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Bioactive potential of copper and chromium doped manganese oxide nanoparticles

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Abstract

Introduction: Copper and chromium-based nanoparticles are employed in the treatment of various diseases due to their antifungal, antiviral, antibacterial, and antioxidant properties. **Objectives:** Recent research conducted at the University of Okara aimed to evaluate the antibacterial, antifungal, and antioxidant potential of copper and chromium-doped manganese oxide nanoparticles. **Methods:** The nanoparticles were synthesized using the hydrothermal method. To determine their antibacterial potential, disc diffusion and agar well diffusion methods were utilized. Characterization of the nanoparticles was performed using powder X-ray diffraction, Fourier transform infrared spectroscopy, and energy-dispersive X-ray spectroscopy to confirm their properties. The antibacterial efficacy of the nanoparticles was tested against *Klebsiella pneumoniae, E. coli,* and *Bacillus subtilis.* **Results:** All antibiotics demonstrated antibacterial activity except Trimethoprim and Amoxicillin, while copper-doped manganese

oxide nanoparticles showed no antibacterial potential. Chromium-doped manganese oxide nanoparticles exhibited antibacterial potential at various concentrations. The antifungal potential of copper nanoparticles was tested against *Fusarium equiseti* and *Rhizopus stolonife*. No inhibition was observed against the growth of *Rhizopus stolonifer*. The antioxidant activity test confirmed that copper and chromium oxide nanoparticles, along with ascorbic acid, possess antioxidant properties. Copper oxide nanoparticles exhibited a maximum antioxidant activity of 67% at a concentration of 0.1 mg/2 ml, while ascorbic acid showed 90%. Chromium oxide nanoparticles demonstrated maximal antioxidant activity of 99%, with ascorbic acid at 83%. Copper nanoparticles had less antioxidant activity than ascorbic acid, whereas chromium nanoparticles had higher activity. **Conclusion:** In conclusion, both copper and chromium-doped manganese oxide nanoparticles exhibit antibacterial, antifungal, and antioxidant activities against different pathogens.

Keywords: Copper nanoparticles, Chromium nanoparticles, Manganese oxide nanoparticles, Antibacterial activity, Antifungal activity, Antioxidant activity

Introduction

The most interesting areas of nanotechnology is the use of nanoparticles (NP) in medicine. NPs are being employed in gene therapy, medication delivery, and the detection and cure of tumor. The scientific and medical communities are particularly interested in these uses of metal oxide NP in biomedicine and cancer treatment (1). Copper oxide NPs (CuONP) has anticancer characteristics, likely by eliminating tumor cells through direct contact or the induction of oxidative stress (2). CuO NPs are a promising possibility for cancer therapy because it has been found that they preferentially destroy tumor cells in a dose-dependent method without harming regular cells. A novel class of alternative anticancer drugs, complexes comprising copper or other metals, has emerged (3). Due to its exceptional physical and chemical characteristics and potential for usage in a variety of applications, CrO has taken a special place in the transition metal oxide series. Because of this, CrO has recently been regarded as a significant study topic. Trivalent Cr2O3 is thermodynamically extra stable than other forms of CrO NPs, such as Cr_2O_5, Cr_3O_8, Cr_5O_{12}, and Cr_6O_{13}, due to its features like high resistivity, hardness, and stability. Because of its excellent catalytic properties and great chemical durability, $Cr_3O_3$is also significant in the chemical industry

(4). For the synthesis of Cr_2O_3 NPs, a number of preparation approaches have been utilized, including the mechanical milling technique hydrothermal method, thermal decomposition, sol-gel method, laser-induced deposition, and microwave refluxing method (5).

The antibacterial capabilities of metal nanoparticles are applied in many fields, such as food, water treatment, and medical equipment manufacturing (6). The production of vacancies, a type of lattice defect, by doping another metal ion into the oxide, modifies the oxide's physical and chemical characteristics to some amount. For instance, doping with copper and iron affects the magnetic characteristics of ZnO powder. Numerous studies on metal doping in the MgO system have been published recently (7) Yoon, Byeon (8) reported that copper nanoparticles had an antimicrobial impact. Copper nanoparticles have been shown to exhibit antifungal and bacteriostatic effects by Cioffi, Torsi (9). . Copper is now employed as a fungicide, antimicrobial, antifouling, and water purifier (10). Nanoparticles' antifungal activity has been successfully demonstrated in the present for a wide range of antifungal uses. The use of NPs as antibacterial and antimicrobial agent has, in the first instance, proven to be effective and has progressed in accordance with (1– 5) despite the challenges associated with controlling microbial development due to the presence of germs that are resistant to conventional antimicrobial agents. Many different mechanisms are thought to explain how nanoparticles have an antimicrobial effect (11). It is simple, inexpensive, and only requires one pot to make nanoparticles utilizing plant-mediated methods, in which phyto-components from plants act as reducing agents to produce the required class of NPs (12). Metallic NPs are excellent at treating wounds and inflammation, according to numerous studies. In addition, manufactured silver nanoparticles exhibit potent anti-inflammatory and antioxidant activities (13).

Numerous bacteria, such as staphylococci and Candida species, can attach to the surface of medical implants (such as bone implants and vascular catheters) and form biofilms on the surfaces of biomaterials. One of the most frequent causes of nosocomial infections, post-operative wound, and bloodstream infections are multi-drug resistant microorganisms (14). These bacteria's infections result in substantial medical expenses that have been steadily rising over time. In this situation, the creation of new antibacterial compounds is promising and merits further investigation (15). The first of these is methicillin-resistant *Staphylococcus aureus* (MRSA), followed by infections with *Escherichia coli (E. coli, colibacilli), Clostridium difficile,* and *legionella pneumophia*

(characteristic of Legionellosis). Copper also has the ability to kill type A influenza viruses. The objective of the current study was to chemically synthesize stable copper and chromium doped manganese oxide nanoparticles and to assess their antifungal efficacy against pathogenic bacteria and fungus and with the antioxidant activity.

Materials and Methods

Study site

The recent study was carried out in the Genetic Research Lab of Zoology Department at The University of Okara, Okara, Pakistan.

Bacteria under study

The copper doped manganese oxide nanoparticles were prepared in the laboratory. To test the antibacterial activity *Klebsiella pneumonia, E. coli* and *Bacillus subtilis* were used The *Fusarium equesiti* and *Rhizopus stolenifer* fungal cultures were used. The antioxidant chemicals and antibiotics were purchased.

The *Klebsiella pneumonia* used in vitro antibacterial study. In accordance with the manufacturer's recommendations, the culture was revived. For 24 hours, *Klebsiella pneumonia* was allowed to develop in a 37°C incubator before being transferred to a 4°C refrigerator until required.

Antibiotics and Nanoparticles concentration

About seven antibiotics (Levofloxacin, Norfloxacine, Gentamicin, Chloramphenicol, Trimethoprim, Amoxicillin, and Ciprofloxacin) were used during the study. Five distinct concentrations of nanoparticles (20 mg, 40 mg, 60 mg, 80 mg, and 100 mg) were collected using the disk diffusion method. The antibiotic Levofloxacine served as the standard (16).

Antibacterial activity

Agar-well diffusion method

The agar-well diffusion technique was used to test the nanoparticle's antibacterial action against the bacterial strains *Bacillus subtilis* and *E. coli*. Prior to use, the bacterial separates were first consistent to 0.5 McFarland standards (106 cfu mL^{-1}) by 18 hours of culture in nutritional broth. 0.5 mL of 0.048 M Barium chloride $BaCl_2$ was added to 99.5 mL of 0.36 N sulphuric acid H_2SO_4

to create the 0.5 McFarland standards. Barium sulfate turbidity standard (4-6 mL) was measured and placed in a test tube with a screw lid. Nutrient agar (MERCK) was mixed in 100 mL of distilled water with a pH of 7.0 to make the nutrient agar medium, after that it was autoclaved. It was allowable to cool to 45 °C. 75 mL of seeded nutritional agar was moved into petri dishes and let to stabilize. A germ-free cork borer with a 6 mm diameter was used to drill wells into the agar. 0.025, 0.05, 0.075, and 0.1mg/ml of Cu-doped manganese oxide were added to the wells before being incubated at 37 °C for around 2 hours. Parallel controls using the appropriate solvents to fill fully were set up. After 24 hours, zones of inhibition on the plates were looked for. The effects were contrasted with Ciprofloxacin at a 5 microgram concentration (17).

Antifungal activity

Using the agar well diffusion technique, the produced NPs' antifungal activity was evaluated. To examine the antifungal effectiveness of certain NPs, fungi cultures were cultivated on potato dextrose medium. To make potato dextrose agar, 500ml of water that had been distilled, 10g of agar, 125g of starch from potatoes, and 10g of sugar were mixed together. Streptomycin was also administered to stop any bacterial development. The autoclaved dextrose agar made from potatoes was heated to 121°C and fifteen kilograms under pressure for 15 minutes. Plates were covered with potato dextrose agar, which was then let to set. After the culture plates had dried in the laminar airflow chamber, wells were drilled into the agar plate with a 5mm conventional cork borer. The University of Okara's Botany Department has identified fungal cultures from papaya and persimmon called *Rhizopus* and *Fusarium*. The relevant wells received various doses of NPs (0.025, 0.05, 0.075, and 0.1 mg/ml). Fungicide was used as the control strategy. The plates were then sealed and kept at 252°C for three days. Three, five, and seven days later, results were seen (18).

Antioxidant activity

2, 2-diphenyl-1-picrylhydrazyl (DPPH) method

About 9.85mg of DPPH was taken in measuring flask and then some methanol was added to dissolve DPPH. After the complete dissolve of DDPH in methanol and no solid particles remained then 50ml of methanol was added and it was shaken thoroughly. The obtained solution was placed in dark cabinet at room temperature for 30 minutes.

With a small alteration, the process was carried out in accord with Bhakya, Muthukrishnan (19) Using the constant radical DPPH, the capacity of Cu doped manganese oxide and ascorbic acid to scavenge free radicals was assessed. A freshly generated 1 ml of DPPH solution was combined with 1.5 ml of various amounts of distilled water (0.02, 0.04, 0.06, 0.08, 0.1, 0.15, and 0.2mg/2ml) and vortexed energetically. After that, the mixture was let to be seated for 30 minutes in the dark at room temperature. With the use of a UVeVis spectrophotometer, the absorbance was measured at 517 nm. 1.5 ml of methanol was used as a blank solution, and DPPH (all the reagents except the sample) was used as a control. The percentage of inhibition, which was calculated using the following formula, used to represent the free radical scavenging action.

$$\% \text{ of scavenging} = \frac{Pc-Ps}{Pc} \times 100$$

Where Ps is the absorption of the CuNPs/ascorbic acid mixture and Pc is the absorbance of the control.

Results

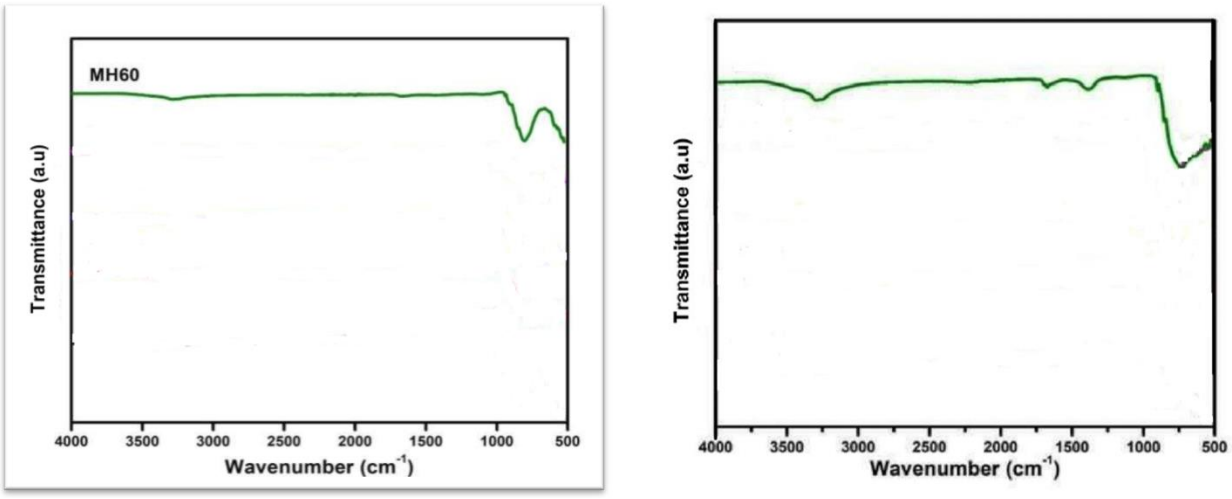
Characterization of nanoparticles

Results from the PXRD analysis of chromium-doped manganese oxide nanoparticles indicated that MnO_2 was the predominant phase, with minor inclusions of CrO_3 and $MnCrO_4$. The acquired patterns showed a consistent decrease in the intensity of the MnO_2 peak as the incorporation of chromium increased, influenced by the peaks of CrO_3. MnO_2, which is tetragonal in shape and belongs to the $P4_2/mnm$ space group, was identified as the primary phase.

Fourier Transform Infrared FTIR spectra of samples

All distinctive signals of the samples were visible in the FTIR spectra. In the 1000 to 500 cm^{-1} range, the bending and stretching vibrations of individual metal and oxygen bonds were observed. The FTIR spectra corroborate the findings. High structural symmetry is indicated by a simple FTIR pattern, as shown in Figure 1(a). The Fourier Transform Infrared (FTIR) spectra, depicted in the figure, clearly display all the distinctive signals of the samples. Peaks below 750 cm^{-1} confirm the vibration of the Mn-O bond, while the Mn-O stretching bond is observed at

521.22 cm^{-1}. High structural symmetry is further revealed by the FTIR pattern shown in Figure 1(b).



a) FTIR spectra of Cu NPs

b) FTIR spectra of Cr NPs

Figure 1: Shows the Fourier Transform Infrared FTIR) spectra of samples

Antibacterial assay using antibiotics

The growth of Klebsiella pneumoniae was slightly inhibited by the antibiotics. Table 1 below shows the effects of seven different antibiotics on the growth of *Klebsiella pneumoniae.* Levofloxacin, Norfloxacin, Gentamicin, Chloramphenicol, Amoxicillin, and Ciprofloxacin exhibited antibacterial activity, whereas Trimethoprim did not show any antibacterial properties against *Klebsiella pneumonia.*

Table 1: Zone diameters of antibiotics against *Klebsiella pneumoniae*

Antibiotics	Symbols	Concentrations	Susceptible	Intermediate	Resistant	Findings	Result
Levofloxacin	LEV	5µg	≥17	14-16	≤13	25mm	Susceptible
Norfloxacine	NOR	10µg	≥17	13-16	≤12	7mm	Resistant
Gentamicin	CN	10µg	≥15	13-14	≤12	10mm	Resistant
Chloramphenicol	C	30µg	≥18	13-17	≤12	18mm	Susceptible

Trimethoprim	SXT	25µg	≥16	11-15	≤10	No zone	Resistant
Amoxicillin	AML	10µg	≥18	14-17	≤13	10mm	Resistant
Ciprofloxacin	CIP	5µg	≥21	16-20	≤15	6mm	Resistant

Antibacterial assay using Cu and Cr nanoparticles:

The antibacterial activity of the Cu nanoparticles was assessed using different concentrations (20, 40, 60, 80, and 100 mg) applied on Whatman paper against *Klebsiella pneumoniae,* with Levofloxacin serving as a positive control. The experimental results demonstrated that Levofloxacin exhibited greater antibacterial potential than the nanoparticles. The effect of the Cr nanoparticles at various concentrations (20, 40, 60, 80, and 100 mg) was tested against bacteria by submerging Whatman paper in the nanoparticle solutions. The nanoparticles had no effect on the growth of bacteria, whereas Levofloxacin showed significant antibacterial activity. This is indicated in table 2.

Table 2: The antibacterial effect of Cu and Cr doped manganese oxide on *Bacillus subtilis* and *E.coli*

Nanoparticles	**Concentration**	**Samples**	
		Bacillus subtilis	*E.coli*
		Zone in mm	Zone in mm
Cu60	0.025	7	6
	0.05	7	7
	0.075	7	7
	1	7	7
Positive control	(Ciprofloxacin)	34	37
Cr	0.025	0	7
	0.05	0	7.5
	0.075	5	7
	1	6	7
Positive control (Ciprofloxacin)		33	31

Antifungal assay

To assess the antifungal potential of Cu and Cr nanoparticles, their activity was tested against *Fusarium equiseti* and *Rhizopus stolonifer*. The results were observed on the third, fifth, and seventh days. For Fusarium equiseti, the maximum zone of inhibition was observed on day seven, while the minimum was observed on day three.

For the Cu nanoparticles, on the third day, the zones of inhibition for *Fusarium equiseti* were 0.2, 0.9, 1.0, and 3.0 at concentrations of 0.025, 0.05, 0.075, and 0.1, respectively. The concentration of 0.1 produced the largest zone of inhibition, while 0.025 produced the smallest. On the fifth day, the zones were 1.9, 2.3, 1.9, and 2.2 at concentrations of 0.025, 0.05, 0.075, and 0.1, respectively. The concentration of 0.05 produced the largest zone of inhibition, while 0.025 and 0.075 produced the smallest. On the seventh day, the zones were 2.5, 3.0, 2.4, and 2.5 at concentrations of 0.025, 0.05, 0.075, and 0.1, respectively. The concentrations of 0.1 and 0.025 produced the highest zones of inhibition, while 0.075 produced the lowest.

For the Cr nanoparticles, on the third day, the zones of inhibition for *Fusarium equiseti* were 0.5, 0.6, 1.9, and 2.0 at concentrations of 0.025, 0.05, 0.075, and 0.1, respectively. The concentration of 0.1 produced the largest zone of inhibition, while 0.025 produced the smallest. On the fifth day, the zones were 1.3, 1.8, 2.1, and 2.6 at concentrations of 0.025, 0.05, 0.075, and 0.1, respectively. The concentration of 0.1 produced the largest zone of inhibition, while 0.025 produced the smallest. On the seventh day, the zones were 2.2, 3.0, 4.0, and 4.5 at concentrations of 0.025, 0.05, 0.075, and 0.1, respectively. The concentration of 0.1 produced the largest zone of inhibition, while 0.025 produced the smallest. This can be seen in table 3.

Table 3: Shows the concentration of nanoparticles and the zone of inhibition against *Fusarium equesiti*

Antifungal activity of *Fusarium equesiti*				
Cu	Concentration	Day 3	Day 5	Day 7
	0.025	0.2	1.9	2.5
	0.05	0.9	2.3	3

	0.075	1	1.9	2.4
	0.1	3	2.2	2.5
Cr	0.025	0.5	1.3	2.2
	0.05	0.6	1.8	3
	0.075	1.9	2.1	4
	0.1	2	2.6	4.5

Antioxidant assay

The antioxidant activity test confirmed the antioxidant capabilities of both ascorbic acid and copper oxide nanoparticles (CuO NPs). Ascorbic acid demonstrated 90% antioxidant activity at the tested concentration, whereas CuO NPs exhibited a maximum antioxidant activity of 67% at 0.1 mg/2 ml. At a lower concentration of 0.04 mg/2 ml, CuO NPs showed only 9% antioxidant activity. These results clearly illustrate that CuO NPs have lower antioxidant activity compared to ascorbic acid.

Furthermore, the antioxidant activity test indicated that both ascorbic acid and chromium oxide nanoparticles (CrO NPs) possess antioxidant properties. Ascorbic acid displayed 83% antioxidant activity at the same concentration where CrO NPs showed a maximum antioxidant activity of 99%. The lowest observed antioxidant activity for CrO NPs was 89% at a concentration of 0.1 mg/2 ml. These findings highlight that CrO NPs exhibit higher antioxidant activity than ascorbic acid. This comparative analysis is summarized in Table 4.

Table 4: Shows the concentrations of metals and the percentage of antioxidant property

Metals Nanoparticles	**Concentrations**	**Test Sample**	**Ascorbic acid**
Cu doped NPs	0.02	16%	81%
	0.04	9%	83%
	0.06	33%	85%
	0.08	55%	86%
	0.1	67%	90%

	0.15	31%	87%
	0.2	30%	85%
Cr doped NPs	0.02	98%	81%
	0.04	99%	83%
	0.06	92%	85%
	0.08	97%	86%
	0.1	89%	90%
	0.15	91%	87%
	0.2	92%	85%

Discussion

The goal of the current work was to evaluate the Cu and Cr doped manganese oxide nanoparticle's antioxidant, antimicrobial, and antifungal activities.

For antioxidant properties, 1 ml of freshly made DPPH was mixed with Cu doped manganese oxide nanoparticles. After the solution's creation, it was left in the dark for 30 minutes. Cu oxides NPs have antioxidant properties, according to the results of this activity. Seven different concentrations of NPs (0.02, 0.04, 0.06, 0.08, 0.1, 0.15, and 0.2) were used for the experiment, and ascorbic acid was used at the same concentration to compare the antioxidant properties. The maximum antioxidant property was investigated at 0.1 NPs and the minimum at 0.04. The findings indicate that the chosen NPs are less effective antioxidants than ascorbic acid. Alam, Al Qahtani (20) evaluated the antioxidant properties of a new copper-zinc-manganese trimetal oxide nanocomposite. The produced nanocomposite exhibits significant antioxidant activity, with scavenging activity measured at 31, 62, 125, 250, and 500 g/mL, respectively, to be 76.58 0.30, 76.89 0.44, 81.41 30, 82.58 0.32, and 84.36 0.09%. The outcomes demonstrate that nanoparticles' (NPs) antioxidant activity was concentration-dependent.

For antioxidant properties, 1 ml of newly prepared DPPH was combined with freshly prepared Cr doped manganese oxide nanoparticles. The solution was then prepared and left in the dark for 30 minutes. The outcomes of this experiment demonstrated the antioxidant properties of Cr oxide

nanoparticles. Seven different concentrations of NPs (0.02, 0.04, 0.06, 0.08, 0.1, 0.15, and 0.2) were used in the experiment, and ascorbic acid was used at the same concentration to compare the antioxidant properties. The highest concentration for antioxidant activity was 0.04, and the lowest was 0.1. The findings demonstrate that the chosen NPs have excellent antioxidant properties that are superior to ascorbic acid. The same outcomes were obtained by Keshari, Srivastava (21) on a different nanoparticle, confirming the antioxidant action of vitamin C (ascorbic acid) and AgNPs. Vitamin C has a 24.28% antioxidant activity compared to 29.55% for AgNPs. The silver nanoparticles have more antioxidant activity than vitamin C; according to the antioxidant techniques.

On *Fusarium* and *Rhizopus*, antifungal action was demonstrated. For this, *Fusarium* and *Rhizopus* were removed from papaya and persimmon. In petri dishes, various NP concentrations (0.025, 0.05, 0.075, and 0.1 mg/ml) and fungicide were applied. Days 3, 5, and 7 saw observations on the culture. On day 3, the concentration of o.1 showed the highest zone of inhibition and 0.025 the lowest. Day 5 revealed a maximal inhibition zone at 0.1 concentration and a minimum at 0.025. On day 7, the maximum zone of inhibition was at doses of 0.01 and the minimum was at 0.025. The outcomes demonstrated that the corresponding NPs have an antifungal impact on *Fusarium*. Bramhanwade, Shende (22) found concurrent outcomes when employing Cu nanoparticles to combat *F. equiseti, Fusarium. Fusarium c.,* and *F. oxysporum* were chosen as the three different crop harmful fungus against which the in vitro antifungal efficacy of produced copper NPs was investigated. It's interesting to note that the investigated crop pathogenic fungus was effectively combated by copper nanoparticles. Amphotericin B was employed as a typical antifungal drug for antifungal action. The zone of inhibition for copper nanoparticles against *F. equiseti* was 25 mm in diameter, with *F. culmorum* (19 mm) and *F. oxysporum* (20 mm) following closely after. The Kirby-Bauer disk diffusion method was used to assess the antifungal activity (23). Three duplicates of the research were kept on file. In vitro antifungal action of chemically produced copper NPs in combination with the commercial antifungal drug Bavistin was also reported by Kanhed, Birla (24) against four different plant pathogenic fungus, including *P. destructive, F. oxysporum, A. alternata,* and *C. lunata.* All of the plant pathogenic fungus that was used in their research was actively inhibited by copper nanoparticles. To find out the antifungal characteristics, Kasana, Panwar (25) created copper nanoparticles in a range of diameters from 5 to 280 nm. Copper

nanoparticles produced biologically exhibit potent antifungal properties that stop the spread of dangerous fungus. It has also been observed that copper nanoparticles have antifungal efficacy against the pathogenic fungus *Phytophthora infestans, Fusarium culmorum, Fusarium graminearum,* and *Fusarium oxysporum*. The current study's findings indicate that the NPs had no impact on *Rhizopus* growth.

It was tested on *Klebsiella pneumonia, Bacillus subtillis,* and *E. coli* for antibacterial activity. Five concentrations (20 mg, 40 mg, 60 mg, 80 mg, and 100 mg) of Cu-doped manganese oxide nanoparticles were tested for antibacterial action by using the disk diffusion method, and seven antibiotics (Levofloxacin, Norfloxacin, Gentamicin, Chloramphenicol, Trimethoprim, Amoxicillin, and Ciprofloxacin) were tested using the same technique. The antibiotic levofloxacine served as the standard. Nanoparticles have a negligible impact on the growth inhibition of *Klebsiella pneumonia*. Nanoparticles were utilized at four different doses (0.025, 0.05, 0.075, and 0.1) to perform antibacterial activity on *Bacillus subtilis* and *E. coli.* In this activity, ciprofloxacin served as a positive control. *Bacillus subtilis* did not exhibit a zone of inhibition at doses of 0.025 or 0.05, and its zone of inhibition peaked at 0.1. The similar zone of inhibition was present in *E. coli* at doses of 0.025, 0.075, and 0.1, with a maximum at 0.05. The outcomes demonstrated that nanoparticles of manganese oxide doped with Cu have an antibacterial impact. Trimetal oxide nanocomposite reportedly exhibits strong anti-Escherichia coli activity, according to Mir Alam, Al Qahtani (20). The outcomes of the bactericidal rate of several Cu-doped materials were reported by Cui, Wu (26). A high amount of antibacterial action is indicated by the bactericidal rate value. The bactericidal rate in Cu-doped samples was substantially higher at 15 minutes than it was in the pure MgO sample. According to Renné, Lindner (27) PAA-CuI nanoparticles are a useful addition to glass ionomer-based products since they significantly boost the antibacterial properties of those materials. Using optical density at 600 nm and a comparison of the size of the inhibitory zone diameter, Samavati, Ismail (28) reported the antibacterial action of the Cu-doped ZnO NPs generated by the sol-gel method against *Escherichia coli* (Gram negative bacterium) cultures. It is discovered that ZnO nanoparticles, whether pure or doped, exhibit adequate antibacterial activity, which increases with Cu doping.

Nanoparticles were utilized at four different doses (0.025, 0.05, 0.075, and 0.1) to perform antibacterial activity on *Bacillus subtilis* and *E. coli*. In this activity, ciprofloxacin served as the positive control. *Bacillus subtilis* did not exhibit a zone of inhibition at doses of 0.025 or 0.05, and its zone of inhibition peaked at 0.1. The similar zone of inhibition was present in *E. coli* at doses of 0.025, 0.075, and 0.1, with a maximum at 0.05. The outcomes demonstrated that nanoparticles of manganese oxide doped with Cr have an antibacterial impact. Alam, Al Qahtani (20) used the trimetal oxide nanocomposite, which exhibited strong antibacterial activity against *Escherichia coli*. In order to evaluate the antibacterial properties of silver nanoparticles, Keshari, Srivastava (21) created them. Using the bacterial growth inhibition approach, the bacteriostatic and bactericidal activity of silver nanoparticles against *Escherichia coli* was assessed. Silver nanoparticles' antibacterial potency and Minimum Inhibitory Concentration (MIC) were calculated for the bacteria. The MIC value of silver nanoparticles was 8 mg/ml (*E. coli*) (21).

Conclusion

In conclusion, the antibacterial potential of the nanoparticles was evaluated against *Klebsiella pneumoniae, Bacillus subtilis,* and *E. coli*. The growth of *E. coli* and *Bacillus subtilis* was inhibited by the nanoparticles. The antifungal potential was assessed against *Fusarium* and *Rhizopus*, with the nanoparticles inhibiting the growth of *Fusarium* but showing no effect on *Rhizopus*. The antioxidant activity of the nanoparticles was compared with that of ascorbic acid, and the results confirmed that the nanoparticles possess greater antioxidant properties than ascorbic acid. Overall, the findings indicate that copper and chromium nanoparticles exhibit significant antioxidant, antibacterial, and antifungal properties.

List of abbreviations

Fourier Transform Infrared: FTIR

Manganese oxide: MnO

Chromium oxide: CrO_3

Barium chloride: BaCl2

Sulphuric acid: H2SO4

2, 2-diphenyl-1-picrylhydrazyl: DPPH

Copper: Cu

Chromium: Cr

Nanoparticles: NPs

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Ethics Approval and Consent to Participate

The study was conducted in accordance to the declaration of Helsinki. The consent of publication was obtained.

Human and Animal Rights

The study followed the tents of human and animal rights.

Conflict of Interest

None

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