Research Article

Unlocking the Phytochemical Wealth of *Berberis aristata*: An Endangered Himalayan Medicinal Shrub

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Abstract | *Berberis aristata* (Berberidaceae) is a well-known medicinal plant widely used in traditional systems due to its diverse pharmacological properties. However, the species is increasingly threatened due to extensive root harvesting, raising serious concerns regarding its conservation. Therefore, exploring alternative plant parts beyond roots may provide a more sustainable approach for its utilization. The present study aimed to evaluate the extraction yield qualitative and quantity physicochemical characteristics of different plant parts (leaves, stem bark, and roots) of *B. aristata*. Plant materials were extracted using ethanol, methanol, and aqueous solvents, and extraction yields were determined. Physicochemical parameters, including total ash, acid-insoluble ash, and moisture content, were analysed following standard procedures. Qualitative phytochemical screening and quantitative estimation of total alkaloids, tannins, saponins, flavonoids, and phenolics were carried out using spectrophotometric methods. Methanol extracts exhibited the highest extraction yield, particularly in leaves (5.0%). Leaves showed the highest total ash (2.19%) and moisture content (76.00%), while roots recorded the lowest values. Qualitative analysis confirmed the presence of major phyto-constituents with variation across plant parts and solvents. Quantitative analysis revealed that roots contained the highest alkaloid content (18.75 ± 0.65 mg AE/g), leaves exhibited maximum tannin (185.25 ± 1.75 mg GAE/g), flavonoid (54.95 ± 1.2 mg QE/g), and phenolic content (62.23 ± 0.63 mg GAE/g), whereas stem bark showed the highest saponin content (38.78 ± 0.82 mg DE/g). These findings demonstrate the differential distribution of phytochemicals in *B. aristata* and highlight the potential of aerial parts as sustainable alternatives to roots for pharmaceutical applications.

Received | May 14, 2026; **Accepted** | June 23, 2026; **Published** | July 22, 2026
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Citation | Tariq, N., A.R. Malik, P.A. Sofi, I.A. Peerzada, A. Singh, T. Mushtaq, N.A. Pala, M. Mushtaq, M. Jamir and P.T. Fayaz. 2026. Unlocking the phytochemical wealth of *Berberis aristata*: An endangered Himalayan medicinal shrub. *Journal of Plant Health, Ecology and Evolution,* 2(1): 24-34.
DOI | https://dx.doi.org/10.17582/journal.pjar/2026/2.1.24.34
Keywords | *Berberis aristata*, Phytochemical profiling, Extraction yield, Secondary metabolites, Spectrophotometric analysis, Medicinal plants, Sustainable utilization

Introduction

The Himalayan region is recognized as one of the hotspots of global biodiversity, where ecological, phytogeographical and evolutionary factors favor species richness. The bio-geographically unique nature of the region supports the maximum number of endemic species, harbouring about 18, 440 species of plants, of which 25.3% are endemic to the Asian region, a high proportion of which possesses unique medicinal properties (Malik *et al*., 2024a). India is a storehouse of a wide spectrum of ethno-medicinally important plant species and is one of the 18 mega biodiversity with more than 2500 plant species applied in various alternative and complementary medicines of medicinal importance (Mipun *et al*., 2023a). Berberis belongs to the dicotyledonous family; Berberidaceae and is the largest genus among the 16 genera, constituting about 70-80% of total species in the family (Khan *et al*., 2016a). *Berberis* has approximately 500 species distributed across the globe (Europe, Siberia, China, Afghanistan, India, Nepal and North-South America) out of which 60 species have been reported from the Indian Himalayas (Kaur *et al*., 2023). In homeopathy and ethnic medicine, the species have been used as medicine for their anti-inflammatory, anti-bacterial, anti-cancer, antiarrhythmic, hypoglycemic and hepatoprotective properties (Khan *et al*., 2016a). *Berberis aristata* commonly known as "Daru Haldhi, Kashmoi, Kashmal, Chitra, Kawdachh" is an endangered spinous medicinal shrub of western Himalayan region occurring in rare and sporadic conditions at an altitudinal range between 1800-2800 m above mean sea level (Thakur *et al*., 2019; Nisha, 2023a). The plant is widely distributed from the western Himalayas to Srilanka, Bhutan and hilly areas of Nepal (Choudhary *et al*., 2021). It is also found in the Nilgiri hills in south India (Sharma *et al*., 2018). The plant has glossy dark green and ovate leaves, stalked flowers and woody, yellowish brown roots with a thin covering of bark (Yadav, 2018a). Fruits are globose to ovoid; usually cover with bloom as in plums. The fruit colour is aconite violet (Komal *et al*., 2011a). *Berberis aristata* has been recognized for its pharmaceutical and medicinal properties (Alvarez *et al*., 2009; Nisha, 2023). It is also used in the printing and dyeing industry (Malik *et al*., 2024a). The roots, stems, leaves and fruits of Berberis aristata are traditionally used to treat wounds, diabetes, inflammations and jaundice. The extracts have been reported for antibacterial, antiviral, antifungal, antiarrhythmic, anticancer, anti-inflammatory and antidiabetic profiles (Yadav, 2018). The major chemical constituent of *Berberis aristata* is berberine, a quaternary isoquinoline alkaloid that is typically found in the roots and stems with numerous pharmacological activities (Komal *et al*., 2011a). A very valuable ayurvedic preparation 'Rasaut' an extract of either leaves, stem or root is prepared from this plant (Moin *et al*., 2023a). It is utilized as a blood cleaner, tonic and purgative for kids. It is also prescribed for skin conditions and jaundice (Alamzeb *et al*., 2013). The unbated exploitation of *B. aristata* roots and stem for its berberine alkaloid (Verma *et al*., 2017) and the non-availability of propagation protocol, agronomic ignorance, habitat loss, lack of motivation among stakeholders and complete dependence on natural population have rendered the species under immense threat in nature and IUCN has categorized it as endangered species of Indian Himalayan Region (Ali *et al*., 2008).

Although *Berberis aristata* is widely valued for its root-derived phytochemicals, its predominant use has led to extensive root harvesting, raising concerns regarding its conservation status. Despite this, limited attention has been given to the comparative evaluation of phytochemical constituents in other plant parts, particularly leaves and stem bark, which may serve as potential alternatives. This gap restricts the development of sustainable utilization strategies and highlights the need for comprehensive quantitative assessment of phytochemical constituents across different plant parts. Therefore, the present study reports a comparative and standardized quantitative assessment of major phytochemical constituents in the root, leaves and stem bark of *Berberis aristata.*

Materials and Methods

The root, stem bark, and leaves of *Berberis aristata* DC. were collected from Sindh Forest Range, Ganderbal, Jammu and Kashmir, during the autumn season (October–December). The plant material was collected in duplicate to minimize sampling errors. The collected specimens were identified and authenticated at the Centre for Biodiversity and Taxonomy, Department of Botany, University of Kashmir, Hazratbal, Kashmir. Proper voucher specimens were prepared and deposited in the herbarium of the Department of Botany, University of Kashmir, under Voucher No. 9354-KASH. Fresh root, stem bark, and

leaf samples were shade dried at room temperature (20 ± 2°C) and pulverized into coarse powder. The powdered material of each plant part was successively extracted with ethanol, methanol, and distilled water using a mechanical shaker. The extracts obtained were filtered and concentrated under reduced pressure using a rotary evaporator with a water bath maintained at 50°C. The concentrated extracts were transferred into sterile vials and stored in a refrigerator at 4°C until further use.

Physicochemical analysis

Physicochemical analysis of root, stem bark, and leaf samples was carried out following standard procedures described in the *Ayurvedic Pharmacopoeia of India* (Government of India, 2007) and WHO guidelines for medicinal plant materials (WHO, 1998).

$$Percentage\ yield\ (\%) = \frac{Weight\ of\ extract}{Weight\ of\ powdered\ sample\ taken} \times 100$$

Total ash content was calculated using the formula:

$$Total\ ash\ content = \frac{(Weight\ of\ dish\ along\ with\ ash\ (g) - the\ weight\ of\ empty\ dish\ (g)}{Weight\ of\ sample\ (g)} \times 100$$

Moisture content was determined as:

$$Moisture\ content = \frac{Wet\ weight\ of\ sample - dry\ weight}{wet\ weight\ of\ sample} \times 100$$

Acid insoluble ash was determined as:

$$Acid\ insoluble\ ash = \frac{weight\ of\ dish\ with\ insoluble\ ash\ (g) - weight\ of\ empty\ dish\ (g)}{Weight\ of\ sample\ (g)} \times 100$$

Qualitative analysis

The plant extracts obtained by using different solvent extraction process and is subjected to different phytochemical tests to identify the plant constituents by using standard following methods Sofowara (1993) and Harborne and William (1973).

Quantitative estimation

Total flavonoid content (TFC): Using a colorimetric technique with the aluminium chloride, total flavonoid contents were determined (Kumar *et al.*, 2008). Aqueous and ethanolic extracts that were adjusted to fall within the linearity range i.e. (400µg/ml), or Aliquots of extract solutions were taken and made up the volume 3ml with methanol and various dilutions of standard solution of the standard solution of Quercetin (10-100µg/ml) were added to 10ml volumetric flask. The aforementioned combination received 0.3ml of 5% $NaNO_2$. 0.3ml of 10% $AlCl_3$ was added after 5 minutes. After 6 min, 2ml of 1 M NaOH was added and distilled water was used to get the volume up to 10ml. The absorbance was then measured at 520 nm in comparison to a freshly made reagent blank

Test	Procedure	Observations (Indicating positive test)
Detection of Carbohydrates		
Benedict's test	0.5 mL filtrate + 0.5 mL Benedict's reagent; heated in boiling water bath for 2 min	red precipitate
Detection of protiens		
Millon's and Ninhydrin test	1 mL plant sample + 1 mL 40% NaOH + few drops $CuSO_4$	violet/pink color
Detection of Alkaloids		
Dragendroff's	Few mL filtrate + 1-2 mL Dragendroff's reagents	A reddish-brown precipitate
Detection of Tannins		
Ferric chloride test	1mL filtrate + 3mL distilled water + 3 drops 10% Ferric chloride solution	Blue green colour
Detection of saponins		
Foam test	0.5gm plant extract + 2mL water (vigorously shaken)	Persistent foam for 10 min
Detection of Flavonoids		
Ammonia test	Few mL aqueous filtrate + conc. H_2SO_4 + 5 mL dilute NH_3	yellow color
Detection of phenolic compounds		
Ferric cyanide test	3 mL ethanolic extract + few drops ferric cyanide (warm in water bath)	greenish to black color
Detection of terpenoids		
Salkowski test	5 mL extract + 2 mL chloroform + 3 mL conc. H_2SO_4	reddish-brown
Detection of phytosterols		
Acetic anhydride test	0.5 g ethanolic extract + 2 mL conc. H_2SO_4 + 2 mL acetic anhydride	violet/blue/green colour

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after the solution had been well mixed. The extracts total flavonoid concentration was calculated as a percentage of Quercetin equivalent per 100 g dry weight of sample.

Total phenols content (TPC)

Total phenolic content was determined using the Folin–Ciocalteu colorimetric method as described by Singleton and Rossi (1965). An aliquot of the plant extract was mixed with diluted Folin–Ciocalteu reagent and allowed to react for a few minutes. Subsequently, sodium carbonate solution was added to the mixture to neutralize the reaction and facilitate color development. The reaction mixture was then incubated at room temperature for a specified period to allow the formation of a blue-colored complex. The intensity of the color, which is proportional to the phenolic content present in the sample, was measured spectrophotometrically at 765 nm against a suitable blank. Gallic acid was used as the standard for calibration, and the results were expressed as milligrams of gallic acid equivalents (mg GAE/g) of the sample.

Total alkaloid content (TAC)

The methodology of Harborne (1973) was employed to determine alkaloid in the species. 200 ml of 10% acetic acid in ethanol was added to 5 g of the sample, which was then weighed into a 250 ml beaker. The mixture was then covered and left to stand for 4 h. After filtering, the extract was concentrated on a water bath to one-quarter of the original volume. Concentrated ammonium hydroxide was added drop by drop to the extract. After allowing the whole solution to settle, the precipitated material was collected, cleaned with dilute ammonium hydroxide and then filtered. The alkaloid, which was dried and weighed, is the residual.

Total tannin content (TTC)

A plastic bottle measuring 50 ml was filled with 500 mg of the sample. A mechanical shaker was used to mix in 50 ml of distilled water for an hour. This was built up to specification and filtered into a 50 ml volumetric flask. Then, 2 ml of 0.1 M $FeCl_3$ in 0.1N HCl and 0.008 M potassium ferro cyanide were added to 5 ml of the filtered and pipetted into a test tube. Within 10 minutes, the absorbance at 700 nm was determined. The determination of tannin was done by Van-Buren and Robinson (1981) methodology.

Total saponin content (TSC)

The Obadani and Ochuko (2002) methodology was adopted. 100 cm^3 of 20% aqueous ethanol and 20 g of each sample were added to a conical flask after the samples had been grounded. The samples were heated over a hot water bath for 4 h while being continuously stirred at about 550°C. Filtering the mixture allowed the residue to be extracted again using 200 ml of 20% ethanol. Over a water bath at around 90 °C, the mixed extracts were reduced to 40 ml, transferring the concentration into a 250 ml separatory funnel, 20 ml of diethyl ether was added and shaken vigorously. While the ether layer was discarded, the aqueous layer was recovered. The purification process was repeated. n-butanol 60 ml was added. Two separate washes of 10 ml of 5% aqueous sodium chloride were performed on the combined n-butanol extracts. In a water bath, the residual solution was warmed. The samples were dried in oven to a constant temperature following evaporation.

Statistical analysis

All data are expressed as mean ± SD (n= 3). Differences among plant parts were assessed by one-way ANOVA followed by Tukey's HSD post-hoc test ($\alpha = 0.05$).

Results and Discussion

Extraction yield

The extraction yield is a measure of the solvent efficiency to extract specific components from the original material. The results were reported in Table 1 and illustrated in Figure 1. Our results showed that maximum percent yield was obtained in leaves (5.0%), when *Berberis aristata* was extracted by methanol with followed by root (4.6%) and stem bark (4.6%). While the Ethanol extraction showed comparatively lower yields ranging with leaves (4.0%), followed by root (2.6%) and stem bark (2.0%). *B. aristata* when extracted by aqueous solvent gave the minimum yield per centage with leaves and root (3.8%) followed by stem bark (2.6%). Our results showed that methanol was efficient in extracting phytochemicals more than other solvents attributed to its higher polarity and better solubilizing capacity for a wider range of phytochemicals in the species. The same results have been seen in other *Berberis* species, as well (Bhatt *et al.*, 2012). These findings are in agreement with previous studies that have shown that solvents like methanol, which are polar solvents, are more efficient at extracting the bioactive compounds from the other plant materials (Ncube *et al.*, 2008).

Table 1: *Percentage extraction yield of different solvent extracts from various plant parts of B.aristata.*

Solvent	Plant part	Extraction yield (%)
Ethanol	Stem bark	2.0
	Leaves	4.0
	Root	2.6
Methanol	Stem bark	4.6
	Leaves	5.0
	Root	4.6
Aqueous	Stem bark	2.6
	Leaves	3.8
	Root	3.8

Physicochemical parameters

The results of physicochemical properties of *B. aristata* shown in Table 2 reveals that the ash content of the various plant sections was comparatively similar among different parts of the species, with values of 2.17%, 2.19%, and 2.11%, respectively for the stem bark, leaves, and root. However, the leaves had the highest content of acid insoluble ash (0.62%), followed by roots (0.50%) and stem bark (0.39%). Similarly, the leaves had the highest moisture content (76.00%), followed by stem bark (63.04%) and root (52.38%). The observed results of moisture content recorded for *B. aristata* leaves in this study is can be compared to that reported by Chauhan *et al.* (2014), who found values between 58–78% in fresh leaves of different *Berberis* species.

Preliminary phytochemical screening

The preliminary qualitative screening of the extracts is presented in Table 3 and showed that alkaloids were present with the well-documented presence of berberine, an isoquinoline alkaloid, as the principal bioactive constituent of *B. aristata* (Katiyar *et al.*, 2012). Tannins and saponins were the most common compounds identified in most of the extracts especially the methanol and aqueous fractions which is expected since they are polar compounds. Flavonoids were found to be present in extracts of stem bark and leaf. Flavonoids have been reported to possess antioxidant and anti-inflammatory properties in many studies (Kumar and Pandey, 2013). Some metabolites might not have been found in the aqueous extract because of polarity; water is not able to dissolve polar compounds well. These findings justify the reason for pharmaceutical application of *B. aristata* and hence validating its use. Similar results were observed in previous phytochemical screenings conducted on the same plant species (Sutalangka *et al.*, 2013).

Table 2: *Comparison of physiochemical parameters of different plant parts of Berberis aristata.*

Parameter	Stem bark (% w/w)	Leaves (% w/w)	Root (% w/w)
Total ash content	2.17	2.19	2.11
Acid insoluble ash	0.39	0.62	0.50
Moisture content	63.04	76.00	52.38

Quantitative analysis

Total alkaloid content: The results of the quantitative evaluation of alkaloids, phenols, tannins, flavonoids and saponins are presented in Table 4. Alkaloids are important group of secondary metabolites of *Berberis* genus, of which previous studies attributed some of the medicinal properties of barberry to the presence of these compounds (Zhaleh *et al.*, 2025). In fact, barberry is known to be a rich source of various types of alkaloids with antioxidant and therapeutic

Table 3: *Preliminary phytochemical screening of different solvent extracts of Berberis aristata.*

Metabolite	SB-E	SB-M	SB-A	L-E	L-M	L-A	R-E	R-M	R-A
Carbohydrates	+	+	-	-	-	+	+	+	-
Proteins	-	-	+	-	-	+	+	-	+
Alkaloids	+	+	-	+	-	-	+	+	+
Tannins	-	+	+	+	+	+	+	+	+
Saponins	-	+	+	+	+	+	+	+	+
Flavonoids	+	+	-	+	-	-	-	+	+
Phytosterols	+	+	+	-	-	-	+	+	-
Terpenoids	+	+	+	-	-	+	-	+	-
Polyphenols	-	+	-	+	-	-	-	+	-

SB= Stem bark, L= Leaves, R= Root, E= Ethanol, M= Methanol, A= Aqueous (+) Presence, (-) Absence

Table 4: *Quantitative phytochemical content (mean ± SD, n = 3) of leaves, stem bark, and roots of Berberis aristata.*

Compound	Leaf	Bark	Root	Anova
Alkaloid (mg AE/g)	10.80 ± 1.20a	14.36 ± 0.54b	18.75 ± 0.65c	F = 99.38 p < 0.001
Tannin (mg GAE/g)	185.25 ± 1.75c	34.79 ± 0.30a	109.79±0.29b	F= 23606.32 p < 0.001
Total saponin content (mg DE/g)	8.96±0.24a	38.78±0.82b	11.56±2.2a	F = 661.23 p < 0.001
Total flavonoid content (mg QE/g)	54.95±1.2c	9.69±0.3a	35.27±0.6b	F = 3678.70 p < 0.001
Total phenol content (mg GAE/g)	62.23±0.63c	4.23±0.9a	29.15±1.4b	F = 3608.71 p < 0.001

Different lowercase letters within a row indicate significant differences among plant parts (Tukey's HSD, α = 0.05). AE = atropine equivalent; GAE = gallic acid equivalent; DE = diosgenin equivalent; QE = quercetin equivalent.

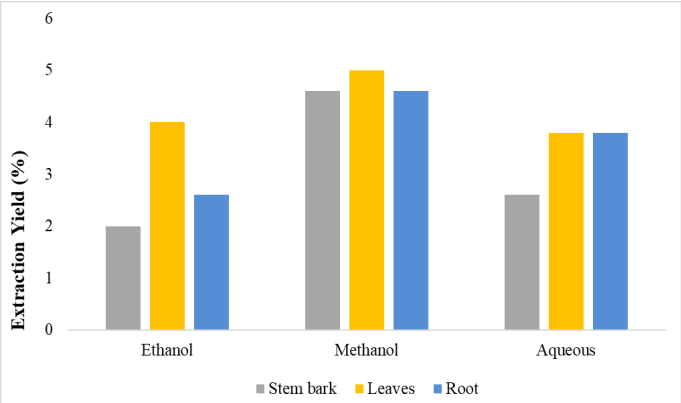

Figure 1: *Extraction yield (%) of different solvent extracts of Berberis aristata.*

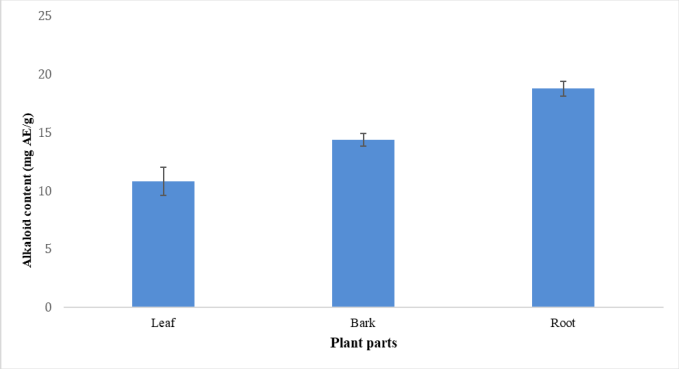

Figure 2: *Total alkaloid content (mg AE/g) in different plant parts of Berberis aristata. Values represent mean ± SD (n=3).*

properties (Och *et al.*, 2021). Berberine is considered one of the main alkaloids of *Berberis* genus, many studies have focused on this valuable alkaloid in various *Berberis* species. Garhwal *et al.* (2010), by studying *B. asiatica*, *B. aristata* and *B. lycium*, revealed that the berberine content of these three species is different and also that their roots contain much more berberine content compared to the stem. The results of the current study display that total alkaloid content differed significantly among the three plant parts (F= 99.38, p < 0.001; Table 4). The highest content of total alkaloid was observed in the root (18.75 ± 0.65 mg AE/g), followed by bark (14.36 ± 0.54 mg AE/g), while leaves showed the lowest content (10.8 ± 1.2 mg AE/g) of total alkaloid (Figure 2). All three plant parts were significantly different from one another (Tukey's HSD, p < 0.01; CLD: c, b, a for roots, bark, and leaves, respectively). This distribution corroborates with previous studies reporting maximum alkaloid accumulation in roots and stem bark of *Berberis* species due to the localization of berberine and related isoquinoline alkaloids in ground tissues (Imenshahidi and Hosseinzadeh, 2016; Zhaleh *et al.*, 2025).

Total tannin content

The term "tannin" originates from the application of these compounds to tan animal hide into leather (Pizzi, 2021). Tannins are naturally occurring substances which can be found in almost all parts of most plant life. These compounds have been shown to play an important part in protecting the plant against fungal, bacterial and insect attacks, and also aid in maintaining plant health when water availability decreases during times of drought (Pizzi and Cameron, 1986). In the present study, tannin content showed the greatest absolute variation among the phytochemicals examined ($F_{2,6}$ = 23606.32, p < 0.001; Leaves (185.25 ± 1.75 mg GAE/g) exhibited the highest level of tannins within *B. aristata*, followed by the tannin content of roots (109.79 ± 0.29 mg GAE/g), and the lowest tannin content was detected in the bark (34.79 ± 0.30 mg GAE/g) (Figure 3). All three plant parts differed significantly from one another (Tukey's HSD, p < 0.001; CLD: c, a, b for leaves, bark, and roots, respectively). Although the levels of tannins appear to be relatively low in most species of *Berberis*, the *B. aristata* root samples (10.97%) were found to contain significantly higher percentages of tannins compared to that found in *B. microphylla* (9.53%), *B. asiatica* (1.7%), *B. chitria* (0.73%), and *B. lycium* (0.96%) (Srivastava *et al.*, 2013b). Tannins within the *Berberis* genus are primarily used for their pharmacological and therapeutic benefits, such as being both astringents

and antimicrobials, in traditional medicinal practices including Ayurveda (Sharma *et al.*, 2024a). Therefore, given the significant amount of tannins present throughout the various parts of *B. aristata*, it could represent a strong natural compound with significant potential for the development of new pharmaceutical products.

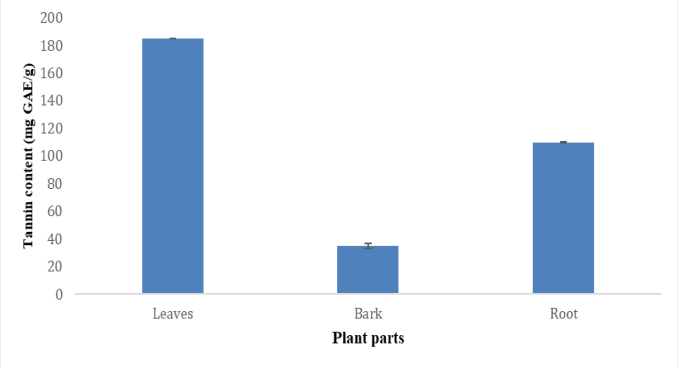

Figure 3: *Total tannin content (mg GAE/g) in different plant parts of Berberis aristata. Values represent mean ± SD (n=3).*

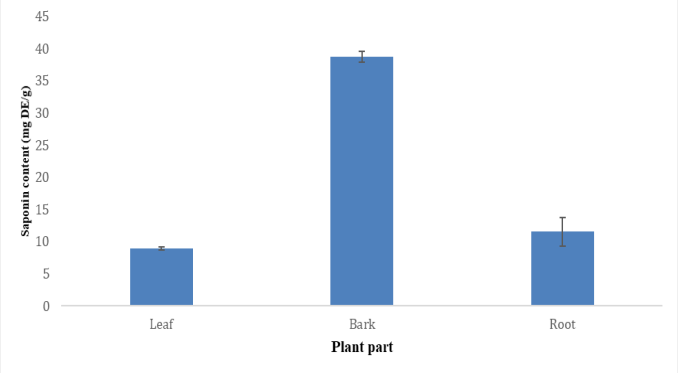

Figure 4: *Total saponin content (mg DE/g) in different plant parts of B. aristata. Values represent mean ± SD (n=3).*

Total saponin content

A significant effect of plant part on saponin content was observed ($F = 661.23$, $p < 0.001$; Table 4) Stem bark contained the highest total saponin content (38.78 ± 0.82 mg DE/g), substantially exceeding root (11.56 ± 2.2 mg DE/g) and leaf (8.96 ± 0.24 mg DE/g) tissues (Figure 4). Stem bark differed significantly from both leaves and roots (Tukey's HSD, $p < 0.001$), whereas saponin concentrations in leaves and roots were not significantly different from each other ($p = 0.065$; CLD: a, b, a for leaves, bark, and roots, respectively). This preferential accumulation may reflect the involvement of saponins in protecting structural tissues against microbial invasion and insect predation, particularly in the outer protective layers of the plant (Sparg *et al.*, 2004). Moreover, the concentration of saponins is greater in *B. aristata* than in *B. microphylla* (36.0 mg DE/g) and *B. vulgaris* (3.0 mg DE/g) (Furrianca *et al.*, 2017; El-Sayed *et al.*, 2011). From a medicinal perspective, saponins from *Berberis* species have shown antimicrobial, anti-inflammatory, and antioxidant activities in various studies, which is consistent with how these plants have been used traditionally across South Asia and the Middle East for centuries (Srivastava *et al.*, 2013b). Some researchers have also pointed toward possible hepatoprotective and immunomodulatory effects, which is particularly relevant today given the growing interest in plant-based alternatives or complements to synthetic drugs (Sharma *et al.*, 2024a). Beyond medicine, the foaming and emulsifying behaviour of saponins has also attracted attention in the food and cosmetic industries (Francis *et al.*, 2002).

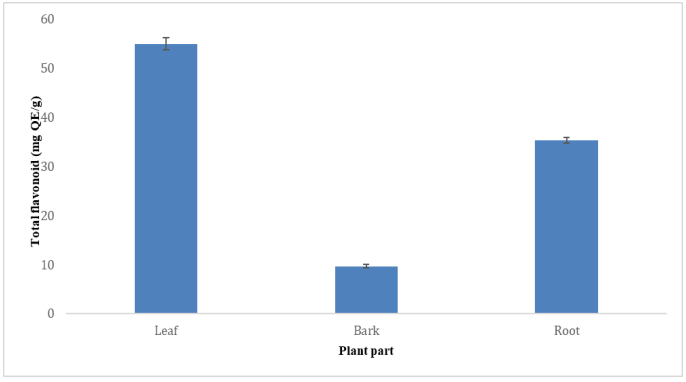

Figure 5: *Total flavonoid content (mg QE/g) in different plant parts of B. aristata. Values represent mean ± SD (n=3).*

Total flavonoid content

Flavonoids are one of the most studied groups of secondary metabolites in higher plants because they are the main constituents of plant pigments (Awal *et al.*, 2025). Flavonoids are potent antioxidants because of their free radical scavenging activity (Pal *et al.*, 2009). Flavonoid content varied significantly among plant parts ($F = 3678.70$, $p < 0.001$; Table 4) As shown in Figure 5, the highest level of total flavonoid was found in leaves (54.95 ± 1.2 mg QE/g) and then showed a decreasing trend in the root (35.27 ± 0.6 mg QE/g) and stem bark (9.69 ± 0.3 mg QE/g). All pairwise comparisons were statistically significant (Tukey's HSD, $p < 0.001$; CLD: c, a, b for leaves, bark, and roots, respectively). This pattern is in agreement with the physiological role of flavonoids in photoprotection, UV filtration, and antioxidant defence in photosynthetically active tissues

(Fernández-Poyatos *et al.*, 2019a). Comparable leaf-dominant flavonoid accumulation has been reported in *Berberis* and other medicinal taxa (Gul *et al.*, 2023).

Total phenol content

Total phenol content differed significantly among plant parts (F= 3608.71, p < 0.001; Table 4, The total phenolic content varied from 4.23 to 62.23 mg GAE/g. Leaf extract of *B. aristata* contained the highest phenolic content, followed by roots. Stem bark of *B. aristata* contained the least amount of phenol (4.23 ± 0.9 mg GAE/g) (Figure 6). While comparing different plant parts of *Berberis* species, greater amounts of phenols and flavonoids in leaves of *B. vulgaris* and *B. croatica* were reported (Koncic *et al.*, 2010). Higher phenolic quantity in leaves is expected due to their function as major antioxidants and photoprotective compounds in metabolically active aerial tissues (Fernández-Poyatos *et al.*, 2019a). In line with these observations (Zhaleh *et al.*, 2025), *Berberis integerrima* has also been shown to preferentially accumulate phenolics in its leaves compared to roots and stems.

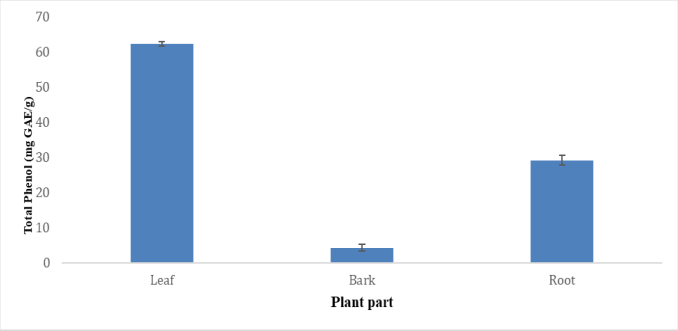

Figure 6: *Total phenol content (mg GAE/g) in different plant parts of B. aristata. Values represent mean ± SD (n=3).*

Conclusion

In summary, the occurrence patterns of alkaloids, saponins and phenolic compounds in various organs of *B. aristata* show differences and there are certain organ-preference in these compounds. It has been shown that roots have the highest level of alkaloids. The dominant compounds in the leaf were total flavonoids, tannin and phenol while saponins occurred in the highest concentration in the stem bark. The findings suggest that aerial organs including the leaf and stem bark which are usually not much utilized could be good substitutes for roots in the extraction of specific compounds. The information is important in the view of sustainable use and conservation of the species as *B. aristata* have been considered to be critically endangered in the face of overexploitation of roots. In conclusion, the research makes a contribution towards improving our knowledge about *B. aristata* in terms of its phytochemistry and helps pave the way for alternative exploitation of certain organs for medicinal or industrial purposes. Further research is necessary on compound identification and bioactivity validation.

Acknowledgments

This work was supported by the Centre of Excellence in Herbal Technology, Forest Products and Utilization (FPU), Faculty of Forestry (FOF), Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, which provided the necessary laboratory facilities and technical support.

Novelty Statement

The present study bridges a critical knowledge gap by providing an integrated phytochemical and phsico-chemical assessment of different plant parts of Berberis aristata using multiple extraction solvents. The findings establish leaves and stem bark as valuable reservoirs of bioactive compounds, offering a sustainable substitute for root exploitation. This work not only advances the phytochemical understanding of an endangered Himalayan medicinal plant but also provides a scientific foundation for its conservation and sustainable utilization in the pharmaceutical and herbal industries

Author's Contribution

Nisha Tariq: Conceptualization, field investigation, data collection, data analysis, and manuscript writing (original draft preparation).
A.R. Malik: Supervision, study design, project administration, and critical review and editing of the manuscript.
Nazir A. Pala: Assistance in data interpretation and manuscript editing.
Peerzada Ishtiyak Ahmad: Provision of laboratory facilities and technical support.
P.A. Sofi: Management and coordination responsibility for the research activity planning and execution.
Tahir Mushtaq: Visualization and data presentation.

Amerjeet Singh: Verification of the overall replication, reproducibility of results, and other research outputs.
Mehvish Mushtaq and Moamenla Jamir: Manuscript review and editing.
Peerzada Tabish Fayaz: Providing technical assistance during laboratory work.

Generative AI and AI assisted technology statement

The authors declare that no generative AI and AI assisted technology was used in the creation of this manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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