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"The differentiating factor of Prorresina is the combination of tradition with innovation"
Amílcar Aleixo

New markets for natural resin and the challenges of the sector
António Mendes Ferreira

Digitalization and Robotization in the second Transformation Industry of Natural Resin
University of Aveiro

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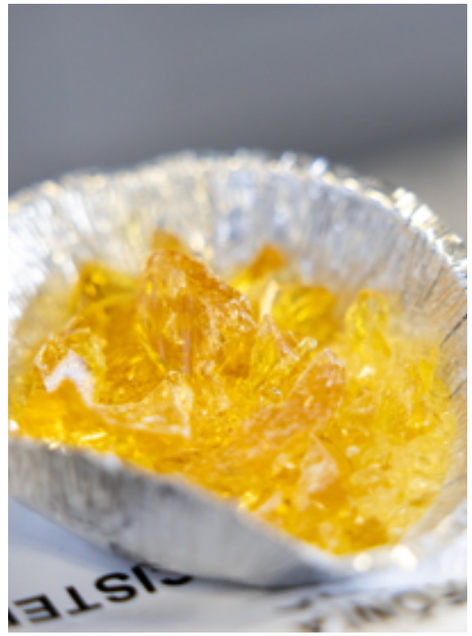

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EDITORIAL

It is with great honor that we present the second edition of Resinae, where we give greater emphasis to the Natural Resin transformation industry in Portugal.

In a global context, Natural Resin plays a vital role in economy and innovation. At the European level, the policies defined by the European Commission within the Bioeconomy strategy, align with the use and valorization of bio, natural products such as Natural Resin, emphasizing the sustainable management of natural resources, a reduced dependence on non-renewable and unsustainable resources, adapted to climate change mitigation, aiming to enhance European competitiveness, and creating employment. Furthermore, this strategy strongly contributes to the European Green Deal, as well as initiatives for industrial innovation, circular economy, and clean energy.

Portugal, with its edaphoclimatic conditions, is a privileged location for the sustainable production of Natural Resin, in line with the overarching goals of the European Bioeconomy strategy. Despite adversities such as forest fires, a reduction in the pine forest area, and global competition, the resilience of the Portuguese Natural Resin transformation industry is clear. In 2022, Portuguese companies in the first and second transformation achieved sales totaling 1.377,4 million euros, representing an increase of 10.8% compared to the previous year.

This edition provides a comprehensive view of upcoming opportunities, highlighting the complex and promising evolution of the Natural Resin industry, where tradition meets innovation, shaping the future of this vital sector in Portugal and worldwide

Carlos Fonseca
CTO CoLAB ForestWISE

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Committed to expanding horizons and exploring new territories, RN21 focuses firmly on developing new applications and in strengthening existing markets. We aim to foster synergies between the first and second transformation, as well as with key entities in emerging markets.

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AMÍLCAR ALEIXO | INTERVIEW

"THE DIFFERENTIATING FACTOR OF PRORRESINA IS THE COMBINATION OF TRADITION WITH INNOVATION."

Prorresina is a first transformation of Natural Resin company located in Alvares, in the municipality of Góis. This family-owned business has been operating continuously since 1921, founded by Manuel Pedro Aleixo, the grandfather of Amílcar Aleixo, the current owner of the company.

At its foundation, Prorresina was one of fourteen first transformation companies in the region, and today it is the only one that remains. Situated where there was once an extensive pine forest, it has progressively been replaced by fast-growing species due to wildfires in the region. The changing landscape and the scarcity of raw materials associated to it, led to the closure of many first transformation companies that relied on the surrounding pine forest. The resilience of Prorresina is attributed to its capacity for innovation and the strong trust relationship with its consumers and suppliers. The raw material they transform now comes from all over the country, but the quality of their products, turpentine, and pine rosin from Portuguese pines, remains unchanged. "What a company needs the most is the trust of consumers and suppliers, that is fundamental," says Amílcar Aleixo.

Another differentiating factor for Prorresina is the combination of tradition with innovation. In this company, the transformation of Natural Resin is done using the traditional method, which involves cleaning the resin followed by its distillation using only steam. Distillation is carried out by traditional methods, through steam injection, without the use of reactors and without the addition of chemicals. The resulting products are turpentine and rosin, mostly for export. In the case of turpentine, due to its high alpha-pinene content (80 to 85%), Portuguese maritime pine turpentine is sought after not only by the perfume industry but also for other uses such as varnishes, sealants, cleaning products, pharmaceuticals, cosmetics, rubber industry, paints, solvents, and thinners. As for rosin, its advantage lies in its higher melting point compared to rosins from other species, making it suitable for various products and industries, including cosmetics (such as depilatory waxes and makeup), solder for electronic components, the music industry (for string instruments), shoe industry, coatings (paints and varnishes), road marking and printing inks, soap manufacturing, adhesive industry (band-aids, stickers, tape, etc.), as well as the fiber and textile industry. These products stand out for their natural and renewable origin from Portuguese maritime pines. As we can see, these raw materials, due to their chemical properties, have great potential for various industries, providing a viable alternative to fossil-based raw materials.

Prorresina also stands out in the national and international market of resinous products by offering turpentine and rosin certified with Organic Origin. Another feature highlighted by Amílcar Aleixo, as a differentiator for Prorresina, is its proximity to the European market, the world's largest consumer of rosin and turpentine. Prorresina can expedite its products quickly, ensuring they reach the customer rapidly—something impossible for its major international competitors, particularly companies based in Brazil or China. The ability to provide high-quality products in small quantities is another differentiating factor for Prorresina, allowing it to target specific niches that consume smaller volumes.

Located in the interior, this family-owned company also contributes to territorial cohesion, directly through job creation and indirectly by purchasing resin from resin tappers. It is a family-oriented business that employs local labor, where employees are considered part of the family, and this closeness is one of the factors for its success and resilience. However, dealing with rurality is also a challenge for the company. Born from an opportunity created by the surrounding pine forest, it found itself isolated and with limited access to

distribute its products. Prorresina has been fighting adversities and isolation since its foundation, which remains one of the main challenges identified by Amílcar Aleixo. Another challenge is related to the territory and the changing landscape it has undergone. The owner of Prorresina expresses hope for the recovery of the pine forest area and emphasizes the importance of managing young pine stands for resin tapping. He also raises concerns about the lack of investment in forest management for the remaining pine stands in the region.

The identification and selection of the Natural Resin sector for investment by the Portuguese Recovery and Resilience Plan (PRR) under Component 12, Sustainable Bioeconomy, must be used to differentiate Portuguese Natural Resin. This unique and unprecedented opportunity in the sector must be seized to promote national Natural Resin and differentiate it as a natural and renewable product. The attention given to this sector must be used to raise public awareness of the potential of this raw material in various industries.

As Amílcar Aleixo mentioned, nobody wants chewing gum made from petroleum-derived chemicals or to eat fruit coated with hydrocarbons. This is a unique opportunity to boost the sector.

The participation in the Integrated Project RN21 has provided Prorresina with the opportunity to modernize and implement energy-efficient measures, contributing to the company's climate transition. Prorresina also participates in measures to valorize the waste generated from Natural Resin processing, demonstrating the company's environmental concern and the pursuit of a way to capitalize on what is now considered waste. This reflects the company's commitment to circular solutions and the creation of added value.

Amílcar Aleixo emphasizes the need to fight for the future and the valorization and differentiation of Natural Resin as a biological, natural, and renewable product. He stresses that the future of the sector lies in alternative positioning, as it is impossible to compete with the prices practiced by the competition. It is urgent to explore niches that would value Portuguese Natural Resin and leverage the proximity to Europe.

Portugal can deliver its products to major consumers in Central Europe within a few days, while competitors' products take months to arrive. It is essential to use this advantage to our benefit.

Finally, it is worth highlighting the Certification of Natural Resin, conceived as part of the Integrated Project RN21.

With the Natural Resin brand, our products will gain more visibility and increase their value for consumers, as it will distinguish products made with a natural, healthy, sustainable, environmentally friendly resource that is more easily recyclable. It is crucial to differentiate natural products, such as pine resin and its derivatives, from those derived from petroleum, which are not natural, sustainable, recyclable, and, most importantly, not as healthy to consume.

Amílcar Aleixo
Owner of Prorresina

Amílcar Aleixo emphasizes the need to fight for the future and the valorization and differentiation of Natural Resin as a biological, natural, and renewable product.

A FORESIN, SUSTAINABLE SYNERGIES RESIFOREST, is an environmental consulting and engineering company based in A Coruña, Spain, dedicated to promoting and innovating the resin sector in Galicia. Their activities focus on planning and managing R&D projects, providing consultancy services to forest owners, technicians, and public administrations, and offer training to achieve sustainable forest management.

How do you assess the evolution of the resin sector in Galicia? And what are the main challenges it faces?

Like what was observed in Portugal, resin extraction re-emerged in Spain in 2010 and, five years later, in Galicia. Initially, with only 3 resin extraction teams and a production of 7.000 kg, it now has 16 resin teams and a production of almost 200.000 kg. Challenges such as the lack of tradition in the resin sector in Galicia, operational issues like unfamiliarity with resin extraction techniques, and social challenges hindered the sector's development. Another challenge was the reluctance of forest owners due to concerns about resin extraction affecting wood quality.

Another challenge faced by the sector was the rejection of this activity by forest owners due to potential effects of resin extraction on wood quality. In an area where the primary use of pine forests is timber exploitation, there was reluctance regarding the potential impact of resin extraction on wood quality. Additionally, there was some uncertainty among forest owners, technicians, and administrators regarding the compatibility of resin extraction with the phytosanitary conditions of the stands, a critical factor in the current context of global climate change and the serious threats posed by invasive exotic pathogens such as the pinewood nematode (*Bursaphelenchus xylophilus*) or the resinous cancer (*Fusarium circinatum*).

Currently, the main challenge faced by the sector is the resin market, as the revenue of this activity depends on fluctuating international raw material prices.

Despite these challenges, the potential for resin extraction in northeast Galicia is significant, given the large pine forest area suitable for resin extraction.

What regional policy measures have been implemented to boost this sector?

The Galician public administration has actively promoted the resin sector through legislative measures and direct economic support. In May 2020, the Rural Environment Council of Galicia issued Decree 73/2020, regulating resin exploitation in the region's forests.

This decree allows resin extraction from pine species like *P. pinaster*, *P. radiata*, and *P. nigra* for 3 to 5 years before final tree cutting, provided the normal diameter is above 25 cm.

The Law 7/2012, of June 28, on forests and Common Lands of Galicia, determines in its article 79 the

different categories of instruments for forestry planning and management. It indicates that references to good practices and indicative silvicultural or forestry management models serve as forestry management instruments. These instruments guide the management and utilization of forests and Common Lands based on the analysis of existing species and their management according to their final destination.
In February 2021, Annex I of the May 2014 Order, which establishes silvicultural models for the forest districts of Galicia, was modified to incorporate new forestry management models. Among these models is the PMR (Mixed Wood and Resin Production), designed for the mixed production of timber and resins in pine forests.
Concerning economic support, the Galician Agri-Food Quality Agency (AGACAL) provides funding for research projects, and both AGACAL and the Galician Forestry Industry Agency (XERA) offer training programs. The Rural Environment Council also introduced a support program for understory management in resinous pine forests.

Regarding technical innovations in resin extraction, what innovations have been implemented? What are the main advances in this area?

In the northwest of Galicia, where pine forests are primarily used for timber production, resin extraction is not traditional, thus innovations have been not only technological but also social.
The ACREMA Operational Group, led by FORESIN, optimized resin extraction systems, compared different extraction methods and stimulant pastes, and concluded that resin production was higher in *P. pinaster* than in *P. radiata*. The use of stimulant pastes increased resin production by 70%, with Cunningham paste (active ingredient ethephon) showing the best results. Traditional extraction methods produced 40% more resin, than the mechanical method.
The study also examined the impact of resin extraction on the structural quality of wood, concluding that resin extraction in the last 3 to 5 years before tree cutting did not alter the mechanical and structural properties of *P. pinaster* wood. Resin extraction increased wood density, and there was no clear evidence that resin-extracted trees were more susceptible to pests and diseases.

“The main challenge faced by the sector is the resin market, as the revenue of this activity depends on fluctuating international raw material prices.”

Regarding the quality of natural resin, especially *P. pinaster* resin, what chemical or physical properties differentiate this product?

The quality of *P. pinaster* resin can vary based on its chemical and physical properties, which influences its application and market value. In terms of resin extraction, a high-quality resin is characterized by a higher rosin and turpentine content, and lower water and impurity content.
According to the ACREMA project results, the resin extraction method significantly affects turpentine percentage and rosin color. The resin collected in closed containers using mechanical methods had lower impurity content and 20% more turpentine than the resin collected in open containers. The acidity index of rosin showed no differences, but the color index, according to the Gardner scale, was higher in

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CEO of the environmental consulting and engineering company FORESIN

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Forestry Engineer specializing in Environmental Management and Sustainability

colophony from resin collected in open containers than the resin collected in close containers. This darker rosin has lower market value and demand than lighter rosin.

Can the differentiating properties of *P. pinaster* resin leverage the valorization of natural resin and its potential entry into new markets?

This is the premise of the PICARE Operational Group, "Revaluation of Galician pine forests through resin quality," coordinated by FORESIN, in cooperation with the Biological Mission of Galicia, the Center for Technology and Wood Foundation (CETEMAS), the company Xagoaza Pinaster SL, the company Transformação Agrária (TRAGSA), and as an independent professional, Roberto Alfonso Touza.

Resin has been used for centuries in various applications, from perfumes and adhesives to traditional medicine. The quality of resin is crucial for its positioning in an increasingly demanding market. The chemical composition of resin is essential for evaluating its quality. Compounds like terpenes, phenols, and other aromatic chemicals are key in determining resin quality.

The valorization of resin involves maximizing its differentiating properties. By understanding and highlighting these properties, companies can position resin as a high-quality product in a competitive market, creating added value. The collaborative effort of the entire value chain, from resin extractors to the first and second transformation industry and the market, is essential for achieving this.

In your opinion, could quality be a factor that leverages the appreciation of natural resin and its potential entry into new markets?

The extraction methodology is, in our understanding, the key aspect that will allow us to position resin based on its properties. Therefore, it is crucial to continue the development and optimization of resin extraction methods that collect resin in closed containers, as well as the development of stimulant pastes based on natural compounds or even the development of resin extraction methods without using stimulant pastes.

On the other hand, it is also important to continue the work of characterizing and determining the chemical composition of resin with the aim of increasing the added value of this product and promoting its entry into more specialized markets. Collaboration from the entire value chain, from resin extractors to the first and second transformation industry, to the market, is essential to achieve this goal.

Resin is a natural and renewable product with the potential to replace fossil-based raw materials. This is a differentiating factor that should be promoted to enter in new markets concerned with sustainability and environmental responsibility.

In summary, the differentiating properties of resin can play a fundamental role in its appreciation and entry into new markets. Therefore, understanding and promoting these properties are essential to fully exploit the potential of resin in a quality market.

“Based on the results obtained , we can confirm that the resin extraction method has a significant effect on the percentage of turpentine obtained (and consequently, of rosin). The resin collected in closed containers, using the mechanized method, showed a lower impurity content compared to the resin collected in open containers, and a 20% higher turpentine content. The extraction methodology is, in our understanding, a key aspect that will allow us to market resin based on its properties.”

@ United Resins

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THE NEW MARKETS FOR NATURAL RESIN AND THE CHALLENGES OF THE SECTOR

It is with a great sense of responsibility, that I am pleased to address the legacy of a raw material that has surrounded us for thousands of years and that I believe will have many new lives in the future. I am referring to pine rosin and its derivatives.

As far as we know, the first application of pine rosin dates to the Ancient Egypt, where it was used in the mummification process, to ensure preservation.

In Portugal, it played a significant role in the naval industry, serving to waterproof the caravels used in the Portuguese maritime expansion, which took us so far to the East and West. Ironically, it is in those distant points reached by the caravels, where today, several centuries later, we source that same rosin, transported in containers by sea.

In this immense interval, rosin has had great influence and importance. In the last century, many chemists and engineers began to perceive the enormous reactive potential of the constituents of this raw material, which predominantly contains Abietic acid-type acids in its composition. From there, they dedicated themselves to the development of its derivatives, a process that continues to this day.

For a successful rosin derivatives industry, there is something upstream that must be ensured and that determines the flow throughout the entire value chain. It is the pine forest. In the mid-20th century, there was a generous and abundant forested area of maritime pine, with mature forests capable of guaranteeing the necessary diameters for resin extraction stipulated in successive legislations, drafted even before the 1950s. Portugal has legislation on resin extraction activity, even though the state is a small landowner, making it the only country with this presence and aptitude. As a consequence of the attention given to this activity, in the 1960s and 1970s, resin became one

“It will be difficult to find raw materials for the industry with the same renewable character, (...) for the future of new generations.

António Mendes Ferreira
CEO of United Resins and United Biopolymers

of Portugal's main exports, with dozens of distilleries spread across much of our territory and thousands of people operationally involved, with thousands of owners benefiting from their forest assets. It was also in the 1970s that there was a significant increase in the processing capacity of pulp and paper industries, leading to the rampant substitution of pine with species such as eucalyptus, with the argument of a significant increase and a more immediate profitability.

After a few decades, in the new century, the narrative changed to the desertification of interior areas, pine forests reduction to a third of what they once were, the lack of property registration, and omission of respective owners, and the scourge of seasonal fires, already socially and politically accepted as an inevitability that finds an inviting habitat in the current forest scenario.

As is often the case in everything, men and markets are indelibly linked to various occurrences, notably the decline we have all witnessed, which was based on issues of professional, corporate, and social organization, competitiveness, and challenges from other technologies. Despite all the visibility of the resin sector, to this day, we have never managed to organize an association for our industry that was sufficiently versatile, robust, endowed with a representative agenda, and capable of aggregating the complementary interests of the entire value chain in such a way that it could reach the various authorities that have governed in recent decades. It is a truth that may disturb some but reflects the reality and represents another decisive factor for the declining of forestry intervention and distillation activities that we have all experienced, particularly since the 1980s.

In the previous decade, there was still some healthy consolidation, with the emergence of distilleries on a larger scale, to the detriment of various small

productions. Perhaps this was one of the few consistent aggregation movements that occurred in the sector, but it was not accompanied upstream in the forestry part. However, industrial companies producing derivatives, the so-called second transformation, emerged, starting operations in the early 1980s. During this period, a decisive political phenomenon occurred: Portugal joined the then EEC, now the European Union.

This political step, combined with China's opening to export markets, accelerated the decline, with distinct but both effective contours. On the one hand, the inflow of funds to develop the country led most of the workforce to public works, something that persists to this day. On the other hand, China was able to place rosin on the European markets at very competitive prices. For the record, in the transition to the new century, they displayed prices below $400 per ton.

The combination of these two simultaneous movements and the lack of a structured state support plan for the sector led to the almost disappearance of resin extraction activity and consequently, the loss of commercial influence in the main European markets. Despite this combination, the derivatives industry continued to flourish in Portugal.

As markets are inherently dynamic, they always make room for more competitive or technologically diversified materials, or ideally, both. In this challenging and vibrant scenario, credible alternatives to pine rosin emerged, notably tall oil resin derived from the black liquor of Nordic pulp mills, motivated by what was already happening in the United States, with major paper companies promoting business units for derivatives of this type of rosin. Winning proposals also came from the hydrocarbon sector, with petrochemical companies from Europe and the United States taking the lead.

In the early years of the 21st century, about 25-30 years after the peak of pine rosin and its derivatives, they were overshadowed by tall oil derivatives and hydrocarbon-based versions. By this time, Portugal no longer had a significant presence in rosin production, and China, since 2007, had been losing momentum in production. This decline fostered the growth of tall oil-derived resins, the widespread use of fossil-based resins in most typical applications, and of course, the rise of rosin production in Brazil, where, interestingly, the main players are Portuguese entrepreneurs, a situation that persists to this day.

One can imagine the competitive jolts and logistical challenges that this dynamic brought to second

transformation industries. On several occasions, they gathered and stood before Ministers, Secretaries of State, as well as various organizations to revitalize the activity in Portugal, aiming for upstream vertical integration. However, their aspirations were definitively thrown when not a single step had been taken on the ground, and some government bodies were already moving forward to discuss and enforce a new legal framework for an activity in convalescence.
Faced with these and other impediments, there was no alternative but to continue supplying derivative factories with rosin, mainly from South America. As I mentioned earlier, like the caravels that sailed with winds both against and in favor, we, like caravels, went from China to Brazil in a few years, not to mention passages through Vietnam and Indonesia.
We witnessed the consolidation of the derivatives industry, with Investment Funds buying and selling companies, creating conglomerates at the international level with sales exceeding billions. These companies were mostly allocated to tall oil and hydrocarbons, originating from major pulp and paper companies and petrochemicals. Their ambition was always to conquer positions that were naturally dominated in the past by pine rosin derivatives.
Contrary to the mainstream, Portuguese entrepreneurs in the second transformation sector remained resolute and independent. As if driven by an intrinsic genetic root with its own will, they were the only ones in this century to create new manufacturing units, increase production capacity in existing ones, while other international corporations reduced or withheld to manipulate the market.
It was through resilience, the development of technical and technological skills, know-how, and innovation that we managed to maintain our position, which in Portugal had everything to be overshadowed by all these movements. Even so, they influenced a leading Portuguese company to invest in tall oil as an alternative. However, the derivatives industry remained revitalized and motivated to find new paths in its value chain.
The RN21 Consortium is another essential catalyst that allowed overcoming barriers between stakeholders and directing the focus towards previously neglected sectoral interfaces, creating synergies and development platforms for new portfolios and various applications, reaching new market segments. This is the desired goal for this sector, which, with its long history, has experienced ups and downs but is now, in my opinion, on the right side of the economic cycle as it has not been for a long time.
The goals of carbon neutrality, the narrative of sustainability, fit perfectly with pine rosin. It will be difficult to find raw materials for the industry with the same renewable character, embodying in its essence the green carbon that we all aspire to for the future of new generations. It is time for everyone, from forestry intervention, 1st and 2nd transformation, end customers, to government agencies, to identify with this greater good. Together, in an unpretentious and constructive way, we should be able to reduce the carbon footprint in the supply chain logistics. As it is worth remembering, this raw material has been, in recent decades, and continues to be, 10.000 km away to the east or west - not even cod has a parallel, which is 4.000 km away from our tables.
We must dissipate what separates us because there is much more that should unite us. Only then can we positively frame a project to enhance the available forest area to ensure production and productivity and face the expected future increase in demand for this raw material, with a novel distinction compared to the fossil carbon of our current market-leading competitors.
At the beginning of the RN21 Consortium, all second transformation companies were represented in a meeting with the former Minister of the Environment, expressing our concern about the approximately 8.000 hectares of planned enhancement, arguing that there should be at least 50.000 hectares. It was mentioned that in this PRR program, managed by Environmental Fund, there would be no space for more, but our premises were well noted, and future programs should pay attention to increasing the enhancement of resinous areas.
Historically, we have almost always been separated, and we have come this far. I can only believe that if the entire value chain walked united and as a group, we will reach higher and farther. Keeping this sector consistent, coherent, and balanced it is more than a design, it is a duty!

CRISTINA FRUTUOSO | OPINION

INNOVATION FOR A MORE SUSTAINABLE WORLD

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“Our participation in the consortium is to elevate the technological level of colophony-derived resins produced in Portugal by partners to access new applications and replace hydrocarbon-based resins.”

Cristina Frutuoso
Corporate Director of R&D

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Colquimica Adhesives is globally recognized for innovation, with a special focus on product and production process innovation and research and development. Over the years, this competitive advantage has resulted in sustainable partnerships with key players in different sectors and throughout the value chain in which we are involved. We have a solid track record of projects with suppliers in the hotmelt industry and with customers in new and diverse solutions for different market segments.

We are facing an environmental emergency that requires cooperation from governments, society, and businesses. Organizations need to participate in this transition, both in their processes and in the products, they bring to the market. Colquímica Adhesives has recently taken a significant step in this field with the launch of the new brand of bio-based adhesives, Kmelt Essence. This brand features a portfolio of products formulated with bio-based raw materials, representing a new line of adhesives with environmental certification and improved adhesion due to the incorporation of natural resins. This step represents a significant step towards a more circular economy and provides Colquímica Adhesives' customers with an alternative to fossil-based raw materials.

The Essence product range has various industrial applications, particularly in the packaging, hygiene and medical, mattress, and filter industries. Certified by the DIN CERTCO institute, which evaluates the percentage of bio-based content in its formulation, this range also includes products with not only bio-based raw materials but also more sustainable polymers (catalyzed by metallocene).

These products, compared to those commonly used in the adhesive industry (based on EVA polymers), are more sustainable in their application. They feature reduced manufacturing temperatures, lower consumption, and allow for increased efficiency by reducing downtime on production lines.

The Essence range, already on the market, aims to replace components of non-renewable origin, fossil fuels, with bio-based products such as pine rosins. In doing so, we support and promote the circular economy, by reducing waste and recovering products that would otherwise be discarded. Moreover, by using these raw materials, we are significantly contributing to the reduction of emissions associated with fossil fuels.

In the economic sustainability aspect, the Essence range in its formulation includes a significant percentage of natural resin derivatives. As Portugal has a robust resin industry, the use of these raw materials in our product formulation will contribute to the growth of the economy for these stakeholders and, consequently, the national economy. This is expected to lead to greater incorporation of national bio-based raw materials, with a significant reduction in the carbon footprint associated with transportation.

By 2030, we aim to increase our consumption of bio-based raw materials from around 7% to approximately 20%. This is one of the main factors motivating Colquímica Adhesives presence in the Integrated Project RN21 - Innovation in the Natural Resin Sector to Strengthen the National Bioeconomy.

Our participation in the consortium implies the development of new colophony derivatives by partners who aim to address technological disadvantages compared to hydrocarbon-based resins. Natural resins, due to their nature, have characteristics sought after by the adhesive industry such as high adhesiveness to challenging substrates, flexibility, compatibility with certain natural materials, etc. However, natural resins face some obstacles such as a yellowish color, odor, compatibility with certain polymers, and thermal stability. The project will involve collaborative work between universities and the second transformation industry of Natural Resin, at the molecular level, with the goal of addressing these issues and achieving the desired success through product reengineering. Throughout this process, Colquímica will provide the necessary feedback for the optimization of the new resins. In summary, the aim is to elevate the technological level of colophony-derived resins produced in Portugal by partners to access new applications and replace hydrocarbon-based resins! Our overarching goal is to contribute to creating a more sustainable future for the generations to come and continuously work on solutions with higher added value.

ROGÉRIO RODRIGUES | OPINION

CONTRIBUTION TO THE ECONOMIC SUSTAINABILITY OF RESIN EXTRACTION ACTIVITY IN PORTUGAL

At present, a broad array of partners is deeply committed to promoting the production of Portuguese Natural Resin in response to the major objectives outlined in the Component 12 – sustainable Bioeconomy – of the Portuguese Recovery and Resilience Plan. This promotion is mainly focused on three lines of action: strengthening the productive capacity of pine forests, increasing resin extraction productivity, and increase the interest in resin extraction as a productive activity.

In addition to the technological changes intended for this project, such as the incorporation of new techniques for natural resin extraction, the genetic improvement of maritime pine for resin production, a training program for new resin tappers, and making this activity more attractive to producers, it is also essential to consider the territory in which this activity takes place, which is mainly on private and community property (with a small percentage reserved for National Forests), and the current forest management models in use for maritime pine.

The economic sustainability of resin extraction, primarily based on maritime pine, a pioneer species, native, highly productive, and economically valuable, is highly dependent on external factors that trigger the implementation of a broader national strategy to promote and support forest management.

A more rigorous observation of the current state of Portuguese maritime pine forests, despite their extraordinary resilience to known disturbances, easily reveals that we are falling short in terms of the main criteria and indicators of sustainable forest management adopted by Portugal in the 3rd Ministerial Conference for the Protection of Forests in Europe (June 1998).

Indeed, over the past 25 years, Portugal has lost approximately 30% of its pine area, with this decline being more severe in the last decade due to recurring rural fires and pests' dissemination, both accompanied by abandonment and subsequent lack of active management. In addition to the regression experienced in terms of forest occupation by this species, the state of maritime pine stands is concerning, with over 60% consisting of irregular stands with approximately 50% having diameters below 15 cm (6th National Forest Inventory, 2015).

Indeed, this scenario does not guarantee the conditions and processes required for sustainable forest management criteria: i) appropriate maintenance and increase of forest resources and their contribution to the global carbon cycle; ii) maintenance of phytosanitary and vitality of forest ecosystems; iii) maintenance and promotion of the productive functions of forests (both wood and non-wood); iv) appropriate maintenance, conservation, and promotion of biological diversity in forest ecosystems; v) appropriate maintenance and promotion of protective functions in forest management (mainly soil and water); vi) maintenance of other socio-economic functions and conditions.

On the other hand, considering that the European industry is the world's leading consumer of resin

"The economic sustainability of resin extraction, primarily based on maritime pine, a pioneer, native, highly productive, and economically valuable species, is highly dependent on external factors that need the implementation of a broader national strategy to promote and support forest management."

Rogério Rodrigues
Director of Integrated Project RN21

derivatives and that less than 1% of the world's natural resin is produced in Europe, in my opinion, Portugal should make a strategic investment to promote a greater forest production integration of this sector, which would improve business sustainability. To do so, a structural shift in the professionalization of active forest management in areas with potential for resin production, with special attention to Common Lands (while also supporting privately managed areas) is necessary. This change should focus on i) a more collaborative and participatory strategy in active land management by organizations of forestry producers and other related living organization; ii) the promotion and support of autonomous joint management structures, including the technical empowerment of these structures (Commons Lands and other simplified structures for the management of Common Lands); iii) the investment in new management models for this species that contemplate both resin and timber production; iv) the continuous investment and simplification of funding mechanisms, based on flat-rate investment. These measures will make it possible to boost forest management in large-scale areas (Common Lands), resolving the lack of active management in which many of these areas are found. This lack of management is motivated by the erosion of Government staff and structures that manage them (technicians, forest guards and operational). The implementation of the above-mentioned measures will also improve the capacity to execute the planning and budgeting required by forest management throughout its production cycle.

Considering at least a decade of continuous support to a dedicated and comprehensive strategy, based on sharing the management effort and encouraging the application of best practices, will pave the way for the economic and social sustainability of this sector, with the multiplication of territorial units of active forest management, and consequently a Government adopting a less "interventionist" role in the direct management of community areas, focusing its efforts on greater dynamism, regulation, planning, and supervision. Simultaneously, showcasing the best examples of sustainable forest management in its National Forests.

This paradigm shift will have a significant economic, environmental, and social impact, contributing to job creation in rural areas and for the generation of economic value. This strategy should be supported by principles of efficiency and stability in the measures to be implemented, focusing on goals and simplifying the paths to achieve them. This will also contribute to effective cohesion and territorial identity. Closing the cycle, active forest management in Common Lands and privately managed areas (where new mechanisms and effective incentives should also be created for the promotion of sustainable forest management, especially in Forest Intervention Zones) will create conditions for greater forest resilience to rural fires and increase biodiversity.

Lastly, to boost this sector, in addition to the technological advancements to be implemented in resin extraction techniques for optimization, part of which have already been developed in projects and are present in the Integrated Project RN21, the Government should also promote legal changes allowing the introduction of new resin extraction techniques and the introduction of new silvicultural management models that reconcile resin and timber production.

"Considering that the European industry is the world's leading consumer of resin derivatives and that less than 1% of the world's natural resin is produced in Europe, in my opinion, Portugal should make a strategic investment to promote a greater forest production integration of this sector, which would improve business sustainability."

FORESIN

INNOVATION AND OPTIMIZATION OF NATURAL RESIN EXTRACTION SYSTEMS

The ACREMA Operational Group "Adaptation of resin extraction activities to pine stands for wood production purposes" was established in 2018 under the call for Supra-Autonomous Operational Groups, an instrument to promote and accelerate innovation in rural areas through the European Association for Innovation in Agricultural Productivity and Sustainability (AEI-agri), within the framework of the Spanish National Rural Development Program 2014-2020.

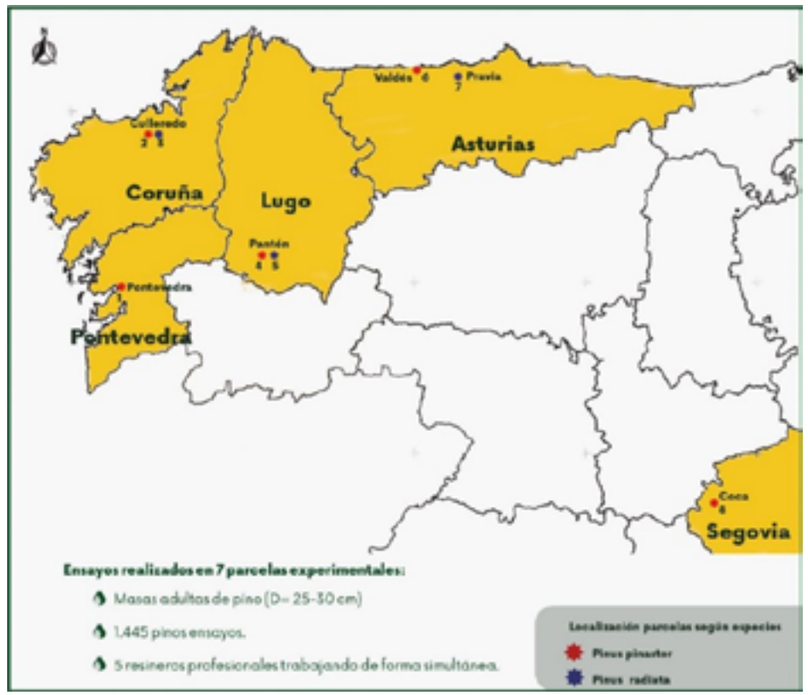


Figure 1. Location of maritime pine stands (*Pinus pinaster* Ait.) and radiata pine stands (*Pinus radiata* D. Don) monitored in the GO-ACREMA project.

The innovation project promoted by the ACREMA Operational Group (GO-ACREMA) was approved in 2020 and was in progress from May 2021 to March 2023, with the aim of increasing the productivity of *Pinus pinaster* Ait. and *Pinus radiata* D. Don stands through the integration of innovative Natural Resin exploitation. The goal was to obtain quality natural resin as a complement to the existing wood production, thereby enhancing the profitability of the forest stand. The project was integrated into the current silvicultural models in the northeast of Spain.

The results obtained by GO-ACREMA were organized into four sections: i) innovation and optimization of natural resin extraction systems for use in pine stands managed for wood production; ii) simulation of resin production and pine phytosanitary conditions; iii) innovation in resin quality analysis; and iv) positive extras associated with resin exploitation.

In this article, we will focus on the results achieved in the first section, innovation and optimization of resin extraction systems adapt to pine stands managed for wood production. To analyze and optimize natural resin extraction systems, the first variable considered in the trials was the species present in the GO-ACREMA operating area in northwest Spain (Figure 1): *P. pinaster* (maritime pine) and *P. radiata* (radiata pine). The second variable considered was the location; trials conducted in maritime pine were carried out in Godos (Pontevedra), Culleredo (A Coruña), Ferreira de Pantón (Lugo), Valdés (Asturias), and Coca (Segovia). The trials conducted in radiata pine were carried out in Culleredo (A Coruña), Ferreira de Pantón (Lugo), and Pravia (Asturias).

In each of these 8 plots, different resin extraction methodologies were investigated, and different resin-stimulating pastes were tested. Two resin extraction methods compatible with the production of quality wood were tested: the mechanical circular renewal method and the traditional method (Figure 2). And a third method exclusively used for low-quality pine stands, for wood production for chipping (energy use and/or panel sector), the borehole method (Figure 3).

The traditional resin extraction method was performed in an upward direction, with renewals every 14 days and an incision of 16 cm. The mechanical method was also performed in an upward direction with a frequency of 14 days. However, the renewal area was tested using drills of different diameters, 5 cm, 6 cm, and 7 cm. The borehole method was performed in 3 rows simultaneously, as shown in Figure 3, in an upward direction, with a 14-day interval between each new incision.

The stimulating pastes tested were ASACIF paste (active ingredient, salicylic acid) and CUNINGHAM paste (active ingredient, ethephon). Control trees were resin-extracted without the application of stimulating paste.

Resin production data were collected during the campaigns of 2021 and 2022. The analysis of production data revealed an increase of 25% and 27% in 2022 for maritime pine and radiata pine, respectively. However, this production increase depended on the resin extraction method used: the traditional method recorded an increase of 34.5%, the mechanized method 30.22%, and the borehole method 9%. From these results, it can be concluded that the borehole method showed the least variation between campaigns, although further studies are needed to justify the observed differences. The detailed analysis of production by resin extraction method and stimulating paste recorded in 2022, is presented in Table 1 for the 8 study plots.

Figure 2 – Resin extraction methodologies compatible with the production of quality wood. From left to right, traditional method and mechanized method.

Figure 3 – Resin extraction methodologies in low-quality pine stands, borehole.

The analysis of the production data in the two campaigns highlighted the following results:
- Resin production in maritime pine was higher than in radiata pine by 15 to 30%, depending on the extraction method.
- Resin production in maritime pine was 22% higher than that recorded in radiata pine using salicylic and Cunningham pastes, while in the control group (without stimulating paste), the difference reached 30%.
- Stimulating pastes increased resin production by 70% for non-invasive methods (traditional and mechanized methods) and by 40% for the borehole method.
- Field data analysis indicates that the most efficient stimulating paste was Cunningham, regardless of the resin extraction method used.
- The borehole method produced 8.5% more resin compared to the traditional method in maritime pine and 15% more in radiata pine, demonstrating the potential of this method of resin extraction in low-quality stands intended for wood chip production.
- The mechanized method showed productions 40% lower than those observed using the traditional method in maritime pine and 48% less in radiata pine (depending on the location and stimulating paste used).
- Regarding the different diameters tested in the mechanized method, no significant differences were observed.

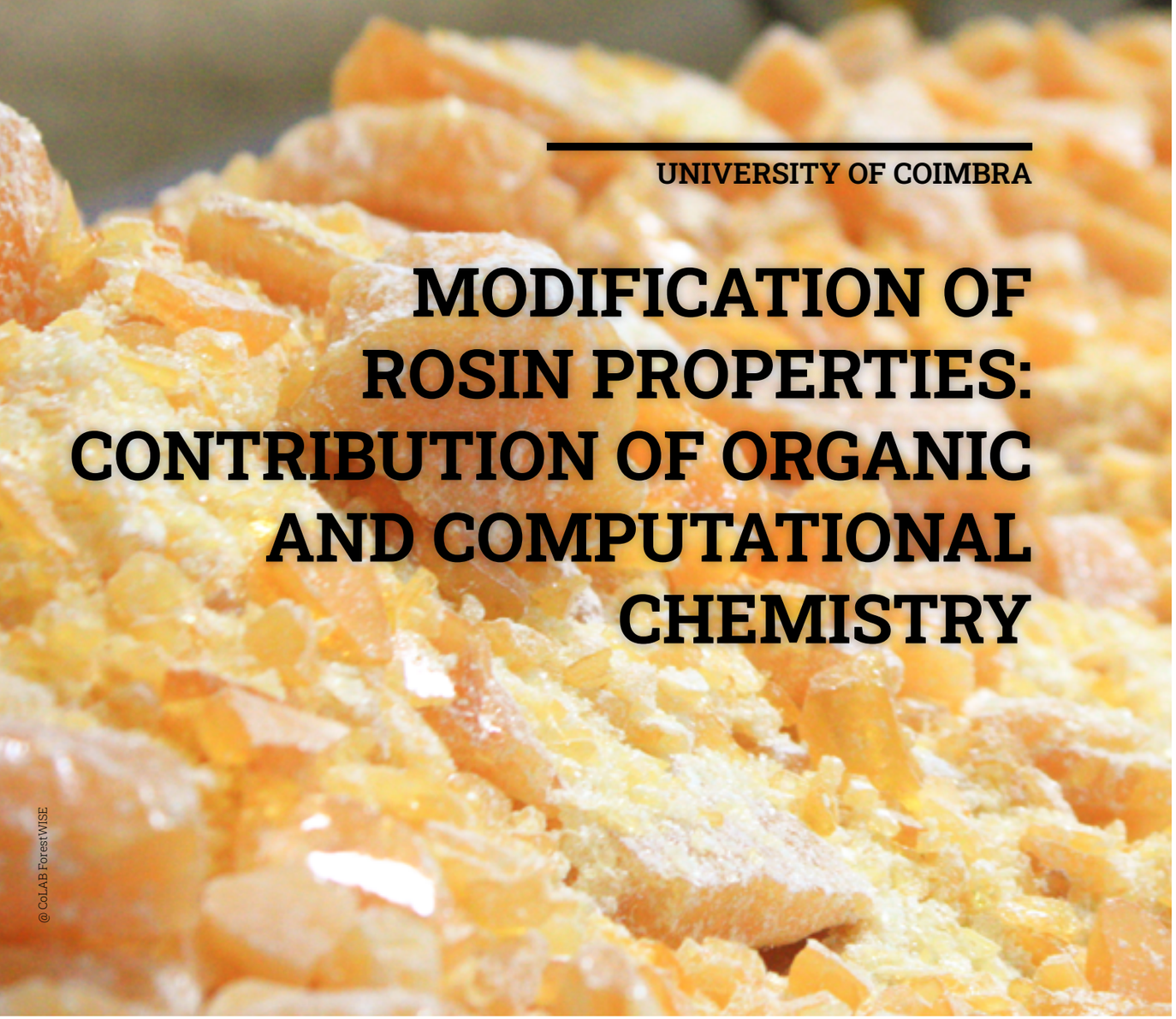
In the GO-ACREMA trials, a positive correlation between tree diameter and resin production was also observed, both in maritime pine (0.23) and radiata pine (0.31). This positive relation was also observed for tree size (diameter, crown diameter, and total height) and thermal regime (average, minimum, and maximum temperatures). On the other hand, a negative relation was observed between resin production and tree density, indicating a decrease in resin production as competition increased.
The results obtained with the mechanized method are encouraging since this method also reduces the physical effort of the worker, improving working conditions and making resin extraction a more attractive activity for young individuals. Another advantage of this method is the quality of the resin obtained. As it is a closed system, the resin has fewer impurities and a higher volatile content. It is necessary to continue optimizing this resin extraction methodology, as well as waste management associated with the use of bags.

Erika Martínez and María Escudeiro Rossignoli
Foresin

Table 1. Natural resin production, in grams, for the 8 study plots of maritime pine and radiata pine, using different resin extraction methods and stimulating pastes, for the year 2022.

		Maritime pine					Pine-insignis		
Resin Tapping	Stimulating paste	ASTURIAS	CORUÑA	LUGO	PONTEVEDRA	SEGOVIA	ASTURIAS	CORUÑA	LUGO
Borehole	CONTROL	1429.2	1353.7	1247.2	2970.3	1963.7	543.7	1693.0	1248.3
	CUNNINGHAM	3471.7	3222.3	2565.7	4082.8	4435.3	2235.3	3792.8	2638.2
	SALICYLIC	3682.2	2712.8	1229.8	3288.3	3724.0	1991.0	3737.7	2174.0
Mecanic Method	CONTROL	197.7	348.9	404.5	465.3	576.3	181.7	469.3	216.7
	CUNNINGHAM	1438.4	1844.7	1646.1	1453.0	2512.5	1090.9	1706.1	1289.9
	SALICYLIC	753.8	2053.9	1910.5	1404.3	2779.3	988.1	1757.8	666.7
Traditional Method	CONTROL	412.7	644.5	698.7	851.3	1443.1	366.9	641.0	697.2
	CUNNINGHAM	2351.4	2841.3	2782.2	4030.0	3374.7	1824.7	2422.3	2860.1
	SALICYLIC	1846.3	2846.1	2677.6	3038.0	3874.7	1688.6	2271.0	2970.6

Figure 1. Main industrial applications of rosin and its derivatives



UNIVERSITY OF COIMBRA

MODIFICATION OF ROSIN PROPERTIES: CONTRIBUTION OF ORGANIC AND COMPUTATIONAL CHEMISTRY

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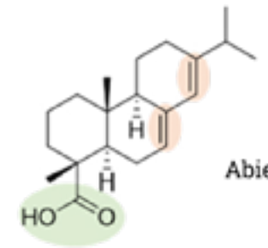
Addition reactions
Oxidation reactions
Reduction reactions
Dehydrogenation reactions



Abietic acid

Esterification reactions
Decarboxylation reactions
Reduction reactions
Salt formation

Figure 2. Main modification reactions of abietic acid. Carboxylic group identified in green and carbon-carbon double bonds in orange.

range of transformations, which are generally more synthetically accessible. These transformations allow the modification of certain characteristics, such as hydrophobicity or the ability to interact with other materials, according to the properties to be incorporated into the final product and targeting a specific application.

Among all the reactions presented in Figure 2, the formation of salts, esterifications (on the carboxyl group), Diels-Alder reactions (addition to double bonds), and polymerization reactions are perhaps the most explored. For example, salts and esters derived from rosin, with their main application focusing on the development and improvement of the properties of paints, varnishes, and fungicides. Regarding derivatives from cycloaddition reactions and polymerizations, these result in materials applicable, for instance, in the paper industry and adhesives, respectively.

The esterification of abietic acid and the other components of rosin involves their reaction with alcohols. Typically, the alcohols used in these esterification reactions are triethylene glycol, glycerol, and pentaerythritol, giving rise to the corresponding di-, tri-, and tetra-esters, which have substantially distinct physicochemical properties (e.g., physical state at room temperature, viscosity, softening point, among others). In turn, these properties impact the characteristics of hot-melt adhesives, modifying adhesive and cohesive properties, flexibility, cohesion, etc.

Cycloaddition reactions, especially the Diels-Alder reaction, are widely used in the synthesis of new resinous derivatives (Figure 3). Although abietic acid has two conjugated double bonds in its structure, the Diels-Alder reaction requires the isomerization of abietic acid into levopimaric acid, achieved at elevated temperatures. The latter is subsequently intercepted by a dienophile (e.g., maleic acid, maleic anhydride, p-benzoquinone). The most studied cycloadduct, considered one of the most promising derivatives from an industrial perspective, is maleopimaric acid, obtained from the Diels-Alder reaction with maleic anhydride. Maleopimaric acid is a resin acid known for being easily obtained and being an intermediate of great importance in the synthesis of a wide range of new resinous derivatives. Some of the most well-known transformations of this adduct take advantage of the reactivity of the anhydride group present in the molecule, allowing, for example, the synthesis of imides containing a wide range of substituents. Additionally, being a cyclic anhydride, ring-opening reactions, leading to the formation of two additional carboxylic acid groups in the molecule, and the possibility of subsequent functionalization, can allow the synthesis of polymers from these precursors. Using maleopimaric acid as a starting reagent, it is also possible to prepare epoxy resins or chiral ligands.

Polymerization reactions allow the transformation of abietic acid into high molecular weight polymers that exhibit improved mechanical properties, making them ideal for applications where material strength and durability are essential. It is worth noting that the presence of an acid group in the structure of

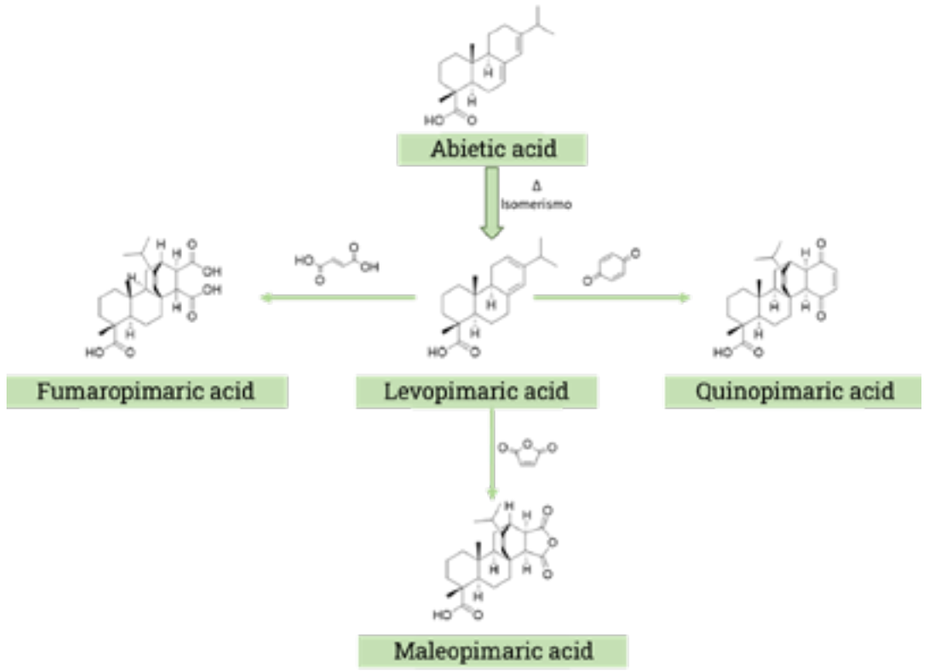


Figure 3. Some examples of transformations of abietic acid into derivatives.

maleopimaric acid also allows functionalization at that position, leading to the formation of other derivatives of great practical interest, including esters derived from glycerol and pentaerythritol.

The mentioned examples illustrate how the structural modification of abietic acid is a notable example of how carefully designed chemical transformations can be used to alter the properties of rosin, allowing the creation of innovative materials with added value and products capable of playing relevant roles in different industrial applications of resins. Organic Chemistry, by its essence, is the area of Chemistry that has most extensively contributed to progress in this field. Computational Chemistry, starting from theoretical models of chemical structure and reactivity, contributes to the proposal, selection, and validation of experimental approaches. By combining the laboratory experience of organic chemists with the use of computational models, it is possible to optimize synthesis processes and define successful strategies for obtaining a particular product in a much shorter time, acting in a targeted manner, and saving resources.

The theoretical and computational tools available today are numerous, versatile, and powerful. From very

very precise but computationally expensive quantum mechanical methods, which can still be used to study chemically complex systems, to classical molecular modeling methods that allow the study of complex chemical systems and materials in a very short time, producing results of excellent quality. The theoretical tools available nowadays for use in both academia and industrial environments are diverse and versatile, easily adaptable to problems that arise during the development of a product or industrial process. Molecular modeling methods should be combined with modern planning and optimization methods and data analysis based on artificial intelligence and multivariate statistics, which have progressively become auxiliary tools with enormous analytical potential in Chemistry, including Organic Chemistry. As mentioned earlier, the high diversity of compounds present in rosin makes it a raw material with high scientific and industrial value. However, the fact that rosin is composed of a large number of compounds makes structural modifications, particularly those requiring complex reactions, a huge scientific challenge, inseparable from the very nature of rosin chemistry. The same can be said when considering the seemingly simpler task of characterizing raw materials or products, as well as the purification processes necessary to obtain a final product of quality. In fact, all these operations are complex and expensive procedures, for which the joint use

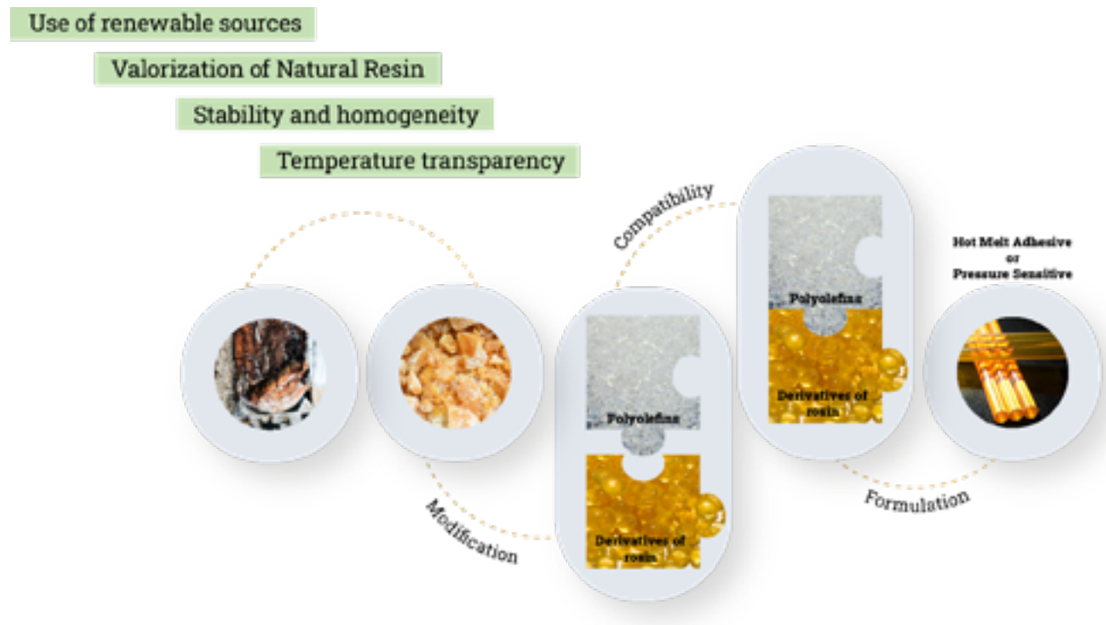


Figure 4. The Resfinas project

of Organic Chemistry and Computational Chemistry becomes crucial to ensure an effective strategy for the ultimate goal of achieving an improvement in synthetic processes leading to the production of new products with greater structural diversity and enhanced properties.

Currently, the Organic Chemistry and Molecular Thermodynamics and Spectroscopy groups of the Center for Chemistry at the Department of Chemistry of the University of Coimbra are participating in two projects of great importance aimed at valorizing rosin: the **Resfinas** project and the **Resetfinas** project, developed under the Integrated Project RN21, in collaboration with the company United Resins, and financed by Component 12 - Sustainable Bioeconomy, of the Recovery and Resilience Plan (PRR) - Natural Resin Sector.

The **Resfinas** project aims to achieve the compatibility of rosin resins with polyolefins produced by metallocene catalysis through the structural modification of rosin components. With this project, the goal is also to promote the use of raw materials from renewable sources, enhance the value of natural resins, and obtain adhesive products with high stability, homogeneity, and transparency (Figure 4). The design of sustainable and innovative chemical transformations developed within this project has involved the use of advanced Computational Chemistry methods. The utilization of these methods has accelerated laboratory strategies, both in experimental planning and in the interpretation of obtained results.

The **Resetfinas** project aims to develop a laboratory infrastructure to produce rosin derivatives that are

are more flexible and robust. This infrastructure should be capable of withstanding significant variations in pressure and vacuum, coupled with distinct temperature profiles in different processing environments. The project also aims to develop various types of reactions and combine them in controlled polymerization processes to obtain derivatives with differentiated chemical and technological performance compared to current standards. The current derivatives do not achieve a sufficient degree of structural modification to allow for broad compatibility with all elastomers and block copolymers used in the adhesives and rubber industries, especially with the new polyolefins obtained by metallocene catalysis.

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UNIVERSITY OF AVEIRO

DIGITALIZATION AND ROBOTIZATION OF PROCESSES IN THE SECOND TRANSFORMATION INDUSTRY OF NATURAL RESIN

The digitization and robotization of processes in the second transformation industry of natural resin, driven by the Integrated Project RN21, represent a significant advance in the sector. These two technological trends, digitization and robotization, are reshaping the way companies operate and promise to dramatically improve the efficiency, quality, and competitiveness of operations. Digitization involves the integration of digital technologies into all operation aspects, while robotization employs sophisticated industrial robots to automate complex tasks. The integration of these elements is essential for Industry 4.0, where the interconnection of machines, systems, and humans drives intelligent and efficient production. Furthermore, the use of the Digital Twin concept allows for the creation of precise virtual replicas of processes, enabling real-time simulation, analysis, and optimization. In the context of the Integrated Project RN21, these technologies converge to enhance operational efficiency, product quality, and the competitiveness of companies in the natural resin transformation industry. In the following sections, we will detail how digitization, robotization, and Digital Twin can be successfully applied in this evolving sector.

Digitalization

Digitization is redefining how we live and work. This transformation process involves the integration of digital tools and systems into various aspects of a company's operation. In the current competitive landscape, digitization has become essential for companies to stay relevant and thrive, enabling organizations to adapt to rapidly changing market conditions, meet customer expectations, and optimize processes for greater efficiency and productivity. Digitization is a key characteristic of Industry 4.0 and plays a fundamental role in this context. In Industry 4.0, digitization refers to the integration and use of advanced digital technologies in all aspects of the production chain. For the natural resin transformation industry, it is no different, and the Integrated Project RN21 promotes the digitization of companies in this sector, aiming for greater efficiency and productivity on the path to Industry 4.0.

Digitization is the use of digital technologies to change a business model and provide new revenue streams and value-generating opportunities [1]. It involves integrating digital tools and systems into various aspects of a company's operation, from management and communication to production and customer service. Digitization brings significant benefits to the natural resin transformation industry, including improvements in operational efficiency, product quality optimization, traceability, sustainability, data-driven decision-making, and supply chain integration. By adopting digital technologies, companies can increase productivity, transparency, and innovation while meeting the market demand for sustainable and high-quality products.

Industry 4.0

Industry 4.0 refers to a new phase of the industrial revolution that combines technological advancements such as the Internet of Things (IoT), Artificial Intelligence (AI), advanced robotics, 3D printing, augmented reality, and other digital technologies to create smarter, more efficient, and connected production systems. This new industrial era aims for the interconnection of machines, systems, and humans through digitization and automation to enhance productivity, flexibility, and production customization[2]. In Industry 4.0, factories and production processes are characterized by the collection and real-time analysis of large volumes of data, enabling more informed and predictive decision-making. Additionally, machine-to-machine communication and the integration of the entire value chain are crucial, aiming to create an intelligent production network. Industry 4.0 has the potential to transform not only how products are manufactured but also how companies operate and interact with their customers. This industrial revolution can be highly beneficial for the Natural Resin transformation industry through the Integrated Project RN21, increasing efficiency, reducing costs, improving quality, customizing products and services, and paving the way for new business models and innovation.

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Robotics

Robotics has played a crucial role in the automation of industrial processes worldwide. With technological advancements, industrial robots have become increasingly sophisticated, efficient, and versatile, offering significant benefits to industries, such as increased productivity, improved product quality, and cost reduction. The natural resin transformation industry will also benefit from the robotization of its production processes through the Integrated Project RN21, resulting in increased operational efficiency and productivity, paving the way for an increasingly automated and technologically advanced future in this industry.

Definition of Industrial Robotics

Industrial robotics is a field of engineering that deals with the design, development, implementation, and control of robots used in industrial environments. Industrial robots are programmable, multifunctional, and reprogrammable machines capable of performing complex tasks autonomously or in collaboration with human operators. They are designed to carry out a wide range of activities, from product assembly, material handling, welding, painting, to quality inspection and packaging[3].

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Requirements for Industrial Robotics Systems

The robotization of production processes involves the careful consideration of various fundamental requirements that are applicable across different industrial environments. To ensure the successful implementation of industrial robotic systems, the following requirements are crucial:

- **Operational Efficiency:** Robotic systems should be designed to optimize process efficiency by reducing production time, minimizing waste, and maximizing overall productivity.
- **Precision and Repeatability:** The precision of robots is crucial to ensure accurate task completion over time, ensuring consistent product quality and minimize operational errors.
- **Safety:** The integration of safety systems is essential to protect operators and other equipment from potential collisions or hazardous situations during interactions with robots.
- **Flexibility:** Robotic systems must be adaptable to different tasks and production processes, allowing for quick reconfiguration to respond to new requirements and variations in production.
- **Communication and Integration:** The ability to integrate with other automation and control systems is essential to enable efficient communication between robots and other devices in the manufacturing environment.
- **Simplified Maintenance:** Robotic systems should be designed with ease of maintenance in mind, allowing for quick diagnostics and efficient replacement of parts.
- **Costs and Return on Investment (ROI):** Cost-benefit analysis is crucial to determine the feasibility of implementing robotic systems and ensure a favorable long-term return on investment.
- **Training and Skill Development:** Operators should receive adequate training to operate, monitor, and interact with robots, maximizing their productivity and safety in the workplace.
- **Regulatory Compliance:** Robotic systems must comply with relevant regulations and safety standards for the industrial sector in which they are being applied.

Careful consideration of these requirements provides a solid foundation for the successful implementation of industrial robotics systems in various production processes, resulting in increased efficiency, productivity, and competitiveness for companies in the Natural Resin transformation industry.

Digital Twin

The use of Digital Twin has become increasingly relevant and impactful across industries, including the natural resin transformation industry. This technology enables the creation of a digital replica of a product, process, or physical system, allowing for real-time monitoring, simulation, and analysis. Through Digital Twin, companies in the natural resin transformation industry can gain a comprehensive view of their industrial processes to optimize decision-making, increase operational efficiency, and reduce maintenance costs. Consequently, it becomes possible to predict failures and conduct simulations before implementing changes in the actual industrial process, allowing for testing various scenarios and optimize the production process.

A Digital Twin is a computer-generated model representing real objects or systems [4]. Introduced in 2002 by Michael Grieves, this concept has since evolved significantly in terms of associated concepts and technologies [5]. The Digital Twin is created from data related to the physical and operational characteristics of the product, machine, or process. These characteristics include the material list, mechanical properties, control logic, operational state, performance, and diagnosis of the physical object. The Digital Twin concept consists of a real space with the physical object, a virtual space with the virtual object, and data exchange between them [6]. In this way, the Digital Twin can be seen as a digital replica of the physical object or system.

The primary characteristic of a Digital Twin is real-time data exchange, allowing continuous or periodic synchronization between the physical object and its virtual model, known as the Digital Thread [7]. This enables the Digital Twin not only to replicate the physical object but also to precisely mimic its behavior. The flow of information is mainly from the physical object to the virtual object. However, the virtual object can send data and information to the physical object. The implementation of a Digital Twin has many advantages for the management and testing of the physical object. For example, using models and machine learning techniques, it is possible to predict future behaviors to enhance and optimize the productivity of the process associated with the physical object. A common use of Digital Twins for this purpose is to avoid service interruption during maintenance situations.

A Digital Twin can also be used for continuous monitoring through real-time data acquisition. This allows the Digital Twin to provide information to assist in decision-making and control of the physical system. Digital Twins can also provide a testing platform to verify different scenarios, choosing the most efficient one, thereby increasing the system's performance.

Integration between Digitalization and Robotics

In the context of the Integrated Project RN21, the installation of digital platforms and robotic systems is anticipated to improve industrial processes, foreseeing an increase in the efficiency and quality of these processes. In this sense, the Digital Twin will operate within digital platforms to create a virtual environment for the simulation of real robotic systems, reliably representing the processes associated with that system. Consequently, the Digital Twin is the integration between the previously mentioned digitalization and robotization, combining the advantages of each one into a comprehensive and versatile system. These robotic systems will be used to produce rosin derivatives, and the Digital Twin will be crucial to optimize and increase the efficiency of these production processes. The Digital Twin will exchange information between the virtual system and the real system, such as production rates, system bottlenecks, operating conditions, breakdowns, control parameters to optimize production, structural integrity levels of assets, failure modes and rates, as well as requirements for short-term repairs and replacements. This information can also be used to perform "what-if" simulation scenarios, optimizing production and reducing downtime, thereby increasing the productive efficiency of the robotic system.

CONCLUSION

In conclusion, the digitization and robotization of processes in the second transformation industry of natural resin represent a technological revolution that promises to radically transform how companies operate in this sector. Digitization is opening up new possibilities, allowing companies to improve operational efficiency, product quality, and sustainability, while robotization offers advanced automation that drives productivity and cost reduction. The integration of these technologies is essential to achieve the goals of Industry 4.0, creating smarter and more connected production environments. Additionally, the use of the Digital Twin concept allows for real-time simulation and optimization of processes, reducing risk and increasing efficiency.

Within the scope of Integrated Project RN21, these innovations are being strategically applied to improve industrial processes in the natural resin transformation industry. The combination of digitization, robotization, and Digital Twin is propelling the second transformation industry of natural resin towards a more efficient, competitive, and technologically advanced future. Companies adopting these technologies are well-positioned to face the challenges of the current market and explore new opportunities for growth and innovation. Integrated Project RN21 is an inspiring example of how technology can be successfully applied to drive the transformation of the industry.

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IEETA, DETI, LASI, University of Aveiro

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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.

The public presentation of the Integrated RN21 Project, held on October 10, 2023, at the facilities of United Resins in Figueira da Foz, was a significant milestone in disseminating the project and raising awareness about the importance of the Natural Resin sector. Bringing together the Consortium RN21 representatives from Industry, Academia, Government, Administration and others, the event was a crucial opportunity to introduce the Project's objectives, initiatives, and expected impact.
Communication and dissemination are fundamental elements in achieving the goals of the Integrated Project. The planned communication actions will achieve these objectives by promoting knowledge about Natural Resin, highlighting its properties, benefits, and applications, as in disseminating the achieved results in the Project and promoting the entire value chain.
Communication plays a central role in consolidating the image of Natural Resin and its derivatives as sustainable and value-added products.
To achieve the proposed objectives, RN21 aims to implement a diversified communication strategy, covering both online and in-person actions. Online activities include establishing a website, social media presence, podcasts, and webinars used to disseminate information about the project, its initiatives, and results, while serving as channels for interaction and discussions about Natural Resin.
The Project will also conduct in-person activities such as lectures, workshops, and field visits, providing valuable opportunities for partners to meet, exchange ideas, and establish strategic collaborations.
The dissemination of resin applications and its derivatives is the primary objective of the Integrated Project's communication. This dissemination aims to promote the sustainable, natural, and renewable nature of products derived from natural resin, thereby encouraging the market to integrate these products.
Therefore, RN21 aims to create and register a distinctive brand associated with a Certification Seal that will enable a more effective communication of the specific benefits that products with this Seal offer compared to others in the market, emphasizing their natural, renewable, and sustainable origin. We hope to foster the entire value chain, creating employment and territorial cohesion, thereby contributing to climate transition.

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

In November, we released the second episode of our podcast 'Resina Natural 360°'. In this podcast we invited the President of Resipinus, Marco Ribeiro, to speak about 'Technological Innovations in Resin Exploitation and Forest Management of Maritime Pine Stands.' This podcast is the perfect opportunity to delve into fascinating and specific details of this innovative project, led by the CoLAB ForestWISE.

RN21 WEBINAR

On December 12th, at 2:30 PM, the next RN21 webinar will take place. We will be inviting Maria Emília Silva, Assistant Professor at the University of Trás-os-Montes and Alto Douro and researcher at CITAB - Center for Research and Technology in Agro-Environmental and Biological Sciences, as speaker. She will be discussing 'Natural Resin Extraction Techniques: Traditional and Innovative Methods.' Registration available on the Project's website.

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