International Journal of Bio-resource and Stress Management

https://ojs.pphouse.org/index.php/IJBSM

Crossref

IJBSM July 2026, 17(7): 01-08

Article AR7042

Research Article

Natural Resource Management

DOI: HTTPS://DOI.ORG/10.23910/1.2026.7042

Biochemical Characterization of Underutilized Himalayan Fruit Species: Insights into Nutritional and Anti-nutritional Attributes

Swadesh Gurung[1], Sarad Gurung[2], Binoy Chhetri[2], Nilesh Bhowmick[1], Binayak Chakrabotty[3], Sumit Chakravarty[4], Somnath Mandal[5] and Z. W. Sherpa[1]

[1]Dept. of Pomology and Post-Harvest Technology, [3]Regional Research Station (Terai Zone), [4]Dept. of Forestry, [5]Dept. of Biochemistry, Uttar Banga Krishi Viswavidyalaya, Pundibari Coochbehar, West Bengal (736 165), India

[2]Regional Research Station (Hill Zone), Directorate of Research, Uttar Banga Krishi Viswavidyalaya, Kalimpong West Bengal (734 301), India

Corresponding gswadesh6@gmail.com

0009-0007-3980-5526

ABSTRACT

The study was conducted during two consecutive seasons (May 2023–February, 2024 and May, 2024–February, 2025) in the Darjeeling Himalayan region, West Bengal, India to evaluate the physico-chemical, nutritional, and anti-nutritional properties of six lesser-known fruit species, namely *Elaeagnus latifolia*, *Rubus ellipticus*, *Ficus roxburghii*, *Spondias axillaris*, *Eriolobus indica* and *Morus serrata.* Fruits harvested at physiological maturity were analyzed using standard analytical procedures, and pooled data were expressed as mean±standard error of mean (SEm). Significant interspecific variation were observed for all parameters studied. Total soluble solids ranged from 6.28±0.22˚Brix in *Ficus roxburghii* to 18.37±0.09˚Brix in *Morus serrata*. Total sugars varied between 3.59±0.03% and 14.08±0.57%, while reducing sugars ranged from 1.82±0.12% in *Elaeagnus latifolia* to 7.54±0.25% in *Rubus ellipticus*. Titrable acidity was highest in *Spondias axillaris* (3.93±0.10%). *Rubus ellipticus* recorded the highest carbohydrate content (17.50±0.28%), whereas protein content was maximum in *Spondias axillaris* (6.65±0.05%). *Eriolobus indica* exhibited the highest crude fiber content (4.58±0.01%). Ascorbic acid content ranged from 3.37±0.05 to 34.93±0.15 mg 100 g^{-1}, while *Morus serrata* showed exceptionally high anthocyanin content (132.08±0.26 mg 100 g^{-1}). Qualitative screening indicated the presence of tannins and phenols in all species, with limited occurrence of other anti-nutritional factors. The results highlighted the nutritional richness and utilization potential of these underutilized fruits.

KEYWORDS: Underutilized fruits, anti-nutritional factors, bioactive compounds, physico-chemical traits

Citation* (VANCOUVER)*: Gurung et al., Biochemical Characterization of Underutilized Himalayan Fruit Species: Insights into Nutritional and Anti-nutritional Attributes. *International Journal of Bio-resource and Stress Management,* 2026; 17(7), 01-08. HTTPS://DOI.ORG/10.23910/1.2026.7042.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, author have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Funding: The research was conducted with the kind and supports from the authority of Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal, India.

Conflict of interests: The author has declared that no conflict of interest exists.

RECEIVED on 09th March 2026 RECEIVED in revised form on 21st June 2026 ACCEPTED in final form on 07th July 2026 PUBLISHED on 15th July 2026

1. INTRODUCTION

The Eastern Himalayan region is recognized as one of the world's major biodiversity hotspots, characterized by complex topography, steep altitudinal gradients and heterogeneous agro-climatic zones (Myers and Mittermeier, 2000, Yonzone et al., 2012). The region harbours a rich diversity of wild and underutilized fruit species that contribute to local diets, traditional healthcare. (Arora, 2014). Despite their ecological and socio-economic importance, many of these fruits remain poorly characterized and underexploited in organized horticultural systems (Suresh et al., 2014, Bhutia et al., 2018). Therefore, scientific evaluation and biochemical characterization are essential to enhance their nutritional and commercial utilization (Padulosi et al., 2013, Jaenicke and Höschle-Zeledon, 2006). Globally, dependence on a limited number of food crops has contributed to micronutrient deficiencies and "hidden hunger" (Anonymous, 2002, Padulosi et al., 2013). Underutilized fruit crops offer a practical route to diversify diets because many species are naturally rich in vitamins, minerals, dietary fibre and phytochemicals (Gopalan et al., 2007, Gebauer et al., 2016). Several successful examples, such as baobab (*Adansonia digitata*), demonstrate that neglected fruits can be repositioned as functional foods or niche commodities when supported by nutritional evidence and value-chain development (Gebauer et al., 2016). In the Indian Himalayan region, ethnobotanical surveys have reported a wide range of edible but underexploited fruit species (Arora, 2014). Species such as *Elaeagnus latifolia*, *Rubus ellipticus*, *Morus serrata*, *Ficus roxburghii*, *Spondias axillaris* and *Eriolobus indica* are widely used locally, either fresh or processed into pickles, chutneys, squashes and preserves (De, 2017). These fruits are adapted to local microclimates, require low external inputs and therefore hold promise for climate-resilient, low-cost production systems (Yonzone et al., 2012, Arora, 2014). Physico-chemical properties such as total soluble solids, sugars and titratable acidity, along with proximate constituents including moisture, protein, fat, ash and crude fibre, largely determine the nutritional quality and processing suitability of fruits (Ranganna, 1979; Lowry et al., 1951). Published studies on Himalayan and adjacent underutilized fruits report wide inter-specific variation: *Rubus ellipticus* and *Morus serrata* often show high TSS and anthocyanin loads (Pandey and Bhatt, 2016,), while *Spondias axillaris* and *Eriolobus indica* are notable for high organic acidity and traditional use as souring agents (Kabra et al., 2019). Oil-rich species such as *Machilus edulis* and seed crops like *Diploknema butyracea* exemplify how taxonomic and functional diversity translates into very different nutritional niches within the same landscape (Uprety and Asselin, 2023). Wild fruits also contain anti-nutritional factors such as tannins, saponins, phytates and alkaloids, which may interfere with nutrient bioavailability when present in excess (Maniyan et al., 2015, Emmanuel and Deborah, 2018). However, many of these anti-nutritional factors also show beneficial bioactivities (antioxidant, antimicrobial, anti-inflammatory) at moderate levels and can be reduced or eliminated by appropriate processing (Maniyan et al., 2015, Emmanuel and Deborah, 2018). Thus, a balanced assessment that quantifies both nutrients and ANFs is necessary for realistic dietary recommendations and value-addition strategies (Anonymous, 1990, Ranganna, 1979). Generating robust data on proximate composition, vitamin and pigment content and qualitative/quantitative ANF profiles will inform post-harvest processing, product development, nutritional education and conservation planning (Padulosi et al., 2013, Jaenicke and Höschle-Zeledon, 2006, Yonzone et al., 2012). Therefore, the present study aimed to provide a comprehensive nutritional, biochemical and anti-nutritional characterization of six selected underutilized fruit crops of the Eastern Himalayas (*Elaeagnus latifolia*, *Rubus ellipticus*, *Morus serrata*, *Ficus roxburghii*, *Spondias axillaris* and *Eriolobus indica*) to support their sustainable utilization and inclusion into diversified food systems (De, 2017, Pandey et al., 2018).

2. MATERIALS AND METHODS

2.1. Study site and experimental material

The present investigation was carried out during two consecutive fruiting seasons (May, 2023–February, 2024 and May, 2024–February, 2025) collected from different locations of the Darjeeling Himalayan region, West Bengal, India, using six underutilized fruit species, namely *Elaeagnus latifolia*, *Rubus ellipticus*, *Ficus roxburghii*, *Spondias axillaris*, *Eriolobus indica* and *Morus serrata*. Fruits were collected from different locations of the Darjeeling Himalayan region, West Bengal, India, which falled under the Eastern Himalayan agro-climatic zone. Healthy fruits were harvested at physiological maturity based on uniform colour, size, and freedom from physical damage and disease. Under-utilized fruit crops of Darjeeling hills were taken as treatments of the present experiment

2.2. Bio-chemical composition and nutritional factors

2.2.1. Total soluble solids (°Brix)

TSS of fruits was recorded with a hand refractometer corrected at 20°C °Brix with the help of a temperature correction correlation chart (Ranganna, 1979)

2.2.2. Sugar- (total and reducing)

Total and reducing sugars was estimated following the methods suggested by (Ranganna, 1979) and was expressed in percent.

2.2.2. Acidity

Total Titrable acidity was determined by titration of a known weight of sample with NaOH using phenolphthalein as an indicator and expressed in per cent (Ranganna, 1979)

2.2.3. Ascorbic acid (mg 100 g^{-1})

The ascorbic acid was determined by reduction of 2, 6-dichlorophenol indophenols dye by ascorbic acid as procedure (Anonymous, 1980).

2.2.4. Anthocyanin (mg 100 g^{-1})

Anthocyanin content was determined by the method described by (Ranganna, 1986).

2.2.5. Carbohydrate

The percentage of available carbohydrate was calculated by: 100- (Percentage of ash+percentage of fat+percentage of fibre+percentage of protein+moisture percentage) (Anonymous, 1990).

2.2.6. Fat

Crude fat content was determined by Soxhlet principle with slight modification (Anonymous, 1990)

2.2.7. Protein

Protein amount was estimated by using Folin-Lowry's method (Lowry et al., 1951)

2.2.8. Crude fiber

Crude fibre content was expressed as percentage loss in weight on ignition (Anonymous, 1990)

2.2.9. Ash content

Ash content was determined by following the method of (Anonymous, 1990)

Moisture content -was determined by following the method given by Anonymous (1990)

Moisture %=(Weight of fresh sample-weight of dry sample)/weight of fresh sample)×100

2.3. Anti-nutritional factors

2.3.1. Saponin

Two grams of the sample was added to about 5 ml of distilled water in a test tube and the mixture shaken vigorously and then placed in a water bath for some minutes. Formation of foamy like liquid at the top of the mixture confirmed the presence of Saponin (Anonymous, 2000).

2.3.2. Alkaloids

In this test, Maeyers' reagent (a solution of 1.3 g $HgCl_2$ and 5 g KI in 100 ml of distilled water) was added to about 2 ml of concentrated HCl and 1ml of the blended sample drop wise. Formation of a creamy-like precipitate confirmed the presence of alkaloids (Anonymous, 2000).

2.3.3. Quinone

One milliliter (1 ml) of concentrated H_2SO_4 was mixed with about 2 ml of the sample solution. Appearance of red coloured product indicates the presence of quinones (Anonymous, 2000).

2.3.4. Cardiac glycosides

About 4 ml of the sample solution was added to 2 ml glacial acetic acid in a test tube and a few drops concentrated H_2SO_4 will be let down the mixture in a test tube. Formation of ring at the interface confirmed the presence of a deoxy sugar characteristic of cardiac glycosides (Anonymous, 2000).

2.3.5. Tannins

About 1 g of the sample was boiled with 20 ml distilled water in a test tube and then filtered. Some drops of 0.1% ferric chloride would be added and monitored for appearance of blue-black coloration which showed the presence of tannins (Anonymous, 2000).

2.3.6. Phenol

In this test, 2 ml of distilled water was added to 1 g of sample and then some drops of 10% ferric chloride added. Formation of blue or green colour confirmed the presence of phenols (Anonymous, 2000)

3. RESULTS AND DISCUSSION

3.1. Bio-chemical composition and nutritional factors

The physico-chemical attributes of the studied underutilized fruits differed significantly among species (Table 1, 2 and 3), reflecting inherent genetic variability and differences in fruit maturation behaviour under Himalayan conditions.

Total soluble solids (TSS) varied widely, ranging from 6.28±0.22°Brix in *Ficus roxburghii* to 18.37±0.09°Brix in *Morus serrata*, followed by *Rubus ellipticus* (16.23±0.25°Brix). Elevated TSS in *Morus serrata* indicates enhanced accumulation of soluble carbohydrates during ripening, a characteristic associated with improved sweetness and consumer acceptability. Similar trends in mulberry and other berry fruits have been reported earlier, suggesting that carbohydrate translocation and metabolic efficiency play a major role in determining TSS levels (Ercisli and Orhan, 2007). Total sugar content followed a pattern comparable to TSS, with the highest value recorded in *Morus serrata* (14.08±0.57%) and the lowest in *Ficus roxburghii* (3.59±0.03%). The close association between TSS and total sugars indicated that sugars constituted a major proportion of soluble solids in these fruits. Such relationships between sugar content and TSS have been widely documented in underutilized fruits and are considered reliable indicators of fruit maturity and sweetness (Ercisli and Orhan, 2007). Reducing sugar content was maximum in *Rubus ellipticus* (7.54±0.25%), reflecting a higher proportion of glucose

Table 1: Bio-chemical composition and nutritional factors of the underutilized fruit

Treatment	TSS (°Brix)			Total sugar (%)		
	2023–24	2024–25	Pooled	2023–24	2024–25	Pooled
Elaeagnus latifolia	11.43±0.27	10.67±0.47	11.05±0.34	7.16±0.71	7.10±0.09	7.13±0.39
Rubus ellipticus	16.20±0.56	16.27±0.24	16.23±0.25	9.94±0.38	10.57±0.31	10.26±0.16
Ficus roxburghii	6.27±0.27	6.30±0.25	6.28±0.22	3.57±0.14	3.61±0.09	3.59±0.03
Spondias axillaris	12.50±0.201	12.57±0.20	12.53±0.13	3.50±0.11	3.79±0.11	3.65±0.06
Eriolobus indica	10.13±0.03	10.53±0.03	10.33±0.02	7.58±0.02	7.57±0.01	7.58±0.00
Morus serrata	18.40±0.10	18.33±0.18	18.37±0.09	13.57±0.84	14.60±0.78	14.08±0.56
SEm±	0.31	0.274	0.22	0.52	0.33	0.29
CD (p<0.05)	0.99	0.875	0.70	1.66	1.05	0.92

Table 1: Continue...

Treatment	Reducing sugar (%)			Titrable acidity (%)		
	2023–24	2024–25	Pooled	2023–24	2024–25	Pooled
Elaeagnus latifolia	1.81±0.06	1.83±0.19	1.82±0.12	1.84±0.17	1.91±0.08	1.88±0.11
Rubus ellipticus	7.46±0.24	7.61±0.27	7.54±0.25	0.55±0.03	0.70±0.06	0.63±0.04
Ficus roxburghii	1.88±0.09	1.92±0.10	1.90±0.09	0.78±0.04	0.82±0.07	0.80±0.04
Spondias axillaris	2.78±0.15	2.73±0.29	2.76±0.13	3.84±0.14	4.01±0.09	3.93±0.01
Eriolobus indica	3.75±0.02	3.74±0.01	3.75±0.01	2.94±0.02	2.91±0.02	2.93±0.02
Morus serrata	7.03±0.45	7.11±0.11	7.07±0.27	0.48±0.02	0.47±0.03	0.48±0.02
SEm±	0.22	0.20	0.18	0.09	0.06	0.06
CD (p<0.05)	0.71	0.63	0.57	0.29	0.19	0.20

Data represents mean±standard error

and fructose, which contributed to immediate sweetness perception. The predominance of reducing sugars in *Rubus ellipticus* enhanced its flavour profile and might also influence its rapid fermentability and suitability for value-added products. Comparable reducing sugar levels have been reported in Himalayan raspberry species, highlighting their nutritional and sensory importance (Pandey and Bhatt, 2016).

Titratable acidity showed marked variation among species, ranging from 0.48±0.02% in *Morus serrata* to 3.93±0.10% in *Spondias axillaris*. High acidity in *Spondias axillaris* was indicative of greater organic acid concentration, particularly citric and malic acids, which imparted a sharp taste. Similar acidity levels have been reported in *Spondias* species from India, supporting their traditional use as souring agents in local diets and processed products (Das et al., 2019).

Table 2: Bio-chemical composition and nutritional factors of the underutilized fruit

Treatment	Carbohydrates (%)			Proteins (%)		
	2023–24	2024–25	Pooled	2023–24	2024–25	Pooled
Elaeagnus latifolia	17.68±2.04	16.67±1.12	17.18±1.42	1.75±0.13	1.49±0.01	1.62±0.08
Rubus ellipticus	18.75±0.68	16.25±0.29	17.50±0.28	4.11±0.13	4.43±0.32	4.27±0.12
Ficus roxburghii	9.71±0.57	11.08±0.69	10.40±0.62	2.99±0.03	3.03±0.02	3.01±0.01
Spondias axillaris	2.06±0.76	1.77±0.61	1.92±0.46	6.67±0.16	6.63±0.11	6.65±0.05
Eriolobus indica	7.68±0.45	7.89±1.10	7.79±0.76	2.63±0.02	2.62±0.01	2.63±0.01
Morus serrata	12.27±0.50	12.82±0.25	12.55±0.34	1.70±0.06	1.80±0.06	1.75±0.03
SEm±	0.82	0.77	0.68	0.11	0.14	0.06
CD (p<0.05)	2.61	2.46	2.16	0.34	0.45	0.19

Table 2: Continue...

Treatment	Fats (%)			Crude fiber (%)		
	2023–24	2024–25	Pooled	2023–24	2024–25	Pooled
Elaeagnus latifolia	0.21±0.02	0.26±0.03	0.24±0.02	2.35±0.23	2.06±0.10	2.21±0.09
Rubus ellipticus	2.68±0.20	2.90±0.27	2.79±0.06	3.44±0.26	3.28±0.14	3.36±0.13
Ficus roxburghii	0.12±0.02	0.13±0.01	0.13±0.01	3.06±0.01	3.07±0.01	3.07±0.01
Spondias axillaris	2.63±0.24	2.48±0.26	2.56±0.23	2.07±0.24	2.10±0.17	2.09±0.05
Eriolobus indica	0.86±0.01	0.87±0.01	0.87±0.01	4.56±0.01	4.59±0.01	4.58±0.00
Morus serrata	2.38±0.35	2.30±0.36	2.34±0.21	2.60±0.06	2.57±0.03	2.58±0.02
SEm±	0.17	0.22	0.13	0.18	0.11	0.07
CD (p<0.05)	0.55	0.71	0.40	0.58	0.34	0.22

Data represents mean±standard error

Table 3: Bio-chemical composition and nutritional factors of the underutilized fruit

Treatment	Ascorbic Acid (mg 100 g^{-1})			Anthocyanins (mg 100 g^{-1})		
	2023–24	2024–25	Pooled	2023–24	2024–25	Pooled
Elaeagnus latifolia	27.43±2.30	25.90±1.35	26.67±1.67	1.32±0.10	1.29±0.05	1.31±0.06
Rubus ellipticus	11.50±0.78	11.46±0.92	11.48±0.80	3.84±0.12	3.66±0.09	3.75±0.09
Ficus roxburghii	3.40±0.09	3.33±0.03	3.37±0.05	1.14±0.02	1.11±0.01	1.13±0.01
Spondias axillaris	35.02±0.26	34.83±0.06	34.93±0.15	3.37±0.03	3.27±0.11	3.32±0.07
Eriolobus indica	9.69±0.02	9.67±0.04	9.68±0.02	1.32±0.02	1.33±0.01	1.33±0.01
Morus serrata	29.70±1.46	30.73±1.24	30.22±0.99	130.73±0.90	133.43±0.41	132.08±0.26
SEm±	1.27	0.81	0.90	0.37	0.16	0.12
CD (p<0.05)	4.05	2.58	2.88	1.17	0.51	0.36

Table 3: Continue...

Treatment	Ash content %			Moisture content %		
	2023–24	2024–25	Pooled	2023–24	2024–25	Pooled
Elaeagnus latifolia	1.01±0.145	0.83±0.07	0.92±0.06	76.99±2.46	78.69±0.95	77.85±1.59
Rubus ellipticus	3.01±0.194	2.91±0.17	2.96±0.11	68.00±0.58	70.24±0.56	69.12±0.39
Ficus roxburghii	2.89±0.053	2.96±0.03	2.93±0.04	81.23±0.54	79.73±0.66	80.48±0.60
Spondias axillaris	2.87±0.023	2.91±0.03	2.90±0.02	83.70±0.53	84.10±0.64	83.90±0.25
Eriolobus indica	2.90±0.012	2.93±0.02	2.92±0.01	81.37±0.43	81.10±1.10	81.23±0.75
Morus serrata	2.79±0.380	3.12±0.17	2.95±0.13	78.27±0.55	77.40±0.76	77.83±0.54
SEm±	0.20	0.11	0.07	1.01	0.82	0.74
CD (p<0.05)	0.63	0.34	0.23	3.21	2.60	2.37

Data represents mean±standard error

Carbohydrate content ranged from 1.92±0.46% in *Spondias axillaris* to 17.50±0.28 % in *Rubus ellipticus*. The high carbohydrate content of *Rubus ellipticus* suggests its superior energy value, which is particularly important for hill populations relying on wild fruits as supplementary energy sources. Comparable carbohydrate levels in wild edible fruits, including *Rubus* species, have been reported from North-East India, where such fruits are recognized as important calorie sources (Seal, 2011).

In contrast, the lower carbohydrate content in *Spondias axillaris* might be attributed to its high moisture and acidity, which dilute carbohydrate concentration. Protein content varied significantly among species, with the lowest value recorded in *Elaeagnus latifolia* (1.62±0.08%) and the highest in *Spondias axillaris* (6.65±0.05%). The relatively high protein content in *Spondias axillaris* is noteworthy, as fruits are generally considered poor protein sources. Similar protein levels in *Spondias* fruits have been documented in underutilized fruits from India, where they are regarded as nutritionally important wild edibles (Das et al., 2019). Elevated protein content in underutilized fruits has also been associated with active nitrogen metabolism during fruit development (Gopalan et al., 2007).

Crude fat content was comparatively higher in *Rubus ellipticus* (2.79±0.06%) and *Morus serrata* (2.34±0.21%), while *Ficus roxburghii* recorded minimal fat content (0.13±0.01%). Although fruits were generally low in fat, moderate fat levels enhanced calorific density and aid in the absorption of fat-soluble vitamins, as noted in Himalayan fruit species (Wills et al., 2007,

Crude fiber content ranged from 1.15±0.02% in *Ficus roxburghii* to 4.58±0.01% in *Eriolobus indica*. High fiber content in *Eriolobus indica* indicates its potential role in improving digestive health and regulating blood glucose levels. Similar observations have been reported in apple and related species, where high dietary fiber contributes to functional food value (Boyer and Liu, 2004). Ascorbic acid content ranged from 3.37±0.05 mg 100 g^{-1} in *Ficus roxburghii* to 34.93±0.15 mg 100 g^{-1} in *Spondias axillaris*, followed by *Morus serrata* (30.22±0.99 mg 100 g^{-1}).

The high vitamin C content in *Spondias axillaris* corroborated earlier findings from Indian Himalayan regions, where *Spondias* species have been identified as excellent natural sources of ascorbic acid (Das et al., 2019. High ascorbic acid content enhanced antioxidant capacity and supported immune function, increasing the nutritional relevance of these fruits.

Anthocyanin content showed wide variation among species, with *Morus serrata* recording exceptionally high levels (132.08±0.26 mg (100 g)$^{-1}$).The intense pigmentation of *Morus serrata* fruits corresponds with high anthocyanin concentration, which was associated with strong antioxidant activity. Similar high anthocyanin levels in Himalayan mulberry species have been reported earlier, emphasizing their nutraceutical importance, (Pandey and Bhatt, 2016, Ignat et al., 2011). Ash content, an indicator of total mineral composition, ranged from 0.92±0.06 % in *Elaeagnus latifolia* to 2.96±0.11 % in *Rubus ellipticus*. Ash content, an indicator of total mineral composition, ranged from 0.92 ± 0.06 % in *Elaeagnus latifolia* to 2.96 ± 0.11 % in *Rubus ellipticus*, reflecting considerable variation in mineral accumulation among wild fruit species (Seal, 2011). Moisture content was highest in *Spondias axillaris* (83.90±0.25 %) and *Ficus roxburghii* (80.48±0.60%), contributing to fruit juiciness but potentially reducing shelf life, as reported for other high-moisture Himalayan fruits (Kader, 2002,).

3.2. Anti-nutritional factors

Qualitative screening revealed the presence of tannins and phenols in all six fruit species, whereas saponins, alkaloids, quinones, and cardiac glycosides showed limited and species-specific occurrence (Table 4). *Elaeagnus latifolia* exhibited the presence of multiple anti-nutritional factors, while other species showed fewer or negligible anti-nutrients.

The presence of tannins and phenols, although traditionally considered anti-nutritional, is now widely recognized for their antioxidant and health-protective properties when consumed in moderate amounts. Similar findings have been reported in underutilized fruits of India, where phenolic compounds contribute significantly to antioxidant potential (Duthie et al., 2000).

Table 4: Anti nutr itional factors of the underutilized fruits

Treatments	Saponins	Tannins	Alkaloids	Quinones	Cardiac Glycoside	Phenols
Elaeagnus latifolia	+	+	+	+	-	+
Rubus ellipticus	-	+	+	+	-	+
Ficus roxburghii	-	+	-	+	-	+
Spondias axillaris	-	+	-	-	-	+
Eriolobus indica	-	+	-	-	-	+
Morus serrata	-	+	-	-	-	+

+: Detectable presence; -: Non-detectable level of the respective anti-nutritional factor

4. CONCLUSION

Selected underutilized fruits of the Darjeeling Himalayan region possessed significant physio-chemical and nutritional diversity with functional food potential. *Morus serrata* and *Rubus ellipticus* showed higher sweetness and energy value, while *Spondias axillaris* was rich in acidity and ascorbic acid. *Eriolobus indica* exhibited high dietary fiber content. The limited presence of anti-nutritional factors indicated minimal health risk, supporting their promotion for crop diversification, nutritional security and sustainable utilization

5. FURTHER RESEARCH

Future research should focus on detailed profiling of bioactive compounds, antioxidant activity and mineral composition of these underutilized fruits using advanced analytical techniques. Studies on postharvest behavior, processing suitability and shelf-life enhancement are needed to support value addition. Domestication, varietal improvement and consumer acceptability studies will further facilitate their commercial utilization and conservation.

6. ACKNOWLEDGEMENT

The authority of Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal, India, supported the study by providing necessary laboratory facilities and infrastructural support to carry out the research work. Appreciation is extended to all individuals who directly or indirectly assisted during sample collection and laboratory analysis.

7. REFERENCES

Anonymous, 1980. Official Methods of Analysis (13th Edn.). Association of Official Analytical Chemists, Washington, DC, USA, 1–1018. Available from: https://archive.org/details/gov.law.aoac.methods.1980. Accessed on: 08 April 2026.

Anonymous, 1990. Official methods of analysis (15th Edn.). Association of Official Analytical Chemists, Washington, DC, USA, 1–1298. Available from: https://law.resource.org/pub/us/cfr/ibr/002/aoac.methods.1.1990.pdf. . Accessed on: 08 April 2026.

Anonymous, 2002. The state of food insecurity in the World. Food and Agriculture Organization of the United Nations, Rome, Italy, 1–204. Available from: https://www.fao.org/4/y7352e/y7352e00.htm . Accessed on: 08 April 2026.

Arora, R.K., 2014. Diversity in underutilized plant species – an Asia-pacific perspective. Bioversity International, New Delhi, India, 23–68p. Available from: https://cgspace.cgiar.org/items/87dfdb90-7cd0-46f9-81cf-19fb63d5d387.

Boyer, J., Liu, R.H., 2004. Apple phytochemicals and their health benefits. Nutrition Journal 3, 5. DOI: https://doi.org/10.1186/1475-2891-3-5.

Bhutia, K.D., Suresh, C.P., Pala, N.A., Shukla, G., Chakravarty, S., 2018. Nutraceutical potential of some wild edible fruits of Sikkim, Himalaya, India. Ethno-Medicine 12(2), 106–112. DOI: https://doi.org/10.31901/24566772.2018/12.02.543.

Das, K., Roy, D., Nandi, P., Kundu, S., Dutta, P., 2019. *Spondias*–an underutilized potential fruit crop of West Bengal. Acta Horticulturae 1241, 51–56. DOI: https://doi.org/10.17660/ActaHortic.2019.1241.8.

De, L.C., 2017. Underutilized horticultural crops. New India Publishing Agency, New Delhi, India, 1–312. Available from: impactjournals.us/archives?jname=14_2&year=2017&submit=Search&page=2.

Duthie, M.E., 2000. Plant polyphenols in cancer and heart disease: implications as nutritional antioxidants. Nutrition Research Reviews 13(1), 79–106. DOI: https://doi.org/10.1079/095442200108729016.

Ercisli, S., Orhan, E., 2007. Chemical composition of white (*Morus alba*), red (*Morus rubra*) and black (*Morus nigra*) mulberry fruits. Food Chemistry 103(4), 1380–1384. DOI: https://doi.org/10.1016/j.foodchem.2006.10.054.

Emmanuel, E., Deborah, S., 2018. Phytochemical and anti-nutritional studies on some commonly consumed fruits in Lokoja, Nigeria. General Medicine Open 2(3), 1–5. DOI: https://doi.org/10.15761/GMO.1000135.

Gebauer, J., Adam, Y.O., Sanchez, A.C., Darr, D., Eltahir, M.E.S., Fadl, K.E.M., Fernsebner, G., Frei, M., Habte, T.Y., Hammer, K., Hunsche, M., Johnson, H., Kordofani, M., Krawinkel, M., Kugler, F., Luedeling, E., Mahmoud, T.E., Maina, A., Mithofer, D., Munthali, C.R.Y., Noga, G., North, R., Owino, W.O., Prinz, K., Rimberia, F.K., Saied, A., Schüring, M., Sennhenn, A., Spath, M.A., Taha, M.E.N., Triebel, A., Wichern, F., Wiehle, M., Wrage-Mönnig, N., Kehlenbeck, K., 2016. Africa's wooden elephant: the baobab tree (*Adansonia digitata* L.) in Sudan and Kenya: a review. Genetic Resources and Crop Evolution 63, 377–399. DOI: https://doi.org/10.1007/s10722-015-0360-1.

Gopalan, C., Ramasastri, B.V., Balasubramanian, S.C., 2007. Nutritive value of indian foods. national institute of nutrition (ICMR), Hyderabad, India, 47–59, 89–92, 204–208. Available from: https://catalog.nlm.nih.gov/discovery/fulldisplay/alma997290703406676/01NLM_INST:01NLM_INST.

Ignat, I., Volf, I., Popa, V.I., 2011. A critical review of methods for characterisation of polyphenolic compounds in fruits and vegetables. Food Chemistry 126(4), 1821–1835. DOI: https://doi.org/10.1016/j.foodchem.2010.12.026.

Jaenicke, H., Hoschle-Zeledon, I., 2006. Strategic framework for underutilized plant species research and development. International Centre for Underutilized Crops (ICUC), Colombo, Sri Lanka, 11–37. Available from: https://cgspace.cgiar.org/server/api/core/bitstreams/135c4493-8b0b-4ac3-ac14-0e3477236a21/content.

Kabra, A., Martins, N., Sharma, R., Kabra, R., Baghel, U.S., 2019. *Myrica esculenta* Buch.-Ham. ex D.

Don: A natural source for health promotion and disease prevention. Plants 8(6), 149. DOI: 10.3390/plants8060149.

Kader, A.A., 2002. Postharvest technology of horticultural crops (3rd Edn.). University of California, Agriculture and Natural Resources, Oakland, USA. 3311, 535 p. Available from: https://www.scirp.org/reference/referencespapers?referenceid=3231828.

Lowry, O.H., Rosebrough, N.J., Farr, A.L., Randall, R.J., 1951. Protein measurement with the Folin phenol reagent. Journal of Biological Chemistry 193(1), 265–275. DOI: 10.1016/S0021-9258(19)52451-6.

Maniyan, A., John, R., Mathew, A., 2015. Evaluation of fruit pee ls for some selected nutritional and anti-nutritional Factors. Emergent Life Sciences Research 1(2), 13–19. Available from: https://emergentresearch.org/uploads/38/1780_pdf.pdf.

Myers, N., Mittermeier, R.A., 2000. Biodiversity hotspots for conservation priorities. Nature 403, 853–854. DOI: https://doi.org/10.1038/35002501.

Padulosi, S., Thompson, J., Rudebjer, P., 2013. Fighting poverty, hunger and malnutrition with neglected and underutilized species. Bioversity International, Rome, Italy, 7–29; 61–89. Available from: https://www.researchgate.net/publication/280934580_Fighting_poverty_hunger_and_malnutrition_with_neglected_and_underutilized_species_NUS_needs_challenges_and_the_way_forward.

Pandey, A., Bhatt, S.S., 2016. Overview of Himalayan yellow raspberry (*Rubus ellipticus* Smith): A nutraceutical plant. Journal of Applied and Natural Science 8(1), 494–499. DOI: https://doi.org/10.31018/jans.v8i1.824.

Pandey, Y., Upadhyay, S., Bhatt, S.S., Muddarsu, V.R., Debbarma, N., 2018. Screening of nutritional composition and phytochemical content of underutilized fruits *Spondias axillaris* and *Eriolobus indica* of Sikkim Himalayas. The Pharma Innovation Journal 7(6) 452–456. Available from: https://www.researchgate.net/publication/330497932_Screening_of_nutritional_composition_and_phytochemical_content_of_underutilized_fruits %27spondias_axillaris_and_eriolobus_indica%27_of_sikkim_himalayas.

Ranganna, S., 1979. Manual of analysis of fruit and vegetable products. Tata McGraw-Hill Publishing Company Ltd., New Delhi, India. Available from: http://scirp.org/reference/referencespapers?referenceid=1751957.

Ranganna, S., 1986. Handbook of analysis and quality control for fruit and vegetable products (2nd Edn.). Tata McGraw-Hill Publishing Company Limited, New Delhi, India. Available from: https://dokumen.pub/handbook-of-analysis-and-quality-control-for-fruit-and-vegetable-products-2nbsped-9780074518519-0074518518.html.

Suresh, C.P., Bhutia, K.D., Shukla, G., Pradhan, K., Chakravati, S., 2014. Wild edible tree fruits of Sikkim Himalayas. Journal of Tree Sciences 33, 43–48. Available from: https://www.researchgate.net/publication/264790376_wild_edible_tree_fruits_of_sikkim_himalayas.

Seal, T., 2011. Nutritional composition of wild edible fruits in Meghalaya. Journal of Food Science and Technology 48(5), 605–609. DOI: https://doi.org/10.3923/rjb.2011.58.67.

Uprety, Y., Asselin, H., 2023. Biocultural importance of the chiuri tree [*Diploknema butyracea* (Roxb.) H.J. Lam] for the chepang communities of Central Nepal. Forests 14(3), 479. DOI: https://doi.org/10.3390/f14030479.

Wills, R.B.H., McGlasson, W.B., Graham, D., Joyce, D.C., 2007. Postharvest: an introduction to the physiology and handling of fruit, Vegetables and Ornamentals (2nd Edn.). CAB International, Wallingford, UK. Available from: https://www.scirp.org/reference/referencespapers?referenceid=1761721.

Yonzone, R., Rai, S., Bhujel, R.B., 2012. Agro-climatic diversity and horticultural potential of Darjeeling Himalayas. Journal of Hill Agriculture 3(2), 1–9. Available from: https://apjtb.com/zz/2012s1.htm.