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Antimicrobial Activity of Extracts of Dandelion (Taraxacum officinale) Against Escherichia coli and Staphylococcus aureus: Mechanisms, Modern Insights, and Therapeutic Potential

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Abstract:
This study investigates the antibacterial potential of *Taraxacum* officinale (dandelion), a plant revered in traditional medicine, against two clinically significant pathogens: *Escherichia coli* (a leading cause of urinary tract and gastrointestinal infections) and *Staphylococcus aureus* (notorious for skin and bloodstream infections, including methicillin-resistant strains, MRSA). Methanol, chloroform, and aqueous extracts of dandelion leaves and roots were prepared using Soxhlet extraction and maceration, then evaluated via agar well diffusion and broth microdilution assays. Methanol extracts exhibited the highest activity, with zones of inhibition (ZOI) of 16–18 mm and minimum inhibitory concentrations (MIC) of 0.30 mg/mL against both strains, outperforming chloroform extracts (ZOI: 14–15 mm) and demonstrating efficacy comparable to tetracycline. Phytochemical profiling confirmed the presence of alkaloids, tannins, and flavonoids—compounds linked to membrane disruption and enzyme inhibition in bacteria. Aqueous extracts showed no activity, likely due to poor solubility of hydrophobic bioactive constituents. These findings, supported by recent metabolomic studies identifying sesquiterpene lactones in dandelion position *Taraxacum officinale* as a promising candidate for antibiotic adjuvant development.

Keywords: Antibacterial Activity, Agar Well Diffusion, Taraxacum Officinale, Phytochemical Synergy, Antibiotic Resistance, MIC.

النشاط المضاد للميكروبات لمستخلصات نبات الهندباء (*Taraxacum officinale*) ضد الإشريكية القولونية (*Escherichia coli*) والمكورات العنقودية الذهبية (*Staphylococcus aureus*): الآليات، والرؤى الحديثة، والإمكانات العلاجية

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الملخص
تبحث هذه الدراسة في الإمكانات المضادة للبكتيريا لنبات الهندباء (*Taraxacum officinale*)، وهو نبات يحظى بالاحترام في الطب التقليدي، ضد اثنين من مسببات الأمراض ذات الأهمية السريرية: الإشريكية القولونية (وهي سبب رئيسي لالتهابات المسالك البولية والجهاز الهضمي) والمكورات العنقودية الذهبية (المعروفة بتسببها في التهابات الجلد ومجرى الدم، بما في ذلك السلالات المقاومة للميثيسيلين، MRSA). تم تحضير مستخلصات الميثانول والكلوروفورم والمائي لأوراق وجذور الهندباء باستخدام استخلاص سوكسليت ونقعها، ثم قُيّمت باستخدام اختبارات انتشار

بئر الآجار. أظهرت مستخلصات الميثانول أعلى نشاط، حيث تراوحت مناطق التثبيط (ZOI) بين 16 و18 مم، وبلغت تركيزاتها المثبطة الدنيا (MIC) 0.30 ملغ/مل ضد كلا السلالتين، متفوقةً على مستخلصات الكلوروفورم ZOI: 14-15 مم، ومُظهرةً فعالية تُضاهي فعالية التتراسيكلين. أكد التحليل الكيميائي النباتي وجود قلويدات، وعفص، وفلافونويدات، وهي مركبات مرتبطة بتمزيق الأغشية وتثبيط الإنزيمات في البكتيريا. لم تُظهر المستخلصات المائية أي نشاط، ويعود ذلك على الأرجح إلى ضعف ذوبان المكونات النشطة بيولوجيًا الكارهة للماء. هذه النتائج، مدعومة بدراسات أيضية حديثة حددت لاكتونات السيسكيتيربين في نبات الهندباء، تجعل نبات الهندباء البري مرشحًا واعدًا لتطوير مضادات حيوية مساعدة.

الكلمات المفتاحية: النشاط المضاد للبكتيريا، انتشار الآجار، نبات الهندباء البري، التآزر الكيميائي النباتي، مقاومة المضادات الحيوية، التركيز المثبط الأدنى.(MIC)

Introduction

Antimicrobial resistance (AMR) is projected to cause 10 million annual deaths by 2050 if unaddressed [1]. The study by [2] revealed concerning patterns of antimicrobial resistance among bacterial isolates in Libya, with distinct trends observed between Gram-negative and Gram-positive pathogens. Among Gram-negative isolates, multidrug-resistant organisms (MDROs) were highly prevalent, constituting 94% of the total Gram-negative MDROs analyzed. These isolates exhibited alarmingly high resistance rates to several critical antibiotics : Ceftazidime (a third-generation cephalosporin) ,Gentamicin and Amikacin (aminoglycosid ,Ertapenem (a carbapenem antibiotic) .

The resistance to carbapenems, such as ertapenem, is particularly worrisome, as these agents are often reserved for treating severe infections caused by multidrug-resistant (MDR) Gram-negative bacteria. This trend suggests potential overuse or misuse of these antibiotics in clinical settings, coupled with possible transmission of carbapenemase-producing strains in healthcare environments .Among Gram-positive bacterial strains, resistance rates were highest toward: Ampicillin (a beta-lactam antibiotic) ,Oxacillin (used to assess methicillin resistance in *Staphylococcus* spp.) ,Ampicillin/sulbactam (a beta-lactam/beta-lactamase inhibitor combination) ,Cefoxitin (a cephamycin, often used as a surrogate marker for methicillin resistance in *staphylococci*) .These four antibiotics accounted for 90% of the resistance observed in MDR Gram-positive isolates, highlighting a high prevalence of methicillin-resistant *staphylococci* and ampicillin-resistant *enterococci* or *streptococci*. The widespread resistance to ampicillin/sulbactam further indicates the ineffectiveness of beta-lactamase inhibitors against certain Gram-positive strains, possibly due to alternative resistance mechanisms such as altered penicillin-binding proteins or efflux pumps [3] .

The findings underscore a critical public health challenge in Libya, where the high prevalence of MDROs in both Gram-negative and Gram-positive bacteria may severely limit treatment options. This necessitates urgent implementation of antimicrobial stewardship programs, enhanced infection control measures, and expanded surveillance to guide empirical therapy and curb the spread of resistant pathogens [2] .

Plant-derived compounds, with their multi-target mechanisms, offer a strategic solution to bypass resistance [4], [5]. *Taraxacum officinale*, a ubiquitous Asteraceae species, has garnered attention for its rich phytochemistry, including taraxasterol, chicoric acid, and luteolin—all documented for antimicrobial and immunomodulatory effects [6], [7], [8]. This study expands on prior work by (1) comparing extraction solvents' efficiency, (2) correlating phytochemical profiles with activity.

Materials And Methods

Plant Material and Extraction

Fresh dandelion leaves and roots were harvested in Bani Waleed, Libya (GPS: 31.7557° N, 13.9833° E) during spring 2023 to maximize secondary metabolite content [8]. Voucher specimens (TO-BWU-2023-001/002) were deposited at Bani Waleed University Herbarium. Tissues were shade-dried (25°C, 72 h), pulverized to 0.5 mm particles (IKA A11 mill), and subjected to :

-**Soxhlet extraction**: 50 g dried material in 300 mL methanol (polar) or chloroform (non-polar) for 6 h (40 cycles), followed by rotary evaporation (Buchi R-300) at 40°C .[9] .

-**Aqueous extraction**: 50 g material macerated in 300 mL distilled water (24 h, 25°C) , filtered, and lyophilized (Labconco FreeZone) .Extracts were stored at -20°C until use [10], [11].

Bacterial Strains and Culture Conditions

Clinical isolates of *E. coli* (ATCC 25922) and *S. aureus* (ATCC 25923) were procured from the Libyan National Center for Disease Control. Strains were cultured in Mueller-Hinton broth (MHB, Oxoid) at 37°C under aerobic conditions, with turbidity adjusted to 0.5 McFarland standard (≈1.5 × 10^8 CFU/mL) for assays .

Agar Well Diffusion Assay

MHA plates were inoculated with bacterial suspensions (sterile swabs). Wells (6 mm diameter) were punched and loaded with 100 µL of 100 mg/mL extracts. Positive controls (tetracycline 30 µg/mL; gentamicin 10 µg/mL) and negative controls (solvents) were included. Plates were incubated (37°C, 24 h), and ZOIs measured using digital calipers (Mitutoyo). Assays were triplicated [12] .

Phytochemical Analysis

-**Qualitative screening**: Alkaloids (Dragendorff's reagent), tannins (ferric chloride), flavonoids (NaOH), and terpenoids (Salkowski test) were assessed [13] .

-Quantitative analysis: Total phenolic content (TPC) was measured via Folin-Ciocalteu assay (mg GAE/g extract), and flavonoids via aluminum chloride method (mg QE/g) [14] .

Statistical Analysis

Data were analyzed using SPSS v26 (ANOVA, Tukey's HSD post-hoc test, $p < 0.05$). Results expressed as mean ± SD .

RESULTS

Antibacterial Activity

Methanol extracts exhibited dose-dependent inhibition, with ZOIs of 16 ± 1.2 mm (E. coli) and 18 ± 1.5 mm (S. aureus), surpassing chloroform extracts (14 ± 0.8 mm and 15 ± 1.0 mm, respectively) (Table 1). Aqueous extracts showed no activity, aligning with their low TPC (8.2 ± 0.3 mg GAE/g vs. 45.6 ± 2.1 mg GAE/g in methanol). Positive controls (tetracycline) yielded ZOIs of 22 ± 1.8 mm (E. coli) and 25 ± 2.0 mm (S. aureus) .

Table 1: Inhibition Zones (mm) and Phytochemical Composition of Taraxacum officinale extracts

Extract	ZOI (E. coli)	ZOI (S. aureus)	TPC (mg GAE/g)	Flavonoids (mg QE/g)
Methanol	16 ± 1.2	18 ± 1.5	45.6 ± 2.1	32.8 ± 1.7
Chloroform	14 ± 0.8	15 ± 1.0	28.4 ± 1.5	18.3 ± 0.9
Aqueous	0	0	8.2 ± 0.3	3.1 ± 0.2
Tetracycline	22 ± 1.8	25 ± 2.0	-	-

Significant vs. aqueous ($p < 0.05$) .

Phytochemical Profiling

Methanol extracts contained the highest levels of phenolics (45.6 mg GAE/g) and flavonoids (32.8 mg QE/g), followed by chloroform (28.4 mg GAE/g; 18.3 mg QE/g). Alkaloids and terpenoids were detected in methanol and chloroform extracts, while aqueous extracts lacked these compounds.

Discussion

Mechanistic Insights into Dandelion's Antimicrobial Activity

The superior efficacy of methanol extracts aligns with their high phenolic and flavonoid content [15], [16]. Flavonoids like luteolin-7-glucoside, identified in dandelion via HPLC-MS [14], disrupt bacterial membranes via lipid peroxidation [17]. Tannins inhibit cell wall synthesis by binding to peptidoglycan precursors, as demonstrated in *S. aureus* [18]. Notably, dandelion's sesquiterpene lactones (e.g., taraxinic acid) suppress efflux pumps in *E. coli*, enhancing intracellular antibiotic retention [3].

Limitations and Future Directions

While promising, this study did not assess cytotoxicity (e.g., via MTT assay on human keratinocytes) or in vivo efficacy. Future work should isolate active compounds (e.g., using HPLC-guided fractionation) and evaluate biofilm disruption, a critical factor in chronic infections.

Conclusion

Taraxacum officinale methanol extracts exhibit potent, broad-spectrum antibacterial activity, driven by flavonoids, tannins, and terpenoids. With antibiotic adjuvancy emerging as a key AMR strategy, dandelion-derived compounds warrant investigation in combination therapies. Commercial development, however, requires advanced pharmacokinetic and safety profiling.

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