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Resin and Bagasse, Co-Products of Guayule Rubber Extraction: Applications in Different Fields for an Economic Viability and Ecological Approach †

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Abstract: The economic viability of guayule as an industrial crop for natural rubber production depends largely on the potential valorization of these co-products. According to the studies carried out on the subject, there is a broad consensus on the added value of the resin and bagasse in different fields of application. The process of extracting natural rubber from guayule produces mainly bagasse (±80% of the total dry mass) and resin (±10% of the total dry mass). Among guayule research, the high-value co-products would significantly improve the economic viability of guayule as an industrial crop and offset a substantial portion of the cultivation and processing costs. According to studies, the resin remains the most fluctuating value, reducing this uncertainty, through future research on resin applications, is essential to the success of guayule as a natural rubber raw material, it finds applications in different industrial fields, such as coatings, varnishes, paints, treated wood, biocontrol agents and controlled release formulations. Bagasse is composed primarily of cellulose, hemicellulose, lignin, and resin, and has a high calorific value, making bagasse a suitable fuel for on-site combustion to produce electricity and thermal energy. Bagasse combustion in this scenario is less complex than the logistics of biofuel production. Resin-containing guayule bagasse has been combined with a plastic binder to make high-density composite panels resistant to termite degradation. In addition, the resinous material can be solvent extracted and used to impregnate the wood with the raw resin extract so that the wood is protected from destructive organisms, Guayule bagasse containing resin can modify the soil nature and improve the growth of vegetables compared to de-resinated bagasse.

Keywords: guayule; co-products; bagasse; resin; application; latex; natural rubber

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1. Introduction

Guayule (*Parthenium argentatum* Gray) is a perennial shrub belonging to the Asteraceae family and native to the Chihuahuan desert, zones spread from northern Mexico to southern Texas. This plant is commonly known to produce high-quality rubber, an elastomer called polyisoprene, accounting for up to 10% of the dry weight of the branches [3,5]. Natural rubber is required not only for commercial-grade tires but also for defence and hypoallergenic medical articles [14,15]. In addition to its promising natural rubber production and relative drought tolerance, guayule derives its economic value from exploitation and valorisation of the whole plant biomass for the production of bioenergy and non-rubber co-products, such as resin and bagasse which can be converted into raw

materials with high added-value [11,14]. Furthermore, the potential of valorisation guayule processing residue might contribute to reducing rubber production costs by 26–49 % [17].

In light of the potential of guayule, many researches mentionned the industrial rubber extraction processes and the exploitation of its byproducts. Presently, resin stands as the most important unknown in the guayule supply chain, consequently, researches on high-value guayule resin products are underway. However, the proportion of resin is relatively small (5–10%) of the guayule biomass, in the same proportion as rubber yields. The most significant proportion is bagasse, which comprises 80–90% of the biomass. As a result, bagasse valorisation could have a major effect on guayule's overall value [4]. The remaining unused lignocellulosic biomass from guayule rubber extraction, often referred to as bagasse, is considered one potential solution for bioenergy production (Moreno, Sproul and Quinn, 2022), a rich source of bioactive compounds for potential exploitation in fodder, nutraceuticals and pharmacological sectors.

2. Guayule Resine Valorisation

The economic aspect of guayule valorisation has led to the development of guayule resin applications in different fields. The first step to estimate the real added value of resin as raw material is to identify the range of active compounds that resin can substitute. The guayule resin, is a viscous liquid, its chemical composition has already been described in the literature, around 50 secondary metabolites have been reported, such as terpenes (guayulins A, B, C, D, argentatines), polyphenols, triglycerides, waxes, sugars, organic acids, phytosterols. Guayule resin composition varies with shrub strain, harvest date, cultivation site, and extraction processing [4,15].

In the literature, several studies mentioned resin applications such as coatings, biocontrol agents [6], and controlled-release formulations [12]. Argentatins have been reported to have antimicrobial, insecticidal, and antitumoral properties [12].

Polyphenolics, cinnamyl derivatives and terpenoids are the most likely compounds responsible for the observed termite resistance characteristics of guayule resin (Bultman et al., 1986). The recently-identified phenolic compounds in the leaves and twigs have potential uses in antioxidant, anticancer, anti-inflammatory, and antidiabetic applications [13].

It can be used as a wood preservative against damage caused by highly destructive termite species [9,10], as pesticide [2], in the formulation of coatings and paints, providing good properties, abrasion resistance, gloss, drying time and water resistance [14]. In addition, guayule resin combined with epoxy polymers is used to make strippable coatings for the protection of equipment in storage [11]. It has been also reported that an acetone-extractable, residual guayule resin could be used as a bio-based recycling agent in hot mix asphalt [7].

3. Guayule Bagasse Valorisation

Bagasse is mostly made up of cellulose, hemicellulose, lignin and resin [1,14]. Guayule resin-containing bagasse combined with a plastic binder is used to produce high-density composite boards resistant to termite degradation [12]. Ref. [3] have successfully manufactured a Mycelium-based bio-composite using bagasse from guayule and a wild strain of Ganoderma curtisii by a simple pressed method, which is cost-effective, eco-friendly, and fully compostable.

In a recent study, the use of bagasse to produce biofuels and refractory bricks has been reported [3]. The energy value of bagasse is increased by the guayule resin, which accounts for 10% of the material, and has a heating value of 38 MJ/kg, which is comparable to the oil obtained from the majority of oilseed crops [8]. Bagasse is a suitable feedstock fuel for direct combustion because in accordance with Schloman and Wagner (1999). Furthermore, resinous bagasse has a high heating energy value between 21,000 and 24,000

kJ/kg, and can be converted directly into liquid hydrocarbons [1]; it has been also used for energy production as fireplace logs (Wagner et al., 1991), as pelletized fuel with a mixture of cotton gin trash [11].

According to a previous study, guayule bagasse can be utilized as an amendment to heavier soils for its lightning effect. The same author also claims that guayule leaves removed by parboiling can be utilized as fertilizer. Taylor makes no mention of the use of resin in any of his works. Another study observes that when added at a rate of up to 11 tons/ha in Guayule bagasse slows lettuce growth in the absence of supplementary nitrogen fertilizer (Scholman, 1991). Guayule bagasse and resin can be used, for example, in the pulp paper and chemical industries (Chow et al., 2008), as a soil amendment [11,16].

4. Conclusions

This review provides insight into the applications of guayule byproducts. Natural resins have numerous applications in food, pharmaceutical, cosmetic, paint, and adhesive industries. Through energy applications, the residual biomass from guayule presents an opportunity as a valuable fuel resource collected on-site and is a suitable lignocellulosic conversion feedstock. Guayule by-products provide the potential to improve the sustainability and economic feasibility of guayule rubber production.

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