



## Research Article

# Phytochemical properties and antioxidant activity of *Echinops persicus* plant extract: green synthesis of carbon quantum dots from the plant extract

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## Abstract

*Echinops persicus* is a species of *Echinops* that can be found in Europe and western Asia especially in Iran. In this paper, the phytochemical properties of *Echinops persicus* were thoroughly investigated and studied. In this way, total amounts of flavonoid, tannins, phenols, carotenoids, saponins, alkaloids, and anthocyanin were measured by various analytical methods. The major phenolic and flavonoid content was found in the root acetone and flower ethanolic extract of the plant. Also, major saponins and carotenoid contents was found in root and leaf of the plant. These measurements were also performed for root, leaf, and flower of the plant in various solvent extracts. The results indicated that *Echinops persicus* is a rich source of secondary metabolites. Also, the plant extract demonstrated a considerable antiradical activity, which evaluated qualitatively as well as quantitatively. The largest capacity to neutralize DPPH radicals was found for root water extract of *Echinops persicus* plant. Finally, the possibility of the plant extract was evaluated for the green preparation of carbon quantum dots (CQDs). As-prepared CQDs were characterized by TEM, HRTEM, UV-Vis, XRD, and EDX analyses.

**Keywords** *Echinops persicus* · Antioxidant · Secondary metabolites · Carbon quantum dots · Green preparation of CQDs

## 1 Introduction

Plants are the richest resource of pharmaceutical molecules, nutraceuticals, food supplements, and chemical frameworks for design of synthetic drugs [1]. They have involved different phytochemicals and enzymes as antioxidant defense to maintain the growth and metabolism system. Newly interest has been focused on natural antioxidants owing to side effects of synthetic antioxidants [2]. To this end, the study of medicinal plants is widely underway. For example, various therapeutic properties have been reported for *Falcaria vulgaris* [3], *Allium saralicum* [4,

5], *Falcaria vulgaris* [6], *Stevia rebaudiana* (bitter fraction) [7] etc.

*Echinops persicus* is a species of *Echinops* that its extract of *Echinops persicus* is traditionally used long time in Iran for the treatment of cough and constipation. This plant can be found in Europe and Western Asia especially in the east of Iran. It was used for the treatment of lung diseases as mucus or discounts, anti-cough and asthma therapy [8]. Other treatments such as suppress of depression, constipation and obesity, fever-reducing and balancing the digestive system, and as anti-cancer activity were also biological activities reported for this plant [9].

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Saponins are a group of active compounds with numerous biological properties that are synthesized from secondary metabolites. They can be found in a large number of plants and crops. It has the least toxic effect on non-target organisms and the environment, and plays an important role in maintaining and developing sustainable crops [10]. According to the hypotheses presented in the literature, saponins have a protective-inhibitory activity against the plant and cause gastrointestinal problems, disruption of peeling, and cytotoxicity in pests. For this reason, these herbal compounds can be sprayed or selected with more saponins varieties as a very effective tool in integrated management programs to preserve agricultural and horticultural products. It also has no carcinogenic, mutagenic and glandular properties and is considered as a safe pesticide [11].

Flavonoids are among the secondary metabolites of the plant that play an important role in human health, due to their antioxidant activity. Recently, flavonoids were used as a reducing agent for the preparation of biocompatible AgNPs, because they have relatively low affinity to the metal surface (they do not contain S or N atom in their structures), which means adsorption of metal ions can be quite simple [12].

Anthocyanins play the role of dye in plants; which plants in red, orange and black colors have the highest amount of anthocyanins. Today, anthocyanins are used as a dye in food, cosmetics and health industries [13]. Tannin is one of the secondary metabolites that cause leather-like skin in plants and fruits. Tannins have an electronic structure that exhibits a synergistic effect in the photocatalytic process [14]. In the food industry tannins are used to clarify wine, beer, and fruit juices. Other industrial uses of tannins include textile dyes, as antioxidants in the fruit juice, beer, and wine industries, and as coagulants in rubber production. Tannins have also anti-tumor, antibacterial and antiviral activities. For example, certain tannins can selectively inhibit HIV replication [14, 15].

Carotenoids are the most widespread class of isoprenoid pigments that are synthesized by photosynthetic organisms in plants, some non-photosynthetic bacteria and fungi [16]. Since animals are unable to synthesize carotenoids, they need to be obtained from plants. Carotenoids also have wide application in cosmetic products due to their photo protection properties against UV radiation. There are over 600 known carotenoids that can be classified into two groups of xanthophyll and carotenes contain only a hydrocarbon chain without any functional group, including  $\beta$ -carotene and lycopene [16, 17].

The use of nanotechnology in all sciences, including medicine, petrochemical, pharmaceutical, materials sciences, defense industries, electronics, quantum computing, etc., has made nanotechnology a major scientific and

industrial challenge for the world [18]. Various methods have been developed for this purpose. The preparation of green nanoparticles using plant extracts is a method that has attracted much attention in recent decades due to environmental issues [19, 20]. Cu [21], Ag [18], Ti [19], and Au [20] are among the NPs successfully prepared from plant extracts. In recent years, there is raising research attention to find methods aimed to produce eco-friendly nanoparticles, which does not use toxic materials [22]. Carbon quantum dots are among the nanoparticles that are considered today because of their extraordinary and unique properties [23]. They are a new generation of nano carbon structures (ex. fullerene, carbon nano tubes, graphene), which has attracted much attention due to its high resistance to light exposure, biocompatibility, low toxicity, high activity toward blue dye removal from the water, economic cost and its abundance in raw materials in nature [24]. Quantum dots synthesized by green methods have many applications in various sciences [23]. For example, CQDs prepared by chitosan (as a precursor) are used in the manufacture of electronic devices [25]. Quantum dots synthesized using glucose and tree date palm are other examples of green synthesis of CQDs that have been used for the biological imaging in the body of living things [26] and luminous diodes respectively [27]. Recently, Yang et al., reported the preparation of high-fluorescence-doped quantum dots from glucose and showed their application in the detection of cancer cells in mice [28].

In this study, secondary metabolites of *Echinops persicus* were studied and quantified in various extractions. In the following, the antiradical/ antioxidant activity of the plant in various organs was measured qualitatively as well as quantitatively. Finally, the green preparation of CQDs was successfully accomplished by the aqueous extract of the plant.

## 2 Experimental

### 2.1 Instruments

Fluorescence spectroscopy analyses were performed on a JASCO FP-6500 spectrofluorometer. Fourier transform infrared (FTIR) analyses for the samples were taken on a JASCO instrument model V-570. UV-visible measurements were done using X-ma 2000 spectrophotometer. The transmission electron microscopy (TEM) images were obtained on a Philips CM120. X-ray diffraction (XRD) measurement was performed with a Bruker D8/ Advance powder X-ray diffractometer. Atomic absorption analyses were conducted using a Shimadzu AA-6300 instrument. High resolution transmission electron microscopy (HR-TEM) was performed using a HR-TEM FEI TEC9G20 apparatus

operated at 200 kV accelerating voltage. Size distribution of CQDs were measured by DLS analysis on a HORIB-ALB550 instrument.

## 2.2 Methods and materials

All materials were provided from Merck or Sigma Aldrich and used as received without further purification. *Echinops persicus* plant was collected from around the city of Birjand- Shokat Abad in Southern Khorasan, Iran in April–May 2019. Rutin, DPPH (1, 1-diphenyl-2-picrylhydrazyl), Folin–Ciocalteu reagent, and ascorbic acid were purchased from Sigma and Merck companies. Gallic acid was purchased from Fluka supplier.

## 2.3 Plant extraction

The fresh and healthy parts of *Echinops persicus* (leaf, stem, root, and flower) were collected from around Birjand–Shokat Abad. After shade drying in a mixer, 5 g of each powdered plant sample was extracted with organic solvents with an increase of polarity at a ratio of 1: 15 (v/v). The extractions were performed by Maceration for the measurement of secondary metabolites.

## 2.4 Measurement of phenolic compounds

To prepare standard solutions, 0.01 g of gallic acid (1000 ppm) was dissolved in 10 ml of 50% EtOH and subsequently 0, 20, 40, 60, 80, 100 and 120 ppm gallic acid solutions were prepared (ESI, Fig. S1). Phenolic compounds were measured by a previously reported method by Škerget et al. [29, 30]. Briefly, 0.5 mL of diluted or standard sample, 2.5 mL of folin ciocalteu reagent (10%) and 2 mL of sodium carbonate solution (7.5%) were mixed in darkness at room temperature. After 1 h of the mixing, the absorbance of the solution was read at 760 nm.

## 2.5 Measurement of total flavonoid compounds

To prepare standard solutions (routine solution 1000 ppm), 0.01 g of routine was dissolved in 10 mL of 50% EtOH and subsequently, 10, 20, 40, 60, 80, 100 and 120 ppm solutions were prepared. The flavonoid content was measured by a colorimetric method (ESI, Fig. S2), which is based on the formation of a flavonoid-aluminum complex with maximum absorption at 415 nm [31]. 1 mL of standard or extract was added to 1 mL of  $AlCl_3 \cdot 6H_2O$  solution. Then, 3 mL of 10% sodium acetate solution was added to the solution. After 40 min, the absorbance of the solutions was recorded at 415 nm. The experiments were performed for hexane, acetone, ethyl acetate, and water extract of flower, leaf, and root of *Echinops persicus*.

## 2.6 Determination of total tannins content

The tannins content of the plant was measured by the dissolution of 10 mg of the desired organ powder to 4.0 mL of distilled water. The resulting solution is then divided into two portions and 1.0 mL of distilled water and 4.0 mL of Conc. HCl, was added to each portion. Absorption of the first part was recorded after heating at 100 °C for 30 min. The absorbance of the second portion was read after the addition of 0.5 mL of ethanol at room temperature. The absorptions were measured at three different wavelengths of 470 nm, 520 nm and 570 nm. The total amount of tannin (TTC in  $g L^{-1}$ ) was calculated using the following formula (1–3) [32].

$$\Delta A_{520} = 1.1 \times \Delta A_{470} \quad (1)$$

$$\Delta A_{520} = 1.57 \times \Delta A_{570} \quad (2)$$

$$TTC = 15.7 \times \text{Min}(\Delta A_{520}) \quad (3)$$

## 2.7 Determination of alkaloids

Analysis of alkaloids in the plant was performed according to the method described by Muthukrishnan and Manogaran [33]. To measure of alkaloid contents, 5.0 g of the dried plant powder (leaves and stems, roots, flowers) was extracted to 200 mL of ethanolic acetic acid 10% and set it aside for 4 h in dark. Then, the resultant solution was filtered by Whatman no. 1 filter paper, and the volume of the residue was reduced to one quarter by heating. After cooling to room temperature, a concentrated ammonia solution was added dropwise until sediment was formed. To make sure that the precipitate is an alkaloid, it was tested with Dragendorff's reagent. The interaction of alkaloid with Dragendorff's reagent on a TLC provides an orange spot, that indicates the presence of alkaloids. The resulting sediment was filtered with a Whatman no. 1 filter paper, dried into the oven, weighted and reported as alkaloid weight in the plant.

## 2.8 Determination of saponins

The content of saponins was determined by a previously reported method [34]. Briefly, 20 g of each part of the dried plant powder (leaves and stems, roots, flowers) was extracted to 200 mL of EtOH 20%. The extraction was performed at reflux conditions for 4 h. The resulting extracts were filtered and kept at 4 °C. The total volume of the extract was concentrated to one quarter by heating. Then, the extracts were further extracted to diethyl ether

(3 × 20 mL) and then *n*-butanol (3 × 20 mL). The organic layers were combined and washed with NaCl solution (5 wt%). The solvent was removed and the resulting sediments were reported as saponins in the plant.

## 2.9 Determination of anthocyanin

Contents of anthocyanin in the *Echinops persicus* plant was measured based on a previously reported protocol [35]. Briefly, 0.1 g of the dry plant was placed in a mortar and rubbed and sanded with 10 mL of acidic methanol (MeOH: HCl (conc.) 1:99). Then, the extract was poured into the test tubes and incubated in the dark for 24 h at 25 °C. Then, it was centrifuged at 4000 rpm for 10 min and the absorbance was recorded at 550 nm. The concentration was calculated using the formula:  $A = \epsilon bc$ , where  $\epsilon = 33,000 \text{ M}^{-1} \text{ cm}^{-1}$  and the results were reported in terms of  $\mu\text{mol}$  per gram of the plant.

## 2.10 Determination of total carotenoids content

To determine total carotenoid content (TCC), 10 g of plant sample (root, flower, or leaf) was extracted to acetone 80% (100 mL) and the resulting solution covered with an aluminum foil and stored at 4 °C for 3 days. Then the solution was filtered with a Whatman no. 1 filter paper. The absorption of the residue was recorded at three different wavelengths of 660, 642, and 470 nm and the desired TCC was measured by the following formula [36, 37]:

$$C_a = 12.25A_{660} - 2.79A_{642} \quad (4)$$

$$C_b = 21.50A_{642} - 5.10A_{660} \quad (5)$$

$$C_{x+c} = \frac{1000A_{470} - 1.82C_a - 85.02C_b}{198} \quad (6)$$

where  $C_a$  and  $C_b$  are the concentrations of chlorophyll (a) and chlorophyll (b) in  $\mu\text{g mg}^{-1}$  of the plant extract respectively, and  $C_{x+c}$  represents the total amount of carotenoids. The ratios of the specific absorption coefficients at  $\lambda_{\text{max}}$  in the blue to  $\lambda_{\text{max}}$  in the red for chlorophylls a, b and average absorption coefficients  $A_{1 \text{ cm}}^{1\%}$  at 470 nm for total carotenoids in various solvents were inserted according to data reported elsewhere [36].

## 2.11 Screening of radical scavenging activity by dot-blot 2,2-diphenyl-1-picrylhydrazyl (DPPH) staining method

The radical scavenging activity of the plant extract was evaluated by a dot-blot DPPH staining method [38]. In this method, the experiment was performed on a silica

gel impregnated with UV-fluorescence indicator (5 × 5 cm plate). DPPH and ascorbic acid were used as control and standard respectively. First, DPPH was spotted on the plate, then the extract was applied on the spot. The scavenging was monitored qualitatively by the color change of spot from purple (blank, no antioxidant activity) to yellow or white, indicating potent antioxidant activity of each extract.

## 2.12 Determination of antioxidant potency of leaf extract by DPPH method

The antioxidant activity of the plant extract was also measured quantitatively by a method developed by Blois using DPPH free radicals [38]. Briefly, various concentrations of water or ethanolic leaf extract were prepared, and for each experiment, 75  $\mu\text{L}$  plant extract was added to 3.9 mL of 0.00463 g/L DPPH solution. The resulting solution was stirred for 30 min in a dark place. The absorbance of the solutions was recorded at 517 nm. The inhibition percentage (IP) of the extract was calculated based on the following Eq. (7):

$$\% \text{Inhibition} = \frac{A_{\text{blank}} - A_{\text{sample}}}{A_{\text{blank}}} \times 100 \quad (7)$$

In this method, the color change of the solution from purple to yellow indicates the quenching of DPPH free radicals by the plant extract. Finally,  $(IC_{50})$  was determined from the plot of %IP versus concentration.

## 2.13 Determination of metal ions in the plant organs

The metal ions preset in various parts of the plant were determined by AAS from the ash prepared from burning the different parts of the plant.

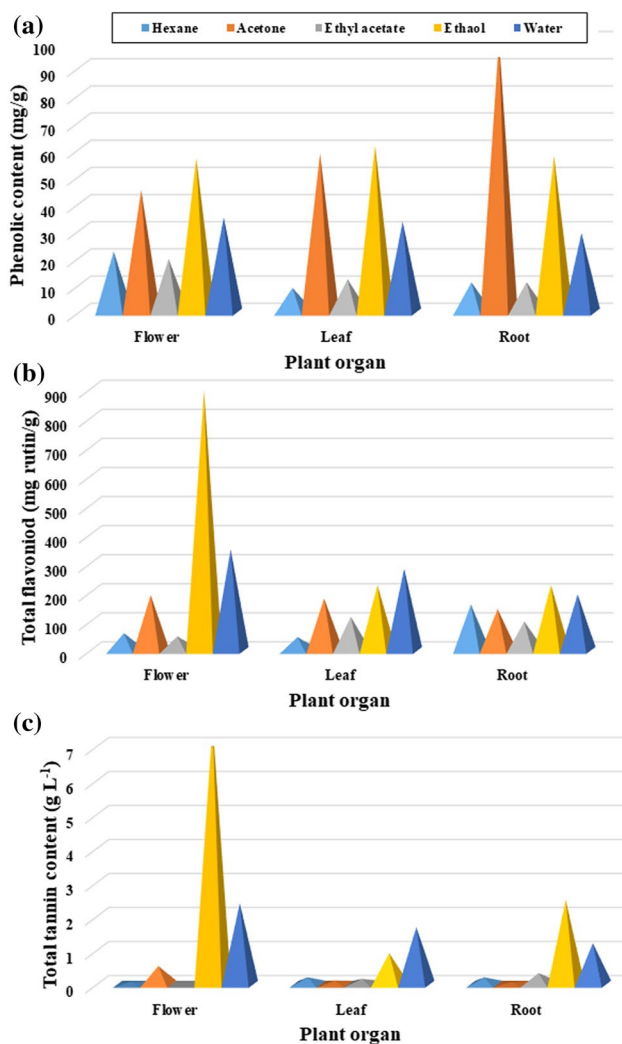
## 2.14 Green synthesis of carbon quantum dots (CQDs) from *Echinops persicus* plant

CQDs were synthesized via a hydrothermal method [39] using all organs of *Echinops persicus* as the carbon source. *Echinops persicus* powder (6.0 g) was added to 75 mL distilled water, ultra-sonicated for 30 min at room temperature and then transferred to a 150 mL Teflon-lined autoclave. The autoclave was placed in the furnace for 10 h at 200 °C. To achieve outmost efficiency, extract concentration and calcination temperature as two effective parameters were also studied and optimized.



### 3 Results and discussion

Figure 1 shows the phenolic, flavonoid, and tannin contents in various organs of *Echinops persicus* plant. Based on the results, the root of the plant has the most content of phenolic compounds. This content was major in acetone and ethanol extract (Fig. 1a). Ethanolic extract of the plant flower, showed the highest content of flavonoid and tannins (Fig. 1b, c). The aerial and root parts of the plant exhibited rather same results for flavonoid and tannin contents (Fig. 1b, c). The results also demonstrated that hexane and next ethyl acetate were the weak solvents for the extraction of phenol, flavonoid, and tannin content for *Echinops persicus* plant. Furthermore, these results suggest that the flower of the plant could be used as an efficient additive



**Fig. 1** Determination of **a** total phenolic, **b** total flavonoid, and **c** total tannin contents in the flower, leaf, and root of *Echinops persicus* plant in various extracts

to drug compositions given that high biological activities [12].

Alkaloid, saponins, anthocyanin, and carotenoid content of the plant were determined in root, flower, and leaf of the plant (Fig. 2a–d). As shown in Fig. 2a, aerial parts of the plant contain the highest amount for alkaloid, anthocyanin, and carotenoids (Fig. 2c, d). The highest amount of saponins was found in the root extract (0.7 g/20 g), however, other contents were lower than leaf or flower (Fig. 2b). The alkaloid values obtained for the different plant organs are shown in Fig. 2c.

Plants have been well known as bio-accumulator from contaminated soil and water. In this point of view, plants are the good evidence for the evaluation of soil nutrition. Moreover, the use of plants through phytoremediation technology is an alternative solution to treat heavy metal contaminated areas and can be used to remediate the environment [40]. Plants show different responses to different heavy metals exposure. Several plants are sensitive while other plants have a high tolerance to several heavy metals. As a consequence of plant-metal interaction, several plants accumulate heavy metals from the soil, which affects their growth and development. However, some plants have a high tolerance and can keep the growth and development even under heavy metals stress. Different responses of plants to heavy metals exposure depend on its level of heavy metals tolerance. For example, the presence of Zn can also change the chlorophyll a fluorescence and antioxidant system parameters [40–42]. So, the determination of heavy metals in the ash of a plant give valuable information about soil nutrition. Table 1 shows the results of the heavy metals present in ash of the flower, leaf, and root of *Echinops persicus* plant. Potassium was the major element in the flower and leaf of the plant. On the other hand, the root of the plant is a rich source of Ca and Mn, which can be directly attributed to the soil. The results clearly indicated that the soil of Shokat Abad in Birjand (Southern Khorasan province) is in relatively good health.

#### 3.1 Antioxidant activity

The ethanol and water extract of *Echinops persicus* was spotted on each row in which the color changes from purple to yellow or white was well observed, that indicating the potent antioxidant activity of the extract when compared to standard ascorbic acid. The results showed that the amount of antiradical activity depends on the type of solvent used for the extraction. The concentration of the extract does not have much effect on the antioxidant activity. The highest antioxidant properties are related to the aqueous and ethanolic extracts (Fig. 3).

After determining the maximum inhibitory effect on the aqueous and ethanolic extracts of the plant

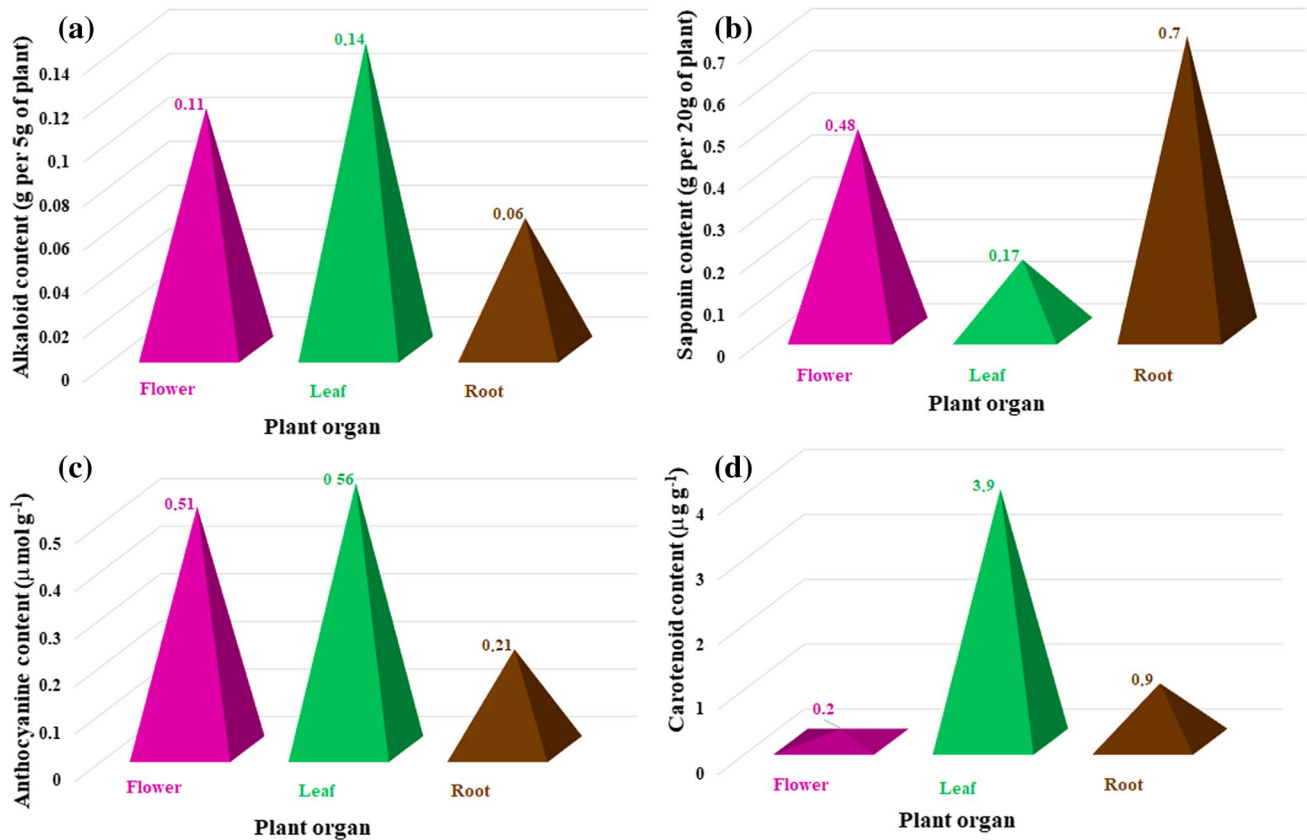


Fig. 2 **a** Alkaloid, **b** saponins, **c** anthocyanin and **d** carotenoid contents in leaf, flower and root of *Echinops persicus* plant

Table 1 Measurement of important heavy metals present in various parts of *Echinops persicus* plant

Organ	Metal content (ppm)							
	Na	Mg	Cu	Zn	Ca	Mn	Fe	K
Flower	86.2	2.0	2.0	2.8	140.8	322.2	41.2	1849.0
Leaf	338.3	3.9	0.8	2.2	377.7	521.8	89.2	1691.6
Root	374.4	5.8	2.4	6.0	395.4	625.2	105.8	130.5

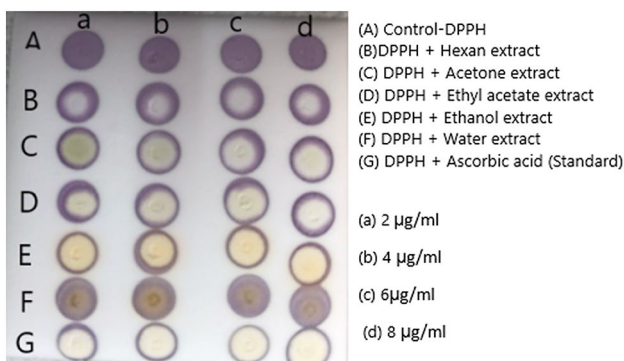
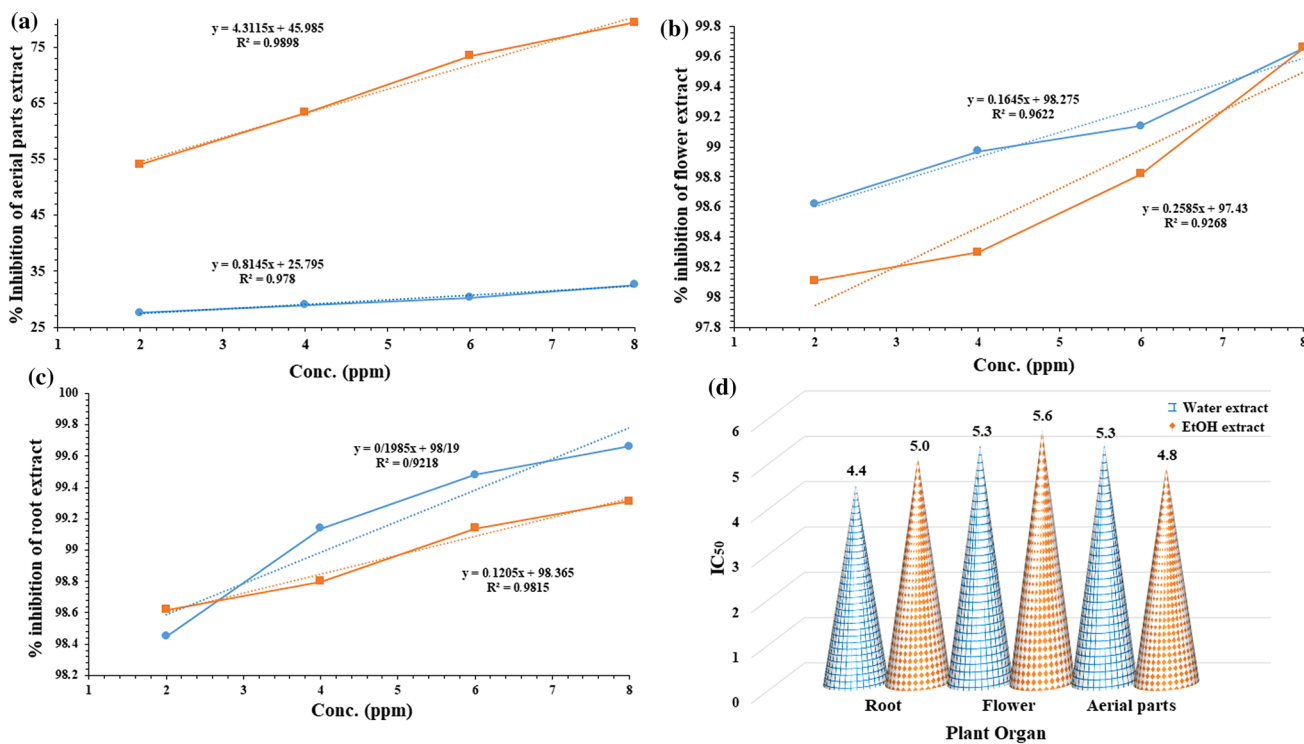


Fig. 3 The dot-blot assay of different extracts of *Echinops persicus* in the presence of DPPH

qualitatively, the inhibition percentage (%Inhibition) of aqueous and ethanolic extracts of different plant organs at different concentrations was studied quantitatively. As shown in Fig. 4, aqueous extracts for flowers and roots contain more antioxidant compounds than aqueous extracts of aerial parts. Then, the concentration of plant extracts with a 50% radical scavenging percentage (i.e.  $\text{IC}_{50}$ ) was calculated by the diagrams (Fig. 4a–c). Low  $\text{IC}_{50}$  indicates greater inhibition [43]. Accordingly, as shown in Fig. 4d, aqueous ( $\text{IC}_{50} = 4.4$ ) and ethanolic ( $\text{IC}_{50} = 5.0$ ) extract of the root have the lowest  $\text{IC}_{50}$  and consequently provide the highest inhibition. On the other hand, the plant flower extract has the least



**Fig. 4** Inhibition percentage of ethanol (orange curves) and water (blue curves) extracts of **a** aerial parts, **b** flower and **c** root extract of *Echinops persicus*. **d** Determination of IC<sub>50</sub> for the plant organs

**Table 2** Comparison of antioxidant activity of some plant species [44–46]

Entry	Plant	Solvent extract	IC50
1	<i>Entandrophragma angolense</i>	EtOH	18.39
2	<i>Uapaca guineensis</i>	EtOH	25.59
3	<i>Aegle marmelos</i>	EtOH	24.90
4	<i>Green tea (Camellia sinensis)</i>	MeOH	6.7
5	<i>Camellia sinensis linn</i>	MeOH	9.7
6	<i>Piper cubeba Linn</i>	MeOH	11.3
7	<i>Syzygium aromaticum</i>	MeOH	9.9

amount of inhibition compared to other plant organs. In order to better understand the inhibitory effect of *Echinops persicus* plant, a comparison was made with several other plants.

As shown in Table 2, IC<sub>50</sub> for *Echinops persicus* is comparable with green tea (*Camellia sinensis*) (Table 2, entry 4), *Camellia sinensis linn* (Table 2, entry 5), and *Syzygium aromaticum* (Table 2, entry 7). More importantly, *Echinops persicus* shows much higher inhibition activity than *Entandrophragma angolense*, *Uapaca guineensis*, *Aegle marmelos*, *Piper cubeba Linn* (Table 2, entries 1–3, 6).

### 3.2 Optimization of temperature and plant extract concentration over the synthesis of CQDs from *Echinops persicus* plant

Two effective factors for the plant extract-mediated preparation of CQDs including temperature and concentration of the plant flower extract were screened. The concentration of 6 g of the plant sample in 75 mL distilled water provided the high intensity and subsequently a high amount of CQDs at 200 °C. With increase and/or decrease of the concentration, intensity decreased (Fig. 5). Then, the preparation of CQDs was evaluated at various calcination temperatures using a concentration of 6 g/75 mL. The highest possible efficiency was obtained at 200 °C (Fig. 5). No improvement in efficiency was observed at higher and/or lower temperatures.

The electronic spectrum of CQDs occurs due to the size of the nanoparticles. UV–Vis spectroscopy is, therefore, an efficient way to monitor the optical properties and quantum size of nanoparticles. CQDs have a relatively wide absorption spectrum, with  $\lambda_{max} = 400–450$  nm [47], which corresponds to the electronic transitions from the first excited level of CQDs. The maximum absorption of CQDs decreases with decreasing particle size. Accordingly, as shown in Fig. 5a, the highest absorption was at concentration of 6 g/75 mL. The maximum absorption of CQDs

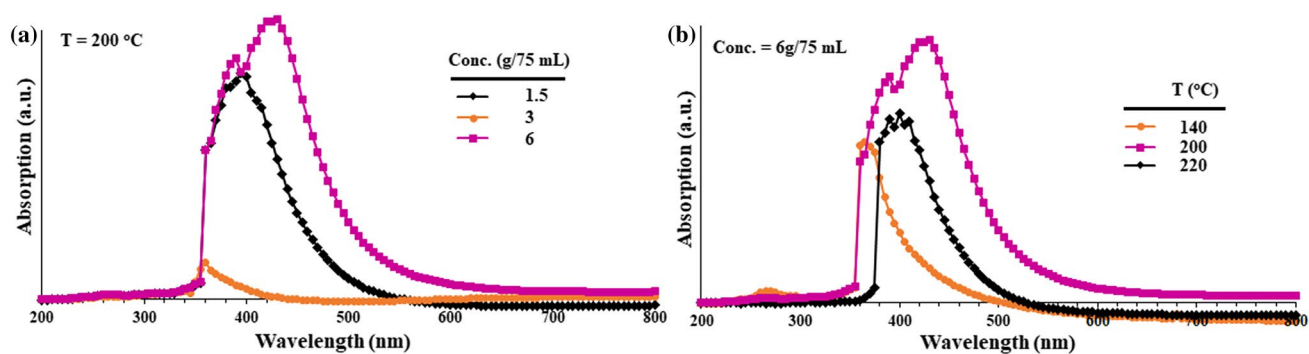


Fig. 5 Optimization of **a** concentration of the plant flower extract and **b** temperature for the preparation of CQDs

decreases with decreasing particle size [47], thus the size of NPs decreasing sharply at lower concentrations. Temperature also had an inevitable effect on the preparation of CQDs. Increasing the temperature to 200 °C, increases the amount of nanoparticles produced (Fig. 5b). As the temperature increases, the absorption peak shifts to lower wavelengths, resulting in a decrease in the size of the nanoparticles.

The images in Fig. 6 show the as-prepared CQDs using flower extract of *Echinops persicus* under natural and UV (325 nm) light. There is a relationship between the color of CQDs under ultraviolet light and their sizes [48, 49]. From the green color of CQDs, it can be estimated that the size of the synthesized CQDs is between 3.5 and 5.5 nm.

### 3.3 Characterization of CQDs

With premium conditions in hand, for comparison, CQDs were obtained from leaf and root in addition to flower extract. FTIR spectra obtained from various parts of the plant were shown in Fig. 7. Almost the same spectra were observed for all of the sources. A broad peak at  $\sim 3300\text{ cm}^{-1}$  was related to hydroxyl groups stretching vibrations [26, 27]. A peak appeared at  $\sim 2930\text{ cm}^{-1}$  represent the C–H

stretching bond as a main characteristic bond for CQDs [50]. Also, a series of peaks around  $1604$  and  $1650\text{ cm}^{-1}$  were assigned to C=C and C=O bonds respectively. A peak with medium intensity represents the C–O bond, which along with previous vibrations confirmed the presence of carboxylic groups [28].

The UV spectrum of CQDs indicates that the size of the flower-derived CQDs is more homogeneous than the other CQDs produced by root or aerial parts, which the deviation from the shape is very low (Fig. 7B) [51].

Figure 7C shows the emission spectrum of the CQDs, that the range of 500–550 nm shows the major absorption corresponding to the green wavelength region. These emission zones are related to the photon emission resulting from the electron–hole hybrid rearrangement. The particle size distribution affects the fluorescence absorption bandwidth, and therefore the more uniform particles give the narrower particle size distribution with a symmetrical fluorescence absorption. On the other hand, the greater particle distribution, provide the wider absorption. Accordingly, the CQDs synthesized by the plant are homogeneous in morphology and in addition, as shown in the figure, the highest color intensity is related to the plant root (Fig. 7C).

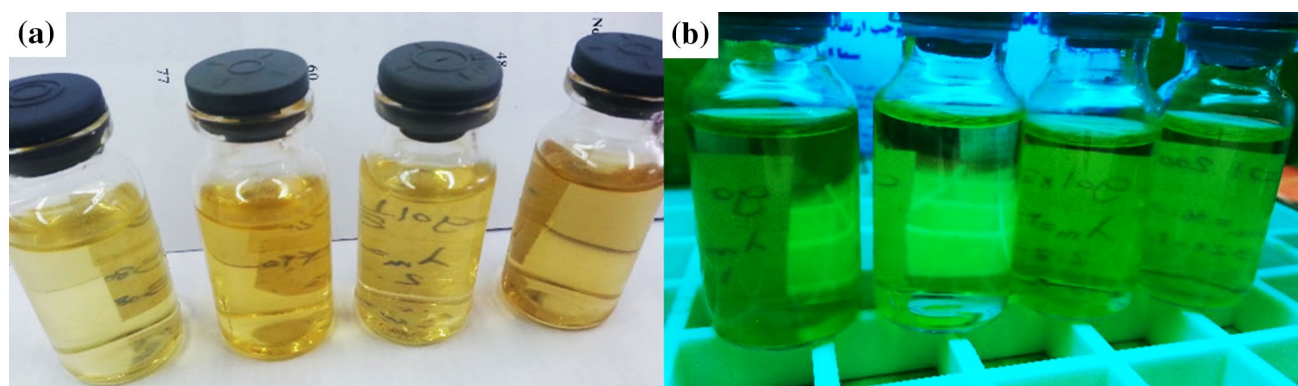


Fig. 6 Images from the as-prepared CQDs from flower extract of *Echinops persicus* under **a** natural light and **b** UV light (325 nm)



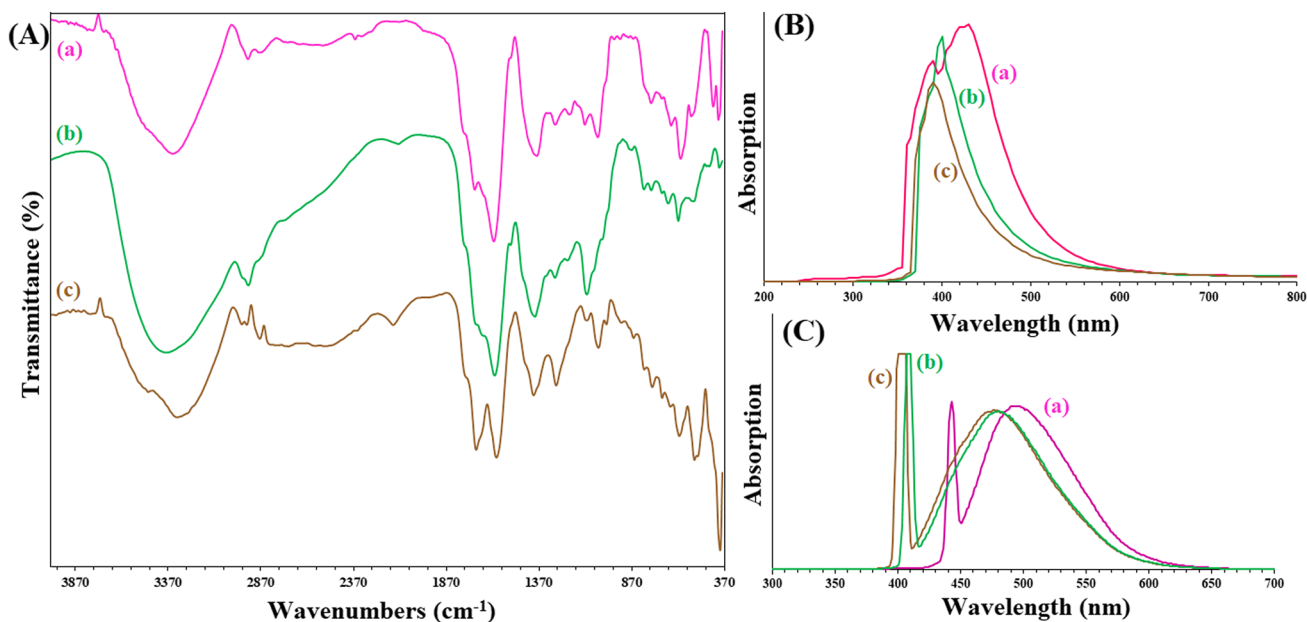


Fig. 7 **A** FTIR, **B** UV-Vis and **C** fluorescence spectra of CQDs prepared from (a) flower, (b) leaf, and (c) root of *Echinops persicus* respectively

X-ray diffraction of the as-prepared CQDs was shown in Fig. 8a. An amorphous peak at  $2\theta = 23^\circ$  corresponds to the characteristic peak for CQDs in agreement with the literature [50, 52]. Note to the presence of Mg in CQDs structure, the sharp crystalline peak at  $2\theta = 29^\circ$  represents the presence of MgO microcrystals according to the literature [53]. However, the overall pattern of the CQDs has good math with KCl sylvite crystal structure [54]. Various elements were detected in the CQDs (Fig. 8b). As expected, major elements were C and O with 40.47 wt% and 40.51 wt% respectively, confirmed the preparation of CQDs. Other elements with an abundance of 3–4 wt% were Mg, K, an Cl.

TEM images of the prepared CQDs confirmed the homogenous distribution and morphology of the NPs. Also, from the images, size of the NPs is between 4–6 nm (Fig. 9). The larger-scale image of the nanoparticles (Fig. 9, right image) also shows a regular shrub structure of the particles (Fig. 9a).

HR-TEM image from CQDs was also confirmed their homogeneous and spherical shapes. As shown in Fig. 9 (inset image), the nanoparticles have a homogeneous dispersion spherical shape with a size of about 5–6 nm. The lattice fringe spacing indicated in the HR-TEM image is 0.222 nm, completely in agreement with the (100) spacing reported for CQDs [55].

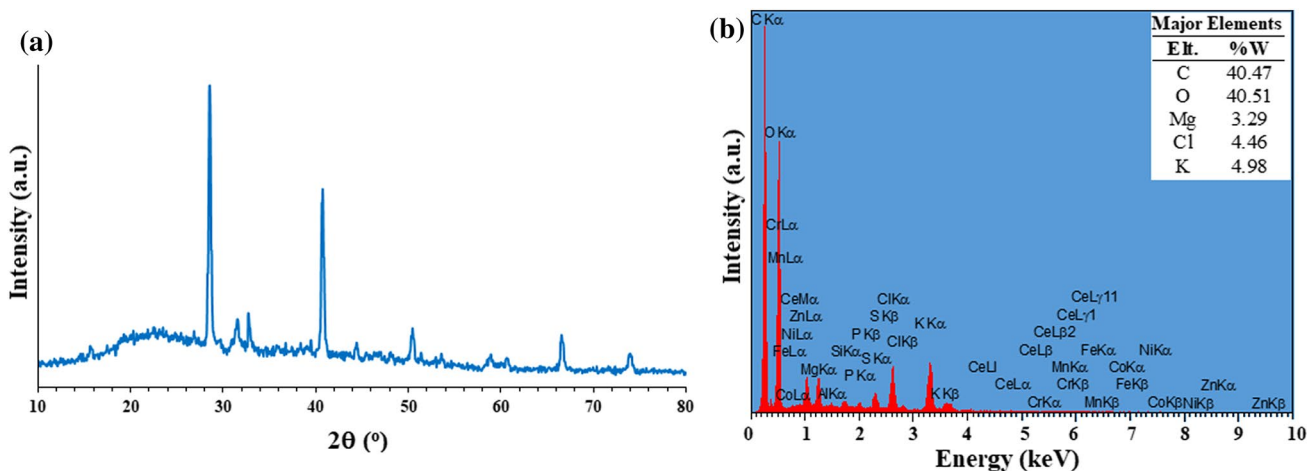
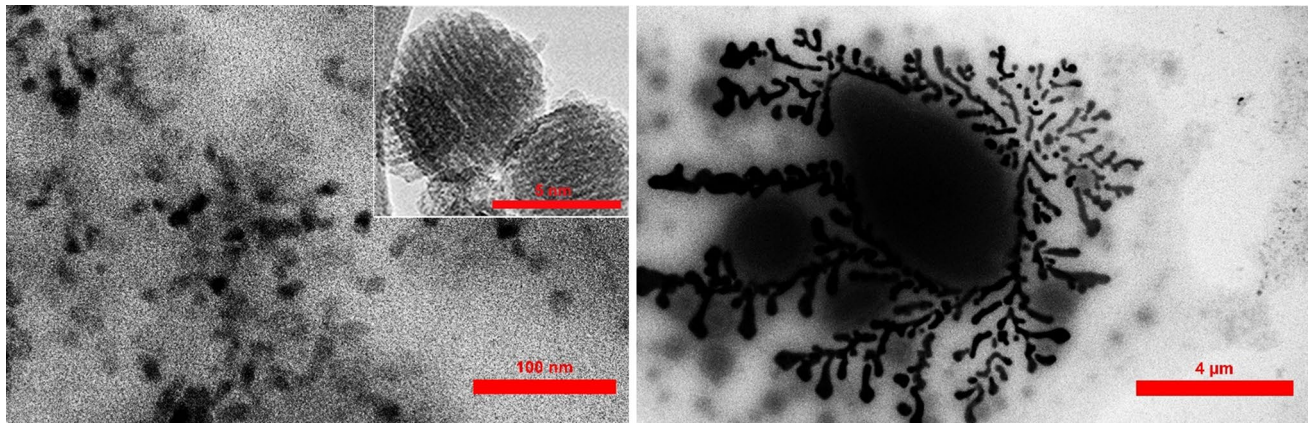
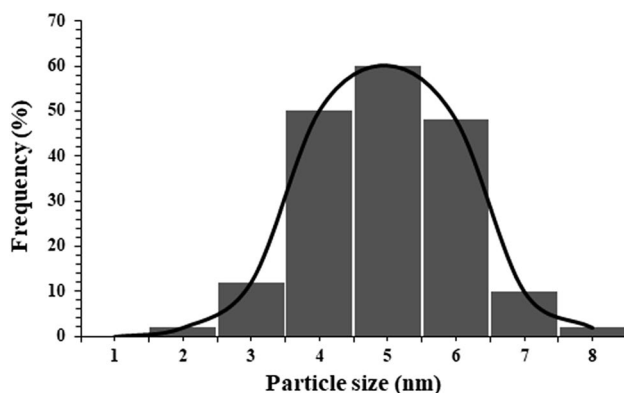


Fig. 8 **a** XRD pattern and **b** EDX analysis of the as-prepared CQDs using flower of *Echinops persicus*



**Fig. 9** TEM, and HRTEM (inset image) images of the as-prepared CQDs using flower extract of *Echinops persicus*



**Fig. 10** Size histogram of the bio-synthesized CQDs using flower extract of *Echinops persicus*

Also, particle size distributions of CQDs revealed a uniform distribution with an average particle size of 4–6 nm, in excellent agreement with TEM, HRTEM, and XRD results (Fig. 10).

## 4 Conclusion

Phytochemical studies on *Echinops persicus* plant revealed that the plant is a rich source of tannins, anthocyanins, phenol, and flavonoid contents. The major phenolic and flavonoid content was found in the root acetone and flower ethanolic extract of the plant as 90 mg/g and 893 mg rutin/g respectively. Also, phytochemical screening of the plant extracts showed the presence of tannins, anthocyanins, and alkaloids as 7.6 g/L, 0.56 μmol/g, and 0.14 g/5 g, respectively for flower and leaf extracts. Also, major saponins and carotenoid contents were found in root and leaf of the plant as 0.7 g/20 g and 3.9 μg/g respectively. An excellent and acceptable antioxidant activity

was found for the plant. The largest capacity to neutralize DPPH radicals was found for root water extract of *Echinops persicus* plant that found to be  $IC_{50} = 4.4$ . Finally, as a green protocol, carbon quantum dots were successfully prepared by 6 g/75 mL of plant extract of *Echinops persicus* at 200 °C. As-prepared CQDs were characterized by XRD, TEM, HRTEM, EDX, FTIR, and UV–Vis analyses. The prepared NPs have a mean size of 3–5 nm with a homogeneous spherical morphology.

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## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no competing interests.

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