JOURNAL OF AGRICULTURE AND APPLIED BIOLOGY
2025, Vol. 6, No. 1, 1 - 12
http://dx.doi.org/10.11594/jaab.06.01.01
E-ISSN: 2723-5106

Research Article

Centaurea dimorpha Viv. (Asteraceae) growing in Algeria extracts as a promising natural cosmetic active ingredient: Broad-spectrum photoprotection and antioxidant efficacy

Salima Azzouzi[1,2], Mostefa Lefahal[1,2], Souheila Louaar[1], El-Hani Makhloufi[1,3], Kamel Medjroubi[1], Salah Akkal[1]*

[1]University Constantine 1, Faculty of Exact Sciences, Unit of the Valorization of Natural Resources, Bioactive Molecules and Physicochemical and Biological Analysis, Constantine 25000, Algeria
[2]University Salah Boubnider Constantine 3, Faculty of Medicine, BP 'B' 72Ali Mendjeli Nouvelle Ville Constantine 25000, Algeria
[3]University Mohamed Boudiaf of M'sila, Faculty of Technology, Base Common ST, BP 166 M'sila 28000, Algeria

Article history:

Received 06 August 2024
Revised 31 August 2024
Accepted 04 September 2024
Published 14 October 2024

Keywords:

broadspectrum photoprotection efficacy
antioxidant activity
critical wavelength
SPF in vitro
UVA/UVB

***Corresponding author:**

E-mail:

salah.akkal@umc.edu.dz

Abstract

Recently, plants have been considered as a valuable natural source of cosmetic active ingredientsowing to their sustainability and weak toxicity. Thus, this study was conducted to investigate the cosmetic efficacy of *Centaurea dimorpha* Viv (Asteraceae), an endemic species of North Africa, as a promising natural cosmetic active ingredient. In the present study, Ethyl acetate and Butanolic extracts obtained from powdered *Centaurea dimorpha* aerial parts were investigated for their phenolic and flavonoid contents, which were evaluatedvia Folin-ciocalteu reagent and aluminium chloride methods, the in vitro antioxidant potential was evaluated by DPPH radical scavenging,phosphomolybdenum and phenanthroline assays, the UVB and broad spectrum protective efficacy was spectrophotometrically assessed by measuring SPF, UVA/UVB ratio and critical wavelength (CW) indices. The highest levels of TPC and TFCwere recorded by the ethyl-acetate extract (119.20 ± 0.32 µg GAE mg^{-1}, 50.65 ± 0.43 µg QEmg^{-1}, respectively). Similarly, this extract displayed a significant antioxidant effect, particularly in the phenanthroline assay (152.63 ± 0.49 µg AAEmg^{-1}). Ethyl acetate extract also showed UVB and broad-spectrum (UVB-UVA) protective efficacy (SPF=12.30 ± 0.001, UVA/UVB ratio=0.63 ± 0.001, λc= 371). The results obtained show the possibility to use Ethyl acetate extract as a promising active ingredient for sunscreen formulations.

How to cite:
Azzouzi, S., Lefahal, M., Louaar, S., Makhloufi, E. H., Medjroubi, K., & Akkal, S. (2025). *Centaurea dimorpha* Viv. (Asteraceae) growing in Algeria extracts as a promising natural cosmetic active ingredient: broad-spectrum photoprotection and antioxidant efficacy. *Journal of Agriculture and Applied Biology, 6*(1): 1 - 12. doi: 10.11594/jaab.06.01.01

1. Introduction

Ultra Violet radiation from the sun, especially UVA (320-400 nm) and UVB (290-320 nm), causes DNA damage, which activates inflammatory processes and skin cancer (Ganesan & Hanawalt, 2016; Schuch et al., 2017). Protecting the human skin from these radiations is therefore, an essential strategy to be considered. In this context, the use of sunscreens is considered as one of the most widely used techniques to ensure photoprotection (Guan et al., 2021). Sunscreen formulations contain active ingredients that function as UV filters (Jansen et al., 2013). Despite their efficacy in protecting human skin, several studies reported that commercial sunscreen active chemicals may be hazardous to humans (Downs et al., 2016), which has raised interest in employing natural ingredients to design sunscreen formulations (Cefali et al., 2016; Serafini et al., 2015).

One of the biological properties of interest in cosmeceuticals is the antioxidant capacity of natural substances. Numerous scientists noted that anti-oxidants are helpful in preserving cosmeticactive ingredients from degradation, and protecting against skin damage (Lohani et al., 2019). Therefore, plant extracts which are rich in anti-oxidant molecules have attracted the interest of cosmetic designers to study their incorporation into cosmetic products (Thibane et al., 2019). In addition to their significance as a potential source of cosmetic ingredients, plant extracts are also considered to be an important reservoir for drug development. Actually, Digoxinextracted from the plant *Digitalis lanata*, has been used in heart diseases (Kumar, 2016). Terpenoid compounds have been shown to possess anti-microbial and anti-viral effects, glycyrrhizin found in the roots of the specie *Glycyrrhiza glabra* is considered as an important antiviral compound (Adeosun & Loots, 2024). The genus *Centaurea* of Asteraceae family contains about 700 species of biennial and perennial plants rarely dwarf shrubs (Bancheva et al., 2022). This genus is divided into three subgenera, *Centaureasensu* stricto, *Lopholoma* (Cass.) Dobrocz.and*Cyanus* (Mill.) Hayek, the Centaurea species are widely present in different open habitats varying in soil type, from inland sand dunes to meadows and from acidic to calcareous grasslands (Wala et al., 2021). Some species such as *Centaurea raphanina spp. mixta* are cultivated because of their commercial benefits and nutritional value, indeed a recent study showed that the cultivated species conserved their proprieties regarding the nutritional value and the quality when compared to the wild one (Petropoulos et al., 2020). The Centaurea taxons are frequently disturbed in Mediterranean area and in Western Asia (Belkassam et al., 2019; Yayli et al., 2005; Ertas et al., 2014).

In the Algerian flora this genus contains about 45 species (Azzouzi et al., 2016). Traditionally, various *Centaurea* have been used as a source of herbal medicines to treat gynecological, digestive, and dermatological problems as well as kidney failure and urinary tract irritation (Reyhan et al., 2004). On the other hand, multiple folk medicinal applications of *Centaurea* species were also cited such as: diuretic, anti-febrile, and anti-malarial (Alamri et al., 2023). Currently, extracts and essential oils of several *Centaurea* species have been reported to have anti-cancer, anti-diabetic, ant, anti-oxidant and antibacterial effects (Fattaheian-Dehkordi et al., 2021; Khammar & Djeddi, 2012). Besides their therapeutic uses, *Centaurea* species are also employed in gastronomy as edible flowers, in cosmetics and as a source of colour in industry (Pires et al., 2018). Polyphenols (flavonoids, lignans, and other phenolic compounds) and sesquiterpene lactone are the two most significant classes of active substances present in *Centaurea* plants (Aktumsek et al., 2011, 2013; Dhouibi et al., 2020). It has been published that sesquiterpene lactones detected in *Centaurea*possess anti-cancer, anti-inflammatory, and anti-microbial effects (Kebbi et al., 2021).

Considering the published data on the phytochemical composition of *Centaurea* species and their richness in polyphenols on the one hand, and the use of some them in the cosmetic field on the other hand, the present study aims at evaluating the aerial part extracts of *Centaurea dimorpha* Viv (endemic in North Africa) as a new natural cosmetic active ingredient for sunscreen cosmetic preparations by assessing their polyphenolic composition, antioxidant, UVB and broad-spectrum photoprotective efficacy.

2. Materials and methods

2.1 Plant Material

C. dimorpha aerial parts of were collected from M'Sila (eastern of Algeria) in May 2018, and the plant was identified by Prof T. Hamel botanist at Annaba University.

2.2 Extracts preparation

C. dimorpha aerial parts were dried in the shade under the condition of a room temperature. An amount of 900 g of dried aerial parts were extracted with boiling 70% methanol at room temperature for 72 h. After filtration, the hydroalcoholic solution was removed using a rotary evaporator under vacuum at 40°C to obtain *CD*-MeOH extract. Then, it was suspended in hot water and kept in the cold overnight, then successively fractionated with Ethyl acetate and Butanol to obtain the *CD*-EtOAc (6g) and *CD*-BuOH (18.6g) extract, which were kept at 4°C until use.

2.2.1 Phytochemical characterization of plant material

TPC was determined using Folin-Ciocalteu reagent (FCR)as described by (Boulacel et al., 2019). TPC was calculated from Gallic acid calibration curve (y= 0.01435 x+0.2567; R^2=0.993; 6.25-200 µgmL1), and estimated as µg GAE mg^{-1}. For the extracts or Gallic acid standard measurement, 300µL of sample was mixed with 1500 µL of FCR (diluted 10-fold). After 4min, 1200 µL of 7.5% $Na_2CO_3$was added, and the solution was kept in dark for 2 h. The absorbance of the obtained mixture was recorded at 765 nm.

TFC was assessed according to the procedure proposed by (Ayad et al., 2018). TFC was calculated from quercetin calibration curve (y= 0.02554 x+0.0078; R^2=0,997; 2.5-40 µgmL^{-1}), and estimated as µg QE mg^{-1}. For the extracts or quercetin standard measurement, 1 mL of 2% $AlCl_3$ (prepared in ethanol) was mixed with 1mL of standard or sample. After, incubation for 10 min in darkness, the absorbance was measured at 415 nm.

2.3 Evaluation of the antioxidant efficacy

The antioxidant efficacy of the extracts was determined through three *invitro* spectrophotometric methods: the DPPH assay, as described by (Almeida et al., 2011); the phenanthroline test, according to (Szyd\lowska-Czerniak et al., 2008) procedure; and the phosphomolybdenum assay, as described by (Cherfia et al., 2020). These methods were previously usedto analyse some plants growing in Algeria (Lefahal et al., 2023). Concisely, the antioxidant activity was determined from ascorbic acid calibration curve (y=-0.03461 x+0.8852, R^2=0.996; 12.5-20 µg mL^{-1}; at 517 nm); (y=0.007221 x+ 0.2383, R^2=0.99; 6.25-50 µg mL^{-1}; at 510 nm) and (y= 0.00632 x- 0.00022, R^2=0.9902; 12.5-500 µg mL^{-1}; at 695 nm) for DPPH, phenanthroline and phosphomolybdenum assays, respectively. The antioxidant efficacy was estimated as µg AAEmg^{-1}.

2.4 Photoprotection capacity of plant material

2.4.1 UV absorption profile

To evaluate the UV absorption potential of *C. dimorpha* extracts, a spectral scan (290-400 nm) was performed as described by (Ayad et al., 2022). Briefly, sample solutions of 0.1 $mgmL^{-1}$(in ethanol) were scanned between 290-400 nm, using a UV/VIS spectrophotometer.

2.4.2 In vitro sun protection factor (SPF) measurement

The extracts and standard (benzophenone 3) were prepared at a concentration of 0.1 $mgmL^{-1}$ in absolute ethanol. The solution's absorbance was measured in the range (290-320 nm) every 5nm, using a UV/VIS spectrophotometer. The SPF was calculated as described by (Mansur et al., 1986), by using the following formula:

$$\text{SPF in vitro} = \text{CF} \sum_{290}^{320} \text{EE}(\lambda).\text{I}(\lambda).\text{A}(\lambda)$$

CF: correction factor; EE(λ): erythemal effect spectrum; I (λ): solar intensity spectrum were constant (Sayre et al., 1979). A(λ): absorbance of the sample.

2.4.3 Broad spectrum protection evaluation

The broad-spectrum protection against UV radiation of the extracts was evaluated by calculating the critical wavelength (CW) and the ratio $\frac{\text{UVA}}{\text{UVB}}$ parameters.

Critical wavelength (CW) determination

CW is determined following the formula developed by (Diffey, 2007).

$$\int_{290}^{\lambda c} \text{A}(\lambda)\text{d}(\lambda) = 0.9 \int_{290}^{400} \text{A}(\lambda)\text{d}(\lambda)$$

A (λ): absorbance at wavelength λ.

The broadspectrum protection against UV radiation is considered when $\lambda_c \geq 370$ nm (Caballero-Gallardo et al., 2022).

2.4.4 Ratio UVA / UVB determination

The ration $\frac{\text{UVA}}{\text{UVB}}$ is another parameter used for the assessment of the broad-spectrum photoprotection (Ferrero et al., 2010; Kostyuk et al., 2018), and it is calculated as follows:

$$\frac{\text{UVA}}{\text{UVB}} = [\int_{320}^{400} \text{A}(\lambda)\text{d}(\lambda) / \int_{320}^{400} \text{d}(\lambda)] / [\int_{290}^{320} \text{A}(\lambda)\text{d}(\lambda) / \int_{290}^{320} \text{d}(\lambda)]$$

Based on the star rating system, the UVA protection is considered: good (**), superior (***), and ≥0.8: maximum (****) when UVA/UVB ratio ≥ 0.4, 0.6 and 0.8, respectively.

Statistical analysis

All measurements were done thrice. The results are expressed as means ± SD, and statistically analysed by the T-Test by using Graphpad prism software. The differences between sampleswere considered significant when $p<0.05$.

3. Result and discussion

3.1 Phytochemical characterization

The outcomes of TPC and TFC areshown in Table 1.

Table 1. The phytochemical contents of CD-EtOAc and CD-BuOH extracts

Samples	TPC (µg GAEmg^{-1})	TFC (µg QE mg^{-1})
CD-BuOH	79.37 ± 1.13***	28.24 ± 0.30***
CD-EtOAc	119.53 ± 0.32***	50.65 ± 0.43***

$^{(***)}$: Significant difference at p< 0.001.

By analysing the results of the phytochemical composition, it is shown that *CD*-EtOAc extractcontains the highest content of phenolic compounds (119.20 ±0.32 µg AGEmg^{-1}) compared to *CD*-BuOH extract (79.37 ± 1.13 µg AGE mg^{-1}). Likewise, for the TFC, *CD*-EtOAc extract contains a substantial amount of flavonoids (50.65 ± 0.43 µg QE mg^{-1}). However, the *CD*-BuOH extract had weak amount of flavonoids (28.24 ± 0.30 µg QE mg^{-1}).

When comparing the outcomes of the current study with those of other works conducted on *Centaurea* species, it is well showed that our data are in agreement with those of numerousscientists who reported the richness of the Centaurea species in polyphenols (Salachna et al., 2021; Özcan et al., 2019). Azzouzi et al. (2016) indicated that TPC and TFC amount in EtOAc extract of *Centaurea choulittiana* Pomel was higher than that present in BuOH extract, which is in line with our results. Similiraly, Lahneche and collaborators (Lahneche et al., 2019), noted that TPC and TFC levels in EtOAc extract of *Centaurea sphaerocephala L* were significant than those detected inBuOH *e*xtract, but their values are higher than those reported for the *Centaurea dimorpha*.

3.2 Antioxidant activity evaluation

The antioxidant efficacy of *C. dimorpha* specieswasestimated with three *in vitro* antioxidantmethods (DPPH, phenanthroline and phosphomolybdenum) and the results are shown in Figure1.

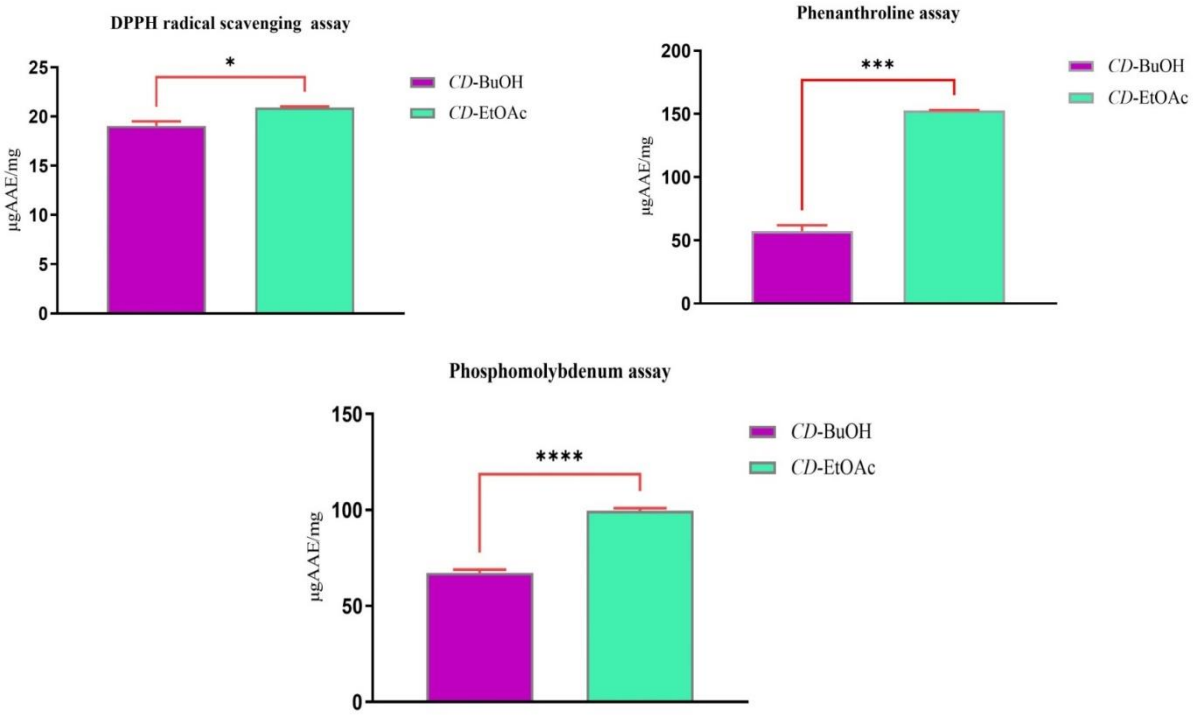

Figure 1. Antioxidant effect of *C. dimorpha* extracts. $^{(****)}$, $^{(***)}$ and $^{(*)}$: Significant difference at p<0.0001, <0.001 and <0.05, respectively

When shed light on the outcomes of the DPPH test, it is clearly observed that the *CD*-EtOAc extract had a good DPPH radical scavenging effect (20.91 ± 0.13 µg AAEmg^{-1}) compared to *CD*-BuOH extract. As for the obtained data of phosphomolybdenum assay (total antioxidant activity), it was also observed that *CD*-EtOAc extract demonstrated substantial efficacy (99.67 ± 1.28 µg AAEmg^{-1}), whereas the *CD*-BuOH extract was less effective (67.28 ± 1.64 µg AAEmg^{-1}). By assessing the results of phenanthroline assay, the results that *CD*-EtOAc extract was found to be more potent with (152.63 ± 0.49 µg AAEmg^{-1}) compared to *CD*-BuOH extract (57.19 ± 4.72 µg AAEmg^{-1}). By assessing the results of phenanthroline assay, it was found that the *CD*-EtOAc extract was more potent with (152.63 ± 0.49 µg AAEmg^{-1}) compared to the *CD*-BuOH extract (57.19 ± 4.72 µg AAEmg^{-1}).

While analysing the results of antioxidant activities of *C. dimorpha* extracts, a good correlation between the three methods was observed, which suggests that*C. dimorpha*secondary metabolites are capable to scavenge free radicals and reduce oxidants, where it was found that *CD*-EtOAc extract displayed significant radical scavenging and oxidant reducing activity compared to *CD*-BuOH extract. Although, the studied extracts had good DPPH radical scavenging activity, the recorded values when using this test were significantly lower than those when using phenanthroline and phosphomolybdenum assays (Figure 2). This could be explained by the fact that the mechanisms of action of the three methods are different, and the limited steric accessibility to the active site of the DPPH could decrease the anti radicalar efficacy (Xie & Schaich, 2014).

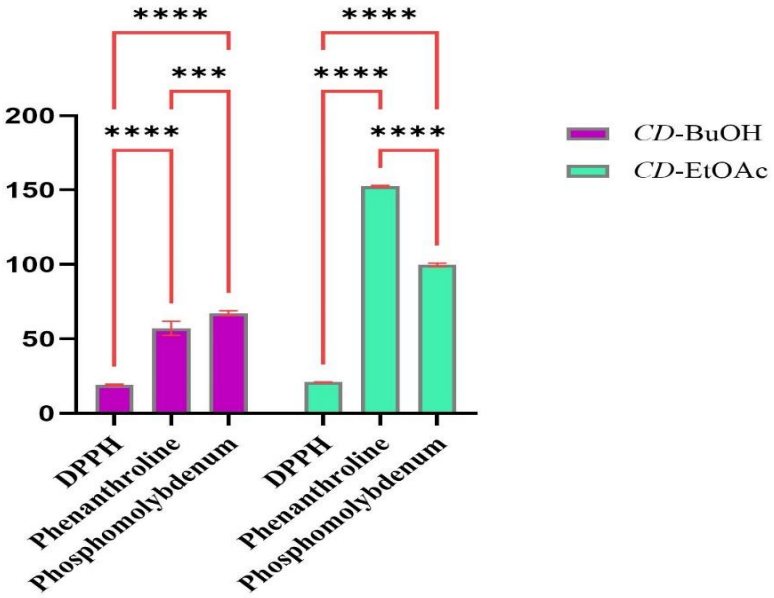

Figure 2. Comparison between antioxidant mechanisms. (****) and (***): Significant difference at p<0.0001 and 0.001

In the current study, *C. dimorpha* extracts showed significant anti-radicalar and reducing effects. Similarly, Bibi and coauthors (Bibi et al., 2024), noted that extracts of *Centaurea iberica* species exhibited significant DPPH scavenging activity and reducing power. Also, Yirtici and coauthors (Yırtıcı et al., 2022) examined the DPPH and phosphomolybdenum activities of *Centaurea sivasica* species and noted that this taxon displayed high activity. In addition, several authors confirmed the radical scavenging and reducing potential of plant extracts belonging to other species (Ayad et al., 2022; Boulacel et al., 2019; Rajurkar & Hande, 2011; Salachna et al., 2021). Consequently, *C. dimorpha* extracts can be used as natural antioxidant agents in several anti-aging formulations.

3.3 Photoprotective activity

3.3.1 UV absorbingprofile

Extracts obtained from plants contain a variety of phytoconstituents, which have UV absorption proprieties, particularly phenolicsand flavonoids. This makes them a promising ingredient for designing new eco-friendly sunscreen formulations.

The results in (Figure 3) show that *C. dimorpha* extracts have the same UV absorption profile. In fact, they absorb both UVB and UVA radiation, but *CD*-EtOAc recorded high absorption in both UVB and UVA range. Based on this, it appears that these extracts could be promising agents with photoprotective capacity.

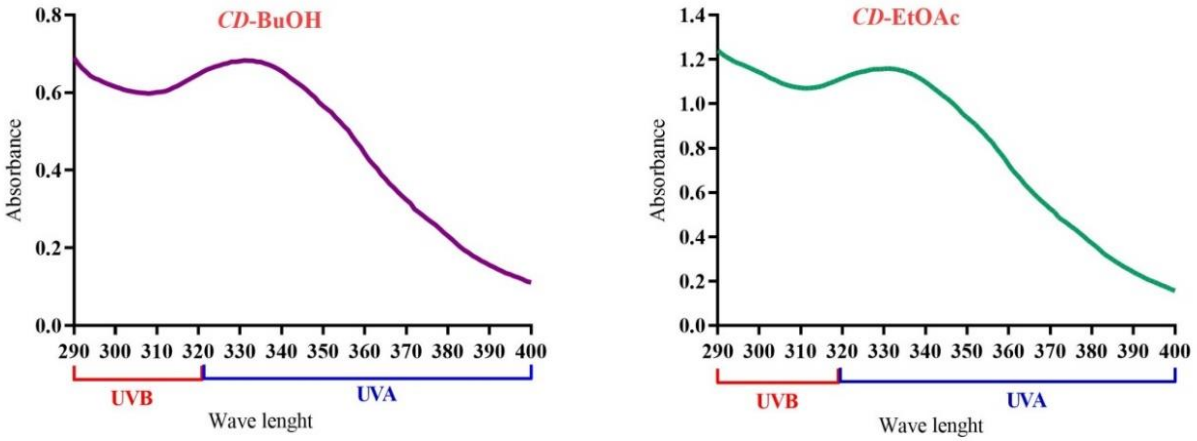

Figure 3. UV absorption profile ofC. dimorpha extracts

3.3.2 In vitro SPF estimation

SPF values (Table 2) showed that the two extracts have UVB photoprotection efficacy since they have met the regulation ruled by the European Commission categories ($SPF_{in\ vitro} \geq 6.0$) (Seregheti et al., 2020).

Table 2. $SPF_{in\ vitro}$ of C. dimorpha extracts and Benzophenone3

Samples	$SPF_{in\ vitro}$
CD-EtOAc	$12.30 \pm 0.001^{***}$
CD-BuOH	$6.82 \pm 0.001^{***}$
Benzophenone 3	$36.43 \pm 0.001^{***}$

(***): Significant difference at $p < 0.001$.

It can be also observed that *CD*-EtOAc extract ($SPF_{in\ vitro}$ =12.30±0.001) was more effective UVB screens than *CD*-BuOH extract ($SPF_{in\ vitro}$ =6.82 ± 0.001). However, these values were significantly lower than that of Benzophenone 3 ($SPF_{in\ vitro}$ = 36.43 ± 0.001), indicating that *CD*-EtOAc and *CD*-BuOH absorb UVB less than the standard. In a study performed by Bensaad and co-authors (Bensaad et al., 2021) the SPF values of the ethyl-acetate and Butanolic extractof *C. tougourensis* (SPF = 8.382 and 56.035, respectively at the concentration of $4 mgmL^{-1}$) were higher than those recorder in the current study. But the results of the *Centaurea dimorpha* are promising since the extract's concentration was very lower ($0.1 mgmL^{-1}$).

Furthermore, when comparing the antioxidant activity results of *C. dimorpha* extracts with their respective SPF values, a correlation was observed between the antioxidant effect and SPF values of *CD*-EtOAc and *CD*-BuOH extracts. This trend was also observed in the correlation between TPC, TFC and $SPF_{in\ vitro}$ values. Similarly, several authors revealed a good correlation between $SPF_{in\ vitro}$, phenolic, flavonoid contents and antioxidant efficacy of various plant species (Lefahal et al., 2021; Mouffouk et al., 2020; Lassoued et al., 2021; Nunes et al., 2018).

Considering the universal cosmetic regulations, and our outcomes, it seems that the *C. dimorpha* extracts especially *CD*-EtOAc can be incorporated in sunscreen formulation as a promising UVB photoprotective ingredient.

3.3.3 UV broad-spectrum protection efficacy evaluation

The measured indices, UVA/UVB ratio and CW, for *CD*-EtOAc and *CD*-BuOH extracts are indicated in (Table 3).

Table 3. UVA/UVB ratio and CW of C. dimorpha extracts

Samples	UVA/UVB ratio	CW (nm)
CD-EtOAc	0.63 ± 0.001***	371 ± 0.00
CD-BuOH	0.69 ± 0.001***	372 ± 0.00

CW: Critical wavelength

The UVA/UVB ratio is used to evaluate the protection against UVA radiation, and according to their values the levels of the protection are classified (Kostyuk et al., 2018). The results showed that both *CD*-EtOAc and *CD*-BuOH extracts displayed a UVA/UVB ratio of 0.63 ± 0.001 and 0.69 ± 0.001, respectively. These values indicate that the studied extracts are effective UVA protectants.

According the US-FDA, all products with CW ≥370nm are considered as broad-spectrum protectants (Wang et al., 2017). Our study's results (Table 3) indicate that both *CD*-EtOAc and *CD*-BuOH have wavelengths values greater than 370 nm, which correlates with FDA's requirement for broad-spectrum protection. In this sense, *C. dimorpha* extracts have the potential for the development of photoprotective cosmetic formulations.

4. Conclusion

In an effort to identify new potential applications of *Centaurea dimorpha* Viv plant as a new cosmetic active ingredient, the current study concluded by revealing, for the first time, the polyphenolic content, antioxidant and photoprotective capabilities of this plant. According to the study's results, *CD*-EtOAc extract had significant levels of TPC, TFC and antioxidant activity. In addition, *CD*-EtOAc extract showed a promising photoprotective effect as a broad-spectrum UV filter. These results suggest that this extract is a promising antioxidant and broad-spectrum UV filter active ingredient for the development of sunscreen cosmetic preparations. However, further *in vivo* and *in vitro* studies should be conducted on *CD*-EtOAc extract to test its toxicity such as skin and eyes irritation to ensure that it is safe for consumers when incorporated into cosmetic formulation.

Acknowledgement

This work was supported by the Ministry of Higher Education and Scientific Research of Algeria

Author's declaration

The authors declare that there are no conflicts of interest related to this article. AS, LM, ME and LS carried out laboratory work and analysed data.SA and KM advised about the laboratory technique and conducted manuscript proofreading before sub-mission. All authors read and approved the final version of the manuscript.

References

Adeosun, W. B., & Loots, D. T. (2024). Medicinal plants against viral infections: A review of metabolomics evidence for the antiviral properties and potentials in plant sources. *Viruses*, *16*(2), 218. CrossRef

Aktumsek, A., Zengin, G., Guler, G. O., Cakmak, Y. S., & Duran, A. (2011). Screening for in vitro antioxidant properties and fatty acid profiles of five Centaurea L. species from Turkey flora. *Food and Chemical Toxicology*, *49*(11), 2914–2920.

Aktumsek, A., Zengin, G., Guler, G. O., Cakmak, Y. S., & Duran, A. (2013). Antioxidant potentials and anticholinesterase activities of methanolic and aqueous extracts of three endemic Centaurea L. species. *Food and Chemical Toxicology*, *55*, 290–296.

Alamri, F. B., Sobahi, T. R., Althagbi, H. I., Abdel-Lateff, A., Alfaifi, M. Y., Mohammed, A. Y., Abdel-Latif, E., & Alarif, W. M. (2023). Bioactivity and molecular docking of lactones isolated from *Centaurea pseudosinaica* Czerep. *Saudi Pharmaceutical Journal*, *31*(6), 773–782. CrossRef

Almeida, M. M. B., de Sousa, P. H. M., Arriaga, Â. M. C., do Prado, G. M., de Carvalho Magalhães, C. E., Maia, G. A., & de Lemos, T. L. G. (2011). Bioactive compounds and antioxidant activity of fresh exotic fruits from northeastern Brazil. *Food Research International*, *44*(7), 2155–2159.

Ayad, R., Cakmak, Y. S., Ozusaglam, M. A., Medjroubi, K., & Akkal, S. (2018). In vitro antioxidant and antimicrobial activities of aerial parts of Algerian *Jurinea humilis* DC (Asteraceae). *Tropical Journal of Pharmaceutical Research*, *16*(12), 2903. CrossRef

Ayad, R., Keskinkaya, H. B., Atalar, M. N., Lefahal, M., Zaabat, N., Makhloufi, E. H., Demirtas, I., Trifa, W., Akkal, S., & Medjroubi, K. (2022). *Jurinea humilis* DC. polarextract: HPLC analysis, photoprotective, antioxidant activities and bioactive content. *Chemistry Africa*. 6, 827-836. CrossRef

Azzouzi, D., Bioud, K., Demirtas, I., Gul, F., Sarri, D., Benayache, S., Benayache, F., & Mekkiou, R. (2016). Phenolic profile and antioxidant activity of *Centaurea choulettiana* Pomel (Asteraceae) extracts. *Combinatorial Chemistry & High Throughput Screening*, *19*(10), 841-846. CrossRef

Bancheva, S., Badalamenti, N., & Bruno, M. (2022). The essential oil composition of *Centaurea immanuelis-loewii* Degen growing wild in Bulgaria and chemotaxonomy of section *acrocentron*. *Natural Product Research*, *36*(20), 5289–5296. CrossRef

Belkassam, A., Zellagui, A., Gherraf, N., Flamini, G., Cioni, P. L., Rebbas, K., & Smaili, T. (2019). Assessment of antioxidant effect of the essential oil and methanol extract of Viv.aerial parts from Algeria. *Acta Scientifica Naturalis*, *6*(1), 54–62.

Bensaad, M. S., Dassamiour, S., Hambaba, L., Bensouici, C., Karima, O., & Kahoul, M. A. (2021). HPLC-DAD phenolics screening and *in vitro* investigation of haemostatic, antidiabetic, antioxidant and photoprotective properties of *Centaurea tougourensis* Boiss. & Reut.*Herba Polonica*, *67*(4), 16–31. CrossRef

Bibi, H., Iqbal, J., Ahsan Abbasi, B., Kanwal, S., Tavafoghi, M., Ahmed, M. Z., & Mahmood, T. (2024). Evaluation and chemical profiling of different *Centaurea iberica* extracts and investigation of different in vitro biological activities. *Journal of King Saud University - Science*, *36*(1), 102992. CrossRef

Boulacel, I., Harkati, B., Ayad, R., Demirtas, I., Laouer, H., & Akkal, S. (2019). Phytochemical studies antibacterial and antioxidant activities of aerial parts of *Ferula lutea* (Poir.) Maire. *Acta Scientifica Naturalis*, *6*(1), 17–25.

Caballero-Gallardo, K., Quintero, R. P., Stashenko, E. E., & Olivero, V. J. (2022). Photoprotective Agents Obtained from Aromatic Plants Grown in Colombia: Total Phenolic Content, Antioxidant Activity, and Assessment of Cytotoxic Potential in Cancer Cell Lines of Cymbopogon flexuosus L. and Tagetes lucida Cav. Essential Oils. *Plants*, *11*(13), 1693. CrossRef

Cefali, L. C., Ataide, J. A., Moriel, P., Foglio, M. A., & Mazzola, P. G. (2016). Plant-based active photoprotectants for sunscreens. *International Journal of Cosmetic Science*, *38*(4), 346–353.

Cherfia, R., Zaiter, A., Akkal, S., Chaimbault, P., Abdelwahab, A. B., Kirsch, G., & Chaouche, N. K. (2020). New approach in the characterization of bioactive compounds isolated from *Calycotome spinosa* (L.) link leaves by the use of negative electrospray ionization LITMSn, LC-ESI-MS/MS, as well as NMR analysis. *Bioorganic Chemistry*, *96*, 103535.

Dhouibi, N., Manuguerra, S., Arena, R., Mahdhi, A., Messina, C. M., Santulli, A., & Dhaouadi, H. (2020). Screening of antioxidant potentials and bioactive properties of the extracts obtained from two Centaurea L. species *Centaurea kroumirensis* Coss. & *Centaurea sicula* L. subspsicula. *Applied Sciences*, *10*(7), 2267.

Diffey, B. L. (2007). A method for broad spectrum classification of sunscreens. *International Journal of Cosmetic Science*, *16*(2), 47–52. CrossRef

Downs, C. A., Kramarsky-Winter, E., Segal, R., Fauth, J., Knutson, S., Bronstein, O., Ciner, F. R., Jeger, R., Lichtenfeld, Y., & Woodley, C. M. (2016). Toxicopathological effects of the sunscreen UV filter, oxybenzone (benzophenone-3), on coral planulae and cultured primary cells and its environmental contamination in Hawaii and the US Virgin Islands. *Archives of Environmental Contamination and Toxicology*, *70*, 265–288.

Ertas, A., Gören, A. C., Boga, M., Demirci, S., & Kolak, U. (2014). Chemical composition of the essential oils of three Centaureaspecies growing wild in Anatolia and their anticholinesterase activities. *Journal of Essential Oil-Bearing Plants*, *17*(5), 922–926. CrossRef

Fattaheian-Dehkordi, S., Hojjatifard, R., Saeedi, M., & Khanavi, M. (2021). A review on antidiabetic activity of Centaurea spp.: A new approach for developing herbal remedies. *Evidence-Based Complementary and Alternative Medicine*, *6*, 1-23. CrossRef

Ferrero, L., Pissavini, M., &Doucet, O. (2010). How a calculated model of sunscreen film geometry can explain in vitro and in vivo SPF variation. *Photochemical & Photobiological Sciences*, *9*(4), 540–551. CrossRef

Ganesan, A., & Hanawalt, P. (2016). Photobiological origins of the field of genomic maintenance. *Photochemistry and Photobiology*, *92*(1), 52–60.

Guan, L. L., Lim, H. W., & Mohammad, T. F. (2021). Sunscreens and photoaging: A review of current literature. *American Journal of Clinical Dermatology*, *22*(6), 819–828.

Jansen, R., Osterwalder, U., Wang, S. Q., Burnett, M., & Lim, H. W. (2013). Photoprotection: Part II. Sunscreen: development, efficacy, and controversies. *Journal of the American Academy of Dermatology*, *69*(6), 867-e1.

Kebbi, S., Ciavatta, M. L., Mahmoud, A. M., Carbone, M., Ligresti, A., Seghiri, R., & Gavagnin, M. (2021). Sesquiterpene Lactones with the 12,8-Guaianolide skeleton from Algerian *Centaurea omphalotricha*. *Biomolecules*, *11*(7), 1053. CrossRef

Khammar, A., & Djeddi, S. (2012). Pharmacological and biological properties of some Centaurea species. *European Journal of Scientific Research*, *84*(3), 398–416.

Kostyuk, V., Potapovich, A., Albuhaydar, A. R., Mayer, W., De Luca, C., & Korkina, L. (2018). Natural substances for prevention of skin photoaging: Screening systems in the development of sunscreen and rejuvenation cosmetics. *Rejuvenation Research*, *21*(2), 91–101. CrossRef

Kumar, A. (2016). Medicinal plants: Future source of new drugs. *International Journal of Herbal Medicine, 4(4), 59-64*.

Lahneche, A. M., Boucheham, R., Ozen, T., Altun, M., Boubekri, N., Demirtas, I., Bicha, S., Bentamene, A., Benayache, F., Benayache, S., & Zama, D. (2019). In vitro antioxidant, DNA-damaged protection and antiproliferative activities of ethyl acetate and n-butanol extracts of Centaurea sphaerocephalaL. *Anais Da Academia Brasileira de Ciências*, *91*(3), e20180462. CrossRef

Lassoued, M. A., Ben Fatma, N. E. H., Haj Romdhane, M., Faidi, A., Majdoub, H., & Sfar, S. (2021). Photoprotective potential of a Tunisian halophyte plant *Carpobrotus edulis* L. *European Journal of Integrative Medicine*, *42*, 101286. CrossRef

Lefahal, M., Makhloufi, E., Ayad, R., Boussetla, A., Elhattab, M., KeskiN, M., & Akkal, S. (2023). Highlighting the cosmeceutical potential of the edible *Bunium alpinum* Waldst & Kit (Apiaceae) growing in Algeria: in vitro antioxidant and photoprotective Effects. *Gazi University Journal of Science*, *36*(1), 108–118. CrossRef

Lefahal, M., Makhloufi, E.-H., Trifa, W., Ayad, R., El Hattab, M., Benahmed, M., Keskin, M., & Akkal, S. (2021). The cosmetic potential of the medicinal halophyte *Tamarix gallica* L. (Tamaricaceae) growing in the eastern part of Algeria: photoprotective and antioxidant activities. *Combinatorial Chemistry & High Throughput Screening*, *24*(10), 1671–1678.

Lohani, A., Mishra, A. K., & Verma, A. (2019). Cosmeceutical potential of geranium and calendula essential oil: determination of antioxidant activity and in vitro sun protection factor. *Journal of Cosmetic Dermatology*, *18*(2), 550–557.

Mansur, J. S., Breder, M. N. R., Mansur, M. C. A., & Azulay, R. D. (1986). Determination of sun protection of sunscreen by ultraviolet spectrophotometry. *AnaisBrasileiros de Dermatologia*, 61, 121–124.

Mouffouk, C., Mouffouk, S., Oulmi, K., Mouffouk, S., & Haba, H. (2020). In vitro photoprotective, hemostatic, anti-inflammatory and antioxidant activities of the species *Linaria scariosa* Desf. *South African Journal of Botany*, *130*, 383–388.

Nunes, A. R., Vieira, Í. G. P., Queiroz, D. B., Leal, A. L. A. B., Maia Morais, S., Muniz, D. F., Calixto-Junior, J. T., & Coutinho, H. D. M. (2018). Use of flavonoids and cinnamates, the main photoprotectors with natural origin. *Advances in Pharmacological Sciences*, *2018*, 1–9. CrossRef

Özcan, K., Acet, T., & Çorbacı, C. (2019). *Centaurea hypoleuca* DC: Phenolic content, antimicrobial, antioxidant and enzyme inhibitory activities. *South African Journal of Botany*, *127*, 313–318. CrossRef

Petropoulos, S. A., Fernandes, A., Dias, M. I., Pereira, C., Calhelha, R., Di Gioia, F., Tzortzakis, N., Ivanov, M., Sokovic, M., Barros, L., & Ferreira, I. C. F. R. (2020). Wild and cultivated *Centaurea raphanina* subsp. mixta: A valuable source of bioactive compounds. *Antioxidants*, *9*(4), 314. CrossRef

Pires, T. C., Dias, M. I., Barros, L., Calhelha, R. C., Alves, M. J., Oliveira, M. B. P., Santos-Buelga, C., & Ferreira, I. C. (2018). Edible flowers as sources of phenolic compounds with bioactive potential. *Food Research International*, *105*, 580–588.

Rajurkar, N. S., & Hande, S. M. (2011). Estimation of phytochemical content and antioxidant activity of some selected traditional Indian medicinal plants. *Indian Journal of Pharmaceutical Sciences*, *73*(2), 146.

Reyhan, A., Küpeli, E., & Ergun, F. (2004). The biological activity of *Centaurea* L. species. *Gazi University Journal of Science*, *17*(4), 149–164.

Salachna, P., Pietrak, A., & Lopusiewicz, L. (2021). Antioxidant potential of flower extracts from Centaurea spp. depends on their content of phenolics, flavonoids and free amino acids. *Molecules*, *26*(24), 7465.

Sayre, R. M., Agin, P. P., LeVee, G. J., & Marlowe, E. (1979). A comparison of in vivo and in vitro testing of sun screening formulas. *Photochemistry and Photobiology*, *29*(3), 559–566.

Schuch, A. P., Moreno, N. C., Schuch, N. J., Menck, C. F. M., & Garcia, C. C. M. (2017). Sunlight damage to cellular DNA: Focus on oxidatively generated lesions. *Free Radical Biology and Medicine*, *107*, 110–124.

Serafini, M. R., Guimarães, A. G., Quintans, J. S., Araújo, A. A., Nunes, P. S., & Quintans-Júnior, L. J. (2015). Natural compounds for solar photoprotection: a patent review. *Expert Opinion on Therapeutic Patents*, *25*(4), 467–478.

Seregheti, T. M., Pinto, A. P. R., Gonçalves, M. da C., Antunes, A. dos S., Almeida, W. da S., Machado, R. S., Silva, J. N., Ferreira, P. M. P., Pessoa, C., & Dos Santos, V. M. R. (2020). Antiproliferative and photoprotective activities of the extracts and compounds from *Calea fruticosa*. *Brazilian Journal of Medical and Biological Research*, *53*(9), e9375. CrossRef

Szyd\lowska-Czerniak, A., Dianoczki, C., Recseg, K., Karlovits, G., & Sz\lyk, E. (2008). Determination of antioxidant capacities of vegetable oils by ferric-ion spectrophotometric methods. *Talanta*, *76*(4), 899–905.

Thibane, V. S., Ndhlala, A. R., Abdelgadir, H. A., Finnie, J. F., & Van Staden, J. (2019). The cosmetic potential of plants from the Eastern CapeProvince traditionally used for skincare and beauty. *South African Journal of Botany*, *122*, 475–483.

Wala, M., Kołodziejek, J., Mazur, J., & Cienkowska, A. (2021). Reactions of two xeric-congeneric species of *Centaurea* (Asteraceae) to soils with different pH values and iron availability. *PeerJ*, *9*, e12417. CrossRef

Wang, S. Q., Xu, H., Stanfield, J. W., Osterwalder, U., & Herzog, B. (2017). Comparison of ultraviolet A light protection standards in the United States and European Union through in vitro measurements of commercially available sunscreens. *Journal of the American Academy of Dermatology*, *77*(1), 42–47. CrossRef

Xie, J., & Schaich, K. M. (2014). Re-evaluation of the 2,2-Diphenyl-1-picrylhydrazyl free radical (DPPH) assay for antioxidant activity. *Journal of Agricultural and Food Chemistry*, *62*(19), 4251–4260. CrossRef

Yayli, N., Yaşar, A., Güleç, C., Usta, A., Kolaylı, S., Coşkunçelebi, K., & Karaoğlu, Ş. (2005). Composition and antimicrobial activity of essential oils from *Centaurea sessilis* and *Centaurea armena*. *Phytochemistry*, *66*(14), 1741–1745.

Yırtıcı, Ü., Ergene, A., Atalar, M. N., & Adem, Ş. (2022). Phytochemical composition, antioxidant, enzyme inhibition, antimicrobial effects, and molecular docking studies of *Centaurea sivasica*. *South African Journal of Botany*, *144*, 58–71. CrossRef