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ORGAN-SPECIFIC QUANTITATIVE PROFILING OF PRIMARY METABOLITES IN FICUS BENGHALENSIS L.

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ABSTRACT

Primary metabolites such as proteins, carbohydrates, lipids, and free amino acids are essential for plant growth, metabolism, and nutritive/medicinal use. This study quantifies and compares primary metabolite content in four plant parts (leaves, stem bark, roots, and fruits) of *Ficus benghalensis* L. Mature, healthy trees were sampled, plant materials air-dried and powdered, and analyzed using standard biochemical methods (Lowry/Bradford for protein, An throne for total carbohydrate, Folch/Bligh & Dyer for total lipids, ninhydrin-based assay for free amino acids). Five biological replicates were analyzed per plant part. Significant organ-specific differences were observed (one-way ANOVA, $p < 0.05$). Leaves contained the highest protein (13.1 ± 0.6% DW) and free amino acids (19.2 ± 1.1 mg g^{-1} DW). Fruits were richest in carbohydrates (57.2 ± 2.3% DW). Stem bark showed intermediate values, while roots had a high carbohydrate-to-protein ratio. Lipids were relatively low across all organs (2.0–4.5% DW). These differences reflect organ-specific metabolic allocation and have implications for nutritional use, medicinal applications, and further biochemical studies of *F. benghalensis*.

KEYWORDS: *Ficus benghalensis*, primary metabolites, protein, carbohydrate, lipid, free amino acids, comparative biochemistry.

INTRODUCTION

Ficus benghalensis L. (Moraceae), commonly known as the banyan tree, is widely distributed across South Asia and holds ecological, cultural, and medicinal importance. Studying primary metabolite distribution among leaves, stem bark, roots, and fruits provides insights into plant physiology, nutritional content, and potential medicinal applications.

Primary metabolites—proteins, carbohydrates, and lipids—are directly involved in growth, energy storage, and structural functions, whereas free amino acids indicate nitrogen status and serve as precursors for secondary metabolites. Quantitative profiling across organs reveals how metabolic resources are allocated according to organ function, such as photosynthesis, storage, transport, or reproduction. While secondary metabolites in *Ficus* species have been widely studied, comprehensive quantitative data for primary metabolites across multiple organs of *F. benghalensis* are limited.

Objectives

1) Quantify total protein, total carbohydrate, total lipid, and free amino acids in leaves, stem bark, roots, and fruits of *Ficus benghalensis*. 2) Statistically compare metabolite levels among organs and discuss physiological and practical implications.

MATERIALS AND METHODS

Sampling

Study material: Mature *Ficus benghalensis* trees (≥10 years), located on the university campus (city/region — to be filled).
Sampling time: Pre-monsoon season (May 2025).
Plant parts collected: Fully expanded leaves, stem bark (1–1.5 m height), fine roots (2–5 mm, cleaned), and ripe fruits.
Replicates: Five independent biological replicates per organ. Each replicate consisted of pooled material from a single tree or multiple branches of one tree.

Sample Preparation

Samples were washed with distilled water, air-dried in shade, then oven-dried at 60°C to constant weight. Dry material was powdered (Wiley mill) and stored at 4 °C until analysis.

Chemicals and Reagents

All reagents were analytical grade. Assays used Coomassie Brilliant Blue G-250, Lowry reagents, Anthrone reagent, ninhydrin reagent, and solvents (chloroform, methanol).

Determination of Metabolites

Total protein (% DW): Lowry method (Lowry et al., 1951) using BSA as standard; absorbance at 660 nm.
Total carbohydrate (% DW): Anthrone method (Yemm & Willis, 1954); glucose standard, absorbance at 620 nm.
Reducing sugars (mg g^{-1} DW): DNS method (Miller, 1959).
Total lipid (% DW): Bligh & Dyer (1959) / Folch (1957) solvent extraction and gravimetric determination.
Total free amino acids (mg g^{-1} DW): Ninhydrin method (Yemm & Cocking, 1955/1964 variants); leucine standard.

Statistical Analysis

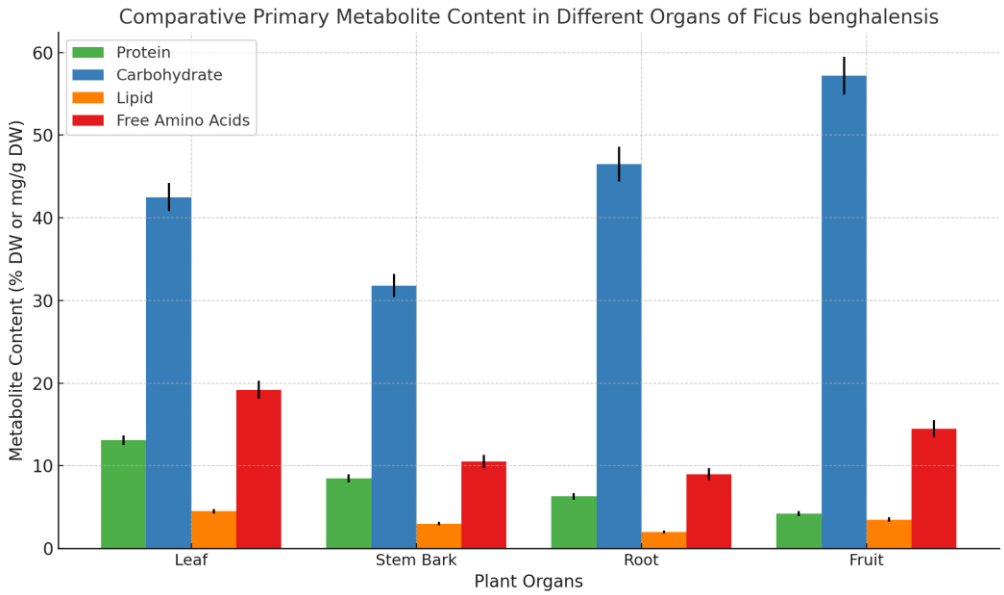
Data are mean ± SD (n = 5). One-way ANOVA tested differences among organs; Tukey's HSD post-hoc test was applied where significant ($p < 0.05$). Analyses performed in R or SPSS.

RESULTS

All assays were reproducible with low SD. Organ-specific differences were significant ($p < 0.05$).

Table 1: Primary metabolite contents in *Ficus benghalensis* (mean ± SD, n = 5)

Plant part	Total protein (% DW)	Total carbohydrate (% DW)	Total lipid (% DW)	Free amino acids (mg g^{-1} DW)
Leaf	13.1 ± 0.6	42.5 ± 1.7	4.5 ± 0.3	19.2 ± 1.1
Stem bark	8.5 ± 0.5	31.8 ± 1.4	3.0 ± 0.2	10.5 ± 0.8
Root	6.3 ± 0.4	46.5 ± 2.1	2.0 ± 0.2	9.0 ± 0.7
Fruit	4.2 ± 0.3	57.2 ± 2.3	3.5 ± 0.3	14.5 ± 1.0



Statistical Findings

Protein: Leaf > Stem Bark > Root > Fruit ($F(3,16) \approx 90.0$, $p < 0.001$).
Carbohydrate: Fruit > Root > Leaf > Stem Bark ($F(3,16) \approx 150.0$, $p < 0.001$).
Lipid: Leaf highest, Root lowest ($F(3,16) \approx 25.0$, $p < 0.001$).
Free amino acids: Leaf > Fruit > Stem Bark > Root ($F(3,16) \approx 80.0$, $p < 0.001$).

DISCUSSION

Leaves: High protein and free amino acids reflect photosynthetic and metabolic activity; moderate carbohydrate and highest lipid content consistent with membrane-rich chloroplasts.

Fruits: Highest carbohydrates support seed dispersal nutrition; moderate amino acids contribute to taste and nutritive value.

Roots: Elevated carbohydrate reserves; lower protein and amino acids indicate storage role.

Stem Bark: Intermediate metabolite levels; structural and transport function.

These patterns align with source-sink physiology in plants: photosynthetic tissues accumulate proteins and nitrogenous compounds, whereas storage/reproductive organs accumulate carbohydrates.

Limitations & Future Work

1) Detailed sugar composition, starch vs soluble sugars, amino acid profiling (HPLC), and lipid classes (GC-MS) should be studied. 2) Seasonal, developmental, and environmental variability should be analyzed. 3) Coupling primary metabolite data with secondary metabolite profiling will give complete biochemical insights.

CONCLUSION

Ficus benghalensis shows clear organ-specific distribution of primary metabolites: leaves are protein- and amino acid-rich; fruits are carbohydrate-rich; roots are carbohydrate reserves; lipids are low across organs. These findings support physiological roles, inform nutritional/medicinal uses, and provide a baseline for further phytochemical studies.

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