprint and increasing the valorization of local forest biomass. By using a natural and renewable raw material such as pine resin, the product's life cycle becomes significantly more sustainable, contributing to national and European climate goals.

From an economic perspective, domestic production of hydrogenated rosin can reduce dependence on imports of synthetic resins and add value to the Portuguese forestry sector. This vertical integration of the production chain represents an opportunity for regional reindustrialization, especially in areas traditionally linked to the resin sector, fostering skilled employment and innovation.

In addition, by-products of the hydrogenation process, such as light fractions and catalyst residues, are being studied for potential energy or chemical reuse.

Compared with hydrocarbon-based resins, widely used in the adhesive industry and recognized for their good stability, but derived from non-renewable sources and often associated with higher VOC (Volatile Organic Compounds) content, hydrogenated rosin resins deliver performance that is comparable or superior in many contexts. They also feature lower toxicity and higher biodegradability, consolidating them as a technically robust and environmentally preferable solution for a more sustainable industry.

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COLAB FORESTWISE

THE NATURAL RESIN SECTOR IN PORTUGAL THROUGH THE FORESTSTATS PLATFORM

Comprehensive knowledge of Portuguese forests is an essential step toward promoting a more informed, efficient, and sustainable management of forest resources. It was with this objective that the ForestSTATS platform was developed, conceived as an aggregator of information and knowledge about the portuguese forest sector. Coordinated by Biond, in collaboration with CoLAB ForestWISE®, the Instituto Superior de Agronomia, and the sectoral associations Forestis and ANEFA, this digital tool was created under the transForm Agenda and funded by the Portuguese Recovery and Resilience Plan (PRR).

ForestSTATS has filled a long-standing gap by gathering and organizing previously scattered, inaccessible, or inconsistent data, making Portuguese forest statistics available to everyone for the first time. The platform integrates official statistical information from multiple sources, namely the National Statistics Institute (INE), the Institute for Nature Conservation and Forests (ICNF), the National Institute of Industrial Property (INPI), and other sectoral databases. The information is organized into 13 thematic areas, encompassing more than 450 variables. Structured according to principles of interoperability and continuous updating, it provides economic, productive, and territorial data through interactive maps, charts, and tables, freely and intuitively accessible.

This article draws on the information available on the ForestSTATS platform to characterize the evolution of the Natural Resin sector in Portugal, providing a quantitative overview of its dynamics over the past decades. The analysis focuses on the following parameters: annual Natural Resin production (1938–2023), and exports and imports of resin-based products (in value and volume). Through these indicators, it aims to outline the economic evolution of the Natural Resin sector, identifying structural trends and contributions to the national forest bioeconomy.

Evolution of National Natural Resin Production

In the mid-20th century, Portugal stood out as one of the world's leading producers of Natural Resin, reaching production levels of around 140.000 tons per year (Figure 1). This peak coincided with the widespread practice of resin tapping in the central and northern regions, where maritime pine (*Pinus pinaster*) covered extensive forest areas established under the afforestation policies of the Estado Novo period.

However, during the 1990s, national production entered a sharp decline due to a combination of structural and contextual factors. Among the most significant were rural abandonment and the resulting shortage of labor, as well as international competition—particularly from China—whose resins entered the European market at more competitive prices, undermining the economic viability of domestic extraction.

Over the following two decades, resin production fell to residual levels. Only in the early 2000s was a modest recovery observed, driven by an increase in the price paid to producers (Figure 2). Nevertheless, this recovery remained limited: in the past five years, average annual production has stabilized around 7.000 tons, far below the levels recorded during the sector's golden age.

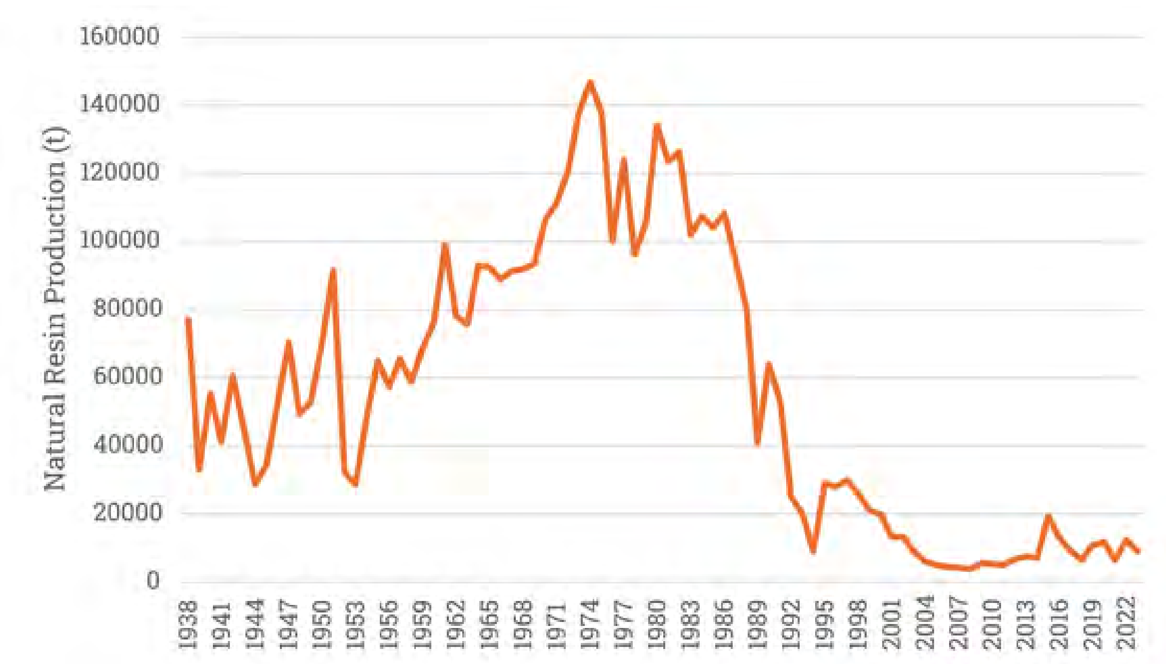

Figure 1 - Natural resin production between 1938 and 2023.

The Processing Industry

Despite the sharp reduction in domestic production, Portugal has retained the technical and industrial know-how associated with Natural Resin processing, maintaining a competitive and technologically advanced transformation sector. National companies have specialized in the valorization of resin and its derivatives, particularly rosin, which serves as the base for a wide range of high-value-added products such as adhesives, paints, varnishes, and cosmetics.

Data available on the ForestSTATS platform reveal that, since the beginning of the statistical series in 1998, imports of resin-based products have steadily increased. This trend reflects not only the need to compensate for the shortage of domestic raw material but also the vitality and production capacity of the Portuguese processing industry (Figure 3). Even with a high dependency on imported raw materials, the sector has managed to preserve its economic relevance and establish itself within the European context as a specialized and innovative transformation hub.

Figure 2 - Natural resin production and price per kilogram from 1999 to 2023.

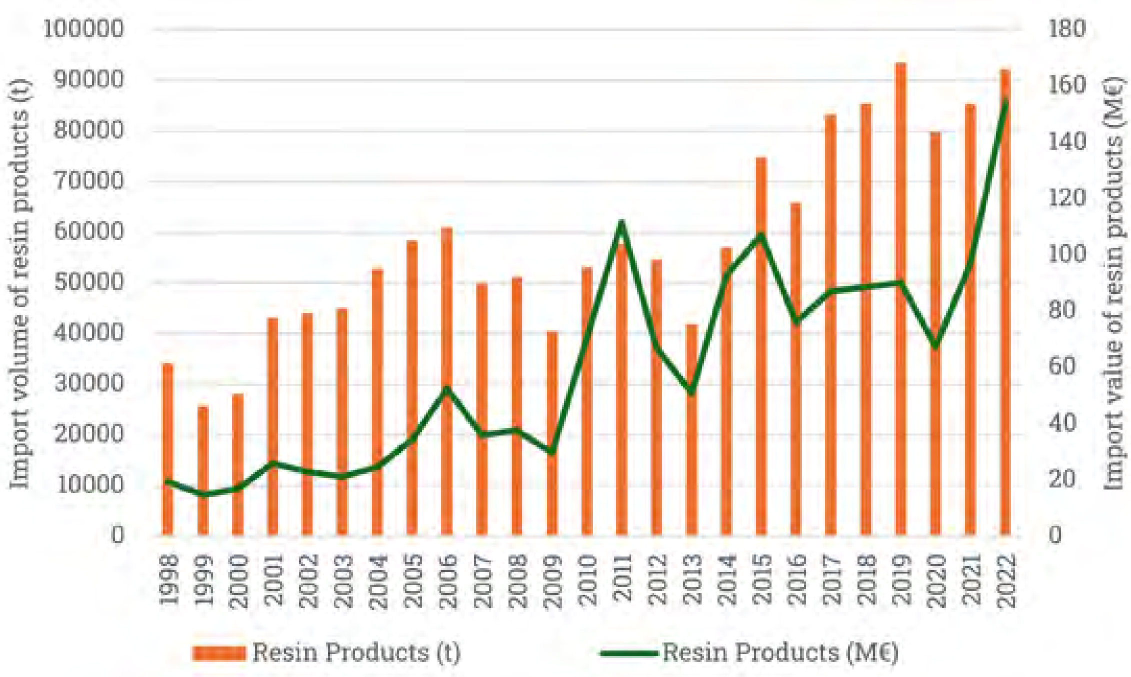

Figure 3 - Imports of resinous products in Portugal between 1998 and 2022.

Competitiveness and Value Creation in the Natural Resin Sector

The positive trade balance of the Natural Resin sector, evidenced by the surplus between imports and exports of resin-based products (Figure 4), confirms the national industry's capacity to generate value. The sector's resilience is based on three key pillars: technological innovation, sustainability of production processes, and diversification of applications for resin derivatives. This dynamic shows that the Portuguese industry has been able to turn a structural limitation, the scarcity of domestic raw material, into an opportunity for specialization, developing high-performance products that strengthen Portugal's competitive position in European value chains. Thus, the continued development of the sector increasingly depends on the alignment between forest production, industrial innovation, and policy frameworks, aimed at stimulating the revival of national resin extraction and fostering a more integrated and circular forest bioeconomy.

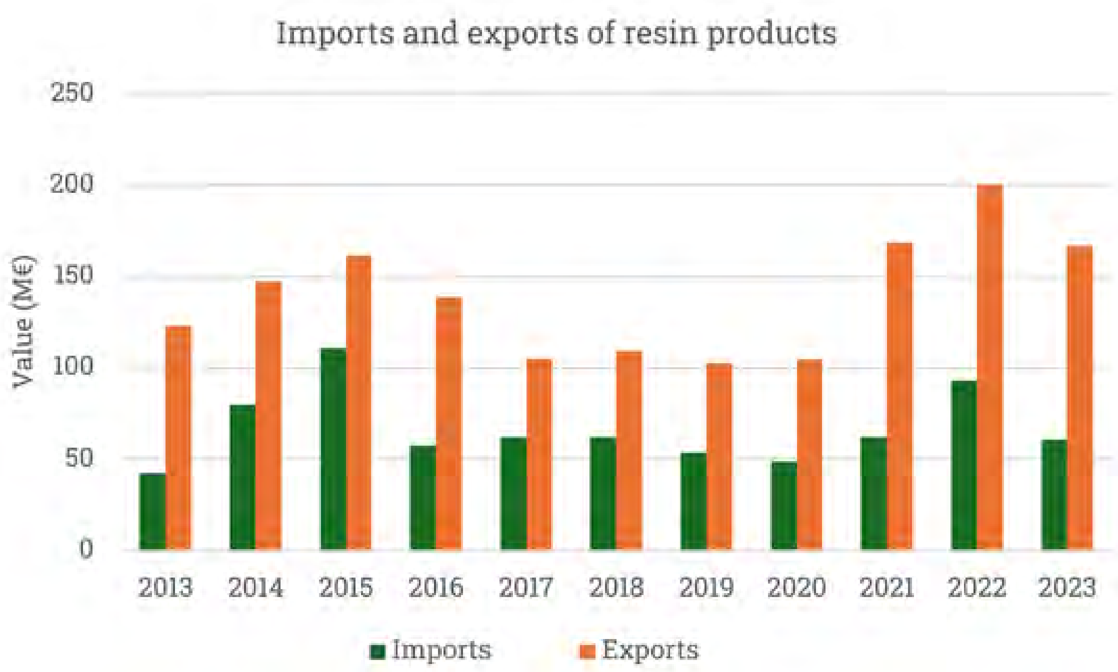

Figure 4 - Imports and exports of resin products (millions of euros), between 2013 and 2023.

Conclusions

The analysis of the evolution of the Natural Resin sector in Portugal highlights the structural and contextual challenges that have shaped its trajectory over the past decades, as well as its capacity to adapt within a global competitive context. The entry of natural resins at lower prices into international markets, combined with the decline in rural labor availability, undermined the economic viability of domestic production.

Nevertheless, the processing industry remained active and competitive, preserving technical expertise and investing in innovation and specialization in high-value-added products.

The recognition of the Natural Resin sector under Component C12 – Sustainable Bioeconomy of the PRR, represents a strategic milestone, confirming its potential as a key resource for the national bioeconomy. Support provided through the PRR has stimulated applied and collaborative research, resulting in tangible progress across the entire value chain, from genetic improvement and mechanization of resin tapping to the development of new rosin derivatives and bio-based biopolymers. The RN21 Integrated Project demonstrated the importance of combining tradition and innovation, opening new markets and positioning Portuguese resin as a material of the future.

The strengthening of the Natural Resin sector, grounded in scientific knowledge, industrial innovation, and the valorization of endogenous resources, presents an opportunity to consolidate a more resilient, sustainable, and competitive forest-based economy, aligned with national and European goals for carbon neutrality and sustainable development.

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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.

FROM FOREST TO FINAL PRODUCT: A NEW ERA FOR EUROPEAN NATURAL RESIN

In today's global landscape, where the climate crisis demands a rapid transition toward low-carbon economies, the demand for renewable and sustainably sourced raw materials is steadily increasing. It is within this context that the brand Resinae® – Pinaster Natural Resin emerges, as part of a measure defined under the Integrated Project RN21, a strategic initiative with a clear objective: to valorize Natural Resin derived from *Pinus pinaster* of European origin, positioning it as a high-performance and sustainable alternative to fossil-based products.

The Resinae® brand is founded on strong pillars of environmental, social, and economic sustainability, supported by internationally recognized forest certification systems (FSC® and/or PEFC). These ensure that only products originating from responsibly managed and traceable forests may bear their identity. The Brand Use Regulation sets out strict eligibility criteria and control standards across the entire value chain, from forest extraction to final commercialization, ensuring authenticity and trust, while clearly delimiting its geographical scope to Europe. The goal is to establish *Pinus pinaster* resin as a benchmark Natural Resin of European reference.

The implementation of the Resinae® brand represents a collaborative effort that transcends national borders. Portugal and Spain are among the main producers of Natural Resin in Europe, and bilateral cooperation between the two countries constitutes a crucial joint strategy to achieve greater scale, strengthen representation, and enhance impact in the European market. By joining forces, a joint front was created to highlight the European attributes of sustainability, traceability, and quality that characterize Natural Resin produced in Europe. This collective effort strengthens the sector's competitiveness in global markets, promotes innovation, and advances the recognition of European *Pinus pinaster* resin as a differentiated and high-value raw material.

The traceability ensured by the Resinae® brand provides the transparency and continuous monitoring required throughout the process. To achieve this, modern technological solutions are being implemented, centered on a digital platform that integrates unique identifiers for the traceability of resin and its derived products. These codes allow auditable records at each stage of the value chain — from forest extraction to industrial transformation and final product integration — enabling interactive access to detailed information about the sustainability of the forests from which the resin is sourced and the industries in which it is processed.

This digital traceability system ensures data security and immutability, guaranteeing compliance with brand criteria while maintaining the flexibility needed to rapidly adapt to new standards or regulatory frameworks. In doing so, it reinforces stakeholder confidence and supports a culture of transparency and accountability across the entire resin value chain.

To validate the Resinae® brand concept and test the performance of the traceability system, a Proof of Concept is being carried out within the footwear sector, in partnership with entities from the Integrated Project RN21 that have been developing new products incorporating Natural Resin. The integration of traceable natural resins into footwear components represents a significant step forward in environmental sustainability, replacing fossil-based materials with renewable, bio-based resources. This transition contributes to reducing carbon emissions, enhancing the value of national forest resources, and promoting circular economy models.

The traceability and certification system functions as a Digital Product Passport (DPP), anticipating and aligning with forthcoming European Union

requirements on eco-design and transparency. Through a digital code, consumers can not only verify the certified origin and sustainable performance of a product but also access its complete story — from the forest to the finished shoe. This ensures product authenticity and transforms the value chain into a source of verifiable, transparent information. For consumers, the impact is equally significant: the growing demand for products with transparent and environmentally responsible origins is met, while access to detailed sustainability information strengthens trust in the Resinae® brand and encourages more conscious, sustainability-driven purchasing decisions.

This Proof of Concept materializes the Resinae® ecosystem, based on the strategic collaboration of RN21 partners across the entire value chain. The process begins with resin extracted from certified Portuguese forests, which is then transformed into rosin and derivatives by national industries and subsequently incorporated into the formulation of adhesives for footwear and biopolymers for sole injection.

The Proof of Concept will provide insight into the technical and commercial feasibility of implementing the brand and will help identify potential constraints in the operationalization of the traceability system.

The Resinae® Proof of Concept demonstrates that it is possible to combine innovation, sustainability, and transparency — transforming European Natural Resin into a symbol of trust and environmental responsibility that unites the forest, industry, and consumers in a shared vision for a sustainable future. By bridging science, industry, and environmental stewardship, Resinae® stands as a seal of trust that truly connects the forest to the consumer.

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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/comunicacao

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/comunicacao

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