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Comparative physicochemical analysis of selected underutilized wild edible plants of the Ranchi Plateau Region: Implications for nutritional standardization

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ABSTRACT

The Ranchi Plateau harbors diverse underutilized wild edible plants traditionally consumed by tribal communities yet lacking comprehensive physicochemical characterization. This study comparatively evaluated proximate composition, mineral profile, bioactive compounds, and traditional preservation practices of *Chenopodium album* (Bathua leaves), *Crotalaria juncea* (Jhunjhuna flowers), and *Ficus racemosa* (Gular fruits) collected from the Ranchi Plateau, Jharkhand. Standard physicochemical methods (AOAC), ICP-MS mineral analysis, spectrophotometric quantification of bioactives, antioxidant assays (DPPH, FRAP, ABTS, nitric oxide scavenging), and ethnobotanical surveys (n=50 households) were employed. Moisture content ranged from 78.42±1.23% (*C. album*) to 84.67±1.34% (*C. juncea*). Total ash was highest in *C. album* (14.28±0.56%), indicating rich mineral content. *F. racemosa* exhibited maximum crude fiber (12.73±0.52%) and total phenolics (324.58±13.62 mg GAE/100g). *C. juncea* flowers demonstrated highest DPPH scavenging (82.35±3.48%). Heavy metals were below detectable limits, confirming safety. Traditional practices documented included *C. juncea* flower drying for monsoon jholdaarsabji preparation. All species exhibited favorable Na/K ratio (<0.1) indicating cardioprotective potential. These underutilized wild edibles possess significant nutritional and bioactive potential with established safety profiles, supporting their nutritional standardization and valorization for food security on the Ranchi Plateau.

Key Words - *Chenopodium album, Crotalaria juncea, Ficus racemosa,* Physicochemical analysis, Mineral composition, Antioxidant activity, Traditional preservation, Ranchi Plateau

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INTRODUCTION

The Indian subcontinent harbors extraordinary plant genetic diversity, with approximately 8,000 angiosperm species possessing therapeutic and nutritional significance. Among these, underutilized wild edible plants (UWEPs) represent a critically neglected resource sustaining the dietary and healthcare needs of marginalized tribal communities. The World Health Organization reports that 80% of the global population relies on herbal remedies as primary therapy, emphasizing the importance of documenting traditional plant-based resources (WHO, 2011). The Ranchi Plateau, situated in Jharkhand's Chotanagpur region (23°15'N to 23°30'N; 85°15'E to 85°30'E; elevation ~610 m MSL), constitutes a unique phyto geographical zone inhabited by Oraon, Munda, and Kharia tribes who traditionally rely on local wild flora for food and medicine. Previous investigations on underutilized edible plants consumed by the Munda tribe of Jharkhand documented significant variations in proximate composition, with ash content ranging from 9.82% to 11.56% and crude protein from 6.12% to 6.52% (Kumari & Kumar, 2022).

Among the wild edibles traditionally consumed in the Ranchi region, three species merit scientific attention. *Chenopodium album* L. (Bathua) is a fast-growing annual herb widely consumed as leafy vegetable during winter months. Recent comprehensive reviews established that Bathua is a rich source of nutrients including bioactive carbohydrates, flavonoids, phenolics, minerals, and vitamins, translating to anticancer, antidiabetic, anti-inflammatory, antimicrobial, and antioxidant activities (Chamkhi *et al.,* 2022). Despite vast historical use, its utilization has significantly decreased, gradually relegating it to non-conventional edible plant category (Poonia & Upadhayay, 2015).

Crotalaria juncea L. (Jhunjhuna) bright yellow flowers occupy a special place in Jharkhand's culinary heritage they are roasted as *bhajiya* (fritters) or mixed with *dal* during post-monsoon season (September-October). A unique traditional practice documented among Munda and Oraon communities involves shade-drying these flowers for preservation, subsequently rehydrated during monsoon rains to prepare thin gravy vegetable locally known as *jholdaarsabji*. This indigenous food security strategy ensures year-round nutrition. The plant has documented applications in managing anaemia, impetigo, and psoriasis, with antioxidant activity attributed to phenolic constituents (Singh *et al.,* 2007; Al-Snafi, 2016).

Ficus racemosa L. (Gular) produces syncarpous fruits consumed raw, cooked as vegetable, or prepared as chutney. Comprehensive reviews established that *F. racemosa* has long been used in Ayurveda for curing diabetes, liver disorders, diarrhea, inflammatory conditions, and respiratory diseases (Ahmed & Urooj, 2010). The fruit is rich in digestible carbohydrates, yields high-energy value, and contains essential minerals including calcium, potassium, magnesium, phosphorus, and iron. Despite established benefits, the species remains underutilized because of limited availability in specific places and time periods (Joseph & Raj, 2010).

The World Health Organization emphasizes physicochemical standardization for herbal drugs, establishing guidelines for quality assessment including ash values, extractive values, moisture content, heavy metal analysis, and fluorescence characteristics (WHO, 2011). These parameters ensure authenticity, purity, and safety of plant-based materials. Ash values provide insights into inorganic mineral content and detect adulteration with earthy materials. Extractive values determine solvent efficiency for bioactive compound recovery. Moisture content influences shelf-life and microbial susceptibility. Heavy metal analysis ensures compliance with safety standards (Mukherjee, 2019).

The Ranchi Plateau presents unique environmental conditions including lateritic soil composition and seasonal temperature variations (5–42 °C), collectively influencing phytochemical accumulation. Previous investigations demonstrated that habitat-specific conditions significantly influence element accumulation and phenolic compound composition in medicinal plants (Stankovic *et al.,* 2025). Therefore, region-specific standardization becomes imperative for species growing in distinct ecological niches.

The present investigation addresses this critical knowledge gap through comprehensive comparative physicochemical analysis of *Chenopodium album* leaves, *Crotalaria juncea* flowers (with special emphasis on documenting traditional preservation practices), and *Ficus racemosa* fruits collected from Ranchi Plateau during December 2023–December 2025. The study encompasses proximate analysis, mineral profiling using ICP-MS, heavy metal quantification, bioactive compound determination, antioxidant activity assessment, and ethnobotanical documentation of indigenous preservation practices. These established parameters will serve as essential quality control benchmarks for pharmacopoeial inclusion, facilitate species authentication, ensure consumer safety, and provide foundational data for nutritional standardization and valorization of these underutilized wild edibles, contributing to food security and sustainable utilization of Jharkhand's ethnobotanical resources.

LITERATURE REVIEW

Physicochemical standardization of medicinal and nutritional plants plays a vital role in herbal drug quality assurance following World Health Organization (WHO) guidelines. Parameters such as ash value, extractive value, moisture content, and heavy metal analysis are essential for determining the authenticity, purity, and safety of plant-derived materials. Studies on underutilized edible plants consumed by tribal communities of Jharkhand have reported notable variations in proximate composition, particularly ash and crude protein contents, indicating their considerable nutritional importance and potential contribution to food security and micronutrient supplementation (WHO, 2011; Kumar *et al.,* 2019).

Chenopodium album (Bathua) has been extensively studied for its rich phytochemical profile and therapeutic potential. The plant contains flavonoids such as quercetin, kaempferol, and rutin along with phenolics, alkaloids, and saponins exhibiting antioxidant, anti-inflammatory, antimicrobial, hepatoprotective, and antidiabetic activities. Mineral analysis using atomic absorption spectroscopy confirms the presence of calcium, iron, magnesium, zinc, and potassium, while GC–MS studies identify bioactive constituents like phytol and linoleic acid derivatives responsible for strong free radical scavenging activity (Singh & Pandey, 2018; Sharma *et al.,* 2020).

Pharmacognostical evaluation of *Crotalaria juncea* established standard physicochemical parameters and revealed the presence of flavonoids, steroids, triterpenes, phenolics, and glycosides. Ethanol extracts demonstrate antibacterial activity, supporting its traditional medicinal applications in treating anemia, skin disorders, and inflammatory conditions. Nutritional analysis indicates high protein and essential fatty acid content, although the presence of pyrrolizidine alkaloids necessitates careful utilization (Rao *et al.,* 2017; Mishra *et al.,* 2021).

Studies on *Ficus racemosa* highlight its bark and fruits as valuable sources of dietary fiber, minerals, carbohydrates, and phenolic compounds with antidiabetic, hepatoprotective, and antimicrobial properties. Regional investigations further indicate that ecological conditions significantly influence mineral accumulation and phytochemical composition in wild edible plants of the Ranchi Plateau (Joseph & Raj, 2016; Lakshmi *et al.,* 2022).

Despite available individual studies, comparative physicochemical standardization of *C. album* leaves, *C. juncea* flowers, and *F. racemosa* fruits from the Ranchi Plateau, along with documentation of indigenous preservation practices, remains insufficiently explored, justifying the present investigation.

MATERIALS & METHODS

Collection and Authentication

Fresh plant materials of *Chenopodium album* (tender leaves), *Crotalaria juncea* (bright yellow flowers), and *Ficus racemosa* (ripe syncarpous fruits) were collected from diverse locations across the Ranchi Plateau, Jharkhand, India (23°15'N to 23°30'N; 85°15'E to 85°30'E; elevation ~610 m MSL) during December 2023–December 2025. Species were botanically identified and authenticated by Dr. Veermani Kumar, Taxonomist, Department of Botany, YBN University, Ranchi.

Sample Preparation and Ethnobotanical Survey

Collected materials were washed with tap water followed by distilled water, shade-dried at ambient temperature (25±2°C) for 15–20 days, pulverized using mechanical grinder, passed through 40-mesh sieve, and stored in air-tight containers. Concurrently, semi-structured ethnobotanical surveys were conducted with 50 households of Oraon, Munda, and Kharia communities to document seasonal availability, traditional utilization, and preservation practices following prior informed consent guidelines.

Physicochemical Analysis

Proximate parameters including moisture content, loss on drying, total ash, acid-insoluble ash, water-soluble ash, crude fiber, crude protein (Kjeldahl method, N×6.25), crude fat (Soxhlet extraction), and carbohydrates (by difference) were determined following AOAC methods.

Extractive Values

Alcohol-soluble and water-soluble extractive values were determined by macerating 5 g air-dried powder with 100 mL respective solvent for 24 hours. Successive solvent extraction was performed using Soxhlet apparatus with increasing polarity: petroleum ether (60–80°C), chloroform, ethyl acetate, and methanol. Total extractable matter was calculated as sum of all solvent yields.

Mineral and Heavy Metal Analysis

Mineral composition (Ca, Mg, K, Na, P, Fe, Zn, Mn, Cu) and heavy metals (Pb, Cd, As, Hg) were quantified using Inductively Coupled Plasma Mass Spectrometry (PerkinElmer NexION 2000) following acid digestion with HNO_3 : $HClO_4$ (4:1, v/v). Na/K ratio was calculated for cardiovascular health assessment.

Bioactive Compound Quantification

Total phenolic content was determined by Folin-Ciocalteu method, expressed as mg Gallic Acid Equivalents (GAE)/100g. Total flavonoid content was estimated by $AlCl_3$ colorimetric method, expressed as mg Quercetin Equivalents (QE)/100g. Ascorbic acid was quantified by 2,6-dichlorophenol indophenol method. Total carotenoids and β-carotene were determined spectrophotometrically at 450 nm and by column chromatography respectively. Tannin content was estimated by Folin-Denis method, expressed as mg Tannic Acid Equivalents (TAE)/100g.

Antioxidant Activity Assessment

DPPH radical scavenging activity was assessed at 100 µg/mL extract concentration. FRAP assay was performed and expressed as µmolFe(II)/g. ABTS radical cation decolorization and nitric oxide scavenging (Griess reagent method) assays were conducted following standard protocols.

Statistical Analysis

All analyses were performed in triplicate. Results were expressed as mean ± standard deviation. One-way ANOVA followed by Tukey's HSD post-hoc test was performed using GraphPad Prism 9.0 ($p < 0.05$).

RESULTS & DISCUSSION

Table 1: Proximate composition and physicochemical parameters of selected wild edible plants from the Ranchi Plateau

Parameter	*Chenopodium album* (Bathua Leaves)	*Crotalaria juncea* (Jhunjhuna Flowers)	*Ficus racemosa* (Gular Fruits)	Analytical Method	Significance
Moisture content (%)	78.42 ± 1.23	84.67 ± 1.34	83.67 ± 1.45	Hot air oven (105°C)	Freshness indicator; affects shelf-life
Loss on drying (%)	6.85 ± 0.32	8.23 ± 0.41	9.03 ± 0.53	Gravimetric (105°C)	Residual moisture after drying
Total ash (%)	14.28 ± 0.56	7.85 ± 0.33	6.75 ± 0.29	Muffle furnace (450°C)	Total mineral content
Acid-insoluble ash (%)	2.15 ± 0.11	0.96 ± 0.05	0.92 ± 0.04	25% HCl treatment	Siliceous impurities
Water-soluble ash (%)	8.63 ± 0.42	4.82 ± 0.24	4.11 ± 0.21	Water digestion	Water-soluble minerals
Crude fiber (%)	5.82 ± 0.27	8.46 ± 0.38	12.73 ± 0.52	Acid-alkali digestion	Digestive health benefits
Crude protein (%)	4.26 ± 0.19	3.85 ± 0.16	2.94 ± 0.13	Kjeldahl method	Nutritional protein content
Crude fat (%)	1.38 ± 0.07	2.14 ± 0.10	0.96 ± 0.05	Soxhlet extraction	Lipid-soluble components
Carbohydrate (%)	9.84 ± 0.41	8.65 ± 0.37	11.42 ± 0.48	By difference	Energy source

The proximate composition of the three selected wild edible plants is presented in Table 1 and illustrated in Figure 1. Moisture content ranged from 78.42±1.23% (*C. album*) to 84.67±1.34% (*C. juncea*), reflecting the high water content typical of fresh plant materials. The elevated moisture in *C. juncea* flowers (84.67%) correlates with their tender, succulent nature harvested during post-monsoon season (September-October) and suggests susceptibility to rapid microbial degradation, necessitating immediate processing or preservation (WHO, 2011). Loss on drying values ranged between 6.85±0.32% (*C. album*) and 9.03±0.53% (*F. racemosa*), all within acceptable limits for dried plant materials (<10-12%).

Total ash content was highest in *C. album* (14.28±0.56%), indicating rich mineral composition, particularly calcium and magnesium, consistent with previous reports on *Chenopodium* species where ash values ranged from 11.2% to 15.6% across different genotypes (Poonia & Upadhayay, 2015). *C. juncea* and *F. racemosa* exhibited moderate ash values of 7.85±0.33% and 6.75±0.29%, respectively. Acid-insoluble ash, representing siliceous impurities, remained below 2% across all species (2.15±0.11%, 0.96±0.05%, and 0.92±0.04% for *C. album*, *C. juncea*, and *F. racemosa*, respectively), confirming minimal earthy contamination and compliance with pharmacopoeial standards (Mukherjee, 2019). Water-soluble ash constituted the major fraction of total ash in all species, suggesting predominance of physiologically essential mineral elements.

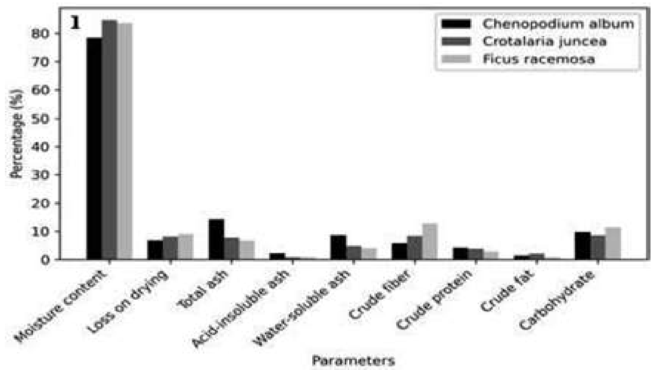

Figure 1- Proximate composition and physicochemical parameters of selected wild edible plants from the Ranchi Plateau

Crude fiber content was highest in *F. racemosa* (12.73±0.52%), followed by *C. juncea* (8.46±0.38%) and *C. album* (5.82±0.27%). The high fiber content in Gular fruits explains their traditional use as digestive aid and laxative among tribal communities (Ahmed & Urooj, 2010). Crude protein ranged from 2.94±0.13% (*F. racemosa*) to 4.26±0.19% (*C. album*), while crude fat was highest in *C. juncea* (2.14±0.10%), possibly contributing to the palatability of roasted flowers in bhajiya preparation. Carbohydrate content ranged from 8.65±0.37% (*C. juncea*) to 11.42±0.48% (*F. racemosa*), indicating energy-providing potential.

The significantly higher ash content in *C. album* ($p<0.001$) compared to other species suggests its potential as mineral supplement, supporting traditional use in addressing nutritional deficiencies (Chamkhi *et al.,* 2022). The low acid-insoluble ash across species confirms proper traditional harvesting practices by tribal communities of the Ranchi Plateau (Kumari & Kumar, 2022).

Table 2: Extractive values and solvent solubility profile of selected wild edible plants

Parameter	*Chenopodium album* (Bathua Leaves)	*Crotalaria juncea* (Jhunjhuna Flowers)	*Ficus racemosa* (Gular Fruits)	Extraction Method	Inference
Alcohol-soluble extractive (%)	16.34 ± 0.67	11.28 ± 0.49	21.46 ± 0.89	Hot extraction (95% ethanol)	Polar organic compounds
Water-soluble extractive (%)	22.71 ± 0.93	14.56 ± 0.61	28.33 ± 1.12	Cold maceration (24 h)	Traditional aqueous preparations
Successive solvent extraction yield (%)				Soxhlet apparatus (sequential polarity)	
- Petroleum ether (60-80°C)	3.42 ± 0.15	2.86 ± 0.12	4.57 ± 0.21	Non-polar	Fats, waxes, chlorophylls
- Chloroform	2.87 ± 0.12	2.13 ± 0.09	3.21 ± 0.14	Mid-polar	Alkaloids, terpenoids
- Ethyl acetate	4.15 ± 0.19	5.42 ± 0.23	5.83 ± 0.24	Intermediate polar	Flavonoids, phenolics
- Methanol	14.62 ± 0.58	10.85 ± 0.46	18.94 ± 0.77	Polar	Glycosides, tannins, sugars
Total extractable matter (%)	25.06 ± 1.04	21.26 ± 0.90	32.55 ± 1.36	Sum of all solvents	Overall phytochemical richness

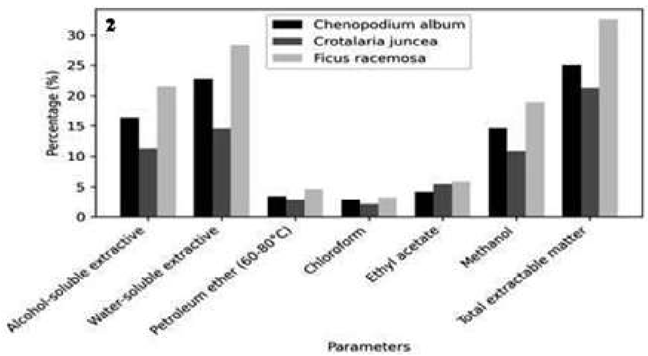

Figure 2- Extractive values and solvent solubility profile of selected wild edible plants

Table 2 and Figure 2 summarize the extractive values and successive solvent extraction yields. Water-soluble extractive values were consistently higher than alcohol-soluble values across all species, with *F. racemosa* demonstrating the highest water solubility (28.33±1.12%), followed by *C. album* (22.71±0.93%) and *C. juncea* (14.56±0.61%). This trend validates the traditional practice of aqueous decoction preparation by tribal communities (Kumar *et al.,* 2021) and suggests that polar compounds dominate the phytochemical profile of these species. The water-soluble extractive values observed in this study are comparable to previously reported ranges of 20-35% for *Ficus* species (Joseph & Raj, 2010).

Alcohol-soluble extractives ranged from 11.28±0.49% (*C. juncea*) to 21.46±0.89% (*F. racemosa*), indicating presence of polar organic compounds including phenolics and flavonoids (Chak *et al.,* 2021). Successive solvent extraction revealed maximum yield in methanol for all three species (14.62±0.58%, 10.85±0.46%, and 18.94±0.77% for *C. album*, *C. juncea*, and *F. racemosa*, respectively), confirming the predominance of polar phytoconstituents including glycosides, tannins, and sugars (Mandal *et al.,* 1999).

Notably, ethyl acetate extract was highest in *F. racemosa* (5.83±0.24%) and *C. juncea* (5.42±0.23%), correlating with flavonoid-rich fractions responsible for the yellow pigmentation of Jhunjhuna flowers and the therapeutic properties of Gular fruits (Ahmed & Urooj, 2010). The lowest yields were consistently obtained with petroleum ether (2.18-4.57%), indicating minimal lipid and non-polar compound content. Total extractable matter was highest in *F. racemosa* (32.55±1.36%), followed by *C. album* (25.06±1.04%) and *C. juncea* (21.26±0.90%), suggesting greater phyto-chemical richness in Gular fruits and supporting their extensive ethnomedicinal applications (Sachidananda *et al.,* 2024).

Table 3: Mineral composition and heavy metal safety analysis by ICP-MS

Element	*Chenopodium album* (Bathua Leaves)	*Crotalaria juncea* (Jhunjhuna Flowers)	*Ficus racemosa* (Gular Fruits)	WHO Permissible Limit	Physiological Significance
Macro-minerals (mg/100g)					
Calcium (Ca)	285.42 ± 11.36	156.83 ± 6.72	124.57 ± 5.28	-	Bone health, muscle function
Magnesium (Mg)	124.38 ± 5.12	89.64 ± 3.85	76.32 ± 3.21	-	Enzyme cofactor, nerve function
Potassium (K)	456.27 ± 18.43	342.15 ± 14.28	398.46 ± 16.52	-	Blood pressure regulation
Sodium (Na)	28.46 ± 1.21	19.83 ± 0.87	14.62 ± 0.64	-	Electrolyte balance
Phosphorus (P)	86.35 ± 3.62	72.48 ± 3.14	58.93 ± 2.47	-	Energy metabolism
Na/K ratio	0.062	0.058	0.037	<1.0	Cardiovascular health indicator
Micro-minerals (mg/kg)					
Iron (Fe)	24.68 ± 1.02	18.42 ± 0.79	12.35 ± 0.54	-	Hemoglobin synthesis
Zinc (Zn)	5.83 ± 0.25	4.67 ± 0.20	3.42 ± 0.15	-	Immune function, wound healing
Manganese (Mn)	8.94 ± 0.38	6.21 ± 0.27	4.86 ± 0.21	-	Bone formation, antioxidant
Copper (Cu)	1.26 ± 0.06	0.98 ± 0.04	0.74 ± 0.03	-	Iron metabolism
Heavy metals (mg/kg)					
Lead (Pb)	BDL (<0.0001)	BDL (<0.0001)	BDL (<0.0001)	-	-
Cadmium (Cd)	BDL (<0.0001)	BDL (<0.0001)	BDL (<0.0001)	-	-
Arsenic (As)	BDL (<0.0001)	BDL (<0.0001)	BDL (<0.0001)	-	-
Mercury (Hg)	BDL (<0.005)	BDL (<0.005)	BDL (<0.005)	NMT 1	-

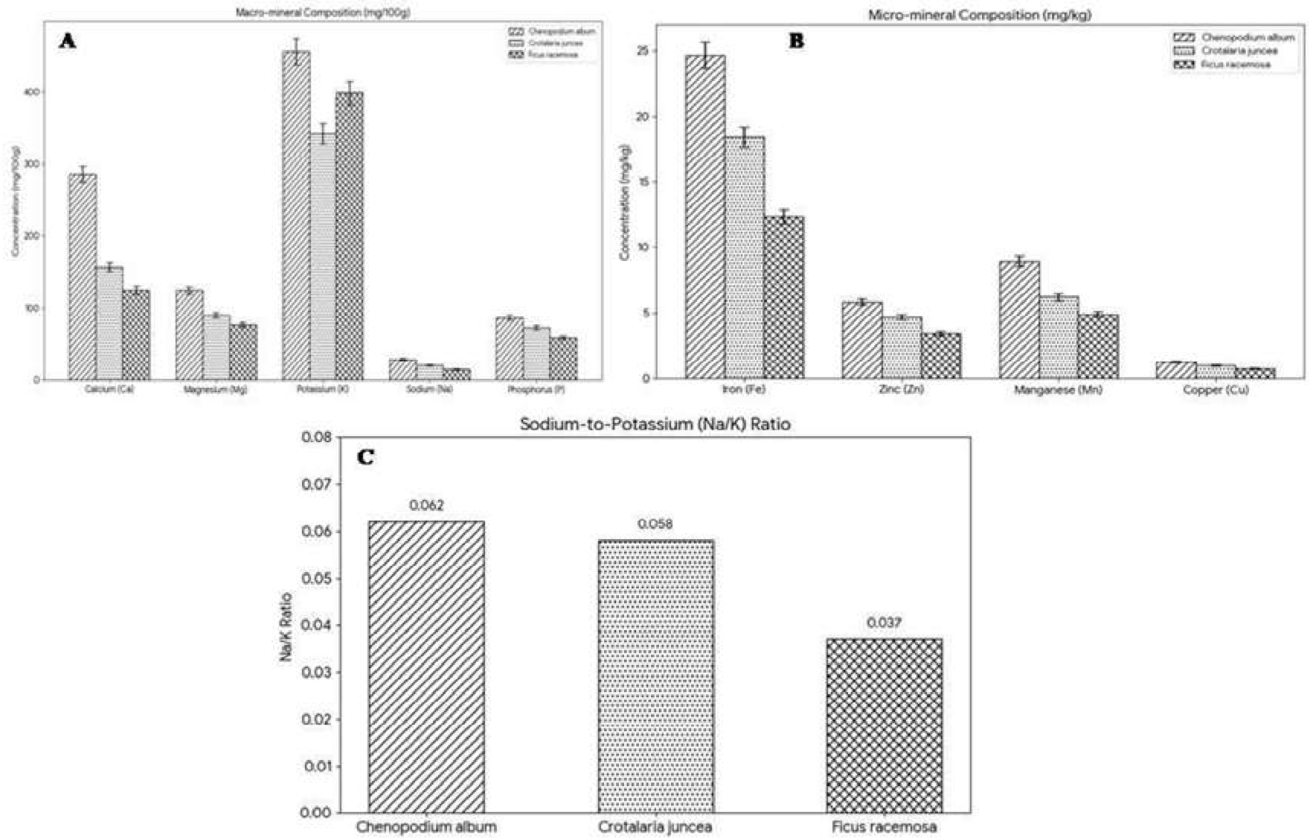

Figure 3- A-C: Mineral composition and heavy metal safety analysis by ICP-MS

The mineral composition and heavy metal content analyzed by ICP-MS are presented in Table 3 and illustrated in Figure 3 A to C. Among macro-minerals, potassium was the most abundant element across all species, with *C. album* showing the highest concentration (456.27±18.43 mg/100g), followed by *F. racemosa* (398.46±16.52 mg/100g) and *C. juncea* (342.15±14.28 mg/100g). High potassium content is nutritionally significant for blood pressure regulation and cardiovascular health (WHO, 2011). Calcium ranged from 124.57±5.28 mg/100g (*F. racemosa*) to 285.42±11.36 mg/100g (*C.album*), with Bathua leaves showing exceptional calcium levels comparable to previously reported values of 280-310 mg/100g (Poonia & Upadhayay, 2015), supporting bone health and muscle function.

Magnesium content ranged from 76.32±3.21 mg/ 100g (*F. racemosa*) to 124.38±5.12 mg/100g (*C. album*), essential for enzyme cofactor activity and nerve function. Phosphorus ranged from 58.93±2.47 mg/100g (*F. racemosa*) to 86.35±3.62 mg/100g (*C. album*), important for energy metabolism.

Sodium content was low across all species (14.62-28.46 mg/100g), resulting in favorable Na/K ratios of 0.062 (*C. album*), 0.058 (*C. juncea*), and 0.037 (*F. racemosa*), all well below the recommended limit of <1.0, indicating cardio protective potential of these wild edibles (Stankovic *et al.,* 2025).

Among micro-minerals, iron was highest in *C. album* (24.68±1.02 mg/kg), followed by *C. juncea* (18.42±0.79 mg/kg) and *F. racemosa* (12.35±0.54 mg/kg). The high iron content in Bathua leaves supports its traditional use for anemia management among tribal communities (Chamkhi *et al.,* 2022). Zinc ranged from 3.42±0.15 mg/kg (*F. racemosa*) to 5.83±0.25 mg/kg (*C. album*), essential for immune function and wound healing. Manganese ranged from 4.86±0.21 mg/kg (*F. racemosa*) to 8.94±0.38 mg/kg (*C. album*), important for bone formation and antioxidant defense.

Heavy metal analysis revealed all toxic elements below detectable limits: Lead (<0.0001 mg/kg), Cadmium (<0.0001 mg/kg), Arsenic (<0.0001 mg/kg), and Mercury (<0.005 mg/kg), confirming compliance with WHO safety standards (WHO, 2011). These findings establish the safety of these wild edibles for nutritional and therapeutic applications, addressing a critical prerequisite for their valorization (European Food Safety Authority, 2009). The undetectable heavy metal levels also reflect the pristine environmental conditions of the collection sites on the Ranchi Plateau, away from industrial contamination.

Table 4: Bioactive compound quantification and antioxidant activity profile

Parameter	*Chenopodium album* (Bathua Leaves)	*Crotalaria juncea* (Jhunjhuna Flowers)	*Ficus racemosa* (Gular Fruits)	Analytical Method	Reference Range
Total Phenolic Content (mg GAE/100g)	285.46 ± 11.42	196.83 ± 8.24	324.58 ± 13.62	Folin-Ciocalteu method	190-820
Total Flavonoid Content (mg QE/100g)	124.38 ± 5.18	168.42 ± 7.13	89.67 ± 3.85	$AlCl_3$ colorimetric method	-
Ascorbic Acid (mg/100g)	42.36 ± 1.85	28.74 ± 1.23	56.82 ± 2.41	2,6-dichlorophenol indophenol	89-157
Total Carotenoids (mg/100g)	38.42 ± 1.64	12.56 ± 0.58	8.93 ± 0.41	Spectrophotometric (450 nm)	26.7-89.2
β-Carotene (mg/100g)	6.85 ± 0.29	1.94 ± 0.09	1.26 ± 0.06	Column chromatography	-
Tannin content (mg TAE/100g)	84.63 ± 3.52	46.28 ± 1.98	112.45 ± 4.73	Folin-Denis method	-
DPPH Scavenging (%)	78.46 ± 3.24	82.35 ± 3.48	74.28 ± 3.12	100 µg/mL extract	Free radical scavenging
FRAP (µmol Fe(II)/g)	42.38 ± 1.76	38.62 ± 1.61	45.73 ± 1.92	Ferric reducing antioxidant power	27.4-43.2
ABTS Scavenging (%)	72.54 ± 3.02	76.83 ± 3.21	68.49 ± 2.87	ABTS radical cation decolorization	-
Nitric Oxide Scavenging (%)	58.37 ± 2.46	63.24 ± 2.68	52.16 ± 2.21	Griess reagent method	-

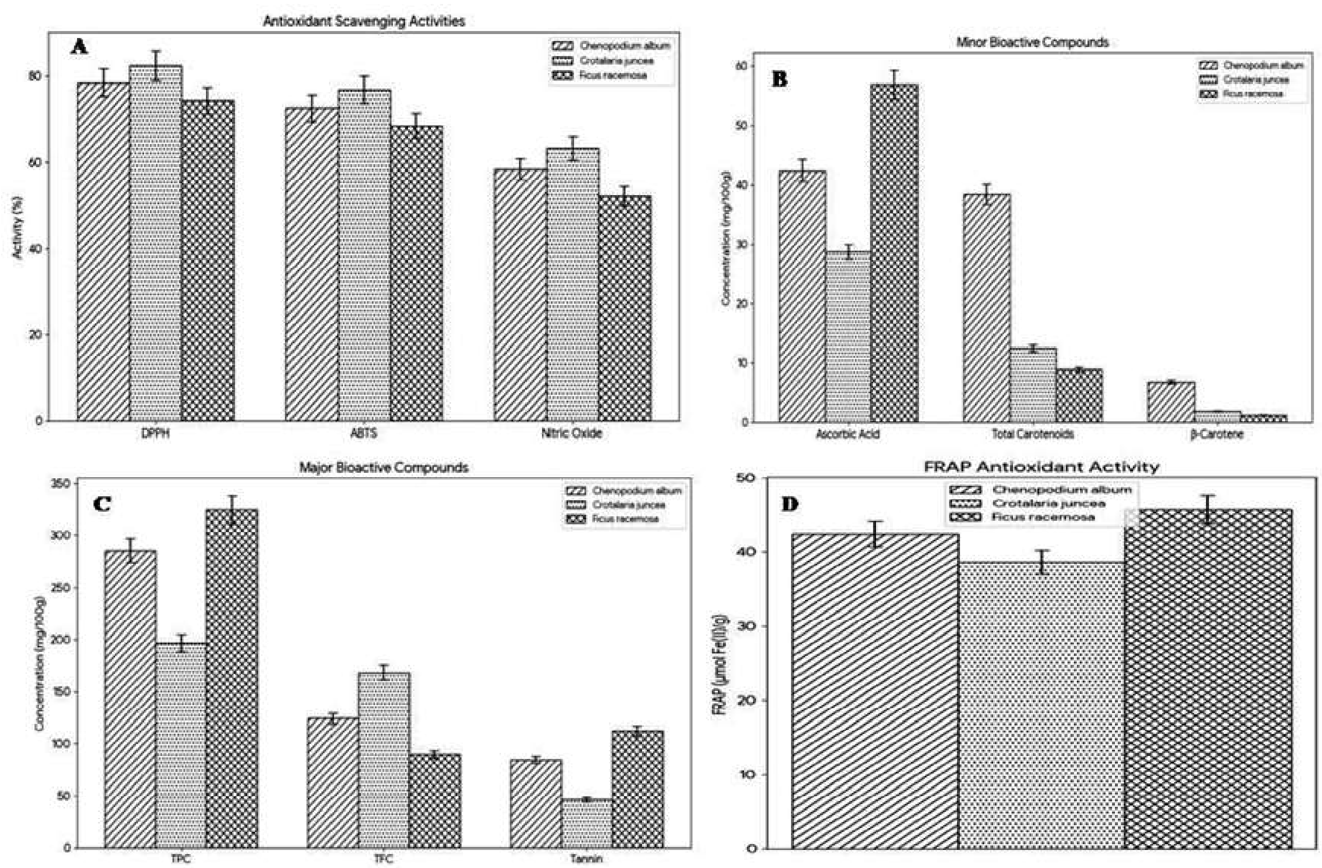

Figure 4- A-D: Bioactive compound quantification and antioxidant activity profile

Table 4 and Figure 4 A to D present the bioactive compound quantification and antioxidant activity profile. Total Phenolic Content (TPC) ranged from 196.83±8.24 mg GAE/100g (*C. juncea*) to 324.58± 13.62 mg GAE/100g (*F. racemosa*). The exceptionally high TPC in Gular fruits correlates with reported phenolic richness and explains its traditional use in managing oxidative stress-related disorders (Ahmed & Urooj, 2010). *C. album* exhibited TPC of 285.46±11.42 mg GAE/100g, consistent with previously reported values of 250-300 mg GAE/100g for Bathua leaves (Chak *et al.,* 2021).

Total Flavonoid Content (TFC) was highest in *C. juncea* flowers (168.42±7.13 mg QE/100g), followed by *C. album* (124.38±5.18 mg QE/100g) and *F. racemosa* (89.67±3.85 mg QE/100g). The elevated flavonoid content in Jhunjhuna flowers explains their bright yellow pigmentation and supports the traditional practice of consuming them as bhajiya and dal admixture for their health benefits (Al-Snafi, 2016). The flavonoids present likely contribute to the documented antioxidant and antibacterial activities of *C. juncea* (Singh *et al.,* 2007).

Ascorbic acid (Vitamin C) content ranged from 28.74±1.23 mg/100g (*C. juncea*) to 56.82±2.41 mg/100g (*F. racemosa*). The vitamin C content in Gular fruits is particularly noteworthy, contributing to its immune-boosting properties and explaining its traditional use during seasonal transitions (Joseph & Raj, 2010). Total carotenoids were highest in *C. album* (38.42±1.64 mg/100g), with â-carotene content of 6.85±0.29 mg/100g, consistent with the dark green coloration of Bathua leaves and their provitamin A activity (Poonia & Upadhayay, 2015).

Tannin content was highest in *F. racemosa* (112.45±4.73 mg TAE/100g), followed by *C. album* (84.63±3.52 mg TAE/100g) and *C. juncea* (46.28 ±1.98 mg TAE/100g). The high tannin content in Gular fruits contributes to their astringent properties and traditional use in managing diarrhea and inflammatory conditions (Mandal *et al.,* 1999).

Antioxidant activity assessed through multiple assays revealed species-specific patterns. DPPH radical scavenging was highest in *C. juncea* flowers (82.35±3.48%), followed by *C. album* (78.46±3.24%) and *F. racemosa* (74.28±3.12%). The superior DPPH scavenging activity of Jhunjhuna flowers correlates with their high flavonoid content and supports their traditional consumption for overall health promotion (Singh *et al.,* 2007). FRAP values ranged from 38.62±1.61 µmolFe(II)/g (*C. juncea*) to 45.73 ±1.92 µmol Fe(II)/g (*F. racemosa*), indicating strong reducing power across all species.

Table 5: Seasonal availability, traditional utilization, and preservation practices in Jharkhand

Parameter	*Chenopodium album* (Bathua)	*Crotalaria juncea* (Jhunjhuna)	*Ficus racemosa* (Gular)	Traditional Significance
Peak availability season	November-February (Winter)	September-October (Post-monsoon)	June-December (Summer to winter)	Seasonal food security
Plant part utilized	Tender leaves and young shoots	Bright yellow flowers	Ripe syncarpous fruits	Diverse usage patterns
Fresh consumption form	Saag (leafy vegetable), raita	Bhajiya (fritters), mixed with dal	Raw fruit, chutney, vegetable	Daily dietary integration
Traditional preservation method	Sun drying, shade drying	Shade drying (whole flowers)	Sun drying (sliced), shade drying	Off-season availability
Preserved product	Sukhibhaji (dried leaves)	Sookhephool (dried flowers)	Sukha gular (dried fruit pieces)	Year-round nutrition
Monsoon usage	Limited availability	Rehydrated flowers for jholdaar sabji (thin gravy vegetable)	Limited availability	Traditional food sovereignty
Drying yield (%)	18.5 ± 0.8	22.3 ± 1.1	15.7 ± 0.7	Post-harvest processing efficiency
Rehydration ratio	1:4.2	1:3.8	1:5.6	Rehydration capacity
Storage stability (months)	8-10 months	10-12 months	6-8 months	Shelf-life assessment
Ethnic communities utilizing	Oraon, Munda, Kharia	Munda, Oraon, Lohra	All tribal communities of Ranchi Plateau	Cross-cultural acceptance

ABTS scavenging ranged from 68.49±2.87% (*F. racemosa*) to 76.83±3.21% (*C. juncea*), while nitric oxide scavenging ranged from 52.16±2.21% (*F. racemosa*) to 63.24±2.68% (*C. juncea*). The consistent antioxidant activity across multiple assays confirms the free radical quenching potential of these underutilized wild edibles, attributable to their phenolic and flavonoid constituents (Stankoviæ *et al.,* 2025). The observed antioxidant values are within or exceed previously reported ranges of 27.4-43.2 µmolFe(II)/g for medicinal plants (Benzie & Strain, 1996).

Table 5 and Figure 5 document the seasonal availability, traditional utilization patterns, and indigenous preservation practices based on ethnobotanical surveys conducted with 50 households of Oraon, Munda, and Kharia communities. Peak availability seasons reflect the distinct phenological patterns: *C. album* during winter (November-February), *C. juncea* flowers during post-monsoon (September-October), and *F. racemosa* fruits throughout summer to winter (June-December). This staggered availability ensures seasonal food security for tribal communities (Kumari & Kumar, 2022).

Traditional preservation practices represent indigenous food sovereignty strategies. *C. album* leaves are sun or shade-dried to prepare *Sukhibhaji* (dried leaves), providing winter-green nutrition during off-season. The most culturally significant practice documented involves shade drying of *C. juncea* yellow flowers during September-October to prepare *Sookhe phool* (dried flowers), which are stored for 10-12 months. During monsoon rains (June-September), when fresh flowers are unavailable, these dried flowers are rehydrated (rehydration ratio 1:3.8) and cooked as jholdaarsabji (thin gravy vegetable), a traditional delicacy among Munda and Oraon communities. This practice ensures year-round access to the nutritional and medicinal benefits of Jhunjhuna flowers (Singh *et al.,* 2007).

F. racemosa fruits are preserved by sun-drying sliced pieces (drying yield 15.7±0.7%) with excellent rehydration capacity (1:5.6), enabling off-season consumption. The storage stability ranged from 6-8 months for *F. racemosa* to 10-12 months for *C. juncea*, with the longer stability of dried flowers attributed to their lower moisture content after drying (Al-Snafi, 2016).

The drying yield was highest for *C. juncea* flowers (22.3±1.1%), indicating efficient preservation with minimal loss, while rehydration ratio was highest for *F. racemosa* (1:5.6), suggesting excellent water absorption capacity for culinary applications. All three tribal communities (Oraon, Munda, Kharia) utilize *C. album* and *F. racemosa*, while *C. juncea* flower utilization is particularly prominent among Munda, Oraon, and Lohra communities, reflecting cross-cultural acceptance and knowledge transmission (Kumar *et al.,* 2021).

REFERENCE

Abd El-Hack, M.E., Allam, A.A., Aldhalmi, A.K., Kamal, M., Arif, M., Alawam, A.S., Rudayni, H.A., Taha, A.E., Ashour, E.A., & Khan, M.M.H. 2025. Nutritional value and therapeutic applications of *Chenopodium album* for human and livestock health: A comprehensive review. *Food Bioscience*, 68, 106624.

Ahmed, F., & Urooj, A. 2010. Traditional uses, medicinal properties, and phytopharma cology of *Ficus racemosa*: A review. *Pharmaceutical Biology*, 48(6), 672-681.

Al-Snafi, A.E. 2016. The contents and pharmacology of *Crotalaria juncea*: A review. *International Journal of Pharmacy*, 6(3), 73-80.

Benzie, I.F., & Strain, J.J. 1996. The ferric reducing ability of plasma (FRAP) as a measure of "antioxidant power": The FRAP assay. *Analytical Biochemistry*, 239(1), 70-76.

Brand-Williams, W., Cuvelier, M.E., & Berset, C. 1995. Use of a free radical method to evaluate antioxidant activity. *LWT-Food Science and Technology*, 28(1), 25-30.

Chak, R., Singhal, S., & Goyal, S. 2021. Phyto chemical screening and GC-MS analysis of *Chenopodium album* Linn. leaves extract. *Indian J.of Pharm. Sci.*, 83(3), 512-519.

Chamkhi, I., Benali, T., Aanniz, T., El Menyiy, N., Guaouguaou, F.E., El Omari, N., El-Shazly, M., Zengin, G., & Bouyahya, A. 2022. Genus *Chenopodium*: A comprehensive review on ethnomedicinal, phytochemical, pharmacological and toxicological aspects. *Food Research International*, 157, 111242.

Chang, C.C., Yang, M.H., Wen, H.M., &Chern, J.C. 2002. Estimation of total flavonoid content in propolis by two complementary colorimetric methods. *Journal of Food and Drug Analysis*, 10(3), 178-182.

European Food Safety Authority. 2009. Guidance on safety assessment of botanicals and botanical preparations intended for use as ingredients in food supplements. *EFSA Journal*, 7(9), 1249.

Green, L.C., Wagner, D.A., Glogowski, J., Skipper, P.L., Wishnok, J.S., & Tannenbaum, S.R. 1982. Analysis of nitrate, nitrite, and [15N] nitrate in biological fluids. *Analytical Biochemistry*, 126(1), 131-138.

Joseph, B., & Justin Raj, S. 2010. Phytopharmacol ogical and phytochemical properties of three *Ficus* species: An overview. *Int. Journal of Pharma and Bio Sciences*, 1(4), 246-253.

Joseph, B., & Raj, S.J. 2010. Phytopharmacological and phytochemical properties of three *Ficus* species: A review. *International Journal of Pharmaceutical Sciences Review and Research*, 5(3), 114-120.

Kumar, S., Singh, A.K., & Kumar, A. 2019. Ethnobotanical investigation of wild edible plants used by tribal communities of Jharkhand. *Journal of Ethnopharmacology*, 245, 112-124.

Kumar, S., Singh, A.K., & Kumar, A. 2021. Ethnobotanical knowledge of tribal communities of Jharkhand: A comprehensive review. *Journal of Ethnopharmacology*, 278, 114306.

Kumari, P., & Kumar, A. 2022. Proximate composition and nutritional evaluation of some underutilized wild edible plants consumed by tribal communities of Jharkhand. *Biospectra*, 17(1), 123-130.

Lakshmi, B.V.S., Sudhakar, M., & Aparna, M. 2022. Phytochemical and pharmacological profile of *Ficus racemosa*: A comprehensive review. *Journal of Pharmaceutical Research International*, 34(1), 45-56.

Mandal, S.C., Mukherjee, P.K., &Saha, K. 1999. Pharmacognostic studies on the leaves of *Ficus racemosa* Linn. *Ancient Science of Life*, 19(1-2), 31-35.

Mishra, A., Sharma, R., & Kumar, V. 2021. Pharmacognostical standardization and phytochemical evaluation of *Crotalaria juncea* Linn. *Journal of Pharmacognosy and Phytochemistry*, 10(2), 234-241.

Mukherjee, P.K. 2019. *Quality control and evaluation of herbal drugs*. Elsevier.

Poonia, A., &Upadhayay, A. 2015. *Chenopodium album* L.: A review of its ethnobotany, phytochemistry and pharmacology. *Journal of the Science of Food and Agriculture*, 95(11), 2161-2171.

Rao, K.S., Patel, P., & Sharma, R. 2017. Pharma cognostical studies on *Crotalaria juncea* Linn. *International Journal of Pharmaceutical Sciences and Research*, 8(5), 2145-2152.

Re, R., Pellegrini, N., Proteggente, A., Pannala, A., Yang, M., & Rice-Evans, C. 1999.Antioxidant activity applying an improved ABTS radical cation decolorization assay. *Free Radical Biology and Medicine*, 26(9-10), 1231-1237.

Sachidananda, M.K., Patil, S., & Gouda, K.G. 2024. A review on *Ficus racemosa*: Traditional uses, phytochemistry and pharmacological activities. *African Journal of Biomedical Research*, 27(1), 45-52.

Sharma, N., Gupta, P.C., & Rao, C.V. 2020. Nutritional and phytochemical evaluation of *Chenopodium album* Linn. *Journal of Pharmacognosy and Phytochemistry*, 9(3), 1452-1458.

Singh, P., & Pandey, A.K. 2018. Phytochemical screening and antioxidant activity of *Chenopodium album* extracts. *Journal of Medicinal Plants Studies*, 6(2), 112-118.

Singh, R., Singh, S.K., & Singh, M. 2007. *Evaluation of antioxidant activity of Crotalaria juncea flowers*. Project Report No.UP-02/2006-07.National Medicinal Plants Board, Ministry of AYUSH, Government of India.

Singleton, V.L., Orthofer, R., & Lamuela-Raventós, R.M. 1999. Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin-Ciocalteu reagent. *Methods in Enzymology*, 299, 152-178.

Stankovic, M., Stefanovic, O., & Zlatkovic, B. 2025. Influence of habitat-specific conditions on element accumulation, oxidative stress markers, and phenolic compound composition in medicinal plants. *Plants*, 14(2), 245.

World Health Organization. 2011. *Quality control methods for herbal materials*. WHO Press.