



Antioxidants and nutritional counters of drumstick (*Moringa oleifera*) germplasm under rainfed semi-arid region

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Received: 30 December 2022; Accepted: 21 August 2023

ABSTRACT

Drumstick (*Moringa oleifera* L.) is a tropical plant with wider adaptability to drought and different agro-climatic conditions. The different plant parts including leaves, fruits, flowers and immature pods are used throughout the world for various purposes due to their high nutritive value. The 34 genetic resources of drumstick along with Thar Harsha variety were investigated in this study during 2019–2021 on quality parameters at ICAR-Central Horticultural Experiment Station, Panchmahals, Vadodara, Gujarat. Results showed that the percentage of dry matter and moisture content ranged from 10.86 to 17.98 and 83.08 to 89.14 (pod), 8.16 to 14.80 and 83.40 to 93.38 (pulp), 16.00 to 22.80 and 72.20 to 84.00 (skin) and 24.62 to 30.54 and 69.46 to 75.38 (leaves), respectively. The total phenolic (TP) content (mg GAE/100 g) in pod (26.36–39.90), pulp (151.54–232.70), rind (73.37–169.06) and leaves (448.21–970.16) were recorded. The pod, pulp and leaf of CHES D-40 accession recorded the highest TP content. While, the rind of CHES D-42 accession recorded the maximum TP content. Similarly, leaves and pods of CHES D-40 showed the highest vitamin C. In 2, 2-diphenyl-1-picryl-hydrazyl-hydrate (DPPH) assay, the antioxidant activity of *M. oleifera* accessions leaves varied from 14.83 to 31.29 $\mu\text{mol TE/g}$. In all nutrient contents of the *M. oleifera* accession dry leaf powder was quantified with wide variation. The accession CHES D-40 recorded the highest N, K, Ca, S, and Fe in leaves, whereas, P and Cu in CHES D-42, Mg and Zn in CHES D-34 leaves. The protein varied from 21.58 to 29.87 g/100 g in leaves, while in pod, 13.00 to 18.00 g/100 g. These results revealed that the potentiality of *M. oleifera* leaves in context to antioxidants and nutrients can be included in diets to supplement our daily nutrient needs.

Keywords: Ascorbic acid, DPPH, Dry matter, Phenols, Plant nutrients, Semi-arid region

Drumstick (*Moringa oleifera* L.) is an important tree whose pods, leaves, flowers, barks and roots have been advocated for traditional and medicinal uses for thousands of years and native to India (Hassan *et al.* 2021). India is the main producer of *M. oleifera* in the world where the southern states of the country significantly contributes due to favourable climatic conditions for growth (Yadav *et al.* 2022). Whole plant is excellent source of nutrients, minerals, flavonoids, phenols and vitamins. Most parts of *M. oleifera*, namely seeds, leaves and pods, were used as components in traditional medicine (Gopalakrishnan *et al.* 2016). The *M. oleifera* has been recognized since ancient times in traditional medicine (Ndhala *et al.* 2014).

In general whole plant suits for industrial purposes but the roots are an alternate source to horseradish; the wood for paper industry; seeds powder for bio water clarifier replacing coagulants for chemicals such as aluminum sulphate; and seed kernels extracted oil for production of

biolubricants (Tshabalala *et al.* 2020, Giuberti *et al.* 2021, Yadav *et al.* 2022).

Analysis of *M. oleifera* for nutrient content, antioxidant activity (AOA) and other traits alluded that it is one of the promising crop which could contribute to increased intake of micronutrients and antioxidants. Therefore, the study was carried out to evaluate the *M. oleifera* germplasm under rainfed semi-arid condition.

MATERIALS AND METHODS

An experiment was conducted at ICAR-Central Horticultural Experiment Station (CIAH RS), Godhra, Gujarat during 2019–20 to study the quality parameters of *M. oleifera*. The experiment consisted of 34 germplasm lines being maintained at ICAR-Central Horticultural Experiment Station (CIAH RS), Godhra, Gujarat (Table 1–4). The leaves and pods of 34 genotypes were collected at horticultural maturity in 3 replicates from the disease free *M. oleifera* trees. The samples were washed with tap water and excess water drained. The fresh samples were used for the analysis of ascorbic acid and remaining sample was dried in an oven dryer. Further procedure for analysis of total phenols and antioxidant activity were followed according to Yadav *et*

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al. (2022). The powdered samples were used for mineral estimation. The prescribed procedure and methods were used for estimation of minerals, moisture, dry matter, ascorbic acid, antioxidants and their activity (Yadav *et al.* 2019, Yadav *et al.* 2022).

Statistical analysis: Data were presented as a mean standard deviation of three replicates and results were statistically analyzed in completely randomized design (one factor analysis) by using the software of CCSHAU, Hisar, Haryana, (website: <http://14.139.232.166/opstat/>) for analysis of variance and test of significance.

RESULTS AND DISCUSSION

Moisture and dry matter content: The moisture and dry matter content was assessed in pod, pulp, skin and leaves (Table 1). The result showed that germplasm CHES D-32 in pod, CHES D-6 in pulp, CHES D-32 in skin and CHES D-40 in leaves were recorded the minimum moisture content resulted higher dry matter in respective accession in different plant parts. Among the four parameters, viz. pod, pulp, skin and leaves of *M. oleifera*, the lowest moisture content was recorded in leaves (CHES D-40) while, pulp of CHES D-26 recorded the highest moisture content. The

Table 1 Comparative evaluation of moisture and dry matter content in pod, pulp, skin and leaves of drumstick germplasm under rainfed semi-arid condition

Germplasm	Moisture (%)				Dry matter (%)			
	Pod	Pulp	Skin	Leaves	Pod	Pulp	Skin	Leaves
CHES D-2	86.02	88.64	77.4	70.52	13.98	11.36	22.6	29.48
CHES D-3	85.92	91.3	80.64	74.16	14.08	8.7	19.36	25.84
CHES D-4	84.4	84.4	78.6	74.26	15.6	15.6	21.4	25.74
CHES D-5	86.14	86.44	80.92	73.24	13.86	13.56	19.08	26.76
CHES D-6	80.4	83.4	82.2	72.7	19.6	16.6	17.8	27.3
CHES D-8	84.18	89.92	81.78	73.6	15.82	10.08	18.22	26.4
CHES D-9	86.82	88.62	80.84	70.96	13.18	11.38	19.16	29.04
CHES D-10	86.98	90.34	83.24	73.9	13.02	9.66	16.76	26.1
CHES D-11	88.86	88.32	82.44	75.36	11.14	11.68	17.56	24.64
CHES D-13	86.3	88.38	81.02	70.8	13.7	11.62	18.98	29.2
CHES D-16	84.44	88.18	80.5	72.16	15.56	11.82	19.5	27.84
CHES D-17	85.52	87.7	80.96	74.76	14.48	12.3	19.04	25.24
CHES D-18	87.7	87.26	82.96	75.38	12.3	12.74	17.04	24.62
CHES D-19	84.76	91.5	79.1	73.06	15.24	8.5	20.9	26.94
CHES D-21	82.66	87.96	77.46	69.88	17.34	12.04	22.54	30.12
CHES D-22	87.84	90.78	81.88	69.76	12.16	9.22	18.12	30.24
CHES D-23	85.44	88.56	82.28	72.74	14.56	11.44	17.72	27.26
CHES D-24	86.34	90.14	81.08	69.96	13.66	9.86	18.92	30.04
CHES D-25	85.88	87.52	81.18	69.96	14.12	12.48	18.82	30.04
CHES D-26	83.98	93.38	79.4	73.74	16.02	6.62	20.6	26.26
CHES D-29	87.08	89.04	82.94	73.6	12.92	10.96	17.06	26.4
CHES D-30	85.2	91.34	81.28	72.24	14.8	8.66	18.72	27.76
CHES D-31	87.52	85.2	81.34	73.9	12.48	14.8	18.66	26.1
CHES D-32	83.08	89.08	77.2	71.14	16.92	10.92	22.8	28.86
CHES D-34	85.38	85	79.84	72.74	14.62	15	20.16	27.26
CHES D-35	83.6	92.3	80.32	71.98	16.4	7.7	19.68	28.02
CHES D-36	84.44	87.54	83.42	70.18	15.56	12.46	16.58	29.82
CHES D-37	86.56	91.84	82.72	71.96	13.44	8.16	17.28	28.04
CHES D-39	87.04	91.42	81.3	72.04	12.96	8.58	18.7	27.96
CHES D-40	87.32	87.64	84	69.46	12.68	12.36	16	30.54
CHES D-42	82.02	85.88	82.8	71.7	17.98	14.12	17.2	28.3
CHES D-45	87.22	89.12	83.7	72.16	12.78	10.88	16.3	27.84
CHES D-50	89.14	85.52	81.14	75.32	10.86	14.48	18.86	24.68
Thar Harsha	85.84	87.38	81.04	74.48	14.16	12.62	18.96	25.52
CD (P=0.05%)	1.354	1.250	1.567	3.532	1.382	0.258	0.552	2.533

germplasm CHES D-42 (pod), CHES D-31 (pulp), CHES D-34 (skin) and CHES D-40 (leaves) recorded maximum dry matter content. Likewise, leaves of CHES D-40 recorded the highest dry matter content among the four parameters. These results are in accordance with findings of Yadav *et al.* (2022). The bulk density, mass and surface area of *M. oleifera* leaves increased with an increase in moisture content while, the bio-yield and yield decreased with an increase in moisture content. The low moisture content of *M. oleifera* powder is an important quality attribute for longer shelf life. The whole plant of *M. oleifera* has been reported as a rich source of proteins, vitamins, minerals, antioxidants etc. and termed as miracle tree. Hence, the higher dry matter yields improve quality traits (Nouman *et al.* 2013, Yadav *et al.* 2022).

Ascorbic acid content: The results regarding the ascorbic acid content in *M. oleifera* germplasms leaves and pulp are shown in Table 2. The ascorbic acid in leaves varies from 333.01 to 502.57 mg/100 g, while in pulp, from 193.04 to 266.11 mg/100 g. The leaves of CHES D-40 recorded highest ascorbic acid (502.57 mg/100 g) followed by CHES D-23 (501.36 mg/100 g) and CHES D-35 (499.70 mg/100 g). In pulp, CHES D-40 recorded the maximum ascorbic acid (266.11 mg/100 g) followed by CHES D-23 (258.05 mg/100 g) and CHES D-36 (257.54 mg/100 g). The similar results were obtained by Singh and Banu (2014) who reported *M. oleifera* as a rich source of ascorbic acid both in fresh leaves (0.16–220.0 mg/100 g) and dry leaves (3.29–92 mg/100 g). The mature leafy greens are consumed in cooked form and being thermolabile nature of ascorbic acid, the human body is unable to harness the benefits of ascorbic acid. In contrast, leaves of *M. oleifera* consumed in fresh form which can help the human body to harness the ascorbic acid (Yadav *et al.* 2022).

Total phenolics: Total phenolics (TP) content varied among the *M. oleifera* germplasm in pod, pulp, skin and leaves (Table 2). The TP content in *M. oleifera* germplasm ranged from 26.36 to 39.90 mg GAE/100 g in pod, 151.55 to 235.22 mg GAE/100 g in pulp, 73.38 to 169.06 mg GAE/100 g in skin and 448.21 to 970.16 mg GAE/100 g in leaves whereas in all four parameters of *M. oleifera* germplasm it ranged from 26.36 to 970.16 mg GAE/100 g. Among pod and leaves of *M. oleifera* germplasm, the maximum TP content was observed in CHES D-40 (39.90 mg GAE/100 g and 502.57 mg GAE/100 g, respectively). Conversely, in pulp and skin, the highest TP contents were observed in CHES D-45 (235.22 GAE mg/100 g and 169.06 GAE mg/100 g, respectively) followed by in CHES D-40 (232.71 GAE mg/100 g and 158.38 GAE mg/100 g, respectively). The leaves of CHES D-40 have significantly higher TP content than their pod, pulp and skin. Similarly, Pakade *et al.* (2013) reported that the TP in *M. oleifera* was almost double than other vegetables. Herein, good amount of TP compositions in leaves depends on germplasm, maturity stage and agro-climatic conditions, which is required for acclimatization of plant under biotic and abiotic stresses (Yadav *et al.* 2022). In line with our

findings, Ali *et al.* (2018) reported that *M. oleifera* is one of the valuable plant bio-stimulant. These findings are in support with results the of Ndhlala *et al.* (2014), Yadav *et al.* (2019), Ozcan M M (2020), Shi *et al.* (2021), Kashyap *et al.* (2022) and Yadav *et al.* (2022). Similarly, it is found important feed supplement in replacement of green fodder being richer sources of phenolics (Nouman *et al.* 2013). The mechanisms behind the antioxidant capacity of phenolic compounds are thought to involve breakdown of oxidative and nitrosative cascade and their capacity to function at cellular levels. These functions enable them to interact and modulate enzymatic activities and, thereby, regulate signal pathways for cell survival and death (Tukun *et al.* 2014).

Antioxidant activity: It is crucial to evaluate the antioxidant potential of extracts using more than one method due to the different mechanisms of antioxidant activity (Shi *et al.* 2021), therefore, DPPH (2,2-diphenyl-1-picryl-hydrazyl-hydrate) method was used (Table 2). In DPPH assay, the trend of antioxidant activity of *M. oleifera* germplasm leaves ranged from 14.83 to 31.29 µmol TE/g, whereas in pod it ranged from 4.85 to 21.36 µmol TE/g. Among leaves, CHES D-45 recorded the highest antioxidant potentiality followed by CHES D-34 and CHES D-40, while in pod, CHES D-34 had higher antioxidant potentiality followed by CHES D-40 and CHES D-45. The higher antioxidant activity of leaves has a linear relationship with phenolic compounds, which helps to develop products that enhance food products oxidative stability (Kashyap *et al.* 2022). These findings are in line with the results of Tukun *et al.* (2014), Ali *et al.* (2018), Nouman *et al.* (2018), Oyeyinka and Oyeyinka (2018), Shi *et al.* (2021), Kashyap *et al.* (2022) and Yadav *et al.* (2022). The higher concentration of phenolic antioxidants results higher antioxidant activity in leaves. Yadav *et al.* (2022) mentioned that the *M. oleifera* leaves are rich in minerals and Zn, Cu and Se are co-factors in antioxidant activity which might be contributing in strong free radical scavenging activity of leaves. *M. oleifera* leaves are also rich in B and Mn which helps in utilization of dietary nutrients in body. Natural antioxidants are always of very high importance for health as a part of food and as a part of cosmetics for topical applications to combat the detrimental effect of free radicals on internal and external organs like skin aging etc (Bhalla *et al.* 2021).

Nutrient content: The results regarding the nutrient content (mg/100 g dw basis) in leaves of *M. oleifera* germplasm are presented in Table 3. The germplasm available at station analyzed for various nutrients recorded wide variability in leaves. The concentration of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulphur (S), iron (Fe), zinc (Zn), manganese (Mn) and copper (Cu) was ranged from 3452.2 to 4780.0, 160.5 to 217.2, 796.4 to 1849.4, 1854.5 to 5052.1, 267.1 to 1255.4, 1423.4 to 4397.2, 8.0 to 94.3, 2.7 to 8.1, 18.4 to 32.9 and 0.8 to 3.8 respectively, in *M. oleifera* dry leaves powder. The highest content of N (4780.0 mg/100g), Ca (5052.1 mg/100 g), Fe (94.3 mg/100 g) and Mn (32.9 mg/100 g) was recorded in CHES D-40 germplasm among 34 germplasm of

Table 2 Comparative evaluation of antioxidants properties of drumstick germplasm pod, pulp, skin and leaves from rainfed semi-arid region

Germplasm	Total phenols (mg GAE/100 g)				Ascorbic acid (mg/100 g)		DPPH (μ mol TE/g)	
	Pod	Pulp	Skin	Leaves	Leaves	Pod	Leaves	Pod
CHES D-2	30.19	173.80	118.94	654.55	428.48	216.72	32.24	6.58
CHES D-3	33.29	191.03	131.56	877.39	375.36	241.92	30.37	11.05
CHES D-4	31.56	181.19	124.70	831.92	472.47	253.01	28.62	10.87
CHES D-5	33.07	189.58	130.02	871.74	313.03	209.16	24.39	14.71
CHES D-6	32.55	186.99	128.27	858.02	415.97	219.74	22.35	12.69
CHES D-8	35.66	205.97	141.33	939.98	469.61	243.94	29.43	14.83
CHES D-9	34.89	199.76	136.99	919.72	415.20	193.04	15.97	9.56
CHES D-10	28.09	161.49	110.64	740.33	421.87	205.63	25.64	11.87
CHES D-11	33.63	193.37	132.49	586.50	333.01	212.19	26.55	12.97
CHES D-13	33.36	191.79	131.73	879.23	494.11	238.40	14.88	9.26
CHES D-16	30.39	174.75	119.60	801.09	478.00	243.94	16.74	8.46
CHES D-17	34.60	198.93	135.99	911.94	473.80	256.54	18.22	11.01
CHES D-18	29.50	169.50	116.42	777.49	423.83	210.68	28.13	10.26
CHES D-19	34.96	201.24	137.70	921.42	425.45	199.59	25.93	13.20
CHES D-21	27.34	156.87	108.10	720.67	429.20	236.38	28.26	14.48
CHES D-22	31.76	182.90	125.04	837.07	445.54	242.93	25.83	14.89
CHES D-23	37.05	198.74	136.33	910.61	501.36	258.05	24.45	13.30
CHES D-24	30.46	174.59	119.74	802.81	409.95	217.23	19.20	9.40
CHES D-25	28.79	164.84	114.04	758.76	498.87	232.85	23.20	12.28
CHES D-26	31.59	182.13	124.25	832.73	345.59	250.49	29.24	19.53
CHES D-29	33.88	194.19	82.42	448.21	445.01	245.95	21.79	11.89
CHES D-30	28.83	166.00	80.07	759.95	449.91	202.11	17.91	7.69
CHES D-31	26.36	151.55	73.38	694.74	394.64	222.27	14.83	4.85
CHES D-32	30.78	176.99	133.19	811.37	487.29	207.15	18.92	9.05
CHES D-34	30.09	272.99	113.89	793.01	457.31	252.00	31.09	21.36
CHES D-35	28.14	161.81	86.87	741.77	499.70	219.24	17.09	7.11
CHES D-36	34.42	197.92	116.63	907.33	348.04	257.54	16.10	6.52
CHES D-37	26.78	153.99	88.34	705.93	472.34	247.47	20.36	10.48
CHES D-39	28.57	162.39	88.29	752.98	474.94	254.02	17.49	7.26
CHES D-40	39.90	232.71	158.38	970.16	502.57	266.11	31.06	20.87
CHES D-42	38.66	221.57	132.10	709.19	454.13	241.42	14.88	15.08
CHES D-45	39.32	235.22	169.06	830.28	413.55	245.45	31.29	17.16
CHES D-50	30.11	170.42	148.07	793.71	394.50	223.78	26.14	16.10
Thar Harsha	36.23	208.66	134.54	657.69	458.10	248.98	29.23	15.46
CD (P=0.05%)	0.58	5.24	21.87	25.06	44.23	3.46	5.38	1.88
SE(m)	0.20	1.81	7.57	8.67	15.30	1.20	1.86	0.65
SE(d)	0.28	2.57	10.70	12.26	21.64	1.69	2.63	0.92
C.V.	0.88	1.39	8.81	1.54	4.96	0.73	11.22	7.60

Table 3 Evaluation of nutritional properties in leaves of drumstick germplasm under rainfed semi-arid condition (DW basis)

Germplasm	N (mg/100 g)	P (mg/100 g)	K (mg/100 g)	Ca (mg/100 g)	Mg (mg/100 g)	S (mg/100 g)	Fe (mg/100 g)	Zn (mg/100 g)	Mn (mg/100 g)	Cu (mg/100 g)
CHES D-2	3,992.4	183.9	1,724.9	2,248.3	672.9	2,337.6	9.3	3.0	20.5	0.2
CHES D-3	3,940.6	202.7	912.9	3,387.2	442.8	3,915.4	8.0	3.9	23.3	0.8
CHES D-4	3,550.3	192.2	1,608.7	2,369.9	511.4	1,815.9	16.2	4.2	25.3	4.2
CHES D-5	4,169.2	201.4	1,059.7	1,854.1	789.1	2,536.2	10.9	2.8	20.1	1.4
CHES D-6	4,231.9	198.2	796.4	4,186.0	516.9	2,706.7	23.6	3.3	27.6	2.6
CHES D-8	4,334.0	217.2	1,001.2	3,017.7	407.0	2,647.9	16.9	7.0	23.4	0.9
CHES D-9	3,803.8	212.5	874.1	3,689.5	510.6	1,717.0	10.0	4.2	18.4	3.2
CHES D-10	3,514.3	171.0	968.6	2,363.2	599.6	2,362.7	30.3	2.7	19.7	2.2
CHES D-11	3,629.1	204.8	1,526.0	3,296.2	554.7	1,982.0	13.9	4.0	30.6	1.9
CHES D-13	3,638.3	203.1	1,019.9	4,367.1	876.7	3,845.2	49.4	6.6	25.8	1.2
CHES D-16	3,923.8	185.1	1,222.5	4,686.7	627.9	2,442.7	39.2	8.0	28.3	0.3
CHES D-17	4,080.1	210.7	1,696.1	4,034.6	856.8	1,423.4	43.7	4.4	24.7	3.4
CHES D-18	3,679.8	179.6	1,347.8	2,538.7	315.2	2,933.9	83.2	3.8	29.9	1.5
CHES D-19	3,622.6	212.9	1,270.1	3,840.1	659.0	2,206.4	22.6	5.9	19.0	0.8
CHES D-21	3,936.8	166.5	1,611.1	2,120.0	671.2	3,635.6	24.3	5.2	22.6	1.9
CHES D-22	4,090.1	193.4	1,849.4	3,697.2	719.5	3,610.5	13.9	6.8	23.3	2.3
CHES D-23	3,452.2	210.4	1,138.0	3,347.7	402.8	3,091.0	17.5	4.9	24.9	1.8
CHES D-24	4,610.4	185.5	1,021.1	4,496.1	455.6	1,856.8	18.7	4.4	20.9	1.3
CHES D-25	4,095.5	175.3	1,298.3	3,244.2	859.9	3,620.7	22.6	3.4	31.7	0.8
CHES D-26	3,901.8	192.4	1,247.6	4,964.4	686.2	2,761.8	40.1	3.1	23.9	2.6
CHES D-29	3,514.1	206.3	1,036.9	3,889.4	419.8	2,181.4	23.5	2.5	26.4	1.0
CHES D-30	3,777.4	175.6	1,516.0	4,653.1	989.4	1,645.5	15.1	5.5	19.2	0.4
CHES D-31	3,726.9	160.5	969.5	3,872.1	431.4	2,343.5	24.3	3.2	27.3	2.2
CHES D-32	3,692.1	187.5	1,114.2	2,693.1	638.9	1,452.4	24.0	5.2	19.8	1.9
CHES D-34	3,915.2	183.2	1,434.7	3,471.4	1,255.4	1,927.7	77.4	8.1	24.2	1.5
CHES D-35	3,637.6	171.4	1,269.9	3,461.7	757.8	3,786.5	18.8	2.9	21.0	1.7
CHES D-36	3,502.7	209.6	1,508.7	3,008.8	929.5	2,483.8	35.1	4.7	24.9	3.0
CHES D-37	3,983.7	163.1	1,041.4	2,219.7	538.3	3,016.8	43.6	3.6	23.6	2.0
CHES D-39	3,998.7	194.9	1,166.8	3,583.5	845.3	3,483.4	35.9	3.2	20.3	2.7
CHES D-40	4,780.0	174.0	1,543.1	5,052.1	1,134.2	4,144.8	94.3	7.2	32.9	3.7
CHES D-42	4,585.7	213.5	1,357.3	4,274.7	964.1	1,402.5	40.6	4.1	28.0	3.8
CHES D-45	4,451.7	178.4	1,573.9	3,889.0	1,002.4	3,372.6	69.2	4.0	21.4	3.1
CHES D-50	3,968.2	211.6	1,331.1	4,946.0	267.1	3,155.4	54.2	3.3	26.5	1.9
Thar Harsha	3,868.0	187.9	1,714.1	4,318.4	923.2	4,397.2	53.1	3.8	20.6	1.1
CD (P=0.05%)	128.6	8.2	69.2	495.9	12.3	103.2	1.9	0.1	0.4	0.2
SE(m)	44.5	2.9	24.0	171.6	4.3	35.7	0.7	0.1	0.1	0.1
SE(d)	63.0	4.0	33.9	242.7	6.0	50.5	0.9	0.1	0.2	0.1
C.V.	1.6	2.1	2.6	6.8	0.9	1.9	2.8	1.6	0.9	4.6

the station conserved under semi-arid condition. The highest P content (217.2 mg/100 mg) was recorded in CHES D-8 followed by CHES D-42 (213.5 mg/100 g), CHES D-19 (212.9 mg/100 g) and CHES D-9 (212.5 mg/100 g) while, the lowest was recorded in CHES D-31 (160.5 mg/100 g). The highest K concentration was recorded in CHES D-22 (1849.4 mg/100 g) followed by CHES D-2 (1724.9 mg/100 g) while, the lowest was estimated in CHES D-6 (796.4 mg/100 g). The maximum concentration of Mg was recorded in CHES D-50 (1255.4 mg/100 g) followed by CHES D-40 (1134.2 mg/100 g) while, the minimum was recorded in CHES D-32 (267.1 mg/100 g) followed by CHES D-18 (315.2 mg/100 g). The highest concentration of S was recorded in Thar Harsha (4397.2 mg/100 g) followed by CHES D-40 (4144.8 mg/100 g) while, the lowest was recorded in CHES D-17 (1423.4 mg/100 g) followed by CHES D-32 (1452.4 mg/100 g). The highest Zn content (8.1 mg/100 mg) was recorded in CHES D-45 followed by CHES D-16 (8.0 mg/100 g) while, the lowest was recorded in CHES D-13 (2.7 mg/100 g). The maximum concentration of Cu was recorded in CHES D-42 (3.8 mg/100 g) followed by CHES D-40 (3.7 mg/100 g) while, the minimum was recorded in CHES D-2 (0.2 mg/100 g) followed by CHES D-3 (0.8 mg/100 g). *M. oleifera* is an excellent source of minerals to overcome the malnutrition especially in children and pregnant women. These results are in conformity with the earlier findings of Annual Report (2020), Shi *et al.* (2021) and Yadav *et al.* (2022). The leaves *M. oleifera* have two to three times higher Ca than the cow milk (Islam *et al.* 2020). The Ca, Fe and P are very essential elements for children and the aged who need higher intakes of such nutrients for hemoglobin, teeth and bone formation. These minerals have contributed to improve coagulum and nervous function (Yadav *et al.* 2022). Fe tablets can be

replaced with *M. oleifera* leaf powder to treat anemia as it has Fe thrice than spinach and 12–14 times than beef. It also helps in making haemoglobin and myoglobin in human body. The intake of *M. oleifera* leaves powder can clinch the nutritional security, reduce the risk of cancer being a powerful anti-cancer agent and its usage within a limited scale is safe and reliable (Kashyap *et al.* 2022, Yadav *et al.* 2022). The consumption of zinc helps in the healing of wounds, growth of sperm cells and synthesis of DNA and RNA (Valdez-Solana *et al.* 2015). Hence, consumption of 70 g per day of *M. oleifera* is satisfactory and avert over accumulation of minerals (Gopalakrishnan *et al.* 2016). CHES D-40 followed by CHES D-34 and CHES D-42 may be utilized for developing functional food based on their good mineral content and antioxidants.

Protein content: The results pertaining to leaves and pulp of *M. oleifera* germplasm are presented in Fig 1 (C.D. 0.805; 0.469 and C.V. 1.605; 1.55, respectively at 5%). Protein content ranged from 21.58 to 29.87 g/100 g in leaves, whereas in pod, it ranged from 13.00 to 18.00 g/100 g. The germplasm CHES D-40 (29.87 g/100 g) recorded the maximum protein content in leaves followed by CHES D-24 (28.82 g/100 g) and CHES D-42 (28.66 g/100 g). Likewise in pod, CHES D-40 (18.00 g/100 g) recorded the maximum protein content followed by CHES D-34 (17.36 g/100 g) and CHES D-42 (17.26 g/100 g). The variation in protein content may be due to diverse germplasm, climate and the geography of development of the crop. Islam *et al.* (2020) reported in a study that leaves and pods of *M. oleifera* have 29–33% and 13% protein content, respectively. He also illustrated that leaves have two times more protein than pods. The same trend of protein content in leaves (10.4–30.29%) mentioned by Kashyap *et al.* (2022). *M. oleifera* leaves can be used as food supplement source as it have more digestible

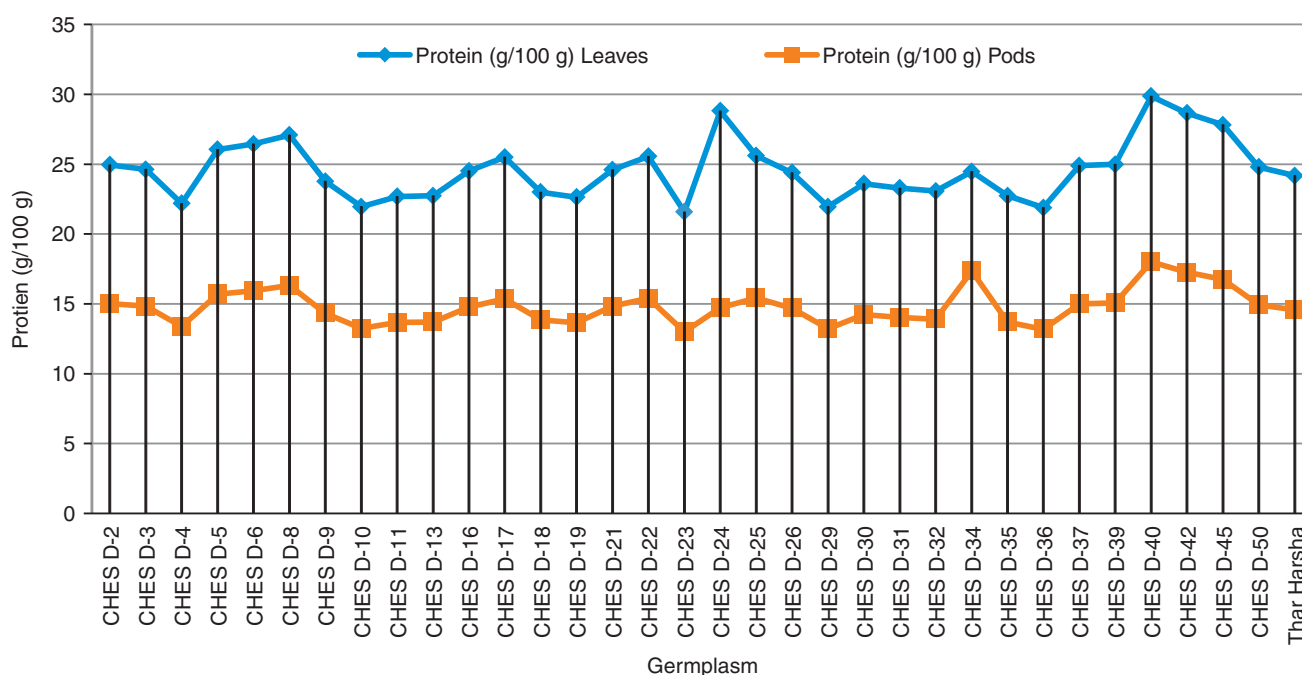


Fig 1 Protein content in leaves of drumstick germplasm under rainfed semi-arid region.

protein than milk. They are also rich source of amino acids which helps in boosting the immune system and meeting a substantial proportion of animal protein (Moyo *et al.* 2011, Singh *et al.* 2018). The values found in the present study are in agreement with the values reported by Valdez-Solana *et al.* (2015). These findings are within the range as reported by Oyeyinka and Oyeyinka (2018), Sultana S (2020), Shi *et al.* (2021), Kashyap *et al.* (2022) and Yadav *et al.* (2022).

M. oleifera is a rich source of digestible protein, micro-nutrients, phyto-chemicals etc. and can save millions of lives by developing different nutraceuticals and functional foods for needy ones. The germplasms CHES D-34, CHES D-40 and CHES D-42 are found promising under semi-arid ecosystem with higher antioxidants and mineral contents which further can be advanced or may be desirable for crop improvement to breed a variety of *M. oleifera* with high antioxidants and nutrients. Concisely, *M. oleifera* is an emerging future crop for developing functional food to meet the nutritional requirement and to diminish the menace of dietary deficiency particularly in developing countries.

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