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Antibacterial Activity of Green Synthesised Silver Nanoparticles on *Saccharomyces cerevisiae*

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Abstract: Green synthesis of nanoparticles is a widely researched and popular direction in the development of nanotechnology. It is a simple, cheap and effective method for obtaining nanoparticles with interesting biological properties. In light of the development of antibiotic resistance to important clinical strains of bacteria, this method was used in the present study to obtain silver nanoparticles with antibacterial activity. The aim of this study was to synthesise silver nanoparticles with antibacterial action by yeast in a process known as "green synthesis". We are also considering the prospect of using silver nanoparticles as an antibacterial substance for drug development. The production of nanoparticles was confirmed by UV spectroscopy. *Staphylococcus aureus* ATCC 25923 and *Escherichia coli* ATCC 25922 test strains and *Staphylococcus aureus* 1536 and *Klebsiella pneumoniae* 520 clinical isolates were used to study the antibacterial effect. The effect of synthesised nanoparticles on the metabolic activity of bacterial cells and their ability to adhere, as well as the minimum inhibitory concentrations (MICs) of synthesised nanoparticles for each of the strains, were determined. Following UV spectroscopy, the nanoparticles obtained were found to have a pronounced peak in optical absorption at 400 nm, corresponding to the plasmon resonance of silver nanoparticles, and demonstrated a high antibacterial effect against all the strains studied.

Keywords: silver nanoparticles; *Saccharomyces cerevisiae*; antibacterial activity; clinical isolates; *Staphylococcus aureus*; *Klebsiella pneumoniae*

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1. Introduction

Green biosynthesis is a modern and effective method for obtaining nanoparticles. Numerous techniques based on yeast green synthesis have been described in studies. For example, silver nanoparticles 5–30 nm in diameter with antibacterial activity against gram-negative and gram-positive bacteria were synthesised using the exudate of the soil fungus *Macrophomina phaseolina* [1]. In another study, *Penicillium italicum* was used to obtain spherical nanoparticles with a diameter of 32–100 nm that have a pronounced antioxidant, antibacterial, and antitumour effect [2]. Nanoparticles around 16 nm in size, which showed antibacterial activity against *Staphylococcus aureus* and *Pseudomonas aeruginosa*, were synthesised with baking yeast *Saccharomyces cerevisiae* [3]. All these studies point to the prospect of the development of cheap drugs against bacterial infections, which is extremely relevant today. The resistance of bacteria to antibiotics is a huge problem. For example, *Klebsiella pneumoniae* has high resistance to β-lactams caused by carbapenemase, leading to its presence in clinical settings [4]. In addition, *K. pneumoniae* has been shown to have hypervirulent strains that cause complex clinical infections inside and outside healthcare

facilities. Such strains cause the development of liver abscesses that can metastasise to distant areas, most often the eyes, lungs and central nervous system. Hypervirulent strains of *K. pneumoniae* are the cause of increased mortality due to clinical infections in hospitals [5,6]. Another example of a dangerous antibiotic-resistant strain is methicillin-resistant *Staphylococcus aureus*, which can spread in medical institutions and public places and cause bacteraemia, endocarditis, skin and soft tissue infections, bone and joint infections, and lethal pneumonia [7,8]. These strains demonstrate the importance of finding effective alternatives to antibiotics to limit the development of antibiotic resistance, especially in clinical and highly virulent strains. Simple methods of nanoparticle synthesis could be a good source for identifying effective antibacterial agents of this kind. The relevance of this study is that simple and effective manipulations could provide a drug with a potentially high antibacterial effect against clinical strains of *Staphylococcus aureus* and *Klebsiella pneumoniae*. The goal of the study was to obtain an effective prototype of a drug with high antibacterial activity against clinical strains.

2. Materials and Methods

2.1. Green Synthesis of Silver Nanoparticles

Subculturing with silver nitrate using a lyophilised culture of *Saccharomyces cerevisiae* 71B—a culture of brewer's yeast—was performed. *S. cerevisiae* 71B for biogenic synthesis was cultivated on 20% glucose with the addition of silver nitrate for 120 h at 28 °C and rotation at 130 rpm. Four different concentrations of silver nitrate solution were used to provide a subculture. The final concentrations of silver nitrate in the nutrient medium were 0.5 mM, 1.0 mM, 1.5 mM and 2.0 mM. As a control, samples were used with sterile deionised water instead of a silver nitrate solution. The volume of all the samples was 5 mL to ensure similar culture conditions. Yeast cells from the supernatant were separated by centrifugation (15 min, 3000 rpm) after 120 h before. Next, the supernatant was sterilised by serial filtration through 0.8 µm and 0.22 µm filters, and the sterile supernatant was used for further research. Finally, lysis of the yeast cell pellet was performed in sterile deionised water at 4 °C for four days. The lysate was then separated from the cell debris by centrifugation and also sterilised through 0.8 µm and 0.22 µm filters and used for further research.

2.2. UV-Spectrophotometry

To understand the kind of silver in the supernatant and yeast lysate, the samples were examined using a spectrophotometric method. This study used the DS-11 FX + spectrophotometer to measure the absorption spectra. The obtained spectra were analysed with the results of studies from the scientific literature. The results of UV spectroscopy confirmed that the obtained samples contained silver nanoparticles matching the values of the plasmon resonance of silver nanoparticles in the range of 400–430 nm.

2.3. Determination of the Concentration of Silver Ions

To establish the correct concentrations of colloidal silver, a quantitative method was applied for the determination of silver ions in solution using a qualitative reaction with potassium iodide. The essence of the reaction is the formation of a yellow precipitate formed by the interaction of iodine with silver ions. The test was performed on a 96-well plate. A solution of silver nitrate of a known concentration was used to construct the calibration curve. Determination of colloidal silver concentrations in the yeast extract and supernatant allowed the determination of the minimal inhibitory concentration.

2.4. Bacterial Strains

Reference strains of microorganisms were used from the collection of typical cultures of *Staphylococcus aureus* ATCC 25923 and *Escherichia coli* ATCC 25922 from the state institution "L. V. Gromashevsky Institute of Epidemiology and Infectious Diseases" of the National Academy of Medical Sciences of Ukraine to determine antibacterial activity. A

clinical isolate of *Staphylococcus aureus* 1536 and a clinical isolate of *Klebsiella pneumoniae* 520 were used as test cultures. These cultures were obtained from the Kyiv Regional Clinical Hospital. Strains were isolated from the wound surfaces of hospital patients. The contents of the wounds were collected with a syringe or swab before antimicrobial therapy. Subsequently, the sensitivity of the microorganisms isolated from the material to antibiotics was determined using a number of nutrient media: MPA (Biolife), Mueller-Hinton (HiMedia), Endo, Saburo agar, blood agar, and elective salt agar (Biolife). The microorganisms were identified using a VITEK 2 compact 15 microbiological analyser (France).

2.5. Bactericidal Activity

The cytotoxicity of samples to bacterial cells was determined using the MTT assay (3-[4,5-Dimethylthiazole-2-yl]-2,5-diphenyltetrazolium bromide; Thiazolyl blue, "Sigma-Aldrich", St. Louis, MO, USA), which is based on the ability of dehydrogenases of living cells to reduce unstained forms of MTT to blue crystalline formazan soluble in DMSO (dimethyl sulfoxide). The assay was performed on a 96-well plate. A (Sarstedt, Nümbrecht, Germany): each sample was added in triplicate, then a test or reference bacterial culture was added and incubated for 18 h. The solution of MTT at a concentration of 0.1 mg/mL was added to the cells and incubated at a temperature of 37 °C for 1.5 h. After incubation, the unreacted reagent was removed and DMSO was added to the cells, before measuring the optical density of the samples on a plate-spectrophotometer with a vertical ray (Thermo Labsystems, Vantaa, Finland) at a wavelength of 490 nm [9].

The bactericidal activity of the samples was evaluated in relation to the index of cell survival. Furthermore, the cells grown in the M9 medium were taken as 100% cell survival in the control sample. Cell survival in the samples was calculated relative to the control.

2.6. The Number of Adhered Cells

The value of adhered cells was measured by fixing cells in plates with crystal violet dye. The test was performed in a similar way to the MTT test. After 18 h of incubation at a temperature of 37 °C, the cells on the plates were fixed and stained with an alcoholic solution of crystal violet. The excess dye was then removed and the plates were washed with deionised sterile water and dried. The cell-adsorbed dye was dissolved in a 70% solution of ethyl and then 50 μL of crystal violet ethyl solution was added to each well of the plate. The optical density of the stained cells was measured on a Multiskan Ascent vertical spectrophotometer (Thermo Labsystems, Vantaa, Finland) at a wavelength of 540 nm. The bactericidal activity of the samples was evaluated in terms of cell survival in comparison with the control cells grown in M9 medium [10,11].

2.7. Statistical Analysis

All the results are presented as the median of the values with an interquartile range: Me [LQ-UQ], where Me = median (50% percentile), LQ = 25% percentile and UQ = 75% percentile. The null hypothesis was tested using the nonparametric Mann-Whitney test and the Wilcoxon matched-pairs test (WMP test). The difference between the compared groups was considered statistically significant at a value of $p < 0.05$. Calculations of median values with an interquartile range were provided using Microsoft Office Excel (2019), and all statistical calculations were performed using STATISTICA version 8.0 (Dell, StatSoft, Inc. 1984–2007, TIBCO, Palo Alto, CA, USA).

3. Results and Discussion

The absorption spectra of the samples obtained from the aqueous yeast extract were analysed (Figure 1). The sample marked as control was a 20% glucose solution. All spectra had an absorption peak of approximately 400 nm. However, the highest peaks were from samples to which silver nitrate had been added at concentrations of 0.5 mM and 1.0 mM. The values of optical density in these peaks were 1.17 and 1.34 respectively, which was 1.8 and 2.2 times higher than the control sample.

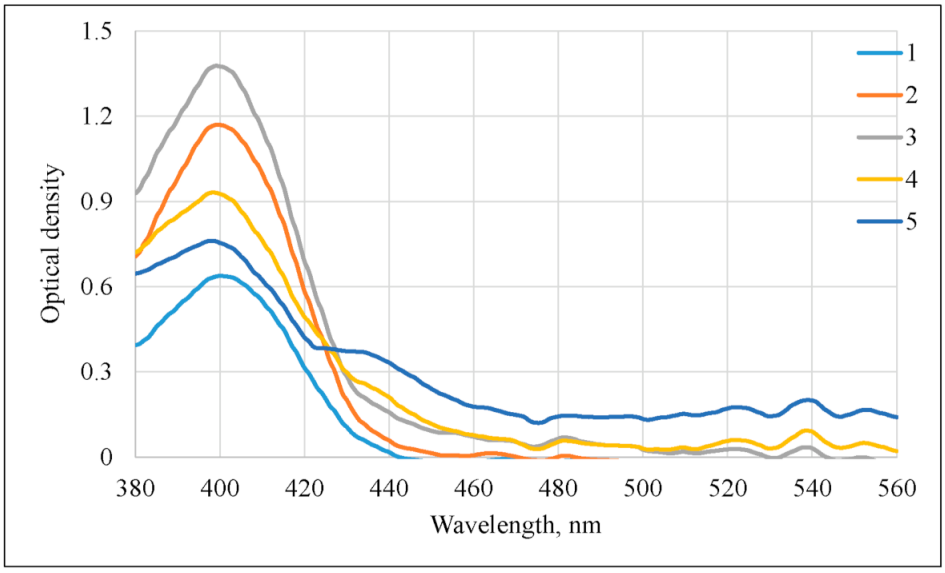


Figure 1. The absorption spectrum of samples obtained from yeast extract. The yeast extracts were obtained from samples of yeast *S. cerevisiae* 71B cultured in 20% glucose solution with the addition of: (1) sterile dH_2O, (2) 0.5 mM $AgNO_3$, (3) 1.0 mM $AgNO_3$, (4) 1.5 mM $AgNO_3$ and (5) 2.0 mM $AgNO_3$.

The next step was to analyse the absorption spectra of the samples obtained from the supernatant. An interesting fact was that the levels of optical absorption of the samples in this study were much higher than in the study of samples of yeast lysate (Figure 2). Again, the highest peaks were shown in samples where silver nitrate concentrations of 0.5 mM and 1.0 mM were used. In these samples, the values of optical density were 9.88 and 8.52 respectively, which were 1.8 and 1.7 higher than the values in the control sample. Furthermore, it should be noted that the values of the optical density of the samples to which silver nitrate had been added at concentrations of 1.5 mM and 2.0 mM were below that of the control sample.

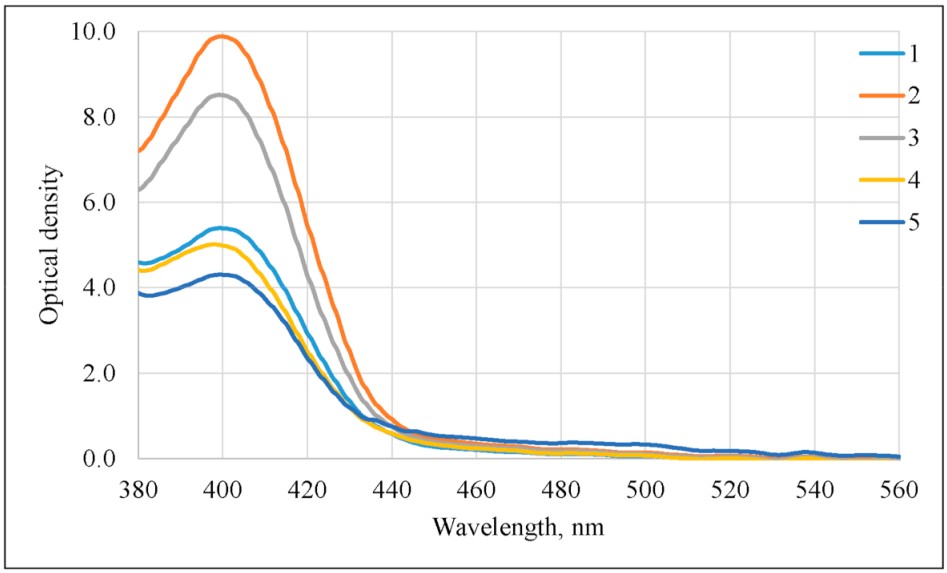


Figure 2. The absorption spectrum of samples obtained from the supernatant. The supernatants were obtained from samples of yeast *S. cerevisiae* 71B and cultured in 20% glucose solution with the addition of: (1) sterile dH_2O, (2) 0.5 mM $AgNO_3$, (3) 1.0 mM $AgNO_3$, (4) 1.5 mM $AgNO_3$ and (5) 2.0 mM $AgNO_3$.

The optical density values in the peaks were compared in samples to which silver nitrate was added at concentrations of 0.5 mM and 1.0 mM to the yeast lysate and supernatant. The optical density of the supernatant was 8.5 times higher for a concentration of 0.5 mM and 6.2 times higher for a concentration of 1.0 mM. The data obtained indicated that the supernatant contained more silver nanoparticles than the yeast lysate. Furthermore, the most effective concentrations were found to be 0.5 mM and 1.0 mM.

The results of studies of the spectra of samples correlated with numerous studies on the biosynthesis of silver nanoparticles. For example, silver nanoparticles obtained by biosynthesis using yeast extract as a reducing and capping agent had an absorption peak of 400 nm [12]. In another study, nanoparticles were obtained from *Rumex hymenosepalus* extract, a plant widespread in large areas of North America. The absorption peak of these nanoparticles was 425 nm, which corresponded to the absorption through surface plasmon in silver nanoparticles [13]. Another work described the synthesis of silver nanoparticles by the yeast strain *Saccharomyces* Sp. BDU-XR1, which was isolated from spontaneous yogurt used in Azerbaijan. The peak of the absorption spectrum of nanoparticles was found in the range of 410–420 nm in a UV spectrophotometer [14]. Thus, compared with the results obtained here, it can be concluded that the supernatants and yeast lysates obtained contained silver nanoparticles. Of course, additional research would be needed to confirm this, but this study confirmed that the supernatant probably contained more nanoparticles of silver than the yeast lysate.

Using a qualitative reaction, the approximate concentration of silver ions in each of the samples was determined. The summary results are presented in Table 1.

Table 1. Final concentration of silver ions in the sample solution.

	Concentration of Silver Ions, mM				
$AgNO_3$, mM **	**Sterile dH_2O**	**0.5**	**1.0**	**1.5**	**2.0**
Supernatant	−0.01 [−0.01; 0.00]	0.03 [0.01; 0.03]	0.05 [0.03; 0.06]	0.04 [0.03; 0.08] *	0.11 [0.11; 0.14] *
Lysate	0.01 [0.01; 0.01]	0.02 [0.02;0.03]	0.04 [0.04; 0.04]	0.07 [0.06; 0.10] *	0.16 [0.15; 0.17] *

* $p < 0.05$. ** The concentration of $ArNO_3$ added to the *S. cerevisiae* 71B culture medium.

In addition, the probability of the results was checked using the Wilcoxon test, which produced interesting results. The concentration of silver ions in the samples of yeast lysate and supernatant with 0.5 mm $AgNO_3$ was found not to be significantly different ($p = 0.77$), i.e., both the yeast extract and the supernatant contained the same amount of silver ions. The same could be said of the samples where the 1.0 mM concentration of $AgNO_3$ was introduced. However, in this case, there was no significant difference between the concentration of silver ions in the supernatant and the yeast lysate since $p = 0.07$. In samples where $AgNO_3$ concentrations of 1.5 mM and 2.0 mM were applied, there were higher concentrations of silver ions in the yeast lysate than in the supernatant ($p = 0.01$ and $p = 0.03$ respectively): 1.75 [1.33; 3.33] and 1.45 [1.07; 1.55] times higher respectively.

The results obtained indicated that at concentrations of 0.5 mM and 1.0 mM, there was no difference in the accumulation of silver ions in different types of samples of yeast lysate and supernatant. Only at high concentrations (1.5 mM and 2.0 mM) could a significant difference be observed.

The last stage of the study was to establish the antibacterial properties of the samples. After 24 h of incubation of test bacterial cultures with yeast lysate samples, there was a significant decrease in the metabolic activity of cells of strains of *S. aureus* ATCC 25923, *S. aureus* 1536 and *K. pneumoniae* 520 for samples with concentrations of 1.0 mM, 1.5 mM and 2.0 mM. Decreased metabolic activity of *E. coli* ATCC 25922 cells was observed in only two concentrations: 1.5 mM and 2.0 mM (Figure 3).

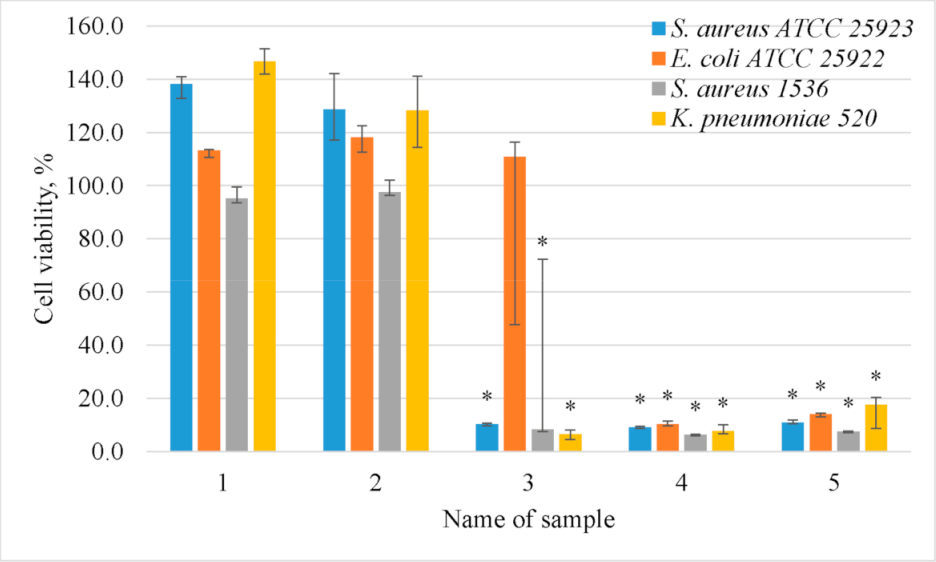


Figure 3. Bacterial cell survival after subculturing with yeast extract by MTT test. The yeast extracts were obtained from samples of yeast *S. cerevisiae* 71B, cultured in 20% glucose solution with the addition of: (1) sterile dH_2O, (2) 0.5 mM $AgNO_3$, (3) 1.0 mM ANO_3, (4) 1.5 mM $AgNO_3$ and (5) 2.0 mM $AgNO_3$. * $p < 0.05$.

The average cell survival in toxic samples of yeast lysate was about 10%. An interesting fact is that there was a sharp decrease in the metabolic activity of cells without a smooth transition. Furthermore, it should be noted that the antibacterial effect of yeast lysates with silver ions was generally higher for clinical isolates, which is a positive result.

When studying the antibacterial action of the supernatant samples, an interesting fact was established. Samples to which 0.5 mM $AgNO_3$ was added showed a significant increase in metabolic activity after 24 h of incubation (Figure 4). Such results were obtained on cultures of *E. coli* ATCC 25922 and *S. aureus* 1536. At the same time, for all studied bacterial cultures, an antibacterial effect of supernatant samples to which silver nitrate was added at concentrations of 1.0 mM, 1.5 mM and 2.0 mM (Figure 4) was shown.

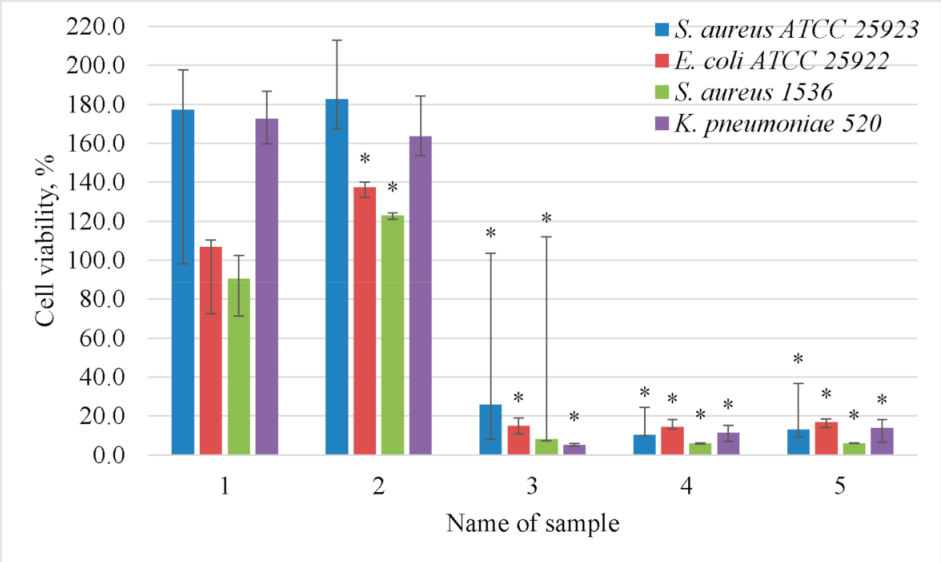


Figure 4. Bacterial cell survival after subculturing with supernatant by MTT test. The yeast extracts were obtained from samples of yeast *S. cerevisiae* 71B, cultured in 20% glucose solution with the addition of: (1) sterile dH_2O, (2) 0.5 mM $AgNO_3$, (3) 1.0 mM $AgNO_3$, (4) 1.5 mM $AgNO_3$ and (5) 2.0 mM $AgNO_3$. * $p < 0.05$.

Quite different results were obtained by studying the number of adhered cells. Analysing the results obtained by subculturing samples of yeast extract with bacterial strains, the cells of the clinical strain *K. pneumoniae* 520 remained adhered at the level of the control cells (Figure 5). A slight decrease in the number of adhered cells compared with the control was observed in the sample with 0.5 mM $AgNO_3$, but this value was still within 97%. This means that the obtained samples of colloidal solutions of silver could reduce the metabolic activity of *K. pneumoniae* 520, but the percentage of attached cells remained high. In this case, the use of such a colloidal solution could not be said to be effective against strain *K. pneumoniae* 520. Samples of yeast extract to which $AgNO_3$ was added at a concentration of 0.5 mM could increase the adhesion of *S. aureus* ATCC 25923 cells, but at higher concentrations, cell adhesion almost did not take place. This correlated with previous results, thus the samples with concentrations of 1.0 mM, 1.5 mM, and 2.0 mM $AgNO_3$ demonstrated effective action against *S. aureus* ATCC 25923 (Figure 5).

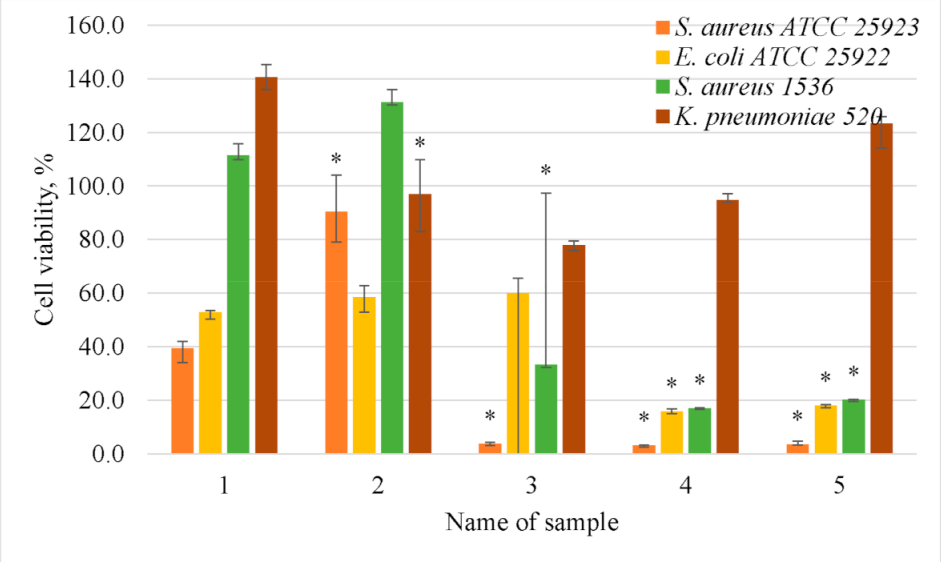


Figure 5. Value of adhered cells after subculturing with yeast extract (crystal violet). The yeast extracts were obtained from samples of yeast *S. cerevisiae* 71B, cultured in 20% glucose solution with the addition of: (1) sterile dH_2O, (2) 0.5 mM $AgNO_3$, (3) 1.0 mM $AgNO_3$, (4) 1.5 mM $AgNO_3$ and (5) 2.0 mM $AgNO_3$. * $p < 0.05$.

Cells of *E. coli* strain ATCC 25922 lost their adhesiveness when using yeast extracts with the addition of $AgNO_3$ at concentrations of 1.5 mM and 2.0 mM. Using the same samples in the study of metabolic activity, these cells also had low metabolic activity. The most effective use of silver-containing yeast extract was against the adhesion of *S. aureus* 1536 cells. The effective concentrations were 1.0 mM, 1.5 mM and 2.0 mM, which fully corresponded with the results obtained in the study of metabolic activity.

The best results were obtained when studying the effect on the adhesion of bacterial strains using samples of the supernatant. The culture of *K. pneumoniae* 520 significantly lost adhesion in all studied samples. Compared with the results of metabolic activity, the most effective samples were those with concentrations of 1.0 mM, 1.5 mM and 2.0 mM $AgNO_3$ (Figure 6). These samples effectively reduced the adhesion of cultures of *S. aureus* 1536 and *S. aureus* ATCC 25923, which correlated with the results obtained in the MTT test.

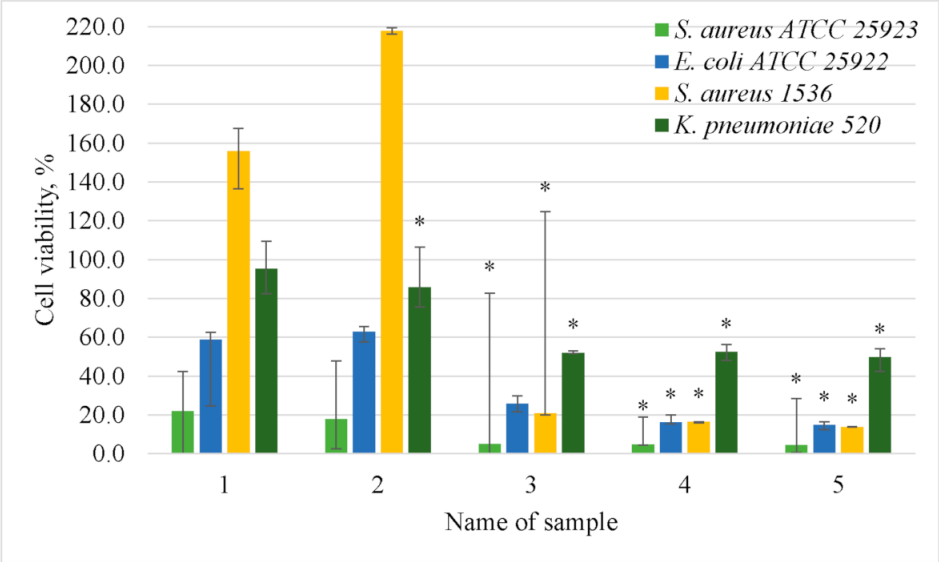


Figure 6. Value of adhered cells after subculturing with supernatant (crystal violet). The yeast extracts were obtained from samples of yeast *S. cerevisiae* 71B, cultured in 20% glucose solution with the addition of: (1) sterile dH_2O, (2) 0.5 mM $AgNO_3$, (3) 1.0 mM $AgNO_3$, (4) 1.5 mM $AgNO_3$ and (5) 2.0 mM $AgNO_3$. * $p < 0.05$.

The culture of *E. coli* ATCC 25922 lost the ability to adhere only when using samples with the addition of 1.5 mM and 2.0 mM $AgNO_3$, while the decrease in metabolic activity was detected in the sample using 1.0 mM $AgNO_3$ (Figure 6).

Biogenic synthesis of nanoparticles is carried out on a range of objects. However, the range of antibacterial activity was quite similar for all nanoparticles obtained by green synthesis. For example, nanoparticles synthesised from *Pimpinella anisum* seed extract had antimicrobial activity against *Staphylococcus pyogenes*, *Acinetobacter baumannii*, *Klebsiella pneumoniae*, *Salmonella typhi* and *Pseudomonas aeruginosa* [15]. Another study described the biogenic synthesis of AgNP using a commercial extract of green tea (*Camellia sinensis*). The synthesised nanoparticles had antibacterial activity against *Staphylococcus aureus*, *P. aeruginosa*, *K. pneumoniae*, *Escherichia coli* and *Salmonella enterica* [16].

An attempt to use pomegranate peel (*Punica granatum*) as a model for the synthesis of silver nanoparticles has also been described, with the synthesised nanoparticles showing high antimicrobial activity on *E. coli*, *P. aeruginosa*, *Proteus vulgaris*, *S. aureus*, *Staphylococcus epidermidis* and *K. pneumonia* [17]. Nanoparticles synthesised on *Pichia kudriavzevii* HA-NY2 and *Saccharomyces uvarum* HA-NY3 showed significant inhibitory activity against *Bacillus subtilis*, *S. aureus*, *Pseudomonas aeruginosa* and *Candida tropicalis* [18]. Therefore, the results of the present study show antibacterial activity correlated with those described in other studies. In addition, this study has expanded information on the antibacterial action of nanoparticles in the yeast synthesis model.

To establish the MICs, summary data on antibacterial activity were used, and the final concentrations of silver nanoparticles in the samples were determined by the qualitative-quantitative reaction. Thus, the MIC was determined based on the results of the MTT test. Summary results are presented in Table 2.

Table 2. Minimum inhibitory concentration (MIC) of samples by MTT test.

Reference Strains		Clinical Isolates	
S. aureus ATCC 25923	*E. coli* ATCC 25922	*S. aureus* 1536	*K. pneumoniae* 520
MIC of yeast extract samples, mM			
0.02	0.04	0.02	0.02
MIC of supernatant samples, mM			
0.03	>0.02	>0.02	0.03

It was established that the lowest concentration of silver ions was sufficient for the manifestation of effective antibacterial action, despite the fact that a significant difference has been found between the samples in previous experiments. This indicates that there may be some effect of the conditions of the experiment, namely the concentration of a solution of silver nitrate added at the beginning of the experiment. It should be noted that against clinical strains of *S. aureus* 1536 and *K. pneumoniae* 520, silver ions had antibacterial activity in lower concentrations than against test cultures of *S. aureus* ATCC 25923 and *E. coli* ATCC 25922.

Moreover, the MIC was established based on the results of the study of the effect on the adhesion property of bacterial cells. Summary results are presented in Table 3.

Table 3. Minimum inhibitory concentration (MIC) of samples by crystal violet test.

Reference Strains		Clinical Isolates	
S. aureus ATCC 25923	*E. coli* ATCC 25922	*S. aureus* 1536	*K. pneumoniae* 520
MIC of yeast extract samples, mM			
0.04	0.07	0.04	—
MIC of supernatant samples, mM			
0.05	0.04	0.04	0.03

Supernatant samples performed better because MICs were lower than in the yeast extract samples. Moreover, this coincides with the results of determining the MIC on the MTT test. Comparing the results obtained from two studies of antibacterial activity of the samples, the concentrations effective against *S. aureus* ATCC 25923, *E. coli* ATCC 25922, *S. aureus* 1536 and *K. pneumoniae* 520 were 0.04 mM contained in the supernatant.

In the study of the antibacterial action of the nanoparticles obtained, the synthesised nanoparticles based on yeast extract were found to have less antibacterial activity compared with the use of the supernatant. This can be explained by the fact that the composition of the yeast extract and the supernatant is different, which may affect the stabilisation of the nanoparticles. Moreover, according to the literature, depending on which resource is used for the synthesis of silver nanoparticles, the type of antibacterial action—bacteriostatic or bactericidal [19]—is determined. This directly depends on the type of plugging and stabilising substances in the biological object used. Many variants of silver nanoparticle biosynthesis are described—algae or plants or their extracts, heterotrophic eukaryotic cell lines and numerous prokaryotes. The shape, degree of dispersion of the obtained colloids, and biological properties and their manifestation can vary from one green approach to another [20,21].

While the biological substances used for the synthesis of nanomaterials consist of similar or identical active ingredients, very often the effect of the obtained nanoparticles, especially on living cells, can vary significantly [22]. Depending on the cultivation conditions, pH value, the composition of the medium and temperature, when using the yeast *Saccharomyces cerevisiae*, stabilising agents can include ethanol and phenols, carboxylic acids and aromatic amines. Since the nanoparticles described showed antibacterial activity against *Staphylococcus aureus*, it could be assumed that in the present study these

agents played a role in particle stabilisation [3]. This may also explain the difference in the antibacterial action of nanoparticles derived from yeast extract and supernatant.

4. Conclusions

The aim of this study was to demonstrate the antibacterial activity of nanoparticles. Determination or confirmation of the physicochemical properties of silver nanoparticles and supernatant in this context was not an object for study. For this reason, to confirm the content of nanoparticles, we limited ourselves to the simplest method—spectroscopy. In this study, yeast extract and supernatant were used to obtain silver nanoparticles. Of all the concentrations added for the biosynthesis of nanoparticles, the best results were produced by concentrations of 0.5 mM and 1.0 mM and confirmed using the spectrophotometric method. Furthermore, this study showed that absorption peaks at 400 nm corresponded to the absorption spectrum of silver nanoparticles. Supernatant-synthesised nanoparticles have higher antibacterial activity than nanoparticles synthesised using yeast lysate. Silver nanoparticles obtained by green synthesis could be used as drugs to treat bacterial infections caused by dangerous hospital strains. It is important to note that nanoparticles do not have an advantage but are an alternative to antibiotics. The problem lies in the resistance of bacteria to antibiotics, which means that other sources of drugs with antibacterial action must be sought.

The next stage of the research will be to study the possibility of using silver nanoparticles as a drug with the determination of cytotoxicity and genotoxicity.

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