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ЕЖЕМЕСЯЧНЫЙ НАУЧНЫЙ ЖУРНАЛ

Медицинские новости Грузии

საქართველოს სამედიცინო სიახლენი

GEORGIAN MEDICAL NEWS

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GMN: Georgian Medical News is peer-reviewed, published monthly journal committed to promoting the science and art of medicine and the betterment of public health, published by the GMN Editorial Board since 1994. GMN carries original scientific articles on medicine, biology and pharmacy, which are of experimental, theoretical and practical character; publishes original research, reviews, commentaries, editorials, essays, medical news, and correspondence in English and Russian.

GMN is indexed in MEDLINE, SCOPUS, PubMed and VINITI Russian Academy of Sciences. The full text content is available through EBSCO databases.

GMN: Медицинские новости Грузии - ежемесячный рецензируемый научный журнал, издаётся Редакционной коллегией с 1994 года на русском и английском языках в целях поддержки медицинской науки и улучшения здравоохранения. В журнале публикуются оригинальные научные статьи в области медицины, биологии и фармации, статьи обзорного характера, научные сообщения, новости медицины и здравоохранения. Журнал индексируется в MEDLINE, отражён в базе данных SCOPUS, PubMed и ВИНИТИ РАН. Полнотекстовые статьи журнала доступны через БД EBSCO.

GMN: Georgian Medical News – საქართველოს სამედიცინო სიახლენი – არის ყოველთვიური სამეცნიერო სამედიცინო რეცენზირებადი ჟურნალი, გამოიცემა 1994 წლიდან, წარმოადგენს სარედაქციო კოლეგიისა და აშშ-ის მეცნიერების, განათლების, ინდუსტრიის, ხელოვნებისა და ბუნებისმეტყველების საერთაშორისო აკადემიის ერთობლივ გამოცემას. GMN-ში რუსულ და ინგლისურ ენებზე ქვეყნდება ექსპერიმენტული, თეორიული და პრაქტიკული ხასიათის ორიგინალური სამეცნიერო სტატიები მედიცინის, ბიოლოგიისა და ფარმაციის სფეროში, მიმოხილვითი ხასიათის სტატიები.

ჟურნალი ინდექსირებულია MEDLINE-ის საერთაშორისო სისტემაში, ასახულია SCOPUS-ის, PubMed-ის და ВИНИТИ РАН-ის მონაცემთა ბაზებში. სტატიების სრული ტექსტი ხელმისაწვდომია EBSCO-ს მონაცემთა ბაზებიდან.

WEBSITE

www.geomednews.com

К СВЕДЕНИЮ АВТОРОВ!

При направлении статьи в редакцию необходимо соблюдать следующие правила:

1. Статья должна быть представлена в двух экземплярах, на русском или английском языках, напечатанная через **полтора интервала на одной стороне стандартного листа с шириной левого поля в три сантиметра**. Используемый компьютерный шрифт для текста на русском и английском языках - **Times New Roman** (**Кириллица**), для текста на грузинском языке следует использовать **AcadNusx.** Размер шрифта - **12**. К рукописи, напечатанной на компьютере, должен быть приложен CD со статьей.

2. Размер статьи должен быть не менее десяти и не более двадцати страниц машинописи, включая указатель литературы и резюме на английском, русском и грузинском языках.

3. В статье должны быть освещены актуальность данного материала, методы и результаты исследования и их обсуждение.

При представлении в печать научных экспериментальных работ авторы должны указывать вид и количество экспериментальных животных, применявшиеся методы обезболивания и усыпления (в ходе острых опытов).

4. К статье должны быть приложены краткое (на полстраницы) резюме на английском, русском и грузинском языках (включающее следующие разделы: цель исследования, материал и методы, результаты и заключение) и список ключевых слов (key words).

5. Таблицы необходимо представлять в печатной форме. Фотокопии не принимаются. **Все цифровые, итоговые и процентные данные в таблицах должны соответствовать таковым в тексте статьи**. Таблицы и графики должны быть озаглавлены.

6. Фотографии должны быть контрастными, фотокопии с рентгенограмм - в позитивном изображении. Рисунки, чертежи и диаграммы следует озаглавить, пронумеровать и вставить в соответствующее место текста **в tiff формате**.

В подписях к микрофотографиям следует указывать степень увеличения через окуляр или объектив и метод окраски или импрегнации срезов.

7. Фамилии отечественных авторов приводятся в оригинальной транскрипции.

8. При оформлении и направлении статей в журнал МНГ просим авторов соблюдать правила, изложенные в «Единых требованиях к рукописям, представляемым в биомедицинские журналы», принятых Международным комитетом редакторов медицинских журналов - http://www.spinesurgery.ru/files/publish.pdf и http://www.nlm.nih.gov/bsd/uniform_requirements.html
В конце каждой оригинальной статьи приводится библиографический список. В список литературы включаются все материалы, на которые имеются ссылки в тексте. Список составляется в алфавитном порядке и нумеруется. Литературный источник приводится на языке оригинала. В списке литературы сначала приводятся работы, написанные знаками грузинского алфавита, затем кириллицей и латиницей. Ссылки на цитируемые работы в тексте статьи даются в квадратных скобках в виде номера, соответствующего номеру данной работы в списке литературы. Большинство цитированных источников должны быть за последние 5-7 лет.

9. Для получения права на публикацию статья должна иметь от руководителя работы или учреждения визу и сопроводительное отношение, написанные или напечатанные на бланке и заверенные подписью и печатью.

10. В конце статьи должны быть подписи всех авторов, полностью приведены их фамилии, имена и отчества, указаны служебный и домашний номера телефонов и адреса или иные координаты. Количество авторов (соавторов) не должно превышать пяти человек.

11. Редакция оставляет за собой право сокращать и исправлять статьи. Корректура авторам не высылается, вся работа и сверка проводится по авторскому оригиналу.

12. Недопустимо направление в редакцию работ, представленных к печати в иных издательствах или опубликованных в других изданиях.

При нарушении указанных правил статьи не рассматриваются.

REQUIREMENTS

Please note, materials submitted to the Editorial Office Staff are supposed to meet the following requirements:

1. Articles must be provided with a double copy, in English or Russian languages and typed or compu-ter-printed on a single side of standard typing paper, with the left margin of **3** centimeters width, and **1.5** spacing between the lines, typeface - **Times New Roman** (**Cyrillic**), print size - **12** (referring to Georgian and Russian materials). With computer-printed texts please enclose a CD carrying the same file titled with Latin symbols.

2. Size of the article, including index and resume in English, Russian and Georgian languages must be at least 10 pages and not exceed the limit of 20 pages of typed or computer-printed text.

3. Submitted material must include a coverage of a topical subject, research methods, results, and review.

Authors of the scientific-research works must indicate the number of experimental biological species drawn in, list the employed methods of anesthetization and soporific means used during acute tests.

4. Articles must have a short (half page) abstract in English, Russian and Georgian (including the following sections: aim of study, material and methods, results and conclusions) and a list of key words.

5. Tables must be presented in an original typed or computer-printed form, instead of a photocopied version. **Numbers, totals, percentile data on the tables must coincide with those in the texts of the articles.** Tables and graphs must be headed.

6. Photographs are required to be contrasted and must be submitted with doubles. Please number each photograph with a pencil on its back, indicate author's name, title of the article (short version), and mark out its top and bottom parts. Drawings must be accurate, drafts and diagrams drawn in Indian ink (or black ink). Photocopies of the X-ray photographs must be presented in a positive image in **tiff format**.

Accurately numbered subtitles for each illustration must be listed on a separate sheet of paper. In the subtitles for the microphotographs please indicate the ocular and objective lens magnification power, method of coloring or impregnation of the microscopic sections (preparations).

7. Please indicate last names, first and middle initials of the native authors, present names and initials of the foreign authors in the transcription of the original language, enclose in parenthesis corresponding number under which the author is listed in the reference materials.

8. Please follow guidance offered to authors by The International Committee of Medical Journal Editors guidance in its Uniform Requirements for Manuscripts Submitted to Biomedical Journals publication available online at: http://www.nlm.nih.gov/bsd/uniform_requirements.html
http://www.icmje.org/urm_full.pdf
In GMN style for each work cited in the text, a bibliographic reference is given, and this is located at the end of the article under the title "References". All references cited in the text must be listed. The list of references should be arranged alphabetically and then numbered. References are numbered in the text [numbers in square brackets] and in the reference list and numbers are repeated throughout the text as needed. The bibliographic description is given in the language of publication (citations in Georgian script are followed by Cyrillic and Latin).

9. To obtain the rights of publication articles must be accompanied by a visa from the project instructor or the establishment, where the work has been performed, and a reference letter, both written or typed on a special signed form, certified by a stamp or a seal.

10. Articles must be signed by all of the authors at the end, and they must be provided with a list of full names, office and home phone numbers and addresses or other non-office locations where the authors could be reached. The number of the authors (co-authors) must not exceed the limit of 5 people.

11. Editorial Staff reserves the rights to cut down in size and correct the articles. Proof-sheets are not sent out to the authors. The entire editorial and collation work is performed according to the author's original text.

12. Sending in the works that have already been assigned to the press by other Editorial Staffs or have been printed by other publishers is not permissible.

Articles that Fail to Meet the Aforementioned Requirements are not Assigned to be Reviewed.

ავტორთა საყურადღებოდ!

რედაქციაში სტატიის წარმოდგენისას საჭიროა დავიცვათ შემდეგი წესები:

1. სტატია უნდა წარმოადგინოთ 2 ცალად, რუსულ ან ინგლისურ ენებზე,დაბეჭდილი სტანდარტული ფურცლის 1 გვერდზე, 3 სმ სიგანის მარცხენა ველისა და სტრიქონებს შორის 1,5 ინტერვალის დაცვით. გამოყენებული კომპიუტერული შრიფტი რუსულ და ინგლისურენოვან ტექსტებში - **Times New Roman (Кириллица)**, ხოლო ქართულენოვან ტექსტში საჭიროა გამოვიყენოთ **AcadNusx.** შრიფტის ზომა – 12. სტატიას თან უნდა ახლდეს CD სტატიით.

2. სტატიის მოცულობა არ უნდა შეადგენდეს 10 გვერდზე ნაკლებს და 20 გვერდზე მეტს ლიტერატურის სიის და რეზიუმეების (ინგლისურ, რუსულ და ქართულ ენებზე) ჩათვლით.

3. სტატიაში საჭიროა გაშუქდეს: საკითხის აქტუალობა; კვლევის მიზანი; საკვლევი მასალა და გამოყენებული მეთოდები; მიღებული შედეგები და მათი განსჯა. ექსპერიმენტული ხასიათის სტატიების წარმოდგენისას ავტორებმა უნდა მიუთითონ საექსპერიმენტო ცხოველების სახეობა და რაოდენობა; გაუტკივარებისა და დაძინების მეთოდები (მწვავე ცდების პირობებში).

4. სტატიას თან უნდა ახლდეს რეზიუმე ინგლისურ, რუსულ და ქართულ ენებზე არანაკლებ ნახევარი გვერდის მოცულობისა (სათაურის, ავტორების, დაწესებულების მითითებით და უნდა შეიცავდეს შემდეგ განყოფილებებს: მიზანი, მასალა და მეთოდები, შედეგები და დასკვნები; ტექსტუალური ნაწილი არ უნდა იყოს 15 სტრიქონზე ნაკლები) და საკვანძო სიტყვების ჩამონათვალი (key words).

5. ცხრილები საჭიროა წარმოადგინოთ ნაბეჭდი სახით. ყველა ციფრული, შემაჯამებელი და პროცენტული მონაცემები უნდა შეესაბამებოდეს ტექსტში მოყვანილს.

6. ფოტოსურათები უნდა იყოს კონტრასტული; სურათები, ნახაზები, დიაგრამები - დასათაურებული, დანომრილი და სათანადო ადგილას ჩასმული. რენტგენოგრამების ფოტოასლები წარმოადგინეთ პოზიტიური გამოსახულებით **tiff** ფორმატში. მიკროფოტოსურათების წარწერებში საჭიროა მიუთითოთ ოკულარის ან ობიექტივის საშუალებით გადიდების ხარისხი, ანათალების შეღებვის ან იმპრეგნაციის მეთოდი და აღნიშნოთ სურათის ზედა და ქვედა ნაწილები.

7. სამამულო ავტორების გვარები სტატიაში აღინიშნება ინიციალების თანდართვით, უცხოურისა – უცხოური ტრანსკრიპციით.

8. სტატიას თან უნდა ახლდეს ავტორის მიერ გამოყენებული სამამულო და უცხოური შრომების ბიბლიოგრაფიული სია (ბოლო 5-8 წლის სიღრმით). ანბანური წყობით წარმოდგენილ ბიბლიოგრაფიულ სიაში მიუთითეთ ჯერ სამამულო, შემდეგ უცხოელი ავტორები (გვარი, ინიციალები, სტატიის სათაური, ჟურნალის დასახელება, გამოცემის ადგილი, წელი, ჟურნალის №, პირველი და ბოლო გვერდები). მონოგრაფიის შემთხვევაში მიუთითეთ გამოცემის წელი, ადგილი და გვერდების საერთო რაოდენობა. ტექსტში კვადრატულ ფჩხილებში უნდა მიუთითოთ ავტორის შესაბამისი N ლიტერატურის სიის მიხედვით. მიზანშეწონილია, რომ ციტირებული წყაროების უმეტესი ნაწილი იყოს 5-6 წლის სიღრმის.

9. სტატიას თან უნდა ახლდეს: ა) დაწესებულების ან სამეცნიერო ხელმძღვანელის წარდგინება, დამოწმებული ხელმოწერითა და ბეჭდით; ბ) დარგის სპეციალისტის დამოწმებული რეცენზია, რომელშიც მითითებული იქნება საკითხის აქტუალობა, მასალის საკმაობა, მეთოდის სანდოობა, შედეგების სამეცნიერო-პრაქტიკული მნიშვნელობა.

10. სტატიის ბოლოს საჭიროა ყველა ავტორის ხელმოწერა, რომელთა რაოდენობა არ უნდა აღემატებოდეს 5-ს.

11. რედაქცია იტოვებს უფლებას შეასწოროს სტატია. ტექსტზე მუშაობა და შეჯერება ხდება საავტორო ორიგინალის მიხედვით.

12. დაუშვებელია რედაქციაში ისეთი სტატიის წარდგენა, რომელიც დასაბეჭდად წარდგენილი იყო სხვა რედაქციაში ან გამოქვეყნებული იყო სხვა გამოცემებში.

აღნიშნული წესების დარღვევის შემთხვევაში სტატიები არ განიხილება.

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ANTIMICROBIAL AND ANTI-INFLAMMATORY ACTIVITY OF PLANT EXTRACTS: PROSPECTS FOR THE DEVELOPMENT OF COMBINED THERAPEUTIC AGENTS

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Abstract.

Introduction: The aim of this study was to investigate the antimicrobial and anti-inflammatory activities of six samples (S1–S6) against pathogenic microorganisms (*Staphylococcus aureus, Escherichia coli*, and *Candida albicans*) and their potential to inhibit inflammatory processes. The primary objectives included identifying the most active compounds, determining their minimal inhibitory concentration (MIC) and minimal bactericidal concentration (MBC), and evaluating their prospects for use in combined therapy of infectious and inflammatory diseases. The importance of this research arises from the growing issue of antibiotic resistance and the necessity of discovering novel therapeutic agents with dual (antimicrobial and anti-inflammatory) activities capable of simultaneously combating infections and reducing inflammation.

Materials and Methods: The study was conducted following ethical standards established by the Helsinki Declaration of the World Medical Association and Good Laboratory Practice (GLP). Six samples (S1–S6) were dissolved in dimethyl sulfoxide (DMSO) at a concentration of 100 mg/mL. Antimicrobial activity was assessed using reference strains of microorganisms: Staphylococcus aureus (ATCC6538), Escherichia coli (ATCC11229), and Candida albicans (ATCC10231). Ampicillin (for bacteria) and Amphotericin B (for fungi) served as positive controls. Antimicrobial activity was evaluated through agar diffusion and broth dilution methods (MIC and MBC). Anti-inflammatory activity was determined by measuring the samples' capacity to suppress nitric oxide (NO) secretion in the Raw264.7 macrophage cell line. Statistical analysis was performed using ANOVA followed by Tukey's test, with significance set at $p < 0.05$.

Results: Sample S2 demonstrated the highest antimicrobial and anti-inflammatory activity, with inhibition zones up to 20 mm, MIC = 7.8125 μg/mL, MBC = 15.625 μg/mL, and significant suppression of nitric oxide (NO) production (75%, IC50 = 20 μM). Samples S1 and S3 showed moderate antimicrobial activity (MIC = 31.25 μg/mL) and NO suppression levels ranging between 60–70%. Samples S4–S6 did not exhibit significant antimicrobial effects. The obtained results highlight the potential of sample S2 for further research and its possible application in treating infectious and inflammatory diseases.

Conclusion: Sample S2 exhibits significant antimicrobial and anti-inflammatory properties, making it a promising candidate for the development of novel therapeutic agents, particularly important in the context of growing antibiotic resistance and inflammatory diseases.

Key words. Antimicrobial activity, anti-inflammatory activity, *Staphylococcus aureus, Escherichia coli*, Candida albicans, MIC, MBC, nitric oxide (NO), combined therapy.

Introduction.

In recent years, the increasing resistance of microorganisms to antibiotics and the prevalence of inflammatory diseases of various etiologies have become critically important issues [1-7]. Widespread and often uncontrolled use of antibiotics has led to the emergence of numerous resistant strains, including Staphylococcus aureus, Escherichia coli, and Candida albicans [1,4,5]. According to WHO (2022), microbial antibiotic resistance is one of the global health threats. At the same time, inflammatory processes remain among the leading causes of both acute and chronic diseases, underscoring the need for safer and more effective therapeutic approaches [3,8].

In this context, compounds possessing both anti-inflammatory and antimicrobial activities are of particular interest. Such substances can simultaneously suppress infection and reduce inflammation, making them promising candidates for combined therapeutic use. Studies have shown that plant extracts from the Asteraceae family, such as Helichrysum italicum and Calendula officinalis, exhibit notable antimicrobial and anti-inflammatory properties [1,5]. These compounds demonstrate dual activity primarily due to their content of flavonoids, polyphenols, and terpenes, which inhibit pro-inflammatory mediators and suppress pathogen growth.

The aim of this study is to investigate the anti-inflammatory and antimicrobial activities of six samples against pathogenic microorganisms (Staphylococcus aureus, Escherichia coli, Candida albicans) and to evaluate their ability to inhibit inflammatory processes.

Materials and Methods.

The study was conducted in strict compliance with international standards and guidelines regulating scientific research. All methods and procedures adhered to ethical principles outlined in the Helsinki Declaration of the World Medical Association and guidelines for laboratory experiments. Experiments followed Good Laboratory Practice (GLP) standards, ensuring the reliability and reproducibility of results, thus confirming their relevance in medical and pharmaceutical practice.

1. **Sample preparation:** Six samples (S1–S6) were provided in solid form and dissolved in dimethyl sulfoxide (DMSO) to achieve an initial concentration of 100 mg/mL. Further serial dilutions were prepared as needed.

2. **Test microorganisms:** Antimicrobial activity was assessed using reference strains: Staphylococcus aureus (ATCC6538) as a model for Gram-positive bacteria, Escherichia coli (ATCC11229) as a model for Gram-negative bacteria, and Candida albicans (ATCC10231) as a model for antifungal activity.

3. **Control agents:** Ampicillin sodium salt (for bacteria) and Amphotericin B (for fungi) were used as positive controls.

4. **Evaluation of antimicrobial activity:** Antimicrobial activity was determined using the agar diffusion method with wells: On nutrient media (LB for bacteria and Sabouraud for fungi), wells of 6 mm diameter were created, into which 20 µL of each sample solution was introduced. Plates were incubated at 37°C for 16–18 hours for bacteria and up to 48 hours for fungi, after which inhibition zone diameters were measured using a caliper. Antimicrobial activity was considered significant with inhibition zones ≥10 mm.

The minimum inhibitory concentration (MIC) was determined using the serial dilution method in 96-well plates: 196 µL of microbial suspension (10^4 CFU/mL) and 4 µL of diluted sample were added to each well. Plates were incubated at 37°C for 18–24 hours. MIC was defined as the lowest concentration at which no visible microbial growth occurred. To determine the minimum bactericidal concentration (MBC), contents of wells with concentrations above the MIC were plated onto nutrient media. MBC was recorded as the lowest concentration showing no microbial growth on the nutrient agar plates.

Anti-inflammatory activity was assessed in vitro using the Raw264.7 macrophage cell line. Cells were stimulated with lipopolysaccharide (LPS) to induce an inflammatory response, after which samples were added to the culture medium at a concentration of 100 µM. Nitric oxide (NO) secretion levels were measured using the Griess reagent. A reduction in NO secretion ≥15% was considered significant. For active samples, IC50 values were additionally determined.

Statistical analysis. All experiments were performed in triplicate (n=3). Results are expressed as mean ± standard deviation. Statistical analyses were conducted using ANOVA followed by Tukey's multiple comparison test. Differences were considered statistically significant at $p < 0.05$.

Results.

The antimicrobial activity of six samples was evaluated using the agar diffusion method. The measured diameters of inhibition zones are presented in Table 1.

As shown in Table 1, samples S1, S2, and S3 demonstrated inhibitory activity against Staphylococcus aureus, with inhibition zones ≥10 mm. Samples S4, S5, and S6 did not exhibit significant antimicrobial activity against the tested microorganisms.

As shown in the figure, sample S2 demonstrated the highest activity against all tested pathogens. For samples exhibiting inhibition zones ≥10 mm, minimal inhibitory concentration (MIC) and minimal bactericidal concentration (MBC) values against Staphylococcus aureus were determined; the results are presented in Table 2.

As shown in Table 2, sample S2 exhibited the highest efficacy, with MIC = 7.8125 µg/mL and MBC = 15.625 µg/mL. The lowest MIC value (7.8125 µg/mL) indicates that S2 is the most effective among the tested samples. Samples S1 and S3 demonstrated moderate antimicrobial activity, whereas sample S4 had significantly higher MIC and MBC values, indicating weak activity. These data clearly confirm the superior performance of sample S2 compared to other samples and highlight its comparability to the control antibiotic (ampicillin).

Table 1. *Diameter of inhibition zones (mm) against various microorganisms.*

Sample	*Staphylococcus aureus*	*Escherichia coli*	Candida albicans
S1	18	12	—
S2	20	15	—
S3	17	13	—
S4	11	—	—
S5	—	—	—
S6	—	—	—

Table 2. *MIC and MBC (µg/mL) values for active samples.*

Sample	MIC (*S. aureus*), µg/mL	MBC (*S. aureus*), µg/mL	P (MIC)	P (MBC)
S1	31.25	62.5	0.02	0.03
S2	7.8125	15.625	0.01	0.01
S3	31.25	62.5	0.02	0.03
S4	500	1000	<0.001	<0.001

Note: *$P < 0.05$ indicates a statistically significant difference from the control antibiotic (ampicillin). These values demonstrate that sample S2 exhibits the highest significant effectiveness ($p = 0.01$) compared to other samples, while sample S4 shows substantially lower activity.*

Table 3. *Inhibition of nitric oxide (NO) secretion and IC50 values for tested samples (S1–S4) in the Raw264.7 macrophage cell line.*

Sample	NO inhibition (%)	IC50 (мкМ)
S1	60	35
S2	75	20
S3	70	25
S4	45	—

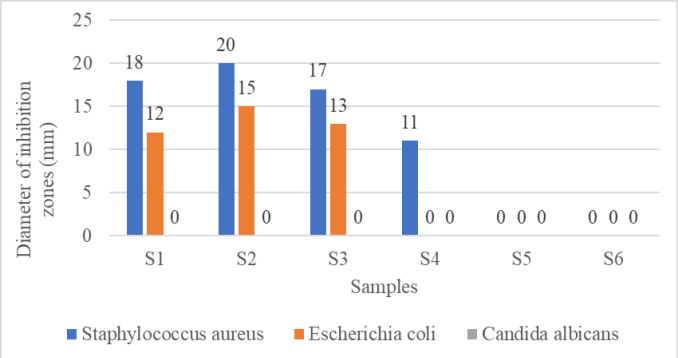

Figure 1. *Inhibition zones (mm) for samples and control agents against three microorganisms (Staphylococcus aureus, Escherichia coli, Candida albicans).*

Subsequently, the anti-inflammatory activity of the samples was assessed based on their ability to inhibit nitric oxide (NO) secretion in the Raw264.7 macrophage cell line.

As shown in Table 3, samples S2 and S3 exhibited the highest anti-inflammatory activity, suppressing NO secretion by 75% and 70%, respectively. Sample S2 displayed the lowest IC50 value (20 µM), indicating its superior efficacy.

Further comparisons were conducted with control agents. The control antibiotic ampicillin demonstrated a significantly higher activity against Staphylococcus aureus (MIC = 0.98 µg/mL and

MBC = 1.95 μg/mL) compared to the tested samples. Although the anti-inflammatory activity of the samples (particularly S2 and S3) was lower than standard anti-inflammatory agents, their results were promising.

Thus, sample S2 demonstrated the greatest antimicrobial and anti-inflammatory activities, highlighting its potential for further development as a multifunctional therapeutic agent.

Discussion.

The results of this study indicate that samples S1, S2, and S3 exhibited substantial antimicrobial activity against Staphylococcus aureus, with inhibition zones ranging from 17 to 20 mm. Considering that plant extracts commonly contain bioactive compounds such as flavonoids, terpenes, and polyphenols, it can be inferred that these substances play a critical role in their antimicrobial mechanism of action. Sample S2 demonstrated the most pronounced activity, reaching a 20 mm inhibition zone and MIC of 7.8125 μg/mL, potentially linked to several mechanisms, particularly the disruption of microbial cell membrane integrity: Flavonoids and terpenes, known for their lipophilic properties, can interact with the lipid bilayer of microbial membranes, increasing permeability and disrupting membrane integrity. This leads to leakage of intracellular components and subsequent cell death. For example, a study by Kumar et al. (2020) demonstrated that flavonoids extracted from plants effectively disrupted the cellular membranes of Staphylococcus aureus [4].

Additionally, certain plant-derived compounds such as polyphenols can inhibit enzymes involved in DNA and protein synthesis, thus preventing bacterial proliferation. The high activity of sample S2 may be related to such compounds that disrupt essential bacterial processes.

Furthermore, polyphenols and related bioactive substances can induce oxidative stress by generating reactive oxygen species (ROS) within microbial cells, resulting in damage to DNA, proteins, and lipids, eventually causing bacterial cell death. These findings align with results reported by Arif et al. (2021), where extracts from the Asteraceae family, specifically Helichrysum italicum, inhibited the growth of Staphylococcus aureus with inhibition zones of 18–22 mm at concentrations of 100 mg/mL. This similarity suggests the presence of bioactive compounds such as flavonoids, terpenes, and essential oils in sample S2, known for their potent antimicrobial properties [1]. Upon detailed analysis, the minimal inhibitory concentration (MIC) of sample S2 was determined to be 7.8125 μg/mL. This result surpasses previously reported values by Kumar et al. (2020), who identified MIC values of 8–16 μg/mL for flavonoid-rich plant extracts [4]. Samples S1 and S3 exhibited moderate antimicrobial activity, with MIC values of 31.25 μg/mL, consistent with the range typically reported for less concentrated plant extracts (Kumar et al., 2020). However, further detailed chemical and mechanistic studies are necessary to fully elucidate their antimicrobial mechanisms and composition [4].

The anti-inflammatory assessment revealed that samples S2 and S3 significantly inhibited nitric oxide (NO) secretion in the Raw264.7 macrophage cell line by 75% and 70%, respectively, suggesting the capability of sample S2 to inhibit lipopolysaccharide (LPS)-induced inflammatory pathways. Potential mechanisms include:

Inhibition of iNOS enzyme: The inflammatory response often induces inducible nitric oxide synthase (iNOS), leading to increased NO secretion. Bioactive compounds present in sample S2 likely inhibit iNOS activity, as similarly reported in studies by Gao et al. (2022) investigating extracts from Helichrysum italicum [3].

Modulation of cytokine pathways: Flavonoids and polyphenols present in S2 may suppress pro-inflammatory cytokines by inhibiting NF-κB activation. This mechanism aligns with findings by Qaralleh et al. (2021), indicating polyphenol-mediated NF-κB inhibition, reducing inflammation [6].

Antioxidant activity: The high antioxidant content in S2 could neutralize reactive oxygen species (ROS), reducing oxidative stress and preventing cellular damage associated with chronic inflammation.

These results underline the dual antimicrobial and anti-inflammatory potential of sample S2, positioning it as a valuable candidate for further investigation and therapeutic application.

The IC50 value for sample S2 was 20 μM, closely aligning with findings by Gao et al. (2022), who reported that extracts of Helichrysum italicum reduced nitric oxide (NO) secretion by 65–78% at concentrations of 100 μM. These authors noted IC50 values of plant extracts ranging from 15–25 μM, indicating that sample S2 is competitively positioned among natural anti-inflammatory agents [3]. The high efficacy of sample S2 in suppressing NO production makes it a promising candidate for further anti-inflammatory research.

Sample S3 also exhibited significant anti-inflammatory activity (IC50 = 25 μM), suggesting potential synergy with other active compounds, warranting further investigation into its chemical composition and mode of action.

A distinctive feature of sample S2 is its dual antimicrobial and anti-inflammatory activities, likely resulting from synergistic interactions among biologically active compounds such as flavonoids, terpenes, and polyphenols. For instance, flavonoids have been reported by Li et al. (2021) to inhibit bacterial growth while simultaneously reducing the secretion of pro-inflammatory cytokines. Terpenes possess lipophilic properties, enabling them to disrupt bacterial membranes and mitigate inflammation via antioxidant system activation. Li et al. (2021) further noted that the combined antimicrobial and anti-inflammatory activities observed in plant extracts were due to the presence of both flavonoids and terpenes [5]. The likelihood of similar bioactive constituents in sample S2 highlights its potential for detailed chemical characterization and development into novel therapeutic agents.

Thus, the antimicrobial and anti-inflammatory mechanisms of sample S2 are attributed to its ability to disrupt bacterial membrane integrity, inhibit critical biosynthetic processes, suppress inflammatory enzymes (such as iNOS), modulate cytokine pathways, and exhibit antioxidant properties protecting tissues from oxidative stress. These findings underscore the significant potential of S2 for developing comprehensive therapeutic approaches targeting infectious and inflammatory diseases.

Limitations and future directions.

Although sample S2 demonstrated high efficacy, its antimicrobial activity remains significantly lower compared to standard antibiotics (ampicillin MIC = 0.98 μg/mL). This highlights the need for optimizing its composition or evaluating its potential as an adjuvant to enhance antibiotic effectiveness.

Practical significance: The results of this study have considerable practical value, demonstrating the potential of plant extracts with dual activity for addressing current medical challenges. Key practical implications and future perspectives include:

Development of novel antimicrobial agents: Sample S2, exhibiting significant antimicrobial activity (MIC = 7.8125 μg/mL against Staphylococcus aureus), may serve as a foundation for creating new antimicrobial formulations. Such formulations could be effective against resistant bacterial strains, including MRSA (Methicillin-resistant Staphylococcus aureus), as indicated by laboratory results.

Development stages include: Chemical characterization to identify active components; Synthesis of analogues of the most active compounds to enhance pharmacological properties; Evaluation of safety and efficacy using cell lines and animal models; Development of combined therapeutic agents for infectious and inflammatory diseases. The unique combination of antimicrobial and anti-inflammatory activities makes sample S2 highly promising for the creation of comprehensive therapeutic preparations capable of simultaneously combating infection and reducing inflammation, particularly beneficial in chronic diseases involving skin infections, respiratory tract, and urogenital systems.

Practical Applications and Antibiotic Resistance Prevention:

Plant-based extracts such as sample S2 have practical potential as alternatives or adjuncts to conventional antibiotics. Potential formulations include topical ointments or creams for skin infections and inflammation, inhalation solutions for respiratory infections, and combined capsules or tablets for systemic therapy. The use of plant-derived agents like S2 can help reduce antibiotic use, thereby limiting the development of antibiotic resistance and enhancing treatment outcomes.

Pharmaceutical standardization opportunities: Standardizing plant extracts with dual antimicrobial and anti-inflammatory activities, such as sample S2, can facilitate quality control, reproducibility, and clinical applicability.

Synergy with antibiotics: Samples such as S2 may also exhibit synergistic interactions when combined with conventional antibiotics. Such combinations could improve therapeutic efficacy, reduce antibiotic doses, and minimize side effects, potentially overcoming antibiotic resistance.

The findings of this study thus highlight the significant potential of active samples, particularly S2, as innovative therapeutic agents. Their unique dual-action properties offer promising opportunities for addressing antibiotic resistance and improving treatments for infectious and inflammatory diseases.

Comparison with antibiotics:

Sample S2 demonstrated substantial antimicrobial activity against Staphylococcus aureus (MIC = 7.8125 μg/mL), although it was notably less effective than the control antibiotic, ampicillin (MIC = 0.98 μg/mL). This discrepancy may be attributed to several factors:

Mechanism of Action: Antibiotics like ampicillin have highly specific targets, such as inhibition of bacterial cell-wall peptidoglycan synthesis. In contrast, plant extracts like S2 typically contain complex mixtures of bioactive compounds that act via multiple, less specific mechanisms, potentially reducing their effectiveness relative to antibiotics with targeted mechanisms.

Concentration of Active Components: Plant extracts are complex mixtures where concentrations of active components can vary significantly. The concentration of key bioactive substances, such as flavonoids or terpenes, in sample S2 may not be sufficient to achieve antimicrobial activity comparable to antibiotics.

Enhancing the efficacy of plant extracts like S2 might involve methods such as increasing active compound concentration, employing chemical modifications, or combining these extracts with conventional antibiotics to leverage synergistic effects. These approaches could significantly improve their therapeutic potential.

Bioavailability and Stability:

Plant extracts often contain complex mixtures of compounds with variable bioavailability and stability, potentially limiting their efficacy compared to antibiotics. In contrast, ampicillin possesses optimized pharmacokinetics and pharmacodynamics, contributing to its superior effectiveness.

Strategies to Improve Plant Extract Efficacy:

Concentration of Active Components: Increasing the concentration of active compounds via selective extraction methods (e.g., using methanol or ethyl acetate) or fractionation techniques can enhance the antimicrobial potential by enriching key bioactive components.

Chemical Modification: Improving the lipophilicity and stability of active compounds, such as synthesizing flavonoid derivatives, may significantly enhance their antimicrobial activity by facilitating penetration through bacterial membranes.

Nanotechnology Application: Encapsulating active compounds within nanoparticles or liposomes could increase their stability, bioavailability, and penetration into microbial cells, thus improving their overall efficacy.

Synergism with Antibiotics: Studying synergistic effects of sample S2 combined with antibiotics like ampicillin could boost overall treatment efficacy, potentially reducing antibiotic doses and minimizing adverse effects, including resistance development.

Potential for Combined Formulations: The dual antimicrobial and anti-inflammatory properties of sample S2 make it particularly attractive for developing combined therapeutic preparations targeting infectious and inflammatory diseases. Combining S2 with conventional antibiotics could enhance therapeutic effectiveness and reduce side effects, including antibiotic resistance.

Thus, although sample S2 shows lower efficacy than ampicillin, its multifunctionality and potential for further optimization through extraction methods, chemical modifications, and

nanotechnology approaches highlight its significant therapeutic promise and competitiveness with traditional antibiotics.

Future research directions:

- Chemical analysis of active samples to identify key bioactive compounds (e.g., flavonoids, terpenes).
- Investigation of the molecular mechanisms underlying sample activity.
- Study of synergistic effects when combined with conventional antibiotics.

Conclusion.

The results indicate that the tested samples, particularly S2, exhibit promising antimicrobial and anti-inflammatory activities, supporting their potential for the development of novel therapeutic agents. This is especially relevant given the increasing antibiotic resistance and demand for effective anti-inflammatory treatments.

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REFERENCES

1. Arif T, Sharma D, Gupta V, et al. Antibacterial and anti-inflammatory activity of plant-derived flavonoids: A review. Phytomedicine. 2021;84:153491.
2. Ciumărnean L, Milaciu M.V, Negrean V, et al. Cardiovascular risk factors and physical activity for the prevention of cardiovascular diseases in the elderly. International Journal of Environmental Research and Public Health. 2022;19:07.
3. Gao M, Li N, Zhang Y, et al. Anti-inflammatory properties of Helichrysum italicum extracts in NO-induced macrophages. Journal of Ethnopharmacology. 2022;283:114594.
4. Kumar S, Singh P, Gupta S, et al. Antimicrobial activity of flavonoid-rich plant extracts against resistant bacterial strains. International Journal of Microbiology. 2020:5681213.
5. Li Y, Cheng X, Wang Q, et al. Dual activity of plant extracts as antibacterial and anti-inflammatory agents: Mechanisms and applications. Frontiers in Pharmacology. 2021;12:671294.
6. Qaralleh H.A, Al-Limoun M.O, Khlaifat A, et al. Antibacterial and antibiofilm activities of a traditional herbal formula against respiratory infection causing bacteria. Journal of Herbal Medicine. 2021;25:100404.
7. Tikhomirova L.I, Shcherbakova L.V, Ilchëva T.N, et al. Obtaining medicinal plant raw materials with a specified chemical composition and antibacterial activity. Russian Journal of Biopharmaceuticals. 2014;6:24-29.
8. Vo T.N.H, Jalilov F.S, Stasyuk N.V, et al. Antibacterial activity of essential oils and their use for decontamination of cabbage seeds from vascular bacteriosis. Plant Protection News. 2014;4:24-28.

Аннотация

Введение: Целью данного исследования было изучить антимикробную и противовоспалительную активность шести образцов (S1–S6) в отношении патогенных микроорганизмов (Staphylococcus aureus, Escherichia coli и Candida albicans), а также их способность подавлять воспалительные процессы. Основными задачами работы являлись выявление наиболее активных соединений, определение их минимальной ингибирующей концентрации (MIC) и минимальной бактерицидной концентрации (MBC), а также оценка перспектив их использования в комплексной терапии инфекционно-воспалительных заболеваний. Важность исследования обусловлена актуальностью проблемы роста антибиотикорезистентности и необходимостью поиска новых терапевтических средств, обладающих двойной (антимикробной и противовоспалительной) активностью, способных одновременно подавлять инфекцию и снижать воспаление.

Материалы и методы. Исследование проведено с соблюдением стандартов этики (Хельсинкская декларация Всемирной медицинской ассоциации, GLP). Для анализа использовались шесть образцов (S1–S6), которые разводили в диметилсульфоксиде (DMSO) до концентрации 100 мг/мл. Оценка антимикробной активности проводилась на референсных штаммах микроорганизмов: Staphylococcus aureus (ATCC6538), Escherichia coli (ATCC11229) и Candida albicans (ATCC10231). В качестве контрольных препаратов применялись ампициллин (для бактерий) и амфотерицин B (для грибков). Антимикробную активность определяли методом диффузии в агаре и серийных разведений (MIC, MBC). Противовоспалительная активность изучалась по способности образцов подавлять секрецию оксида азота (NO) в культуре макрофагов Raw264.7. Статистическая обработка данных осуществлялась методом дисперсионного анализа (ANOVA) с последующим тестом Тьюки, результаты считались статистически значимыми при $p < 0,05$.

Результаты. Наибольшую антимикробную и противовоспалительную активность показал образец S2: диаметр зон ингибирования до 20 мм, MIC = 7,8125 мкг/мл, MBC = 15,625 мкг/мл и выраженное подавление оксида азота (NO) на 75% (IC50 = 20 мкМ). Образцы S1 и S3 проявили умеренную антимикробную активность (MIC = 31,25 мкг/мл) и подавление NO на уровне 60–70%. Образцы S4–S6 значимой антимикробной активности не показали. Полученные результаты подтверждают перспективность S2 для дальнейших исследований и возможного применения в терапии инфекционно-воспалительных заболеваний**.**

Заключение. Образец S2 обладает высокой антимикробной и противовоспалительной активностью и перспективен для разработки новых терапевтических средств, особенно в условиях роста антибиотикорезистентности и воспалительных заболеваний.

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