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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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SYNTHESIS AND ANTIBACTERIAL EVALUATION OF 2-(ALKYLOXY)-N-(2,5-DIMETHYLBENZYL)-N,N-DIMETHYL-2-OXOETHANAMMONIUM CHLORIDES

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Abstract.

Quaternary ammonium compounds (QACs) are widely used cationic surfactants known for their strong antimicrobial activity. Their utility in healthcare, consumer products, and industrial settings stems from their ability to disrupt bacterial membranes rapidly. However, increased use raises concerns about bacterial resistance and environmental persistence. The study aims to synthesize and evaluate a new series of 2-(alkyloxy)-N-(2,5-dimethylbenzyl)-N,N-dimethyl-2-oxoethanammonium chlorides (C6-C12) for antibacterial activity. Developing structurally optimized QACs may improve antibacterial potency while minimizing environmental impact and resistance selection. Tailoring the alkyl chain length and introducing degradable moieties like alkoxycarbonylmethyl could enhance efficacy and biodegradability. The compounds were synthesized by the alkylation of N,N-dimethyl-3,6-dimethylbenzylamine with the corresponding alkyl chloroacetate. QACs were purified and characterized by IR, ^{1}H- and ^{13}C-NMR, and mass spectrometry. Biological activity was assessed by agar diffusion and broth microdilution assays against representative Gram-positive (*Staphylococcus aureus, Bacillus subtilis*) and Gram-negative (*Escherichia coli*, *Shigella flexneri*) bacteria. Comparative activity was evaluated against furazolidone. All compounds exhibited antibacterial effects using the agar-diffusion method, with inhibition zones of up to 35mm. However, the MIC values of the compounds were higher than those of the reference furazolidone. These results indicate that quaternary ammonium compounds combining a 2,5-dimethylbenzyl moiety with an alkyloxycarbonylmethyl chain exhibit moderate broad-spectrum antibacterial activity, making them promising candidates for topical and environmental applications.

Key words. Quaternary ammonium compound (QAC), alkyl chloroacetate, antibacterial activity, Gram-positive bacteria, Gram-negative bacteria.

Introduction.

Modern pharmacology faces a serious problem associated with the growing resistance of pathogenic microorganisms to existing antibiotics. In this context, it is extremely important to expand the arsenal of antimicrobial agents by developing new classes of substances with unique mechanisms of action. Quaternary ammonium salts, due to their ability to effectively destroy a wide range of bacteria, are promising candidates for such developments [1].

The biological action of ammonium salts is due to their structure - positively charged quaternary nitrogen centers interact with negatively charged elements of the cell wall and membrane of bacteria. This leads to the destruction of membrane structures, metabolic disorders, and cell death [2]. Gram-positive bacteria are especially sensitive to such compounds, since their cell wall contains a large amount of peptide glycan and is not protected by an outer membrane, as in gram-negative bacteria [3,4].

The introduction of various functional groups into the structure of ammonium salts is aimed at increasing the efficiency and spectrum of action [5-7]. Alkyl chains in alkyloxycarbonylmethyl radicals make a significant contribution to increasing the hydrophobicity of molecules, which facilitates their penetration through the lipid bilayer of bacterial membranes. This ensures a tighter interaction with membrane lipids and enhances the destruction of cellular structures [8].

The variation in the alkyl chain length (C6-C12) on the alkyloxycarbonylmethyl esters allowed for the synthesis of a homologous series of QACs (3a-g), facilitating SAR studies. Literature indicates that the antimicrobial activity of QACs is significantly influenced by the length of the alkyl chain, with optimal activity often observed in the C_8-C_{12} range. This is attributed to a balance between hydrophobic interactions with microbial membranes and aqueous solubility [9]. Compounds with excessively long alkyl chains may exhibit reduced activity due to decreased solubility and potential aggregation [9,10].

The synthesis of (3a-g) salts offer an alternative to conventional QACs bearing straight alkyl substituents. This structural variation is not merely aesthetic – it significantly influences the physicochemical and biological properties of the compounds. In traditional QACs, long straight alkyl chains (such as C12-C16) are primarily responsible for lipophilic interactions with microbial membranes, leading to membrane disruption and microbial death. However, these long-chain alkyl QACs often suffer from poor water solubility and may accumulate in the environment, raising concerns about persistence and resistance development [11,12]. In contrast, the alkoxycarbonylmethyl substituents introduce a polar ester linkage between the nitrogen center and the lipophilic tail. The ester functionality enhances polarity relative to straight alkyl groups, potentially improving the compound's bioavailability and handling [9]. The ester linker may impose conformational constraints that alter how the molecule interacts with bacterial membranes, potentially improving selectivity or reducing cytotoxicity [13].

The presence of an ester bond makes these molecules more susceptible to enzymatic hydrolysis, which could reduce environmental persistence compared to non-hydrolysable QACs [11,14]. Studies comparing straight-chain QACs with ester-containing analogs have shown that these structural changes can modulate both antimicrobial potency and spectrum [13].

In addition, aromatic groups increase the lipophilic properties of the compounds, which further enhances antibacterial activity. Aromatic radicals can participate in π-π interactions with membrane proteins or other biomolecules, which potentially affects the mechanism of action and selectivity [15]. The incorporation of the 2,5-dimethylbenzyl group was chosen due to its electron-donating methyl substituents, which enhance the nucleophilicity of the benzylamine nitrogen, thereby facilitating the quaternization process. Aromatic substituents, in particular the 2,5-dimethylbenzyl group, can additionally increase the lipophilicity of molecules, facilitating their association with the lipid components of the membrane. This structural feature enhances the interaction efficiency with the membrane, thereby improving the bactericidal effect [16]. Some studies also show that aromatic groups can affect the specificity of binding to membrane proteins and change the mechanism of action of compounds [17].

Such structural features are consistent with known QACs like benzalkonium chloride, where the benzyl group contributes to membrane-disruptive activity [10].

However, there are still no systematic studies aimed at studying the effect of the combination of alkyloxycarbonylmethyl radicals and 2,5-dimethylbenzyl substituents in ammonium salts on antibacterial activity. The study of such structures will allow a more complete understanding of the relationship between chemical structure and biological activity, which is important for the development of new antimicrobial drugs with improved characteristics [18].

Ammonium salts with complex substitution, including an alkyloxycarbonylmethyl radical and a 2,5-dimethylbenzyl group, are promising objects for the development of new antimicrobials that can effectively combat pathogenic and resistant microorganisms.

Materials and Methods.

N,N-dimethyl-3,6-dimethylbenzylamine (CAS 60760-00-1), dodecyl chloroacetate (CAS 6316-04-7), undecyl chloroacetate (CAS 5458-29-7), decyl chloroacetate (CAS 6974-05-6), nonyl chloroacetate (CAS 5451-96-7), octyl chloroacetate (5451-98-9), heptyl chloroacetate (CAS 34589-22-5) hexyl chloroacetate (CAS 5927-57-1), diethyl ether (CAS 60-29-7), calcium chloride (CAS 10043-52-4) were purchased from Merck (European market, Poznan, Poland).

General method of synthesis of 2-(Alkyloxy)-N-(2,5-dimethylbenzyl)-N,N-dimethyl-2-oxoethanammonium chlorides:

The target quaternary ammonium salts were obtained by alkylation of the N,N-dimethyl-3,6-dimethylbenzylamine with the appropriate alkyl 2-chloroacetate.

A solution of the N,N-dimethyl-3,6-dimethylbenzylamine (0.01 mol) was treated dropwise with an equimolar amount (0.01 mol) of the corresponding alkyl monochloroacetate ester. The reaction mixture was stirred at room temperature for several days. The solid product was washed with anhydrous diethyl ether and dried over calcium chloride in a desiccator to yield the pure white crystalline compound.

Characterization of 2-(Alkyloxy)-N-(2,5-dimethylbenzyl)-N,N-dimethyl-2-oxoethanammonium chlorides:

IR spectra were recorded on a Specord IR-75 spectrophotometer. Spectra were acquired in the range 4000-400 cm^{-1}. ^{1}H- and ^{13}C-NMR were recorded on Varian Mercury-300VX spectrometer at 300 MHz for ^{1}H and 75.5 MHz for ^{13}C. DMSO-d_6 was used as the solvent, and TMS served as the internal chemical shift standard. Chemical shifts (δ) are reported in ppm and coupling constants (*J*) in Hz. Mass spectra were obtained on a Xevo G3QTof (HRMS). Analytical TLC was performed on silica gel plates (Silica gel 60 F_{254}, Merck). The mobile phase was a mixture of n-butanol/ethanol/water/acetic acid (10:7:6:4, v/v). After development, spots were confirmed by exposure to iodine vapor.

Determination of antibacterial activity (agar diffusion and serial dilution methods):

The antibacterial activity of compounds 3(a-g) was evaluated using both the agar diffusion method and the two-fold serial dilution method in meat-peptone broth (pH 7.2-7.4). A bacterial load of 2×10^7 cells per *ml* of medium was used for all experiments. The test organisms included Gram-positive strains (*Staphylococcus aureus 209p, Bacillus megaterium 258*) and Gram-negative strains (*Shigella flexneri 6858, Escherichia coli O-55*). Furazolidone was used as a positive control. Test solutions of the compounds and the control drug were prepared in dimethyl sulfoxide (DMSO) at a dilution ratio of 1:20. A volume of 0,1 *ml* of each solution was applied to Petri dishes pre-inoculated with the corresponding microbial strain. After incubation at 37 °C for 24 hours, the antibacterial effect was determined by measuring the diameter (*d, mm*) of the inhibition zones where no bacterial growth was observed [19,20].

For the determination of MIC, serial dilution assays were conducted using 7-8 test tubes containing meat-peptone broth with decreasing concentrations of compounds, starting from 1000 μg/ml. Each tube was inoculated with an equal amount of bacterial suspension prepared from an 18-hour culture. After incubation at 37 °C for 24 hours, the results were assessed visually based on the presence or absence of microbial growth. The MIC was defined as the lowest concentration (μg/ml) of the compound that completely inhibited visible bacterial growth.

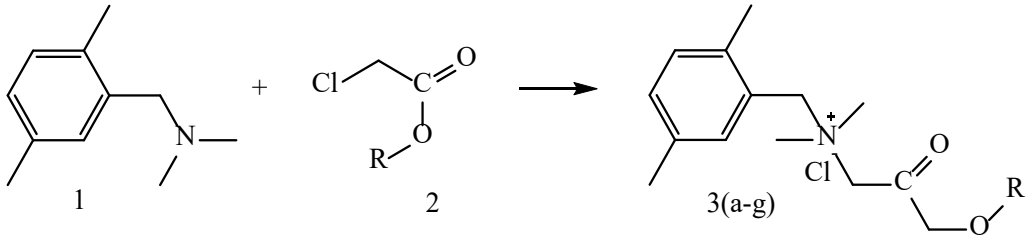
Results.

A series of novel 2-(alkyloxy)-N-(2,5-dimethylbenzyl)-N,N-dimethyl-2-oxoethanammonium chlorides (3a-g) was synthesized via the quaternization reaction of N,N-dimethyl-3,6-dimethylbenzylamine (1) with the corresponding alkyl esters of chloroacetic acid. The reaction scheme is shown in Figure 1.

The synthesized salts were obtained as white, water-soluble, and stable crystalline compounds. Their structure was confirmed using ^{1}H- and ^{13}C-NMR, IR, and mass spectrometry. The spectral data for all compounds are summarized below.

N-(2,5-dimethylbenzyl)-2-(hexyloxy)-N,N-dimethyl-2-oxoethan-1-aminium chloride (3a):

Yield 3.00g, 90%, white, soluble in water, T_m. 129-133 ^0C, IR spectra, ν, sm^{-1}: 815, 848,1506 (C_6H_3), 1746 (C=O), NMR spectra ^{1}H (DMSO-d_6/CCl_4 1/3), δ, m. d.: 0.90-0.99 m (3H, CH_3),



R=(a)C_6H_{13}, (b)C_7H_{15}, (c)C_8H_{17}, (d)C_9H_{19}, (e)$C_{10}H_{21}$, (f)$C_{11}H_{23}$, (g)$C_{12}H_{25}$

Figure 1. *Synthesis of 2-(alkyloxy)-N-(2,5-dimethylbenzyl)-N,N-dimethyl-2-oxoethanammonium chlorides (3a-g).*

1.05-1.25 m (6H, CH_2), 1.55-1.75 m (2H, $\underline{CH_2}CH_2CH_3$), 2.20 s (3H, $CH_3C_6H_3$), 2.25 s (3H, $CH_3C_6H_3$) 3.20 s (6H, N^+CH_3), 4.10 t (2H, *J* 7.0, OCH_2), 5.00 s (2H, $CH_2C{=}O$), 5.15 s (2H, CH_2N), 7.05-7.14 m (2H, C_6H_3), 7.20 d (1H, *J* 1.7, C_6H_3). NMR spectra ^{13}C (DMSO-d6/CCl_4 1/3), δC, m. d.: 13.48, 19.28, 20.22, 21.80, 24.69, 27.68, 30.67, 48.78, 60.48, 63.92, 65.29, 125.72, 130.68, 131.01, 134.69, 134.83, 136.68, 165.03. Mass-spectra HMRS (TOF MS ES+), m/z 306.2435 $[M]^+$, $C_{19}H_{32}ClNO_2$: (calculated for $C_{19}H_{32}NO_2^+$: 306.2433).

N-(2,5-dimethylbenzyl)-2-(heptyloxy)-N,N-dimethyl-2-oxoethan-1-aminium chloride (3b):

Yield 3.30g, 92%, white, soluble in water, T_m. 120-124 ^{0}C. IR spectra, ν, sm^{-1}: 813, 850,1506 (C_6H_3),1747 (C=O) NMR spectra ^1H (DMSO-d_6/CCl_4 1/3), δ, m. d.: 0.85-0.92 m (3H, CH_3), 1.22-1.40 m (6H, CH_2) 1.62-1.70 m (2H, $\underline{CH_2}CH_2CH_3$), 2.35 s (3H, $CH_3C_6H_3$), 2.48 s (3H, $CH_3C_6H_3$) 3.37 s (6H, N^+CH_3), 4.19 t (2H, *J* 7.2, OCH_2), 5.05 s (2H, $CH_2C{=}O$), 5.08 s (2H, CH_2N), 7.13-7.20 m (2H, C_6H_3), 7.37 d (1H, *J* 1.68 C_6H_3). NMR spectra ^{13}C (DMSO-d6/CCl_4 1/3), δC, m. d.: 13.56, 19.33, 20.23, 21.88, 24.97, 27.73, 28.17, 30.99, 48.75, 60.39, 63.86, 65.28, 125.75, 130.68, 131.01, 134.71, 134.80, 136.71, 165.05. Mass-spectra HMRS (TOF MS ES+), m/z 320.2592 $[M]^+$, $C_{20}H_{34}ClNO_2$: (calculated for $C_{20}H_{34}NO_2^+$: 320.2589).

N-(2,5-dimethylbenzyl)-2-(octyloxy)-N,N-dimethyl-2-oxoethan-1-aminium chloride (3c):

Yield 3.20g, 88%, soluble in water, T m. 115-119 ^{0}C. IR spectra, ν, sm^{-1}: 813, 846,1507 (C_6H_3), 1744 (C=O) NMR spectra ^1H (DMSO-d_6/CCl_4 1/3), δ, m. d.: 0.85-0.93 m (3H, CH_3), 1.21-1.42 m (10H, CH_2) 1.64-1.73 m (2H, $\underline{CH_2}CH_2CH_3$), 2.36 s (3H, $CH_3C_6H_3$), 2.47 s (3H, $CH_3C_6H_3$) 3.33 s (6H, N^+CH_3), 4.21 t (2H, *J* 6.88, OCH_2), 4.93 s (2H, $CH_2C{=}O$), 5.01 s (2H, CH_2N), 7.15-7.22 m (2H, C_6H_3), 7.35 d (1H, *J* 1.69 C_6H_3). NMR spectra ^{13}C (DMSO-d6/CCl_4 1/3), δC, m. d.: 13.61, 19.28, 20.26, 21.94, 25.07, 27.76, 28.49, 31.10, 48.89, 60.49, 64.01, 65.37, 125.67, 130.76, 131.08, 134.65,134.89, 136.67, 164.99. Mass-spectra HMRS (TOF MS ES+), m/z 334,2743 $[M]^+$, $C_{21}H_{30}ClNO_2$: (calculated for $C_{21}H_{30}NO_2^+$: 334.2746).

N-(2,5-dimethylbenzyl)-2-(nonyloxy)-N,N-dimethyl-2-oxoethan-1-aminium chloride (3d):

Yield 3.57g, 93%, soluble in water, T m. 110-114 ^{0}C IR spectra, ν, sm^{-1}: 812, 852, 1507 (C_6H_3), 1746 (C=O) NMR spectra ^1H (DMSO-d_6/CCl_4 1/3), δ, m. d.: 0.85-0.93 m (3H, CH_3), 1.20-1.40 m (12H, CH_2) 1.63-1.71 m (2H, $\underline{CH_2}CH_2CH_3$), 2.35 s (3H, $CH_3C_6H_3$), 2.48 s (3H, $CH_3C_6H_3$) 3.36 s (6H, N^+CH_3), 4.20 t (2H, *J* 6.9, OCH_2), 5.02 s (2H, $CH_2C{=}O$), 5.06 s (2H, CH_2N), 7.13-7.19 m (2H, C_6H_3), 7.37 d (1H, *J* 1.7 C_6H_3). NMR spectra ^{13}C (DMSO-d6/CCl_4 1/3), δC, m. d.: 13.59, 19.32, 20.24, 21.95, 25.04, 27.74, 28.55, 28.78, 31.15, 48.79, 60.41, 63.90, 65.31, 125.74, 130.71, 131.03, 134.70, 134.83, 136.70, 165.04. Mass-spectra HMRS (TOF MS ES+), m/z 348.2905 $[M]^+$, $C_{22}H_{38}ClNO_2$: (calculated for $C_{22}H_{38}NO_2^+$: 348.2903.).

N-(2,5-dimethylbenzyl)-2-(decyloxy)-N,N-dimethyl-2-oxoethan-1-aminium chloride (3e):

Yield 3.18g, 80%, soluble in water, T m. 109-113^{0}C IR spectra, ν, sm^{-1}: 813, 850, 1505 (C_6H_3), 1746 (C=O) NMR spectra ^1H (DMSO-d_6/CCl_4 1/3), δ, m. d.: 0.89 m (3H, CH_3), 1.28 m (14H, CH_2) 1.70 m (2H, $\underline{CH_2}CH_2CH_3$), 2.37 s (3H, $CH_3C_6H_3$), 2.47 s (3H, $CH_3C_6H_3$), 3.31 s (6H, N^+CH_3), 4.22 t (2H, *J* 7.2, OCH_2), 4.86 s (2H, $CH_2C{=}O$), 4.97 s (2H, CH_2N), 7.20 m (2H, C_6H_3), 7.33 d (1H, JC_6H_3). NMR spectra ^{13}C (DMSO-d6/CCl_4 1/3), δC, m. d.: 13.48, 19.28, 20.22, 21.80, 24.69, 27.68, 28.50, 28.70, 28.78, 28.88, 30.69, 48.78, 60.48, 63.92, 65.29, 125.72, 130.68, 131.01, 134.69, 134.83, 136.68, 165.03. Mass-spectra HMRS (TOF MS ES+), m/z 362.5312. $[M]^+$, $C_{23}H_{34}ClNO_2$: (calculated for $C_{23}H_{34}NO_2^+$: 362.5300).

N-(2,5-dimethylbenzyl)-2-(undecyloxy)-N,N-dimethyl-2-oxoethan-1-aminium chloride (3f):

Yield 3.54g, 86%, soluble in water, T m. 108-112^{0}C IR spectra, ν, sm^{-1}: 813, 848, 1506 (C_6H_3), 1746 (C=O), NMR spectra ^1H (DMSO-d_6/CCl_4 1/3), δ, m. d.: 0.85-0.92 m (3H, CH_3), 1.21-1.41 m (16H, CH_2) 1.64-1.74 m (2H, $\underline{CH_2}CH_2CH_3$), 2.37 s (3H, $CH_3C_6H_3$), 2.47 s (3H, $CH_3C_6H_3$) 3.33 s (6H, N^+CH_3), 4.22 t (2H, *J* 6.83, OCH_2), 4.93 s (2H, $CH_2C{=}O$), 5.01 s (2H, CH_2N), 7.15-7.22 m (2H, C_6H_3), 7.35 d (1H, *J* 1.68 C_6H_3). NMR spectra ^{13}C (DMSO-d6/CCl_4 1/3), δC, m. d.: 13.61, 19.28, 20.26, 21.98, 25.08, 27.77, 28.57, 28.60, 28.63, 28.85, 28.92, 30.67, 48.91, 64.00, 64.50, 65.37, 125.67, 130.78, 131.08, 134.64, 134.90, 136.67, 164.98. Mass-spectra HMRS (TOF MS ES+), m/z 376.3218 $[M]^+$, $C_{24}H_{36}ClNO_2$: (calculated for $C_{24}H_{36}NO_2^+$: 376.3216).

N-(2,5-dimethylbenzyl)-2-(dodecyloxy)-N,N-dimethyl-2-oxoethan-1-aminium chloride (3g):

Yield 3.62g, 85%, soluble in water, T m.107-111 ^{0}C. IR spectra, ν, sm^{-1}: 812, 846, 948 (C_6H_3),1746 (C=O), NMR spectra ^1H (DMSO-d_6/CCl_4 1/3), δ, m. d.: 0.86-0.92 m (3H, CH_3), 1.20-1.40 m (18H, CH_2) 1.65-1.75 m (2H, $\underline{CH_2}CH_2CH_3$), 2.35 s (3H, *J* 7.2 $CH_3C_6H_3$), 2.45 s (3H, $CH_3C_6H_3$) 3.32 s (6H, N^+CH_3), 4.20 t (2H, *J* 7.1, OCH_2), 5.01 s (2H, $CH_2C{=}O$), 5.06 s (2H, CH_2N), 7.15-7.21 m (2H, C_6H_3), 7.40 d (1H, *J* 1.7 C_6H_3). NMR spectra ^{13}C (DMSO-d6/CCl_4 1/3), δC, m. d.: 13.59, 19.43, 20.23, 21.95,

25.88, 28.57, 28.63, 28.73, 28.85, 28,90, 28,92, 28,96, 31,18, 48.26, 63.37, 63.93, 65.34,126.15, 130.47, 130.92, 134.60, 134.71, 136.42, 165.03. Mass-spectra HMRS (TOF MS ES+), m/z 390.2435 $[M]^+$, $C_{25}H_{44}NO_2Cl$: (calculated for $C_{25}H_{44}NO_2^+$: 390.2433).

Antimicrobial activity of the studied compounds:

In this study, the antimicrobial activity of a series of compounds (3a–3g) against four bacterial species was assessed: *Staphylococcus aureus 209p*, *Bacillus megaterium 258*, *Shigella flexneri 6858*, and *Escherichia coli O-55*. Furazolidone was used as a control drug.

The activity of the compounds was determined by the diameter of the IZ of microorganism growth (mm) and by MIC (μg/ml) (Table 1).

Table 1. *Antibacterial activity (agar diffusion) of compounds 3(a-g).*

Compound	Inhibition zone (mm)			
	Staphylococcus aureus 209p	***Bacillus Megaterium 258***	***Shigella flexneri 6858***	***Escherichia coli O-55***
3a	35	35	35	35
3b	35	35	35	35
3c	35	20	35	35
3d	35	20	35	35
3e	35	25	25	25
3f	35	25	25	25
3g	35	25	28	27
Furazolidone	25	25	24	23

The results showed that compounds 3a and 3b have the maximum and uniform activity, forming inhibition zones with a diameter of 35 mm for all tested microorganisms. These values significantly exceed the activity of the control drug, furazolidone, for which the inhibition zone diameter varied from 23 to 25 mm.

Compounds 3c and 3d demonstrate high activity (35 mm) against *Staphylococcus aureus, Shigella flexneri*, and *Escherichia coli,* but their effectiveness against *Bacillus megaterium* is reduced (20 mm). Similarly, compounds 3e and 3f show moderate activity (around 25 mm) against all tested strains, except for *Staphylococcus aureus*, where the inhibition zone reached 35 mm.

Compound 3g shows slightly increased activity compared to 3e and 3f, especially against *Shigella flexneri* and *Escherichia coli*, with zone diameters of 28 and 27 mm, respectively.

Thus, all the studied compounds are superior to the control drug, furazolidone, which indicates the prospects for their further study as potential antimicrobial agents.

Antibacterial activity of compounds 3a–3g based on MIC:

The results of antibacterial activity based on MIC are presented in Table 2.

Compounds 3a and 3b showed the same MIC of 62.5 μg/mL for all bacteria tested. Similar MIC was observed for *Staphylococcus aureus*, *Shigella flexneri*, and *Escherichia coli* for compounds 3c and 3d, but against *Bacillus megaterium,* the MIC value increased to 250 μg/mL, indicating reduced activity of these compounds against this strain.

Table 2. *Antibacterial activity (serial dilution method) of compounds 3a-g.*

Compound	Minimum Inhibitory Concentration (MIC μg/ml)			
	Staphylococcus aureus 209p	***Bacillus Megaterium 258***	***Shigella flexneri 685***8	***Escherichia coli O-55***
3a	62,5	62,5	62,5	62,5
3b	62,5	62,5	62,5	62,5
3c	62,5	250	62,5	62,5
3d	62,5	250	62,5	62,5
3e	62,5	125	125	125
3f	62,5	125	125	125
3g	62,5	125	125	125
Furazolidone	31,2	31,2	31,2	31,2

Compounds 3e, 3f, and 3g were characterized by an MIC of 62.5 μg/mL against *Staphylococcus aureus* and increased to 125 μg/mL against the other three microorganisms.

Thus, despite the higher MIC values of the studied compounds compared to furazolidone, their uniform and fairly stable activity confirm the prospects of further research.

The study found that all compounds 3a–3g have pronounced antimicrobial activity against Gram-positive and Gram-negative bacteria. Compounds 3a and 3b showed particularly pronounced properties, demonstrating maximum diameters of inhibition zones (35 mm) against all tested strains, which significantly exceeds the activity of the control drug, furazolidone. Furazolidone, despite lower MIC values, forms smaller inhibition zones, which may be due to its physicochemical properties and lower diffusion in the medium.

The data on MIC revealed higher values for the studied compounds compared to furazolidone (31.2 μg/ml), but this does not contradict the results of the inhibition zones. The high efficiency in the inhibition zones is probably due to good diffusion of the compounds into the agar, which contributes to the formation of large zones of bacterial growth inhibition.

The decrease in the activity of compounds 3c and 3d against *Bacillus megaterium*, expressed in an increase in MIC to 250 μg/ml and a reduction in the diameter of the inhibition zone, indicates specific features of the sensitivity of this strain. Similarly, compounds 3e–3g exhibit moderate activity, which is reflected in an MIC of 125 μg/ml and smaller inhibition zones.

Discussion.

The synthesis of novel quaternary ammonium compounds (QACs) featuring 2,5-dimethylbenzyl and alkyloxycarbonylmethyl moieties was achieved through a reaction between N,N-dimethyl-3,6-dimethylbenzylamine and alkyl esters of chloroacetic acid (Figure 1). This method yielded stable, water-soluble crystalline salts with moderate to good efficiency under mild conditions. Spectroscopic analysis confirmed the successful synthesis of the target compounds.

The ^{1}H NMR spectra displayed characteristic singlets around 4.97-5.15 ppm (Table 3), corresponding to the methylene protons adjacent to the quaternary nitrogen and ester carbonyl group, serving as diagnostic signals for the quaternary ammonium structure, which is shown on the example of compound 3d (Figure 2).

Table 3. *Characteristic singlets of QACs (3a-g) (ppm).*

3a	3b	3c	3d	3e	3f	3g
5.15	5.08	5.01	5.06	4.97	5.01	5.06

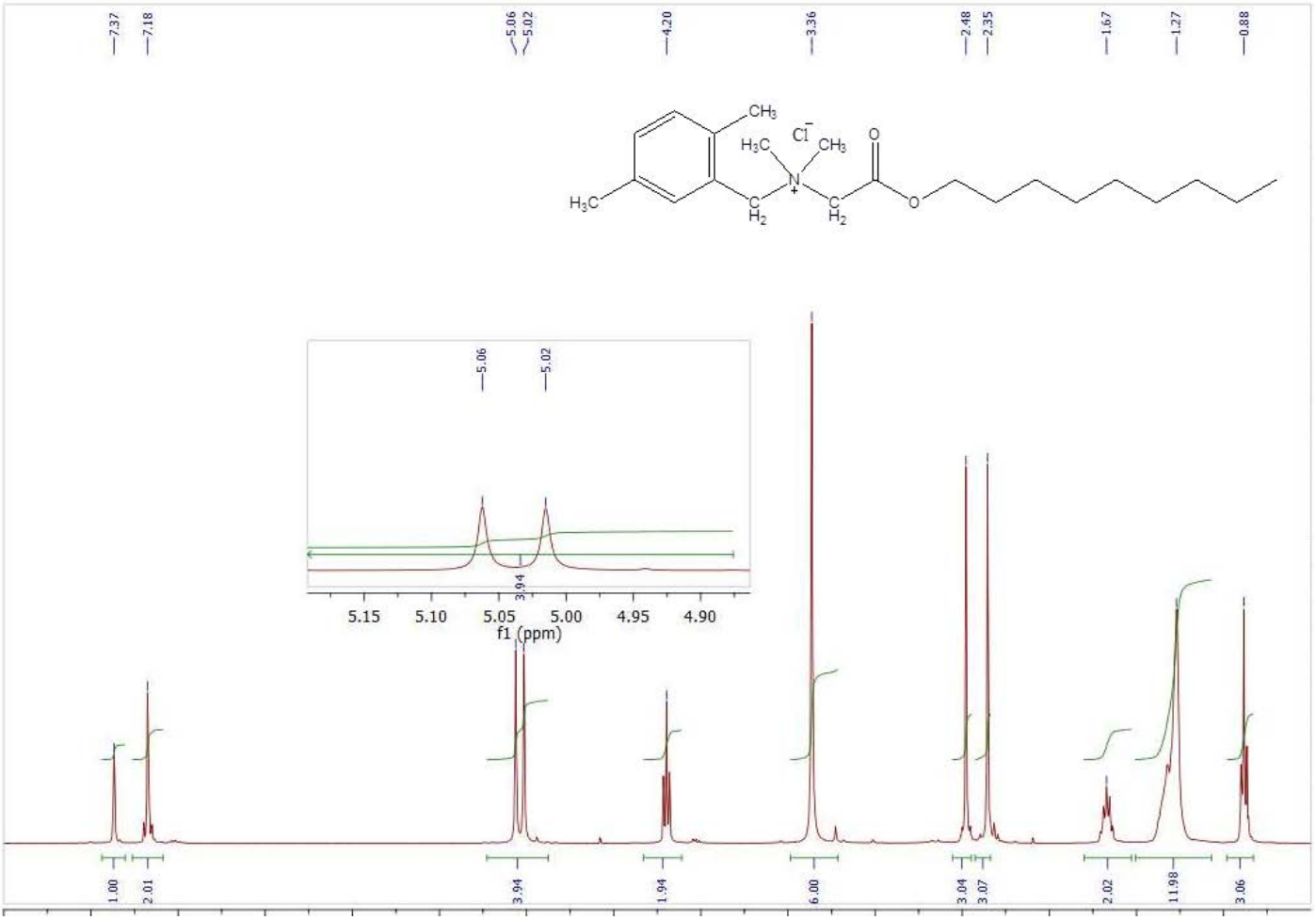


Figure 2. *$_1$H NMR spectra of N-(2,5-dimethylbenzyl)-2-(nonyloxy)-N,N-dimethyl-2-oxoethan-1-aminium chloride (3d).*

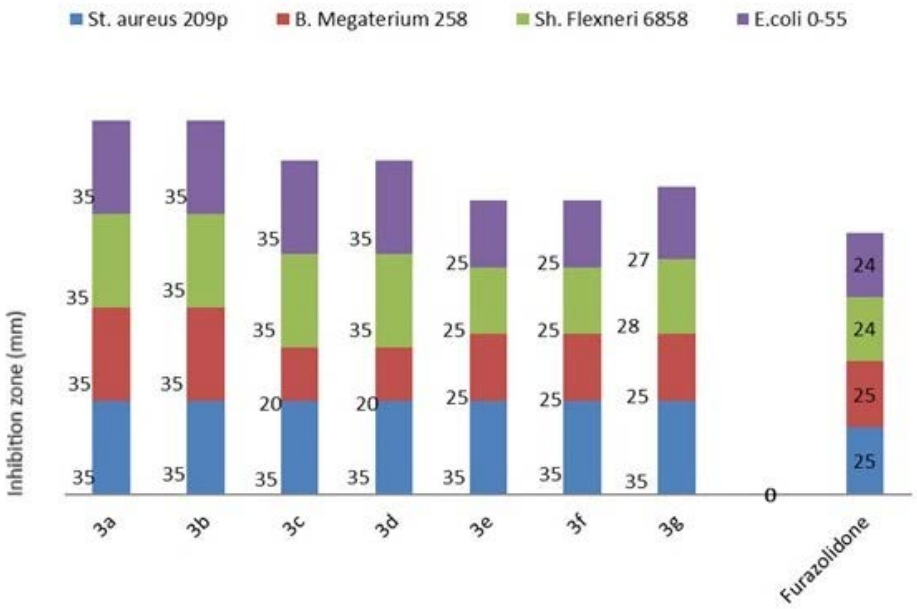


Figure 3. *Antibacterial activity (agar diffusion) of compounds 3(a-g).*

IR and MS data further confirmed the structural integrity of the synthesized salts. The current method contributes to the expanding library of bioactive quaternary salts [16].

To assess the biological relevance of the synthesized structures, a series of antimicrobial assays was conducted on compounds 3(a–g), revealing how variations in chemical composition affect their activity against different bacterial strains (Figure 3).

The obtained data indicate a high antimicrobial potential of the studied compounds of the 3(a–g) series, with noticeable differences in the spectrum and degree of activity. The most pronounced effect was demonstrated by compounds 3a and 3b, which exhibited an equally high inhibitory capacity against all four tested bacterial strains. This suggests that these compounds have a universal mechanism of action targeting fundamental cellular processes that do not depend on the type of cell wall or Gram status of bacteria.

Such targets may include ribosomes, elements of the replication apparatus, or structures of the cytoplasmic membrane [21]. High efficiency against both Gram-positive and Gram-negative bacteria makes these compounds promising candidates for the development of broad-spectrum antimicrobial drugs.

Compounds 3c and 3d showed selective activity, reducing effectiveness against *Bacillus megaterium*, while maintaining full activity against other strains. This may indicate the presence of structural or functional barriers in the *Bacillus megaterium* cell wall that prevent penetration of the active substance, or the presence of specific detoxifying enzymes such as peroxidases or nitroreductases that can inactivate the compound before it reaches the target.

The moderate activity of compounds 3e and 3f, especially against Gram-negative bacteria, may be due to the presence of an outer membrane in these microorganisms, representing a physical barrier to hydrophilic or large molecules. However, the retention of high activity against *S. aureus* indicates that these compounds can selectively interact with cell wall components of Gram-positive bacteria, possibly disrupting peptide synthesis or cross-linking.

Compound 3g showed an intermediate activity profile: it retained high efficacy against *Staphylococcus aureus* and demonstrated increased activity against *Shigella flexneri* and *Escherichia coli* compared to 3e and 3f. This may indicate modified lipophilic properties of the molecule, providing improved penetration through the outer membrane of Gram-negative bacteria. Such properties may result from the introduction of certain functional groups into the molecule, improving intermembrane diffusion.

It is essential to note that the activity of all the studied compounds against at least one or more strains exceeds that of furazolidone, the control drug used.

Thus, the differences in the activity of the studied substances indicate the influence of both the structure of the compounds and the characteristics of the targets in different bacteria. These results highlight the potential for the targeted synthesis of antimicrobial agents with desired properties, both broad- and narrow-spectrum.

Conclusion.

In the present research work, a series of novel QACs was synthesized by the interaction of N,N-dimethyl-3,6-dimethylbenzylamine with the alkyl (C6-C12) chloroacetate. ^{1}H and ^{13}C NMR spectra were used to determine and characterize the structures. IR spectroscopy, HRMS, and TLC further supported the structural integrity and purity of the compounds. The obtained quaternary ammonium salts with alkyloxycarbonylmethyl and 2,5-dimethylbenzyl substituents were tested on Gram-positive (*Staphylococcus aureus 209p*, *Bacillus megaterium 258*) and Gram-negative (*Shigella flexneri 6858*, *Escherichia coli O-55*) bacteria. All QACs showed moderate antibacterial activity.

These findings encourage the continued optimization of the molecular framework to enhance potency and strain selectivity, paving the way for the design of next-generation antimicrobial compounds that can overcome emerging resistance.

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SYNTHESIS AND ANTIBACTERIAL EVALUATION OF 2-(ALKYLOXY)-N-(2,5-DIMETHYLBENZYL)-N,N-DIMETHYL-2-OXOETHANAMMONIUM CHLORIDES

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Abstract

Quaternary ammonium compounds (QACs) are cationic surfactants with strong antimicrobial activity widely used in healthcare, consumer, and industrial products. This study synthesized and evaluated a new series of 2-(alkyloxy)-N-(2,5-dimethylbenzyl)-N,N-dimethyl-2-oxoethanammonium chlorides (C6–C12) for antibacterial efficacy. The compounds were obtained by alkylating N,N-dimethyl-3,6-dimethylbenzylamine with corresponding alkyl chloroacetates. Antibacterial activity, tested against *Staphylococcus aureus*, *Bacillus subtilis*, *Escherichia coli*, and *Shigella flexneri*, showed inhibition zones up to 35 mm. However, the MIC values of the synthesized compounds were higher than those of the reference drug, furazolidone. These findings indicate that incorporating a 2,5-dimethylbenzyl fragment together with an alkyloxycarbonylmethyl chain within a quaternary ammonium framework results in compounds exhibiting moderate, broad-spectrum antibacterial activity.

Keywords: Quaternary ammonium compound (QAC), alkyl chloroacetate, antibacterial activity, Gram-positive bacteria, Gram-negative bacteria.

СИНТЕЗ И АНТИБАКТЕРИАЛЬНАЯ ОЦЕНКА 2-(АЛКИЛОКСИ)-N-(2,5-ДИМЕТИЛБЕНЗИЛ)-N,N-ДИМЕТИЛ-2-ОКСОЭТАНАММОНИЙ ХЛОРИДОВ

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Аннотация

Четвертичные аммониевые соединения (ЧАС) представляют собой катионные поверхностно-активные вещества с выраженной антимикробной активностью, широко используемые в медицинских, бытовых и промышленных целях. В данной работе синтезирована и исследована новая серия 2-(алкилокси)-N-(2,5-диметилбензил)-N,N-диметил-2-оксоэтанаммоний хлоридов (C6–C12) с целью оценки их антибактериальной активности. Соединения получены алкилированием N,N-диметил-3,6-диметилбензиламина соответствующими алкилхлорацетатами. Антибактериальная активность изучена в отношении *Staphylococcus aureus*, *Bacillus subtilis*, *Escherichia coli* и *Shigella flexneri*. Соединения продемонстрировали зоны ингибирования до 35 мм. Однако значения МИК синтезированных соединений оказались выше, чем у референтного препарата фуразолидона. Эти данные свидетельствуют о том, что включение 2,5-диметилбензильного фрагмента вместе с алкилоксикарбонилметильной цепью в четвертичный аммониевый каркас приводит к образованию соединений, проявляющих умеренную антибактериальную активность широкого спектра действия.

Ключевые слова: четвертичные аммониевые соединения (ЧАС), алкилхлорацетат, антибактериальная активность, грамположительные бактерии, грамотрицательные бактерии.

2-(ალკილოქსი)-N-(2,5-დიმეთილბენზილ)-N,N-დიმეთილ-2-ოქსოეთამანონიუმის ქლორიდების სინთეზი და ანტიბაქტერიული შეფასება

ვარდუი სურენ ჰოვსეპიანი, ნაირა არაიკ გევორგიანი, გევორგ გარნიკ საფარიანი, აშოტ ვარგეს ბაბახანიანი, ჰრაჩია მოვსეს სტეპანიანი, გოჰარ მკრტიჩ არაჟიანი

რეზიუმე

მეოთხეული ამონიუმის ნაერთები (QACs) არის კათიონური ზედაპირულად აქტიური ნივთიერებები გამოხატული ანტიმიკრობული აქტივობით, რომლებიც ფართოდ გამოიყენება სამედიცინო, საყოფაცხოვრებო და სამრეწველო დანიშნულებით. ამ ნაშრომში სინთეზირებული და დახასიათებულია 2-(ალკილოქსი)-N-(2,5-დიმეთილბენზილ)-N,N-დიმეთილ-2-ოქსოეთამანონიუმის ქლორიდების (C6–C12) ახალი სერია მათი ანტიბაქტერიული აქტივობის შესაფასებლად. ნაერთები მიღებულ

იქნა N,N-დიმეთილ-3,6-დიმეთილბენზილამინის ალკილქლორაცეტატებთან. ანტიბაქტერიული აქტივობა შესწავლილი იქნა Staphylococcus aureus-ის, Bacillus subtilis-ის, Escherichia coli-ს და Shigella flexneri-ს მიმართ. კავშირებმა აჩვენა 35 მმ-მდე ინჰიბირების ზონები. თუმცა, MIC მნიშვნელობები უფრო მაღალი იყო, ვიდრე საცნობარო პრეპარატის ფურაზოლიდონის. ეს მონაცემები მიუთითებს, რომ 2,5-დიმეთილბენზილის ფრაგმენტის ჩართვა ალკილოქსიკარბონილმეთილის ჯაჭვთან ერთად მეოთხეულ ამონიუმის ჩარჩოში იწვევს ნაერთების წარმოქმნას, რომლებიც ავლენენ ზომიერ ანტიბაქტერიულ აქტივობას მოქმედების ფართო სპექტრით.

საკვანძო სიტყვები: მეოთხეული ამონიუმის ნაერთები (QAC), ალკილ ქლორაცეტატი, ანტიბაქტერიული აქტივობა, გრამდადებითი ბაქტერიები, გრამუარყოფითი ბაქტერიები.