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ORIGINAL PAPERS

PHYTOCHEMICAL PROFILE AND QUALITATIVE EVALUATION OF *TARAXACUM OFFICINALE* L. SPECIES FROM NORTHEASTERN REGION OF ROMANIA

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Abstract: The study presents a systematic pharmacognostic evaluation of *Taraxacum officinale* L. to establish standardized parameters for identity, purity, and quality of herbal products, in accordance with the European Pharmacopoeia. Macroscopic and biometric analyses identified the species by its robust, rugose taproot, runcinate-pinnatifid leaf rosette, and solitary ligulate inflorescence. The reflexed orientation of the outer involucral bracts was confirmed as a primary diagnostic marker. Organoleptic assessments revealed a characteristic bitterness, indicative of sesquiterpene lactones, and a secondary sweetness in the roots corresponding to inulin content. Microscopic examination of pulverized samples, facilitated by chloral hydrate clarification, elucidated critical histological markers. Key diagnostic features included branched, anastomosing laticiferous vessels, reticulate xylem, and irregular inulin crystals. The strategic absence of starch granules served as a definitive marker of purity, distinguishing it from common adulterants. Observations of anomocytic stomata, sinuous epidermal walls, echinate pollen grains (30–40 µm), and pappus fragments confirmed a "whole plant" (in toto) preparation. The integration of these macroscopic and microscopic parameters provides a definitive reference standard for the botanical authentication of T. officinale L. These findings ensure the high degree of botanical purity required for subsequent phytochemical profiling and therapeutic applications.

Keywords: *Taraxacum officinale* L., Phytochemical profile, Inulin, Laticiferous vessels, Anomocytic stomata, Pappus

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1. Introduction

Phytotherapeutic plants have historically served as a cornerstone of traditional medicine, providing a diverse pharmacological toolkit for managing a wide range of human pathologies. In the contemporary era, the integration of advanced biotechnological tools has solidified the role of botanical resources in drug discovery. Rather than being replaced by synthetic chemistry, plants now provide essential biologically active templates that guide the design and synthesis of novel therapeutic agents [1]. Within the biomedical sciences, the current shift toward phytotherapy is increasingly driven by the need for sustainable, eco-friendly pharmacological alternatives to mitigate the escalating risks posed by chemical residues and multidrug-resistant bacterial strains, positioning natural compounds as critical assets in modern clinical pipelines.

The Asteraceae (Compositae) family is one of the most expansive and evolutionarily successful families of angiosperms, encompassing approximately 1,620 genera and exceeding 23,000 species. Characterized by their distinct composite inflorescences and one-seeded achene fruits, members of this family—ranging from herbaceous plants to woody shrubs—exhibit remarkable ecological plasticity, thriving across diverse climatic zones and habitats [2,3]. A prominent genus within this family is *Taraxacum* (dandelion), which, despite its Eurasian origins, maintains a cosmopolitan distribution across vast altitudinal gradients. The genus is characterized by significant taxonomic complexity, with the International Plant Names Index currently recognizing over 3,650 species—a diversity primarily driven by its highly adaptive reproductive strategies [4].

Morphologically, *Taraxacum* is characterized by a resilient perennial taproot and a basal leaf rosette exhibiting high phenotypic plasticity. Its leaves range from smooth to deeply serrated—an adaptation facilitating survival across diverse microclimates. Reproductive success is driven by solitary yellow flower heads (Figure 1) that develop into tufted achenes specialized for long-range anemochory. Beyond morphology, its success as a spontaneous flora stems from a sophisticated antioxidant defense system. By integrating enzymatic and non-enzymatic components, the genus maintains physiological homeostasis under environmental stress [5,6]. These adaptive mechanisms, particularly the upregulation of antioxidant enzymes, not only ensure survival but also drive the high concentration of secondary metabolites responsible for the plant's therapeutic potency.

Fig. 1. *Taraxacum officinale* L. Weber (original)

In the context of the Romanian flora, *Taraxacum* species represent a significant but often undervalued reservoir of bioactive compounds. The specific environmental conditions of the Carpathian region contribute to unique phytochemical signatures that warrant rigorous analytical investigation. Ethnomedicinally, *Taraxacum officinale* L. Weber has been utilized for centuries to treat pulmonary, renal, hepatic, and metabolic disorders, including diabetes [7,8]. Modern pharmacological research has validated these traditional applications, confirming the plant's potent anti-inflammatory, antimicrobial, and antioxidant properties [9,10]. Recently, the genus has gained traction in oncology and hepatology, with studies highlighting its potential as an adjuvant in oncotherapy and its ability to protect against hepatotoxicity by modulating key intracellular signaling pathways [1,11].

2. Experimental

Fresh vegetal product of *Taraxacum* plants at full maturity was collected during the vegetative stage (April-May 2023) from spontaneous flora of the Central Plateau of Moldova region, the northeastern part of Neamt County, Romania (47°06′00″N 26°74′44″E). According to standards set by the European Pharmacopoeia, herbal drugs are defined as raw botanical entities—ranging from whole plants to specific segments or untreated exudates—that are typically preserved through desiccation, though they may be utilized fresh. These preparations are valued in therapeutic contexts for their active principles, a term referring to the specific organic constituents responsible for the drug's pharmacological activity.

All parts of the plant were separated and washed thoroughly with tap water. Fresh plants were used for microscopic evaluation, and some were dried at room temperature on metal sieves and ground to a fine powder. Pharmacognostic analysis encompasses a suite of qualitative and quantitative assessments designed to rigorously verify and establish the identity, purity, and quality of herbal drugs.

Identity parameters include macroscopic examination, microscopic examination, qualitative chemical profiling, and chromatographic analysis

2.1. Macroscopic and organoleptic analysis

Methodology Macroscopic analysis was performed via visual inspection utilizing the unaided eye and low-power magnification (e.g., hand lens) to characterize surface texture and pigmentation. Morphometric data were quantified using calibrated instrumentation (e.g., calipers or a graduated ruler). The European Pharmacopoeia does not provide a generalized, universal protocol for macroscopic examination; rather, specific criteria are detailed in individual monographs.

A. Morphology and color

✓*Subterranean organs* (*Radix*): the root system consists of a robust, branched taproot. The external surface exhibits a dark grey to blackish-brown [12] coloration characterized by longitudinal rugosity (wrinkling), a diagnostic feature of the genus recorded in extensive ethnopharmacological reviews [13]. Lateral roots are distributed along the main axis, often winding in a loose spiral. Upon fracture, the internal parenchyma is whitish to grayish-white, surrounding a central, porous yellow xylem core (wood).

✓*Foliage*: the leaves are arranged in a distinct basal rosette (Figure 1). The blade morphology is lanceolate or oblong-obovate with a runcinate-pinnatifid margin; the deeply incised triangular lobes are retrorse [2] (pointing towards the base). The dentate margins exhibit variable green pigmentation, occasionally displaying anthocyanin-rich reddish-purple hues along the midrib.

✓*Scape:* the inflorescence is supported by an erect, fistular (hollow) scape. This cylindrical, leafless stalk is generally glabrous, though arachnoid pubescence may be observed proximally to the capitulum [8]. Pigmentation is predominantly light green, often grading into reddish-purple in the basal region.

✓*Inflorescence:* each peduncle bears a solitary terminal capitulum composed exclusively of bright golden-yellow ligulate florets (tubular florets are absent) [14]. The styles protruding from the florets are the same color. Diagnostic feature: involucre morphology is critical for identification. While the inner bracts remain erect, the outer bracts are reflexed (recurved downwards), distinguishing *Taraxacum officinale* L. Weber from allied species [8].

✓*Fruit:* is a grayish-brown to olive-brown achene (cypsela), distinctively crowned with a snow-white pappus (Figure 1) attached via a long, slender beak (rostrum), facilitating anemochorous (wind) dispersal.

B. Biometry

The morphometric parameters of the analyzed *Taraxacum* specimens were recorded to evaluate phenotypic variations within the spontaneous flora, following methodology applied in regional antioxidant studies [5].

●Roots: Length ranges from 10–25 cm; crown diameter measures 1–1.5 cm.

●Leaves: Length ranges from 30–40 cm; width measures 1–3 cm.

●Scape: Height ranges from 40–60 cm.

●Inflorescence: Capitulum diameter measures 4–5 cm (Figure 2).

●Fruit: The achene body is minute (3–4 mm), but the 10–12 mm beak significantly increases the total dimensions of the diaspore.

Fig. 2. Vegetal organs of *Taraxacum officinale* L. Weber from Neamt County, Romania (original)

C. Organoleptic evaluation.

✓The organoleptic profile was assessed to verify the quality and identity of the vegetal material, adhering to standardized guidelines for botanical drugs (Ph. Eur. 10th Ed., 2019). A characteristic white, bitter latex is ubiquitous across all tissues.

●Olfactory Assessment: The odor profile was evaluated following mechanical

comminution (crushing) of the sample.

- *Root:* Exhibits a faint sweetness, developing into an earthy, chicory-like aroma upon desiccation or roasting, characteristic of inulin-rich roots [15].

- *Leaf:* Presents a weak, characteristic herbaceous scent, detectable primarily upon mechanical comminution.

- *Scape:* Fresh, herbaceous (green); when it is broken, it has a characteristic latex (milky juice) odor.

- *Flower:* Possesses a faint but distinct honey-like fragrance.

●Gustatory Assessment: Taste was assessed by placing a fragment of the raw drug in

the oral cavity.

- *Root:* The profile is complex, initiating with a slight sweetness (attributable to inulin content, particularly in autumn harvests) which rapidly transitions to an intense, persistent bitterness. This bitterness serves as a qualitative marker for sesquiterpene lactones [16].

- *Leaf*: Characteristics are herbaceous and bitter. Maturity correlates with palatability; vernal (spring) leaves are milder, while older leaves exhibit increased astringency and bitterness [10].

- *Scape*: Bitter, herbaceous; astringency increases with maturity.

- *Flower:* Ligules are sweet and nectar-like, contrasting with the bitter, resinous taste of the involucral bracts.

General: A white, bitter latex is ubiquitous across all plant tissues [17].

Morphological characteristics may exhibit significant variability due to the biological nature of the vegetal source. However, organoleptic properties often serve as preliminary indicators of the underlying chemical composition:

- Yellow pigmentation: Suggests the presence of flavones, xanthones, or carotenoids.
- Red pigmentation: Often indicates anthocyanins.
- Bitter taste: Generally associated with anthracenic derivatives, alkaloids, or cardiotonic glycosides. The persistent bitter taste of the root is a confirmatory organoleptic test for sesquiterpene lactones.

2.2. Microscopic examination of pulverized botanical materials

The objective of this analysis is to elucidate the specific anatomical and histological features of the plant material to confirm its identity.

Methodology. In accordance with Ph. Eur. Chapter 2.8.23 [18], microscopic examination is standardized to be performed on the powdered drug (sieve size 355). To facilitate the observation of cellular structures, chloralhydrate is the most frequently prescribed clearing reagent.

Microscopic analysis of pulverized botanical materials of *Taraxacum sp*. is conducted primarily to establish taxonomic identity and ensure the absence of adulterants. The test material is prepared by mechanical grinding, followed by standardized fractionation using a V-VI mesh sieve. This process ensures sample homogeneity and the removal of macro-particulate fragments that may interfere with optical clarity. To facilitate the observation of diagnostic anatomical features, the powder undergoes a clarification process using reagents such as chloral hydrate. The microscopic preparations must be examined immediately following stabilization to prevent the dissolution of calcium oxalate crystals—crucial diagnostic markers—and to avoid artifact formation due to desiccation.

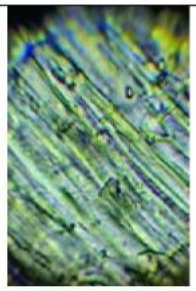
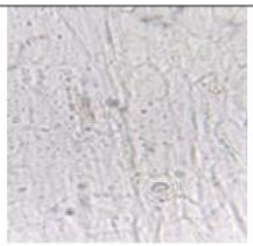
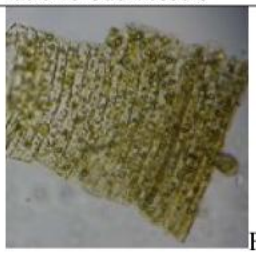
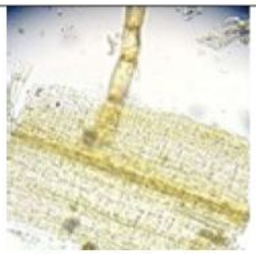
The preparation of the slide follows a standardized thermochemical clarification procedure: *1. Reagent application:* a single drop of chloral hydrate solution (R) is dispensed onto a clean microscopic slide; *2. Inoculation:* a micro-

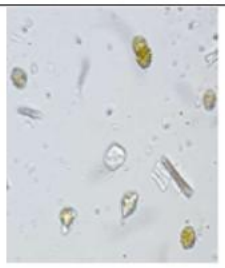
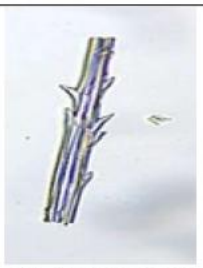
spatula tip of the homogenized botanical powder is introduced into the reagent; *3. Thermochemical clarification:* the slide is subjected to controlled thermal exposure over a flame until the evolution of white vapors and the characteristic pungent odor of chloralhydrate are detected; *4. Mounting:* after cooling, a coverslip is applied. The coverslip must be lowered at an angle to ensure the displacement of air, thereby preventing the entrapment of atmospheric bubbles within the medium; *5. Refinement:* if the optical field remains insufficiently hydrated, additional chloral hydrate solution may be introduced via capillary action at the edge of the coverslip.

Microscopic analysis of pulverized botanical materials serves as a critical diagnostic tool for quality control and pharmacognostic authentication. This analysis focuses on identifying key anatomical markers that persist after the pulverization process, ensuring the absence of adulterants and verifying the species' integrity.

Upon examination of the powdered vegetal organs (typically the root or leaves, and for this analysis, we also examined the flower and fruit/seeds), the following diagnostic elements are observed:

Table 1. Microscopic images from pulverized botanical materials (original photos)

No.	Vegetal organ	Observed element		
1.	Root	 Fig. 3. Parenchymatous tissue with inulin	 Fig. 4. Anastomosing laticiferous vessels	 Fig. 5. Reticulate vessel
2.	Leaf	 Fig. 6. Epidermal fragments with anomocytic stomata	 Fig. 7. Inulin granules within the cell lumen	 Fig. 8. Uniseriate multicellular trichome

3.	Floral, fruit and seed	 Fig. 9. Pollen grains	 Fig. 10. Scabrous pappus bristle	 Fig. 11. Endothecium

The microscopic features identified in the pulverized sample were compared against the diagnostic standards established by the European Pharmacopoeia (Ph. Eur., 10th Edition, vol. I) for *Taraxaci officinalis radix* and *Taraxaci officinalis herba cum radice*.

a. *Authentication of subterranean organs* - the presence of anastomosing laticiferous vessels (Figure 4, Table 1) and inulin crystals (Figure 3, Table 1) serve as the primary histological evidence for the root of *Taraxacum*. According to pharmacopoeial standards, the absence of starch granules is a critical purity marker, as their presence indicates adulteration with other botanical sources or flour-based fillers [15]. The observed parenchymatous tissues containing dense inulin deposits (Figure 3, Table 1) correlate with high-quality root material, often associated with specific seasonal harvests [19].

b. *Verification of aerial parts* - the identification of anomocytic stomata and sinuous epidermal cell walls (Figure 6, Table 1) align with the morphological description of the foliar lamina [2]. Furthermore, the detection of scabrous pappus bristles (Figure 10, Table 1) and multiseriate trichomes (Figure 8, Table 1) indicates that the sample was not limited to the vegetative organs but included the reproductive structures (capitula and cypselae). This suggests a "whole plant" (totalis) preparation, which is valued in traditional medicine for providing a broader spectrum of secondary metabolites, such as flavonoids and sesquiterpene lactones, which underpin the plant's anti-inflammatory and antioxidant efficacy [11, 13, 20].

c. *Quantitative and qualitative integrity* - the clarity of the observed structures (trichomes, vessels, and epidermal fragments) confirms that the chloral hydrate clearing method was effective in removing obscuring cellular debris [8]. No foreign elements, such as stone cells (sclereids) from other Asteraceae or synthetic fibers, were detected, suggesting a high degree of botanical purity and strict adherence to the quality control standards required for pharmaceutical and nutraceutical applications [1, 10].

Table 2. Elemental analyses of microscopic pulverized botanical materials

No.	Vegetal organ	Observed element	Characterization
1	Root	Laticiferous vessels	Fragments of branched, anastomosing latex tubes are present. These structures frequently appear as yellowish-brown cords or granulated channels situated within the parenchyma tissue (Figure 4, Table 1).
		Reticulate vessel	The xylem fragments exhibit vessels with reticulate or spiral thickening, which are characteristic of the vascular organization in the taproot (Figure 5, Table 1).
		Inulin crystals	*Taraxacum officinale* (L.) Weber roots contain inulin. In pulverized form, inulin appears as irregular, colorless, or spheroidal crystalline masses. Starch granules are notably absent (Figure 3, Table 1).
		Parenchyma cells	Large, thin-walled parenchymatous cells are abundant, often collapsed or fragmented, containing the aforementioned inulin deposits (Figure 3, Table 1).
2	Leaf	Epidermal cell	Leaf lamina fragments with distinct reticulate venation and chlorophyll-containing parenchymatous tissue, cells with wavy or sinuous anticlinal walls (Figure 7, Table 1).
		Stomata	Primarily anomocytic (surrounded by cells indistinguishable from other epidermal cells). They are present on both surfaces (amphistomatic) (Figure 6, Table 1).
		Trichomes	Uniseriate, multicellular trichomes are often collapsed or twisted in the powder. The presence of trichomes attached to rectangular epidermal bases is characteristic of the flower scape or involucral bracts. These hairs are crucial for distinguishing *Taraxacum officinale* (L.) from "False Dandelion", which has more rigid, distinct trichomes (Figure 8, Table 1).
		Spiral vessels	Small fragments of the leaf veins showing spiral or annular lignified thickening (Figure 8, Table 1).
3	Flower, fruit and seed	Spiral vessels	Small fragments of veins showing spiral or annular lignified thickening (Figure 11, Table 1)..
		Pappus fragments	Tuft of long, thin, non-glandular multicellular hairs originating from the base of the seed (Figure 10, Table 1).
		Pollen grains	Spherical to polyhedral, approximately 30–40 µm in diameter, with a distinctively echinulate (spiny) exine and three germinal pores (Figure 9, Table 1).

The analyzed sample is a homogenized botanical mixture of *Taraxacum officinale*, containing authentic root, leaf, and floral tissues. The coexistence of laticifers, inulin, with a strategic absence of starch and pappus fragments, provides a definitive blueprint for the botanical identification of the pulverized material, conforming to pharmacopoeial standards.

2.3. General Phytochemical Screening

The qualitative chemical evaluation of *Taraxacum officinale* L. Weber was performed by sequential selective extraction. The powdered plant material was subjected to a polarity-guided fractionation process using three solvent systems: ethyl ether (apolar), ethanol (medium polarity), and distilled water (polar). This procedure resulted in the isolation of three distinct fractions: an ether fraction containing lipophilic constituents and ethanolic and aqueous fractions concentrating on hydrophilic principles. Subsequent identification of the active compounds was achieved by specific chromogenic and precipitation reactions applied to each fraction. Fractionation and partitioning of dissolved substances - this methodology produces three distinct extractive solutions (fractions), segregating the plant metabolites according to their hydrophobicity and hydrophilicity.

Qualitative analysis reveals a distinct chemical compartmentalization based on polarity.

- *Fraction A*: The ether extractive solution contains lipophilic (hydrophobic) compounds.
- *Fraction B*: The alcoholic extractive solution contains amphiphilic and hydrophilic compounds.
- *Fraction C*: The aqueous extractive solution contains highly hydrophilic compounds.

Fraction A, ether extractive solution, selectively isolated lipophilic compounds (carotenoids and fatty acids), limited to the aerial parts (Herba and Flores). *Fraction B*, ethanolic extractive solution, proved to be the most metabolically rich solvent, consistently extracting the primary polyphenolic classes, flavonoids and polyphenolcarboxylic acids - in all plant organs, indicating a predominance of glycosidic and polar derivatives. The floral organ (Flores) presented the greatest chemical complexity, being the only source of anthracenesines, while the root (Radix) was characterized by a strictly hydrophilic profile, dominated by tannins, phenols and polyuronides. *Fraction C*, aqueous extractive solution, facilitated the identification of polyuronides (mucilages and pectic substances) and gallic/catechin tannins.

Table 3. Phytochemical analysis of ethereal extracts of the species *Taraxacum officinale* L.

Identification reaction	**Active principles**	**Radix**	**Herba**	**Flores**
Reaction with H_2SO_4	Carotenoids	-	+	++
Hydrolysis	Fatty acids	-	+	++
Shibata reaction	Flavonic aglycones	-	-	-
Liebermann-Burchard reaction	Steroli/triterpene	+	+	+
Mayer, Bertrand reagents	Alkaloids bases	-	-	-
Borntrager reaction	Emodols	-	-	-
Water vapor training	Volatile oil	-	-	-
Reaction of UV fluorescence	Coumarins	-	-	-

Phytochemical analysis of the ether extracts derived from the organs of *Taraxacum officinale* (root, leaf, and inflorescence) revealed a consistent presence of carotenoids, sterol, and triterpene compounds (Table 3). This was confirmed by the positive result of the Liebermann-Burchard reaction across all studied samples. The distributional uniformity aligns with established literature [15, 21] and validates the efficiency of ether as a non-polar solvent for the isolation of the lipophilic fraction. From a morpho-anatomical perspective, the ubiquitous nature of these metabolites is justified by the abundance of triterpene-based bitter principles, such as taraxasterol, which are primarily sequestered within the laticiferous system distributed throughout the plant body [13, 22]. The generalized positive reaction underscores the presence of phytosterols (e.g., sitosterol, stigmasterol), serving as essential structural components that maintain the fluidity and integrity of plant cell membranes.

In contrast to the terpenoid fraction, the distribution of carotenoid pigments and lipids (fatty acids) exhibited a marked asymmetry, strictly correlated with the physiological specialization of each organ. At the radicular level, these compounds were absent (H_2SO_4 reaction and hydrolysis negative); as an underground organ shielded from light, the root does not synthesize assimilatory pigments, and its primary energy reserve is inulin—a water-soluble polysaccharide that remains insoluble during non-polar ether extraction [19]. Conversely, a progressive increase in lipophilic compounds was observed at both the foliar and floral levels. The presence of carotenoids, as previously established by Tanasa et al. [23], is functionally linked to their role as accessory pigments within foliar chloroplasts. Furthermore, their substantial accumulation within the chromoplasts of the inflorescences provides the intense yellow coloration essential for pollinator attraction. The identification of fatty acids in the aerial portions reflects the composition of the cuticular waxes, which are vital for limiting transpirational loss.

Table 4. Phytochemical analysis of alcoholic extracts of *Taraxacum officinale* L.

Identification reaction	**Active principles**	**Radix**	**Herba**	**Flores**
Reaction with $FeCl_3$	Gallic/catechin tannin	+	+	++
Hydrolysis	Reducing compounds	++	++	++
Shibata reaction	Flavonosides	-	-	+
Liebermann-Burchard reaction	Sterols/triterpenes	-	-	-
Mayer, Bertrand reagents	Alkaloids salts	-	-	-
Ninhydrin	Amino acids	-	-	-
Borntrager reaction	Anthracenesides	-	-	-
Reaction with R. Arnow	Polyphenolcarboxylic acids	+	++	+

The phytochemical investigation of alcoholic extracts derived from T*araxacum officinale* L. demonstrates that ethanol serves as a highly efficient solvent for the extraction of polar secondary metabolites and water-soluble compounds (Table 4). A significant concentration of phenolic derivatives was observed across all organs investigated. Specifically, qualitative tests for tannins ($FeCl_3$) and polyphenolcarboxylic acids (utilizing Arnow's reagent) yielded positive results, with the highest concentration detected at the foliar level. This polyphenolic abundance is consistent with established literature regarding the presence of caffeic, chlorogenic, and chicoric acids, which underpin the species' documented antioxidant and choleretic therapeutic activities [24].

The hydrolysis phase of the alcoholic extract revealed a massive presence of reducing compounds throughout the entire plant. This finding correlates directly with the hydrolysis of inulin in the root—a reserve fructan that releases fructose units—and the accumulation of simple carbohydrates in the aerial organs resulting from active chlorophyll assimilation. A particularly critical analytical distinction was observed in the behavior of flavonoids relative to solvent polarity. While the Shibata reaction remained negative for all organs in the ether extract, it indicated a distinct presence of flavonoids in the inflorescences within the alcoholic extract. This discrepancy confirms that the flavone derivatives in *T. officinale* exist predominantly as heterosides (glycosides) [25]. The attachment of a carbohydrate moiety imparts a polar character to these molecules, rendering them insoluble in non-polar ether but readily extractable in ethanol [16]. This finding is essential for industrial QA/QC, as it dictates the choice of solvent required to ensure the bioactivity of the final commercial product.

Table 5. Phytochemical analysis of aqueous extracts of *Taraxacum officinale* L.

Identification reaction	**Active principles**	**Radix**	**Herba**	**Flores**
Reaction with $FeCl_3$	Gallic/catechin tannin	++	+	+
Fehling's reaction	Reducing compounds	++	++	++
Liebermann-Burchard reaction	Saponosides	-	-	-
Mayer, Bertrand reagents	Alkaloids salts	-	-	-
Acetone/alcohol	Polyuronides	++	++	++
Lugol's reaction	Starch	-	-	-
Thymol reaction	Oses and polioses	-	-	-

The stage of the phytochemical screening utilized water as the primary solvent to target highly polar metabolites and water-soluble compounds. The use of a high-polarity medium facilitated the identification of polyuronides (mucilages and pectic substances) (Table 5). Upon the addition of acetone/alcohol to the aqueous extract, significant precipitation occurred, yielding an intensely positive result across all plant organs. The abundance of these mucilaginous compounds correlates with the emollient and protective properties traditionally associated with aqueous preparations, such as infusions and decoctions [19]. Aqueous extraction further confirmed the presence of polar phenolic compounds; specifically, the tannin reaction ($FeCl_3$) was positive, reaching maximum intensity in the root. Conversely, the absence of alkaloids (Mayer and Bertrand reagents negative) and saponosides (Liebermann-Burchard negative) in this polar extract reinforces the species' safety profile and the lack of these specific secondary metabolites in its chemical composition.

A critical chemotaxonomic observation was made by comparing the Fehling and Lugol tests. An intensely positive reaction was recorded in the Fehling test for all organs, indicating a high concentration of reducing compounds. Simultaneously, the reaction with Lugol reagent was completely negative, confirming the absence of starch. This metabolic asymmetry—the presence of reducing sugars without starch—confirms the classification of *Taraxacum officinale* L. within the Asteraceae family. Physiologically, these taxa do not store energy as starch but as inulin, a water-soluble fructan. During extraction and subsequent partial hydrolysis, inulin releases fructose units, which generate the characteristic red-brick cuprous oxide precipitate in the Fehling reaction without producing the blue starch-iodine complex [26].

The phytochemical screening of *Taraxacum officinale* organs, utilizing staged extraction with solvents of increasing polarity (ether, alcohol, and water), has successfully delineated a complex metabolic profile. A clear physiological distribution of active principles was demonstrated: lipophilic fraction (ether) is dominated by sterols, triterpenes, and carotenoids, with a higher concentration in the aerial organs and polar fractions (alcohol/water) is distinguished by a remarkable richness in antioxidant phenolic compounds, flavonoids (primarily as

heterosides), and polyuronides. The analysis validated the species' chemotaxonomic identity by identifying inulin-type carbohydrate storage and refuted the presence of toxic or irritating principles such as alkaloids or emodols. Cumulatively, these experimental data provide a scientific foundation for the pharmacognostic value of dandelion, supporting its therapeutic application as a choleretic, cholagogue, and diuretic agent [27].

Practical Value in QA/QC and Industry. The qualitative identification of these tissues and metabolites provides a foundational framework for Quality Assurance (QA) and Quality Control (QC) protocols. Within the pharmaceutical and nutraceutical industries, the visual confirmation of the laticiferous system and the characteristic absence of starch (distinguished by inulin storage) serves as a diagnostic "fingerprint." These qualitative markers can be integrated into Standard Operating Procedures (SOPs) as reference benchmarks to verify the identity and purity of raw materials, ensuring that *T. officinale* is not substituted with common adulterants [16].

The most significant result of this study is the spatial mapping of metabolites. The microscopy identified a complex, ramified laticiferous system (latex channels), while the phytochemical screening confirmed a high concentration of triterpenes (like taraxasterol). The laticiferous system serves as the primary reservoir for the plant's lipophilic "bitter principles," which explains why the whole plant exhibits therapeutic potential, as these channels are ubiquitous from root to flower. While governed by a unified genetic template, the plant's organs demonstrate significant metabolic partitioning: roots are optimized for storage (high inulin) and intense bitter compounds (tannins/triterpenes), leaves for defense and metabolism (high polyphenolic acids and flavonoids), and flowers are optimized for reproduction and attraction (maximum carotenoids and lipid residues); this justifies why different pharmaceutical preparations (e.g., diuretics vs. digestive tonics) may prioritize different parts of the plant.

The dual analysis provides a robust framework for industrial validation: microscopy identifies the histological signature (e.g., vessel types, absence of fibers), while phytochemistry confirms the chemotaxonomic profile (e.g., absence of toxic alkaloids), so the lack of alkaloids and saponosides across all solvents confirms the low toxicity profile of the species, making it a safe candidate for long-term nutraceutical use (Table 6).

Table 6. Structural and chemical markers of *Taraxacum officinale* L.: from anatomical features to pharmacognostic value.

Feature	Microscopic observation	Phytochemical result	Industrial conclusion
Energy storage	Absence of starch granules	Negative lugol / Positive Fehling	High-purity inulin source.
Active transport	Dense laticiferous system	High triterpenes (Ether)	Source of bitter tonics.
Surface defense	Waxy cuticle	Unctuous lipid residue	Protective/Barrier properties.
Therapeutic base	Parenchymal tissues	Phenolics / Tannins	High antioxidant potential.

Conclusions

The study establishes a histotaxonomic profile for *Taraxacum officinale* L. by confirming the absolute substitution of starch with inulin as the primary energy reservoir. The convergence of microscopic evidence (amorphous inclusions in parenchymal cells) and chemical validation (negative Lugol/positive Fehling reactions) serves as a diagnostic marker for the *Asteraceae* family. These markers—alongside anomocytic stomata and fenestrate pollen—provide a rigorous standard for botanical authentication, enabling the identification of the species even in pulverized or processed forms where macroscopic features are absent.

It is a direct structural-chemical correlation between the plant's laticiferous system and its defensive potency. The continuous, branched network of latex-bearing canals acts as a unified bio-sequestration site for triterpenes and sterols (e.g., taraxasterols). By strategically positioning these canals in close proximity to nutrient-rich phloem tissues, the plant achieves a "whole-body" defense mechanism. This ensures that any mechanical breach by herbivores triggers an immediate release of defensive metabolites, preventing systemic infection, and justifying the pharmacological use of all plant organs.

The results demonstrate a sophisticated metabolic division dictated by organ-specific physiological requirements. While the subterranean structures are optimized for long-term sequestration (tannins and inulin), the aerial structures prioritize metabolic protection (carotenoids and cuticular waxes). Critically, the identification of flavonoids as polar heterosides—evidenced by their solubility in ethanol but insolubility in ether—dictates that pharmaceutical extraction must utilize high-polarity solvents to ensure the bioavailability of antioxidant and choleretic compounds.

The anatomical differentiation between the storage-heavy radix and the biomechanically optimized scape (which maximizes axial moment of inertia with minimal biomass) reflects an evolutionary trade-off for perennial survival. Furthermore, the variable ratios of palisade to spongy parenchyma and the degree of root lignification serve as "biological records" of environmental adaptation. This high degree of phenotypic plasticity confirms *T. officinale* L. as an ecologically robust species, capable of optimizing its internal architecture to thrive in diverse habitats, from natural meadows to urban-industrial ecosystems.

These pillars collectively provide a framework for QA/QC protocols, ensuring that raw materials are not only authenticated through histology but are also processed using appropriate solvents to maintain their intended therapeutic efficacy.

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