Antioxidant and Anti-inflammatory Properties of Urtica dioica Essential Oil: *In Silico, In Vitro*, and Phytochemical Analysis

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INTRODUCTION

Urtica dioica, commonly known as nettle, is a widely distributed plant used in traditional medicine for its numerous therapeutic properties. The essential oil derived from *Urtica dioica* (UDEO) has gained attention for its potential health benefits, particularly in managing oxidative stress and inflammation. The plant itself contains a wide variety of bioactive compounds, including flavonoids, phenolic acids, terpenoids, and alkaloids, all of which contribute to its pharmacological activities. UDEO has been shown to possess potent antioxidant properties, which are believed to stem from its ability to neutralize free radicals and reduce oxidative damage. Oxidative stress is a critical factor in the development of many chronic diseases, including cardiovascular diseases, neurodegenerative disorders, and certain cancers. The plant's ability to combat oxidative stress makes it a valuable candidate for the development of natural therapeutic agents. In addition to its antioxidant potential, UDEO has demonstrated anti-inflammatory effects in various studies. This study evaluates the antioxidant capacity of UDEO through in silico, in vitro, and phytochemical analyses. By identifying bioactive compounds and their interactions with inflammatory pathways, it aims to uncover the mechanisms behind the plant's therapeutic potential, offering insights for natural interventions in managing oxidative stress and inflammation.

MATERIEL & METHODS

Phytochemical Analysis: Gas chromatography combined with triple quadrupole mass spectrometry (GC-MS/MS) was used to evaluate the sample extracts (Agilent Technology, France). Various injection methods of the multimode inlet (MMI) in chromatography were investigated to achieve lower instrumental detection limits.

Antioxidant Tests: Standard antioxidative tests, including ABTS•+ and Total Antioxidant Capacity (TAC), were conducted to measure UDEO's antioxidant capacity.

In Silico Studies: The major identified compounds of Urtica dioica essential oil (UDEO) were utilized in the in silico analysis to investigate their molecular interactions and confirm their potential anti-inflammatory and healing effects. The 3D chemical structures of the compounds were either collected from the PubChem website or drawn using the ChemDraw software package. The 3D crystal structures of COX-2, TNF-α, and IL-6 receptors were obtained from the RCSB Protein Data Bank (PDB).

RESULTS & DISCUSSION

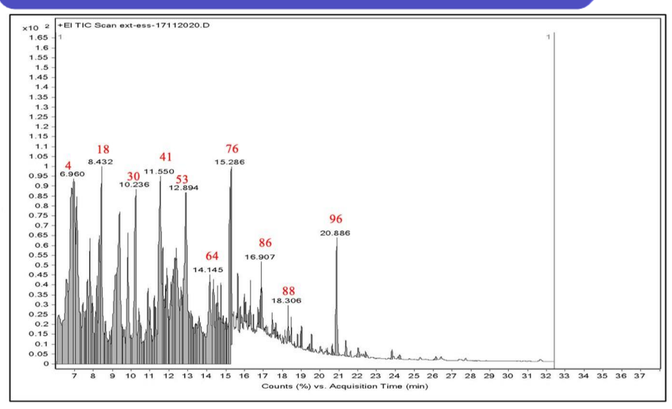


Figure 1

GC-MS/MS Chromatograms of Urtica dioica Essential Oil

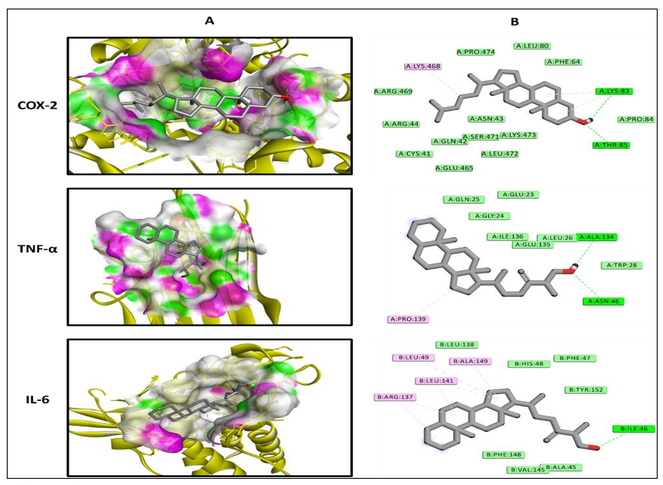


Figure 2

(A) 3D illustration of some Urtica dioica compounds that had the best binding affinities coupled with region of the different targeted receptors: compound no.17 and COX-2, compound no. 53 and TNF-α (B), and compound no. 53 and IL-6, (B): The corresponding diagram of interactions of each complex.

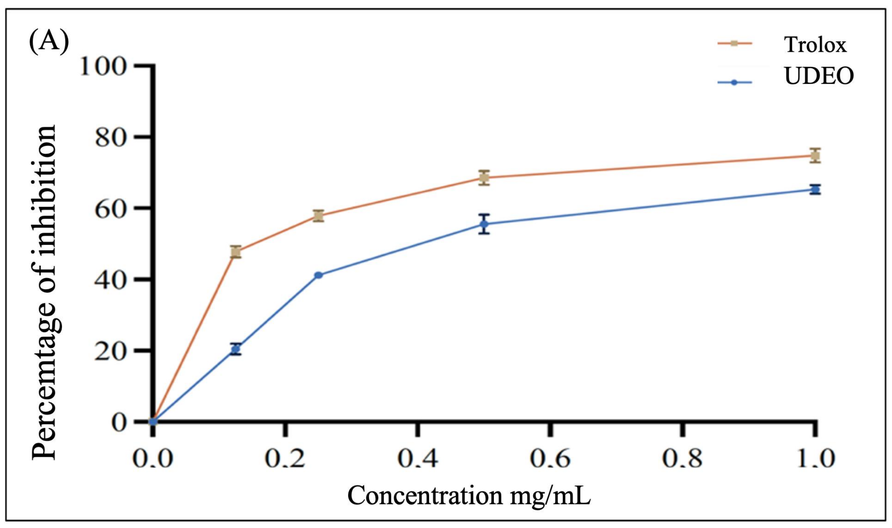
Our results from GC-MS/MS analysis identified 97 compounds in U. dioica essential oil. In silico studies revealed varying binding affinities to COX-2 (−3.2 to −10.3 kcal/mol), TNF-α (−2.9 to −6.5 kcal/mol), and IL-6 (−2.6 to −7.5 kcal/mol), with cholestanol, acetonaphthone, and bicyclo[4, 4, 0]dec-2-ene-4ol showing the strongest interactions with COX-2. Notably, bicyclo[4, 4, 0]dec-2-ene-4ol formed the highest number of H-bonds (n = 3) with key residues, contributing to the stability of the ligand-receptor complexes.

Furthermore, antioxidant assays indicated that UDEO exhibited an IC50 of 0.39 ± 0.055 mg·mL^{-1} against ABTS+ radicals, compared to 0.147 ± 0.002 mg·mL^{-1} for Trolox. The ammonium phosphomolybdate assay showed an antioxidant potency of 0.50 ± 0.16 mg·mL^{-1} for UDEO, which was lower than that of Vitamin C (IC50 = 0.16 ± 0.008 mg·mL^{-1}).

Table 1. Binding affinity of *Urtica dioica* essential oil major identified compounds with the different targeted receptors: COX-2, TNF-α, and IL-6

Compound No.	Binding Affinity (kcal × mol−1)		
	COX-2	TNF-α	IL-6
53	−7.4	−6.5	−7.5
4	−5.9	−5.4	−6.1
5	−5.3	−4.5	−4.5
30	−6.2	−4.8	−6.0
50	−5.7	−4.7	−5.7
64	−4.4	−3.9	−3.8
24	−6.8	−5.9	−6.3
28	−5.8	−5.5	−5.9
76	−6.2	−4.8	−5.3
11	−5.3	−4.0	−4.9
17	−10.3	−6.1	−6.9
49	−8.0	−6.5	−7.1

Table 2. Antioxidant Activity of UDEO



CONCLUSION

In conclusion, this study thoroughly evaluates the antioxidant capacity of Urtica dioica essential oil (UDEO) using in silico, in vitro, and phytochemical analyses. By identifying the bioactive compounds in UDEO and examining their interactions with key inflammatory pathways, we uncover the mechanisms underlying the plant's therapeutic potential.