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FUNCTIONAL CHARACTERIZATION AND PHYTOCHEMICAL PROFILING OF *TERMINALIA CHEBULA* FRUIT

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Abstract
Terminalia chebula, one of the oldest plants cultivated on the earth, is rich in phytochemicals including phenolics, flavonoids, and organic acids. The present study was designed to analyze *Terminalia chebula* fruit and their extracts for nutritional composition and therapeutic potential. The proximate analysis indicated that 6.82±0.25%, 4.03±0.13%, 3.40±0.14%, 18.14±0.63%, 5.36±0.40%, 62.20±0.09% moisture, ash content, crude fat, crude fiber, crude protein and NFE, respectively present in *Terminalia chebula* fruit. The functional properties results revealed that pH of *Terminalia chebula* fruit was acidic and it exhibited the good swelling power, oil holding and water holding capacity. *Terminalia chebula* fruit was found to be rich in iron (815.33±10.33 ppm), zinc (33.66±0.3 ppm), manganese (33.81±0.41 ppm) and also have a good amount of copper, cobalt, calcium, magnesium, and potassium. The FTIR results have shown the presence of alcohol, alkane, aldehyde, thiol, amide and alkyl halide functional groups in chebulic fruit powder. Furthermore, the phytochemical and antioxidant properties of *Terminalia chebula* fruit by using different solvents (Methanol, ethanol and water) were measured and found that methanolic extract showed the higher TPC, TFC and radical scavenging properties.

Keywords: *Terminalia chebula*, Composition, FTIR, Fatty acids, Phytochemicals, Antioxidants

1. Introduction

Terminalia chebula belongs to family combretaceae, is mainly cultivated in Taiwan and India. It is also grown in Pakistan at small scale. It is commonly known as myrobalan, Harad or Haritaki in Pakistan and India. Worldwide, 250 species of plants of genus *Terminalia* are cultivated and seven different varieties of *Terminalia chebula* fruit have been identified (Pfundstein *et al*., 2010). Total annual production of *Terminalia chebula* fruit is 10-15 tons. India is the main exporter of chebulic fruit extract, raw or in crushed form. *Terminalia chebula* called as 'King of Medicine" in Ayurvedic system of medicine. *Terminalia chebula* plant provides many health benefits and used traditionally as remedy for curing multiple disorders such as ulcer, gout, heart disorders, vomiting, bladder disorders, anticaries, antidiabetic, anticancer, antioxidant, antifungal, renoprotective, antiinflammatory, hepatoprotective, antiarthritic and antiviral (Bag *et al*., 2013.)

Terminalia chebula is a traditional herb which contains ellagic acid, chebulic acid, tannic acid, chebulagic acid, ethyl gallate, tannic acid, vitamin C, mannitol, corilagin and many other

substances. A number of studies have recognized that *Terminalia chebula* is used as a therapeutic approach in asthma, worms, cough, piles, fevers, rheumatism and urinary illnesses. It is also used in formulation of an herbal medicine called Triphala churna, which is recommended in infections of digestive tract, liver and in a huge number of diseases. In addition, it also reveals anti-fungal, anti-allergic and antibacterial properties and acts as a heart tonic, controls high blood pressure, decrease cholesterol levels and improves blood circulation. Moreover, *Terminalia chebula* exhibits immune enhancing properties and helps in boosting the body's immune system (Sarala and Krishnamurthy, 2021). *Terminalia chebula* is very popular in ancient healing system like Homeopathy, Unani and Ayurvedic due to its high therapeutic activity. Fruit of chebulic myrobalan is an essential component of herbal formulation called triphala to cure the liver enlargement, gastric problems, hemorrhoids, eye disorders and as purgative. Medicinal and biological properties of *Terminalia chebula* phytochemicals have been studied and it is an important natural source for formulation of herbal medicines to treat various disorders. Fruit is also used in production of colors and dyes for industrial products (Basha *et al*., 2017).

In this study, the fruit of *Terminalia chebula* was evaluated for its chemical composition including proximate and mineral analysis. The functional properties of *Terminalia chebula* fruit was also measured i.e., pH, swelling power, bulk density, oil holding capacity and water holding capacity. The FTIR was performed to identify the functional groups present in fruit. *Terminalia chebula* fruit chemical profile was summarized in current paper along with phytochemical and antioxidant potential.

2. Materials and Methods

2.1. Procurement of raw material and chemicals

Terminalia chebula fruit was procured from local market of Faisalabad, Pakistan. The fruits were sun dried and grind in mortal and pestle to make fine powder. The powder was stored in polythene bags for further analysis. The chemicals used for analysis were purchased from Sigma Aldrich (St Louis, MO, USA) through local vendors.

2.2. Proximate analysis

Terminalia chebula fruit powder was subjected to proximate analysis including moisture, ash content, crude fat, crude fiber, crude protein and nitrogen free extract following the approved methods of (AOAC, 2016).

2.3. Mineral analysis

The minerals including iron, zinc, manganese, copper, calcium, cobalt, magnesium, potassium, sodium, cadmium and lead were measured by following the method of (AOAC, 2016). The samples were prepared by using HNO_3:$HCLO_4$ (10:3) through wet digestion on hot plate until light green or colorless solution was obtained and diluted with 25mL of distilled water. Then, samples were analyzed through Atomic Absorption Spectroscopy (AA240, Varian) and Flame Photometer (Sherwood Scientific Ltd., Cambridge, Model 410).

2.4. Functional properties

2.4.1. pH

The pH of *Terminalia chebula* fruit was observed with the aid of pH meter. Standardization of the equipment was performed through KCl solution. After that the fruit powder mixed with distilled water was used for measuring the pH.

2.4.2. Bulk density

Bulk density of *Terminalia chebula* fruit was observed through following the method of Segura-(Campos *et al*., 2014). Fruit powder (50 g) was poured into measuring cylinder (100 mL) and continuous tapping was done until constant volume achieved. The observed values were put in following equation to find bulk density:

$$Bulk\ Density\ \left({}^{g}/_{cm3}\right) = Volume\ of\ sample\ after\ tapping\ (mL) \div Weight\ of\ sample\ (g)$$

2.4.3. Swelling power

Swelling power of *Terminalia chebula* fruit powder was calculated following the procedure of (AOAC, 2016). The 1 g fruit powder was poured into conical flask along with distilled water (15 mL). The mixture was shaken for 5 min on mechanical shaker at low speed. It was followed by 40 min of heating at 80 ºC in a water bath with constant stirring lead by the transfer of material in a centrifuge tube that was cleaned, dried and pre-weighed. Centrifugation was done for 20 min at 2200 rpm with addition of distilled water (7.5 mL). The supernatant was then put into can that was pre weighed as well as dried at 100 ºC to achieve constant weight after which following equation was used to calculate swelling power:

$$Swelling\ Power = Weight\ of\ sediment\ paste\ (g) \div Weight\ of\ dry\ sample\ (g)$$

2.4.4. Oil holding capacity (OHC)

OHC of *Terminalia chebula* was found out adopting guidelines of (Segura-Campos *et al*., 2014). The 2 g fruit sample was mixed with 25 mL distilled water at 1600 rpm for 30s. After the completion of dispersion, refined corn oil was poured and blended until two separated layers of water and fat were formed. Oil holding capacity of *Terminalia chebula* fruit was described as oil retained (mL) by fruit powder (1 g).

2.4.5. Water absorption capacity (WAC)

Adopting guidelines of (Segura-Campos *et al*., 2014), distilled water (5 mL) was poured into *Terminalia chebula* fruit powder (1 g) in pre-weighed centrifuge tube after. The mixture was vortexed for 2 min and centrifugation of solution at 4000 rpm for 20 min was carried out. Supernatant was discarded and weighed. WAC was found as the water weight bound to dried fruit powder (100 g).

2.5. FTIR analysis

Fourier transform infrared (FTIR) spectroscopy of the samples was carried out following the method of (Saif *et al*., 2021). Structural composition of samples was determined based upon obtained spectra. *Terminalia chebula* fruit powder mixed properly and absorbance was measured within 600-4000 cm^{-1} wavelength. Sample was placed at the sample holder of FTIR spectrometer (Bruker, Germany) and spectrum was obtained for each sample and based upon the peaks at different wave numbers, different functional groups were determined.

2.6. Extraction of *Terminalia chebula* fruit powder

Extract of *Terminalia chebula* fruit powder was prepared by using three different solvents according to the protocol of (Alam *et al*., 2013) with slight modifications. *Terminalia chebula* fruit powder (10 g) was centrifuged with 100 mL of 75 % methanol, ethanol and aqueous at Orbital Shaker (KS-260 Edmund Buhler Gmg H-Ks 15, Germany) for 4hr. Samples was filtered using Whatman filter paper No. 1 and the solvents were evaporated through Rotary Evaporator (Eyela, Japan).

2.7. Phytochemical analysis

2.7.1. Total phenolic content

Total phenolic content (TPC) was measured through Folin-Ciocalteu (FC) Reagent in triplicate by following the procedure of (Skotti *et al*., 2014). For TPC, extract (50 µL) and Folin Ciocalteu reagent (250 µL) were taken in a 5 mL volumetric flask along with 500 µL of 20 % sodium carbonate. The mixture was vortexed and incubated for 30 min at room temperature. The absorbance of this mixture was measured at 765 nm using UV-Vis Spectrophotometer (IRMECO, U2020, Germany). The total phenols were calculated as Gallic acid equivalent (GAE)/g of *Terminalia chebula* fruit.

2.7.2. Total flavonoid content

Total flavonoid content (TFC) of *Terminalia chebula* fruit was measured by following method of (Kalita *et al*., 2013). 1 mL of each extract of *Terminalia chebula* was taken in 10 mL volumetric flask with 4mL of distilled water. Freshly prepared 0.3 mL of $NaNO_2$ (5% w/v) was added simultaneously and leave solution for 5 min. Afterwards, 0.3 mL of $AlCl_3$ (10 % w/v) was included, followed by 6 min incubation, 2 mL of NaOH and 2.4 mL of distilled water were added and mixed thoroughly. The absorbance of samples was taken at 510 nm using UV-Vis Spectrophotometer, against a blank. Total flavonoid content was calculated by using calibration curve of catechin as standard solution and expressed as catechin equivalent (CTE)/g of *Terminalia chebula* fruit.

2.8. Antioxidant analysis

2.8.1. DPPH assay

Ability of *Terminalia chebula* fruit to give hydrogen atom or an electron was estimated following the procedure of (Kumar *et al*., 2021). Each extract (0.5 mL) was poured into DPPH (1-1-diphenyl 2-picryl hydrazyl) solution (2.5 mL, 0.5 mM). Afterwards, mixture was vortexed. Incubation for 20 mins in dark was carried out. Absorbance was noted at 517 nm using UV-Vis Spectrophotometer.

2.8.2. FRAP assay

Ferric reducing antioxidant power of *Terminalia chebula* fruit was assessed through method of (Vemuri *et al*., 2019). Accordingly, FRAP reagent was prepared through adding TPTZ solution (2.5 mL), acetate buffer (25 mL, pH 3.6, 0.3 M) and $FeCl_3.6H_2O$ solution (25 mL). FRAP solution (280 µL) along with extract (20 µL) was mixed and leave for 30 min in dark at room temperature for incubation. Absorbance of samples was observed at 593 nm through UV-Vis Spectrophotometer. The calibration curve was attained using $FeSO_4$ and results were expressed as µM $FeSO_4$/g of fruit.

2.9. Statistical analysis

The data attained from all the parameters were statistically analyzed under complete randomized design following the method of (Montgomery, 2017). To check the level of significance analysis of variance (ANOVA) was applied. The Microsoft excel (Microsoft, Redmond, WA, USA) and Statistix 8.1 were used to express results as mean± standard deviation.

3. Results and discussion

3.1. Proximate analysis

The findings of *Terminalia chebula* fruit powder proximate analysis is presented in Table 1. Results depicted moisture content 6.84±0.25 %, ash 4.03±0.13 % and crude fat 3.40±0.14 % present in *Terminalia chebula* fruit while crude fiber 18.14±0.63 %, crude protein 5.36±0.40 % and NFE 62.20±0.99 %.

Moisture content in *Terminalia chebula* fruit powder was found 6.84±0.25 %. According to (Asati *et al*., 2020), moisture content in *Terminalia chebula* fruit powder was 6.31 % and (Hussain *et al*., 2009) determined the moisture content of chebulic fruit 8.65±0.1 %. The variation in results might be due the difference in temperature conditions, humidity, storage conditions. The food material with the highest ash content had the greater probability to have more mineral content. In the present study, ash content of *Terminalia chebula* fruit powder was found to be 4.03±0.13 %. The ash content in a previous study was estimated in range of 2.61 to 8.56 % in different parts of the plant (Malik *et al*., 2020). Ash content determined by (Asati *et al*., 2020) was 3.48 % in chebulic fruit.

The *Terminalia chebula* fruit powder contains crude fat 3.40±0.14 % in present findings. A previous study by (Malik *et al*., 2020) reported the fat content of *Terminalia chebula* fruit powder and results was quite similar to present study. They found fat content of *Terminalia chebula* was 2.97±0.01 %. Crude fiber in *Terminalia chebula* fruit powder found in present research was 18.14±0.63 %. Crude fiber in *Terminalia chebula* fruit powder was determined 16.45±0.02 % in previous research by Malik et al. [17]. Sarala and Krishnamurthy, [3] found crude fiber content 9.61±0.07 %.

Crude protein in *Terminalia chebula* fruit powder has been found as 5.36±0.40 % in current research. In previous studies, protein in *Terminalia chebula* fruit powder have been reported slightly higher as 8.38±0.22 % by Sarala and Krishnamurthy, 2021. Hussain *et al*., 2009 found crude protein content in *Terminalia chebula* fruit powder lower than other researches about 3.77±0.1 %. Protein content slightly varies in results of different studies which may be due to difference in growing conditions and environmental factors.

Nitrogen free extract (NFE), comprises of carbohydrates i.e., starches, sugars and hemicellulos. These are found as structural component of cellular elements and these are major sources of energy. NFE of *Terminalia chebula* fruit was found high about 62.20±0.99 %. (Hussain *et al*., 2009) found it in range of 83.43±0.09 % higher than the present finding.

The health prompting effect of *Terminalia chebula* fruit powder might be attributed to presence of nutritional components in matrix. *Terminalia chebula* fruit is rich in fiber content which is helpful for many body functions. Protein content of *Terminalia chebula* fruit is not very high but it contains essential amino acids including valine, isoleucine, leucine, threonine, histidine and proline according to (Ikram *et al*., 2020). *Terminalia chebula* fruit exhibited the higher ash content which depicts the presence of more minerals content.

Table 1. Proximate composition of *Terminalia chebula* fruit

Parameter	***Terminalia chebula* (%)**
Moisture	6.84±0.25
Ash Content	4.03±0.13
Crude Fat	3.40±0.14
Crude Fiber	18.14±0.63
Crude Protein	5.36±0.40
NFE	62.20±0.99

Values expressed are means ± standard deviation (n=3)

3.2. Mineral analysis

The results for mineral analysis of *Terminalia chebula* fruit powder are expressed in Table 2. Macro and micro minerals quantified in current research including sodium (Na), potassium (K), magnesium (Mg), iron (Fe), zinc (Zn), copper (Cu), manganese (Mn) and cobalt (Co). The heavy metals that have been detected include cadmium (Cd) and lead (Pb). The results exhibited that cadmium and lead have not been detected in *Terminalia chebula* fruit.

Terminalia chebula fruit is rich in iron content and from current research results it was 815.33±10.33 ppm while sodium and manganese were found in range of 1.29±0.04 and 33.81±0.41 ppm, respectively. *Terminalia chebula* fruit rich in iron. Iron content of current research findings has been similar to Sarala and Krishnamurthy, 2021 that was 870±8.11 ppm. Iron is required for many vital physiological functions. It is mostly existed in protein bound form, as a heme in hemoglobin and in storage protein form as ferritin, myoglobin and hemosiderin (Salnikow *et al*., 2012). Zinc was also detected in an appreciable quantity in chebulic fruit 33.66 ±0.35 ppm, which was found earlier by Hussain *et al*., 2009 as 34.4 ppm in *Terminalia chebula* fruit. Copper was found 7.05±0.05 ppm in chebulic fruit in current research and it was previously determined by Malik *et al*., 2020 as 7.33±0.145 ppm.

Calcium content of *Terminalia chebula* fruit determined in range of 0.93±0.05, which was similar to the previous studies in range of 0.81±0.30 ppm and 0.08 ppm Sarala and Krishnamurthy, 2021. Cobalt present in slightly higher amount than calcium, magnesium and potassium in chebulic fruit. Cobalt was found in range of 5.52±0.22 ppm, similar to the results of Hussain *et al*., 2009. The results of magnesium and potassium in chebulic fruit was similar to the findings of Sarala and Krishnamurthy, 2021 0.26±0.02 and 4.04±0.05 ppm, respectively. Sodium and manganese were reported as 1.56±0.18 ppm and 23.41±1.52 ppm by Sarala and Krishnamurthy, 2021. Variation in mineral content might be due to soil fertility and environmental conditions in which fruit was grown.

Table 2. Mineral analysis of *Terminalia chebula* fruit

Minerals	***Terminalia chebula* (ppm)**
Iron	815.33±10.33
Zinc	33.66±0.35
Manganese	33.81±0.41
Copper	7.05±0.05
Calcium	0.93±0.05
Cobalt	5.52±0.22
Magnesium	0.27±0.01
Potassium	4.01±0.01
Sodium	1.29±0.04
Cadmium	ND
Lead	ND

Values expressed are means ± standard deviation (n=3)

3.3. Functional properties

The results for different functional properties such as swelling power, bulk density, pH, oil holding capacity and water holding capacity are shown in Table 3. The pH of *Terminalia chebula* fruit has been found acidic as 4.43±0.16. Swelling power was found 6.04±0.04 g/g while bulk density of fruit was calculated 0.62±0.01 g/mL. Oil holding capacity of *Terminalia chebula* fruit powder has been found 4.93±0.01 mL/g and water holding capacity 6.28±0.06 mL/g.

The current findings for pH of fruit powder have been in line with Jirankalgikar *et al*., 2012 who found pH of fruit was 4.0 which is acidic in nature. The pH of *Terminalia chebula* fruit powder was reported acidic by Asati *et al*., 2020 also. Bulk density of *Terminalia chebula* fruit was previously determined by Pathak *et al*., 2019 that ranges from 0.61±0.01 g/mL, similar to current research findings.

Table 3. Functional properties of *Terminalia chebula* fruit

Functional Properties	***Terminalia chebula***
pH	4.43±0.16
Swelling Power (g/g)	6.04±0.04
Bulk Density (g/mL)	0.62±0.01
Oil Holding Capacity (mL/g)	4.93±0.01
Water Holding Capacity (mL/g)	6.28±0.06

Values expressed are means ± standard deviation (n=3)

3.5. FTIR analysis

Terminalia chebula fruit powder was analyzed by using Fourier transform infrared spectroscopy and different bands were obtained (Figure 1). The results for IR spectrum shown in Table 5. The IR spectra of chebulic fruit gives more than five bands that indicate the presence of different functional groups in fruit powder. A band at 3375.7877 cm^{-1} showed the presence of alcohols (OH) group stretching. However, at the peak value of 2950.8699 cm^{-1} sp3 hybridization detected, it indicates the presence of alkanes. *Terminalia chebula* fruit powder also showed peaks at 2830.6629 cm^{-1} and 2363.8124 cm^{-1} stretching which indicates the presence of aldehyde compounds and thiol as well as carbon dioxide group respectively. At 2363.8124 $cm^{1,}$ presence of thiol and carbon dioxide indicates the presence of sulfur compounds. The band at 1623.0018 cm^{-1} amide groups shows the presence of protein as it depicts the molecular structure of protein. In IR spectrum, 1486.0217 cm^{-1} band depicts the presence of aromatic compounds and 1108.6276 cm^{-1} indicates the C-O stretching and presence of secondary alcohols in *Terminalia chebula* fruit powder. Bands at 1058.3084 cm^{-1} and 1013.5802 cm^{-1} were attributed to C-F and ROOR' stretching, indicates the presence of alkyl halide and esters.

Table 5. FTIR Spectrum values of *Terminalia chebula* fruit powder

Wave number	Functional group	Vibration type
3375.7877	Alcohol	O-H, Stretching
2950.8699	Alkane	C-H, Stretching
2830.6629	Aldehyde	C-H, Stretching
2363.8124	Thiol, CO_2	S-H, O=C=O stretching
1623.0018	Amide	N-H, Bending
1486.0217	Aromatic	C=C, Stretching
1108.6276	Sec. Alcohol	C-O, Stretching
1058.3084	Alkyl Halide	C-F, Stretching
1013.5802	Esters	(ROOR')

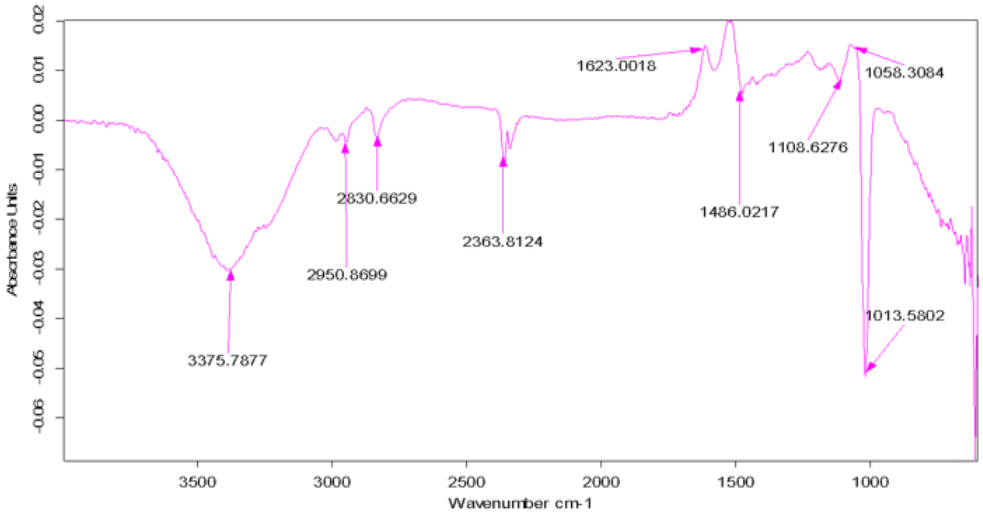

Figure 1. FTIR spectrum of *Terminalia chebula* fruit powder

3.6. Phytochemical and antioxidant analysis

The results of TPC, TFC, DPPH and FRAP are presented in Table 6. The total phenolic content of fruit in methanolic extract exhibited the higher total phenolic content than the aqueous and ethanolic extracts. The results of Bhatt *et al*., 2017 described that TPC of *Terminalia chebula* fruit was 76.67±0.68mg GAE/g. The difference in total phenolic content from different solvent is due to the better extraction capability of methanol and ethanol than water that is related to their ability of form phenolic acids by interconversion of molecules (Bulbul *et al*., 2022). The TFC of *Terminalia chebula* fruit was also higher in methanolic extracts as 34.62±0.01 mg CE/g. The Total flavonoid content was found 15.22±0.63 mg CE/g by Kauser *et al*., 2018 previously. The difference in flavonoid content between different studies depends on time, temperatures, solvents use, their solvation properties and techniques used to evaluate the TFC of *Terminalia chebula* fruit.

The DPPH (1, 1-di phenyl-2-picrylhydrazyl) results showed that radical scavenging activity was high in methanolic extract as 17.63±0.50 % inhibition and low in aqueous extract 10.17±0.13 % inhibition. Malik *et al*., 2020 found the DPPH activity was 16.56 and 12.96 % inhibition in different extracts. The FRAP analysis of *Terminalia chebula* fruit showed that methanol had 21.54±0.14 (µmol Fe^{2+}/g) and aqueous extract had 12.61±0.08 (µmol Fe^{2+}/g). Bhatt *et al*., 2017 and Kanik *et al*., 2021 concluded that there is significant FRAP activity present in *Terminalia chebula* fruit extracts. The presence of reductones plays an important role in the reducing capacity of a compound, which display the antioxidant potential by disrupting the free radical chains and giving a hydrogen atom. So, reducing activity results in the cessation of potentially highly harmful radical chain reactions. The reduction of the Fe3+/ferricyanide complex to the ferrous form is caused by antioxidant reductants present in the polyphenolic extract of *Terminalia chebula*, demonstrating the extract's potent reducing potential (Saha and Verma *et al*., 2016).

Table 6. Phytochemicals and antioxidant analysis of *Terminalia chebula* fruit in extracts

Extracts	TPC (mg GAE/g)	TFC (mg CE/g)	DPPH (% inhibition)	FRAP (µmol Fe^{2+}/g)
TAE	43.87±0.71[c]	12.40±0.48[c]	10.17±0.13[c]	12.61±0.08[c]
TME	68.90±0.64[a]	34.62±0.01[a]	17.63±0.50[a]	21.54±0.14[a]
TEE	54.88±0.39[b]	16.32±0.39[b]	14.59±0.14[b]	16.47±0.06[b]

Values expressed are means ± standard deviation (n=3)
TAE=*Terminalia chebula* Aqueous Extract, TME=*Terminalia chebula* Methanolic Extract
TEE=*Terminalia chebula* Ethanolic Extract

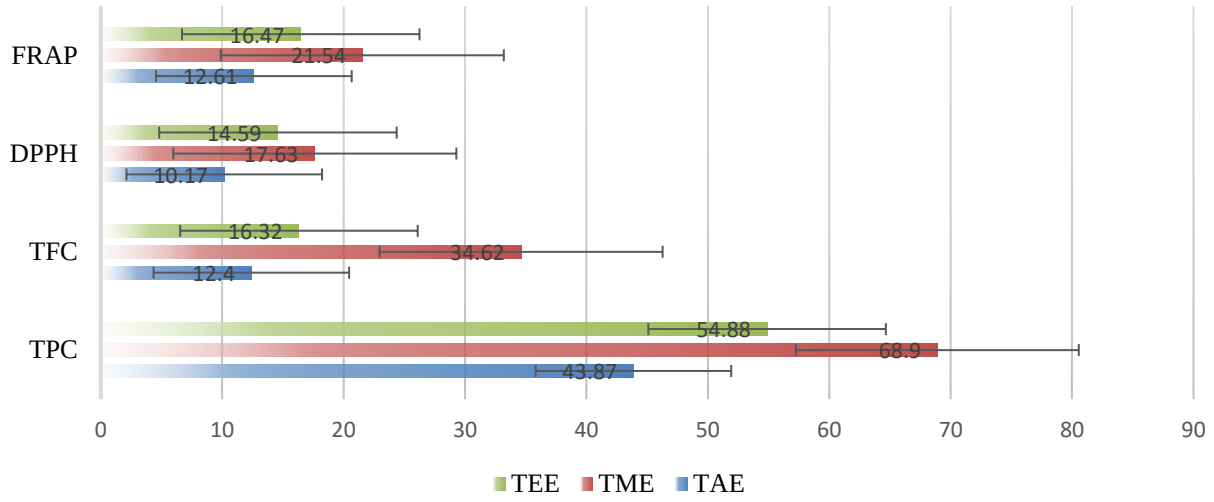

Figure 2. Phytochemicals and antioxidant analysis of *Terminalia chebula* fruit in extracts

Conclusion

Terminalia chebula fruit was evaluated for its chemical profile, fatty acids and functional groups. The proximate analysis showed that it contains higher amount of fiber and ash content. The minerals profile of *Terminalia chebula* fruit was showed it had a good amount of iron, zinc and manganese. The phytochemical and antioxidant profile of fruit was evaluated in three different solvents. The methanolic extract depicted the higher number of phytochemicals and antioxidant profile as compared to other solvents. *Terminalia chebula* fruit depicted a good nutritional profile and functional properties, hence it could be a great food to play a role in prevention of different health conditions.

Declarations

Conflict of interest:
The authors declare no conflict of interest.

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References:

1. Pfundstein, B., S.K. El Desouky, W.E. Hull, R. Haubner, G. Erben and R.W. Owen. (2010). Polyphenolic compounds in the fruits of Egyptian medicinal plants (*Terminalia bellerica*, *Terminalia chebula* and *Terminalia horrida*): Characterization, quantitation and determination of antioxidant capacities. *Phytochemistry*, 71(10):1132-48. https://doi.org/10.1016/j.phytochem.2010.03.018
2. Bag, A., S.K. Bhattacharyya and R.R. Chattopadhyay. (2013). The development of *Terminalia chebula* Retz. (Combretaceae) in clinical research. *Asian Pacific Journal of Tropical Biomedicine*. 3(3): 244–252. https://doi.org/10.1016/S2221-1691(13)60059-3

3. Sarala, P. and S.R. Krishnamurthy. (2021). Distribution, Nutritive Value and Mineral Composition of a Few Medicinal Plants of Shimoga District, Karnataka India. *International Journal of Pharmaceutical Sciences Review and Research*. 69(2): 150-162. http://dx.doi.org/10.47583/ijpsrr.2021.v69i02.023
4. Basha, S.J., J. Reddy, Y.S. Rani, M. Koshma, G. Hanumanthu and S. Dadakhalandar. (2017). A review on *Terminalia chebula*. *International Journal of Pharmacological Research*. 7(10): 187-191 https://doi.org/10.7439/ijpr
5. AOAC, 2016. Official Methods of Analysis. The Association of Official Analytical Chemists. Inc. 20th ed. AOAC Press, Arlington, VA, USA.
6. Segura-Campos, M., E. Barbosa-Martín, A. Matus-Basto, D. Cabrera-Amaro, M. MurguíaOlmedo, M.Y. Moguel-Ordoñez and D. Betancur-Ancona. (2014). Comparison of chemical and functional properties of Stevia rebaudiana (Bertoni) varieties cultivated in Mexican Southeast. *American Journal of Plant Sciences*. 5(3):286-293. DOI: 10.4236/ajps.2014.53039
7. Saif, F.A., S.A. Yaseen, A.S. Alameen, S.B. Mane and P.B. Undre. (2021). Identification and characterization of Aspergillus species of fruit rot fungi using microscopy, FT-IR, Raman and UV–Vis spectroscopy. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*. 246: 119010. https://doi.org/10.1016/j.saa.2020.119010
8. Alam, M.N., N.J. Bristi and M. Rafiquzzaman. (2013). Review on in vivo and in vitro methods evaluation of antioxidant activity. *Saudi Pharmaceutical Journal*. 21(2):143-52. https://doi.org/10.1016/j.jsps.2012.05.002
9. Skotti, E., E. Anastasaki, G. Kanellou, M. Polissiou and P.A. Tarantilis. (2014). Total phenolic content, antioxidant activity and toxicity of aqueous extracts from selected Greek medicinal and aromatic plants. *Industrial Crops and Products*. 53:46-54. https://doi.org/10.1016/j.indcrop.2013.12.013
10. Kalita, P., B.K. Tapan, T.K. Pal and R. Kalita. (2013). Estimation of total flavonoids content (tfc) and anti oxidant activities of methanolic whole plant extract of *Biophytum sensitivum* linn. *Journal of Drug Delivery and Therapeutics*. 3(4):33-7. https://doi.org/10.22270/jddt.v3i4.546
11. Kumar, V., S.R. Chandel, S. Guleria, N. Sharma, A. Sourirajan, P.K. Khosla and K. Dev. (2021). Comparative analysis of phytochemicals, antimicrobial and antioxidant activity of different species of Terminalia from Himachal Pradesh, India. *Vegetos*. 34:528-539. https://doi.org/10.1007/s42535-021-00232-y
12. Vemuri. P.K., L. Dronavalli, P. Nayakudugari, A. Kunta and R. Challagulla. (2019) Phytochemical analysis and biochemical characterization of *Terminalia chebula* extracts for its medicinal use. *Biomedical and Pharmacological Journal*. 12(3). https://dx.doi.org/10.13005/bpj/1783
13. Montgomery, D.C. 2017. Design and Analysis of Experiments. 9th Ed. (John Wiley & Sons. Inc. Hoboken, NJ, USA), pp: 162-264.
14. Asati. S, V. Chandel and A. Choubey. (2020). Extraction and comparative study on physico-chemical, phytochemical analysis of fruits of *Terminalia chebula* and rhizomes of *Curcuma longa*. *Plant Archives*. 20: 4289-4294.
15. Hussain, J., A.L. Khan, N. Rehman, M. Hamayun, Z.K. Shinwari, W. Ullah and I. Lee. (2009). Assessment of herbal products and their composite medicinal plants through proximate and micronutrients analyses. *Journal of Medicinal Plants Research*. 3:1072-1077.
16. Malik, T., V.K. Madan and R. Kumar. (2020). Quantitative estimation of total phenolics content, total flavonoids content, and total antioxidant potential in various promising extracts of Triphala powder and its fruit constituents. *Innovations in Pharmaceuticals and Pharmacotherapy*. 8(4):105-113. DOI: 10.31690/ipp.2020.v08i04.001
17. Ikram, A., F. Saeed, H. Munir, M.T. Sultan, M. Afzaal, A. Ahmed and F.M. Anjum. (2020). Exploring the amino acid profile and microbial properties of locally sweet preserved kachra hareer (*Terminalia chebula*). *Food Science and Nutrition*. 9(2):909-919. https://doi.org/10.1002/fsn3.2056

18. Salnikow, K. (2021). Role of iron in cancer. *Seminars in Cancer Biology*. 76:189-194. https://doi.org/10.1016/j.semcancer.2021.04.001
19. Jirankalgikar, Y.M., R.R. Dwivedi, C.R. Harisha and V.J. Shukla. (2012). Assesement of bhavana samskara by phytopharmacognostical evaluation in haritaki churna. *International Journal of Ayurveda Allied Sciences*. 1:193-197.
20. Pathak, S.S., R.C. Pradhan and S. Mishra. (2019). Physical characterization and mass modeling of dried *Terminalia chebula* fruit. *Journal of Food Process Engineering*. 42(3):e12992. https://doi.org/10.1111/jfpe.12992
21. Bhatt, I.D., S. Rawat, A. Badhani and R.S. Rawal. (2017). Nutraceutical potential of selected wild edible fruits of the Indian Himalayan region. *Food Chemistry*. 215:84-91. https://doi.org/10.1016/j.foodchem.2016.07.143
22. Bulbul, M.R.H., M.N.U. Chowdhury, T.A. Naima, S.A. Sami, M.S. Imtiaj, N. Huda and M.G. Uddin. (2022). A comprehensive review on the diverse pharmacological perspectives of *Terminalia chebula* Retz. *Heliyon*. 8(8):e10220. https://doi.org/10.1016/j.heliyon.2022.e10220
23. Kauser, A., S.M.A. Shah, N. Iqbal, M.A. Murtaza, I. Hussain, A. Irshad, S. Nasir, M. Akram, N. Munir and M. Riaz. (2018). In vitro antioxidant and cytotoxic potential of methanolic extracts of selected indigenous medicinal plants. *Progress in Nutrition*. 20(4):706-712. DOI: 10.23751/pn.v20i4.7523
24. Kanik, B. Singh, J.B. Dhar, G. Jairath, R. Sharma, D. Gopinath, G. Mal. (2021). Antioxidant Potential of Fermented Milk Supplemented with Various Aqueous Herbal Extracts. *International Journal of Food Science and Agriculture*. 5(4): 762-774. DOI: 10.26855/ijfsa.2021.12.025
25. Saha, S. and R.J. Verma. (2016) Antioxidant activity of polyphenolic extract of *Terminalia chebula* Retzius fruits. *Journal of Taibah University Sciences*. 10(6):805-812. https://doi.org/10.1016/j.jtusci.2014.09.003