NICOTIANA TABACUM L.: MORPHOLOGICAL, PHYTOCHEMICAL, AND MICROSCOPIC CHARACTERIZATION OF LEAVES AND STEMS

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ABSTRACT

Nicotiana tabacum L., commonly known as cultivated tobacco, is an annual plant of the Solanaceae family that is widely cultivated for commercial tobacco production. This study provides a comprehensive overview of the morphological, phytochemical, and microscopic characteristics of *N. tabacum* leaves and stems, with particular attention to the composition of biologically active compounds and the potential utilization of post-harvest tobacco residues. The plant is characterized by large leaves, branched inflorescences, bicollateral vascular bundles, glandular and non-glandular trichomes, and calcium oxalate crystals (cystoliths). Phytochemical analysis demonstrated the presence of nicotine, phenolic compounds, polysaccharides, amino acids, and various alkaloids. The concentration of nicotine varied according to the developmental stage and plant organ. Extraction of post-harvest tobacco residues using conventional solvents and Natural Deep Eutectic Solvents (NaDES) demonstrated the potential of these materials as a source of bioactive compounds. NaDES-based extraction resulted in higher phenolic contents than some conventional extraction systems, while selected extracts exhibited considerable alkaloid concentrations and antioxidant activity. The findings indicate that morphological and microscopic characteristics can be used for the identification of *N. tabacum* tissues, while the phytochemical composition of tobacco residues highlights their potential for sustainable biomass utilization and the development of value-added applications.

KEYWORDS

Nicotiana tabacum L., tobacco, morphology, phytochemicals, alkaloids, nicotine, phenolic compounds, microscopic characteristics, Natural Deep Eutectic Solvents, antioxidant activity, tobacco biomass.

INTRODUCTION

Nicotiana tabacum L. is an annual plant belonging to the Solanaceae family and is one of the most widely cultivated species of the genus *Nicotiana*. The plant is grown primarily for the production of tobacco and related commercial products. Under suitable conditions, *N. tabacum* can reach a height of approximately 1–3 m and develops a thick, relatively sparsely branched stem with large oval, elliptic, or obovate leaves. The origin of cultivated tobacco is generally associated with hybridization events involving several *Nicotiana* species, particularly *N. sylvestris* and *N. tomentosiformis*, with possible contribution from *N. otophora*. The species has subsequently undergone extensive cultivation and selection, resulting in numerous cultivated varieties. Tobacco cultivation and processing generate considerable quantities of post-harvest biomass, including leaves, stems, and other plant residues. The accumulation and disposal of these residues may create environmental concerns and represents a challenge for sustainable agricultural production. At the same time, tobacco biomass contains a wide range of biologically active compounds that may be recovered and utilized for alternative purposes.

The investigation of the morphological, phytochemical, and microscopic characteristics of *N. tabacum* is therefore important not only for botanical identification but also for evaluating the potential of tobacco residues as a source of valuable bioactive compounds. In particular, the application of environmentally oriented extraction technologies, such as Natural Deep Eutectic Solvents (NaDES), may provide opportunities for the more sustainable utilization of tobacco biomass.

The aim of this study was to characterize the morphological, phytochemical, and microscopic features of *N. tabacum* leaves and stems and to evaluate the potential of conventional and NaDES-based extraction systems for recovering biologically active compounds from post-harvest tobacco residues.

MATERIALS AND METHODS

Plant material consisted of *Nicotiana tabacum* L. var. Virginia cultivated under controlled conditions. Leaves and stems were collected at different developmental stages for morphological, phytochemical, and microscopic examination. Post-harvest tobacco residues were obtained during topping and tobacco-processing operations. Morphological characteristics, including plant height, stem structure, leaf size and shape, inflorescence characteristics, flower coloration, and fruit morphology, were examined and documented. For phytochemical analysis, tobacco leaf and stem residues were extracted using conventional solvents, including water, acetone, and ethanol, as well as Natural Deep Eutectic Solvents (NaDES). The NaDES systems investigated included LAS, FGS, SALA, CU, and CAP.

The obtained extracts were analyzed for their contents of alkaloids and phenolic compounds. Sugar concentrations and antioxidant activity were also evaluated. Antioxidant activity was determined using ABTS and hydrogen peroxide (H_2O_2) scavenging assays. For microscopic analysis, fresh and dried leaf and stem samples, together with finely powdered plant material, were examined using light microscopy. The investigated anatomical characteristics included epidermal cell morphology, stomatal type, vascular bundle structure, trichome characteristics, mesophyll organization, cortical and medullary tissues, and the presence of calcium oxalate crystals (cystoliths).

RESULTS OF THE STUDY

The morphological examination showed that *Nicotiana tabacum* plants reached approximately 1–3 m in height and developed thick, relatively sparsely branched stems. The leaves were large, with lengths of up to approximately 50 cm, and exhibited oval, elliptic, or obovate shapes. The flowers were arranged in panicles and ranged in coloration from white to pink or red. The fruit was a capsule with a narrow elliptic to ovoid shape and a length of approximately 1.5–2 cm.

Phytochemical analysis demonstrated that nicotine was a major alkaloid component of *N. tabacum*. Its distribution varied among plant organs, with the

highest proportion reported in leaves, followed by stems, roots, and flowers. Nicotine content also increased with plant maturity. In addition to nicotine, the plant contained polysaccharides, phenolic compounds, amino acids, and several classes of alkaloids. Among the identified phenolic compounds were rutin and chlorogenic acid, while amino acids included glutamine, asparagine, and γ-aminobutyric acid (GABA). The phytochemical profile also included pyridine- and indole-related alkaloid compounds. Megastigmatrienone was identified as an important volatile aromatic compound associated with the characteristic fragrance of tobacco. The extraction experiments demonstrated differences in the efficiency of conventional solvents and NaDES systems. NaDES extracts exhibited comparatively high phenolic contents, with values ranging from 18.13 to 21.98 mg AGE/g of tobacco powder. Among the tested systems, CU and FGS, together with acetone/ethanol extracts, demonstrated relatively high alkaloid concentrations, ranging from 6.37 to 11.23 mg ACE/g of tobacco powder. The obtained extracts also demonstrated antioxidant activity in ABTS and H_2O_2 scavenging assays, indicating the presence of compounds capable of contributing to antioxidant activity. These findings support the potential of post-harvest tobacco residues as a source of biologically active metabolites. Microscopic examination revealed characteristic anatomical features of *N. tabacum*. Leaf and stem tissues contained bicollateral vascular bundles, glandular and multicellular non-glandular trichomes, and calcium oxalate crystals (cystoliths). The leaves contained approximately 6–9 glandular trichomes in the examined microscopic fields. Epidermal cells exhibited sinuous anticlinal walls, while the stomata were predominantly anomocytic.

Mature leaves contained abundant cystoliths within the mesophyll. Cross-sections of stems revealed elongated cortical parenchyma, medullary parenchyma, fibers, and vascular bundles. Similar anatomical characteristics could be identified in powdered plant material, although epidermal fragments were less frequently observed. The combination of morphological, phytochemical, and microscopic characteristics provides reliable criteria for the identification and characterization of *N. tabacum* leaves and stems. The presence of characteristic epidermal

structures, trichomes, cystoliths, and bicollateral vascular bundles is particularly useful for anatomical identification. The results further indicate that post-harvest tobacco residues contain compounds of potential industrial interest. The use of NaDES provides an alternative extraction approach that can facilitate the recovery of phenolic and alkaloid compounds while supporting more sustainable utilization of plant-derived biomass. However, further studies are required to determine the safety, biological activity, stability, and practical applicability of the resulting extracts before their use in cosmetic, pharmaceutical, or other applications.

CONCLUSION

Nicotiana tabacum L. is a morphologically and chemically complex plant characterized by distinctive anatomical structures and a diverse phytochemical composition. Its leaves and stems contain biologically active compounds, including nicotine, phenolic compounds, polysaccharides, amino acids, and different classes of alkaloids. Microscopic analysis revealed characteristic diagnostic features, including bicollateral vascular bundles, glandular and non-glandular trichomes, sinuous anticlinal epidermal walls, anomocytic stomata, and calcium oxalate crystals. These characteristics can be used for the reliable identification of tobacco tissues, including powdered plant material.

The phytochemical analysis demonstrated that post-harvest tobacco residues contain compounds with antioxidant and other biologically relevant properties. Extraction using Natural Deep Eutectic Solvents showed promising potential for recovering phenolic and alkaloid compounds from tobacco biomass. Therefore, the valorization of tobacco residues through environmentally oriented extraction technologies may contribute to the sustainable utilization of agricultural biomass and the development of value-added applications.Further research is necessary to establish the safety, biological efficacy, chemical stability, and technological feasibility of the obtained extracts before their potential application in cosmetic, pharmaceutical, or other industrial fields.

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