Research Square

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Nutritional assessment of the leaves and stem of a lesser known wild legume Nogra dalzellii

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Research Article

Keywords: Nogra dalzellii, Proximate composition, Mineral elements, Energy value, Dietary reference intake

Posted Date: November 26th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11551751/v1

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Additional Declarations: No competing interests reported.

Abstract

Nogra dalzellii (Baker) Merr. is a wild legume whose nutritional composition may contribute to its potential as a source of dietary nutrients. The present study aimed to evaluate and compare the proximate composition, pH, energy value and mineral profile of the leaves and stem of *N. dalzellii*. The leaves exhibited higher moisture (7.25%), ash (17.08%), crude protein (10.18%) and carbohydrate (47.65%) contents than the stem, which contained 5.06%, 5.24%, 6.98%, and 34.99%, respectively. Crude fat content was comparatively low in both leaves (1.57%) and stem (1.46%). The pH, energy value and concentrations of major and trace minerals were also determined and the mineral composition was assessed in relation to Dietary Reference Intakes (DRI). The leaves exhibited a pH of 7.7 ± 1.10 and an energy value of 245.45 ± 2.30 kcal/100 g, whereas the stem showed a pH of 7.4 ± 2.84 and an energy value of 181.02 ± 3.01 kcal/100 g. Mineral analysis demonstrated that the leaves contained higher concentrations of calcium (766 ± 5.77 mg/100 g), magnesium (366.7 ± 5.77 mg/100 g), phosphorus (76.7 ± 37.85 mg/100 g), potassium (1760 ± 10.00 mg/100 g) and iron (56.57 ± 0.41 mg/100 g) than the stem. The leaf samples also exhibited higher concentrations of sulphur, boron, copper, manganese, molybdenum and zinc. Sodium was more abundant in the stem (190 ± 10.00 mg/100 g) than in the leaves (96.7 ± 5.77 mg/100 g). The findings of present study indicate that the leaves of *N. dalzellii* possess comparatively higher values for proximates, energy value and a favourable mineral profile. These findings support further investigation of *N. dalzellii* nutritional potential considering its safety, bioavailability and suitability for food or dietary applications.

1. Introduction

Nutrition remains an essential yet unfulfilled challenge for a large section of the global population. According to the 2025 Global Hunger Index (GHI), India ranks 102nd among 123 countries, with score 25.8 that placing in the serious category of hunger. Thus, malnutrition among women aged 15–49 years is about 19%, including deficiencies such as anaemia in over 67% of young children and 57% of women of reproductive age, and protein deficiency in 60% of urban Indians [1, 2]. After cereals, the legumes are the second most important source of food for humans. They provide a rich source of dietary protein, complex carbohydrates, dietary fibre, vitamins and minerals [3]. Legumes are rich in bioactive phytochemicals that play important roles in human metabolism and disease prevention [4]. Proximate analysis is a vital tool to determine the nutrient composition of these plant materials. It involves determination of moisture, crude protein, crude fat, crude fibre, ash and carbohydrates in these food stuffs [5]. This analysis is important for leguminous plants, which are known to contain higher amounts of protein and dietary fibre than cereals [6]. Furthermore, the mineral content of the plants, including essential minerals such as calcium, potassium, magnesium, iron, zinc and phosphorus plays a vital role in determining the medicinal and prophylactic value of the plants [7, 8]. These essential minerals play important roles in human physiology; hence, their precise quantification in unexplored plant species is necessary [9, 10].

Nogra dalzellii (Baker) Merr. is a wild leguminous plant species which is endemic to the Indian states of Karnataka, Maharashtra and Madhya Pradesh [11]. *Nogra* is a small genus comprising only four species worldwide, three of which are found in India and is placed in the subtribe Glycininae which also includes economically important legumes such as *Glycine max*. It grows in dry deciduous forests. It is an herbaceous perennial twinner. Leaves are unifoliate; the stem is 5 m long with golden brown hairs. The present work focused on the evaluation and comparison of the relative composition of leaves and stem of *N. dalzellii*.

2. Materials and Methodology

2.1 Collection and authentication of plant material

Fresh, healthy leaves and stems of *N. dalzellii* were collected from Kolhapur, Maharashtra, India. The plant material was identified and authenticated by Dr. Manoj Lekhak, Department of Botany, Shivaji University, Kolhapur, India. A voucher specimen (Voucher no. PMP01) has been deposited at the Herbarium of the Department of Botany, Shivaji University, Kolhapur, India.

2.2 Preparation of plant material

The collected leaves and stems of *N. dalzellii* were thoroughly washed under tap water to remove soil and other impurities. Then the washed plant material was shade-dried at room temperature until it was completely dry. Then the dried material was ground to a fine powder using a mechanical grinder and sieved. The powdered material was stored in airtight bottles away from direct sunlight until further use.

2.3 Proximate analysis

The proximate composition of the leaf and stem powder of *N. dalzellii* was determined using standard procedures proposed by the Food Safety and Standards Authority of India (FSSAI) and the Association of Official Analytical Chemists [5].

2.3.1 Moisture content

A clean, dry moisture dish with a lid was dried in an oven, cooled in a desiccator and weighed to the nearest 0.001 g (recorded as W). Approximately, 5.0 g of sample was weighed into the dish, covered with a lid and weighed to the nearest 0.001 g (recorded as W1). The lid was removed and the sample was dried in a hot-air oven at 105°C for 2 hours. After drying, the dish was covered and placed in the oven, immediately removed and transferred to a desiccator and cooled for 30–45 minutes to room temperature (25 ± 3°C). The dish was weighed to the nearest 0.001 g (recorded as W2). This procedure was repeated by returning to the oven and drying for an additional 30 minutes or until constant weight was achieved (difference ≤ 0.002 g). Moisture content was calculated by using the formula:

Moisture (%) = (W1 - W2) / (W1 - W) * 100

Where W = mass of empty dish, W1 = mass of dish + sample before drying and W2 = mass of dish + sample after drying.

2.3.2 Total ash content

A cleaned and dried crucible was weighed and recorded (W). Approximately 5 g of the sample was accurately weighed into the crucible and recorded (W1). The sample was ignited gently with a burner flame in a fume hood until it was completely charred. The sample was placed in a muffle furnace at 550°C until ash. The crucible was weighed and the process was repeated every 30 minutes until the weight difference was less than 1 mg (W2). The following formula was used to calculate the percentage of the total ash:

Total Ash (%) = (W2 - W) / (W1 - W) x 100

Where W is the weight of the crucible, W1 is the weight of the crucible and the sample and W2 is the weight of the crucible and the ash.

2.3.3 Crude protein (Kjeldahl Method)

Approximately, 0.5–1.0 g of finely ground plant powder was accurately weighed into a Kjeldahl flask. A volume of 10–15 mL of concentrated sulphuric acid and a suitable catalyst mixture containing potassium sulphate and copper sulphate were added. This was then gently heated and boiled until such time that a green solution was obtained. After cooling, it became blue, then it's diluted and finally transferred to a distillation unit. An excess of 40–50% sodium hydroxide was added to make the solution strongly alkaline. A receiving flask containing 25–50 mL of 4% boric acid solution mixed with a drop of mixed indicator (methyl red + bromocresol green) was used to collect the liberated ammonia. The resulting ammonia-boric acid complex was titrated with standard 0.1N hydrochloric acid solution until such time that the colour change from green to pink was obtained. A blank determination was done in the absence of a sample. Calculation of results:

Nitrogen (%) = (Vs - Vb) × N × 14.01 × 100 / W × 1000

Protein (%) = Nitrogen (%) × F

Vs = volume of acid used for sample, Vb = volume of acid used for blank, N = normality of acid

W = weight of sample, F= protein conversion factor (6.25).

2.3.4 Crude fat

Approximately, 1.0 g of the plant powder was accurately weighed and placed in a fat-free extraction thimble which was later plugged with fat-free cotton. The clean extraction flask was dried in an oven at 105 ± 2°C, then cooled in a desiccator and accurately weighed. The required quantity of petroleum ether (boiling range 60 to 80°C) was then added to the flask and extracted by the Soxhlet apparatus. The solvent was then evaporated in a water bath. The flask containing the extracted fat was dried at 105 ±

2°C for 1 hour and later it was cooled in a desiccator and accurately weighed. The crude fat percentage in the sample was then calculated as follows:

Crude Fat (%) = (W2 - W1) / W x 100

Where W = weight of sample, W1 = weight of empty extraction flask, W2 = weight of flask + extracted fat.

2.3.5 Crude fibre

Approximately, 1.0 g of a moisture- and fat-free sample was measured and transferred to a 500 ml conical flask. 200 mL of 1.25% sulphuric acid solution was added and boiled gently for 30 minutes using a reflux condenser. The sample was then filtered through muslin cloth and washed with hot distilled water until free from acid. The sample was then returned to the flask and 200mL of 1.25% sodium hydroxide solution was added and boiled gently for 30 minutes. The sample was then filtered, washed with hot and distilled water until neutral and then washed with alcohol to remove the remaining fat. The sample was then transferred to a pre-dried and weighed crucible, then dried at 105 ± 2°C to constant weight (W1) and then incinerated in a muffle furnace at 550°C (W2). The crude fibre content was determined as follows:

Crude Fibre (%) = (W1 – W2) / W x 100

Where W = weight of sample, W1 = weight of crucible + dried residue, W2 = weight of crucible + ash.

2.3.6 Total carbohydrate

The calculation for the total content of carbohydrates was done by subtracting the combined content of moisture, protein, fat, fibre and ash from 100.

Total Carbohydrate (%) = 100 - (% Moisture + % Protein + % Fat + % Fibre + % Ash)

2.3.7 Energy value

The gross energy value was calculated using the FSSAI general factors as follows:

Energy (Kcal/100 g) = (%Protein × 4) + (%Carbohydrate × 4) + (%Fat × 9)

2.3.8 Determination of pH

The 25 ml of distilled water was added to 1.0 g each of the leaf and stem powder of *N. dalzellii* which were placed in separate vials. Thereafter, the capped vials were placed on a mechanical shaker for 15 minutes after which the pH was measured [7].

2.4 Mineral analysis

Approximately, 1.0 g of the sample was used for analysis in the process of acid digestion (20–25 ml) and the final volume was made up to 100 mL using distilled water. The instruments that were used for the analysis of the mineral elements in the sample included Atomic Absorption Spectrometer (Thermo

fisher, AA203) for the analysis of copper (Cu), zinc (Zn), magnesium (Mg), manganese (Mn), molybdenum (Mo) and iron (Fe); Flame Photometer (Thermo fisher, FP114) for the analysis of sodium (Na), potassium (K) and calcium (Ca); UV Spectrophotometer (UV-2100, Scanning Type, WL 190–1100 nm) for the analysis of boron (B), phosphorus (P) and sulphur (S).

2.5 Statistical analysis

The proximate and mineral data have been expressed as mean ± SD. All analyses were carried out in triplicate (n = 3). Pearson correlation coefficient (r) of leaf and stem analysis was determined separately by using Excel and R software. p-values of < 0.05 were considered significant.

3. Results and discussion

Proximate composition serves as an important indicator for evaluating and classifying the nutritional potential of individual plant parts or the plant as a whole [12]. The proximate composition of the leaves and stem of *N. dalzellii* was determined in accordance with AOAC standard [5] and FSSAI procedures. The results are presented in Fig. 1 and Tables 1–2. Significant differences were observed; the leaves recorded higher moisture (7.25%), total minerals (17.08%), crude protein (10.18%), carbohydrate (47.65%) and energy (245.45 Kcal/100g) than the stem. In contrast, the stem showed higher crude fibre (46.27%) compared to the leaves (16.27%), while crude fat was comparably low in both (leaf: 1.57%; stem: 1.46%). This is the first report on the proximate and mineral analysis.

Table 1
pH and energy value (Kcal/100 g) of the leaf and stem of *N. dalzellii*.

Variables	**Evaluation**	
	Leaves	**Stem**
pH	7.7 ± 1.10	7.4 ± 2.84
Energy value (Kcal/100g)	245.45 ± 2.30	181.02 ± 3.01
pH and Energy values are mean ± SD		

Table 2
Evaluation of the mineral composition (mg/day) and assessment against Dietary Reference Intakes (DRI): Recommended Dietary Allowance (RDA), Adequate Intake (AI), Tolerable Upper Intake Level (TUL) of minerals for most individuals to the average concentration of minerals, dry powder of N. dalzellii (Baker) Merr. leaves and stem.

Minerals	**Leaves (mg/100g DW)**	**Stem (mg/100g DW)**	**DRI (mg/day)**		**Approximate contribution to RDA (%)**	
			RDA	**UL**	**Leaves**	**Stem**
Major/Macro minerals						
Calcium (Ca)	766 ± 5.77	516 ± 5.77	850–1000	ND	90 – 77	61 – 52
Magnesium (Mg)	366.7 ± 5.77	263 ± 11.54	240–440	350	153 – 83	109 – 60
Phosphorus (P)	76.7 ± 37.85	26.67 ± 5.77	500–600*	ND	15 – 13	5.33–4.44
Potassium (K)	1760 ± 10.00	1560 ± 26.45	2825–3500	ND	62 – 50	55 – 45
Sodium (Na)	96.7 ± 5.77	190 ± 10.00	1600–2000	ND	6 – 5	12 – 10
Sulphur (S)	203 ± 1.54	106.7 ± 10.00	ND	ND	-	-
Trace/Minor minerals						
Boron (B)	1.19 ± 0.015	1.10 ± 0.022	ND	ND	-	-
Copper (Cu)	3.20 ± 0.25	0.08 ± 0.009	ND	ND	-	-
Ferrous (Fe)	56.57 ± 0.41	29.67 ± 0.202	16–32	40–45	353 – 177	185 – 92
Manganese (Mn)	4.50 ± 0.11	0.10 ± 0.010	50*	ND	9	0.2
Molybdenum (Mo)	0.09 ± 0.00	0.05 ± 0.000	ND	ND	-	-
Zinc (Zn)	4.14 ± 0.022	1.19 ± 0.028	8.5–17.6	ND	48 – 23	14 – 7

Data on Recommended Dietary Allowances for Indians given by Indian Council of Medical Research-National Institute of Nutrition (ICMR-NIN) for females and males from 10 to 70 and above. Values are given as mean ± SD. Adequate Intake (AIs) followed by an asterisk*, ND-Not detected

3.1 Moisture content

The moisture content of the leaves (7.25%) was higher than that of the stem (5.06%) of *N. dalzellii*. Both values fall below the critical threshold of 15%, above which microbial proliferation including bacterial and fungal growth accelerates substantially compromising shelf life and active constituents. Low moisture content is desirable for plant materials intended for pharmaceutical formulation, as it ensures long-term stability of bioactive compounds during storage and transportation [13]. The leaf moisture (7.25%) of *N. dalzellii* is comparable to that of *Cassia mimosoides* leaf (7.10%) [14] and *Bobgunnia fistuloides* leaf (10.01%) [15]. The moisture is lower than *Vigna unguiculata* (9.4–13.0% across fifteen varieties, dry-weight basis [16], *Indigofera tinctoria* (12.49%) [17] and slightly lower than *Delonix regia* leaves (8.10%) [17, 18], but higher than the leaf moisture of *Cassia nigricans* (3.92%) [19]. The stem moisture (5.06%) is lower than that of the stem bark of *B. fistuloides* (9.40%) [15], *Indigofera tinctoria* (6.40%) [17], *Daniellia oliveri* (6.25%) [20] and higher than the stem bark of *Cassia nigricans* (4.65%) [19]. This higher moisture in the leaves because leaf cells need water to stay active and perform photosynthesis, whereas the woody stem is made of tough, dry fibers used mainly for support [21].

3.2 Total ash content

The ash content of the leaves of *N. dalzellii* (17.08%) was substantially higher than that of the stem (5.24%). Ash content is a reliable indirect indicator of the total inorganic mineral content of plant material; a high value indicates the presence of biologically important macro and microelements [22]. The remarkably high ash content of *N. dalzellii* leaves (17.08%) exceeds values reported for *Bobgunnia fistuloides* leaf (9.40%) [15], *Clitoria ternatea* leaves (8.73–9.50%) [23], *Lablab purpureus* aerial parts (5.60%) [24] and the range of 5.93–11.18% documented for *Pterocarpus indicus*, *Bauhinia purpurea* and *Tamarindus indica* [25]. The lower leaf ash value includes *Indigofera tinctoria* leaves (13.86%) [17], *Bobgunnia fistuloides* leaves (32.40%) [15], *Cassia nigricans* leaves (8.53%) [19], *Clitoria ternatea* leaves (8.73–9.50%) [23] and *Lablab purpureus* aerial parts (5.60%) [24]. The stem ash of *N. dalzellii* (5.24%) is, by contrast, at the lower end of the Fabaceae stem/stem-bark range, below *Indigofera tinctoria* stem bark (10.42% [17], *Daniellia oliveri* stem bark (9.11%) [20] and *Cassia nigricans* stem bark (11.98%) [19], though comparable to *Delonix regia* leaves (5.21%) [18]. The markedly elevated leaf ash relative to the stem reflects the preferential accumulation of macro and micronutrient ions in metabolically active leaf tissue, where mineral elements serve as cofactors for photosynthetic enzymes, osmotic regulators and structural components of cell membranes, while the comparatively mineral-poor stem is dominated by structural lignocellulose rather than mineral-dense metabolic tissue [26]. The quantitative elemental analysis in Table 2 confirms that the high ash in leaves of *N. dalzellii* reflects genuine mineral richness.

3.3 Crude protein

The crude protein content of the leaves (10.18%) was higher than that of the stem (6.98%) of *N. dalzellii*. The protein content of *N. dalzellii* leaves (10.18%) is higher than that of *Bobgunnia fistuloides* leaves (3.28%) [15], but lower than *Clitoria ternatea* leaves (14.99–17.36%) [23], *Bauhinia purpurea* (28.95%) and *Lablab purpureus* aerial parts (25.40%) [25]. The stem protein (6.98%) is higher than *Indigofera tinctoria* stem bark (5.11%) [17] and close to *Daniellia oliveri* stem bark (6.07%) [20], though lower than *Cassia nigricans* stem bark (10.51%) [19] and comparable to *Cassia fistula* stems (5.62–6.78%) [27]. The

consistent leaf-greater-than-stem protein gradient observed across nearly all comparator species including *N. dalzellii* reflects the concentration of photosynthetic and metabolic machinery and the associated structural and enzymatic proteins in leaf tissue, relative to the comparatively protein-poor lignocellulosic stem [26].

3.4 Crude fat

The crude fat content was low in both the leaves (1.57%) and stem (1.46%) of *N. dalzellii*. Low fat plant materials are preferred in pharmaceutical formulations as they reduce rancidity during storage and improve stability of active constituents [7]. The fat values were reported as higher than *Bobgunnia fistuloides* leaf (0.88%) and stem bark (1.06%) [15], but lower than *Clitoria ternatea* leaves (5.23–5.50%) [23] and *Lablab purpureus* aerial parts (4.20%) [24]. It is, however, comparable to *Indigofera tinctoria* leaves (2.44%) and stem bark (2.00%) [17] and *Daniellia oliveri* stem bark (1.03%) [20], but within the lower range of 0.62–2.95% reported across six tropical Fabaceae legumes by Ikhwanti et al. [25]. The comparably low-fat content in both the leaf and the stem of *N. dalzellii* is consistent with the general characteristic of legume vegetative tissues, which allocate lipids predominantly to membrane-bound structural roles and minimally to storage triacylglycerols [28].

3.5 Crude fibre

The most striking finding of the proximate analysis was the high crude fibre content of the stem of *N. dalzellii* (46.27%) compared to the leaves (16.27%). This reflects the fundamental structural role of lignocellulosic materials, cellulose, hemicellulose and lignin in stem tissues [7]. The stem bark of *Indigofera tinctoria* (54.49% vs. 19.02%) in the leaf [17], *Cassia nigricans* (41.36% vs. 20.64%) in the leaf [19] show substantially elevated fibre relative to the corresponding leaf, validating the structural-tissue interpretation. The exceptionally high stem fibre (46.27%) is comparable to *Stylosanthes guianensis* (42.18%), but higher than *Macroptilium atropurpureum* (28.65%) [25], higher than *Cassia fistula* stems (36.54–37.27%) [27] and *Bobgunnia fistuloides* stem bark (10.13%) [15]. Dietary fibre is associated with significantly reduced risk of type 2 diabetes mellitus, cardiovascular disease and colorectal cancer [29, 30]. The leaf fibre (16.27%) is comparable to *Clitoria ternatea* (8.45–8.77%) [23] and *Lablab purpureus* aerial parts (7.50%) [24], falling just below the crude fibre range of 19.75–42.18% documented for tropical Fabaceae legumes by Ikhwanti et al. [25]. The exceptionally high stem fibre of *N. dalzellii* positions this organ as a candidate dietary fibre source, subject to appropriate processing to reduce any associated anti-nutritional factors [31].

3.6 Carbohydrates

The carbohydrate content of the leaves of *N. dalzellii* (47.65%) was considerably higher than that of the stem (34.99%). The leaf carbohydrate (47.65%) is closely comparable to *Lablab purpureus* aerial parts (46.93%) [24], *Bobgunnia fistuloides* leaves (50.73%) [15] and somewhat higher than *Cassia nigricans* leaves (36.27% nitrogen-free extract [19] and *Indigofera tinctoria* leaves (30.59%) [17], while remaining lower than *Delonix regia* leaves (78.45%) [18]. The stem carbohydrate of *N. dalzellii* (34.99%) were somewhat higher than *Indigofera tinctoria* stem bark (29.98% [17] and considerably higher than *Daniellia*

oliveri stem bark (21.09%) [20] and *Cassia nigricans* stem bark (22.37%) [19]. The lower carbohydrate (nitrogen-free extract) value in the stem relative to the leaf, observed consistently across Fabaceae, including *N. dalzellii*, reflects the partitioning of non-structural carbohydrate towards the metabolically active leaf and the corresponding dominance of structural fibre rather than soluble or storage carbohydrate in stem dry matter [32] dynamically, this stem value (34.99%) falls within the nitrogen-free extract range of 34.33–51.28% across six tropical Fabaceae legumes [25].

3.7 Energy value

The energy value of the leaves (245.45 Kcal/100 g) was higher than that of the stem (181.02 Kcal/100 g) of *N. dalzellii*, directly reflecting the higher protein, fat and carbohydrate contents in leaf tissue [33]. The energy value of the leaves is comparable to *Bobgunnia fistuloides* leaves (223.99 Kcal/100 g) [15], but significantly lower than *Clitoria ternatea* leaves (459.60–489.24 Kcal/100 g) [23], while remaining within the range reported for *Lablab purpureus* aerial parts and *Cassia mimosoides* [14, 24]. The lower energy value of the stem relative to the leaf across *N. dalzellii* and most comparator species is principally attributable to the dilution effect of high structural fibre, which contributes negligibly to metabolisable energy while substantially lowering gross energy density per unit dry mass [34].

3.8 pH

The pH of *N. dalzellii* leaf (7.7 ± 1.10) and stem (7.4 ± 2.84) is nearly neutral and slightly alkaline. The near-neutral pH is beneficial for food-grade processing and pharmaceuticals, as it improves water-holding capacity and also helps to preserve colour pigments such as chlorophyll and carotenoids [35]. Meanwhile, strong acidic and alkaline conditions can induce degradation of bioactive compounds such as flavonoids and polyphenols [36].

3.9 Mineral composition

The mineral composition of the leaves and stem of *N. dalzellii* is presented in Table 2. The leaves were richer in most macro and trace minerals compared to the stem, consistent with the general role of leaves as the primary site of mineral accumulation in plants [22]. All mineral values are assessed against the Dietary Reference Intakes (DRI) recommended by the Indian Council of Medical Research – National Institute of Nutrition for Indians aged 10 to 70 years [37].

3.9.1 Calcium

The calcium content of the leaves (766.7 ± 5.77 mg/100 g) was higher than that of the stem (516.67 ± 5.77 mg/100 g) of *N. dalzellii*. Both values represent substantial contributions to the ICMR-NIN RDA of 850–1000 mg/day, supplying 76.7–90.2% from leaves and 51.7–60.8% from the stem. Calcium is critical for bone and teeth mineralisation, neuromuscular function, blood coagulation and enzymatic catalysis [9, 22]. Comparatively, the leaf calcium (766.7 mg/100 g) of *N. dalzellii* is higher than that reported for *Clitoria ternatea* leaves (660 mg/100 g) [23] and *Vigna unguiculata* leaves (540–600 mg/100 g) [22]. Among Fabaceae genera, calcium accumulation in leaves shows marked variation: *Sesbania grandiflora*

leaves are recorded at ~ 1200 mg/100 g while *Cajanus cajan* leaves range 800–1100 mg/100 g [22]. The stem calcium (516.67 mg/100 g) of *N. dalzellii* is also higher than most comparative Fabaceae stems, consistent with the high ash content (5.24%) of the stem; both organs are valuable plant-based calcium sources for lactose-intolerant and vegetarian people [38].

3.9.2 Magnesium

The magnesium content of the leaves (366.7 ± 5.77 mg/100 g) was higher than that of the stem (263 ± 11.54 mg/100 g). Both values fall within the established Fabaceae range (100–500 mg/100 g) and contribute 83.3–152.8% (leaf) and 59.8–109.6% (stem) of the ICMR-NIN RDA of 240–440 mg/day. It is noteworthy that the leaf magnesium content approaches the tolerable upper limit for supplemental intake of 350 mg/day; accordingly, this plant material should be consumed in controlled quantities. Comparatively, the leaf magnesium of *N. dalzellii* (366.7 mg/100 g) is higher than *Clitoria ternatea* leaves (300 mg/100 g = 0.30%) [39] and *Lablab purpureus* leaves (~ 159 mg per cup cooked, corresponding to ~ 100–200 mg/100 g dry weight) [24]. The high magnesium content of *N. dalzellii* leaves supports its potential use in managing hypertension, type 2 diabetes mellitus and cardiovascular disease, since legumes rich in potassium, magnesium and dietary fibre have a well-documented positive effect on blood pressure management [40].

3.9.3 Phosphorus

The phosphorus content of the leaves (76.7 ± 37.85 mg/100 g) was higher than that of the stem (26.67 ± 5.77 mg/100 g), representing modest contributions of 12.8–15.3% (leaf) and 4.4–5.3% (stem) to the ICMR-NIN RDA of 500–600 mg/day. Comparatively, these values are lower than *Clitoria ternatea* leaves (570 mg/100 g = 0.57%) [23], *Lablab purpureus* leaves (233 mg) [24] and *Vigna radiata* leaves [22]. Despite this, the leaf-to-stem gradient in phosphorus (76.7 vs. 26.67 mg/100 g) is consistent with the greater metabolic activity of leaf tissue, where phosphorus-dependent processes, including photosynthesis, cellular ATP synthesis and metabolic signalling, are highly concentrated [26]. Furthermore, the combination of high calcium and low phosphorus in both organs yields a highly favourable Calcium-to-Phosphorus (Ca:P) ratio well above 1.0, which is widely associated with enhanced bone mineralisation and a reduced risk of bone resorption [41].

3.9.4 Potassium

The potassium content of the leaves (1760 ± 10.00 mg/100 g) was higher than that of the stem (1560 ± 26.45 mg/100 g) of *N. dalzellii*. Both values are within the established Fabaceae range of 1500–4000 mg/100 g and contribute 50.5–62.5% (leaf) and 44.6–55.2% (stem) of the ICMR-NIN RDA of 2825–3500 mg/day. Potassium is the dominant mineral cation in plant tissues and is critical for blood pressure regulation, cardiac function, osmotic balance and nerve impulse conduction [9]. Comparatively, the leaf potassium of *N. dalzellii* (1760 mg/100 g) is higher than that of *Clitoria ternatea* leaves (1420 mg/100 g = 1.42 g/100 g) [23] and *Lablab purpureus* seeds (1235 mg/100 g) [24]. It is comparable to potassium values documented for *Cajanus cajan* leaves (~ 1500–1800 mg/100 g) and *Vigna unguiculata* leaves (~ 1600–2000 mg/100 g) [22]. The consistently high potassium in both organs of *N. dalzellii*, combined with

low sodium (Na: K ratio ~ 0.054 in leaf and ~ 0.064 in stem), represents a nutritionally favourable cardiovascular profile, since a high K:Na ratio is widely associated with reduced hypertension risk [42].

3.9.5 Sodium

The sodium content of the stem (190 ± 10.00 mg/100 g) was marginally higher than that of the leaves (96.7 ± 5.77 mg/100 g) of *N. dalzellii*, representing modest contributions of 4.8–6.0% (leaf) and 5.0–6.2% (stem) to the ICMR-NIN RDA of 1600–2000 mg/day. The low sodium content in both organs is nutritionally desirable and supports use as a dietary supplement for hypertensive patients. Comparatively, the sodium values of *N. dalzellii* are comparable to those of *Cajanus cajan* and *Vigna unguiculata* leaves, which are generally low in sodium (~ 80–150 mg/100 g dry weight) [22].

3.9.6 Sulphur

The sulphur content of the leaves (203 ± 1.54 mg/100 g) was higher than that of the stem (106.67 ± 5.77 mg/100 g). No established DRI has been set for sulphur, as dietary sulphur is typically obtained through the sulphur-containing amino acids methionine and cysteine [9]. Sulphur is a structural component of proteins (cysteine and methionine), coenzymes (CoA, lipoic acid) and vitamins (thiamine and biotin) and is essential for maintaining protein tertiary structure through disulphide bonds. The sulphur values of *N. dalzellii* (0.11–0.20% dry weight) are within the normal range reported for legume dry matter (0.2–0.5%) [43] and consistent with values documented for other Fabaceae members including *Glycine max* (soybean; ~0.25–0.45%) and *Cajanus cajan* (~ 0.15–0.35%) [22].

3.9.7 Iron

The iron content of the leaves (56.57 ± 0.42 mg/100 g) was marginally higher than that of the stem (29.67 ± 0.20 mg/100 g) of *N. dalzellii*. Both values represent outstanding contributions to the ICMR-NIN RDA of 16–32 mg/day: 51.8–103.6% for leaves and 49.0–97.9% for stem. Comparatively, the iron content of *N. dalzellii* leaves (56.54 mg/100 g) is higher than that of *Sphenostylis sternocarpa* (10.83 mg/100g) and *Cajanus cajan* seeds (13.97 mg/100 g) [44] but lower than *Nesphostylis bracteata* leaves (116.377 mg/100g) [45] and lentil seeds (65.5mg/100g) [46]. The iron values of *N. dalzellii* are significant from a public health perspective, given the high prevalence of iron-deficiency anaemia. Plant-derived iron occurs primarily as non-haem iron (Fe^{3+}), whose bioavailability is enhanced by co-consumption with vitamin C and reduced by phytates, oxalates and tannins commonly present in legumes [47].

3.9.8 Zinc

The zinc content of the leaves (4.14 ± 0.06 mg/100 g) was notably higher than that of the stem (1.19 ± 0.03 mg/100 g) of *N. dalzellii*. The leaf zinc contributes 23.5–48.7% of the ICMR-NIN RDA of 8.5–17.6 mg/day. Comparatively, the leaf zinc of *N. dalzellii* (4.11 mg/100 g) is comparable to *Clitoria ternatea* leaves (0.14–1.25 mg/g dry weight) [48] and *Vigna radiata* leaves [22]. The considerably lower stem zinc (1.19 mg/100 g) confirms that the leaf is the nutritionally superior organ for zinc provision in *N. dalzellii*. The excess iron increases the risk of liver cancer.

3.9.9 Copper, manganese, boron and molybdenum

The copper content of the leaves (3.20 ± 0.17 mg/100 g) was substantially higher than the stem (0.08 ± 0.01 mg/100 g). Comparatively, the leaf copper of *N. dalzellii* is higher than *that of Clitoria ternatea leaves (*1.80–3.71 mg/100 g) [23]. Copper-dependent enzymes, including superoxide dismutase, plastocyanin and laccase, are concentrated in leaf tissue, explaining the leaf-to-stem gradient. The manganese content of the leaves (4.50 ± 0.11 mg/100 g) greatly exceeded that of the stem (0.10 ± 0.01 mg/100 g) and contributes 50–125% of the ICMR-NIN AI of 2–5 mg/day. Manganese is an essential cofactor for Mn-SOD and is involved in proper brain function and bone formation [9]. Boron was present in comparable amounts in leaves (1.19 ± 0.02 mg/100 g) and stem (1.10 ± 0.02 mg/100 g), consistent with values reported for wild Fabaceae leaves (~ 0.5–2.0 mg/100 g) [22]. Molybdenum was detected at very low concentrations in leaves (0.09 ± 0.00 mg/100 g) and stem (0.05 ± 0.00 mg/100 g), consistent with its status as an ultra-trace element required in catalytic amounts as a cofactor for xanthine oxidase and aldehyde oxidase [49]. The consistent pattern of leaves > stem for most trace minerals further confirms the nutritional superiority of the leaf over the stem as a mineral source in *N. dalzellii*. This has also been reported for leaves of *S. chinensis* [50].

3.9.10 Correlation analysis

Pearson correlation analysis was performed for leaf and stem samples to determine correlations between proximate composition and minerals. A highly significant correlation was found between calcium and sulphur it showing a positive correlation in both leaf and stem parts (r = 1.00***) and only in leaf magnesium and sodium, which are correlated in muscle contraction and relaxation. Other positive correlations were observed in crude fat and phosphorus, crude fiber and boron, manganese and sodium and manganese and sodium, where they are significant (r = 1.00*) in the leaf. For the stem, copper and sodium (r = 1.00*). On the other hand, some negative correlations are found. In leaf crude fiber and potassium (r = -1.00*), carbohydrate and copper (r = -1.00*) and potassium and boron (r = -1.00*) and for the stem phosphorus and ash (r = -1.00**), crude fat and potassium (r = -1.00**), energy and carbohydrate (r = -1.00*), carbohydrate and calcium and sulphur (r = -1.00*), energy and calcium and sulphur (r = -1.00*) and molybdenum and manganese (r = -1.00*). The correlation matrix is graphically represented as a heatmap (Fig. 2). Circle size and colour intensity represent the magnitude of the correlation coefficient, with positive correlations shown in red and negative correlations in blue.

4. Conclusions

The proximate and mineral analyses of *N. dalzellii* revealed a clear organ-specific distribution of nutrients biologically consistent with documented patterns across the family Fabaceae. The leaves are the primary reservoir for protein, total minerals, carbohydrate, calcium, magnesium, potassium, iron, zinc, copper and manganese, while the stem is characterised by exceptionally high crude fibre and sodium, reflecting a distinct mechanical role. The very high ash content of the leaves and confirmed high levels of calcium, magnesium, potassium and iron supported the traditional use of this plant in folk medicine for mineral-related ailments such as anaemia, bone weakness and nutritional deficiencies. The appreciable crude protein in leaves suggested the possibility of bioactive peptide extraction for antihypertensive and

antioxidant pharmaceutical applications. The very high crude fibre of the stem positions it as a potential nutraceutical ingredient for the prevention and management of type 2 diabetes mellitus, cardiovascular disease, obesity and colorectal cancer [29, 30]. The consistently favourable Na: K ratio (~ 0.054 in leaf), low fat content (≤ 1.57%) and absence of toxic mineral levels collectively make *N. dalzellii* a safe and nutritionally well-balanced dietary supplement. The energy contribution of *N. dalzellii* leaves, combined with their appreciable mineral and protein contents, suggested a well-balanced nutritional profile with potential utility as a health-promoting dietary supplement and functional food ingredient.

Declarations

Consent to Publication

Not applicable.

Consent to Participate

Not applicable.

Ethical Approval

Not applicable.

Conflict of interest

The authors declare no conflict of interest.

Plant Ethics Statement

The plant material was identified and authenticated by Dr. Manoj Lekhak, Department of Botany, Shivaji University, Kolhapur, India. A voucher specimen (Voucher no. PMP01) has been deposited at the Herbarium of the Department of Botany, Shivaji University, Kolhapur, India.

Plant Ethics Declaration

The collection of plant materials in this study complied with local and national guidelines, and all ethical issue was considered during the data collection, analysis and writing of the manuscript.

Funding

The authors declare that no financial support, grants or other forms of funding were received during the preparation of this manuscript.

Author Contribution

Methodology, software, formal analysis, writing—original draft preparation, PMP; conceptualization writing—review and editing, supervision, JJC. Both the authors have read and agreed to the published version of the manuscript.

Acknowledgement

The authors extend their appreciation to the Head, Department of Botany and the Principal, Yashavantrao Chavan Institute of Science, Satara for providing necessary laboratory facilities. Thanks to Mr. P. H. Mahadik for helping the statistical analysis.

Data Availability

The datasets used in this study are publicly available. The processed datasets generated during the current study are available from the corresponding author upon reasonable request.

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Figures

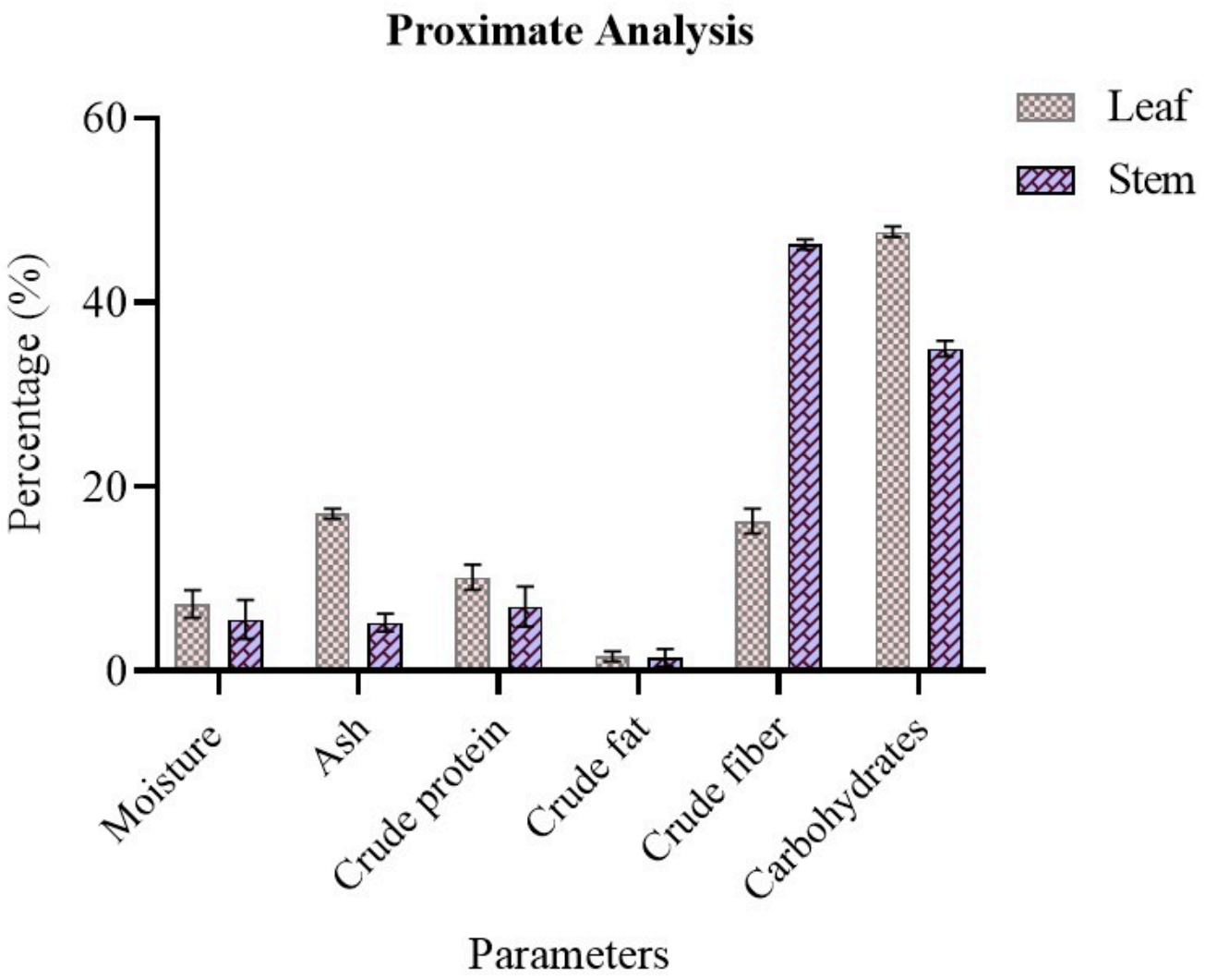

Figure 1

Proximate analysis (Moisture, Crude protein, Crude fat, Crude fibre and Carbohydrates) of the leaves and stem of *N. dalzellii* on Dry weight basis (Mean ± SD)

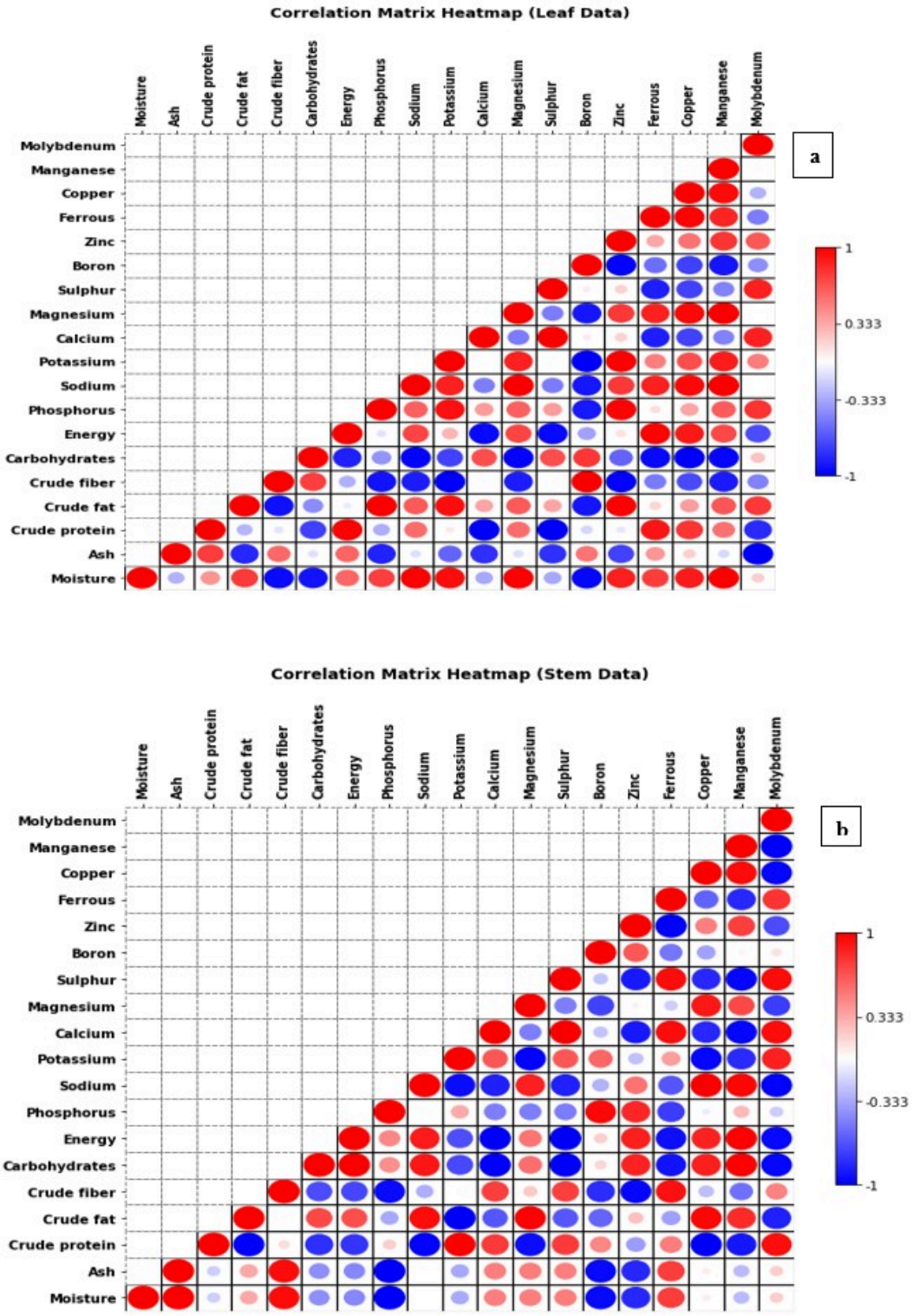

Figure 2

Pearson correlation heatmap of proximate and mineral analysis of *N. dalzellii* (Baker) Merr. (a) Leaf, (b) Stem (red = positive, blue = negative).