ISNN:2181-1296



SHAROF RASHIDOV NOMIDAGI
SAMARQAND DAVLAT UNIVERSITETI

САМАРКАНДСКИЙ ГОСУДАРСТВЕННЫЙ
УНИВЕРСИТЕТ ИМЕНИ ШАРОФА РАШИДОВА

SAMARKAND STATE UNIVERSITY NAMED
AFTER SHAROF RASHIDOV

ILMIY AXBOROTNOMA

НАУЧНЫЙ ВЕСТНИК
SCIENTIFIC JOURNAL

ANIQ VA TABIIY FANLAR SERIYASI

Matematika, Mexanika, Informatika
Fizika, Kimyo, Biologiya, Geografiya

№ 1/1 (149)
2025

ISSN 2181-1296

ILMIY AXBOROTNOMA

НАУЧНЫЙ ВЕСТНИК SCIENTIFIC JOURNAL

2025-yil, 1-son (149/1) ANIQ VA TABIIY FANLAR SERIYASI

Matematika, Mexanika, Informatika, Fizika, Kimyo, Biologiya, Geografiya

Samarqand viloyat matbuot boshqarmasida ro‘yxatdan o‘tish tartibi 09-25.
Jurnal 1999-yildan chop qilina boshlagan va OAK ro‘yxatiga kiritilgan.

BOSH MUHARRIR **R. I. XALMURADOV, t.f.d., professor**
BOSH MUHARRIR O‘RINBOSARLARI: **H.A. XUSHVAQTOV, f-m.f.d., dotsent**

TAHRIRIYAT KENGASHI:

Sh.A.Alimov	- O‘zFA akademigi	**M.X.Ashurov**	- O‘zFA akademigi
S.N.Lakayev	- O‘zFA akademigi (SamDU)	**B.J.Axmedov**	- O‘zFA akademigi
M.M.Kamilov	- O‘zFA akademigi	**Q.G‘.G‘ulomov**	- O‘zFA akademigi
A.G.Yagola	- Moskva davlat universiteti professori (Rossiya)	**A.A.Zaxidov**	-Texas Nanotexnologiya instituti professori (AQSh)
Alberto Del Bimbo	-Florensiya universiteti professori (Italiya)	**N.B. Ferapontov**	- Moskva davlat universiteti professori (Rossiya)
Sh.Tugizov	-Kaliforniya universiteti professori (AQSh)	**V.L.Popov**	-Berlin texnika universiteti professori (Germaniya)
A.S.Soleev	- f.-m.f.d., professor (SamDU)	**N.F.Bunkin**	- Moskva davlat texnika universiteti professori (Rossiya)
I.A.Ikromov	- f.-m.f.d., professor (SamDU)	**Haji Akber Aisa**	-Xinjiang tibbiyot universiteti professori (Xitoy)
B.X.Xo‘Jayarov	- f.-m.f.d., professor (SamDU)	**E. A. Abduraxmonov**	- k.f.d., professor (SamDU)
L.Sabirov	-f.-m.f.d., professor (SamDU)	**N. K. Muxamadiyev**	- k.f.d., professor (SamDU)
A.Jumaboyev	-f.-m.f.d., professor (SamDU)	**L. A. Bulavin**	- Kiev milliy universiteti
X.Bozorov	-k.f.d., professor (SamDU)	**X. Q. Xaydarov**	- b.f.d., professor (SamDU)
O.Q.Quvondiqov	-f.-m.f.d. professor (SamDU)	**Z. I. Izzatullayev**	- b.f.d., professor (SamDU)
A.Z.Xasanov	-f.-m.f.d. professor (SamDU)	**A.B.Hasanov**	-tex.f.d., professor (SamDU)
Muhammad Suzuri bin Hitam	- Terengganu universiteti professori (Malayziya)	**Sh. T. Xoliqulov**	- q.-x.f.d., professor (SamDU)
K.D.Kuliyev	- f.-m.f .n. professor (SamDU)	**S. B. Abbosov**	- g.f.d., professor (SamDU)
A.M.Xolxo‘jayev	-f.-m.f.d., professor (SamDU)	**M.E. Mo‘minov**	-f.-m.f.d., professor (SamDU)
J.Abdullayev	-f.-m.f.d., professor (SamDU)	**I.I.Jumanov**	-tex.f.d., professor (SamDU)
A.R.Axatov	-tex.f.d., professor (SamDU)	**N.S.Mamatov**	-tex.f.d., professor (TIQXMMI)
D.B.Xursanov	- g.f.f.d., dotsent (SamDU)	**A.Sh.Yarmuxamedov**	-f-m.f.n., dotsent (SamDU)
F.Nazarov	-tex.f.f.d., dotsent (SamDU)	**X.S.Xaydarov**	-f-m.f.n., dotsent (SamDU)

Obuna indeksi – yakka tartibdagi obunachilar uchun **- 5583,**
tashkilot, korxonalar uchun **- 5584**

M U N D A R I J A
C O N T E N T S

№	Maqola nomi	Article title	Bet/ page
1	Triplet CdSe/CdS/ZnS kvant nuqtalariga asoslangan nanokompozitlarning fizik-kimyoviy xossalari **Bahronova N., Abdibanatova G., Kulmirzayeva S., Kolyadin V., Ishankulov A.**	Physicochemical properties of nanocomposites based on triplet CdSe/CdS/ZnS quantum dots **Bahronova N., Abdibanatova G., Kulmirzaeva S., Kolyadin V., Ishankulov A.**	**5-10**
2	Zaryadlangan BTZ qora tuynuklarning P-V kritikligi va barqarorlik tahlili **Umrzoqov F., Rakhmatov B.**	P-V criticality and stability analysis of charged BTZ black holes **Umrzokov F., Rakhmatov B.**	**11-16**
3	Diffuziyali jarayon bilan berilgan tenglamalar sistemasini avtomodel tahlili **Mamatov A.**	Self-similar analysis of a system of equations given by a diffusion process **Mamatov A.**	**17-25**
4	Ma'lumotlar bazasini loyihalashtirishda evolyutsion usullarini qo'llash algoritmlari **Nurmamatov M.K.**	Algorithms for using evaluation methods in database design **Nurmamatov M.K.**	**26-32**
5	Tarkibida aralvan erituvchilar bo'lgan kuchli elektrolitlar eritmalaridan pvs bo'kish kinetikasini o'rganish **Atavullaeva Sh., Tursunova G., Trobov H, Ferapontov N.**	Study of the kinetics of pva swelling from solutions of strong electrolytes containing mixed solvents **Atavullaeva Sh., Tursunova G., Trobov Kh, Ferapontov N.**	**33-38**
6	Kasallik belgilari va kasalliklar o'rtasidagi bog'liqlikni aniqlashning mantiqiy modeli va dasturiy ta'minoti **Abdirofiev N.**	Logical model and software for determining the relationship between diseases and their symptoms **Abdirofiev N.**	**39-46**
7	Umumiy nisbiylik nazariyasida tortishish maydonida perigeliynning siljishi va yorug'lik nurlanishining burilishi **Turimov B., Karshiboev Sh.**	Perihelion shift and light bending by a gravitational object in general relativity **Turimov B., Karshiboev Sh.**	**47-56**
8	Bentonit gillarini boyitish orqali uning struktura tuzilishiga ta'sirini o'rganish **Mamadoliyev I., Abdikamalova A., Raxmanova F.**	Studying the impact of bentonite clay on its structural structure through enrichment **Mamadoliyev I., Abdikamalova A., Rakhmanova F.**	**57-63**
9	Ba'zi d-elementlar ionlarining kversetin va rutin bilan komplekslari sintezi va ularning barqarorlik konstantalarini baholash **Ergashova Sh.I., Ismatov D.M., Mukhamadiev N.K.**	Synthesis of complex compounds of ions of some d-elements with quercetin and rutin and assessment of their stability constants **Ergashova Sh.I., Ismatov D.M., Mukhamadiev N.K.**	**64-68**
10	Anilinning tebranish modlarini polarizatsiyalangan raman va umumlashgan 2D Raman korelyatsion spektroskopiyasi yordamida konsentratsiyaga bog'liq holda tahlil qilish **Yormatov Sh.**	Concentration-dependent analysis of aniline vibrational modes using polarized raman and generalized 2d raman correlation spectroscopy **Yormatov Sh.**	**69-75**
11	Glioksalning eritmalar bilan hosil qilgan kompleslarining shakllanish mexanizmlarini noemperik hisoblash yordamida o'rganish **Jumabayev A., Norqulov A., Mahammadiyev S.**	Study of formation mechanisms of complexes formed with glyoxal solutions using quantum chemical calculations **Jumabaev A., Norkulov A., Makhammadiyev S.**	**76-90**

12	Materialining nomukammal elastikligi hisobga olingan doiraviy plastinkaning tasodifiy ko‘ndalang tebranishlari **Dusmatov O., Khasanov J.**	Transverse vibrations of a circular plate taking into account the imperfect elasticity of the material **Dusmatov O., Khasanov J.**	**91-95**
13	Diskret hardy tipidagi tengsizliklar uchun yangi ekvivalent shartlar **Kuliev K., Turaqulov T.**	New equivalent conditions for discrete hardy-type inequalities **Kuliev K., Turakulov T.**	**96-105**
14	To‘rtta tub sonning kvadratlari yig‘indisi ko‘rinishida ifodalanuvchi sonlar haqida **Imamov O.**	On numbers representable as the sum of four squares of prime numbers **Imamov O.**	**106-110**
15	$CD_3Hal\cdots HCl$ (Hal = F, Cl, Br) komplekslarini IQ spektrlari va DFT hisoblari asosida tekshirish **Khujamov U., Murodov G., Hushvaktov H., Nurmurodova G.**	Investigation of $CD_3Hall\cdots HCl$ (Hal = F, Cl, Br) complexes based on ir spectra and dft calculations **Khujamov U., Murodov G., Khushvaktov H., Nurmurodova G.**	**111-121**
16	Uch o‘lchamli qo‘zg‘alishga ega Fridrixs modelining sonli tasviri **Husenova J.T.**	Numerical range of the Friedrichs model with rank three perturbation **Husenova J.T.**	**122-127**
17	Quyi molekulyar dori vositalarini modifikatsiyasida polialdegidinulinni qo‘llanilishi **Rakhmonberdiev G.R., Bocheka A.M., Ibragimova K.S., Tilakov J.R., Khusenov A.Sh.**	Application of polyaldehydinuline for modification of low molecular drugs **Rakhmonberdiev G.R., Bocheka A.M., Ibragimova K.S., Tilakov J.R., Khusenov A.Sh.**	**128-133**

UDC: 616.62. https://doi.org/10.59251/2181-1296.2025.v1.149.1.3393

APPLICATION OF POLYALDEHYDINULINE FOR MODIFICATION OF LOW MOLECULAR DRUGS

G.R.Rakhmonberdiev[1], A.M.Bocheka[2], K.S.Ibragimova[1], J.R.Tilakov[1], A.Sh.Khusenov[1]
[1.]Tashkent Institute of Chemical Technology, Tashkent, Uzbekistan.
[2.]NRC Kurchatov Institute - PNPI – IMC.

G.R.Rakhmonberdiev
Tashkent Institute of Chemical Technology, Tashkent, Uzbekistan..

Received: 17.02.2025
Revised: 26.02.2025
Accepted: 10.03.2025
Published: 29.03.2025

Publisher: Samarkand State University named after Sharof Rashidov.

Abstract. By periodate oxidation of inulin, samples of polyaldehydinulin with varying degrees of oxidation have been obtained. The obtained polyaldehydinulines were used for the chemical modification of the low molecular weight drug adriamycin. It has been found that the quantitative content of adriamycin in the reaction products depends on the degree of oxidation of polyaldehydinulin. Using IR-spectroscopy, it has been proven that the chemical binding of adriamycin to polyaldehydinulin occurs through covalent azomethine bonds. When synthesized inulin-adriamycin was hydrolyzed in an acidic (pH 2.0) and slightly alkaline environment (pH 7.4), it has been proven that the drug has a prolonged release. The presence of adriamycin in the composition of polyaldehydinulin has been also substantiated by UV spectroscopy.

Keywords: polysaccharides, inulin, periodate oxidation, adriamycin, hydrolysis.

Quyi molekulyar dori vositalarini modifikatsiyasida polialdegidinulinni qo‘llanilishi

Annotatsiya. Inulinni periodat oksidlash orqali turli oksidlanish darajasiga ega bo‘lgan polialdegidinulin namunalari olindi. Polialdegidinulin quyi molekulyar adriamisin dori vositasini kimyoviy modifikatsiyasi uchun qo‘llanildi. Reaksiya mahsulotlari tarkibida adriamisinni miqdori polialdegidinulinni oksidlanish darajasiga bog‘liqligi aniqlandi. IQ-spektroskopiya usuli yordamida adriamisin polialdegidinulin bilan kovalent azometin bog‘lar orqali bog‘lanishi isbotlandi. Polialdegidinulin tarkibida adriamisin mavjudligi UB-usuli yordamida ham aniqlandi. Inulin-adriamisin kislotali (pH 2.0) va kuchsiz ishqoriy (pH 7.4) muhitda gidrolizga uchratilganda dori vositasi prolongatsiyalangan holatda ajralib chiqishi ko‘rsatildi.

Kalit so‘zlar: polisaxaridlar, inulin, periodat oksidlash, adriamisin, gidroliz.

Применение полиальдегидинулина для модификации низкомолекулярных лекарственных веществ

Аннотация. Путем периодатного окисления инулина были получены образцы полиальдегидинулина с различной степенью окисления. Полученные полиальдегидинулины были использованы для химической модификации низкомолекулярного лекарственного средства-адриамимицина. Было установлено, что количественное содержание адриамицина в продуктах реакции зависит от степени

окисления полиальдегидинулина. Методом ИК-спектроскопии доказано, что химическое связывание адриамицина с полиальдегидинулином происходит через ковалентные азометиновые связи. Присутствие адриамицина в составе полиальдегидинулина было также обосновано методом УФ-спектроскопии. При гидролизе синтезированного инулин-адриамицина в кислой (pH 2.0) и слабощелочной среде (pH 7.4) было доказано, что лекарственное средство имеет пролонгированное высвобождение.

Ключевые слова: полисахариды, инулин, периодатное окисление, адриамицин, гидролиз.

Introduction. At present, due to the exacerbation of environmental problems, the shortage and high cost of synthetic materials, and the decrease in mineral reserves, the use of plant materials is becoming particularly relevant. In this regard, the development of new chemical materials based on renewable plant materials is of great importance. Chemical modification of polysaccharides can significantly improve their physicochemical properties. The use of modified polysaccharides allows to expand the area of their practical application.

For example, the introduction of aldehyde groups into the macromolecule of natural polymers allows for increasing the reactivity of polysaccharides and using them to chemically modify low-molecular-weight pharmaceuticals or biologically active substances to prolong their effects [1-5]. The chemical addition of low molecular weight biologically active compounds to polysaccharide macromolecules allows obtaining new polymer derivatives with prolonged action, low toxicity, and high physiological effectiveness [6-10].

One of the urgent problems of modern biomedical chemistry is the creation of environmentally safe methods of drug modification. To solve these problems, it is most suitable to carry out the immobilization of low-molecular-weight biologically active substances into the structure of polyaldehyde polysaccharides through easily hydrolyzable covalent azomethine bonds. This method of chemical modification is safe because the reaction proceeds at low temperatures and in an aqueous medium without the participation of hazardous solvents [11,12]. Additionally, some studies have proven that by changing the quantitative composition of aldehyde groups in the polymer chain of oxidized polysaccharides, it is possible to obtain reaction products with various physicochemical properties [13-15].

Taking the above into account, the purpose of this work was to obtain polyaldeginulin and its use for the chemical modification of the antitumor agent adriamycin.

Experimental part.

Obtaining polyaldehydinulin with different oxidation states. 500 mg of inulin (*inulin isolated from the Muzhiz variety of Jerusalem artichoke*) with a molecular mass of 5600 Da was dissolved in 100 ml of acetate buffer solution with a pH of 4.5. After complete dissolution of inulin, 200 mg of NaIO were added to the solution. The periodate oxidation reaction continued at a temperature of 25°C for 1-5 hours. To complete the periodate oxidation reaction, 15 ml of pure ethylene glycol was added and stirred for 10 minutes. Then the solution was dialyzed against distilled water for 48 hours using dialysis bags with a protein transfer limit of 2000 Da. The finished products were separated from the pre-frozen aqueous solution by sublimation of water. The oxidation state of the obtained samples was calculated by the method of iodometric titration.

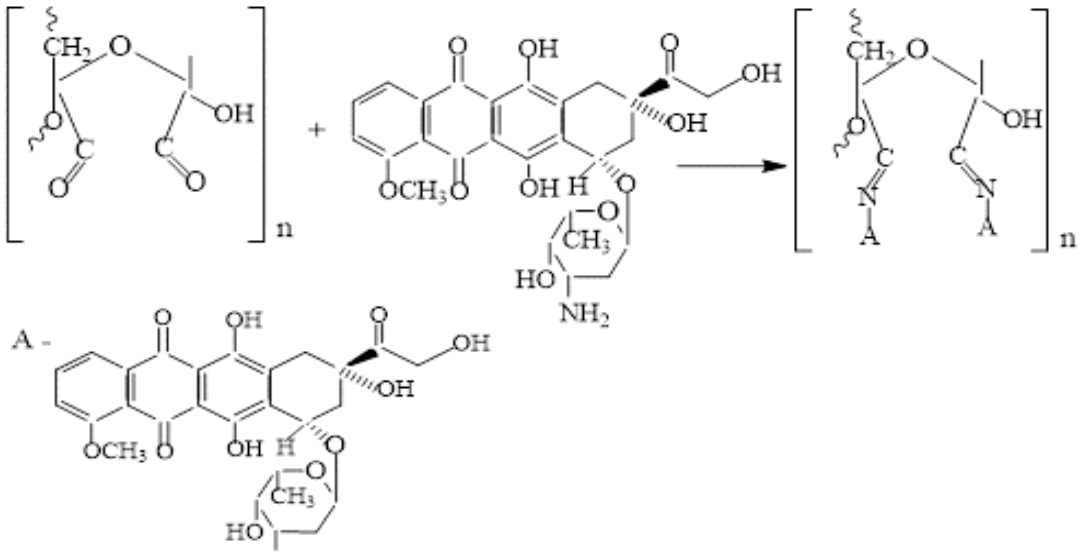
Chemical modification of adriamycin with polyaldehydinulin. 250 mg of polyaldehydinulin was dissolved in 50 ml of distilled water. After complete dissolution of the polyaldehydinulin, 100 ml of a phosphate buffer solution with a pH of 8.0-8.2 was added to the solution, followed by 160 mg of adriamycin and stirred for 5 hours at room temperature. The conjugate solution was dialyzed against distilled water for 24 hours. The product was separated by sublimation drying.

Studying the structure of inulin-adriamycin. The IR-spectra of all the obtained compounds were recorded on a Vector-22 IR-spectrometer in the 400-4000 cm^{-1} wavelength region in KBr tablets (3 mg of sample/300 mg of KBr). Spectrophotometric studies of the samples were carried out on a UV 1280 spectrophotometer (Shimadzu, Japan) in the wavelength range of 200-800 nm. The nitrogen content in the samples was determined using elementary analyzer an Eura EA (Italy).

Determination of the release rate of Adriamycin was carried out in a dialyzer with a pH of 2.0 and 7.4 in a buffer solution, the cells of which are separated by a membrane with a protein permeability limit of 2000 Da. For this purpose, a calibrated graph of the dependence of the optical density of adriamycin solutions on the concentration λ_{max}=490 nm was obtained. Then 100 mg of the polymer conjugate was dissolved in 50 ml of buffer solution and placed in one of the dialyzer compartments. A buffer solution (pH 2.0 or 7.4), belonging to another section, was added. After this, the dialyzer was placed in a thermostat at a temperature of 37°C. After a certain time interval, a sample was taken from the buffer solution compartment to determine the content of free adriamycin in the UV spectrum at λ_{max} = 490 nm.

Results and their discussion. To obtain the polymer form of adryamycin, polyaldehydinulin samples with different oxidation states were obtained. The choice of polyaldehydinulin as a matrix for adryamycin can be justified for the following reasons: firstly, the amount of aldehyde groups in the oxidized inulin allows modification of adryamycin under mild synthesis conditions; secondly, it is possible to obtain reaction products with different amounts of a low-molecular-weight substance with different oxidation states of polyaldehydinulin; thirdly, the chemical addition of adryamycin to polyaldehydinulin macromolecules gives it long-term release under physiological environmental conditions.

Since the adriamycin molecule contains a primary NH_2 group capable of reacting with the aldehyde groups of oxidized inulin, the reaction proceeds as follows with the formation of an azomethine bond:



The data presented in the table indicate the influence of the oxidation state of polyaldehydinulin on some characteristics of the reaction products.

Table

Influence of the degree of inulin oxidation on the characteristics of the reaction products

№	Oxidation degree of inulin	Nitrogen content, %	Adriamycin content ,%	Molecular mass, Da	Yield, %
1	16.5	1.6	5.8	4200	81.0

2	25.4	2.0	7.0	4270	76.3
3	31.5	2.5	9.2	4500	74.0
4	39.0	3.2	11.5	5160	70.5

According to the results presented in the table, the quantitative content of adriamycin in the reaction products depends on the degree of oxidation of polyaldehydinulin. With an increase in the content of aldehyde groups in oxidized inulin, the content of adriamycin increases from 5.8 to 11.5%. The decrease in the yield of the reaction products is explained by the fact that the polyaldehyde begins to undergo partial destruction in the alkaline medium in which the synthesis occurred (pH 8.0-8.2).

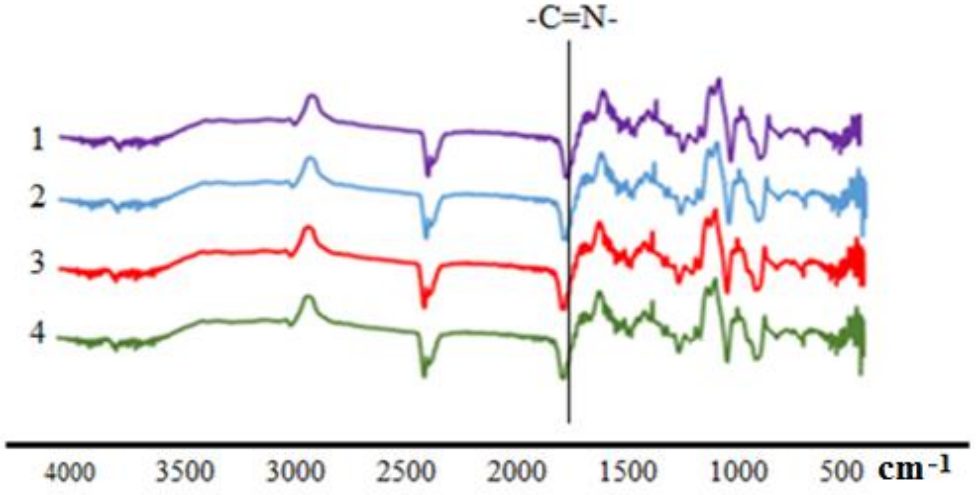


Fig.1. IR-spectra of inulin-adriamycin with a quantitative content of 5.8% (1), 7.0% (2), 9.2% (3) and 11.5% (4).

When studying the synthesized samples by IR-spectroscopy, an absorption band in the region of 1645-1658 cm^{-1} was detected. These data prove that the chemical addition of adriamycin to the macromolecules of polyaldehydinulin occurs through covalent -C=N- bonds. Since azomethine bonds can undergo hydrolysis in acidic or alkaline environments, we studied the release rate of adriamycin.

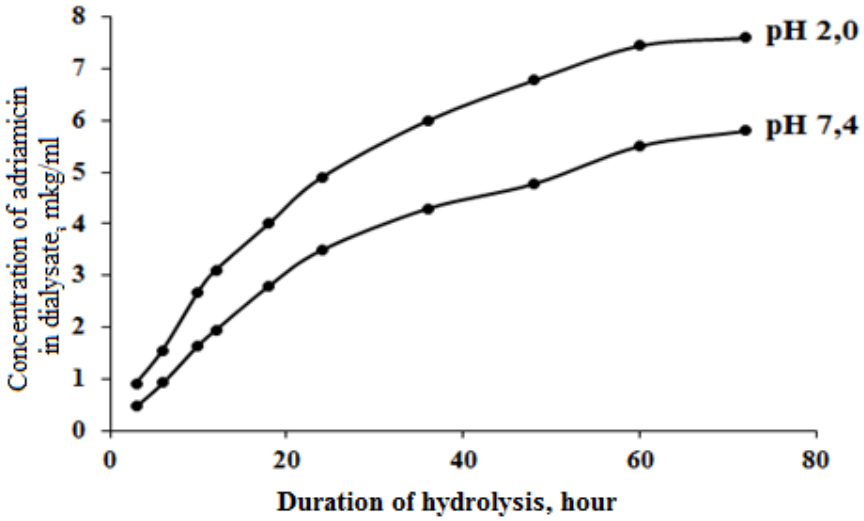


Fig.2. The release rate of the drug from inulin-adriamycin at different pH values of the medium (the initial content of adriamycin in inulin is 11.5%).

The research results showed that the azomethine bond formed between adriamycin and polydehydinulin in the polymer conjugate exhibits varying stability in the model medium of gastric juice (pH 2.0) and bloodstream (pH 7.4). At the same time, the increase in the concentration of adriamycin in the buffer solution occurs gradually, which proves the presence of a prolonged effect and controlled release of the cytotoxic agent.

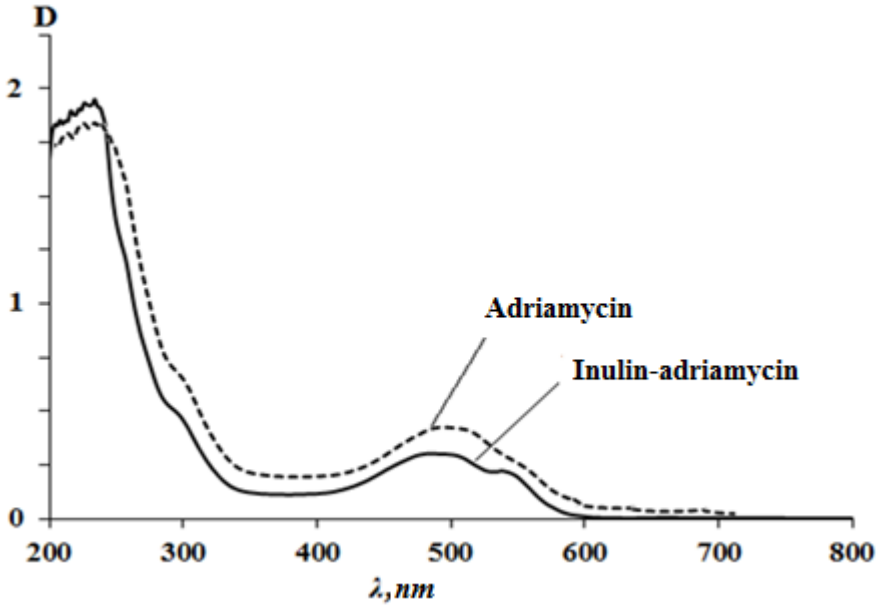


Fig.3. UV-spectra of adriamycin (c=1.5 mg/ml) and inulin-adriamycin (c=5 mg/ml).

UV spectroscopy was used to substantiate the composition of the reaction products. It was established that the initial adriamycin at a concentration of 1.5 mg/ml has intensive absorption in the region of 490 nm. The synthesized inulin-adriamycin also exhibited absorption in the region of 490 nm at a concentration of s=5 mg/ml. This indicates the presence of low-molecular-weight adriamycin in inulin.

Conclusion. Thus, for the first time, inulin derivatives containing aldehyde groups were used for the chemical modification of the low molecular weight drug adriamicin. It was established that the quantitative composition of adryamycin depends on the degree of oxidation of polyaldehydinulin. The structure of the obtained inulin-adriamycin samples was proven by elemental analysis, IR- and UV-spectroscopy. After the chemical binding of adryamycin with polyaldehydinulin, a slow release of adryamycin was detected at pH values of 2.0 and 7.4. This indicates that inulin-adriamycin has a prolonged effect.

References

1. Rakhmonberdiev G., Ibragimova K., Tilakov J., Khusenov A. Isolation and comparative study of various polymorphic forms of inulin. E3S Web of Conferences. 434. 02025. (2023).
2. Asere T.G.,Mincke S., Folens K. Dialdehyde carboxymethyl cellulose cross-linked chitosan for the recovery of palladium and platinum from aqueous solution. Reactive and Functional Polymers. 141. 145-154. (2019).

3. Rakhmonberdiev G.R., Sidikov A.S., Yusupov R.D., Zainutdinov U. N., Kazantseva D.S. Pemostatic materials based on acetylcellulose and Lagoden. Chemistry of Natural Compounds. 33(3). 347-349. (1997).
4. Luo H., Lan H., Cha R., Yu X., Gao P., Zhang P., Jiang X. Dialdehyde Nanocrystalline Cellulose as Antibiotic Substitutes against Multidrug-Resistant Bacteria. ACS Applied Materials & Interfaces. 13(29). 33802-33811. (2021).
5. Rakhmonberdiev G.R., Sidikov A.S., Yusupov R.D., Zainutdinov U.N., Kazantseva D.S. Synthesis of a hemostatic drug from cellulose acetate. Chemistry of Natural Compounds. 34 (2). 192-194. (1998).
6. Akhmedov O.R., Shomurotov Sh.A., Turaev A.S., Sidarenka A.V. Dependence of Antimicrobial Effects of Guanidine-containing Pectin Derivatives from Some Structural Characteristics. Drug Development and Registration. 11(2). 38-45. (2022).
7. Tang L., Lin F., Li T., Cai Z., Hong B., Huang, B. Design and synthesis of functionalized cellulose nanocrystals-based drug conjugates for colon-targeted drug delivery. Cellulose. 25(8). 4525-4536. (2018).
8. Liu K., Xu Y., Lin X., Chen L., Huang L., Cao S., Li J. Synergistic effects of guanidine-grafted CMC on enhancing antimicrobial activity and dry strength of paper. Carbohydrate Polymers. 110. 382-387. (2014).
9. Muchova M., Munster L., Capakova Z., Mikulcova V., Kuritka I., Vicha J. Design of dialdehyde cellulose crosslinked poly (vinyl alcohol) hydrogels for transdermal drug delivery and wound dressings. Materials Science and Engineering: C. 111242. (2020).
10. Akhmedov O.R. Shomurotov Sh.A., Rakhmanova G.G., Turaev A.S. Synthesis and Study of Biological Activity of Sulfamic Polysaccharide Derivatives. Russian Journal of Bioorganic Chemistry. 43. 716-721. (2017).
11. Dalei G., Das S., Pradhan M. Dialdehyde cellulose as a niche material for versatile applications: an overview. Cellulose. 29. 5429-5461. (2022).
12. Isupova Z.Y., Khashirova S.Y., Zhanistov A.A., Kvashin V.A., Khakyasheva E.V., Musaev Y.I., Malkanduev Y.A. New metal complexes derived from guanidine-containing dialdehyde cellulose. Fibre Chem. 49. 437-441. (2018).
13. Koshani R., Tavakolian M., van de Van TGM Natural emulgel from dialdehyde cellulose for lipophilic drug delivery. ACS Sustain Chem Eng. 9. 4487-4497. (2021).
14. Kang X., Deng L., Yi L., Ruan C-Q., Zeng K. A facile method for preparation of green and antibacterial hydrogel based on chitosan and water-soluble 2,3- dialdehyde cellulose. Cellulose. 28. 6403-6416. (2021).
15. Akhmedov O.R., Shomurotov S.A., Turaev A.S. Comparative Studies of the Chemical Interaction of Guanidine with Dialdehyde Cellu-Lose And Pectin. Russian Journal of Bioorganic Chemistry. 49(7). 1587-1595. (2023).