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Silica Nanoparticles Biosynthesis from *Saccharomyces* sp. with antimicrobial activity

Doaa Abdelhady Ahmed Osman [1], Mervat G. Hassan[1], Ahmed A. Hamed[2], M O.Abdel-Monem[1] and Mahmoud S.Shahin[3]

[1]Microbiology Dept., Faculty of Science, Benha University, Benha, Egypt.
[2]Microbial Chemistry Dept., National Research Centre, El-Buhouth Street, Dokki, Cairo, Egypt.
[3]Main laboratories for Egyptian Army
E-mail: mervat.hassan@fsc.bu.edu.eg

Abstract

The present study focuses on the isolation of *Saccharomyces* spp. from bakery yeast samples and their potential for biosynthesizing silica nanoparticles (SiNPs) with antibacterial properties. Yeast samples were collected from four different bakeries in Benha to ensure strain diversity, and multiple isolates were successfully obtained. Screening for silica nanoparticle biosynthesis revealed significant variations among the isolates, with DO1S4 and DO4S1 exhibiting the highest biosynthesis potential (+++), indicating strong enzymatic activity and effective interaction with silica precursors. Moderate biosynthesis (++) was observed in isolates DO1S1 and DO2S3, while several isolates showed weak or no biosynthesis activity. The antibacterial activity of SiNPs synthesized from the highly active strain DO1S4 was evaluated against *Escherichia coli* and *Staphylococcus aureus*. The biosynthesized SiNPs demonstrated significant antibacterial effects, with inhibition rates of 77.025% against *E. coli* and 52.02% against *S. aureus*. However, their efficacy was lower than ciprofloxacin (5 µg/mL), which exhibited inhibition rates of 99.05% and 98.25%, respectively. The enhanced effect against *E. coli* compared to *S. aureus* is likely due to differences in bacterial cell wall structures, affecting nanoparticle penetration and antimicrobial efficiency. The antibacterial activity of the biosynthesized SiNPs is attributed to mechanisms such as reactive oxygen species (ROS) generation, membrane disruption, and interference with bacterial cellular functions. These findings highlight the potential of *Saccharomyces* sp. as a biogenic source for silica nanoparticle synthesis and their application in antimicrobial treatments. Further optimization of biosynthesis conditions, exploration of molecular mechanisms, and evaluation of biocompatibility are necessary for potential clinical and industrial applications. The study underscores the significance of microbial-derived nanomaterials in developing alternative antimicrobial agents, particularly in the context of growing antibiotic resistance.

Key Words: Silica Nanoparticles; *Saccharomyces* sp. And antimicrobial activity

Introduction

Silica nanoparticles (SiNPs) consisting of silica (SiO_2) have been of great interest in recent years due to their promising applications in sensing, imaging, drug delivery, catalysis, and other biomedical applications. SiNPs are rigid, hollow spheres which in general, have a diameter ranging from 5 to 100 nm and possesses a highly porous structure. The inner porosity allows for the encapsulation of various molecules of interest [1] [2]. The SiNPs surface can be easily functionalized with various biomolecules or chemicals thereby providing a platform to detect target analytes or react with other compounds. Growth of silica shell on luminescence nanocrystals has been well established and silica shell has been employed on various luminescence nanoparticles to prolong or maintain their free luminescence intensity. All these unique properties of silica shell nanoparticles (SiSNs) have resulted in the widespread use of SiSNs in developing sensors for gases, metal ions, biological molecules, drugs etc. SiNPs have silica (SiO2) as a primary constituent and they exhibit outstanding biocompatibility, simplicity in preparation and ease of curtailing pore size, particle size and morphology. Owing to these characteristics, SiNPs have been extensively explored for targeted drug delivery, bio-imaging, bio-sensing, anti-cancer studies, diagnostics, tumor cell tracking etc [3] [4].[5]. Nanotechnology is an emerging field with the potential to revolutionize many sectors in terms of technology, research and application. Nanoparticles (NPs) are materials ranging from 1 to 100 nm in size. Potential and wide applications of NPs have enhanced research and development in the field of nanotechnology. In the past two decades, silica nanoparticles (SiNPs) have garnered much attention due to their diverse applications. SiNPs being one of the earliest nanoparticles explored and researched, have witnessed no recession in

interest. SiNPs have gained a widespread attention owing to their extensive applications in drug delivery,

biomedical imaging, anticancer studies, biosensing etc. [6] [7][8]

Recent studies have demonstrated that yeast, including the genera Saccharomyces and Candida, can produce silica nanoparticles as an unwanted by-product after the uptake of soluble silicates. They accumulate silica either intracellularly or extracellularly in the form of opal, which can be visually assessed as the translucent appearance of the cells. Opal formation is a response to environmental conditions, such as a nutrient imbalance in the medium. Similar to diatoms, yeast also express a class of silaffin-like proteins, which play a key role in controlling biogenic silica formation. Because of their convenient size for handling, excellent growth properties, genetic tractability and large-scale usability, yeast have been proposed as ideal bioreactors for the biomineralization of silica to produce silica nanoparticles [9]. [10]

The mechanism by which silica is formed has been well established in the model organism Saccharomyces cerevisiae. The yeast takes up silicates through the sulfate transporter Sili1, which is responsible for transporting water-soluble monosilicic acid. Silica is precipitated in the cytoplasm by the action of silica-precipitating proteins Sil18p and Sil22p, which have polycationic properties. Silica forms intracellular opal bodies in the form of hierarchically structured spheres through a combination of biomolecular and physical processes[11]. Sis1p is a cytosolic chaperone that assists in the proper folding of Sil18p and Sil22p [12]. [13]. Mutations in the silaffin-like genes interfere with the formation of opal in yeast. Biosilica formation occurs during the yeast's exponential growth phase, and a significant amount of silica is precipitated when the growth stops, indicating that growth conditions affect the silica precipitation reaction. The yield of silica nanoparticles can be optimized by controlling the medium pH, temperature or growth conditions. Silica nanoparticles can be produced either during the growth phase or the stationary phase. [14]][15]

Silica nanoparticles (SiNPs) synthesized from *Saccharomyces* sp. are typically characterized using multiple analytical techniques to determine their structural, morphological, and chemical properties. Fourier Transform Infrared Spectroscopy (FTIR) is used to identify functional groups present on the nanoparticle surface, detecting characteristic Si–O–Si stretching vibrations and assessing organic residues from the yeast extract that may contribute to nanoparticle stabilization. Silica nanoparticles (SiNPs) have emerged as potent antimicrobial agents due to their unique physicochemical properties, including high surface area, stability, and biocompatibility. These nanoparticles exert their antimicrobial effects through multiple mechanisms, such as disrupting bacterial cell membranes, generating reactive oxygen species (ROS), and interfering with essential cellular processes. The small size of SiNPs allows for efficient penetration into microbial cells, leading to structural damage and metabolic inhibition. Their effectiveness has been demonstrated against a wide range of bacterial strains, including *Escherichia coli* and *Staphylococcus aureus*, making them promising candidates for biomedical and industrial applications.[16][17] Additionally, functionalization of silica nanoparticles with antimicrobial agents further enhances their bactericidal activity, reducing the risk of bacterial resistance development. [18]. .[19][20]

Material and methods

Yeast Sample Collection

Crude yeast samples were collected from Banha on March 6, 2024. The samples were transported under sterile conditions for further analysis.

Isolation of *Saccharomyces sp.*

The isolation of *Saccharomyces* sp. was performed using the serial dilution method, following standard microbiological protocols [21], [22]. The yeast sample was diluted 10× in the diluent solution (e.g., saline solution, peptone water, or peptone salt solution) by adding 25 g (solid sample) or 25 mL (liquid sample) into a flask containing 225 mL of diluent solution. This constituted the first dilution (10^{-1}). The sample was homogenized for 1–5 minutes using a wrist-action shaker, peristaltic agitator, magnetic stirrer, orbital shaker, or a blender. Aseptic transfer of 1 mL from the 10^{-1} dilution into a tube containing 9 mL of diluent solution was performed, resulting in a 100× dilution (10^{-2}). The homogenized suspension was transferred aseptically to another tube containing 9 mL of diluent solution, creating a 1000× dilution (10^{-3}). This dilution process was repeated as needed, depending on the yeast population present in the samples. Typically, dilutions up to 10^{-7} were satisfactory. The diluted samples were then spread onto agar plates for yeast enumeration following incubation. After incubation for four to seven days, colony growth was observed. Individual colonies were picked and subcultured onto agar petri dishes for further characterization.

Fermentation of Isolated Yeast in YPG Broth for Yeast Filtrate Preparation

The isolated *Saccharomyces* sp. was cultured in Yeast Peptone Glucose (YPG) broth to facilitate fermentation and obtain the yeast filtrate. The YPG medium, composed of yeast extract, peptone, and glucose, was prepared under sterile conditions to support optimal yeast growth. The inoculated broth was incubated at an appropriate temperature with constant agitation to enhance aeration and promote metabolic activity. After the fermentation period, the culture was centrifuged to separate the yeast biomass, and the supernatant (yeast filtrate) was collected for further applications.

Biosynthesis of Silica Nanoparticles using saccharomyces filtrate

The biosynthesis of silica nanoparticles was carried out using a biogenic approach, wherein microbial metabolites facilitated the synthesis. The precursor solution containing silicate compounds was exposed to yeast-derived biomolecules under controlled pH and temperature conditions. The reaction mixture was stirred continuously for uniform particle formation. The synthesized silica nanoparticles were collected by centrifugation, washed with distilled water, and dried for further characterization.

Antimicrobial Activity of Biosynthesized Silica Nanoparticles

The antimicrobial activity of the biosynthesized silica nanoparticles was evaluated using the polystyrene 96-well plate technique against two bacterial strains: *Escherichia coli* and *Staphylococcus aureus*. A bacterial suspension of 0.5 McFarland standard was prepared and inoculated into nutrient broth. The biosynthesized silica nanoparticles were added at different concentrations, and the plates were incubated at 37°C for 24 hours. Optical density measurements at 600 nm were recorded using a microplate reader to assess bacterial growth inhibition. Negative controls (without nanoparticles) and positive controls (with a standard antibiotic) were included in the assay.

Results

Bakery yeast sample collection

The collection of bakery yeast samples from different locations in Benha was conducted to assess the diversity and potential of *Saccharomyces* sp. isolates for further applications, such as nanoparticle biosynthesis and antimicrobial studies. As shown in the Table 1, four different samples (DO1, DO2, DO3, and DO4) were collected from four distinct bakeries within Benha. This approach ensures that the study captures a range of environmental and processing conditions that could influence yeast viability, metabolic activity, and strain variability. By sourcing yeast from multiple bakeries, potential variations in microbial composition can be examined, which may impact the efficiency of yeast-based biosynthesis of silica nanoparticles. Differences in fermentation conditions, ingredient sources, and bakery sanitation practices may also contribute to strain diversity, influencing growth rates, biochemical properties, and nanoparticle production capabilities. The collected yeast strains will undergo further characterization to determine their suitability for industrial applications. Evaluating these isolates for fermentation efficiency, tolerance to different conditions, and potential antimicrobial properties will provide valuable insights into their biotechnological potential. Moreover, this systematic sampling approach enhances the reliability of the study by reducing bias and ensuring that findings are representative of naturally occurring yeast populations in local bakeries

Table 1. Bakery yeast sample collection

Serial	Sample code	Location
1	**DO1**	**Benha Bakery 1**
2	**DO2**	**Benha Bakery 2**
3	**DO3**	**Benha Bakery 3**
4	**DO4**	**Benha Bakery 4**

Isolation of *saccharomyces* from collected bakery yest samples

The isolation of *Saccharomyces* sp. from bakery yeast samples was successfully carried out using the serial dilution method, ensuring the selection of viable yeast colonies for further study. As shown in Table 2 Figure 2, multiple isolates were obtained from each bakery sample, indicating a diverse population of *Saccharomyces sp* strains within the collected samples. The number of isolates varied among the different bakery sources, with DO1 yielding four isolates (DO1S1–DO1S4), DO2 and DO3 yielding three isolates each, and DO4 yielding a single isolate. The variation in the number of isolates among samples may be attributed to differences in environmental conditions, yeast handling practices in bakeries, and the microbial composition of the bakery environment. Factors such as flour quality, fermentation duration, and contamination from surrounding microorganisms may also influence the yeast diversity within the samples. The isolated *Saccharomyces* sp. will undergo further characterization to determine their morphological, physiological, and biochemical properties. This step is crucial for selecting the most efficient strains for applications such as fermentation, bioactive compound production, and nanoparticle biosynthesis. Identifying yeast strains with high fermentation efficiency and desirable metabolic characteristics will be beneficial for industrial and biotechnological applications.

Table 2. Isolated of *saccharomyces* from collected bakery yest samples

Serial	Sample code	Isolate code
1	DO1	DO1S1 DO1S2 DO1S3 DO1S4
2	DO2	DO2S1 DO2S2 DO2S3
3	DO3	DO3S1 DO3S2 DO3S3
4	DO4	DO4S1

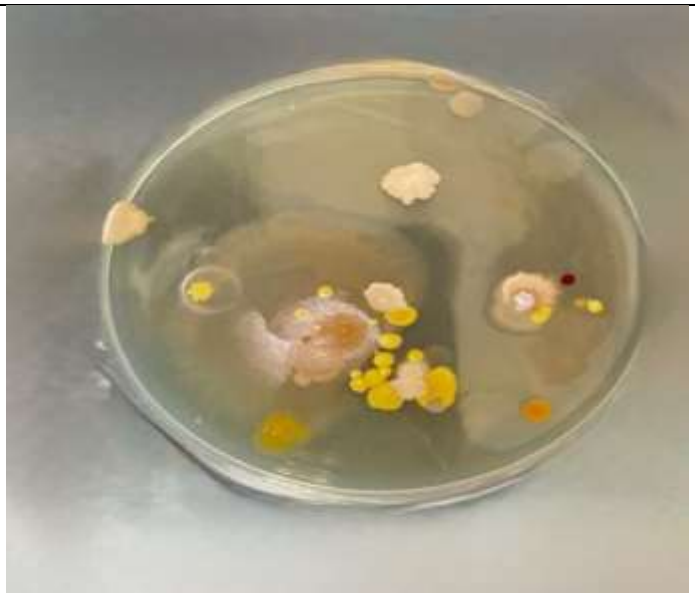

Fig. 1. Isolation of *Saccharomyces sp*.

screening of silica nanoparticles biosynthesis ability of isolated *saccharomyces sp*

The screening of *Saccharomyces sp*. isolates for their ability to biosynthesize silica nanoparticles (SiNPs) revealed significant variation in their nanoparticle production potential, as indicated by the observed color changes (Table 4). The presence of color change serves as a qualitative indicator of successful silica nanoparticle formation, with varying intensities denoted by "+", "++", and "+++" symbols.

Among the tested isolates, DO1S4 and DO4S1 demonstrated the highest biosynthesis potential, as indicated by the strongest color change (+++), suggesting an efficient bioreduction and nanoparticle formation process. This may be attributed to the metabolic activity of these strains, including their enzymatic capabilities, extracellular biomolecules, and tolerance to silica precursor compounds.

Moderate biosynthesis activity (++) was observed in isolates DO1S1 and DO2S3, indicating their potential for silica nanoparticle synthesis but possibly at a lower efficiency compared to the highly active strains. Meanwhile, weak biosynthesis activity (+) was detected in DO3S1, suggesting a limited ability to facilitate nanoparticle formation.

Interestingly, the majority of the isolates (DO1S2, DO1S3, DO2S1, DO2S2, DO3S2, and DO3S3) exhibited no visible color change (-), indicating an absence or minimal biosynthesis activity. This could be due to strain-specific variations in metabolic pathways, enzyme expression, or differences in their interaction with the silica precursor. The lack of biosynthesis ability in some isolates suggests that not all *Saccharomyces* strains possess the required biochemical mechanisms for effective silica nanoparticle production.

The observed differences in biosynthesis potential highlight the importance of strain selection for further applications in nanotechnology. Future studies should focus on optimizing biosynthesis conditions,

characterizing the nanoparticles produced, and investigating the molecular mechanisms behind the variation in biosynthesis ability among *Saccharomyces sp* isolates. Selecting and enhancing the most efficient strains through genetic or metabolic engineering could improve their suitability for industrial-scale silica nanoparticle production.

Table3. screening of silica nanoparticles biosynthesis ability of isolated *saccharomyces sp.*

Serial	Isolate code	Color change due to formation
1	**DO1S1**	++
2	**DO1S2**	-
3	**DO1S3**	-
4	**DO1S4**	+++
5	**DO2S1**	-
6	**DO2S2**	-
7	**DO2S3**	++
8	**DO3S1**	+
9	**DO3S2**	-
10	**DO3S3**	-
11	**DO4S1**	+++

Antibacterial activity of the biosynthesized silica nanoparticles

The antibacterial activity of biosynthesized silica nanoparticles (SiNPs) derived from *Saccharomyces* sp. isolate DO1S4 was evaluated against *Escherichia coli* and *Staphylococcus aureus*, with ciprofloxacin (5 µg/mL) used as a standard antibiotic control (Table 5). The results demonstrated that SiNPs exhibited notable antibacterial effects, though their efficacy was lower compared to ciprofloxacin. Against *E. coli*, the biosynthesized SiNPs showed an inhibition zone of 77.025%, which suggests a significant antimicrobial effect. However, ciprofloxacin displayed a higher inhibition rate (99.05%), indicating its superior bactericidal activity. The antibacterial effect of SiNPs against *E. coli* could be attributed to their ability to generate reactive oxygen species (ROS), disrupt bacterial cell membranes, and interfere with essential cellular functions.

Similarly, against *S. aureus*, the biosynthesized SiNPs exhibited an inhibition zone of 52.02%, which was notably lower than ciprofloxacin (98.25%). The reduced antibacterial effect against *S. aureus* compared to *E. coli* may be due to differences in bacterial cell wall structures. Gram-negative bacteria (*E. coli*) possess an outer membrane that may enhance interactions with SiNPs, facilitating their antimicrobial activity. In contrast, the thick peptidoglycan layer of Gram-positive bacteria (*S. aureus*) may act as a barrier, reducing the nanoparticles' penetration and antimicrobial efficiency. Although the biosynthesized SiNPs did not match the antibacterial potency of ciprofloxacin, their significant inhibitory effects suggest potential applications in antimicrobial treatments, especially in combination with existing antibiotics to enhance efficacy and combat antibiotic resistance. Further studies should focus on optimizing nanoparticle synthesis, exploring their mechanism of action, and evaluating their cytotoxicity to determine their suitability for clinical and industrial applications.

Table ٤. Antibacterial activity of the biosynthesized silica nanoparticles using DO1S4

	e.coli	s. arues
DO1S4 Silican nanoparticles	**77.025**	**٥٢.٠٢**
Ciprofl(5ug/ml)	**99.05**	**98.25**

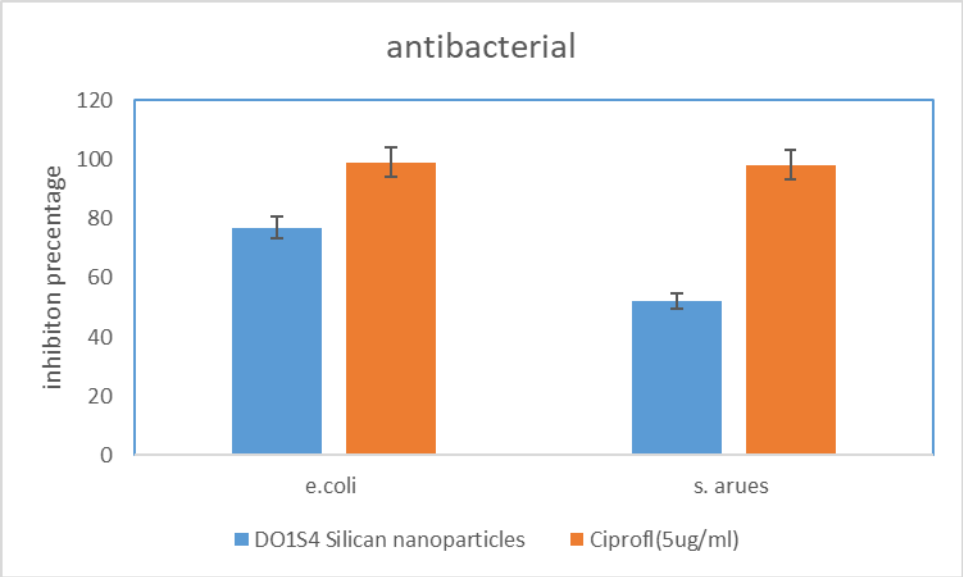

Fig. 2. Antibacterial activity of the biosynthesized silica nanoparticles using DO1S4

Antioxidant activity

The antioxidant activity of the biosynthesized silica nanoparticles using DO1S4 was evaluated through DPPH scavenging activity. The results indicate that the DO1S4 silica nanoparticles exhibited a scavenging activity of 45.025%, whereas ascorbic acid, used as a standard antioxidant, demonstrated a higher scavenging activity of 70.05%. These findings suggest that the biosynthesized silica nanoparticles possess notable antioxidant potential, though lower than that of ascorbic acid.

Table 5. Antioxidant activity of the biosynthesized silica nanoparticles using DO1S4

	Antioxidant activity DPPH scavenging activity
DO1S4 Silican nanoparticles	45.025
Ascorbic acid	70.05

ADME and Physicochemical Properties of Silica

The physicochemical properties of silica suggest that it has limited drug-like characteristics. With a molecular weight of 60.08 Da, it falls well below the typical range for orally bioavailable drugs, making it small enough for potential cellular uptake. However, its logP value of -0.62 indicates a relatively hydrophilic nature, suggesting that silica may not readily permeate lipid membranes, which could impact its absorption and distribution. The low number of hydrogen bond acceptors (2.00) and the absence of hydrogen bond donors (0.00) suggest minimal interactions with biological molecules via hydrogen bonding, which may limit its bioavailability. Additionally, silica adheres to Lipinski's Rule of 5, but its low quantitative estimate of drug-likeness (QED = 0.35) suggests suboptimal drug-like characteristics. Silica exhibits moderate human intestinal absorption (0.66) and oral bioavailability (0.77), indicating that a fraction of the compound can be absorbed through the gastrointestinal tract. However, its aqueous solubility (-3.70 log mol/L) suggests limited solubility, which can influence its dissolution rate and subsequent absorption. The hydration free energy (-5.24 kcal/mol) is relatively favorable, supporting moderate solubility. On the other hand, its negative cell effective permeability (-4.23 log(10^{-6} cm/s)) suggests that silica has poor permeability across cellular membranes, which may restrict its bioavailability.

The high blood-brain barrier (BBB) penetration score (0.99) indicates that silica has a high probability of crossing the BBB, which may be of interest for neurological applications or toxicity concerns. Plasma protein binding (69.76%) is moderate, suggesting that a significant portion of silica in circulation may be bound to plasma proteins, potentially affecting its free, active concentration. However, its volume of distribution

(0.00 L/kg) suggests that it may not extensively distribute into tissues beyond the bloodstream.

Silica shows negligible inhibition of major cytochrome P450 (CYP) enzymes, including CYP1A2, CYP2C19, CYP2C9, CYP2D6, and CYP3A4. This suggests a low likelihood of metabolic interactions with drugs metabolized by these enzymes. Additionally, silica is a weak substrate for CYP2C9, CYP2D6, and CYP3A4, indicating that it is not extensively metabolized by these pathways.

The reported half-life of silica (13.53 hours) suggests a relatively moderate elimination rate, which could be beneficial in maintaining systemic exposure. However, its low hepatocyte clearance (0.00 µL/min/10^6 cells) and moderate microsomal clearance (1.72 µL/min/mg) suggest that silica is not efficiently eliminated via hepatic metabolism, possibly leading to prolonged circulation. Silica presents several toxicity concerns. Its high mutagenicity score (0.99) indicates a significant potential for genetic mutations, which could raise concerns regarding carcinogenicity. This is further supported by its high carcinogenicity score (0.81), suggesting a potential risk of long-term exposure. Additionally, silica shows a high probability of inducing drug-induced liver injury (0.80), emphasizing possible hepatotoxic effects. Its acute toxicity LD50 value (1.62 log(1/(mol/kg))) suggests moderate toxicity upon acute exposure. Moreover, silica has a high skin reaction probability (0.95), indicating a potential risk of dermal irritation or allergic responses. Regarding specific receptor interactions, silica has negligible binding to androgen receptors, aryl hydrocarbon receptors, and estrogen receptors, indicating a low likelihood of endocrine disruption. However, its potential mitochondrial membrane disruption (5.23e-04) and interactions with tumor protein p53 (3.22e-03) may suggest possible cytotoxic effects, warranting further investigation in biological systems.

Table 6. ADME-Tox and Physicochemical Properties

Category	Property	Value	DrugBank Percentile	Units
Physicochemical	Molecular Weight	60.08	1.86%	Dalton
	LogP	-0.62	17.80%	log-ratio
	Hydrogen Bond Acceptors	2.00	16.38%	#
	Hydrogen Bond Donors	0.00	11.77%	#
	Lipinski Rule of 5	4.00	63.80%	# of 4
	Quantitative Estimate of Druglikeness (QED)	0.35	27.72%	-
	Stereo Centers	0.00	22.49%	#
	Topological Polar Surface Area (TPSA)	34.14	17.66%	Å^2
Absorption	Human Intestinal Absorption	0.66	20.32%	-
	Oral Bioavailability	0.77	46.22%	-
	Aqueous Solubility	-3.70	37.69%	log(mol/L)
	Lipophilicity	0.49	34.28%	log-ratio
	Hydration Free Energy	-5.24	87.71%	kcal/mol
	Cell Effective Permeability	-4.23	94.18%	log(10^{-6} cm/s)
	PAMPA Permeability	0.33	26.72%	-
	P-glycoprotein Inhibition	0.02	29.74%	-
Distribution	Blood-Brain Barrier Penetration	0.99	94.34%	-
	Plasma Protein Binding Rate	69.76	43.47%	%
	Volume of Distribution at Steady State	0.00	36.49%	L/kg
Metabolism	CYP1A2 Inhibition	2.78e-04	5.23%	-
	CYP2C19 Inhibition	1.77e-03	4.03%	-
	CYP2C9 Inhibition	1.15e-04	2.40%	-
	CYP2D6 Inhibition	3.54e-04	3.57%	-
	CYP3A4 Inhibition	3.44e-06	3.22%	-
	CYP2C9 Substrate	0.01	3.53%	-
	CYP2D6 Substrate	0.01	1.20%	-
	CYP3A4 Substrate	0.12	13.65%	-
Excretion	Half-Life	13.53	59.40%	hr

	Drug Clearance (Hepatocyte)	0.00	5.85%	µL/min/10^6 cells
	Drug Clearance (Microsome)	1.72	30.67%	µL/min/mg
Toxicity	hERG Blocking	1.22e-03	1.32%	-
	Clinical Toxicity	0.01	9.07%	-
	Mutagenicity	0.99	99.50%	-
	Drug-Induced Liver Injury	0.80	71.04%	-
	Carcinogenicity	0.81	98.49%	-
	Acute Toxicity LD50	1.62	8.65%	log(1/(mol/kg))
	Skin Reaction	0.95	96.94%	-
	Androgen Receptor (Full Length)	2.50e-04	1.05%	-
	Androgen Receptor (Ligand Binding Domain)	3.04e-04	4.58%	-
	Aryl Hydrocarbon Receptor	3.03e-05	0.93%	-
	Aromatase	4.23e-05	3.10%	-
	Estrogen Receptor (Full Length)	0.03	10.04%	-
	Estrogen Receptor (Ligand Binding Domain)	5.38e-04	3.92%	-
	Peroxisome Proliferator-Activated Receptor Gamma	1.18e-05	3.96%	-
	Nuclear Factor (Erythroid-Derived 2)-Like 2/ARE	0.02	14.23%	-
	ATPase Family AAA Domain-Containing Protein 5	2.18e-05	3.33%	-
	Heat Shock Factor Response Element	9.41e-04	9.62%	-
	Mitochondrial Membrane Potential	5.23e-04	8.88%	-
	Tumor Protein p53	3.22e-03	23.34%	-

Discussion

This study focused on the isolation of *Saccharomyces sp*. from bakery yeast samples and their potential to biosynthesize silica nanoparticles (SiNPs) with antimicrobial properties. .

Scientist zamani etal, has reached to the use of nanotechnology to enhance oil reservoir recovery as a means to meet energy demands by increasing oil production and reducing costs. In his research, he used *Saccharomyces cervisiae* yeast for biochemical production of silica nanoparticles. This yeast is cultivated in its own culture medium. This yeast solution made after the addition of Sodium Silicate Precursor placed in the proper conditions of growth, i.e., temperature of 29 °C, away from the types of contamination and the passage of time, reducing the silica nanoparticles from the initial precursor. In this research, after performing the silica nanoparticle production processes, identification tests such as FTIR, XRD, SEM, DLS and TGA are performed. Then, in order to investigate the effect of this nanoparticle on the production efficiency of the oil, these nanoparticles were added to injectable solutions to an oil-wet micro-model with different concentrations of 250 ppm, 500 ppm and 1000 ppm. It was observed that the difference in the effect of nanoparticles produced by the biochemical method and commercial nanoparticles purchased in the injection process and on the measurement of the production efficiency of oil was that biosynthesized nanoparticles increased oil production efficiency by about 5–7 percent relative to commercial nanoparticles. [23]

in recent years, mesoporous silica nanoparticles have attracted attention as a promising component of multimodal nanoparticle systems. Mesoporous silica nanoparticles are excellent candidates for many biomedical applications because of their straightforward synthesis, tunable pore morphologies, facile functionalization chemistries, low-toxicity degradation pathways in the biological milieu, and capacity to carry disparate payloads (molecular drugs, proteins, other nanoparticles) within the porous core. Lykov, A.etal, applied a screening of therapeutic

efficacy of silica-loaded antibiotics, in comparison with their officinal forms, based on the dynamics of growth of *Staphylococcus aureus*, Pseudomonas aeruginosa, and *Escherichia coli* in vitro and in experimental models of sepsis induced by various strains of microorganisms in mice (CBAxC57BL/6)F1 has been performed. The expediency of using this modification of antibiotics to enhance their therapeutic efficacy inexperimental sepsis has been demonstrated. [24] [25]

Yeast samples were collected from four different bakeries in Benha to ensure diversity in the strains, which could influence their biosynthetic capabilities The isolation process yielded multiple *Saccharomyces sp*. strains, with some bakery samples providing a higher number of isolates than others. This variation suggests differences in environmental conditions, yeast handling, and microbial competition within the bakery environments. Further characterization of these isolates is necessary to determine their metabolic capabilities and industrial potential.

Yeasts according to invention are classified in the kingdom Fungi, phylum Ascomycota, in subphylum *Saccharomycotina*, in the class *Saccharomycetes*, in the order *Saccharomycetales*, in the family *Saccharomycetaceae*, and in the genus *Saccharomyces*, with about 1500 species currently described. *Saccharomyces cerevisiae*, known as "baker's yeast", can reside in diverse environmental niches. S. cerevisiae is probably the best studied of all the yeast species in terms

of physiology and genetics, and definitely of immense industrial significance because of its involvement in fermentation of bread, beer, or wine. It is an ideal source of different enzymes and vitamins, considered as nutrient supplement and can treat antibiotic-related diarrhea .

Rapid growth and easy control of mass production of yeasts using simple nutrient culture medium altogether make yeast as the preferred microorganism for NP synthesis, as compared to other microbes.[26][27][28]

Screening for silica nanoparticle biosynthesis ability among the isolates revealed significant differences in their nanoparticle-producing capacity, as indicated by observable color changes.

Since For the nanoparticles formation, different biological agents react differently with different metal solutions. Either extracellularly or intracellularly, numerous microbes produce different inorganic materials and mechanism differs from one organism to another both intra or extracellularly.[29],[30][31][32]

Isolates DO1S4 and DO4S1 demonstrated the highest biosynthesis potential (+++), indicating strong enzymatic activity and efficient interaction with silica precursors, likely due to enhanced biomolecular secretion facilitating nanoparticle formation. Moderate biosynthesis activity (++) was observed in isolates DO1S1 and DO2S3, while a few isolates showed weak biosynthesis (+). However, several isolates, including DO1S2, DO1S3, DO2S1, DO2S2, DO3S2, and

DO3S3, exhibited no visible biosynthesis activity (-), suggesting strain-specific variations in metabolic pathways or enzymatic deficiencies affecting silica nanoparticle formation. These findings highlight the importance of strain selection for nanoparticle biosynthesis, as not all *Saccharomyces sp*. strains possess the necessary biochemical mechanisms to facilitate efficient nanoparticle production. Further studies should investigate the molecular basis of these variations, optimize biosynthesis conditions, and explore the role of specific biomolecules involved in silica nanoparticle formation.

The biosynthesized SiNPs from the highly active strain DO1S4 were further evaluated for antibacterial activity against *Escherichia coli* (Gram-negative) and *Staphylococcus aureus* (Gram-positive). The results showed that SiNPs exhibited significant antibacterial effects, with an inhibition rate of 77.025% against *E. coli* and 52.02% against *S. aureus*. However, their efficacy was lower compared to ciprofloxacin (5 µg/mL), which exhibited inhibition rates of 99.05% and 98.25% against *E. coli* and *S. aureus*, respectively. The stronger antibacterial activity against *E. coli* compared to *S. aureus* may be attributed to structural differences in their cell walls. *E. coli*, a Gram-negative bacterium, has an outer membrane that might facilitate interactions with SiNPs, increasing their antimicrobial efficacy. In contrast, the thick peptidoglycan layer of *S. aureus* (Gram-positive) may act as a barrier, reducing nanoparticle penetration and overall effectiveness. The antibacterial effects of biosynthesized SiNPs could be due to multiple mechanisms, including the generation of reactive oxygen species (ROS), disruption of bacterial cell membranes, and interference with essential cellular processes.

Despite the lower antibacterial efficacy compared to ciprofloxacin, the biosynthesized SiNPs demonstrate promising antimicrobial potential. Their ability to inhibit bacterial growth suggests possible applications in developing new antimicrobial agents, particularly for combating antibiotic-resistant strains. Future studies should focus on optimizing nanoparticle synthesis to enhance their antimicrobial potency, elucidating their precise mechanisms of action, and evaluating their biocompatibility and cytotoxicity for potential clinical and industrial applications. Additionally, exploring synergistic effects with conventional antibiotics could provide a novel approach to improving antimicrobial strategies and addressing the growing challenge of antibiotic resistance. The antioxidant activity of the biosynthesized silica nanoparticles using DO1S4, as

assessed by DPPH scavenging activity, revealed a moderate free radical scavenging capability of 45.025%. Although this activity is lower than that of ascorbic acid (70.05%), a well-known antioxidant, it still indicates the potential of these nanoparticles in mitigating oxidative stress. The observed activity may be attributed to the presence of bioactive compounds associated with the biosynthesis process, which could enhance the radical scavenging ability of the nanoparticles.

The lower activity of DO1S4 silica nanoparticles compared to ascorbic acid might be due to differences in their mechanisms of action. Ascorbic acid, a small and highly reactive molecule, can efficiently donate electrons to neutralize free radicals, whereas silica nanoparticles may act through different pathways, such as surface-mediated interactions or gradual electron transfer. Furthermore, the size, surface charge, and composition of the nanoparticles could influence their antioxidant potential.

Despite the lower scavenging activity, the antioxidant properties of biosynthesized silica nanoparticles are still significant, as they may offer additional advantages such as biocompatibility, stability, and potential synergistic effects when incorporated into biomedical or pharmaceutical applications. Future studies should focus on optimizing the synthesis parameters to enhance their antioxidant capacity, as well as investigating their mechanisms of action and potential applications in oxidative stress-related diseases. The ADME and physicochemical profile of silica indicate limited drug-like properties, with moderate absorption, poor permeability, and minimal metabolism. While it has a high potential for BBB penetration, its toxicity profile raises significant concerns, particularly regarding

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mutagenicity, carcinogenicity, and liver toxicity. These findings suggest that silica may have limited therapeutic applications unless appropriately formulated to mitigate toxicity and enhance bioavailability.

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