International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
IJABR 2024; 8(6): 366-372
www.biochemjournal.com
Received: 02-04-2024
Accepted: 10-05-2024

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Harvesting liquid gold: Innovative techniques in pine resin tapping

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DOI: https://doi.org/10.33545/26174693.2024.v8.i6e.1338

Abstract
Resin tapping in pine trees, a practice with deep historical roots, has significant ecological, economic, and social impacts. This review explores various resin tapping techniques, from traditional methods to modern innovations, and their effects on trees and forest ecosystems. It highlights resin's role as a vital raw material for numerous industries, underscoring its economic importance. Additionally, the article examines the societal benefits of resin tapping, such as job creation, community development, and cultural preservation. It further illustrates diverse resin-tapping methods and emphasizes the necessity of sustainable forest management. These examples show how resin extraction can be conducted in an environmentally responsible manner, balancing resource use with ecosystem health. By analyzing both the benefits and challenges of resin tapping, the review provides a comprehensive understanding of its multifaceted impacts, offering insights into best practices that support both economic growth and ecological sustainability.

Keywords: Resin tapping, pine trees, sustainable forestry, ecological impact, economic importance

Introduction

To protect themselves from harmful creatures, plants secrete a broad array of defensive chemicals that hinder, repel, or otherwise hinder the advancement of intruders (López-Álvarez *et al.*, 2023) [10, 11]. The invaders' natural predators may be enticed by these compounds as well. Resin is a great example of one of these protective substances. It is a thick liquid that many plant species secrete and which contains both volatile and non-volatile secondary metabolites, with the exact ratios varying from species to species (Doughari, 2012) [27]. The main components are mono- and sesquiterpenes as well as resin acids. In most cases, specialized cells that can build various structures to hold resin under pressure are responsible for both the production and storage of resin. In response to injury to plant tissues, resin either ejects or entraps the intruder. Furthermore, the volatile compounds in the resin evaporate when exudation starts and the material comes into contact with air. This leaves behind a semi-crystalline mass that acts as a protective barrier, sealing the wound and ensuring that no further insects or pathogens can access the internal tissues (Trapp & Croteau, 2001) [28].

A wide variety of plant taxa use resin production as a defense mechanism; this includes species from orders as diverse as Asparagales, Malvales, Apiales, and Coniferales, among many others (Zas *et al.*, 2020) [24, 25]. However, gymnosperms-specifically, members of the Pinaceae family, which has as many as 10 genera and 230 species found all over the globe-are the primary resin producers in temperate zones. The Pinus genus receives the most funding for resin production among the Pinaceae family members. Resin is abundant in pine trees, present in all parts of the plant (stems, roots, limbs, needles, and even cones), and accounting for 10–20% of the tree's dry mass. A network of resin ducts interconnected in three dimensions forms the storage structure for pine resin. Damage to resin canals causes the resin that has built up in this web of tube-like structures to leak out in quantities that can be quite substantial, depending on the species.

Many cultures have relied on pine tree resin for thousands of years due to its many practical applications. Resin tapping refers to the process of extracting resin from trees by creating holes in live tree stems and then collecting the resin that runs out of those holes (Sharma *et al.*, 2018) [18].

According to previous studies (Palma *et al.*, 2016) [14], the traditional methods of inflicting wounds destroyed thin strips of wood in addition to bark and cambium, leading to significant lesions and affecting tree growth and timber quality. According to recent research (Van der Maaten *et al*., 2017) [21], modern wounds do not enter the wood, which lessens their effects on tree growth and allows the collection of resin to flow from the exposed resin channels in the xylem and phloem. While resin had a variety of early-stage applications, including mummification in Egypt and traditional medicine, the 15th century saw a dramatic increase in the demand for pine resin as a waterproofing agent in Europe's booming shipbuilding industry.

Resin has retained a significant industrial niche since the 19th century, when the chemical industry emerged. Liang *et al.* (2023) [21], listed several pharmaceutical, cosmetic, emulsifier, adhesive, chewing gum, and paint products that included oleoresin or one of its derivatives. As the industry became more professional, researchers made great strides in improving tapping techniques and exploitation efficiency. This led to a steady accumulation of knowledge in the various fields involved in resin production, including the development of new extraction methods and the use of chemical stimulants to boost production. The production of resin in countries that had traditionally produced it, such as Spain, France, the USA, and Portugal, rose steadily until the 1980s, when new producers in subtropical regions entered the market and effectively monopolized it, causing traditional areas to produce almost no resin at all (Williams *et al*., 2017) [22]. Synthetic resins reduced resin tapping exploitations. In the 2000s, the resin tapping sector saw a revival in southwest Europe due to the industry's focus on renewable bioproducts as an alternative for petroleum derivatives and the need to revitalize pine forests economically and environmentally (Touza *et al*., 2021) [20]. The usage of fossil fuels, which are not replenishable, in many industrial operations has raised environmental concerns. Numerous products can be made more sustainable and eco-friendlier by substituting pine resin for petroleum derivatives, according to studies. Hydrogenated turpentine is utilized in modern printer inks and jet fuels (Lema *et al*., 2024) [4]. Researchers have been studying pine resin's production, chemical qualities, and extraction processes more than ever before as the sector sees a renaissance, all to boost profits.

Resin biosynthesis

Several genetic and external factors affect how complex resin pine trees make. Tree bark, cambium, and wood all have resin ducts or tunnels that help make resin and store it. Here, encased parenchyma cells send out sticky substances through these pathways. Isopentenyl diphosphate (IPP) and dimethylallyl diphosphate are the building blocks for the biosynthesis of resin acids, phenolic compounds, mono- and sesquiterpenes, and other complex resin parts (Heinze *et al*., 2021) [5]. The pine tree genome contains instructions for making terpene synthases and cytochrome P450 monooxygenases, which speed up the process of making these chemicals (Lah *et al*., 2013) [29]. It's possible for temperature, humidity, the brightness of the light, and biotic stresses like bug populations and pathogen infections to cause the resin to form. Injuries caused by machines may play a role. These stresses turn on genes that make resin and secretions, which build up resin at the site of the damage or infection. Resin that helps wounds heal keeps the body safe from bugs and infections.

Resin Production Factors

The age, health, and surroundings of pine trees all affect how much resin they make and how good it is. Younger trees make less resin. The resin tubes in older trees get bigger, which means they make more resin. Still, older trees may not have as much oil available because their bodies are dying and their metabolisms are slowing down. A tree's health affects how much resin it makes. When trees are sick or worried, they may make less resin because they have less energy. Oliveira *et al*. (2019) [1] say that trees that are healthy and can properly take in water and nutrients produce more bark. Resin output is affected by elevation, soil type, temperature, and amount of rain or snow. Resin-making plant cells do best in warm, wet places, away from dry and cold places. Trees that grow in grounds and climates that are high in nutrients make better resin. To sum up, the production of pine tree resin is affected by many external, physiological, and genetic factors. To get the most resin out of their trees and the best resin extraction, commercial forestry companies need to fully understand these systems and the rules that govern them.

Traditional Uses of Pine Resin

Indigenous peoples have used pine resin for centuries in their daily lives and ceremonies. Its adaptability makes it essential to many daily and cultural practices. Pine resin has traditionally been used medicinally by Indigenous societies. Anti-inflammatory and antibacterial characteristics make it ideal for treating skin infections, wounds and burns topically. Pine resin has several historical and current uses, including bandage adhesive and respiratory therapy. Many indigenous groups employ pine resin in ceremonies and offerings due to its spiritual value. It can create a sacred mood and purify the air during ceremonies like incense. Aromatic pine resin smoke is believed to send prayers and well wishes to the afterlife and help people connect with nature (García-Méijome *et al*., 2023) [4].

Indigenous communities have traditionally employed pine resin, a natural glue, for craft and art. It binds materials in traditional dwellings, weapons, and equipment. Pine resin adhesives make artistic goods more durable and long-lasting. Indigenous tribes have long used pine resin for waterproofing and preservation. A thin covering protects wooden tools, containers, and receptacles from insects, dampness, and rotting. Pine resin coating made these things sturdier and more long-lasting. Indigenous tribes have traditionally sealed and preserved with pine resin. It seals gourd and clay pot seams, preventing air and bacteria from damaging food. Pine resin gives foods and drinks in its containers a slight taste. Indigenous peoples have used pine resin as a dye and pigment to produce a spectrum of hues in fabrics, pottery, and body art. It can make many colours using minerals, plant extracts, and animal ingredients. Pine resin pigments and dyes are popular for their durability and fade resistance.

Environmental Stewardship: Indigenous peoples process pine resin and other natural resources sustainably because they value nature. Maintaining pine trees and their ecosystems through traditional harvesting will preserve biodiversity and ecological balance. Indigenous pine resin knowledge and practices teach environmental resource management and preservation (Meena & Akash, 2023) [13]. Indigenous peoples' longtime use of pine resin shows their dedication to preserving their unique cultural history. These customs have lasted because they help us maintain our heritage and beliefs while adapting to new situations. Indigenous people regard pine resin as a symbol of their past and identity.

Indigenous societies have relied on pine resin for eons for its spiritual, cultural, and utilitarian uses. The significance of traditional knowledge and practices in creating harmony and resilience in human-environment interactions is highlighted by its varied features and sustainable harvesting practices, which emphasize the fundamental relationship between Indigenous peoples and the natural world.

Methods of Resin Tapping

Methods for tapping In the Landes de Gascogne region of France, around 1850, Pierre Hugues created the first pine resin tapping method, which is being used today, for instance, in Indonesia. Steele outlines the principles of the fishbone tapping method in a US patent that he received in 1869. In the future, the approach would undergo some changes in the 1950s carried out by Mazek Fialla in Europe, eventually becoming what is known today as the Rill method, which is used in India (Cunningham, 2012) [30] (Fig. 1).

Methods for tapping pine resin utilized globally

- **Chinese method:** The secondary xylem is reached by daily cutting a V-shaped groove that points downwards. About 1.2 meters above ground level is where the first groove is cut, and further grooves are created below it. The groove extends over the tree's circumference, reaching approximately halfway. An artificial chemical is not employed. China is the primary user of this approach.
- **American method:** A 15-to-18-day interval is used to cut a horizontal groove. The first of the grooves is cut twenty centimeters above ground level. The only parts taken out are the phloem and bark. The grooves range in height from 2 to 3 cm and measure around one-third of the tree's girth in length (Zaluma *et al*., 2022) [23]. A paste containing 18–24% sulphuric acid (H_2SO_4) is used as a stimulant. Examples of stimulants used as chemical adjuvants in paste formulation include salicylic acid and 2-chloroethyl-phosphonic acid, both of which are ethylene precursors. Countries including Brazil, Argentina, Portugal, and Spain adopt this technique.
- **Hugues or French method:** The secondary xylem is reached by cutting 8 to 10 cm wide slices into the trunk every 10 to 15 days. After two years of extraction, the cut surface may reach a height of 1.8 m from the ground. This technique, which originated in France in the middle of the nineteenth century, is primarily employed in Indonesia today.
- **Mazek or Rill method:** With each passing 3–7 days, V-shaped grooves 2–3 mm wide are sliced. We carved the grooves upwards. A spray containing a stimulant consisting of half hydrochloric acid (HCl) and half sodium bicarbonate (H_2SO_4) is sprayed on. At the moment, this technique is in use in India and Indonesia. Although other extraction methods have been investigated, they have not yet seen substantial commercial application. For example, the borehole approach and the Eurogem closed-blaze method (Zas *et al*., 2020) [24, 25] involve collecting the oleoresin in a sealed receiver.

Fig 1: Different tapping techniques

Chemical stimulation

In the early 1920s, American researcher Eloise Gerry set out to discover how pine resin was made. Her work laid the groundwork for what is now known as the "American method," the sole modern tapping technique that has been officially recognized. Russia also came up with the idea of chemical stimulation around the same period. Chemical stimulation refers to the process of increasing pine resin production by the use of chemical products that are applied to pine trees. Several items have been tested since Hessel was given the first US patent in 1936 (Jakubowski *et al*., 2023) [6]. R.W. Clements [9] was granted a US patent in 1967 for describing the first paste-form chemical stimulant. Before this, the pine resin was sprayed onto the opening incision to facilitate its flow. Sulfuric acid (H_2SO_4) was the active ingredient in this stimulating paste. In a subsequent US patent, Wolter detailed the preparation of a stimulant paste that included CEPA (2-chloroethylphosphonic acid) in addition to sulphuric acid. Following its application to the wound, CEPA travels up the pine stem, where it decomposes under the right chemical circumstances to produce ethylene. When pine trees detect ethylene, they begin to produce resin (Lempang *et al*., 2017) [8]. Not long ago, salicylic acid was shown to be an effective component of stimulant paste for pine tapping, and it is already being sold commercially in certain regions of Brazil.

Micro-tapping

The last bouts of traditional tapping occurred in September of both years and at the same time, parallel studies were performed utilizing micro-tapping techniques to examine the effects of the stimulant pastes. These tests were carried out on separate trees that were located near the ones that were subjected to the traditional tapping. Following the previous description, 48 trees were chosen and measured at each site (four in 2020 and six in 2021). Four trees were randomly assigned per treatment and block to one of the four stimulant treatments - CTR, CUN, SAL, and ZET-within three ecologically homogenous blocks of sixteen trees each. Following Zas *et al.* (2020) [24, 25], micro-tapping was carried out. In short, the bark was marked in a 10-by-10-centimeter window at 50 cm above ground level. Then, using an arch punch and a hammer, a disc of 1.5 cm in diameter was removed from the remaining bark, phloem, and cambium, being careful not to damage the xylem. Next, a small amount of the stimulant paste (about 0.5 g) was dabbed onto the inside of the incision. Affixing pre-weighted 50 ml

Falcon® plastic vials was the next step, after which the holes were sealed with specially-made plastic devices (Zevgolis *et al*., 2022) [26]. Periodically, vials were replaced to investigate the kinetics of resin flow following injury. The amount of resin that flowed out of the wounds was measured gravimetrically (with a precision of 0.01 g) on certain days following the wounding in the 2020 campaign and on certain days following the wounding in the 2021 campaign. After that, for each period, we calculated the resin flow rate (in grams per day) and utilized it as the dependent variable in our temporal dynamic analysis. On the last day of each campaign's evaluation, the accumulated resin flow was also calculated.

Modern Techniques and Innovations in Resin Tapping

Modern techniques and innovations in resin tapping have significantly advanced the efficiency and sustainability of the practice. Automated tapping tools are a big step forward. Precision cuts in the bark are made by automated, battery-powered tools in these systems. This made extracting the resin more efficient while also lowering the amount of work that needed to be done. Better bags and tubs for collecting resin help keep it clean and increase its output (Maaten *et al*., 2017) [21]. Acids like sulfuric acid, ethephon, and 2-chloroethylphosphonic acid are now commonly used to speed up the flow of glue. More advanced types of these stimulants have made the process work better and are better for the world.

Another big new idea is controlled wounding ways that use micro-tapping, which means making smaller, more precise cuts to get the resin out. This method keeps the tree healthy so that it doesn't get hurt as easily. This makes fruits last longer. Techniques for making very small cuts make the flow of oil even better and help the trees live a long time. In biotechnology, trees that naturally make more resin and are less likely to get diseases are chosen genetically and bred to make more resin (Puente-Villegas *et al*., 2020) [15]. The biochemical regulation study aims to make the ways that trees make resin better.

The ways that modern resin tapping is done are also better for the earth. To keep pine forests safe for the long term, rules have been put in place for sustainable harvesting. Integrated pest management methods are also used to keep trees that have been cut down safe from diseases and pests without harming the environment. All of these new ideas are meant to make resin tapping more effective and last longer, while also being good for the environment and the economy.

Comparison of Methods in Terms of Efficiency and Sustainability

Comparing traditional resin tapping methods to current ones shows some important variations in efficiency and environmental friendliness. Tapping is faster and more precise with mechanical tools than with manual trimming or bark peeling. Automation reduces the time and energy needed for resin extraction, increasing production (López-Álvarez *et al.*, 2023) [10, 11]. The second method generates more resin per tree than the first, which uses no chemicals. The first way is traditional. This strategy maximizes tree use to boost efficiency.

Controlled wounding technologies like micro-tapping keep wounds closed longer than traditional approaches. These treatments prevent tree damage with tiny incisions, making them essential for pine forest health and productivity. Winding the trees into coils keeps them healthy and productive during multiple tapping cycles, making resin collection efficient and environmentally friendly. Biotechnological innovations like biochemical modulation and genetic selection boost resin yields and damage tolerance in tree species, improving sustainability.

Pine forest ecosystem and biodiversity conservation can be achieved using modern, ecologically sustainable technologies. Sustainable harvesting and integrated pest management are examples (Du *et al.*, 2022) [2]. Resin collection using these methods will protect forest ecosystems. Modern methods increase resin extraction efficiency while practicing sustainability, environmental friendliness, and resource conservation.

Environmental and Ecological Impact

Tree-ring growth: tapped versus untapped faces

There were clear patterns of growth before resin tapping, as shown by the mean raw tree-ring width (TRW) and STD of cores from both the tapped and untapped faces. The TRW of the two faces began to diverge. Specifically, between 2002 and 2004, the tapped face had much lower values (TRW decrease) than the untapped face (TRW increase), with the difference being greater than 2 mm. Nevertheless, the period was the only one in which the disparity in STD (i.e., STD increase – STD decrease) was statistically significant (p<0.05).

Tree-ring growth: tapped versus untapped trees

Here we offer the tree-ring width series together with its metadata and chronological statistics. There was more age variability and a little older average age for resin-tapped trees compared to untapped trees. Yet, 90% of both the tapped and untapped trees belonged to the mature forest stage, meaning they were older than 40 years. Therefore, tree ring growth was unaffected by the age difference between the two tree species (Lukmandaru *et al*., 2021) [12]. Although tapped trees had lower AC1 and SNR than untapped trees, the values of MS, R bar, and GLK were similar for the two groups. Except for the two years following resin tapping, STD showed that tapped and untapped trees exhibited constant inter-annual variability throughout the research period. During 2000 and 2001, the STD of tapped trees was considerably lower than that of untapped trees, according to the independent sample t-test (p<0.05). Despite this, tapped trees' tree-ring development eventually returned to normal levels and even exceeded the same inter-annual fluctuations seen in untapped trees.

Responses to climate variables: tapped versus untapped trees

During the two periods preceding resin tapping, there were no discernible variations in the climatic responses of trees that had been tapped for resin and those that had not. Furthermore, during the two pre-resin-tapping epochs, particularly from 1967 to 1982, the associations between resin-tapped and untapped tree-ring growth and climatic variables were minimal. In addition, from 1983 to 1999, there was a slight correlation between the STD of resin-tapped and untapped trees and February precipitation, but a negative correlation with the PDSI from February to May. The tree-ring growth responses of tapped and untapped trees in the period after resin extraction were different, though. It showed that drought-related environmental variables were more strongly correlated with growth of both untapped and resin-tapped trees after resin extraction compared to before resin tapping. Additionally, tree-ring growth in resin-tapped trees was more affected by these variables. The correlation between tapped trees and temperature was stronger than that between untapped trees and temperature ($r = -0.76$ and $r = -0.61$, respectively), even though there was a significant negative correlation between the mean temperature of the early growing season (May-July) and both tapped and untapped trees (Garcia-Forner *et al*., 2021) [21]. Additionally, during the early growing season (May-July), the tree-ring growth of tapped trees showed a negative association with VPD and a positive correlation with the PDSI. In contrast, the growth of untapped trees did not exhibit a significant link with either VPD or PDSI. After resin tapping, the model explained 59.01% of the variation in STD for tapped trees and 28.81% for untapped trees, according to the commonality analysis. Over 95% of the total explained variance was accounted for by the following factors for both tapped and untapped trees: the pure effects of the May-July temperatures; the joint effects of temperature and the PDSI; and the joint effects of temperature, the VPD, and the PDSI (Zeng, Xiaomin, *et al*. 2023) [31]. Specifically, for tapped trees, this was 30.38% of the explained variance, and for untapped trees, it was 13.26%. While temperature accounted for more than 95% of the total explained variance, the similarity analysis between the first-order difference of STD and the most significant climate variables showed that the model-explained variances for tapped and untapped trees were similar (53.9 and 53.59%, respectively). Within the study period, the STD of tapped trees exhibited consistent inter-annual changes, except for lower values in 2000 and 2001. Hence, after omitting 2000 and 2001, we proceeded to compute the correlation coefficients between STD and the most important environmental factors for the time after resin tapping. Over the May–July period, the tapped trees' STD correlation coefficient with VPD and PDSI, respectively, dropped and were comparable to the untapped trees. Findings like these suggest that lower STD values in 2000 and 2001 may have influenced the difference in tree-ring climatic responses between tapped and untapped trees (Xiaomin, *et al*. 2021) [31].

Economic and social aspects of resin tapping

Economic importance of resin tapping

Resin tapping is very important to the economies of many countries, especially those with lots of pine woods, like China, India, Brazil, and Portugal. Pine tree resin is an important raw material for many businesses, such as those that make glues, varnishes, sealants, and many chemical products. The global resin market has grown a lot because it can be used in so many different ways. Construction, medicines, and food processing are just a few of the industries that are driving demand.

The economy needs to tap resin for more reasons than just getting money by selling resin (Rodríguez-García *et al*, 2021) [5] that the business helps millions of people around the world make a living by giving them work. This is especially true in the woods and in rural places where there might not be many other ways to make some cash. The resin tapping business is important for many jobs. One example is people who work in forests and cut trees. Some other jobs involve making and selling plastic goods. By paying for the building of facilities and public services in places that make resin, the money constructed from tapping resin also helps national economies.

Market Demand and Commercial Uses of Resin

Because it can be used in so many ways, pine resin is in high demand and will stay that way. It is another name for pine resin and is used to make things like oil and rosin. It is also used to make paints, inks, and varnishes and as a solvent. Rosin, on the other hand, is used to make plastic goods, glues, and stuffing for paper. Resin products are also used in the drug industry because they can be used to treat infections and lower inflammation (Soliño *et al*., 2018) [19].

In the food business, derivatives of pine resin are used to make things blend better and add taste. They improve the taste and length of food. Pine resin sales have gone up even more because more people want natural and eco-friendly products. Pine resin can be used over and over again and has less of an effect on the environment than manufactured resins. As the resin market grows, businesses that tap it stay in business, and academics are pushed to find new ways to extract and work with resin.

Socio-economic benefits to local communities

Resin tapping is good for local economies and communities, especially in places that are farther away and have more trees. Many people can count on stable jobs at the company, which helps lower poverty rates and raise living standards. In resin tapping, there is work for both skilled and unskilled workers because the job can be done by people with different levels of schooling and experience. The community as a whole gain when families pay for things like healthcare, education, and transportation with the money they make from tapping resin.

The success of a resin-tapping business can help local economies in a way called the "multiplier effect." To make their point clear, resin tappers often shop at local markets, which helps small businesses and services in the area (Zeng *et al*., 2023) [31]. Because these businesses are spread out, local economies are better able to handle changes like drops in food prices and other economic problems. Also, people who work in the resin-tapping business usually support long-term management and protection of forest resources. Resin production depends on healthy forests, so groups that cut down trees for resin have a reason to keep forests healthy. This could lead to better care for the environment and protection efforts, which would protect forest areas for many years to come.

Resin tapping can bring people together and help them keep their practices alive. It can also be good for business. Many cultures have used resin tapping, which is a popular method that has been around for a long time. Rodrigues-Honda *et al*. (2023) [16] found that keeping up with this practice helps to protect cultural history and builds community pride and personal identity at the same time. Training courses and cooperatives can make the social benefits bigger by giving resin tappers education and training and making sure they work in a safe and fair place. In conclusion, resin tapping is an important part of the economy because it creates many jobs and makes a lot of money, has many uses that make it more popular, and helps nearby towns in substantial social and economic ways.

Case studies

1. **Finland:** Sustainable Resin Tapping in Northern Europe Finns have been resin tapping for a very long time, especially in the north where there are lots of pine trees. There are many eco-friendly ways to get resin from trees that have been pushed by the Finnish Forest Research Institute (Metla). For example, Finland has used micro-tapping to make sure that trees are hurt as little as possible while still getting the most oil out of them (Garcia-Forner *et al.*, 2021) [21]. It was possible because people from the local communities and the forest businesses worked together. The resin industry has grown thanks to this method, which also helps the country's income and keeps the forests' natural beauty.
2. **Spain:** Traditional Resin Tapping in Mediterranean Forests Resin tapping has been done for a long time in Spain, especially in the Mediterranean area where Aleppo pine (*Pinus halepensis*) and coastal pine (*Pinus pinaster*) are grown in large numbers. Traditional resin tapping is still a big way for rural communities to make money, even though globalization and falling demand for natural resins are making it harder to do. Cooperatives and local groups are very important in places like Andalusia and Catalonia for keeping traditional tapping methods alive and selling resin-based goods to specific groups of people. While more modern methods are slowly being used, Spain's experience shows how traditional ways of tapping resin can help rural communities keep their jobs and cultural traditions alive. (Soliño, Mario, *et al*., 2018) [19].

Conclusion

The complex process of tapping pine trees for resin affects ecosystems, businesses, and people. Traditional methods preserve culture and strengthen communities, while modern ones boost resin output. Both new and ancient resin extraction technologies have pros and cons, therefore environmental, economic, and social aspects must be considered. For resin tapping to survive, current technology, conventional wisdom, and ecological considerations must be used. Resin resources and forest ecosystems must be preserved by researchers, forest managers, communities, and legislators working together on successful programs.

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