Egypt. J. Chem. Vol. 67, SI: M. R. Mahran, pp. **1957 - 1965** (2024)

Egyptian Journal of Chemistry

http://ejchem.journals.ekb.eg/

Dillenia indica L. Fruits Cultivated in Egypt: Nutritional Features

Hanaa Salah Ebrahim[a], Seham Salah Eldin El-Hawary[b], Gihan Fouad Ahmed[a], Essam Mostafa Abd El-Kadder[c], and Marwa Yousry. Issa[b] *

[a]*National Nutrition Institute, General Organization For Teaching Hospitals and Institutes, Cairo, Egypt*

[b]*Pharmacognosy Department, Faculty of Pharmacy, Cairo University, Cairo, Egypt*

[c]*Timber Trees Department, Horticulture Research Institute, Agriculture Research center, Giza, Egypt*

Abstract

South Asia is the home to many tropical trees, most famously the elephant apple (*Dillenia indica* L.). Mostly found in Assam, in the northeast of India and not grown for commercial purposes, elephant apples are used in many different culinary recipes in their native country. The current study aims to characterize the nutritional and biochemical properties of the fruit constituents. The ethanol extract physicochemical properties and phytochemical screening study were presented. The fruit is proved to have considerable concentrations of flavonoids and phenolics. The fruit fatty matter analysis exposed that carbohydrates were more than 50%. Additionally, lupeol and betulin were the main terpenoids. Arachidic acid was the dominant fatty acid. Advanced nutritive value detection demonstrated the presence of minerals and vitamins, while potassium (11667 mg/kg) and vitamin A (1.30 μg/g) were the leading. Furthermore, apigenin (661.6 μg/g) and ellagic acid (1064.71μg/g) were the highest flavonoids and phenolics. The study revealed glycine (3780.77 μg/g) as the prominent amino acid for the first time, in addition to eight essential amino acids. The fruits offer special nutritional significance. Beyond its dietary value, *D. indica* fruit has been associated with other health benefits.

Key words: *Dillenia indica* fruit, lipid profile, amino acids, minerals, vitamins.

1. Introduction

In North East India, the elephant apple (*Dillenia indica* Linnaeus) is a widely available and essential medicinal plant growing in Assam. However, most of its fruits are wasted since it is mismanaged and misused. Mature fruits are utilized to make jam and pickles, whereas, immature fruits are often used to make seasoning and sauces due to their acidic flavor. It is called "Bettakanigalu" in Tamil, Kattaral, Punna, Vazchpunna in Malayalam, Chalta, Karambel in Hindi, Avartaki, Bhavya, and Bharija in Sanskrit, and Revadi in Telugu. It belongs to the Dilleniaceae family and bears the Latin scientific name *D. indica* L., which honors German botanist Johann Jacob Dillenius [1]. According to estimates from the World Health Organization (WHO), 80 % of individuals in affluent nations receive their primary care mostly from natural products [2]. The tree of *D. indica* L. is 10–20 m tall, small–medium sized, evergreen with a bole that is somewhat bent and either no or little buttress. An inflorescence is a single, terminal flower. The fruit is indehiscent, globose to spherical, green when immature, and turns yellow-orange when fully ripe. Five thick sepals shield it. When the fruit is young, the ovate, yellow seed has a white aril and is wrapped in a sticky, transparent fluid within the carpel [3]. The tree different parts are esteemed for their therapeutic properties. Elephants consume the fruit, which is widely recognized for its edible, apple-shaped, yellow-green tint. Fruits can be eaten either cooked or raw; while the thick sepals are used to prepare curries and drinks due to their sour taste. *Dillenia* purified components and extracts have been shown to have therapeutic efficacy and are useful in folk medicine [4, 5]. The properties of its extracts include antibacterial, antioxidant [6, 7], analgesic, and antidiabetic [8, 9] effects. Furthermore, the process of wound healing is brought about by its anti-inflammatory qualities [10]. When blended with sugar, fruit pulp, which is juicy and jelly-like, can be used as a digestive aid, laxative, tonic, and in treatment of coughs and chest problems [11]. It was also utilized as a cooling agent to alleviate the body and treat fever [12]. Furthermore, the hepato-protective potential of *D. indica* L. seeds was demonstrated [13]. It is a common anxiousness remedy in Ayurvedic medicine. Burn wounds are treated with its mucilage [14]. GC-MS analyses have contributed in the identification and characterization of phytochemicals contained in different plant extracts [15, 16]. The quantitative concentrations of phenolic compounds were detected using the HPLC analysis method [17]. Numerous active ingredients were reported by *D. indica* L., including flavonoids, vitamins [18], phytosterols [7, 19], and minerals [20]. Furthermore, glutamic acid in the leaf extract was identified by Biswas and Pandita [21]. Sufficient consumption of whole fruits throughout life, with a focus on fruit fiber may have positive incomes [22] such as; protecting the gastrointestinal tract [23]; encouraging long-term weight management; lowering the risk of metabolic syndrome and type 2 diabetes [24],

*Corresponding author e-mail: marwa.issa@pharma.cu.edu.eg (Marwa Yousry Issa)

Receive Date: 26 August 2024, Revise Date: 19 October 2024, Accept Date: 26 October 2024

DOI: 10.21608/ejchem.2024.315326.10264

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management of cardiovascular disease, and lung cancer [25, 26]. Determining the nutritional value of *D.indica* L. fruits was our study goal. In keeping with this, it would appear vital to include details regarding the existence and concentrations of bioactive substances in addition to the typical nutrient assessment. In addition to GCMS analysis for the fruit fatty matter, the physicochemical parameters, phytochemical analysis, total phenolic/flavonoid contents, vitamins, minerals, and amino acids were assessed by HPLC in the fruit crude extract.

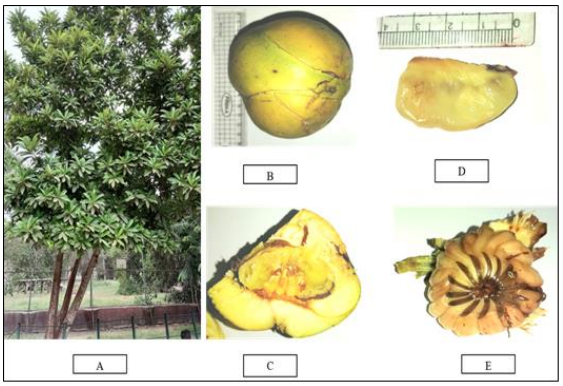

Figure 1: A, *D.indica* L. tree (X=0.042); B, Fruit of *D.indica* L. (X=0.4); C, T.S of *D.indica* L. (X=2); D, T.S Seed of *D.indica* L. fruit (X=0.8); E, Seeds group (X=0.8)

2. Materials and Methods

2.1. Plant material: Fruits of *D. indica* L. were gathered from the Zoo; Therese Labib, an agriculture engineer and former director of the Orman Botanical Garden, graciously identified the plant identity. Voucher specimen was kept at the herbarium of Faculty of Pharmacy, Cairo University (28.7.23).

2.2.* Phytochemical study*: The fruits of *D. indica* L. (3 kilograms) were cleaned with distilled water, cut into small pieces, and then dried at 60 ℃ for a day. Afterwards, they were coarsely ground by an herbal grinder. According to Shaikh and Patil [27], the powder was tested individually for alkaloids and/or nitrogenous bases, flavonoids, saponins, tannins, sterols/triterpenes, phenolics, and carbohydrates.

2.3. Proximate analysis: The determination of the fruits physicochemical properties was adopted according to WHO recommendations [28, 29].

***2.4.* Total flavonoid and phenolic content:** the dried methanolic extract of 0.5 g was weighed and dissolved in 50 mL of 80% methanol. Using the method of Blainski [30] with modifications to the Folin-Ciocalteu method, the total phenolic content was identified. The samples were read at 730 nm using a spectrophotometer (Shimadzu PC-1650, Kyoto, Japan). The total phenolic content was expressed as milligrams of gallic acid equivalent (GAE).

Using quercetin as a reference, the total flavonoid concentration of the fruit extract was ascertained through the application of the aluminum chloride colorimetric method [31]. The total flavonoid content was conveyed as milligrams of quercetin equivalents (QE).

2.5. GC-MS analysis

Preparation of non-saponifiable substance in accordance with modified British Pharmacopeia [32]. Along with Rozema and Mitchell [33], fatty acids methyl ester (FAME) analysis of fruit hexane extract was carried out via GC-MS analysis at the National Research Center, Department of Medicinal and Aromatic Plants. A TRACE GC Ultra Gas Chromatograph (Thermo Fisher Scientific, Third Avenue Waltham, MA USA), coupled with a thermo mass spectrometer detector (ISQ Single Quadrupole Mass Spectrometer), with a TG-5MS column (30 m x 0.25 mm i.d., 0.25 μm film thickness) was used. Helium was used as a carrier gas at a flow rate of 1.0 mL/min and a split ratio of 1:10 using the following temperature program: for the unsaponifiable matter, 55 ℃ for 1 min; rising at 5 ℃ /min to 300 ℃ and held for 15 min. The injector and detector were held at 280 ℃ .For FAME was performed at 80 ℃ for 1 min; rising at 4 ℃ /min to 300 ℃ and held for 5 min. The injector and detector were held at 240 ℃. Diluted samples (1:10 *n*- hexane, v/v) of 0.2 μL of the mixtures were always injected. Mass spectra were obtained by electron ionization (EI) at 70 eV, using a spectral range of m/z 35-550. Most of the compounds were identified comparing the mass spectra with authentic chemicals, Wiley, and NIST spectral library collections.

2.6. Vitamins analysis

Finely chopped fresh fruits were weighed out and extracted using 10 milliliters of 80% methanol for a duration of one hour at room temperature. The resulting extracts were filtered. Water soluble (vitamin C) was extracted using an altered version of the method previously reported [34]. Agilent 1260 series was used to perform HPLC analysis. The separation was carried out using Eclipse C8 column (4.6 mm x 150 mm i.d., 5 μm). The mobile phase consisted of 0.01%TFA: MeoH (70:30) at a flow rate of 1 mL/min. Isocratic mobile phase was programmed. The multiple wavelength detector (MWD) detector was adjusted at 248 nm. The injection volume was 10 μL for each of the samples. The column temperature was maintained at 40 ℃.

While fat-soluble vitamins were extracted and analyzed using, the an Agilent HPLC equipped with C18 column (4.6 mm x 250 mm i.d., 5 μm) [35]. The mobile phase was methanol: acetonitrile 65:35 and the flow rate was 1 mL/min. The injection volume was 20 μL. The DAD was adjusted at 295, 254 nm. The fluorescence detector was adjusted at 290/330 nm (Excitation/Emission) at 40 ℃.

2.7. Total heavy metals determination

D. indica L. fruits were cut into pieces and dehydrated for 24 hours at 60 ℃ to obtain the powder. The sample was then digested as follows: In a muffle furnace, 5.0 g of powder were dry-ashed for 16 hours at a temperature as high as 450 ℃. 2.5 ml of concentrated HNO_3 was added to the ash after it had cooled and then moistened with distilled water. After the crucible was set on a heated plate, a watch glass was placed over it. For one hour, the digestion was carried out at a temperature between 90 and 95 ℃ to produce white ash. After allowing the sample to cool, the ash was dissolved in 5 milliliters of 9.25% HCl and the mixture was once again digested on a hot plate until the white fumes subsided and the sample reached 2 milliliters. After letting the digest cool, 20 milliliters of

distilled water were added, and a Whatman filter No. 41 was used to filter the mixture. The filtered material was then placed in a polyethylene container to await analysis after being diluted to the 50 mL standard volumetric flask mark [36]. Agilent 5100 Inductively Coupled Plasma – Optical Emission Spectrometer (ICP-OES) with Synchronous Vertical Dual View (SVDV), Victoria, Australia was used for determination of heavy metals. A blank and three or more standards were used to generate the calibration curve for each series of measurement intensities [37]. Verification was done with NIST (National Institute of Standards and Technology) and Merck external reference standards for accuracy and precision.

***2.8.* HPLC settings for flavonoid and phenolic content determination**

The fruit extract (25 mg/10 mL) and authentic samples (1 mg each in 5 mL) were prepared in MeOH, membrane filtered and used for HPLC. The process of separation was completed utilizing Eclipse C18 column (4.6 mm x 250 mm i.d., 5 μm). The components of mobile phase were water (A) and 0.05 % trifluoroacetic acid in acetonitrile (B) at a flow rate of 0.9 mL/min. The following was the sequential linear gradient programming for the mobile phase: 0 min (82% A); 0–5 min (80% A); 5-8 min (60% A); 8-12 min (60% A); 12-15 min (82% A); and 15-20 (82%A). The multi-wavelength detector was monitored at 280 nm. The injection volume was 5 μL at 40 °C [38].

2.9. Amino acid detection

136 mg of *D. indica* L. dry fruit extract was mixed with 5 mL H_2O and 5 mL of HCl (Note: final conc. of HCl is 6 M) then cooked for 24 hours at 100 °C, and after that filtered. Finally, 1 mL of the filtrate was dried and suspended in 0.1 M HCl and injected in HPLC [39]. HPLC examination was completed by an Agilent 1260 series using SUPELCO Discovery® BIO Wide C18 column (4.6 mm x 250 mm i.d., 5 μm). The mobile phase contained buffer (sodium phosphate dibasic and sodium borate), pH 8.2 (A), and ACN: MeOH: H_2O 45:45:10 (B) at a flow rate of 1.5 mL/min. The mobile phase was programmed consecutively in a linear gradient at 98 % A-2 % B (0 min), at 33.4 min it reached (43 % A – 75.5 % B), at 39.3 min it reached 100%B, then it returned to 98 % A- 2 % B at 40.0 min. The DAD was observed at 338nm (Bandwidth 10 nm). The fluorescence detector was accustomed as follows: from 0 to 28 min at 340/450 nm (Excitation/Emission) and from 28 to 40 min at 266/305, at 40 °C.

3. Results and Discussion

3.1. Proximate analysis of the *D. indica* L. fruit powder analysis comprises determining the percentage of ash, protein, lipids, fiber, and moisture, table (1). Pre-analysis results showed that the extract encloses 9.01 % moisture. Ash and crude fiber contents were 3.17 and 12.83, respectively. Protein and lipid contents were 7.40 % and 0.97 %, respectively. The nutritive value is 59 k calories for each 100 g. According to these findings, the fruit has the highest concentration of vital nutrients. High fiber and low-fat content, both of which are essential to human health. The dietary fiber health claim has been approved by the Food and Drug Administration and statements that eating fruits and vegetables high in dietary fiber and consuming less fat (around 30 % of calories) may help avoid certain malignancies [40].

Table 1: Proximate analysis of the* D. indica *L. fruit

Content	Percentage
Moisture content	9.01±0.09
Ash	3.17±0.09
Fat	0.97±0.31
Crude fibers	12.83±0.29
Protein	7.40±0.20
Total calories / 100 g	59 k

3.2. Phytochemical Screening

The phytochemical investigation findings showed that the alcoholic extract of *D. indica* L. fruits included flavonoids and terpenoids at high concentrations, sterols, and tannins but not alkaloids, table (2). Terpenoids, flavonoids, and polyphenols are only a few of the compounds found in medicinal plants of the *Dillenia* species that have specific positive effects on illnesses and medical problems. These substances often work collectively to promote health [9].

Table 2: **Phytochemical screening of the fruits of *D. indica* L.**

Compounds class	Presence
Alkaloids and / or Nitrogenous bases	-
Flavonoids	++
Phenolic	+
Sterols and/or triterpenoids	++
Tannins	+
Saponins	-
Carbohydrates	++

(+) Present; (-) Absent; (++) More prominent.

3.3. Results of total phenolics/ flavonoids

The study outcomes revealed that *D. indica* L. fruits contain high levels of phenolic and flavonoid constituents 407.91 (mg GAE/L) and 331.84 (mg QE/L), respectively. Phenolic compounds significantly improve human health by reducing the risk factors for a variety of physiological and degenerative illnesses [41]. The remarkable activity seen in reactive oxygen species scavenging may be attributed to *D. indica* high phenolic content [42].

3.4. GC-MS analysis

Previous GC-MS analysis reported the identification of lupene and sterols [4, 7]. The GC-MS analysis of *D. indica* L. fruits led to the identification of a number of different compounds in the saponifiable and unsaponifiable matter, aromatic diterpenoid, triterpenoid, and saturated fatty acid groups were tabulated along with their area percentage and retention times, table (3). FAME analysis showed the identification of saturated fatty acids representing 97.18 % demonstrated in figure (2) and table (3). Arachidic acid dominated and was detected at (27.65%). The unsaponifiable matter analysis was illustrated in figure (3) and table (4). Fruit extract of *D. indica* L. showed 22 unsaponifiable compounds representing 99.07 %. The percentage of total identified hydrocarbons was 52.65%. Nonacosane has the highest percentage at 10.24 followed by octacosane at 10.01. Nine terpenoid components were detected at 46.42 % and the most abundant was lupeol at 8.18%, followed by Betulin (3β-28-dihydroxy-lup-20(29)-ene) at 7.71 %.

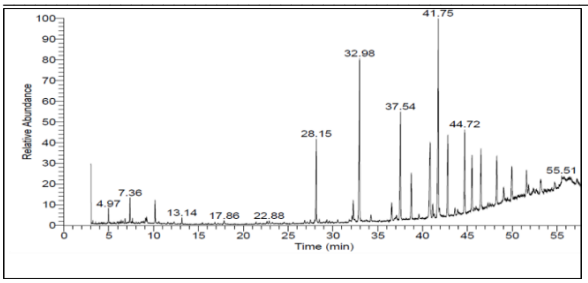

Figure 2: Total ion chromatogram for GC/MS of FAME of *D. indica* L. fruit

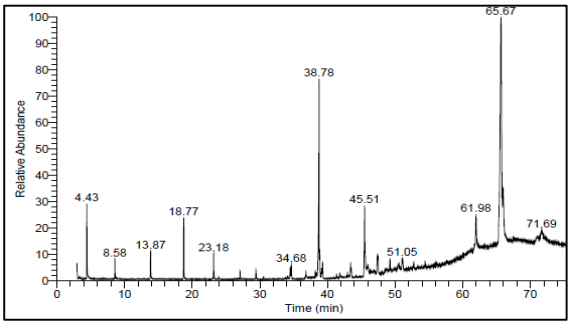

Figure 3: Total ion chromatogram for GC/MS OF un-saponifiable matter of *D. indica* L. fruit

Table 4: Components found in the GC/MS analysis of the FAME of *D. indica* L. fruit

Fatty acids corresponding to Identified FAME	Rt	RRt	Area%
Lauric acid	9.23	0.24	8.62
Methyl stearate	36.56	0.97	16.69
Arachidic acid	37.53	1.00	27.65
Docosanoic acid	41.75	1.11	11.61
Lignoceric acid	45.52	1.21	14.36
Palmitic acid	49.40	1.31	18.25

RRt: relative retention time relative to Arachidic acid.

Table 3: Components identified by the GC/MS analysis of the unsaponifiable matter of D. indica L. fruit

No	Identified Components	Rt	RRT	M.W	Area%
1.	Undecane	4.43	0.11	156.31	2.10
2.	Dodecane	8.58	0.21	170.33	4.21
3.	Tridecane	13.86	0.35	184.36	1.09
4.	Pentadecane, 2,6,10,14-tetramethyl	18.77	0.47	346.6	2.05
5.	1-Nonadecene	23.18	0.59	266.5	1.11
6.	Hexacosane	29.44	0.75	366.7	4.92
7.	Heptacosane	34.51	0.88	380.7	2.48
8.	Octacosane	38.78	0.99	394.8	10.01
9.	*n*-heptacosan-7-one	39.01	0.99	396.7	5.29
10.	Nonacosane	39.14	1.00	408.8	10.24
11.	Triacontane	39.30	1.004	422.8	3.09
12.	Lupeol (3*β*-hydroxy -lup-20(29)-ene)	43.44	1.10	426.7	8.18
13.	Betulin (3*β*-28-dihydroxy-lup-20(29)-ene)	45.98	1.16	442.7	7.71
14.	Stigmasterol (3*β*,22E-Stigmasta-5,22-dien-3-ol)	47.51	1.21	412.6	5.32
15.	*β* - Sitosterol (3*β*-Stigmast-5-en-3-ol)	49.25	1.25	414.7	4.82
16.	Cycloartenone	50.01	1.27	424.7	2.32
17.	Betulinaldehyde (3 *β*-hydroxylup-20(29)-en-28-al)	50.55	1.29	440.7	6.48
18.	3 *α*,23-dihydroxy lup-20(29)-ene	51.05	1.30	486.7	2.30
19.	Betulinic acid (3 *β*- hydroxy- lup-20(29)-en-28-oic acid)	62.97	1.60	456.7	3.81
20.	6*β*-20-dihydroxy lupan-3-one	65.01	1.66	458.7	3.80
21.	*n*-nonatriacontan-18-one	68.02	0.94	563.2	3.21
22.	Tetratetracontane	71.69	1.83	619.2	4.35

RRt: relative retention time relative to nonacosane

3.5. HPLC analysis of vitamin and mineral content

Results of the vitamins and mineral analysis are illustrated in tables (5&6) and figures (4&5). The fruits of *D.indica* L. contain vitamins A, C, and E with concentrations, of ca. 1.24, 0.46, and 1.30 *µ*g/g respectively. Mineral analysis showed that the fruit contains many valuable and useful elements like potassium, sodium, phosphorus, calcium, iron, and zinc at 11667, 267, 1000, 833, 16.3, 2.7, and 2.7 mg/kg, respectively. While manganese is < 0.05 mg/kg. *D. indica* L. is shown to offer a wide range of vital nutrients and possible health advantages, making it almost an ideal food [43].

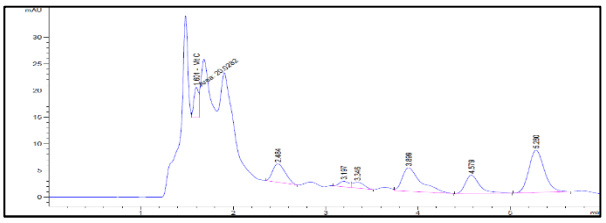

Figure 4: HPLC chromatogram of vitamin C in *D.indica* L. fruits extract

Table 5: **D.indica** ***L. fruit vitamins content***

Compound	Area	ConC. *µ*g/ml	ConC. *µ*g/g
Vit A	77.65	4.323	1.30
Vit C	20.0	0.62	1.24
Vit E	38.91	1.531	0.46

Table 6: ***D. indica*** **L. fruits mineral content**

Mineral	Conc in mg/kg
Potassium	11667
Sodium	267
Phosphorus	1000
Calcium	833
Manganese	< 0.05
Iron	16.3
Zinc	2.7

Conc. unknown = (Area unknown /Area known) Conc. Known.

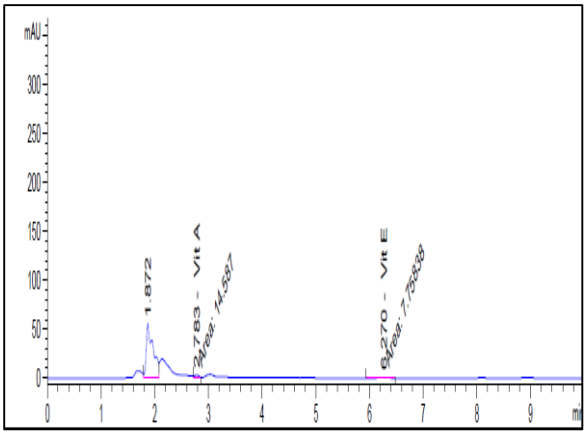

Figure 5: HPLC chromatogram of fat-soluble vitamins in D. indica L. fruits extract

The concentrations of the identified phenolics and flavonoids were illustrated in table (7) expressed as micrograms per gram dry powder. Chromatogram was shown in figure (6). HPLC analysis of phenolic and flavonoid compounds in *D. indica* L. fruits led to the recognition of seven phenolic acids (Gallic, and chlorogenic acids, methyl gallate, caffeic, syringic, ellagic acids, vanillin, and cinnamic acid) and four flavonoids (Daidzein, quercetin, apigenin, hesperetin). Ellagic acid was the major phenolic constituent with concentrations of 1064.71 (*µ*g/g), while the major flavonoid was apigenin with concentrations of 661.68 (*µ*g/g).

3.6. HPLC Determination of phenolics and flavonoids

The goal of this study was to estimate the phenolic and flavonoid contents of *D. indica* L. fruits. Quantification was based on peak area computation (an external standard approach), and identification of individual components was carried out by comparing their retention durations with those of authentic samples that were readily available and similarly tested. The following formula was used to determine the concentrations

Table 7: Concentration of phenolics and flavonoids in fruits of **D.indica** ***L. as identified by HPLC analysis***

Item	Retention time (min)	Conc. (*µ*g/g)
Gallic acid	3.330	961.67
Chlorogenic acid	4.138	455.12
Methyl gallate	5.500	24.97
Caffeic acid	5.929	30.29
Syringic acid	6.465	168.23
Ellagic acid	8.642	1064.71
Cinnamic acid	13.983	4.74
Daidzein	12.212	18.27
Querectin	12.693	311.43
Apigenin	14.438	661.68
Hesperetin	15.514	148.53

3.7. Advanced amino acids analysis

The examination of amino acids configuration by HPLC showed that the *D. indica* fruit extract contains, high concentrations of glycine, proline, glutamic acid, aspartic acid, and phenylalanine, at 3780.77, 2643.46, 746.25, 639.96, and 545.23 *µ*g/g, respectively (Table 8 and figure 7). Additionally, it contains serine, histidine, threonine, arginine, alanine, tyrosine, valine, methionine, phenylalanine, isoleucine, and leucine, and given the growing importance of *D. indica* in nutrition, the research showed that the fruit extract provides appropriate concentrations of essential amino acids.

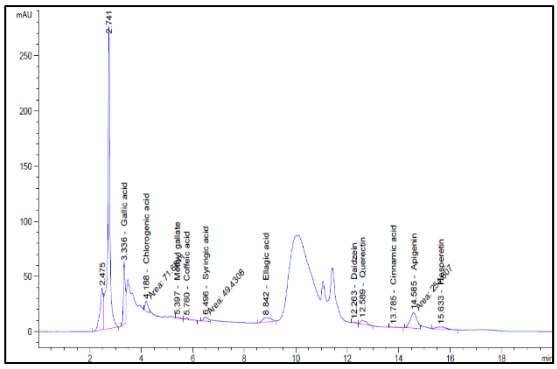

Figure 6: HPLC chromatogram of **D.indica** ***L. fruits extract at λ= 280 nm***

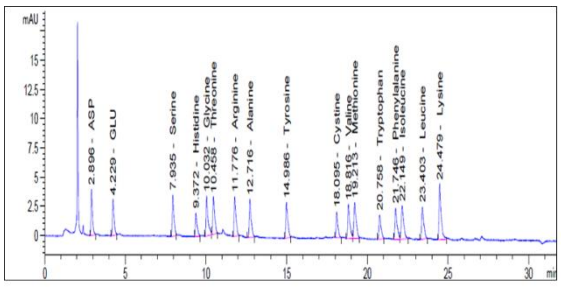

Figure 7: HPLC chromatogram of amino acid analysis of **D. indica** ***L. fruit extract***

Table 8: Amino Acid contents of *D.indica* L. fruit extract

Amino acid	Conc. (*µ*g/g)	Amino acid	Conc. (*µ*g/g)
Glycine	3780.77	Alanine	373.72
Proline	2643.46	Lysine	346.67
Glutamic acid	746.25	Valine	282.44
Aspartic acid	639.96	Isoleucine	217.23
Phenylalanine	545.23	Methionine	203.63
Serine	440.02	Threonine	193.37
Leucine	408.36	Histidine	138.99
Arginine	392.82	Tyrosine	138.01

4. Discussion

Assessment of *Dillenia indica* L. fruit indicates the fruit as a rich source of nutraceuticals and studies concur with a large body of prior research that shows fruits are widely recognized as a significant source of micronutrients like vitamins, minerals, fibers, and antioxidants [44]. GC analysis of hexane extract of *D. indica* fruit resulted in identification of variety of components, which may lead to vital activities as hepatoprotective and antioxidant [13]. The high fiber content of the fruit and the mucilaginous material of the seeds may be the cause of the high carbohydrate contents [45]. The primary fatty acid was arachidic acid, which is essential for cell function in general and for the neurological, skeletal, and immunological systems in particular [46]. Lauric and palmitic acids can control metabolic diseases, which may be brought on by these fatty acids reverse effects on muscle and fat [47]. Fruit hydrocarbons as nonacosane and octacosane have the potential to be antioxidants and antimicrobials [48, 49]. These days, natural polysaccharides are becoming more and more important in the development of various drug delivery systems [50]. The fruit polysaccharides possessed valuable antioxidant activities [51]. The fruit extract contains numerous terpenoid substances, which offer a wide spectrum of valuable pharmacological assets, such as anti-inflammatory, anti-hyperglycemic, anti-dyslipidemic, antioxidant, and anti-mutagenic effects as reported previously [52]. In addition to its anticancer qualities and protective benefits on a variety of organs, lupeol has numerous actions in the treatment of diabetes and asthma [53]. Particularly in the immune cells within the central nervous system, betulinic acid clearly possesses anti-inflammatory qualities [52]. HPLC examinations reported ellagic and gallic acids as major phenolics of *D.indica*. Which have anti-inflammatory and antioxidant properties [54], recent research suggest that it may be beneficial for neurodegenerative complaints [55-58]. Apigenin and quercetin the major flavonoids have antioxidant, diabetic-preventing, neurotropic, and tumor-suppressive properties [59-62]. It is the first time of the HPLC quantification of *D. indica* fruit amino acids, indicating representable concentrations. Glycine enhances several aspects of the metabolic syndrome [63]. Proline has a significant rule in wound healing [64]. Eight essential amino acid (phenylalanine, valine, threonine, tryptophan, methionine, leucine) were demonstrated, which are used to make protein , they act as metabolism factors, and detoxification [65]. Numerous studies have demonstrated that dietary supplementation with amino acids regulates gene expression, promotes growth of the small intestine and skeletal muscle, or lowers excessive body fat [66]. The fruit has sufficient levels of elements essential to human health and cell metabolism [44]. Vitamins C and E are vital nutrients that function as antioxidant and are important as co-factors and regulators of several immune system pathways [67, 68]. Vitamin A is crucial for brain development, regulating gene products, neurogenesis, neuronal survival, and synaptic plasticity [69]. A 100 g serving of fruit meal can frequently supply upto 30 and 20 percent of the daily requirements for potassium, phosphorus, and iron, in addition to 30% of total fibers and approximately 59 kal according to the Recommended Dietary Allowances (RDAs) [70]. The importance of the essential minerals, to health is becoming more widely recognized [71]. Many different physiologic effects are elicited by increased dietary fiber intake, not just locally in the gut but also systemically [72]. Global agricultural systems are recognizing changes in fruit quality production due to climate changes, which have significant effects on human nutrition and farmer livelihoods [73]. The protein and fiber contents were in agreement with those of the fresh fruits gathered from Kushtia, Bangladesh local market (6.81 and 1.38, respectively) [74]. In comparison with the fruits collected from Pathum Thani, Thailand which have lower moisture content and higher percentage of fiber, ash and protein, our sample has an approximate content of fat and phenolic content. Vitamin C content was higher in the fruits collected from Ayeyawady region, and the mineral analysis indicated copper, sulphur and rubidium [75]. Temperature, light, and nutritional status are minimal factors that affect the physiological, biochemical, and molecular processes involved in fruit development and quality [76]. *Dillenia indica* is one of the reported species to have therapeutic activities, the effect of betulin aldhyde, betulin, betulinic acid, lupeol, and sitosterol, were indicated from the Indian *Dillenia* fruits [12]. So *Dillenia indica* L. fruit could be considered as functional food while it can provide health benefits beyond basic nutrition and satiation, playing a key role in preventing emerging diseases linked to poor nutrition and digestive issues [77].

5. Conclusions

6. Fruit from the *D. indica* L. plant contains a range of bioactive micronutrients, including vitamins C, E, and A, which have various antioxidant properties. In addition to minerals, which can meet the demands of human diet. Both energy metabolism and the growth of healthy bones depend on magnesium and calcium. Together with calcium, phosphorus aids in the development and strength of bones. This fruit is low in fat and high in fiber and protein

contents. Glutamic and aspartic acids are among the amino acids that are physiologically essential for regular nervous system processes. The fruits offer distinct functional and nutritional benefits due to their diverse phytochemical composition, which includes terpenoids, fatty acids, carbohydrates, and mucilage. Beyond its nutritional value, a high flavonoid and phenolic contents may result in several health benefits. It is suggested that *Dillenia* may contribute significantly to overall nutritional health. However, further biological studies are needed to explore the effect of nutritive and therapeutic possessions of *Dillenia* fruit micronutrients and phytoconstituents.

7. Conflicts of interest

The writers have reported no conflicts of interest.

8. Acknowledgments

9. The authors did not include any acknowledgements.

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