Nigerian Research Journal of Chemical Sciences (ISSN: 2682-6054)
Volume 14, Issue 1, 2026

Efficacy of Silver Nanoparticles for Microbial Removal in Meat and Poultry Processing Wastewater

*[1]Aondoakaa Steve Nomor, [1]Faith Favan Girgir, [2]Dooshima Shiriki
[1]Department of Chemistry, Rev. Fr. Moses Orshio Adasu University, Makurdi
[2]Department of Biological Sciences, Rev. Fr. Moses Orshio Adasu University, Makurdi
*Corresponding author: snomor@bsum.edu.ng; nomorsteve@gmail.com

Accepted: *January 17, 2026.* **Published Online**: *January 23, 2026*

ABSTRACT

This study assessed the efficacy of silver nanoparticles (AgNPs) in treating meat and poultry processing wastewater. The AgNPs were synthesized via chemical reduction method, and characterized using ultraviolet-visible (UV-Vis) spectroscopy and scanning electron microscopy (SEM). The UV-Vis results confirmed the successful synthesis of AgNPs, with a surface Plasmon resonance peak at 425 nm. The SEM analysis revealed significant agglomeration and a rough surface morphology, beneficial for pollutant adsorption and microbial interaction. Pre-treatment analysis of the wastewater revealed high microbial loads, including bacteria (*coliforms*, *staphylococci*) and fungi. Aerobic plate count (APC) of 3.3 x 10^7 CFU/mL was observed for raw poultry wastewater inoculated on nutrient agar (NA) and serially diluted to 10^{-6} after 48 h of incubation. Post-treatment results demonstrated significant reduction in microbial counts across all tested media. An APC count of 1 x 10^5 CFU/mL at 10^{-5} serial dilution over the same duration of incubation was recorded for poultry wastewater after treatment with AgNPs. Therefore, the efficacy of silver nanoparticles in treating meat and poultry wastewater provides an alternative way of recycling wastewater for drinking, and of reducing environmental pollution from the meat and poultry sector of the food industry.

Keywords: Contamination, culture media, microbiological analysis, silver nanoparticles, synthesis.

INTRODUCTION

The rise in the world's population has increased demand for clean drinking water, making this essential resource scarcer. The pollution of aquatic bodies, particularly wastewater from the meat and poultry processing industries, exacerbates this problem even further [1]. Innovative solutions are crucial since conventional water treatment techniques are finding it difficult to keep up with the growing demand.

The incorporation of nanoparticles, especially silver nanoparticles, has become a potential remedy for this dilemma. AgNPs have outstanding antibacterial qualities, which enable them to effectively eradicate microorganisms from wastewater. Research has demonstrated the effective use of AgNPs in a variety of applications, such as the elimination of harmful bacteria from wastewater [2]. In addition to being effective, the use of AgNPs in water treatment is also relatively environmentally friendly. The high efficiency of AgNPs, which is a result of their vast surface area, makes them more effective at removing pollutants. Wastewater from the processing of meat and poultry has a complicated composition, having high levels of biogenic materials, blood remnants, and organic matter, all of which add to its pollutant load. Additionally, it has high levels of biochemical oxygen demand, indicating the presence of organic components that decompose naturally and require oxygen to do so; like proteins, lipids, and carbohydrates. Effective separation techniques are required during treatment since the wastewater frequently contains suspended particles (animal tissues, grease, and fat). The industry frequently finds that the microbiological contamination present in these effluents cannot be adequately addressed by the traditional wastewater treatment techniques [3] which culminate in the use of chlorine for disinfection. As a result, there is a strong demand for creative and effective methods to lessen the negative environmental effects of wastewater.

The processing of meat and poultry is an important aspect of the world's economy and food production. In Nigeria, in particular, it is a major factor in supplying protein to country's expanding population. But this industry's growth has also resulted in a concerning rise in wastewater production, creating a complex environmental problem. Meat and poultry processing industries release untreated or insufficiently treated effluents into water bodies, which negatively impact aquatic ecosystems and may jeopardize human health [2]. The presence of various contaminants and possibly pathogenic bacteria in wastewater from the processing of meat and poultry is one of the main causes for concern [3]. The continued presence of these pollutants directly endanger aquatic life, and the possible spread of dangerous germs via water sources could have detrimental effects on public health [4]. A wide variety of microorganisms, including bacteria, viruses, and parasites, are present in the wastewater produced during the processing of meat and poultry [5].

The potential for these bacteria to cause aquatic and food borne infections makes them especially dangerous [3].

The procedures of sedimentation, filtration, and floatation are used to remove solid particles in physical treatment. Although these techniques are good at lowering suspended particles, they might not be able to sufficiently address microbiological pollutants, which would call for additional treatment strategies [5]. Coagulants and flocculants are frequently used in chemical treatments to improve the removal of organic materials and suspended solids. Although these techniques help to lower the overall pollution load, their effectiveness in limiting harmful bacteria varies and may call for further precautions. Microorganisms are used in biological treatments to decompose organic materials [1]. Anaerobic digestion and activated sludge techniques are frequently employed to reduce the organic content of wastewater. These techniques can be useful in lowering biochemical oxygen demand (BOD), but they might not always result in the appropriate degrees of microbial disinfection.

The antibacterial characteristics of silver nanoparticles stem from their capacity to discharge silver(I) ions (Ag^{+}), which engage in interactions with the intracellular components and cell membranes of microorganisms. This contact causes cellular integrity to be disrupted, which impedes essential cellular functions and results in microbial death. AgNPs have proven effective against a wide range of microorganisms, such as fungi, viruses, and bacteria [4]. Their antimicrobial action is facilitated by production of reactive oxygen species (ROS), which induce oxidative stress, and disrupt microbial cell signaling. Silver nanoparticles (AgNPs), are a potential new class of nanomaterials with a wide range of uses, especially in environmental remediation [5]. High surface area, reactivity, and stability are some of their distinctive physicochemical qualities that make them appealing for treating microbial contamination in a variety of contexts, including wastewater treatment.

A number of investigations have demonstrated the exceptional antibacterial efficacy of AgNPs in waste water treatment. Research conducted by scientists showed that AgNPs have strong bactericidal action against common waterborne pathogens including S*taphylococcus aureus* and *Escherichia coli*. It has been regularly found that AgNPs can damage microbial cell membranes and impair cellular activities in a variety of microbial strains [6].

Wadata market is a major centre for meat and poultry production in Makurdi, the Benue State capital, from where the effluents are channeled into River Benue, the major source of water for the populace. In spite of studies conducted on this subject elsewhere, no comprehensive study has been conducted to quantify the pollution levels of wastewater discharged from this sector of the food industry. The lack of such an empirical data creates a critical gap in understanding the magnitude of pollution associated with meat and poultry production in this locality.

Other researchers [7, 8] have also looked at the potential benefits of integrating AgNPs with conventional wastewater treatment techniques to enhance synergistic effects. AgNP-enhanced coagulation-flocculation and activated sludge treatment methods demonstrated improved removal of chemical and microbiological pollutants. These results point to the possibility of enhancing overall efficacy by including AgNPs into current treatment infrastructures. Despite the fact that AgNPs have demonstrated efficient microbial control, questions have been raised about possible eco-toxicity and the release of silver ions into the environment. In order to evaluate the overall environmental sustainability of AgNPs, it is essential to comprehend their fate and transport in treated wastewater [9, 10]. Research has been done to improve AgNP synthesis and dosage for wastewater treatment. AgNP performance and possible toxicity can be adjusted by regulating their size, shape, and stability. These investigations provide insightful information about how to create ideal circumstances for real-world applications [11, 12].

The aim of this study was to investigate the potency of silver nanoparticles in eliminating microorganisms in meat and poultry processing wastewater from the slaughterhouse in Wadata market of Makurdi metropolis, Benue State, Nigeria. The objectives of the study were to: (i) synthesize and characterize silver nanoparticles (ii) ascertain the baseline microbial load in wastewater from meat and poultry processing and (iii) apply the as-prepared silver nanoparticles to treat the wastewaters.

MATERIALS AND METHODS

Reagents

Silver nitrate, $AgNO_3$ (>98% purity) and trisodium citrate dihydrate ($Na_3C_6H_5O_7.2H_2O$) (>98% purity), both of Molychem India were used as purchased, without further treatments.

Preparation of silver nanoparticles

Silver nanoparticles used in this study were synthesized using the citrate reduction method of Lee and Meisel [13] with modification by scaling down by a factor of 5. Briefly, a 5 mM concentration of $AgNO_3$ was prepared by dissolving 0.0849 g of silver nitrate in 100 mL of distilled water (distilled water was used in the absence of nano pure water) and the mixture brought to the boil.

To the boiling solution, 2 mL of 1% tri- sodium citrate dihydrate solution (prepared by dissolving 0.1 g of the salt in 10 mL of distilled water) was added drop wise using a dropping pipette. Greenish-yellow AgNPs (Plate 1) were formed in about ten minutes of addition of sodium citrate. The equation for the citrate reduction of silver nitrate is given as:

$$2Ag^{+} + C_6H_5O_7^{3-} \rightarrow 2Ag + C_5H_4O_5^{2-} + H^{+} + CO_2 \quad (1)$$

Plate 1: Freshly synthesized 5 mM silver nanoparticles

Characterization of chemically synthesized silver nanoparticles

UV-Vis spectroscopy

Absorption spectrophotometry was carried out by the method of Khaydarov *et al* [14] using a Genesys 150 Thermo Scientific spectrophotometer. The spectrophotometer was put on and allowed to warm for at least 15 minutes after which it was calibrated with distilled water as blank. The sample (2 mL) was measured into a cuvette, placed in the spectrophotometer and scanned across 300 nm -700 nm to capture the absorption spectrum. The surface Plasmon resonance peak was identified at 425 nm, confirming the presence of AgNPs.

Scanning electron microscopy

Scanning electron microscopy was conducted following the method of Goldstein [15] using the SEM model Phenom ProX G6 of Thermos Fischer Scientific, Phenom World, Eindhoven, The Netherlands. The sample was placed on double adhesive tape on a sample stub and coated with 5 nm of gold using a sputter coater (Model Q150R by Quorum Technologies). The sample was then placed in the chamber of the SEM machine, where it was viewed via NaVCaM for focusing and minor adjustments. It was subsequently transferred to SEM mode for further focusing and automatic brightness and contrast adjustment. The morphologies at different magnifications were recorded and stored.

Microbiological Analysis

Sample collection

Sterilized sample bottles were used to collect two samples each of meat and poultry processing wastewater from Wadata market, in Makurdi, Benue State. The samples were collected from the butchered meat and poultry wash water from the wash bowl. The samples had foul odour.

Culture media and their preparation

The media used in this study include nutrient agar [(NA) TM media 341, ISO 13485:2016, India)], eosin methylene blue (EMB) agar (TM media 371, ISO 9001:2015, India), mannitol salt agar [(MSA) TM media 206, ISO 11133:2014, India], and sabouraud dextrose agar[(SDA) TM media 387, ISO 9001:2015, India]. All the media were prepared and sterilized according to the manufacturer's instructions.

Wastewater treatment for meat and poultry

The method of Adesemoye *et al* [16] was adopted for the treatments. This involved the addition of the chemically synthesized silver nanoparticles to the wastewater samples in the ratio of 10:25 (2:5) by volume, that is, 10 mL of AgNPs to 25 mL of the wastewater batch. The treated wastewater was left to stand for 5 h after which sediments were observed to have settled at the bottom of the beaker. The supernatants were decanted into other beakers and serial dilution was carried out on all the treated samples. The respective media were prepared and used accordingly for sample inoculation adapting the pour plate method. The inoculated samples were allowed to set and incubated. Observations were made after 24 hours and 48 hours of incubation for the bacteria. The fungi plates (SDA media) were incubated for up to five days with daily observation to ascertain the emergence of molds and yeast; their counts recorded appropriately. It was observed that the treated wastewater had less odour and was clearer than the raw samples.

RESULTS AND DISCUSSION

The UV-Vis spectrum for the characterization of synthesized silver nanoparticles is presented in Figure 1.

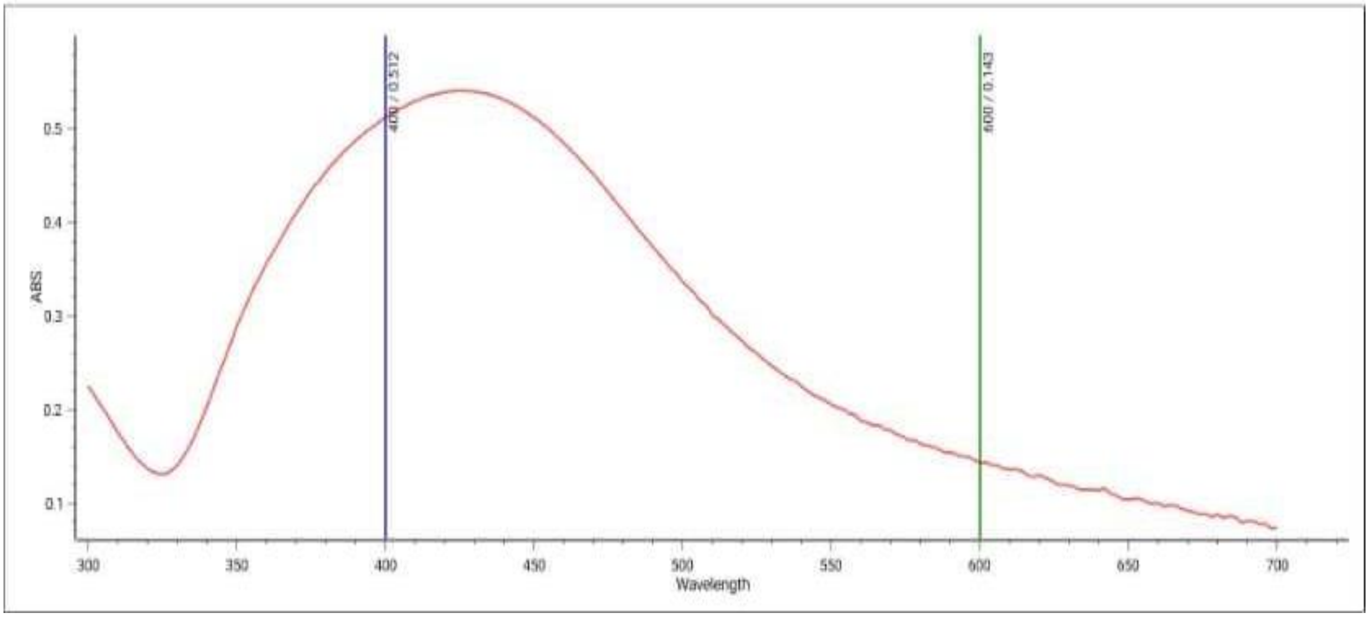
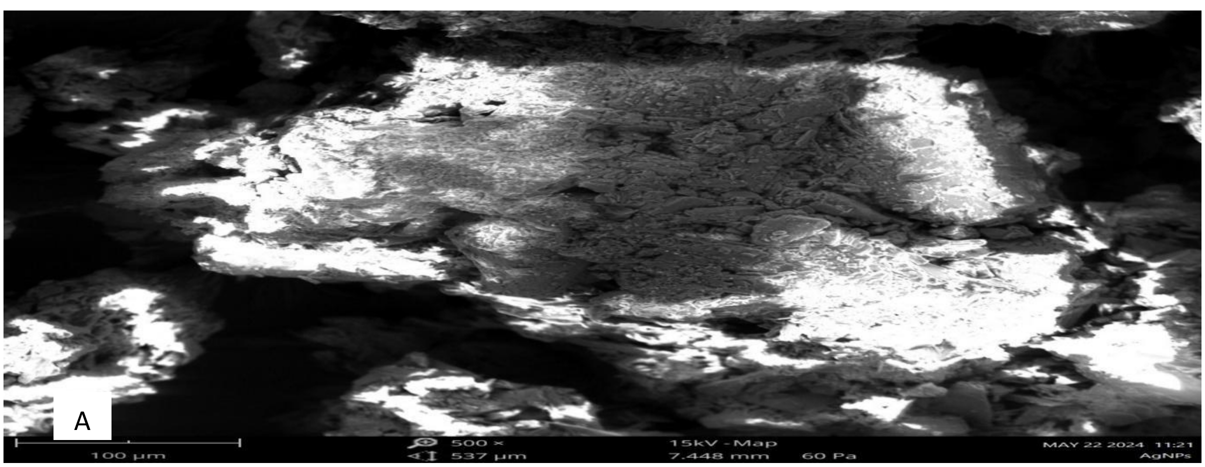


Figure 1: UV-Vis spectrum of 5 mM AgNPs after 72 h of preparation. The spectrum was obtained on GENESYS 150 model, in the wavelength range of 300 – 700 nm.

Characterization using scanning electron microscopy (SEM)

The SEM images of the nanoparticles are presented in Figure 2 (A &B).



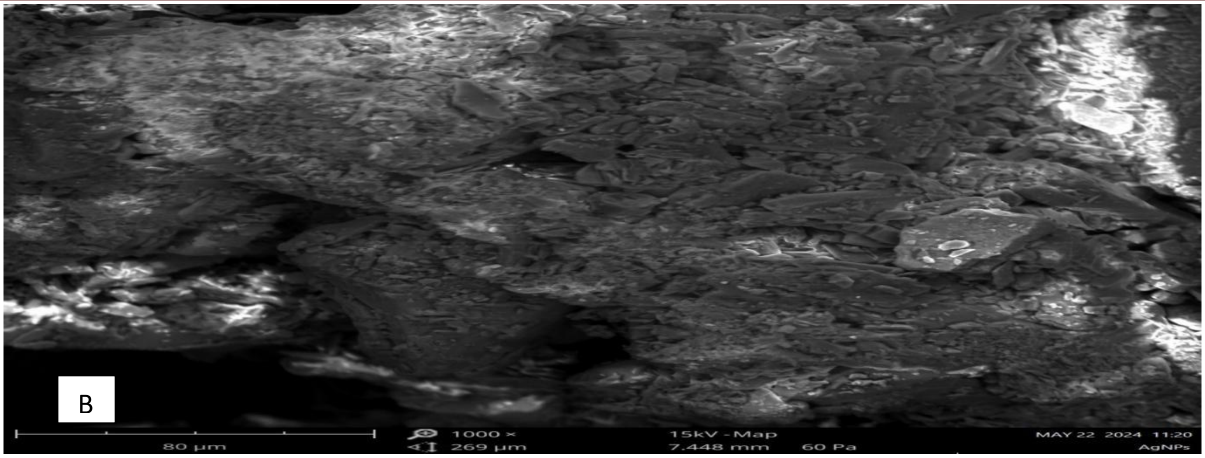


Figure 2: A & B: Images of SEM at a magnification of (A) 500x and (B) 1000x respectively

Image details: Image 2A: 500x magnification, scale bar: 100 µm, field of view: approx. 537 µm

Image 2B: 1000x magnification, scale bar: 80 µm, field of view: approx. 269 µm

Pre-treatment results from the meat and poultry processing wastewater with the four media

In estimating total microbial load, the number of organisms on the plates with distinct growth was counted after incubation. Fungal and bacterial population were then estimated and recorded as colonies per dilution power after 24 h and 48 h of the pre-treatment as presented in Tables 1 – 4.

Table 1: Total aerobic bacteria count from nutrient agar (NA) in pre-treatment analysis.

Duration (h)	Sample	CFU/mL					
		10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}
24	RWWM	Too numerous to count	9.5×10^3	8.6×10^4	6.2×10^5	4.0×10^6	3.1×10^7
48	RWWM	Too numerous to count	9.7×10^3	9.0×10^4	6.7×10^5	4.3×10^6	3.6×10^7
24	RWWP	Multiple growths	8.8×10^3	7.8×10^4	5.9×10^5	4.7×10^6	3.0×10^7
48	RWWP	Multiple growths	9.1×10^3	7.9×10^4	6.2×10^5	5.1×10^6	3.3×10^7

Key: RWWM = Raw wastewater of meat; RWWP = Raw wastewater of poultry

Table 2: Pre-treatment analysis of *coliform* count from eosin-methylene blue agar (EMB)

Duration (h)	Sample	CFU/mL					
		10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}
24	RWWM	Too numerous to count	Too numerous to count	1.21 x 10^5	9.9 x 10^5	8.4 x 10^6	6.7 x 10^7
48	RWWM	Too numerous to count	Too numerous to count	1.27 x 10^5	1.03 x 10^6	8.9 x 10^6	7.1 x 10^7
24	RWWP	9.7 x 10^2	7.9 x 10^3	6.8 x 10^4	5.7 x 10^5	5.2 x 10^6	3.0 x 10^7
48	RWWP	1.0 x 10^3	8.0 x 10^3	7.1 x 10^4	6.1 x 10^5	5.5 x 10^6	3.2 x 10^7

Key: RWWM = Raw wastewater of meat; RWWP = Raw wastewater of poultry

Table 3: *Staphylococcus* count from mannitol salt agar (MSA) before treatment

Duration (h)	Sample	CFU/mL					
		10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}
24	RWWM	Too numerous to count	1.14 x 10^4	9.1 x 10^4	8.2 x 10^5	6.1 x 10^6	4.0 x 10^7
48	RWWM	Too numerous to count	1.17 x 10^4	9.2 x 10^4	8.4 x 10^5	6.3 x 10^6	4.3 x 10^7
24	RWWP	8.0 x 10^2	7.7 x 10^3	6.1 x 10^4	5.6 x 10^5	4.3 x 10^6	3.9 x 10^7
48	RWWP	8.5 x 10^2	7.9 x 10^3	6.6 x 10^4	5.9 x 10^5	4.4 x 10^6	3.9 x 10^7

Key: RWWM = Raw wastewater of meat; RWWP = Raw wastewater of poultry

Table 4: *Fungal, yeast and mold* count from sabouraud dextrose agar (SDA) before application of AgNPs

Duration (h)	Sample	CFU/mL					
		10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}
54	RWWM	1.3 x 10^2	1.1 x 10^3	7.0 x 10^1	1.0 x 10^4	-	-
72	RWWM	2.2 x 10^2	1.8 x 10^3	1.7 x 10^4	1.0 x 10^5	9.0 x 10^5	5.0 x 10^6
54	RWWP	1.9 x 10^2	6.0 x 10^2	4.0 x 10^3	3.0 x 10^4	2.0 x 10^5	1.0 x 10^6
72	RWWP	2.0 x 10^2	1.4 x 10^3	1.0 x 10^4	7.0 x 10^4	6.0 x 10^5	5.0 x 10^6

Key: RWWM = Raw wastewater of meat; RWWP = Raw wastewater of poultry

Post-treatment results from the meat and poultry processing wastewater with the four media.

The AgNPs showed antimicrobial activity against all microorganisms. In samples exposed to silver nanoparticles, growth inhibition was observed; varying from partial to almost total, compared with untreated controls as presented in Tables 5 - 8.

Table 5: Post-treatment analysis of the total aerobic bacteria count from nutrient agar (NA).

Duration (h)	Sample	CFU/mL					
		10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}
24	TMWW	4.0×10^{1}	2.0×10^{2}	1.0×10^{3}	1.0×10^{4}	1.0×10^{5}	-
48	TMWW	2.8×10^{2}	8.0×10^{2}	4.0×10^{3}	3.0×10^{4}	2.0×10^{5}	1.0×10^{4}
24	TPWW	7.0×10^{1}	5.0×10^{2}	4.0×10^{3}	1.0×10^{4}	-	-
48	TPWW	1.1×10^{2}	7.0×10^{2}	4.0×10^{3}	3.0×10^{4}	1.0×10^{5}	-

Key: TMWW = Treated meat wastewater; TPWW = Treated poultry wastewater

Table 6: *Coliform* count from eosin-methylene blue agar (EMB) after the application of AgNPs

Duration (h)	Sample	CFU/mL					
		10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}
24	TMWW	7.0×10^{1}	3.0×10^{2}	-	-	-	-
48	TMWW	1.2×10^{2}	7.0×10^{2}	-	-	-	-
24	TPWW	-	-	-	-	-	-
48	TPWW	1.1×10^{1}	-	-	-	-	-

Key: TMWW = Treated meat wastewater; TPWW = Treated poultry wastewater

Table 7: *Staphylococcus* count from mannitol salt agar (MSA) in post-treatment analysis

Duration (h)	Sample	CFU/mL					
		10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}
24	TMWW	130	700	4.0×10^{3}	3.0×10^{4}	-	-
48	TMWW	200	1300	8.0×10^{3}	5.0×10^{4}	3.0×10^{5}	-
24	TPWW	-	-	-	-	-	-
48	TPWW	21	200	-	-	-	-

Key: TMWW = Treated meat wastewater; TPWW = Treated poultry wastewater

Table 8: Analysis of *Fungal, yeast and mold* count from sabouraud dextrose agar (SDA) after treatment with AgNPs

Duration (h)	Sample	CFU/mL					
		10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}
54	TMWW	20	-	1000	-	-	-
72	TMWW	20	100	1000	-	-	-
54	TPWW	-	-	-	-	-	-
72	TPWW	10	100	-	-	-	-

Key: TWWM = Treated meat wastewater; TPWW = Treated poultry wastewater

Interpretation of UV-Vis spectroscopy results

The UV-Vis spectrum provided showed an absorption peak at 425 nm after 72 h of synthesis, confirming the stability of the nanoparticles. This absorption peak is characteristic of silver nanoparticles (AgNPs) due to the surface Plasmon resonance (SPR) which arises from the collective oscillation of free electrons on the nanoparticle surface when exposed to light, which typically appears in the range of 400 nm - 450 nm.

The absorbance at a shorter wavelength (red shift) has higher energy than the absorbance at a longer wavelength (blue shift) which has a lower energy. The higher absorbance at 425 nm supports the presence of AgNPs and the absorbance values at 400 nm and 600 nm further support the presence of well-dispersed nanoparticles. Khaydarov and co-workers [14] reported SPR peaks around 420 nm for silver nanoparticles synthesized using various methods, aligning with the results in this research. Similar absorbance patterns were observed in studies by Song & Kim [17], who reported strong SPR peaks for AgNPs synthesized via chemical reduction methods.

Interpretation of SEM images

Significant agglomeration which can reduce the effective surface area of nanoparticles, hence impact their reactivity and interaction with contaminants in wastewater treatment can be observed in both images of Figure 2. This common challenge of agglomeration of AgNPs [18] could be due to inadequate stabilization, which suggests an increase in the amount of stabilizing agent for increased antimicrobial activity.

Morphology and effectiveness in wastewater treatment is another important feature of the SEM images. The rough and irregular surface may enhance the adsorption of pollutants from wastewater due to increase in active sites. This finding is in agreement with those of Kora & Arunachalam [19] who highlighted that the rough surface morphology and high surface area of silver nanoparticles contribute significantly to their ability to adsorb and degrade pollutants in wastewater. The crystalline structures seen in the image of higher magnification indicates that the nanoparticles have regions of crystalline order, beneficial for certain catalytic and antimicrobial properties.

In terms of size, individual nanoparticles are not clearly discernible due to agglomeration, but the images suggest that individual particles could be much smaller. Pal et al [20] indicated that smaller, well-dispersed AgNPs exhibit higher antimicrobial activity due to the larger surface area to volume ratio, which allows for more efficient interaction with microbial cells. This viewpoint, which forms the general basis for the application of nanoparticles is relevant to this study as optimizing particle size could enhance the effectiveness of AgNPs in wastewater treatment, especially for future studies.

Microbiological analysis of pre-treatment results

Pre-treatment results show high microbial counts in both meat and poultry processing wastewater samples across all media types, indicating contamination with bacteria, *coliforms, Staphylococcus, and fungi* (Tables 1 – 4). This trend, reported elsewhere [21] suggests that meat and poultry wastewater can be positive to tests based on indicators of pathogenic microorganisms derivable from the meat and poultry contamination with the pathogens. Plate counts ranged from "too numerous to count" to many colonies per dilution power. The high microbial loads in untreated meat and poultry processing wastewater poses a significant risk to public health, as these microorganisms may include pathogens capable of causing food borne illnesses. The presence of *enterobacteria* and *coliforms* indicates faecal contamination, highlighting poor hygiene practices or inadequate wastewater treatment in the processing facilities [22, 23]. Staphylococcus counts suggest potential skin or respiratory tract contamination, which could occur during handling or processing of meat and poultry products. Fungal contamination may arise from environmental sources or inadequate sanitation measures within the processing facilities [24]. These results are consistent with existing literature on the microbial load in wastewater from meat and poultry processing facilities, highlighting the need for effective treatment methods [25]. The results highlight the critical necessity for efficient wastewater treatment plans in facilities that process meat and poultry in order to reduce microbiological contamination and guarantee food safety.

Implementing stringent hygiene practices and proper sanitation protocols can help prevent microbial contamination at various stages of processing. Regular monitoring of wastewater quality is essential to identify potential sources of contamination and prevent food borne outbreaks.

Post-treatment results

Antibacterial efficiency of chemically synthesized AgNPs were studied against *Enterobacterocae, coliform, Staphylococcus, fungal, yeast and molds using* four media, spread plate technique and pour plate method. The reduction in microbial load is shown in Tables 5 – 8. It was shown that AgNPs nanoparticles were effective against microorganisms. These results are consistent with the literature, where the ability of nanoparticles to significantly inhibit microorganisms of different types is reported [22 - 26]. It was reported that the AgNPs activity strongly damaged the bacteria membranes leading to cell death. Asadi & Moenpour [27] studied the antibacterial effect of silver nanoparticles on bacteria from wastewater and reported that silver nanoparticles are efficient in eliminating bacteria. The results showed that bacterial elimination efficiency intensified through increasing the amount of nanoparticles. Increasing the amount or concentration of nanoparticles therefore boosts the elimination of bacteria.

These results are consistent with the literature, where the ability of nanoparticles is reported to significantly inhibit microorganisms of different types [22]. The observed growth inhibition suggests that silver nanoparticles effectively target and inhibit the growth of bacteria, fungi, and other microorganisms present in the wastewater samples.

The ability of AgNPs to exert antimicrobial activity against multiple microbial species highlights their potential utility as a disinfection agent in wastewater treatment processes. Samples treated with AgNPs exhibited significant growth inhibition compared to untreated controls, indicating the effectiveness of silver nanoparticles in reducing microbial contamination even of thermophilic bacteria that thrive in the temperature range of 40 ℃ to 120 ℃ [26].

Silver nanoparticles show promise as a novel approach for wastewater treatment in meat and poultry processing facilities, offering a cost-effective and environmentally friendly solution to microbial contamination [28]. Further research is warranted to optimize the dosage and application of AgNPs in wastewater treatment processes, ensuring maximum efficacy while minimizing potential adverse effects on human health and the environment [29].

The research results indicate significant microbial contamination in untreated meat and poultry processing wastewater, highlighting the need for effective treatment measures to meet environmental standards and ensure public health protection [29, 30].

The findings in this research support existing literature on the microbial contamination challenges in meat and poultry processing wastewater and highlights the potential of AgNPs as an effective antimicrobial agent for wastewater treatment in these industries. Studies have shown that AgNPs can be successfully employed in wastewater treatment processes to reduce microbial contamination and improve water quality, offering a sustainable solution to address microbial pollution in food processing wastewater [31 - 35].

The use of AgNPs in meat and poultry processing wastewater treatment aligns with the growing interest in nanotechnology-based solutions for environmental remediation and food safety applications, reflecting ongoing efforts to innovate and improve existing wastewater treatment technologies [36, 37].

CONCLUSION

This study investigated the efficacy of silver nanoparticles (AgNPs) in eliminating microorganisms in meat and poultry processing wastewater. The synthesis and characterization of AgNPs were confirmed through UV-Vis spectroscopy and scanning electron microscopy (SEM), demonstrating the successful production of well-dispersed nanoparticles with significant antimicrobial properties. The SEM images show that the synthesized silver nanoparticles are effective in treating wastewater, as evidenced by their surface morphology and agglomeration behaviour. The comparison with existing literature supports the idea that optimizing synthesis parameters to reduce agglomeration and improve surface characteristics can further enhance the performance of AgNPs in environmental applications.

Pre-treatment analysis of the wastewater revealed high microbial loads, including bacteria, *coliforms, Staphylococcus,* and *fungi,* indicating substantial contamination. Post-treatment results showed a marked reduction in microbial counts across all tested media, affirming the potent antimicrobial activity of AgNPs. These findings align with existing literature, emphasizing the potential of AgNPs as effective agents for wastewater treatment.

This research underscores the importance of implementing robust wastewater treatment protocols in meat and poultry processing facilities to comply with environmental standards and protect public health. Adoption of innovative technologies like treatment with AgNPs can help achieve regulatory compliance and ensure sustainable water management practices in Nigeria.

REFERENCES

[1] Grosser, A., Pradhan, S.; Jena, B., Biswal, B.; Acharya, S. & Acharya, L. (2021). Effects of silver nanoparticles on performance of anaerobic digestion of sewage sludge and associated microbial communities. *Bioresource Technology Reports* 12.

[2] Kumar, I. & Bhattacharya, J. (2019). Assessment of the role of silver nanoparticles in reducing poultry mortality, risk and economic benefits. *Applied Nanoscience* https://doi.org/10.1007/s13204-018-00942-x

[3] De Silva, K.N., Fernando, S.S. & Weerasinghe, S.D. (2021). Comparative study on larvicidal activity of green synthesized silver nanoparticles and *Annona glabra* (Annonaceae) aqueous extract to control *Aedes albopictus*. *Journal of Applied Biology & Biotechnology*, 9(3).

[4] Daneshniya, M., Samani, R. J., Emamifar, A. & Alizadeh, M. (2020). Investigating the application of silver nanoparticles in active food packaging: Antimicrobial properties and synthesis methods. *Journal of Food Science and Technology*, 57(11).

[5] Zorraquín-Peña, I., Cueva, C., Bartolomé, B., Moreno-Arribas, M.V., (2020). Silver Nanoparticles against Foodborne Bacteria. Effects at Intestinal Level and Health Limitations. *Microorganisms*, 8, 132.

[6] Li, W., Xu, Q., Huang, R., Tang, J. & Yu, J., (2018). Characterization and antimicrobial activity of silver nanoparticles synthesized with the peel extract of mango. *Materials Chemistry and Physics*, 217.

[7] Kumara, P., Alam, M. & Siddiqi, W.A., (2019). Usage of nanoparticles as adsorbents for wastewater treatment: an emerging trend. *Sustainable Materials and Technologies* 22(3), e00128 DOI: 10.1016/j.susmat.2019.e00128

[8] Gupta, A., Tandon, M. & Kaur, A., (2020). Role of metallic nanoparticles in water remediation with special emphasis on sustainable synthesis: a review. *Nanotechnol. Environ. Eng.* 5, 27. https://doi.org/10.1007/s41204-020-00092-y

[9] Zhang, Y., Wu, F., Sajjad, W., Adnan, M., Wang, W., Bibi, N., Shah, K. & Yali, Z., (2021). Green synthesis of silver nanoparticles and their shortcomings: Animal blood as a potential source for silver nanoparticles: A review. *Journal of Cleaner Production*, 293.

[10] Jain, K., Patel, A.S., Pardhi, V.P. & Flora, S.J.S., (2021). Nanotechnology in Wastewater Management: A New Paradigm Towards Wastewater Treatment. *Molecules*, 26, 1797. https://doi.org/10.3390/ molecules26061797*

[11] Song, J.Y., Jang, H.K. & Kim, B.S., (2017). Biological synthesis of gold and silver nanoparticles using extracts of *Sasa borealis*. *Journal of Nanotechnology*, 18(10).

[12] Patel, K., Singh, R. & Patel, D. K., (2021). Biogenic synthesis of silver nanoparticles and their applications: A review. *Journal of Nanoscience and Nanotechnology*, 21(5).

[13] Lee, P.C. & Meisel, D., (1982). Adsorption and surface-enhanced Raman of dyes on silver and gold sols. *Journal of Physical Chemistry*, 86, 3391 - 3395

[14] Khaydarov, R. R., Khaydarov, R. A., Gapurova, O., Estrin, Y. & Scheper, T., (2009). Electrochemical method for the synthesis of silver nanoparticles. *Journal of Nanoparticle Research*, 11.

[15] Goldstein, J. I., Newbury, D. E., Michael, J. R., Ritchie, N. W.M., Scott, J. H.J, & Joy, D. C., (2017). *Scanning Electron Microscopy and X-ray Microanalysis*, 4th ed. Springer.

[16] Adesemoye, A.O., Opera, B.O. & Makinde, S.C.O. (2006). Microbial content of abattoir wastewater and its contaminated soil in Lagos, Nigeria. *Afri. J. Biotechnol*. 5(20),1963-1968.

[17] Song, J.Y. & Kim, B.S., (2009). Rapid biological synthesis of silver nanoparticles using plant leaf extracts. *Bioprocess and Biosystems Engineering*, 32(1).

[18] Shah, T. & Saeed, K. (2020). Experimental study on silver nanoparticles: synthesis, photodegradation and analysis. *Journal of Advances in Science and Engineering* (3), 37 – 42 www.sciengtexopen.org/index.php/jase

[19] Kora, A.J. & Arunachalam, J., (2011). Assessment of Antibacterial Activity of Silver Nanoparticles on *Pseudomonas aeruginosa* and Its Mechanism of Action. *World J. Microbiol. Biotechnol*, 27, 1209–1216

[20] Pal, S., Tak, Y. K. & Song, J. M. (2007) Does the antibacterial activity of silver nanoparticles depend on the shape of the nanoparticle? A study of the gram-negative bacterium *Escherichia coli*. *Appl Environ Microbiol*, 73,1712–1720

[21] Mor-Mur, M. & Yuste, J. (2010) Emerging Bacterial Pathogens in Meat and Poultry: An Overview. *Food Bioprocess Technol*., 3, 24 – 35. DOI: 10.1007/s11947-009-0189-8

[22] Ahsan, M. I., Khan, M. B., Das, M. & Akter, S. (2020) Poor hygiene, facilities, and policiesat slaughterhouses: a key threat to public health and environment. Bangladesh Journal of Veterinary and Animal Sciences, 8(2), 1 – 9

[23] Saud, N., Tariq, S. & Ijaz, M., (2017). Detection and prevalence of *Staphylococcus aureus* in meat and meat products in Lahore, Pakistan. *Pakistan Journal of Zoology*, 49(2)

[24] Hansen, M., Sørensen, S., Giversen, T. & Mortensen, A., (2019). Microbial quality of meat from broilers slaughtered under various conditions. *Food Microbiology*, 77.

[25] Sohail M., Hume M. E., Byrd J. A, Nisbet D. J., Ijaz A., Sohail, A., Shabbir M. Z. & Rehman, H. (2012). Effect of supplementation of prebiotic mannan-oligosaccharides and probiotic mixture on growth performance of broilers subjected to chronic heat stress. *Poultry Science*, 91,2235–2240.

[26] Jahan, I., Matpan-Bekler, F., Tunç, A. & Güven, K., (2024). The Effects of Silver Nanoparticles (AgNPs) on Thermophilic Bacteria: Antibacterial, Morphological, Physiological and Biochemical Investigations. *Microorganisms*, 12(2), 402. https://doi.org/10.3390/ microorganisms12020402

[27] Asadi, S. & Moenpour, F., (2019). Inactivation of *Escherichia coli* in water by silver coated $Ni_{0.5}Zn_{0.5}Fe_2O_4$ magnetic nanocomposite: a Box–Behnken design optimization. *Applied Water Science*, 9,23. https://doi.org/10.1007/s13201-019-0901-4

[28] Morones, J. R., Elechiguerra, J. L. Camacho, A., Holt, K., Kouri, J.B., Ramírez, J. T. & Yacaman, M. J., (2005). The bactericidal effect of silver nanoparticles. *Nanotechnology*, 16, 2346 - 2353

[29] Rai, M., Yadav, A. & Gade, A., (2009). Silver nanoparticles as a new generation of antimicrobials. *Biotechnol Adv*. 27(1),76-83. http://dx.doi.org/10.1016/j.biotechadv.2008.09.002

[30] Shan, J., Li, X., Yang, K., Weijun, X., Wen, Q., Zhang, Y., Lihui, Y., Weng, L.; Teng, Z. & Wang, L., (2019). Efficient Bacteria Killing by Cu_2WS_4 Nanocrystals with Enzyme-like Properties and Bacteria-Binding Ability. *ACS Nano*, 13, 13797–13808.

[31] Sondi, I. & Salopek-Sondi, B., (2004). Silver Nanoparticles as Antimicrobial Agents: A Case Study on *E. coli* as a Model for Gram-Negative Bacteria. *J. Colloid Interf. Sci.*, 275, 177–182

[32] Kumarasamyraja, D. & Jeganathan, N.S., (2013). Green synthesis of silver nanoparticles using aqueous extract of *Acalypha indica* and its antimicrobial activity. *International Journal of Pharma and Bio Sciences* 4(3), 469 - 476

[33] Vural, A., Erka, M. E. & Yesilmen, S. (2006) Microbiological quality of retail chicken carcasses and their products in Turkey, *Madycyna Wet*. 62(12), 1371 - 1374

[34] Nel, A., Xia, T., Ma -¨dler, L. & Li, N. (2006) Toxic potential of materials at the nanolevel. *Science* 311, 622–627.

[35] Guzmán, M., Dille, J. & Godet, S., (2012). Synthesis and antibacterial activity of silver nanoparticles against gram-positive and gram-negative bacteria. *Nanomedicine*: *Nanotechnology*, *Biology and Medicine* 8(1), 37 - 45

[36] Schacht, V. J., Newmann, L. V., Sandhi, S. K., Chen, L., Henning, T., Klar, P. J., Theophel, K., Schnell, S. & Bungle, M. (2012) Effects of silver nanoparticles on microbial growth dynamics. *Journal of Applied Microbiology*, 114, 25 – 35.

[37] Kah, M., Beulke, S., Tiede, K. & Hofmann, T. (2013). Nanopesticides: State of knowledge, environmental fate and exposure modelling, *Critical Reviews in Environmental Science and Technology*, 43(16), 1823-1867. http://www.tandfonline.com/doi/abs/10. 1080/10643389.2012.671750.