Indian Journal of Ecology (2024) 51(4): 732-737
DOI: https://doi.org/10.55362/IJE/2024/4301

Manuscript Number: 4301
NAAS Rating: 5.38

Comparison of Phenolic Content, Flavonoid Content and Antioxidant Activities of *Phyllanthus emblica* L. From North-East, India

K. Pung Rozar, Suresh Kumar*, Rajnish Sharma[1], Shijagurumayum B. Sharma Milica M. Nongrum and Jyoti Jopir

Department of Forestry, Mizoram University, Aizawl, (Mizoram)-796 004, India
[1]Department of Biotechnology, Dr YS Parmar UHF, Nauni, Solan-173 230, India
E-mail: suresh@mzu.edu.in

***Abstract*:** The study was focused on investigating the antioxidant activity of *Phyllanthus emblica* fruits collected from different regions of North-East, India. The antioxidant properties of the fruit were examined using a DPPH radical scavenging test and a reducing power assay after it was extracted with methanol and ethyl acetate. There were significant variations in the total phenolic, flavonoid, and antioxidant activity depending on the population and solvent used. The phenol ranges from 57.87 (Khasi Hills) to 126.32 mg GAE/g (Garo Hills). The maximum and minimum flavonoid was between 20.14 (KRB) and 45.25 mg QE /g (LNL). The IC_{50} of the extracts ranges between 10.67 (GH) to 42.96 (RTM).The findings highlight the considerable potential of aonla extracts from North-East India as antioxidants. Furthermore, chemical composition and biological activity of these extracts are influenced by the specific population and solvent employed in the extraction process. These results contribute to understanding of the diverse antioxidant properties of Indian gooseberry and emphasize the need for further investigation into its regional variations and optimal extraction methods.

Keywords: DPPH*, Emblica officinalis*, North-East India, Population, Reducing power

Aonla, also known as the Indian gooseberry (*Phyllanthus emblica* L. syn *Emblica officinalis* Gaertn.), is a medium-sized tree growing up to 20 m in height. It is one of the major native fruits of the Indian subcontinent and valued for its therapeutic and medicinal benefits (Wali et al 2015). Aonla fruits are utilised in a variety of ayurvedic formulations and value-added products, and contain a wide range of chemical components, like tannins, phenols and alkaloids (Sachan et al 2013). Due to its potent biological and antioxidant properties, amla prevents a wide range of ailments as it contains essential nutrients and a high concentration of vitamin C (Dasaroju and Gottumukkala 2014). ROS produced as a result of cellular metabolism and many other biochemical reactions, like hydroxyl radicals, superoxide radicals and hydrogen peroxide are the main causes of oxidative damage in aerobic cells, including protein denaturation, mutagenesis, and lipid peroxidation.

Free radicals play a significant role in the etiology of some severe diseases, including diabetes, inflammation, atherosclerosis, cataracts, liver cirrhosis, cancer, neurological disorders, and liver disease, these diseases could potentially be improved by compounds that can scavenge free radicals (Liu et al 2008). Phenolic compounds are one of the most diverse and commonly found groups of secondary metabolites from plants, and are responsible for a wide range of beneficial impacts in a wide range of illnesses due to their Antioxidant activity, which aids in the protection of cells from oxidative harm induced by reactive oxygen species (Soobrattee et al 2005). Antioxidants, which are produced by the body as well as obtained from dietary sources and nutraceuticals, regulate the amount and availability of free radicals. The combined effects of phenols, flavonoids, and ascorbic acid were discovered in the study by Reddy et al (2011), which indicated the antioxidant nature of *Emblica officinalis.* The phenolic content and antioxidant properties of aonla populations and various solvents used in fruit extracts have been studied. For instance, Liu et al (2008) reported a great degree of variability in the phenolic and anti-oxidant properties of fruit extracts from several populations of aonla from China. A significant variation was also recorded in the phenolic and antioxidant properties of aonla extract from different solvents used for extraction (Verma et al 2018). However, the diversity of the antioxidant properties from Northeast India's aonla population hasn't received much attention even though the region has wide geographic variations in terms of altitudes, climates, soils and forest type etc. The region also comes under the Indo-Burma biodiversity hotspot. Therefore, this paper aimed to study the phenolic and antioxidant activity of methanolic and ethyl acetate extract of *Emblica* fruits collected from different

regions of northeast India, using well-established in vitro testing methods.

MATERIAL AND METHODS

The study was conducted in the Forestry Department of Mizoram University in 2021-2022. The aonla fresh fruits were collected at harvest maturity from nine locations of seven states of North-East, India, viz., Aizawl-Mizoram (AZW), Champaknaga- Tripura (CPK), East Karbi Anlong-Assam (KRB), Garo hills- Meghalaya (GH), Khasi hills - Meghalaya (KH), Lunglei,- Mizoram (LNL), Maram-Manipur (MRM), Roing-Arunachal Pradesh (RNG), Rotomi-Nagaland (RTM). The fruits were stored in air-tight packets until analysis.

The fruits were oven air-dried at 40ºC for 24 hours and the dried fruits were ground uniformly. Two solvents were used for the preparation of extraction i.e., methanol and ethyl acetate. Dried aonla fruit powder (100 g) was extracted with 800 ml of the respective solvents for 24 hours in a conical flask and the extracts were shaken from time to time, after 24 hours and were filtered through Whatman paper 1. The methanolic and ethyl acetate extracts were then concentrated at 45 ºC in a Rota-vapor under low pressures. The end residue was collected in a container (air-tight) and stored at 4ºC for further analysis.

Blois (1958) approach was modified slightly to evaluate the extracts' ability to scavenge DPPH free radicals. The absorbance was measured in a UV-visible spectrophotometer at 517 nm. The IC_{50} values were calculated using a non-linear regression method. Ascorbic acid was used as the standard reference. The DPPH scavenging % was determined as

$$\text{DPPH scavenging \%} = \frac{\text{Control absorbance} - \text{Sample absorbance}}{\text{Control absorbance}} \times 100$$

The reducing power of aonla was determined using the Oyaizu method (1986) at absorbance 700 nm. Reducing power increases as the absorbance of the reaction mixture increases. With slight modifications, the Folin-Ciocalteu technique was employed to assess the total phenolic content of the extract (Baba and Malik 2015) at 650 nm absorbance. The total phenolic content was calculated using the calibration curve and expressed in mg of gallic acid equivalent per gram of dry weight. The aluminum chloride colorimetric technique was used to determine flavonoid concentration (Liu et al 2008). The absorbance was measured at 510 nm, and quercetin was used to create a standard curve. The flavonoid concentration was measured in milligrams of quercetin equivalent (QE) per gram of dry basis.

Statistical analysis: SPSS (25) and Microsoft Excel were used for statistical analysis. IC_{50} values were obtained using least-squares-based linear regression methods.

RESULTS AND DISCUSSION

Plant antioxidant activity is related to the redox characteristics of phenolic chemicals, which are important components of plants. There were significant differences in phenolic from various *P. emblica* populations in both methanol and ethyl acetate extracts. The phenol content in methanol extract ranged from 69.80 (CPK) to 126.32 mg GAE/g (GH) (Table 2). The maximum phenol content in ethyl acetate extract was in MRM (115.15 mg GAE/g) while the minimum content was in KH (57.87 mg GAE/g). MRM with 35.35 QE/g had the highest flavonoid content and KRB with 20.14 mg QE/g, the lowest flavonoid content from methanol extract. Among ethyl acetate extracts the flavonoid content ranges between 26.08 mg QE/g (KH) and 45.25 mg QE/g (LNL). Liu et al (2008) also reported significant variations in phenol and flavonoid content from different regions in China. The variation in the total polyphenol content among different aonla extracts could be attributed to factors such as distinct maturity stages, diverse genetic makeup, and varying

Table 1. Coordinates of the different regions of North-East India selected for aonla fruit collection

Region	State	Code	Latitude	Longitude	Elevation (m)
Aizawl	Mizoram	AZW	23°45'32"N -23°48'26.19"N	92°38'45"E - 92°39'51"E	622 - 850
Champaknagar	Tripura	CPK	23°47'42"N - 23°49'22"N	91°29'04"E - 91°31'32"E	79 -137
East Karbi Anlong	Assam	KRB	25°50'00"N - 25°53'55"N	93°24'23"E - 93°28'29"E	218 - 230
Garo Hills	Meghalaya	GH	25°29'50"N - 25°31'51"N	90°35'22"E - 90°37'30"E	293 - 524
Khasi Hills	Meghalaya	KH	25°38'45"N - 25°54'59"N	91°52'15"E - 91°59'26"E	903 - 1114
Lunglei	Mizoram	LNL	22°50'53.0"N -22°48'58"N	92°47'45.3"E - 92°49'11"E	927 - 1452
Maram	Manipur	MRM	25°24'18"N - 25°25'44"N	94°04'58"E - 94°05'56"E	1309 - 1667
Roing	Arunachal Pradesh	RNG	28°05'58"N -28°11'26"N	95°49'01"E - 95°51'35"E	358 - 797
Rotomi	Nagaland	RTM	26°03'51"N -26°05'09"N	94°23'57"E - 94°26'22"E	702 - 1112

growing conditions (Hilton 1973). Other studies have found considerable differences in the phenolic content of *Syzygium jambos* and *Scrophularia striata* related to climatic parameters such as average temperature, rainfall and concentration of nutrients in the soil (Rezende et al 2015, Zargoosh et al 2019).

Extracts from all *Phyllanthus emblica* exhibited substantial free radical scavenging activities (Table 3, 4). Among the methanolic extracts, Garo population showed the highest activity (IC_{50} 10.67 µg/ml) with 89% inhibition, while the CPK (IC_{50} 16.76 µg/ml) population showed the lowest activity with 59.3% inhibition. Among ethyl acetate extracts the highest activity was from KRB regions (IC_{50} 9.82 µg/ml) with 82.32% inhibition whereas the lowest activity was recorded from RTM regions (IC_{50} 42.96 µg/ml) with 25.67% inhibition. The IC_{50} scavenging activity of ascorbic acid was 8.22 µg/ml.

The reducing power is a rapid and easy screening method for determining antioxidant capability. The presence of antioxidants causes the Fe3+/ferricyanide complex to be converted into its ferrous state in this assay. This change can be seen by observing the production of Perl's Prussian blue at a wavelength of 700 (Alam et al 2016). A greater absorbance value at 700 nm indicates an increase in sample reduction power (Lih et al 2001). This study evaluated the ferric-reducing activity of different extracts of aonla from different regions (Table 5). With increasing concentrations of the extracts, the absorbance increases too. There were significant differences among the aonla populations, whereas low significant differences were observed between ethyl acetate and methanolic extracts. All the aonla populations' extracts showed high reducing power activity. Ascorbic acid and gallic acid were used as standards to compare with aonla extracts.

Methanol extracts from RNG (0.445 ± 0.008) populations showed the maximum reducing power while the least reducing power was recorded in CPK MET (0.273±0.007) populations at 300µg/ml concentration. In the extracts of ethyl acetate, the reducing power also ranges from 0.230 ± 0.014 (RTM population) to 0.454 ±0.009 (KRB population) at 300 µg/ml concentration. Compared to the tested extracts, the positive reference standards had a relatively stronger reducing power. The reducing power of ascorbic acid at 300 µg/ml concentration was recorded at 0.79 and gallic acid at 0.89.Compounds of phenolic and flavonoids play a significant role in antioxidant activity by neutralizing free radicals through hydrogen atom donation. Additionally, their chemical structure is well-suited for scavenging free radicals (Amarowicz et al 2004). Other literature also reported a linear correlation between the phenol and flavonoid with antioxidant activity capacity (Liu et al 2008, Jan et al 2013,

Table 3. IC_{50} values of methanolic and ethyl acetate extracts of *Phyllanthus emblica* fruits from North-East India

Sample	IC_{50}	
	Methanol	Ethyl acetate
AZW	14.41	12.47
CPK	16.76	14.03
GH	10.67	10.67
KH	14.32	26.75
KRB	14.85	9.82
LNL	15.82	11.91
MRM	14.12	15.50
RNG	12.48	12.16
RTM	16.00	42.96
Standards (Ascorbic acid)	8.22 (IC_{50})	

Table 2. Phenol and flavonoid content of aonla fruits from different regions of North-East India

Sample	Phenol (mg GAE/g)		Flavonoid (mg QE/g)	
	Methanol	Ethyl acetate	Methanol	Ethyl acetate
AZW	98.05^{d}	82.12^{e}	22.81^{bc}	39.14^{bc}
CPK	69.80^{g}	105.96^{b}	21.73^{bc}	41.06^{ab}
GH	126.32^{a}	89.67^{d}	33.25^{a}	43.11^{ab}
KH	123.92^{a}	57.87^{g}	23.79^{bc}	26.08^{e}
KRB	102.79^{c}	99.52^{c}	20.14^{c}	37.39^{bcd}
LNL	87.49^{e}	98.95^{c}	21.85^{bc}	45.25^{a}
MRM	116.75^{b}	115.15^{a}	35.35^{a}	31.59^{de}
RNG	104.48^{c}	78.59 ^{e}	26.86^{b}	34.18^{cd}
RTM	81.21^{f}	67.28 ^{f}	21.23^{c}	34.43^{cd}

Means within the same column followed by the same letter, do not differ significantly at P ≤0.05

Table 4. DPPH radical scavenging activities of aonla extracts (methanol and ethyl acetate) from different regions of North-East India (Mean ± SD)

Parameters	Concentration (µg/ml)						
	2.50	2.50	5.00	7.50	10.00	15.00	20.00
Ascorbic acid	16.06 ± 0.9	16.06 ± 0.9	28.81 ± 1.8	47.90 ± 2.5	61.07 ± 1.0	89.64 ± 1.1	92.22 ± 0.7
AZW MET	9.13 ± 1.0	9.13 ± 1.0	16.69 ± 1.1	26.47 ± 1.1	34.91 ± 0.4	52.11 ± 1.2	69.33 ± 1.0
CPK MET	9.76 ± 0.9	9.76 ± 0.9	16.34 ± 0.8	24.44 ± 1.1	27.60 ± 0.5	46.37 ± 0.7	59.30 ± 1.5
GR MET	15.51 ± 1.5	15.51 ± 1.5	25.37 ± 0.9	37.33 ± 0.9	46.64 ± 0.8	68.13 ± 0.4	89.07 ± 1.0
KH MET	13.44 ± 1.1	13.44 ± 1.1	21.18 ± 1.4	29.67 ± 1.1	35.60 ± 0.7	52.43 ± 0.3	67.53 ± 0.5
KRB MET	8.95 ± 0.8	8.95 ± 0.8	16.58 ± 0.9	23.57 ± 1.3	34.68 ± 1.0	50.50 ± 0.7	67.31 ± 1.5
LNL MET	8.98 ± 1.4	8.98 ± 1.4	16.49 ± 0.8	25.19 ± 1.0	30.81 ± 0.7	47.79 ± 0.6	62.88 ± 1.0
MRM MET	12.81 ± 1.4	12.81 ± 1.4	20.77 ± 0.8	28.53 ± 0.8	36.47 ± 1.1	52.93 ± 0.9	68.82 ± 1.3
RNG MET	15.72 ± 0.8	15.72 ± 0.8	23.47 ± 0.8	33.06 ± 0.7	42.92 ± 1.6	61.66 ± 1.1	72.78 ± 0.8
RTM MET	9.53 ± 1.2	9.53 ± 1.2	17.25 ± 0.8	24.09 ± 1.0	32.84 ± 0.9	46.76 ± 0.7	61.88 ± 0.7
AZW.A	12.78 ± 1.0	12.78 ± 1.0	22.40 ± 1.0	32.48 ± 1.1	40.39 ± 1.0	58.95 ± 1.3	78.18 ± 0.9
CPK E.A	15.14 ± 0.7	15.14 ± 0.7	21.29 ± 0.9	29.78 ± 1.8	37.98 ± 0.9	52.94 ± 1.4	68.40 ± 0.9
GR E.A	14.46 ± 1.6	14.46 ± 1.6	25.48 ± 1.7	36.52 ± 0.9	47.03 ± 0.7	69.02 ± 0.7	89.86 ± 1.0
KH E.A	4.48 ± 0.6	4.48 ± 0.6	8.57 ± 0.9	12.22 ± 1.0	17.98 ± 1.1	28.10 ± 0.5	37.14 ± 0.9
KRB E.A	21.26 ± 1.2	21.26 ± 1.2	32.61 ± 0.9	42.15 ± 1.0	51.19 ± 0.7	74.38 ± 0.5	82.32 ± 0.5
LNL E.A	14.68 ± 1.1	14.68 ± 1.1	24.20 ± 1.1	34.09 ± 1.7	42.78 ± 1.1	61.26 ± 0.4	80.07 ± 0.9
MRM E.A	8.98 ± 2.1	8.98 ± 2.1	16.55 ± 1.	23.85 ± 1.1	32.71 ± 1.0	48.41 ± 1.1	64.34 ± 1.0
RNG E.A	21.29 ± 1.1	21.29 ± 1.1	33.08 ± 0.9	44.79 ± 1.6	56.56 ± 1.9	76.14 ± 0.2	83.51 ± 1.7
RTM E.A	8.03 ± 0.8	8.03 ± 0.8	8.99 ± 1.0	11.77 ± 0.8	15.15 ± 0.4	20.72 ± 1.1	25.61 ± 0.8

MET – Methanol, E.A – Ethyl acetate, LNL – Lunglei, KH- Khasi hills, AZW – Aizawl, MRM – Maram, KRB – Karbi Anglong, RTM – Rotomi, GR- Garo hills, CPK – Champaknagar, RNG – Roing

Table 5. Reducing power of aonla fruits from nine populations of North-East India (at absorbance 700nm) (Mean ± SD)

Parameter	Concentration(µg /ml)					
	50	100	150	200	250	300
Ascorbic Acid	0.206 ±0.009	0.354 ± 0.007	0.471 ± 0.004	0.547 ± 0.007	0.681 ± 0.008	0.787 ± 0.007
Gallic Acid	0.259 ±0.008	0.437 ±0.003	0.527 ±0.006	0.636 ±0.007	0.790 ±0.011	0.892 ±0.013
AZW MET	0.073 ±0.005	0.121 ±0.004	0.205 ±0.032	0.251 ±0.027	0.306 ±0.009	0.370 ±0.009
CPK MET	0.052 ±0.003	0.105 ±0.007	0.156 ±0.014	0.197 ±0.007	0.215 ±0.007	0.273 ±0.007
GAR MET	0.090 ±0.005	0.163 ±0.014	0.205 ±0.014	0.291 ±0.037	0.333 ±0.011	0.378 ±0.011
KH MET	0.064 ±0.002	0.115 ±0.006	0.218 ±0.008	0.250 ±0.015	0.312 ±0.018	0.352 ±0.021
KRB MET	0.086 ±0.006	0.154 ±0.005	0.220 ±0.037	0.269 ±0.024	0.313 ±0.005	0.345 ±0.005
LNL MET	0.058 ±0.006	0.091 ±0.002	0.149 ±0.045	0.204 ±0.02	0.242 ±0.020	0.288 ±0.020
MRM MET	0.085 ±0.003	0.147 ±0.006	0.174 ±0.01	0.225 ±0.018	0.296 ±0.017	0.330 ±0.017
RNG MET	0.096 ±0.003	0.175 ±0.004	0.234 ±0.005	0.319 ±0.013	0.382 ±0.008	0.445 ±0.008
RTM MET	0.177 ±0.004	0.222 ±0.009	0.244 ±0.01	0.303 ±0.021	0.350 ±0.029	0.403 ±0.029
AZW E.A	0.095 ±0.008	0.151 ±0.005	0.242 ±0.019	0.306 ±0.009	0.346 ±0.046	0.341 ±0.030
CPK E.A	0.070 ±0.009	0.118 ±0.004	0.165 ±0.004	0.224 ±0.006	0.292 ±0.021	0.330 ±0.007
GAR E.A	0.124 ±0.004	0.172 ±0.007	0.241 ±0.007	0.320 ±0.024	0.348 ±0.041	0.347 ±0.003
KH E.A	0.077 ±0.005	0.125 ±0.005	0.202 ±0.005	0.252 ±0.003	0.306 ±0.002	0.307 ±0.002
KRB E.A	0.107 ±0.003	0.175 ±0.007	0.283 ±0.002	0.358 ±0.003	0.426 ±0.009	0.454 ±0.009
LNL E.A	0.086 ±0.004	0.145 ±0.014	0.209 ±0.004	0.289 ±0.004	0.334 ±0.015	0.395 ±0.013
MRM E.A	0.063 ±0.004	0.122 ±0.034	0.159 ±0.021	0.193 ±0.007	0.253 ±0.012	0.332 ±0.020
RNG E.A	0.111 ±0.003	0.225 ±0.007	0.311 ±0.011	0.407 ±0.007	0.435 ±0.017	0.449 ±0.007
RTM E.A	0.039 ±0.004	0.076 ±0.004	0.136 ±0.054	0.146 ±0.004	0.178 ±0.009	0.230 ±0.014

See Table 3 for details

Table 6. Correlation coefficients (*r*) between IC_{50} values of DPPH and phenolic content

	Correlation coefficients (r)	
	Phenol	Flavonoid
DPPH (Methanol)	-0.80	-0.70
DPPH (Ethyl Acetate)	-0.62	-0.49

Aryal et al 2019). In methanol extracts, negative significant correlation was recorded between IC_{50} DPPH radical scavenging activity with both phenol and flavonoid (Table 6). In ethyl acetate extracts, the correlation of IC_{50} radical scavenging activity of DPPH with phenol and flavonoid was also negative.

CONCLUSION

The phenol and flavonoid content, as well as the DPPH radical scavenging activity and reducing power of *Phyllanthus emblica* extracts from different regions of North-East, India showed significant differences among different extracts, indicating that various factors such as genetic makeup, growing conditions, and maturity stages of plants affect the content of bioactive compounds and their bioactivities. Among the different populations of aonla, the highest values were obtained from the Garo Hills population. The DPPH scavenging activity and reducing power of the extracts also varied significantly, where the Garo Hills population showing the most activity. The study also found that the DPPH radical scavenging activity and reducing power of the extracts was concentration-dependent. The findings also suggest that the fruits of *P. emblica* have the potential to serve as natural antioxidants that can be beneficial for protecting the liver, cells, and body against the damaging effects of oxidation. Additionally, they can alleviate oxidative stress in various pathological conditions. These findings may have an impact on the development of natural antioxidant products and also serve as a basis for further research on the health benefits of *P. emblica* extracts and identify the active compounds responsible for the observed activities.

AUTHORS' CONTRIBUTION

KPR has done the research work, analyzed the data and drafted the paper. SK has supervised the work and helped in the experimentations. SBS, MMN and JJ have been involved in the experimentation and correction of the manuscript. All authors read, provided critical feedback, and approved the manuscript.

ACKNOWLEDGEMENT

The authors would like to express gratitude to the Department of Biotechnology, Ministry of Science and Technology, New Delhi, India, for their valuable support and contribution.

REFERENCES

Alam AK, Hossain AS, Khan MA, Kabir SR, Reza MA, Rahman MM, Islam MS, Rahman MAA, Rashid M and Sadik MG 2016. The antioxidative fraction of white mulberry induces apoptosis through regulation of p53 and NFκB in EAC cells. *PLoS One* **11**(12): 1-18.

Amarowicz R, Pegg R, Rahimi P, Barl B and Weil J 2004. Free-radical scavenging capacity and antioxidant activity of selected plant species from the Canadian prairies. *Food Chemistry* **84**: 551-562.

Aryal S, Baniya MK, Danekhu K, Kunwar P, Gurung R and Koirala N 2019. Total phenolic content, flavonoid content and antioxidant potential of wild vegetables from Western Nepal. *Plants* **8**(6): 156.

Baba SA and Malik SA 2015. Determination of total phenolic and flavonoid content, antimicrobial and antioxidant activity of a root extract of *Arisaema jacquemontii* Blume. *Journal of Taibah University for Science* **9**(4): 449-454.

Blois MS 1958. Antioxidant determinations by the use of a stable free radical. *Nature* **181**: 1199-1200.

Dasaroju S and Gottumukkala KM 2014. Current trends in the research of *Emblica officinalis* (amla): A pharmacological perspective. *International Journal of Pharmaceutical Sciences Review and Research* **24**(2): 150-159.

Hilton PJ and Palmer-Jones R 1973. Relationship between the flavanol composition of fresh tea shoots and the theaflavin content of manufactured tea. *Journal of the Science of Food and Agriculture* **24**: 813-818.

Jan S, Khan MR, Rashid U and Bokhari J 2013. Assessment of antioxidant potential, total phenolics and flavonoids of different solvent fractions of *Monotheca buxifolia* fruit. *Public Health Research and Practice* **4**(5): 246-254.

Lih SL, Su TC and Wen WC 2001. Studies on the antioxidative activities of Hsian tsao (*Mesona procumbens* Hemsl) Leaf Gum. *Journal of Agricultural and Food Chemistry* **49**: 963-968.

Liu X, Zhao M, Wang J, Yang B and Jiang Y 2008. Antioxidant activity of methanolic extract of emblica fruit (*Phyllanthus emblica* L.) from six regions in China. *Journal of Food Composition and Analysis* **21**(3): 219-228.

Oyaizu M 1986. Studies on products of browning reaction. Antioxidative activities of products of browning reaction prepared from glucosamine. *The Japanese Journal of Nutrition and Dietetics* **44**(6): 307-315.

Reddy VD, Padmavathi P, Kavitha G, Gopi S and Varadacharyulu N 2011. *Emblica officinalis* ameliorates alcohol-induced brain mitochondrial dysfunction in rats. *Journal of Medicinal Food* **14**(1-2): 62-68.

Rezende WP, Borges LL, Santos DL, Alves NM and Paula JR 2015. Effect of environmental factors on phenolic compounds in leaves of *Syzygium jambos* (L.) Alston (Myrtaceae). *Modern Chemistry and Applications* **3**: 157.

Sachan NK, Gangwar SS, Sharma R and Kumar Y 2013. An investigation into phyto-chemical profile and nutraceutical value of amla (*Emblica officinalis* Gaertn), *International Journal of Modern Pharmaceutical Research* **2**: 1-7.

Soobrattee MA, Neergheen VS, Luximon-Ramma A, Aruoma OI and Bahorun T 2005. Phenolics as potential antioxidant therapeutic agents: Mechanism and actions. *Mutation Research - Fundamental and Molecular Mechanisms of Mutagenesis* **579**: 200-213.

Verma M, Rai G and Kaur D 2018. Effect of extraction solvents on phenolic content and antioxidant activities of Indian gooseberry

and guava. *International Food Research Journal* **25**(2): 762-768.

Wali VK, Bakshi P, Jasrotia A, Bhushan B and Bakshi M 2015. Aonla. *Directorate of Extension, SKUAST-Jammu*, 1-30.

Zargoosh Z, Ghavam M, Bacchetta G and Tavili A 2019. Effects of ecological factors on the antioxidant potential and total phenol content of *Scrophularia striata* Boiss. *Scientific Reports* **9**(1): 16021.

Received 21 April, 2024; Accepted 15 July, 2024