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Unlocking the lipid potential of underutilized wild leafy vegetables and fruits from Telangana, India

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Abstract

The present study evaluated the fatty acid composition of wild edible leafy vegetables (05) and fruit (03) with special emphasis on saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), total unsaturated fatty acids (TUFA), and the unsaturated to saturated fatty acid ratio (UFA/SFA). The GC-FID analysis revealed considerable variation between leaf and fruit samples with respect to fatty acid distribution and nutritional quality. Total 16 different fatty acids (12 saturated and 4 unsaturated) were present in the analyzed leafy vegetables and wild fruits. In leafy vegetables, SFA content ranged from 16.45% to 40.98%, MUFA from 26.37% to 70.94%, PUFA from 7.51% to 44.48%, and TUFA from 59.2% to 83.56%. Among the leaves, *Corchorus aestuans* L. exhibited the lowest SFA content (16.45%), highest TUFA content (83.56%), and highest UFA/SFA ratio (5.08), indicating a highly desirable fatty acid profile. *Celosia argentea* L. showed exceptionally high MUFA content (70.94%), whereas *C. aestuans* recorded the highest PUFA level (44.48%). In fruit samples, SFA ranged between 20.81% and 36.49%, MUFA between 15.47% and 50.02%, PUFA between 29.18% and 48.04%, and TUFA between 63.51% and 79.2%. Among the fruit samples, *Diospyros chloroxylon* Roxb. showed the highest MUFA content (50.02%) and TUFA content (79.2%), while *Diospyros melanoxylon* Roxb. exhibited the highest PUFA content (48.04%) but comparatively higher SFA content (36.49%). The UFA/SFA ratio varied from 1.44 to 5.08 across all samples, with most samples recording values above 3.0, indicating the predominance of health-promoting unsaturated fatty acids over saturated fatty acids. Overall, underutilized leafy vegetables and fruits demonstrated high levels of unsaturated fatty acids, suggesting their potential as nutritionally valuable sources of beneficial lipids with possible applications in functional foods and nutraceutical development.

Keywords: Underutilized, leafy vegetables, wild edible fruit, GC-FID, fatty acids, food

Introduction

Most plant-derived fatty acids are naturally occur in the cis configuration, which introduces structural bends that improve membrane flexibility, receptor function, insulin sensitivity, and cardiovascular performance [1]. Commercial cum synthesized trans fatty acids, which increase LDL cholesterol, promote insulin resistance, and contribute to vascular inflammation and atherosclerosis [2], cis-unsaturated fatty acids offer substantial protective effects against metabolic disorders. The existence of monounsaturated fatty acids in leaves and fruits such as oleic acid improve lipid metabolism by reducing LDL cholesterol, increasing HDL cholesterol, and enhancing insulin sensitivity, thereby reducing obesity and type-2 diabetes risk [3]. Polyunsaturated fatty acids are vital to human health as they cannot be synthesized endogenously and must be acquired from dietary sources. These fatty acids regulate membrane fluidity, endothelial function, immune responses, and gene expression [4]. Omega-3 fatty acids, particularly alpha-linolenic acid, contribute to brain development, cognitive function, anti-inflammatory processes, and cardiovascular protection through conversion to EPA and DHA [5]. Similarly, omega-6 fatty acids viz. linoleic acid are vital for tissue healing and membrane integrity, though excess dietary ratios relative to omega-3 may increase inflammatory responses [6]. Leafy vegetables and fruits are also valuable components of human nutrition since they offer essential amino acids, vitamins, minerals, dietary fiber, and beneficial fatty acids required for normal physiological functions [7]. These metabolites regulate gene expression, suppress inflammatory cytokines, improve immune responses, maintain blood-brain barrier integrity, and enhance neurological health [8-10].

In Telangana, several nutrient-rich edible plant species remain underutilized due to limited public awareness and a continued reliance on cereal-based diets ^[11]. Globally, approximately one billion people are expected to include wild edible plants into their daily diets, highlighting their substantial role in food and nutritional security ^[12]. Ethnobotanical studies have documented the use of more than 7,000 naturally occurring edible plant species for human consumption ^[13]. As conventional food crops alone are increasingly inadequate to meet the rising global food demand, research efforts have intensified toward the identification, evaluation, and promotion of underutilized and emergency food plants ^[14]. Given the nutritional importance and diverse biological functions of these underutilized edible species, assessing their fatty acid composition is crucial for evaluating their nutritional significance and potential therapeutic benefits. Therefore, the present study examines the fatty acid profiles of selected

underutilized wild edible leafy and fruits vegetables of Telangana, namely *Achyranthes aspera* L., *Celosia argentea* L., *Corchorus aestuans* L., *Leucas aspera* (Willd.) Link, *Senna occidentalis* (L.) Link and *Diospyros melanoxylon* Roxb., *Diospyros chloroxylon* Roxb., *Ziziphus oenoplia* (L.) Mill., to assess their suitability as functional food resources for improving human health and nutritional security.

Materials and Methods

Collection and processing of leave and fruit samples

The selected wild leafy vegetables and fruits were collected from Dulapally Forest of Telangana (Fig.1). The plant samples were identified and authenticated by Taxonomist of the Institute. All leaves and fruits samples were washed with water and dried under oven at 45 °C till constant weight. The dried leaves and fruits were milled into powder and stored for analysis.

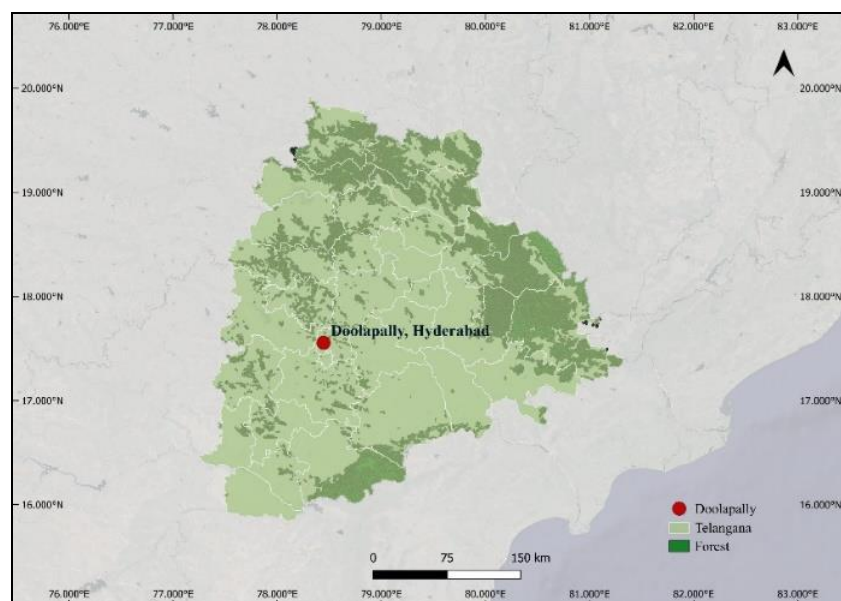


Fig 1: Study area for underutilized leaves and fruits

Preparation of fatty acid methyl ester (FAME)

Oil was extracted from the powder using hexane in a Soxhlet extraction system (Soxtherm, C. Gerhardt GmbH & Co. KG, Germany). Approximately 100-150 mg of the extracted oil was methylated by treating it with 2 mL of 13% methanolic KOH at 55 °C for 6 min. The organic phase was then extracted with hexane and washed repeatedly with distilled water until a neutral pH was achieved. The hexane phase was dried over anhydrous sodium sulfate and reduced under a stream of nitrogen to obtain fatty acid methyl esters (FAMES). Prior to gas chromatographic analysis, the extracted oil was converted into methyl esters to enhance its volatility. Fatty acid profiling was performed using gas chromatography following the method described by Anjani and Yadav ^[15] with slight modifications.

Fatty acid profile using Gas Chromatograph equipped with a Flame Ionization Detector:

The fatty acid profile was analyzed using an Agilent 7890B Gas Chromatograph (Agilent Technologies, USA) equipped with a Flame Ionization Detector (FID) and an auto-sampler. Separation of fatty acid methyl esters (FAMES) was achieved on a DB-225 capillary column (30 m × 250 µm i.d., 0.25 µm film thickness). Nitrogen was used as the

carrier gas at a constant flow rate of 1.2 mL/min. The initial oven temperature was maintained at 110 °C for 2 min, followed by an increase to 220 °C at a rate of 6 °C/min. A 0.2 µL sample was injected into the column at a split ratio of 20:1. Both the injector and detector temperatures were maintained at 230 °C. Fatty acids were identified by comparing their retention times with those of the Supelco 37-component FAME standard mixture, and their relative composition was calculated based on peak area percentages using EZ Chrom Elite Compact software for post-run chromatographic analysis ^[15].

Statistical Analysis

All the experiment were done in triplicate and given in Mean ± SD. The data was analyzed using SPSS version 27.0. One way Analysis of variance (ANOVA) was carried out to assess the significance of differences among the treatments. Post-hoc test (Duncan multiple range test) was performed to compare the means of the treatments. Heatmap was prepared using Origin Pro. 2025.

Results

GC-FID analysis of fatty acid profiles presented that unsaturated fatty acids are dominated over saturated fatty

acids in all five wild edible leafy vegetables and three wild edible fruits, underscoring their nutritional importance and potential health-promoting properties. The detected saturated fatty acids included caproic (C6:0), caprylic (C8:0), capric (C10:0), lauric (C12:0), myristic (C13:0), palmitic (C14:0), stearic (C18:0), arachidic (C20:0), behenic

(C22:0), and lignoceric acids (C24:0), while the unsaturated fatty acids included palmitoleic (C16:1, n-7), oleic (C18:1, n-9), linoleic (C18:2, n-9,12), and α -linolenic acids (C18:2, n-9,12,15). Overall, 14 fatty acids were identified in the leafy vegetables, while 15 fatty acids were detected in the wild edible fruit samples (Fig.2).

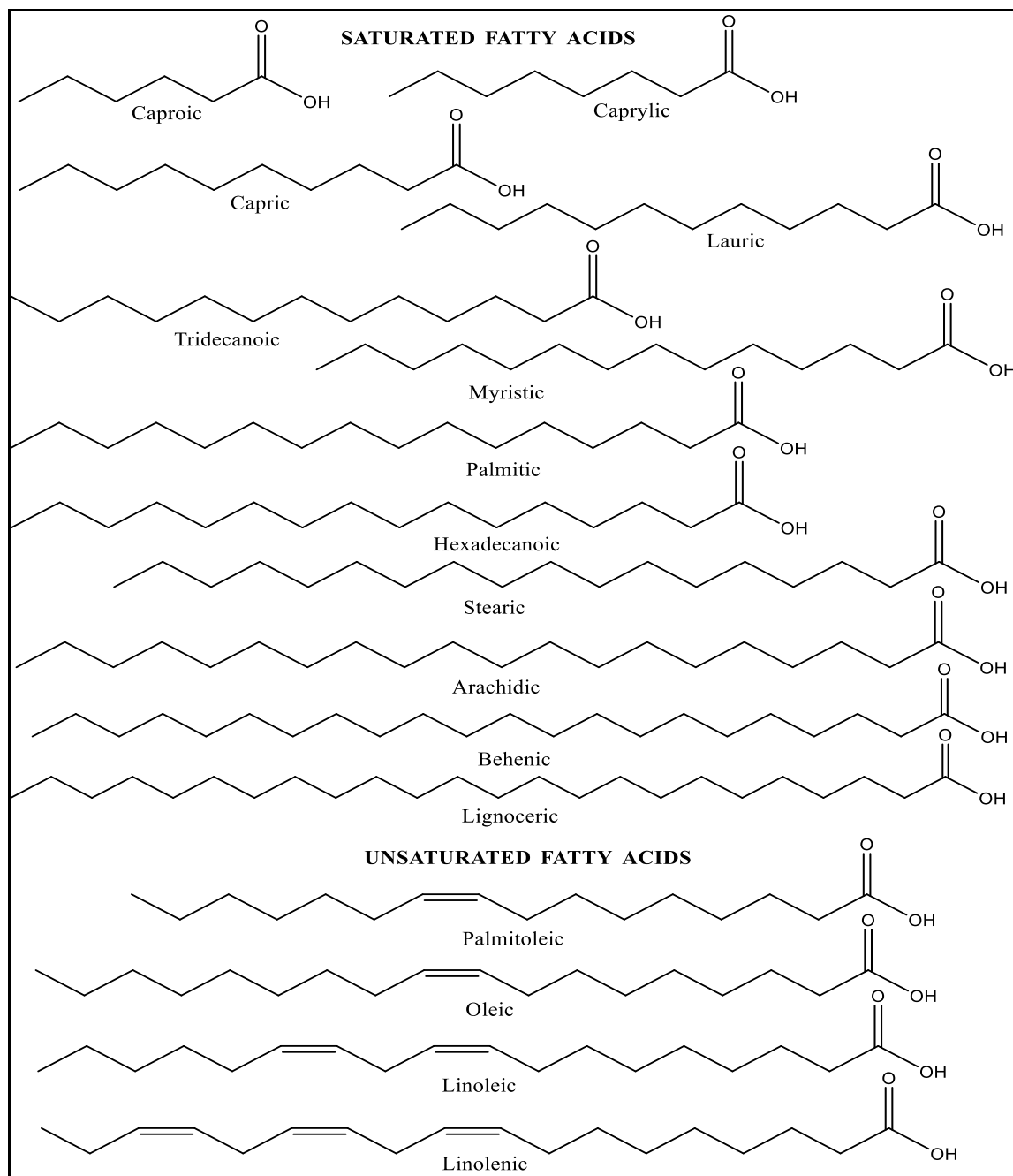


Fig 2: Structures of identified fatty acids in underutilized leaves and fruits

Fatty acid profile of wild leafy vegetables

A significant predominance of unsaturated fatty acids over saturated fatty acids have been observed. Among the identified compounds in leaves, oleic acid was the major fatty acid in most leaf samples, ranging from 26.26% to 70.71% (Table 1 and Fig-3-7). Among the leafy vegetables, *C. argentea* exhibited the highest oleic acid content (70.71%), followed by *L. aspera* (52.87%), *A. aspera* (46.58%), and *C. aestuans* (38.92%). Linoleic acid was also present in substantial amounts, particularly in *C. aestuans* (30.95%), *A. aspera* (27.47%), *S. occidentalis* (26.15%), and *L. aspera* (24.57%) (Fig.11). Notably, *C. aestuans*

showed comparatively higher linolenic acid content (13.53%), indicating the presence of nutritionally important omega-3 fatty acids. Palmitic acid was the predominant saturated fatty acid, varying between 7.10% and 13.36%, with the highest level recorded in *L. aspera*. *S. occidentalis* showed an unusually high arachidic acid content (22.03%) compared to other leaf samples. Overall, the leaf samples demonstrated a favorable fatty acid profile characterized by higher levels of monounsaturated and polyunsaturated fatty acids, suggesting good nutritional and functional potential (Fig. 11).

Fatty acid profile of wild edible fruits

The wild edible fruits showed that the all-fruit samples were significantly rich in unsaturated fatty acids, with noticeable variation among the samples (Table-2 and Fig.8-10). Oleic acid was identified as the predominant fatty acid in *D. chloroxylon* (49.90%) and *Z. oenopolia* (41.40%), while *D. melanoxyton* showed a comparatively lower oleic acid content (15.27%). In contrast, sample *D. melanoxyton* contained the highest proportion of linoleic acid (47.36%), followed by *D. chloroxylon* (28.94%) and *Z. oenopolia* (17.44%). A remarkably higher linolenic acid content was observed in sample *Z. oenopolia* (17.75%), suggesting its importance as a potential source of omega-3 fatty acids. Of all the saturated fatty acids identified, palmitic acid was the most abundant, exhibiting a range of 6.08% to 8.91%, whereas stearic acid content varied between 3.86% and 7.69%. Considerable amounts of arachidic acid were also detected, especially in *D. melanoxyton* (17.54%) and *D. chloroxylon* (7.76%). Additionally, small quantities of behenic and lignoceric acids were present in the fruit samples. The overall fatty acid composition of the fruits reflects their nutritional significance owing to the substantial presence of mono- and polyunsaturated fatty acids (Fig.2).

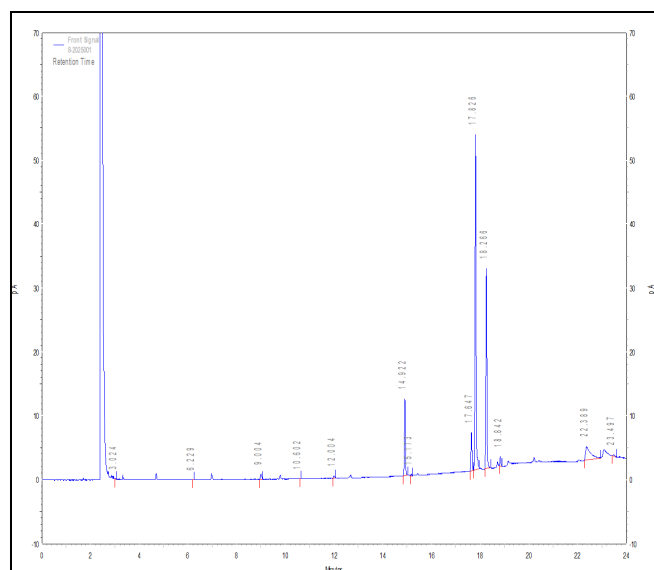


Fig 3: GC chromatogram of *Achyranthus aspera*

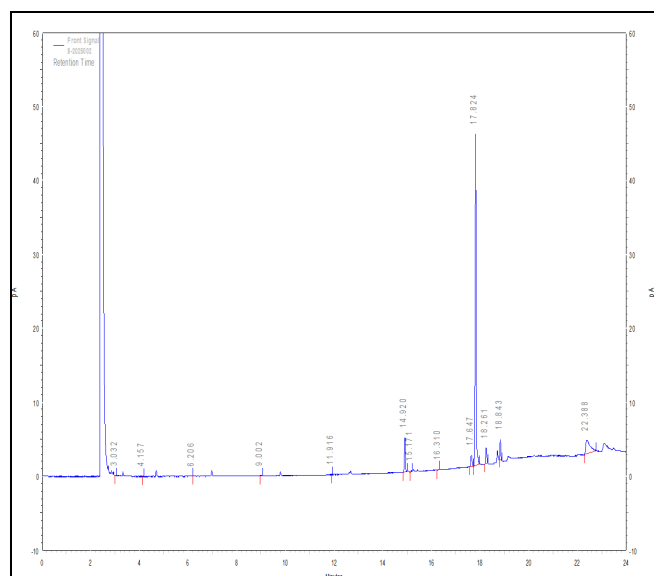


Fig 4: GC chromatogram of *Celostia argentea*

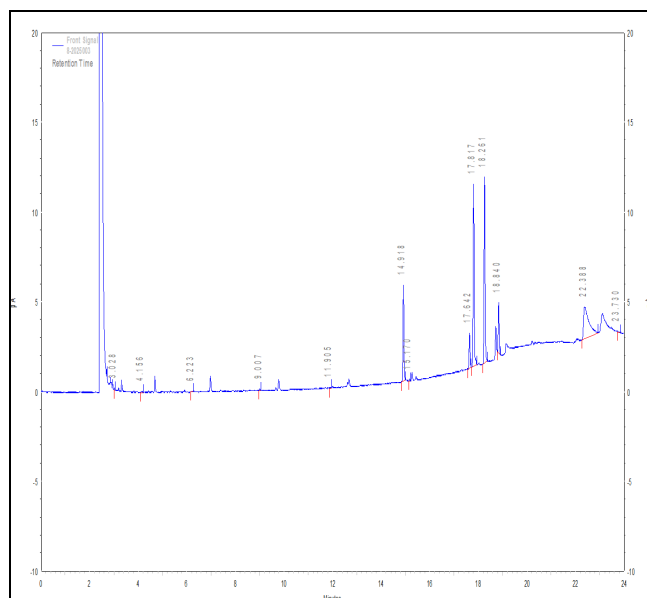


Fig 5: GC chromatogram of *Senna occidentalis*

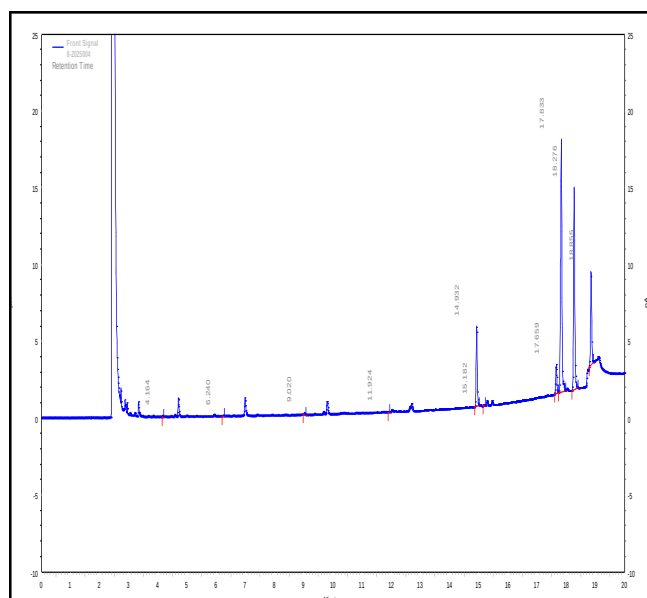


Fig 6: GC chromatogram of *Chorchonus aestunas*

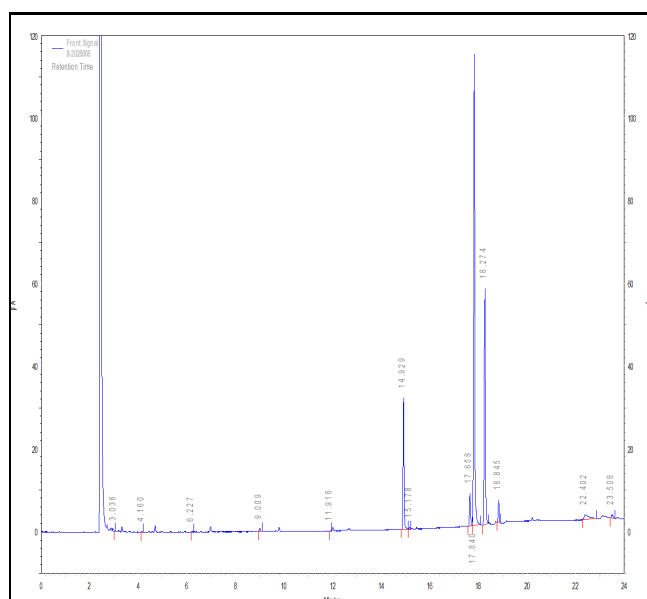


Fig 7: GC chromatogram of *Leucas aspera*

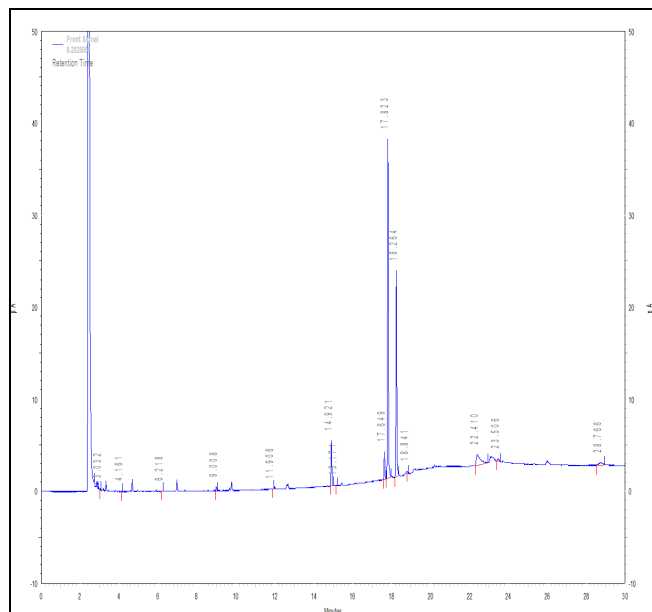
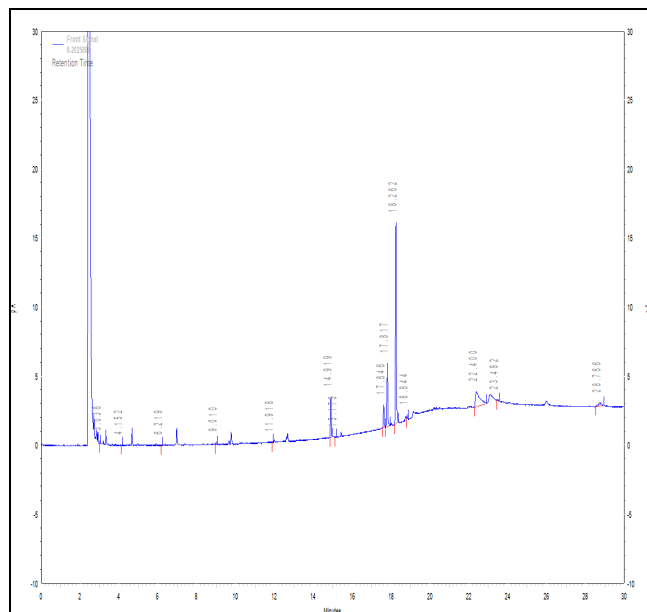
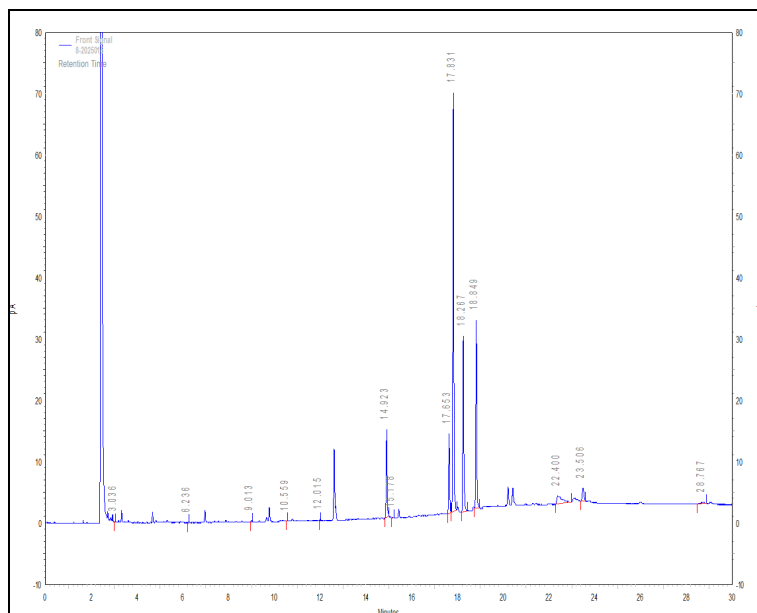
Fig 8: GC chromatogram of *Diospyros chloroxylon*Fig 9: GC chromatogram of *Diospyros melanoxylon*Fig 10: GC chromatogram of *Ziziphus oenopolia*

Table 1: Fatty acid profile of selected underutilized leafy vegetables

S.N	Name of species	<i>A. aspera</i>		<i>C. argentea</i>		<i>C. aestuans</i>		<i>L. aspera</i>		<i>S. occidentalis</i>	
		R.T	% area	R.T	% area	R.T	% area	R.T	% area	R.T	% area
1	Caproic acid (C6:0)	3.02	0.04±0.01 ^b	3.03	0.1±0.01 ^a	nd	-	3.04	0.03±0.01 ^b	3.03	0.12±0.02 ^a
2	Caprylic acid (C8:0)	nd	-	4.16	0.1±0.01 ^c	4.16	0.17±0.01 ^b	4.16	0.06±0.02 ^d	4.16	0.19±0.02 ^a
3	Capric acid (C10:0)	6.23	0.03±0.00 ^b	6.21	0.01±0.00 ^c	6.24	0.14±0.01 ^a	6.23	0.04±0.00 ^b	6.22	0.1±0.00 ^c
4	Lauric acid (C12:0)	9.00	0.65±0.01 ^a	9.00	0.24±0.01 ^d	9.02	0.28±0.01 ^c	9.01	0.33±0.00 ^b	9.01	0.33±0.02 ^b
5	Tridecanoic acid (C13:0)	10.60	0.02±0.00 ^a	nd	-	nd	-	nd	-	nd	-
6	Myristic acid (C14:0)	12.00	0.31±0.01 ^a	11.92	0.04±0.01 ^d	11.92	0.09±0.01 ^c	11.92	0.02±0.00 ^e	11.91	0.14±0.0 ^b
7	Palmitic acid (C16:0)	14.92	10.01±0.0 ^d	14.92	7.18±0.20 ^e	14.93	11.57±0.0 ^c	14.93	13.39±0.0 ^a	14.92	12.96±0.06 ^b
8	Palmitoleic acid (C16:1, n-7)	15.17	0.12±0.01 ^d	15.17	0.23±0.00 ^a	15.18	0.16±0.02 ^c	15.18	0.19±0.01 ^b	15.17	0.11±0.00 ^d
9	Stearic acid (C18:0)	17.65	5.25±0.08 ^a	17.65	2.42±0.13 ^e	17.66	4.23±0.07 ^c	17.66	3.48±0.03 ^d	17.64	4.83±0.04 ^b
10	Oleic acid (C18:1, n-9)	17.83	46.58±0.61 ^c	17.82	70.71±1.2 ^a	17.83	38.92±1.21 ^d	17.84	52.87±1.16 ^b	17.82	26.26±0.72 ^e
11	Linoleic acid (C18:2, n-9,12)	18.27	27.47±0.46	18.26	3.32±0.3	18.28	30.95±0.95	18.27	24.57±0.35	18.26	26.15±0.72
12	Linolenic acid (C18:2, n-9,12,15)	18.84	1.22±0.03 ^b	18.84	4.19±0.09 ^e	18.86	13.53±0.39 ^a	18.85	2.26±0.06 ^d	18.84	6.5±0.25 ^c
13	Arachidic acid (C20:0)	22.39	8.03±0.14 ^c	22.39	11.48±0.25 ^b	nd	-	22.40	2.23±0.08 ^d	22.39	22.03±0.28 ^a
14	Behenic acid (C22:0)	23.50	0.26±0.04 ^b	nd	-	nd	-	23.51	0.54±0.05 ^a	23.73	0.26±0.03 ^b

Values in columns represent parameter mean; row with similar letter (s) are not significantly different at P<0.05; S: Saturated; US: Unsaturated; RT: Retention time; n.d: Not detected

SFA, MUFA and PUFA composition of wild leafy vegetables and fruits

The leafy vegetable and fruit showed significant fatty acid variation mainly in the saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), total unsaturated fatty acids (TUFA), and the ratio of unsaturated to saturated fatty acids (UFA/SFA) (Table-3 and Fig. 12). Overall, across all samples, unsaturated fatty acids were present at higher levels than saturated fatty acids, indicating a nutritionally favorable lipid profile. The SFA content ranged from 16.45% to 40.98%, with the lowest value recorded in sample *C. aestunas* (16.45%) and the highest in sample *S. occidentalis* (40.98%). Lower saturated fatty acid content is generally considered beneficial because excessive consumption of saturated fats is associated with increased cardiovascular risk. In contrast, the MUFA content varied between 15.47% and 70.94%, where *C. argentea* exhibited the highest

MUFA level (70.94%), indicating the predominance of heart-healthy monounsaturated fats, while *D. melanoxylon* showed the lowest MUFA content (15.47%). The PUFA content ranged from 7.51% to 48.04%, with the highest value observed in sample *D. melanoxylon* (48.04%), and followed by *C. aestunas* (44.48%). From a nutritional perspective, polyunsaturated fatty acids are highly important as they include essential fatty acids that contribute to cardiovascular health, brain function, and anti-inflammatory activities.

The total unsaturated fatty acid (TUFA) ranged from 59.2% to 83.56%. *C. aestunas* exhibited the highest TUFA value (83.56%), indicating a superior unsaturated fatty acid composition, whereas *S. occidentalis* showed the lowest TUFA content (59.2%). The dominance of unsaturated fatty acids in all samples suggests that both leaves and fruits possess nutritionally beneficial lipid profiles and may have potential applications as functional food resources.

Table 2: Fatty acid profile of selected underutilized wild fruits

S.N	Name of species	<i>D. chloroxylon</i>		<i>D. melanoxylon</i>		<i>Z. oenopolia</i>	
	Fatty acids	R.T	% area	R.T	% area	R.T	% area
1	Caproic acid (C6:0)	3.03	0.13±0.02 ^b	3.04	0.29±0.03 ^a	3.02	0.03±0.00 ^c
2	Caprylic acid (C8:0)	4.16	0.1±0.01 ^b	4.15	0.13±0.02 ^a	nd	-
3	Capric acid (C10:0)	6.22	0.06±0.02 ^b	6.22	0.17±0.02 ^a	6.22	0.03±0.00 ^b
4	Lauric acid (C12:0)	9.01	0.5±0.05 ^a	9.01	0.54±0.03 ^a	9.00	0.15±0.01 ^b
5	Tridecanoic acid (C13:0)	nd	-	nd	-	10.60	0.03±0.00 ^a
6	Myristic acid (C14:0)	11.91	0.05±0.00 ^c	11.92	0.1±0.03 ^b	12.00	0.11±0.01 ^a
7	Palmitic acid (C16:0)	14.92	6.08±0.31 ^b	14.92	8.91±4.7 ^a	14.92	8.24±0.64 ^a
8	Palmitoleic acid (C16:1, n-7)	15.17	0.12±0.03 ^b	15.17	0.2±0.01 ^a	15.17	0.07±0.01 ^c
9	Stearic acid (C18:0)	17.65	3.86±0.27 ^c	17.65	5.52±0.29 ^b	17.64	7.69±0.28 ^a
10	Oleic acid (C18:1, n-9)	17.82	49.9±0.91 ^a	17.82	15.27±0.47 ^c	17.82	41.40±0.63 ^b
11	Linoleic acid (C18:2, n-9,12)	18.26	28.94±0.91 ^b	18.26	47.36±1.00 ^a	18.26	17.44±0.76 ^c
12	Linolenic acid (C18:2, n-9,12,15)	18.84	0.24±0.02 ^b	18.84	0.68±0.05 ^b	18.84	17.75±0.45 ^a
13	Arachidic acid (C20:0)	22.41	7.76±0.63 ^b	22.40	17.54±0.45 ^a	22.38	4.17±0.08 ^c
14	Behenic acid (C22:0)	23.51	0.67±0.06 ^b	23.48	0.46±0.03 ^c	23.49	2.06±0.08 ^a
15	Lignoceric acid (C24:0)	28.77	1.6±0.05 ^b	28.77	2.83±0.16 ^a	28.77	0.84±0.05 ^c

Values in columns represent parameter mean; row with similar letter (s) are not significantly different at $P<0.05$. S: Saturated; US: Unsaturated; RT: Retention time; n.d: Not detected

Unsaturated fatty acids to saturated fatty acids (UFA/SFA) ratio is a key nutritional indicator that reflects the balance between health-promoting unsaturated fats and less desirable saturated fats. In this investigation, the UFA/SFA ratio ranged from 1.44 to 5.08. *C. aestunas* exhibited the highest ratio (5.08), representing that unsaturated fatty acids are five times higher as compared to saturated fatty acids, reflecting an excellent nutritional profile and potential cardio protective properties. In contrast, *S. occidentalis* showed the lowest ratio (1.44), suggesting a comparatively

higher contribution of saturated fatty acids. Most samples recorded UFA/SFA ratios above 3.0, which is considered favorable from a nutritional and health perspective. A higher UFA/SFA ratio is generally associated with reduced cholesterol accumulation, improved lipid metabolism, enhanced membrane fluidity, and lower risk of cardiovascular diseases. Overall, the results demonstrate that the studied leaf and fruit samples are rich sources of beneficial unsaturated fatty acids and possess promising nutritional significance.

Table 3: Saturated and unsaturated fatty acid composition of underutilized leafy vegetables and wild fruits (%)

S.N	Species	SFA	MUFA	PUFA	TUFA	UFA/SFA
1	<i>A. aspera</i>	24.6±0.16 ^c	46.7±0.59 ^d	28.69±0.43 ^e	75.39±1.02 ^d	3.06±0.06 ^d
2	<i>C. argentea</i>	21.57±0.22 ^d	70.94±1.19 ^a	7.51±0.13 ^g	78.45±1.07 ^{bc}	3.64±0.08 ^b
3	<i>C. aestunas</i>	16.45±0.09 ^e	39.08±1.21 ^f	44.48±0.61 ^b	83.56±1.82 ^a	5.08±0.08 ^a
4	<i>L. aspera</i>	20.1±1.8 ^d	53.06±1.14 ^b	26.83±0.41 ^f	79.89±1.55 ^b	3.97±0.2 ^b
5	<i>S. occidentalis</i>	40.98±0.21 ^a	26.37±0.72 ^g	32.65±0.47 ^d	59.2±1.19 ^f	1.44±0.03 ^f
6	<i>D. chloroxylon</i>	20.81±0.76 ^d	50.02±0.88 ^c	29.18±0.89 ^e	79.2±1.77 ^{bc}	3.81±0.05 ^b
7	<i>D. melanoxylon</i>	36.49±0.48 ^b	15.47±0.47 ^h	48.04±0.95 ^a	63.51±0.47 ^e	1.74±0.03 ^e
8	<i>Z. oenopolia</i>	23.35±0.69 ^c	41.47±0.64 ^e	35.19±1.21 ^c	76.66±1.85 ^{cd}	3.28±0.01 ^c

Values in columns represent parameter mean; row with similar letter (s) are not significantly different at $P<0.05$. SFA: Saturated fatty acid; MUFA: Monounsaturated fatty acid; PUFA: Poly unsaturated fatty acids; TUFA: Total Unsaturated fatty acid; UFA: Unsaturated fatty acids

Discussion

Compared with the widely consumed spinach (*Spinacia oleracea*), the evaluated underutilized leafy vegetables exhibited distinct fatty acid profiles. Spinach is well-known for its remarkably high polyunsaturated fatty acid (PUFA) content (68.0-87%) depending on genotype and cultivation conditions^[16-17]. Spinach is rich in α -linolenic acid (44.5-75.7%) which contribute to the higher PUFA. The present study found that *C. aestuans* had highest PUFA content (44.48%) followed by *S. occidentalis* (32.65%), *A. aspera* (28.69%), and *L. aspera* (26.83%). However, studied leafy vegetables contained substantially higher monounsaturated fatty acid (MUFA) due to their elevated oleic acid content as compared to spinach. The highest MUFA proportion was found in *C. argentea* (70.94%) with oleic acid (70.71%) of

total fatty acids followed by *L. aspera* and *A. aspera*. By contrast, spinach contains relatively low MUFA concentrations, with total MUFA reported at 8.1% and oleic acid at 5.4%^[16]. Pereira *et al.*^[17] further reported a maximum oleic acid content of only 3.09% across the spinach genotypes evaluated. Spinach contains approximately 23.9% SFA, dominated by palmitic acid (9.5-19.7%)^[16-17]. Among the studied leaves, *S. occidentalis* had the highest SFA content (40.98%), largely due to elevated levels of arachidic acid (22.03%) and palmitic acid (12.96%) while remaining species showed SFA contents closer to those reported for spinach. It has been found that limited studied have been done on the selected leafy vegetable.

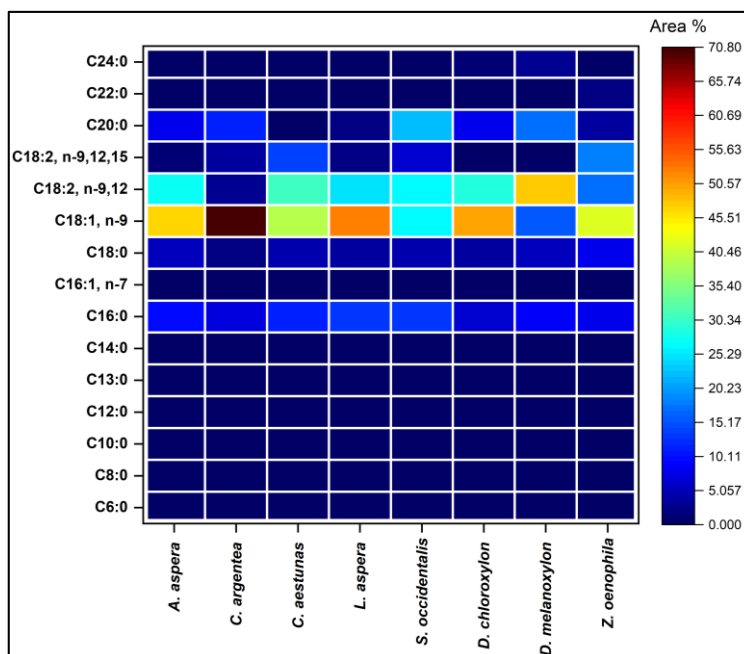


Fig 11: Heatmap showing variation in the fatty acids of wild leafy vegetable and fruits

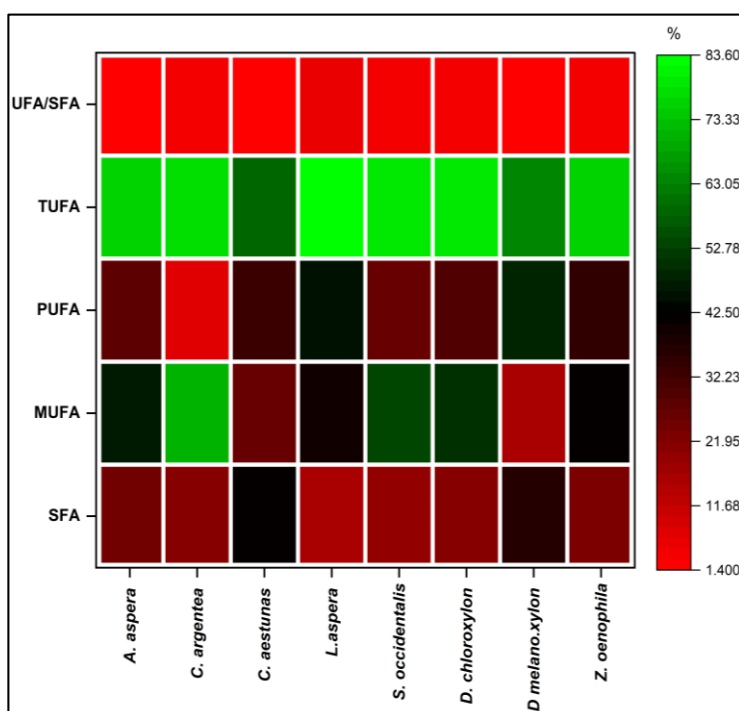


Fig 12: Heatmap showing variation in the saturation and unsaturation levels in wild leafy vegetable and fruits

Kumar *et al.*,^[18] reported that PUFAs were predominated fatty acids in *A. aspera* leaves, specifically dominated by α -linolenic acid (1058.07 mg/100g) and linoleic acid (604.87 mg/100g). However, *A. aspera*, in the present study, contained 28.69% PUFA (linoleic acid-27.47 and α -linolenic acid-1.22%). *L. aspera* had 26.83% PUFA (linoleic acid-24.57% and linolenic acid-2.26%). In contrast, Anandan *et al.*,^[19] also found high concentration of linolenic acid (22.97%) in the methanolic extracts of *L. aspera* leaves. The *C. argentea* exhibits an exceptionally high MUFA with higher oleic acid (70.71%). This result agrees well with the literature value of 6-octadecenoic acid methyl ester 26.59% as the major fatty acid in the methanolic leaf extract of *C. argentea*^[20]. Similarly *L. aspera* and *A. aspera* also had higher level of oleic acid (53.06%) and (46.7%) respectively. However, Kumar *et al.*,^[18] reported the lower level of oleic acid in *A. aspera* leaves (164.81 mg/100g). *S. occidentalis* showed uniquely high SFA content significantly influenced by a high concentration of arachidic acid (22.03%) and palmitic acid (12.96%). The palmitic acid is consistently identified as the dominant saturated fatty acid among other leaf species. *L. aspera* had 13.39% palmitic acid which is closely aligns with the literature value of palmitic acid (17.17%) in the same plant^[19]. Furthermore, Sharma *et al.*,^[20] detected 14.04% palmitic acid in *C. argentea* leaves while 7.18% was found in the present study.

Wild edible fruit analysis revealed that *D. chloroxylon* and *Z. oenoplia* are rich in MUFA content which is primarily driven by oleic acid (49.9%) in *D. chloroxylon* and 41.40% in *Z. oenoplia*. This findings aligns with the literature values of oleic acid (39.91%) in the seed oil of *D. chloroxylon* and (53.38%) in *Z. oenoplia* seed oil^[21-22]. These findings are in agreement with Bouzid *et al.*^[23], who demonstrated that oleic acid is the predominant fatty acid in *Ziziphus lotus* fruits, representing 50.65% to 60.25% of the total fatty acid composition. However, *D. melanoxylon* has a much lower MUFA content (15.47%), with oleic acid contributing only 15.27%. *D. melanoxylon* had highest PUFA content (48.04%) among the evaluated fruits, which is almost entirely composed of linoleic acid (47.36%). In contrast, *D. chloroxylon* and *Z. oenoplia* possess comparatively lower total PUFA fractions of 29.18% and 35.19%, respectively. The linoleic acid in *D. chloroxylon* was found higher than the reported value 18.01%^[22]. *Z. oenoplia* had a balanced PUFA profile having linoleic acid (17.44%) and a notably high α -linolenic acid (17.75%). This is also in line with Murthy *et al.*,⁽²¹⁾ result who reported linoleic acid (20.28%) but recorded only trace amounts of linolenic acid (1.02%) in *Z. oenoplia*. This is also supported by the literature that similar genus *Ziziphus jujube* fruit also have higher linoleic acid (110 mg/100g)^[7]. Saturated Fatty Acids (SFA) content was highest in *D. melanoxylon* (36.49%), with higher content of arachidic acid (17.54%) and palmitic acid (8.91%). *D. chloroxylon*, has SFA content of 20.81% primarily arachidic acid at 7.76% and palmitic acid at 6.08%). This is considerably lower than the 38.23% total SFA reported by Murthy *et al.*,^[22] a discrepancy largely due to detecting a much higher palmitic acid content (28.06%) in the seed oil. SFA content in *Z. oenoplia* is 23.35%, comprising palmitic acid (8.24%) and stearic acid (7.69%). This closely agrees with literature values of SFA content (25.31%) in *Z. oenoplia*, with nearly identical values for palmitic acid (9.84%) and stearic acid (9.62%)^[21].

The high proportion of unsaturated fatty acids is considered nutritionally beneficial because these lipids serve as essential structural components of biological membranes and act as precursors for signaling molecules and hormones involved in metabolism, immunity, and neuroprotection. Importantly, naturally occurring plant-derived fatty acids exist predominantly in the *cis* configuration, which confers beneficial effects on membrane fluidity and cardiovascular health. Caproic acid, detected in most leafy vegetables and fruit samples except *C. aestunas*, is rapidly oxidized in mitochondria without requiring the carnitine transport system, contributing to ketone body production and energy supply during glucose deprivation^[24]. It also exhibits antibacterial activity that supports beneficial gut microbiota^[25]. Caprylic acid similarly promotes ketogenesis, improves lipid profiles, provides neuroprotective effects, and regulates appetite while reducing oxidative stress and inflammation^[26-27]. Capric acid functions as an anticonvulsant, suppresses inflammatory pathways, and enhances mitochondrial biogenesis^[28-29]. Lauric acid, present in all samples, serves as a rapid energy source and demonstrates insulin-sensitizing, antioxidant, and antimicrobial properties^[30-31]. Myristic acid (C14) is essential for N-myristoylation, a post-translational modification involved in membrane anchoring and cellular signaling^[32]. Although it supports omega-3 phospholipid enrichment and antimicrobial defense, excessive intake may elevate LDL cholesterol^[33]. Palmitic acid (C16) is a major endogenous fatty acid that serves as a precursor of stearic and palmitoleic acids and is an important structural component of membrane phospholipids^[34]. Stearic acid (C18) is generally cholesterol-neutral and contributes to membrane stability, mitochondrial function, thermogenesis, and neurotransmitter regulation^[35]. The very-long-chain saturated fatty acids *viz.* arachidic acid contributes to membrane signaling and myelin precursor synthesis^[36], behenic acid influences insulin sensitivity and lipid digestion^[37], while lignoceric acid is essential for myelin sheath formation and peroxisomal metabolism^[38]. Among the monounsaturated fatty acids, palmitoleic acid acts as a lipokine that promotes fatty acid oxidation and reduces triglyceride accumulation, thereby helping prevent fatty liver disease^[39]. Oleic acid, a major omega-9 fatty acid, is associated with cardioprotective, neuroprotective, and immunomodulatory effects. It supports neuronal membrane integrity, reduces β -amyloid accumulation, and suppresses pro-inflammatory mediators such as IL-6^[40]. The essential polyunsaturated fatty acids also contribute substantially to health benefits. Linoleic acid enhances cholesterol clearance, supports mitochondrial ATP production, and maintains epidermal barrier function^[41]. α -Linolenic acid serves as a precursor of EPA and DHA, which generate specialized pro-resolving mediators involved in anti-inflammatory responses and neuroprotection^[42]. It also promotes fatty acid oxidation, lowers triglycerides, and improves circulating lipid profiles through modulation of PPAR- α and SREBP-1c signaling^[43]. These coexistence of medium-chain, long-chain, and very-long-chain fatty acids in these edible leaves and fruits highlights their metabolic versatility. Such fatty acid richness suggests that these underutilized leafy vegetables and wild fruits can contribute to dietary energy supply, improve lipid metabolism, support mitochondrial efficiency, and provide protective effects against inflammatory, neurodegenerative, and cardiovascular disorders.

Conclusions

The findings of this study indicate that underutilized leafy vegetables and wild fruits have a promising fatty acid composition characterized by a high proportion of unsaturated fatty acids over saturated fatty acids. Most of the exhibited high levels of monounsaturated and polyunsaturated fatty acids, which are known for their beneficial effects on human health. Leafy vegetables, particularly *C. aestunas* showed a superior lipid profile with the lowest SFA content, highest TUFA, and highest UFA/SFA ratio, indicating strong nutritional potential. Among the fruit samples, *D. chloroxylon* and *D. melanoxylon* were notable for their higher MUFA and PUFA contents, respectively, although some samples showed relatively higher saturated fatty acid levels. The UFA/SFA ratio across most samples remained above the desirable threshold, reflecting a healthy balance of fatty acids and suggesting potential cardioprotective properties. Overall, the diverse fatty acid composition, particularly the abundance of mono- and polyunsaturated fatty acids, highlights the nutritional and therapeutic potential of these wild edible leafy vegetables and fruits. Therefore, further studies are needed to evaluate these leafy vegetables and wild fruits, as their consumption may contribute to improved metabolic health, reduced risk of chronic diseases, and enhanced nutritional security.

Conflict of Interest

The authors have no conflict of interest to report.

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