

Article

Natural Latex from *Diplorhynchus Condyllocarpon* as a NO₂ Trap

Kenneth Kaunda ¹  and Maria Jerzykiewicz ^{2,*} ¹ Department of Pure and Applied Chemistry, University of Zambia, Lusaka 10101, Zambia; kenneth.kaunda@unza.ac.zm² Faculty of Chemistry, University of Wrocław, 50-383 Wrocław, Poland

* Correspondence: maria.jerzykiewicz@uwr.edu.pl

Featured Application

The main objective of this work was to perform an exploratory preliminary analysis of latex from the *Diplorhynchus condyllocarpon* tree for the presence of natural rubber to find alternative sources of rubber that retain all the properties of *Hevea brasiliensis* rubber and/or exhibit other properties that could be used industrially to diversify the natural rubber supply chain. Instrumental analytical methods used for this purpose included NMR, FTIR, ICP-OES, and elemental analysis. The obtained results were compared with corresponding data reported in the literature. As human activities continue to intensify, environmental pollution has become an increasing concern, highlighting the need for effective environmental monitoring tools. Therefore, the secondary goal of this study was to investigate the reaction of NO₂ with the rubber fraction of *Diplorhynchus condyllocarpon* latex, focusing on the effect of rubber as a spin trap and the formation of radicals that can be studied using EPR.

Abstract

The objective of this study was to introduce *Diplorhynchus condyllocarpon* as a potential latex source. In addition, the physicochemical properties of the polymer as a trap for NO₂ were investigated. Advanced spectroscopic methods, such as FTIR-ATR, EPR, and ¹H and ¹³C NMR, were used in addition to traditional elemental analysis to evaluate the properties of the latex. Analysis of latex from the *Diplorhynchus condyllocarpon* tree revealed the presence of rubber. In addition to rubber, analyses revealed the presence of other aromatic and aliphatic compounds in the latex sample. The presence of semiquinone radicals indicates the presence of antioxidant phenolic structures in *Diplorhynchus condyllocarpon*. The reaction of latex with NO₂ resulted in the formation of a stable nitroxyl radical, as proven by the characteristic EPR parameters.

Keywords: *Diplorhynchus condyllocarpon*; latex; nitroxyl radical; EPR; FTIR; NMR; semiquinone radicals; NO₂ trapping



Academic Editors: Dario Savoca and Silvia Orecchio

Received: 26 May 2026

Revised: 8 July 2026

Accepted: 13 July 2026

Published: 16 July 2026

Copyright: © 2026 by the authors.

Licensee MDPI, Basel, Switzerland.

This article is an open access article distributed under the terms and conditions of the [Creative Commons Attribution \(CC BY\)](https://creativecommons.org/licenses/by/4.0/) license.

1. Introduction

The best-known latex-producing plant is the natural rubber plant, *Hevea brasiliensis*. *Hevea brasiliensis* is currently the sole major commercial source of natural rubber. Natural rubber (*cis*-1,4-polyisoprene) constitutes approximately one-third of the latex volume and cannot be fully replaced by synthetic rubbers in many key applications because of its superior elasticity, resilience, abrasion and impact resistance, and heat dispersion [1–4]. Latex is a colloidal aqueous emulsion of *cis*-1,4-polyisoprene particles (≈30–40% by weight)

in water ($\approx 55\text{--}65\%$), with particles coated with proteins, lipids, and phospholipids [5–8]. These non-rubber components, including proteins and lipids, significantly influence the mechanical properties and processing behavior [4]. Natural rubber is used in tens of thousands of products (often estimated to be ca. 40,000–50,000), including tires, gloves, condoms, and other medical devices, where its mechanical performance is critical [2,5–8]. Global production ($\sim 14\text{--}15$ million tons/year) already lags behind demand and is constrained by *Hevea*'s strict tropical requirements and disease vulnerability [2–4].

Herein, we present the results of selected analyses of latex from *Diplorhynchus condylocarpon* as an alternative to *Hevea*. *Diplorhynchus Condylocarpon* is a small tree or shrub that grows to about 2 m in height. Each fragrant blossom produces two firm, dark-brown, fruit-shaped pods. For this reason, the tree is also known as the Horn Pod Tree [9]. This species is found mainly in southern Africa, including Angola, Zambia, Zimbabwe, Malawi, Mozambique and South Africa. It grows on dry, sandy–loamy savanna soils, meadows, forests, and stony slopes [10]. The tree is a member of the *Apocynaceae* family, which produces both latex and rubber [11]. *Diplorhynchus condylocarpon* produces a sticky bluish-white latex, a characteristic common to members of the *Apocynaceae* family. However, its potential commercial utilization as a latex source has not yet been studied.

Nitrogen dioxide (NO_2) is one of the most important atmospheric pollutants and is recognized worldwide as a major environmental and public health concern [12]. It is generated primarily through high-temperature combustion processes, including vehicle emissions, fossil fuel combustion, industrial activities, and biomass burning [13]. In the atmosphere, NO_2 plays a crucial role in photochemical smog formation and contributes to the production of tropospheric ozone and secondary particulate matter, both of which significantly affect air quality [14]. In addition, NO_2 participates in atmospheric oxidation processes and contributes to acid deposition, resulting in adverse effects on terrestrial and aquatic ecosystems [12,14]. Exposure to NO_2 has been associated with numerous adverse health effects, including respiratory inflammation, decreased lung function, increased susceptibility to respiratory infections, and exacerbation of chronic respiratory diseases such as asthma and chronic obstructive pulmonary disease [15]. The World Health Organization has identified NO_2 as a priority air pollutant requiring continuous monitoring because even relatively low concentrations may negatively impact human health [16].

Consequently, the development of simple, sensitive and environmentally friendly methods for the detection and monitoring of NO_2 remains an important scientific and technological challenge [17]. Biological and naturally derived materials capable of interacting with and stabilizing reaction products of NO_2 are of particular interest because they may provide alternative approaches for environmental monitoring and pollutant detection.

Many organisms can provide a natural and effective system for monitoring environmental pollution levels. One of the most well-known bioindicators is lichens, which are used to determine air pollution levels. Besides assessing pollution based on the presence or absence of lichens, the use of electron paramagnetic resonance (EPR) has been proposed to examine the presence of nitrogen oxide (IV) in the air [18,19]. The formation of iminoxyl radicals in lichens after reaction with NO_2 has been observed under laboratory and natural conditions. These radicals are stable and can be detected using this technique [18–21]. Nitrogen-containing radicals are also formed by the reaction of NO_2 with lignin found in wood and the cell walls of some algae [20]. Because plants absorb NO_2 from the air, natural rubber could also potentially act as a spin trap and enable NO_2 detection via radical formation. Formation of nitrogen-containing radicals by reaction with NO_2 could have different pathways depending on the structure of the initial natural organic matter. As a result, different radicals could be produced, from β -diketone iminoxyls (like in lichens or humic

substances) [18,19], while for carbon-chain polymers nitroxyl radicals are formed [21]. The type of radical formed can be very easily established with the use of EPR.

The study, thus, had two primary objectives: (i) to evaluate *Diplorhynchus condylocarpon* as a potential future source of natural latex and (ii) to demonstrate the potential application of natural latex as a NO₂ trap for environmental monitoring. In addition, latex-derived products are expected to undergo similar reactions with NO₂, highlighting the broader relevance of these findings. The formation of nitrogen-containing radicals is strongly influenced by phenolic structures naturally present in the latex matrix, as these compounds participate in electron-transfer reactions [21]. The pathways of these redox reactions are also affected by the metal-ion composition of the latex; therefore, the concentrations of metal ions were determined.

2. Materials and Methods

Latex was collected from three mature *Diplorhynchus condylocarpon* trees in Mpika town in Muchinga Province of Zambia in the month of May, a month after the rainy season, by making shallow incisions in the bark. The exuded latex was collected into glass bowls. It was cleaned by sieving to remove foreign particles, packed into glass containers and stored at room temperature. It was then freeze-dried (temp. ~−48 °C) to obtain an enabling analyte.

2.1. Experiment with NO₂

Concentrated HNO₃ was added dropwise to a flask containing copper metal (about 5 g), yielding NO₂, which was then piped to the closed vessel containing the small piece of previously freeze-dried sample. Dropping of HNO₃ was stopped when brown NO₂ fumes appeared in a closed glass container. The reaction was conducted for 30 min. The experiment was repeated four times, for different pieces of rubber.

2.2. Latex Analysis

The percentage composition of the elements (C, H and N) was determined in triplicate using the apparatus Vario EL Cube from Elementar, Langenselbold, Germany. Oxygen content was calculated from the difference. Metal-ion content was established for each of the four samples on the Thermo Fisher Scientific spectrophotometer, iCAP 7400 DUO ICP-OES, Waltham, MA, USA. The samples were prepared as follows: previously weighed portions were mixed with concentrated HNO₃ and then mineralized using a microwave mineralizer (Plazmatronics, Wrocław, Poland). Analyses were performed in quadruplicate. ¹H and ¹³C NMR spectra were made for latex dissolved in deuterated chloroform on a Bruker Avance III NMR (Karlsruhe, Germany) spectrophotometer at 500 MHz. FTIR spectra were performed for standard parameters in KBr pellets on the Bruker Vertex 70 spectrometer (Karlsruhe, Germany). X-band EPR spectra of dry latex were obtained with a Bruker Elexsys E500 spectrometer (Karlsruhe, Germany) at room temperature. For simulation of the spectra, SimFonia by Bruker (Karlsruhe, Germany) was used.

3. Results

3.1. Physicochemical Properties of Latex from *Diplorhynchus Condylocarpon*

Elemental analysis of the freeze-dried latex fraction revealed that the material was dominated by a hydrocarbon-rich polymeric phase (Table 1). Results of the same analysis repeated after 3 months showed very insignificant variation, indicating that the bulk composition remained stable during storage.

Table 1. Freeze-dried latex elemental content.

	C(SD) [%]	H(SD) [%]	N(SD) [%]	O(SD) [%]
First Measurement	78.28(0.15)	9.18(1.31)	0.17(0.03)	12.36(1.22)
After 3 Months	78.67(0.65)	10.48(1.58)	0.17(0.02)	10.68(2.08)

The elemental composition reported corresponds to the freeze-dried whole latex rather than to an isolated rubber fraction. *Hevea brasiliensis* typically contains approximately 87–89 wt% carbon and 10–12 wt% hydrogen, reflecting the hydrocarbon composition of *cis*-1,4-polyisoprene. The slightly lower carbon content observed here reflects the presence of co-extracted plant metabolites, including terpenoids, fatty acids and phenolic compounds commonly found in non-*Hevea* latex systems [22–24]. The elemental analysis reflects the composition of the freeze-dried whole latex and indicates the presence of substantial non-rubber constituents. Therefore, the evidence for the presence of natural rubber is derived primarily from NMR and FTIR spectroscopic analyses, which demonstrate the occurrence of a *cis*-1,4-polyisoprene phase. Isolation and characterization of the purified rubber fraction will be necessary to establish its composition and properties relative to commercial *Hevea brasiliensis* rubber. A feature of note is the very low nitrogen content, suggesting that the latex contains relatively small quantities of proteins. This is advantageous from an industrial application perspective, as protein residues in *Hevea* latex are known to contribute to latex allergenicity in medical gloves [25].

Minimal change in elemental composition after three months shows that the polymeric hydrocarbon backbone is chemically stable under ambient conditions, with no significant oxidative degradation or volatilization of minor organic components. Such stability is an important prerequisite for industrial processing.

The metal-ion content in the analyzed sample was very low (Table 2). Metal ions like titanium, arsenic, lead, strontium, manganese, cadmium and cobalt were not detected. Content of inorganic elements in plant latex is very important because laticifers transport not only polymer particles but also dissolved mineral nutrients absorbed from the soil [20]. Similar elemental profiles have been reported for latex obtained from *Hevea brasiliensis* and other members of the *Apocynaceae* family, including *Periploca angustifolia* [26]. As metals influence rubber elasticity, hardness and aging behavior and are also able to catalyze radical oxidation in polyisoprene, their low concentration in the studied sample is a positive welcome result.

^1H and ^{13}C spectra show the presence of rubber in latex as well as the presence of other aromatic and aliphatic compounds.

The ^1H NMR spectrum of the latex (Figure 1) reveals three dominant resonances characteristic of the repeating unit of *cis*-1,4-polyisoprene, the principal structural polymer in natural rubber. Signal A at 1.69 ppm corresponds to the allylic methyl protons ($-\text{CH}_3$) attached to the double bond of the isoprene unit. A resonance at signal C at 2.03 ppm arises from methylene protons ($-\text{CH}_2-$) located adjacent to the double bond along the polymer backbone. Signal B at 5.12 ppm corresponds to the vinylic proton ($-\text{CH}=\text{}$) associated with the unsaturated carbon–carbon double bond. These spectroscopic data indicate the presence of a *cis*-1,4-polyisoprene phase with characteristic features similar to those reported for other natural rubber-producing species, e.g., *Periploca angustifolia* and the gold standard for natural rubber, *Hevea brasiliensis*, although quantitative comparison of microstructural parameters was beyond the scope of the present study [26]. The agreement indicates that the polymer present in *Diplorhynchus condylocarpon* latex possesses the same 1,4-addition microstructure and unsaturated hydrocarbon backbone characteristic of natural rubber. Additional minor resonances between 0.5 and 1.5 ppm indicate the presence of saturated

aliphatic compounds, likely derived from plant lipids and terpenoids. A weak signal near 6.5 ppm suggests the presence of aromatic metabolites, which are also commonly detected in the latex of *Apocynaceae* species. With all the above signal peaks taken together, the ^1H NMR spectrum confirms that the major resonances observed in the NMR spectra are consistent with the presence of a *cis*-1,4-polyisoprene phase, although the relative proportions of rubber and non-rubber constituents were not quantified in the present study. The polymer phase corresponds to *cis*-polyisoprene chains with a high degree of stereoregularity. The values of chemical shifts on the obtained spectrum correspond to literature values obtained for natural rubber from *Periploca angustifolia*, a species belonging to the *Apocynaceae* family, as well as *Diplorhynchus Condyllocarpon*, the proposed candidate for the sourcing of natural rubber for commercial use [26].

Table 2. Metal-ion content in freeze-dried latex. Measurement in 4 replications. Standard Deviation in brackets.

Metal	[mg/g] (SD)
Calcium, Ca	1.81 (0.628)
Potassium, K	5.00 (0.085)
Chromium, Cr	0.096 (0.027)
Iron, Fe	0.86 (0.142)
Nickel, Ni	0.11 (0.0391)
Zinc, Zn	0.089 (0.419)
Aluminum, Al	0.24 (0.087)
Barium, Ba	0.082 (0.024)
Copper, Cu	0.081 (0.050)
Magnesium, Mg	1.41 (0.19)
Sodium, Na	0.77 (0.42)

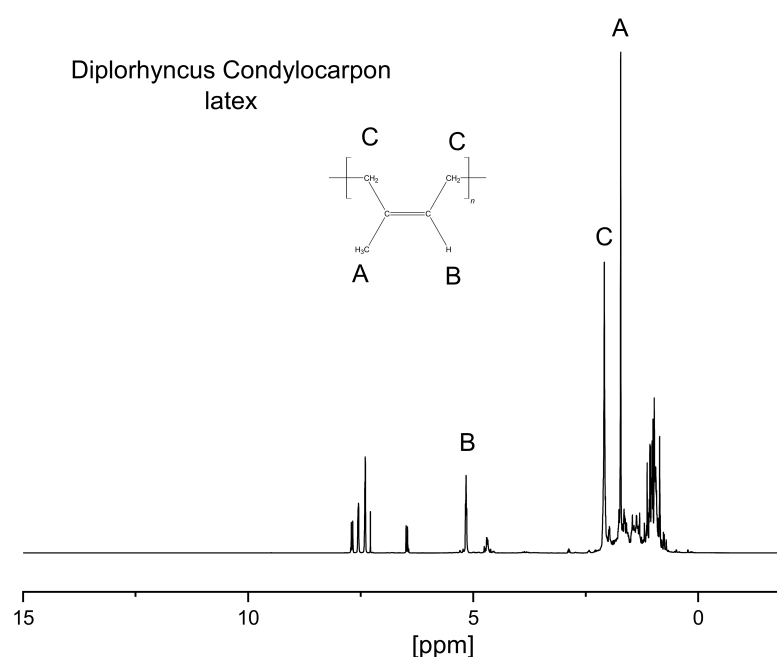


Figure 1. Spectrum of ^1H NMR latex from *Diplorhynchus condyllocarpon*.

The ^{13}C NMR spectrum (Figure 2) provides further insight into the microstructure and stereochemistry of the polymer backbone. Five major resonances characteristic of the *cis*-1,4-polyisoprene repeating unit were observed. Signals B at 135.55 ppm and E at 125.38 ppm correspond to the sp^2 carbons of the $\text{C}=\text{C}$ double bond, while C at 32.24 ppm and D at 26.30 ppm arise from the methylene carbons of the polymer backbone. Signal A at 23.48 ppm is attributed to the methyl carbon of the isoprene unit. The observed chemical shifts are consistent with those reported for high-*cis* natural rubber, confirming that the polymer chains possess a *cis*-1,4 configuration. In natural rubber systems, this stereoregular arrangement arises from enzymatic polymerization of isoprene units within plant laticifers and results in atactic polymer chains with highly regular *cis*-configured double bonds.

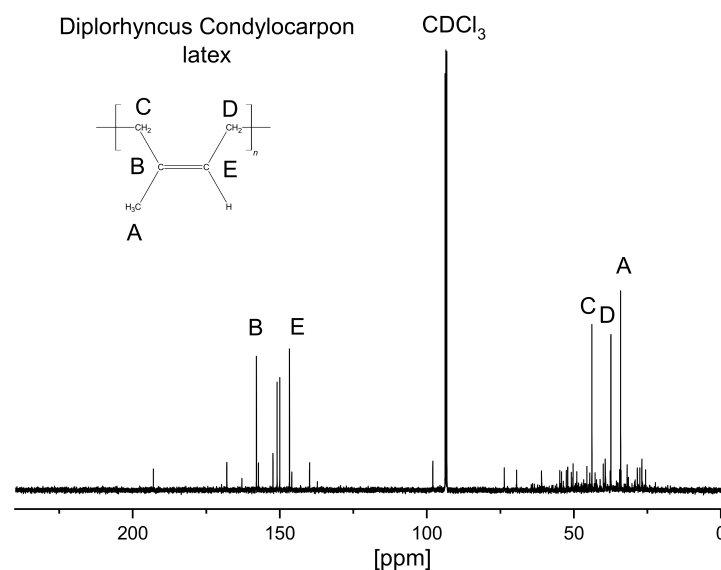


Figure 2. Spectrum of ^{13}C NMR latex from *Diplorhynchus condylocarpon*.

This microstructure is responsible for the characteristic elasticity, strain-induced crystallization and viscoelastic behavior of natural rubber. Importantly, the ^{13}C NMR spectrum obtained for *Diplorhynchus condylocarpon* latex closely resembles that reported for latex from *Periploca angustifolia* [26], suggesting that these two *Apocynaceae* species produce polyisoprene with similar stereochemical microstructures.

Minor signals in the aliphatic and aromatic regions further support the presence of non-rubber organic constituents, consistent with the observations from the proton spectrum. ^1H and ^{13}C spectra show the presence of rubber in latex as well as the presence of other aromatic and aliphatic compounds. But it should be kept in mind that examined samples were not purified, but just freeze-dried latex.

The FTIR spectrum of the freeze-dried latex (Figure 3) provides additional evidence for the presence of *cis*-1,4-polyisoprene. Strong absorption bands at 2961, 2927, and 2855 cm^{-1} correspond to $\text{C}-\text{H}$ stretching vibrations of methyl and methylene groups within the hydrocarbon backbone. The band at 1639 cm^{-1} is assigned to $\text{C}=\text{C}$ stretching vibrations, which arise from the unsaturated double bond of the isoprene unit. Additional bands at 1377 cm^{-1} and 1250 cm^{-1} correspond to $\text{C}-\text{H}$ bending and skeletal vibrations, while the absorption at 833 cm^{-1} represents the out-of-plane deformation of $=\text{C}-\text{H}$, a diagnostic vibrational mode associated with *cis*-1,4-polyisoprene. These spectral features closely match those reported for natural rubber derived from both *Hevea brasiliensis* and *Periploca angustifolia* [26]. The presence of the characteristic 833 cm^{-1} band provides strong evidence that the polymer backbone predominantly adopts the *cis* configuration, as the corresponding band in *trans*-polyisoprene appears at significantly different frequencies. In addition to the polyisoprene

signals, several bands associated with minor organic constituents were observed. A broad absorption at 3425 cm^{-1} corresponds to O–H stretching vibrations, suggesting the presence of alcohols or phenolic compounds.

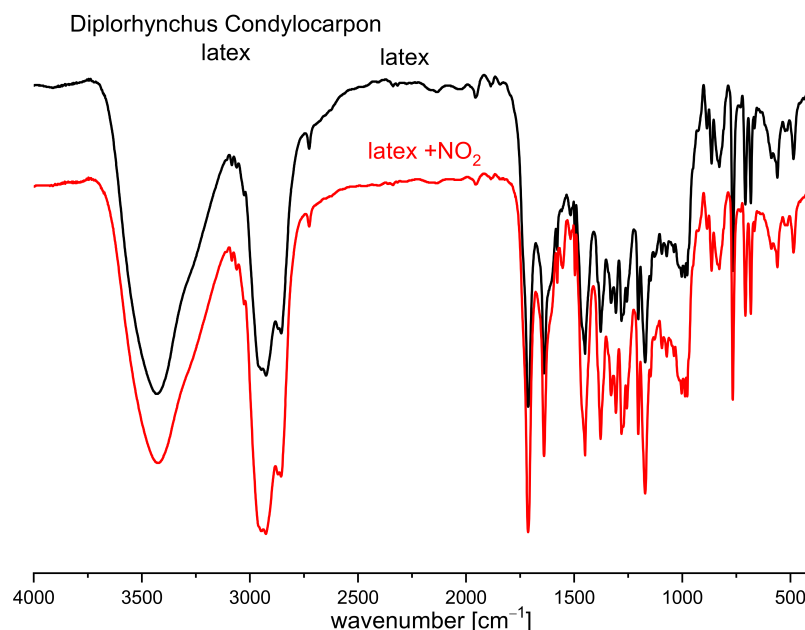


Figure 3. FTIR spectra of untreated and NO_2 treated latex from *Diplorhynchus Condyllocarpon*.

The band at 1712 cm^{-1} indicates C=O stretching vibrations, which may originate from esters, ketones or oxidized terpenoid species. The absorption at 766 cm^{-1} is characteristic of aromatic C–H bending vibrations, further supporting the presence of aromatic metabolites.

To evaluate the stability of the polymer during storage, the FTIR spectrum was re-measured after three months storage. The resulting spectrum was essentially identical to the initial one, indicating that no detectable structural changes occurred within the polymer backbone during the 90-day storage stability analysis under ambient conditions.

The EPR spectrum exhibited a single resonance signal (Figure 4), with no resolved hyperfine splitting or anisotropic features. The value of g-parameter 2.0040 is characteristic for a semiquinone radical structure [27]. Semiquinones are observed in natural organic matter where polyphenolic species play an important antioxidant role [28].

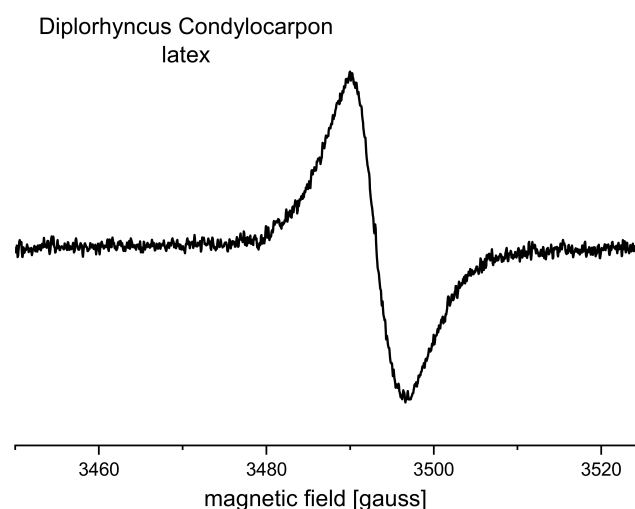


Figure 4. EPR spectra of semiquinone radicals in *Diplorhynchus Condyllocarpon*.

Semiquinone radicals are formed in redox equilibria between hydroquinones and quinones (Figure 5). These radicals are stabilized by the natural matrix in which they are embedded, making the unpaired radical inaccessible to external factors. The equilibria could be shifted by pH redox potential change.

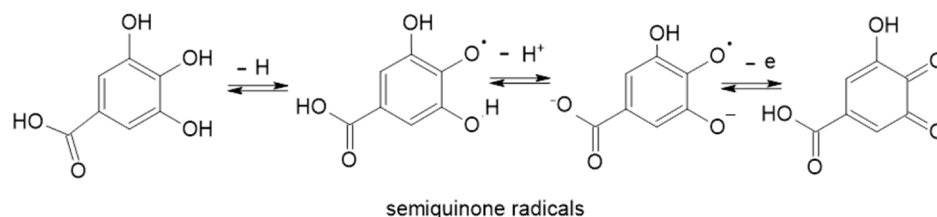


Figure 5. Radicals in polyphenol equilibria.

3.2. NO_2 Trapping by Latex from *Diplorhynchus Condyllocarpon*

A new radical was formed as a product of the reaction of latex and NO_2 (Figure 6). The shape of the EPR spectra varied from the previously observed single-line type. Observed spectra revealed an anisotropic hyperfine structure attributed to the interaction of an unpaired electron with a nitrogen nucleus ($I_N = 1$). EPR parameters obtained from simulation were characteristic of nitroxyl radicals [20] and remained unchanged during subsequent measurements performed one month later. Due to the presence of the $\text{C}=\text{C}$ double bonds in the studied latex sample, the reaction with NO_2 occurred spontaneously without the need for an additional UV radiation source. Formation of nitroxyl radicals is characteristic of synthetic rubber. However, exposure to NO_2 can induce polymer degradation through radical chain reactions as observed in synthetic isobutene–isoprene rubber [29].

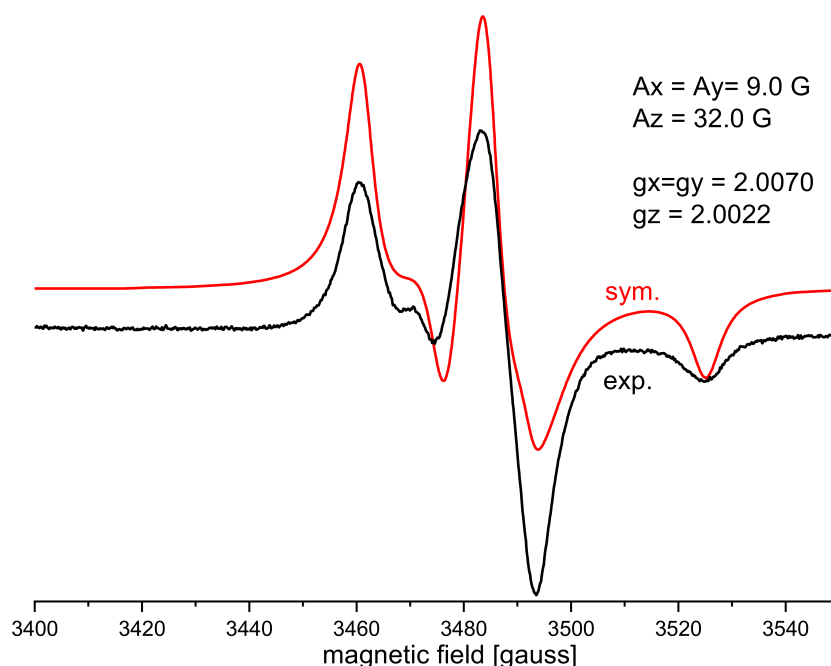


Figure 6. EPR spectrum of *Diplorhynchus Condyllocarpon* treated with NO_2 ; black line; experimental spectrum; red line: simulation spectrum.

Elemental analysis repeated after the reaction of sample latex with NO_2 showed that percent mass content of nitrogen increased from 0.17% to 0.5%, while percent mass content of oxygen increased from 10.68 to 12.36% to 13.94%, confirming that a reaction had occurred. The mass percent contents of carbon and hydrogen were 75.35% and 9.43%, respectively. The small difference in carbon and hydrogen is the result of total mass change

due to NO_2 incorporation by the substitution to the double bond in isoprene units. This increase in nitrogen content and the simultaneous increase in oxygen concentration indicate incorporation of nitrogen- and oxygen-containing functionalities into the latex matrix. However, the total nitrogen content determined by elemental analysis cannot be directly correlated with the concentration of radicals detected by EPR spectroscopy, as some of the newly formed nitrogen species could be diamagnetic, and thus EPR-silent. Reactions of NO_2 with unsaturated polymers are known to produce numerous nitrogen-containing species, all of which originate from the reaction of NO_2 with carbon–carbon double bonds ($\text{C}=\text{C}$), yielding both diamagnetic and paramagnetic products [20,21].

Surprisingly, the FTIR spectra did not show spectacular differences between the spectra of the raw latex and the latex after NO_2 treatment. After careful analysis of the spectra, an increase in the intensity of one band was observed. An asymmetric N–O stretching vibration at 1550 cm^{-1} , marked in Figure 7, confirmed the reaction. The band at 1639 cm^{-1} originating from the $\text{C}=\text{C}$ stretching vibration remains unchanged, indicating that NO_2 reacted with a small amount of rubber. These FTIR observations indicate qualitative evidence consistent with limited chemical modification of the latex matrix rather than quantitative proof of the extent of reaction.

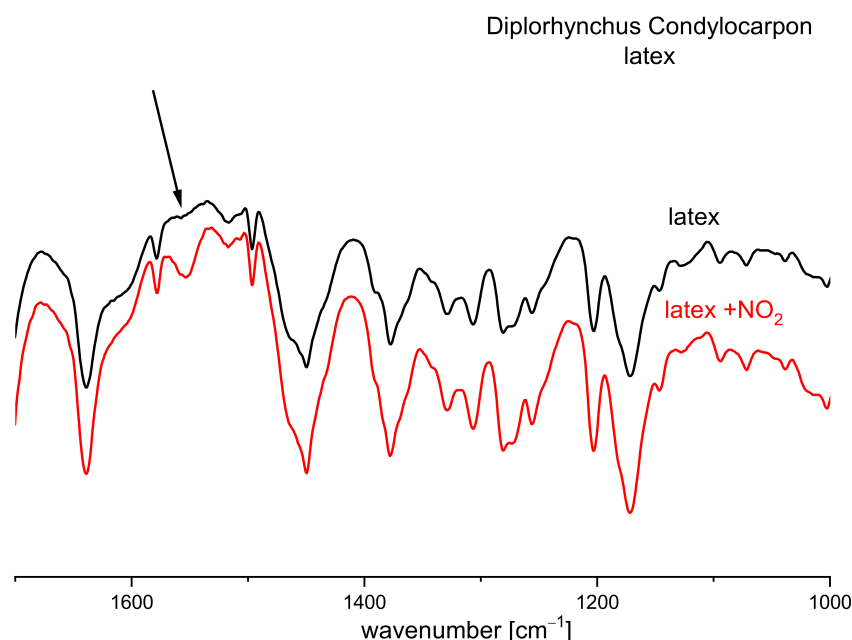


Figure 7. FTIR spectra of untreated and NO_2 -treated latex from *Diplorhynchus Condyllocarpon*.

4. Discussion and Conclusions

This study provides the first physicochemical characterization of latex obtained from *Diplorhynchus condyllocarpon* and demonstrates its potential relevance both as a source of natural rubber and as a reactive matrix for NO_2 -induced radical formation. Elemental analysis, FTIR spectroscopy, and ^1H and ^{13}C NMR spectroscopy collectively confirmed the presence of *cis*-1,4-polyisoprene as the dominant polymeric component of the latex. The spectroscopic characteristics closely resemble those reported for natural rubber obtained from *Hevea brasiliensis* and other members of the *Apocynaceae* family. The latex also contains minor aromatic and aliphatic constituents, indicating that further purification and compositional analyses will be required to fully characterize the material. Presented preliminary studies indicate potential to perform further analysis of *Diplorhynchus condyllocarpon* latex as a possible new source of rubber.

The observed stability of the elemental composition and FTIR spectra during three months of storage suggests that the latex exhibits good chemical stability under ambient conditions. EPR spectroscopy further revealed the presence of stable semiquinone radicals, indicating the occurrence of naturally occurring phenolic antioxidant structures within the latex matrix.

Exposure of the latex to NO₂ resulted in the formation of stable nitrogen-containing radicals whose EPR parameters are consistent with nitroxyl radicals. The accompanying increase in nitrogen and oxygen content determined by elemental analysis, together with the appearance of characteristic FTIR bands, confirms that a chemical reaction between the latex matrix and NO₂ had occurred. These findings demonstrate that *Diplorhynchus condylocarpon* latex can interact with nitrogen dioxide; moreover, the formed radical is stable, detected by EPR spectroscopy. The reaction of latex with NO₂ generates not iminoxyl radicals, which have been studied in the literature for environmental monitoring [12], but nitroxyl radicals formed through NO₂ reactions with rubber. However, results of analysis indicate that latex still acts as a spin trap and is an effective matrix for NO₂ analysis using EPR. This potentially allows for the use of latex in environmental monitoring, but this topic requires further research.

Author Contributions: Conceptualization, K.K. and M.J.; methodology, M.J.; software, M.J.; validation, K.K. and M.J., formal analysis, M.J.; resources, K.K.; original draft preparation, review and editing, K.K. and M.J. All authors have read and agreed to the published version of the manuscript.

Funding: This research was supported by the grant awarded to Mr. Kenneth Kaunda by The Directorate of Research, Innovation and Development of the University of Zambia to kickstart the study.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding author.

Acknowledgments: The authors, Kenneth Kaunda and Maria Jerzykiewicz, would like to acknowledge the contribution of the Directorate of Research, Innovation, and Development of the University of Zambia in awarding the seed grant to Kenneth Kaunda to kickstart the study and the Department of Pure and Applied Chemistry for making available facilities necessary for the study. The authors would also like to acknowledge and thank Maria Jolanta Korabik, for scientific support.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Tang, C.; Yang, M.; Fang, Y.; Luo, Y.; Gao, S.; Xiao, X.; An, Z.; Zhou, B.; Zhang, B.; Tan, X. The rubber tree genome reveals new insights into rubber production and species adaptation. *Nat. Plants* **2016**, *2*, 16073. [[CrossRef](#)] [[PubMed](#)]
2. Nakano, Y.; Mitsuda, N.; Ide, K.; Mori, T.; Mira, F.R.; Rosmalawati, S.; Watanabe, N.; Suzuki, K. Transcriptome analysis of Pará rubber tree (*H. brasiliensis*) seedlings under ethylene stimulation. *BMC Plant Biol.* **2021**, *21*, 420. [[CrossRef](#)] [[PubMed](#)]
3. Tan, Y.; Cao, J.; Tang, C.; Liu, K. Advances in genome sequencing and natural rubber biosynthesis in rubber-producing plants. *Curr. Issues Mol. Biol.* **2023**, *45*, 9342–9353. [[CrossRef](#)] [[PubMed](#)]
4. Yong, J.; Lu, G.; An, Y.; Lang, S.; Zhang, H.; Chen, R. Characterization of cis-polyisoprene produced in *Periploca sepium*, a novel promising alternative source of natural rubber. *Comm. Biol.* **2025**, *8*, 372. [[CrossRef](#)]
5. Sell, A.M.; Visentainer, J.E.L. Natural Rubber Latex Allergy. In *Allergic Diseases—Highlights in the Clinic, Mechanisms and Treatment*; InTech: London, UK, 2012. [[CrossRef](#)] [[PubMed](#)]
6. Kuasuwan, T.; Meethong, M.; Inaek, N.; Puechpon, P.; Obchoei, S.; Runsaeng, P. RNA Interference-Mediated Silencing of HbREF and HbSRPP Genes Reduces Allergenic Protein Content While Maintaining Rubber Production in *Hevea brasiliensis*. *Int. J. Mol. Sci.* **2025**, *26*, 9944. [[CrossRef](#)] [[PubMed](#)]

7. Bae, S.W.; Jung, S.; Choi, S.C.; Kim, M.Y.; Ryu, S.B. Lipid Composition of Latex and Rubber Particles in *Hevea brasiliensis* and *Taraxacum kok-saghyz*. *Molecules* **2020**, *25*, 5110. [\[CrossRef\]](#) [\[PubMed\]](#)
8. Rousset, A.; Amor, A.; Punvichai, T.; Perino, S.; Palu, S.; Dorget, M.; Pioch, D.; Chemat, F. Guayule (*Parthenium argentatum* A. Gray), a Renewable Resource for Natural Polyisoprene and Resin: Composition, Processes and Applications. *Molecules* **2021**, *26*, 664. [\[CrossRef\]](#) [\[PubMed\]](#)
9. Coates Palgrave, K. Trees of southern Africa. *Veld Flora* **1977**, *63*, 8.
10. Plaizier, A.C. *A Revision of Adenium, Roem. & Schult. and of Diplorhynchus Welw. Ex Fic. & Hiern (Apocynaceae)*; Mededelingen Landbouwhogeschool: Wageningen, The Netherlands, 1980.
11. Leeuwenberg, A.J.M.; Kupicha, F.K. Apocynaceae. In *Flora Zambesiana*; Royal Botanic Gardens Kew: London, UK, 1985; Volume 7, Issue 2, pp. 395–503.
12. Huangfu, P.; Atkinson, R. Long-term exposure to NO₂ and O₃ and all-cause and respiratory mortality: A systematic review & meta-analysis. *Environ. Int.* **2020**, *144*, 105998. [\[CrossRef\]](#) [\[PubMed\]](#)
13. Liu, J.; Cohen, J.; He, Q.; Tiwari, P.; Qin, K. Accounting for NO_x emissions from biomass burning and urbanization doubles existing inventories over South, Southeast and East Asia. *Commun. Earth Environ.* **2024**, *5*, 255. [\[CrossRef\]](#)
14. Xuan, H.-F.; Liu, C.; Zhang, P.; Chu, B.; Liang, L.; He, Q. A Review of Laboratory Studies on the Heterogeneous Chemistry of NO₂: Mechanisms and Uptake Kinetics. *J. Phys. Chem. A* **2025**, *129*, 815–835. [\[CrossRef\]](#) [\[PubMed\]](#)
15. Chen, Z.; Liu, N.; Tang, H.; Gao, X.; Zhang, Y.; Kan, H.; Deng, F.; Zhao, B.; Zeng, X.; Sun, Y.; et al. Health effects of exposure to sulfur dioxide, nitrogen dioxide, ozone, and carbon monoxide between 1980 and 2019: A systematic review and meta-analysis. *Indoor Air* **2022**, *32*, e13170. [\[CrossRef\]](#) [\[PubMed\]](#)
16. Jarvis, D.J.; Adamkiewicz, G.; Heroux, M.-E.; Rapp, R.; Kelly, F.J. *WHO Guidelines for Indoor Air Quality: Selected Pollutants*; WHO: Geneva, Switzerland, 2010.
17. Jian, J.; Chang, Y.; Chang, S.-P.; Chang, S.-J. Biotemplate-Assisted Growth of ZnO in Gas Sensors for ppb-Level NO₂ Detection. *ACS Omega* **2023**, *9*, 1077–1083. [\[CrossRef\]](#) [\[PubMed\]](#)
18. Jezierski, A.; Bylinska, E.; Seaward, M.R.D. Electron paramagnetic resonance (EPR) investigations of lichens—1: Effects of air pollution. *Atmos. Environ.* **1999**, *33*, 4629–4635. [\[CrossRef\]](#)
19. Jezierski, A.; Czechowski, F.; Jerzykiewicz, M.; Golonka, I.; Drozd, J.; Bylinska, E.; Chen, Y.; Seaward, M.R. Quantitative EPR study on free radicals in the natural polyphenols interacting with metal ions and other environmental pollutants. *Spectrochim. Acta A Mol. Biomol. Spectrosc.* **2002**, *58*, 1293–1300. [\[CrossRef\]](#) [\[PubMed\]](#)
20. Gaponova, I.S.; Davydov, E.Y.; Lomakin, S.M.; Pariiskii, G.B.; Pokholok, T.V. Features of stable radical generation in lignin on exposure to nitrogen dioxide. *Polim. Degrad. Stab.* **2010**, *95*, 1177–1182. [\[CrossRef\]](#)
21. Parriskii, G.B.; Gasponova, I.S.; Davydov, E.Y. Reactions of nitrogen oxides with polymers. *Russ. Chem. Rev.* **2000**, *69*, 985. [\[CrossRef\]](#)
22. Salomé Abarca, L.F.; Klinkhamer, P.G.L.; Choi, Y.H. Plant Latex, from Ecological Interests to Bioactive Chemical Resources. *Planta Med.* **2019**, *85*, 856–868. [\[CrossRef\]](#) [\[PubMed\]](#)
23. Das, S.; Divya, D.; Dubey, A.; Ashish, A.; Pal, S. Chemical bioactivity of plant latex as an herbal panacea. *Int. J. Health Sci.* **2022**, *6*, 2528–2545. [\[CrossRef\]](#)
24. Gracz-Bernaciak, J.; Mazur, O.; Nawrot, R. Functional Studies of Plant Latex as a Rich Source of Bioactive Compounds: Focus on Proteins and Alkaloids. *Int. J. Mol. Sci.* **2021**, *22*, 12427. [\[CrossRef\]](#) [\[PubMed\]](#)
25. Parisi, C.A.S.; Kelly, K.J.; Ansotegui, I.J.; Gonzalez-Díaz, S.N.; Bilò, M.B.; Cardona, V.; Park, H.S.; Braschi, M.C.; Macias-Weinmann, A.; Piga, M.A.; et al. Update on latex allergy: New insights into an old problem. *World Allergy Organ J.* **2021**, *14*, 100569. [\[CrossRef\]](#) [\[PubMed\]](#)
26. Dghim, F.; Bouaziz, M.; Mezghani, I.; Boukhris, M.; Neffati, M. Laticifers identification and natural rubber characterization from the latex of *Periploca angustifolia* Labill. (Apocynaceae). *Flora-Morphol. Distrib. Funct. Ecol. Plants* **2015**, *217*, 90–98. [\[CrossRef\]](#)
27. Lamar, R.T.; Gralian, J.; Hockaday, W.C.; Jerzykiewicz, M.; Monda, H. Investigation into the role of carboxylic acid and phenolic hydroxyl groups in the plant biostimulant activity of a humic acid purified from an oxidized sub-bituminous coal. *Front. Plant Sci.* **2024**, *15*, 1328006. [\[CrossRef\]](#) [\[PubMed\]](#)
28. Jerzykiewicz, M.; Ćwieląg, I.; Jerzykiewicz, W. The antioxidant and anticorrosive properties of crude glycerol fraction from biodiesel production. *J. Chem. Technol. Biotechnol.* **2009**, *84*, 1196–1201. [\[CrossRef\]](#)
29. Davydov, E.Y.; Gaponova, I.S.; Pokholok, T.V.; Vorotnikov, A.P.; Pariiskii, G.B.; Zaikov, G.E. Features of mechanism of free radical initiation in polymers under exposure to nitrogen oxides. *Polym. Adv. Technol.* **2008**, *19*, 475–484. [\[CrossRef\]](#)

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.