Chapter 16

Role of Silver Nanoparticles in Poultry Health

Syed Muhammad Faizan[1], Zain ul Abadeen[2], Amalash Shakoor[3], Noman Yousaf Fridi[3], Tayyab Zafar[4] and Muhammad Asif Javed[1]

[1]Department of Pathology, Faculty of Veterinary Science, University of Agriculture, Faisalabad
[2]Department of Pathobiology, Riphah College of Veterinary Science, Riphah International University-Lahore Campus Raiwind Road, Lahore
[3]Directorate of Poultry Research Institute, Livestock and Dairy Development, Punjab Pakistan
[4]Department of Clinical Medicine and Surgery, Faculty of Veterinary Science, University of Agriculture Faisalabad.
*Corresponding author: syedfaizan3506@gmail.com

ABSTRACT

Poultry sector is one of the vibrant sectors all around the world and plays significant role in countries GDP. Pakistan is the 11th largest poultry meat-producing country and plays a significant role in countries GDP. Despite of this flourishing status and discriminatory position poultry sector suffers a lot due to certain challenges. Infectious disease such as viral bacterial and fungal diseases is the major concern for poultry industry. Among these infectious diseases, bacterial infection is the major problem that causes heavy economic losses due decrease in productivity. Furthermore, poultry sector suffers a lot in terms of high mortality and morbidity. To overcome the problem of bacterial infection antimicrobial agents are used commonly. Under dose, Excessive and absurd antibiotic usage in the poultry industry leads to antibiotic resistance. Due to ban on usage of the antimicrobial agents in some countries there is need to develop some alternative to antibiotics which can help to tackle the issue of antimicrobial resistance. Nanotechnology also helps to overcome the problem of multi drug resistance in the field of veterinary medicine particularly in poultry. Nanotechnology also considers as a novel tool to improve animal production and health status. Among metallic nanoparticles, silver nanoparticles are more suitable nanoparticles that can be used to overcome the challenge of antimicrobial resistance. Silver nanoparticles are less toxic and can be used against a variety of pathogenic organisms which have a harmful impact on the poultry industry.

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INTRODUCTION

The poultry sector is powerful all around the world. Along with that plays a vital role in the economy. The poultry industry is huge and can offer employment directly and indirectly to millions of people all over the world. In Pakistan, the current status of the industry indicates that the poultry industry produces more than 700 billion rupees. The poultry sector generated 177.9 billion rupees compared with in 2019 in which this industry generated about 99.9 billion rupees. In Pakistan, the annual production of broiler meat is around 2160 tonnes. The total contribution of broiler meat in the country is 35.5%. More than 15000 environmentally controlled poultry houses have been developed all over the country with capacities ranging from 5000 to 500,000 broilers. The per capita broiler meat consumption in Pakistan is about 51 kilograms (Pakistan Economic Survey, 2022-23). Regardless of this progressive status, the poultry sector suffers a lot due to various challenges. Infectious diseases are the foremost factors that cause mammoth monetary damage to the poultry industry due to morbidity and mortality. As a result of these problems, the cost of the treatment to tackle these infectious diseases problems has also been increased. Several viral and bacterial diseases are the main problems in the poultry industry (Logue et al., 2017). Antimicrobials are the agents are widely used in poultry industry for growth promotion, treatment and for disease control. Poor selection, overuse, and misuse of antimicrobial agents may lead to development of the antimicrobial resistance (Logue *et al.*, 2017). Antimicrobial resistance has been considered extensively in human, livestock and poultry products. Recently antimicrobial resistance is a global health challenge when the bacterial pathogen no longer responds to medicine, making infection tough for treatment. (Logue et al., 2017).

Nano medicine is the use of medical science in combination with nanotechnology. Nanotechnology is an advanced progress in the world of medical science that has various advantageous aspects. Nanotechnology is the branch that deals with particles of less than 100 nm. The word Nano is a Greek word that means dwarf. Nanotechnology is an important tool

of molecular biology and medicine because the process of life is maintained by a series of biological events at the molecular level in the cell machinery (Pinnada et al., 2012). Nanotechnology proves to be beneficial in the field of animal and human medicine practices. Nanotechnology is a revolutionary invention in the world of medicinal science. Nanotechnology has been used in the fields of diagnosis, DNA sequencing, gene therapy, and tissue engineering. Nanotechnology also helps to overcome the problem of multi-drug resistance in the field of veterinary medicine particularly in poultry (Daud et al., 2022). Nanotechnology also considered as a novel tool to improve animal production and health status (Bai et al., 2018). Along with that through nanotechnology, medical science found another way to overcome the challenge of multidrug resistance due to their broad-spectrum antimicrobial activity against bacteria and considered as an alternative strategy to combat with multidrug resistance problem.

Multidrug Resistance Problem in Poultry

Antimicrobial resistance is the resistance of the antimicrobial drug particularly used in poultry farming against dreadful microorganisms. Antibiotics are regularly used to control the propagation of the microorganism. Under dose, excessive and absurd antibiotic usage in the poultry industry leads to antibiotic resistance. Various pathogenic microorganisms showed resistance against antibiotics which are also used regularly in human beings on a large scale. Since 2006, the use of antimicrobial agents has been banned due to antimicrobial resistance problems by the European Union (EU) implemented Regulation (EC) No. 1831/2003, and legislation was implemented by food drug authority called Veterinary Feed Directive (VFD) drugs (Van et al., 2012; Chand et al., 2016). This results in the re-emergence of severe poultry diseases in European countries like Norway (Gangadoo et al., 2016). It was also noted that increased intestinal disorders was seen associated with removal of these feed additives and alternative strategies should be adopted (Sharma et al., 2021).

How Antimicrobial Resistance Problem Developed in Poultry

Antimicrobial agents usually used in poultry inhibit the propagation of the different bacterial populations by bactericidal substances (e.g. beta-lactams) or by killing the bacteria by bacteriostatic substances (e.g. macrolides). Antimicrobial resistance can be produced through chromosomal gene variation and can also be produced by acquiring resistant genes from different organisms. Treatment through antibiotics results interchanging of resistant elements both within and across bacterial growth that leads to formation, survival and proliferation of the bacteria (Kazemnia et al., 2014).

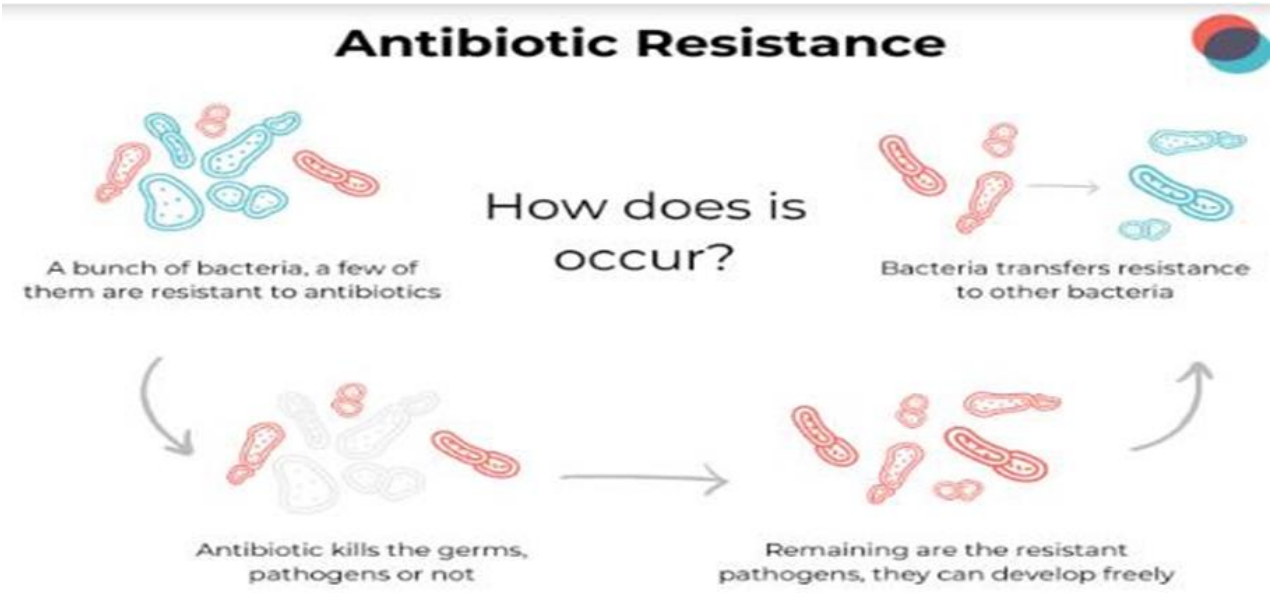

Fig. 1: The mechanism of development of the antibacterial resistance (https://www.labtoo.com/en/blog/antibiotic-resistance)

Use of Metal Nanoparticles as Antimicrobial agents in poultry

The usage of Metallic nanoparticles as an alternative to antimicrobial agents is a latest advancement in poultry farming to overcome the challenge of antimicrobial resistance. Metal nanoparticles are an important tool and possess antimicrobial abilities biosensing, cancer therapy, and bioimaging (Ge et al., 2014). Nanoparticles prepared from essential minerals are minor in dimension and have different physical and chemical properties. Due to their small size these nanoparticles are usually absorbed in an abundant amount in the gastrointestinal tract and produce their biological effect in the targeted tissues in animals. Metallic nanoparticles such as zinc oxide, copper oxide, and silver nitrate own durable antimicrobial properties and dreadful organisms that cause severe disease in poultry. Metal oxide nanoparticles produced strong antibacterial effects against lethal organisms such as *Salmonella,* and *Escherichia coli* which causes the problem in poultry (Sirelkhatim et al., 2015).

Silver Nanoparticles

Silver Nanoparticles are very Fine Particles of Silver

These particles are ten to a hundred nanometers outsized and vary from the silver as they have different colors such as yellow, as opposed to the silver. This is due to Plasmon absorbance. Incident light rays create oscillation in free electrons on the surface of nanoparticles, causing them to absorb electromagnetic radiation, creating different colors reflected (Daud et al., 2022).

Properties of Silver Nanoparticles

Silver (Ag) nanoparticles have enhanced physico-chemical properties. Ag nanoparticles are non-toxic compared to other metallic components. Along with that have high electrical and thermal conductivity. Highly stable and less cost-effective compared to gold and platinum. Chemically Ag nanoparticles are more stable and have enhanced catalytic activity. Ag nanoparticles displays strong antimicrobial and antifungal properties which attract the scientific community to develop silver nanoparticles based disinfectant products (Rashid et al., 2013).

Properties of Silver Nanoparticles in Poultry Production

In the field of poultry production, Ag Nanoparticles may function as a substitute for antimicrobial agents. Along with that Ag nanoparticles can also be used as a growth promoter in poultry (Ravikumar et al., 2012). Silver nanoparticles similar to other metal composites such as zinc and copper that are used as growth promoters in poultry nutrition, modify the gastrointestinal tract. The silver nanoparticles can affect the microbial population in the intestinal tract and as a result, can improve the immune status of the broiler birds. The silver nanoparticles can also help to increase the growth performance of the broiler birds. Currently, the effect of Ag nanoparticles is seen in chicken embryos on oxidative stress parameters, growth, and development (Sawosz et al., 2009). Ag nanoparticles can be used as carriers available to oxygen and might be considered as a modulator of the mechanism. Silver nanoparticles display exceptional biological properties. Nanoparticles possess' broad-spectrum bactericidal activity against gram-negative and gram-positive bacteria (Sawosz et al., 2009). Due to these exceptional properties, Ag nanoparticles possess discriminatory status in the world `of pharmaceutical and medical devices (Monteiro et al., 2009; Rai et al., 2009)

Silver Nanoparticles as Antimicrobial Agent

Elemental silver occurs naturally and it is considered as non-toxic, non-invasive and non-allergic. One of the most suitable properties of this component is that silver does not accumulate in the tissue of the body (Singh et al., 2008). The metallic silver nanoparticles are below 200 nm in for greater microbial effect than silver salts (Yun et al., 2017). Much experimental analysis showed that silver nanoparticles can be effectively used as an antimicrobial agent against various organisms (Roth et al., 2009). Currently, there has been transformed attention in the use of silver nanoparticles as an antimicrobial agent. Metallic silver components and its ions have long been recognized to have exceptional antibacterial properties. The presentation of nanotechnology has empowered silver to be caused to Nano size (1-100nm) and have enormous functional service area (Rena et al., 2009).

Synthesis of Silver Nanoparticles

Silver nanoparticles can be synthesized by physical, chemical and biological methods. Physical methods involve electrochemical, Ultra sonication, laser ablation, irradiation, evaporation and condensation. Chemical reduction method was used to prepare silver nanoparticles by chemical process. Biologically silver nanoparticles can be prepared by fungi, yeast and plant extracts. (Manyasree et al., 2018)

Mechanism of Action of Ag Nanoparticles as an Antibacterial Agent

The antibacterial activity of silver nanoparticles depends upon the size of the nanoparticles. As far as the size of the nanoparticles decreases the activity of the silver nanoparticles increases. Silver nanoparticles with a diameter of less than 10 nm directly interact with bacteria. Ag nanoparticles increase the permeability of the membrane. After that, silver nanoparticles attach with the thiol groups in the respiratory enzymes and lead to the deactivation of the enzyme. The interaction of the Ag nanoparticles with the respiratory enzymes generates reactive oxygen species which tends to produce oxidative stress (Pinnada et al., 2012). As a result of the oxidative stress, destruction of bacteria occurs. Another mode of action of Ag nanoparticles is the interaction of the Ag nanoparticles with deoxyribose nucleic acid which inhibits the replication of the bacteria. Along with that silver nanoparticles can destroy peptidoglycan layer in the cell wall, can cause structural alteration in the cell wall and nuclear membrane, can affect ribosomes and constrains protein synthesis (Khalil et al., 2020).

Routes through which Silver Nanoparticles given

Silver Nanoparticles can be administered in the broilers through various routes such as oral route and respiratory route by Inhalation. Along with that can be given by injection and In-ovo inoculation can also be done (Mayer et al., 2009). After the up taking of the nanoparticles through different route like inhalation, ingestion, and skin contact silver nanoparticles are diffused into the bloodstream and distributed to various organs and tissues (Mohanraj et al., 2007).

Role of silver Nanoparticles in Poultry

Silver Nanoparticles as Feed Supplement in Poultry

Silver nanoparticles are the most suitable feed supplement in the poultry industry. The current status of the poultry industry showed that silver nanoparticles appeared as a modern tool to increase health status and feed conversion ratio. Silver nanoparticles not only destroy harmful bacteria in gastro-intestinal tract but also help in proliferation of the beneficial bacteria (Mahmoud. 2012).

Silver Nanoparticles as Antibacterial agents against different Poultry Diseases

Silver nanoparticles are repeatedly used in the poultry industry as the colloidal solution in poultry due to their antimicrobial property. Silver nanoparticles are attached with cellular structure and purpose in straight ways to remove bacteria from the body (Mahmoud, 2012). Silver nanoparticles can be used as antimicrobial agents against multi-drug-resistant bacteria (Ali et al., 2020). Metal nanoparticles such as Ag nanoparticles have potential to exhibits powerful antimicrobial role against variety of dreadful microorganism like *Escherichia coli* and *Staphylococcus aureus*. Acceptable antibacterial activity against these bacteria was seen (Kumar et al., 2020). Nanoparticles prepared with metallic components always prove to be potential antimicrobial agents against *Salmonella typhimurium* and *Staphylococcus aureus*. It was also analyzed from the study that silver nanoparticles can be replaced with antimicrobial agents as a suitable alternative (Akbar et al., 2019). In-vitro analysis also discovered use of silver nanoparticles can induce strong antibacterial effects against *Escherichia coli* and *Klebsiella*. Use of silver nanoparticles can produce significant to stop the proliferation of microorganisms (Khalil et al., 2020). Silver nanoparticles own durable antimicrobial properties against deadly pathogens linked to poultry. Use Nanoparticles against poultry pathogens like *Escherichia coli, Salmonella,* and *Campylobacter* helps control this problem. (Duffy et al., 2018). Silver nanoparticles had an outstanding antibacterial outcome against *B.subtilis* and *E. coli*. Various observations from the study presented that the antibacterial action of silver nanoparticle solution had a durable effect against these organisms. (Arifin et al., 2020). The antimicrobial action of silver nitrate nanoparticles can be used as antimicrobial agents against gram-positive and gram-negative bacteria. Gram-negative bacteria are more vulnerable to nanoparticles as compared to the gram-positive. Furthermore, Silver nanoparticles are more time-dependent and the capacity of these nanoparticles gets lowered by increasing the size and lessening the concentration of nanoparticles (Karvani et al., 2011).

Silver nanoparticles are also seen as valuable against organisms like bacteria and fungi. The development of antibacterial resistance against numerous pathogenic organisms due to the irrational use of antibiotics in the poultry industry has convinced the world to control the microbial population through alternative modes. To overcome this problem silver nanoparticles are considered as a more suitable antimicrobial agent against against *Salmonella* and *Escherichia coli* isolated from chickens (Mohamed et al., 2018). Silver nanoparticles can be used separately or in combination with other metal nanoparticles. The combination of zinc and silver nanoparticles can increase the antibacterial effects manifold as compare to use them alone (Fardin et al., 2016). Silver nanoparticles proved to be sensitive to bacteria that were highly resistant to standard antibiotics (Roy et al., 2020). Silver nanoparticles also help to improve the growth health, immunological and hematological status of the broiler birds challenged with microorganism. Along with that Ag Nanoparticles can help to modulate TNF alpha and NF-KB levels which are expressively increased in broiler birds that received silver nanoparticles (Vadalasetty et al., 2018). Use of silver nanoparticles at different levels can induce pathological impact on the intestine and liver of the broiler birds. The height of the intestinal brush border remarkably increased after treatment with Ag nanoparticles (Ahmadi et al., 2009). These nanoparticles can affect the immune response and antioxidant activity in poultry (Hafeez et al., 2020). Long-term use of silver nanoparticles helps in tackling issues related to antimicrobial resistance and the use of silver and zinc oxide nanoparticles as effective antimicrobial agents and lack of resistance issues (Saleem et al., 2015).

Role of Silver Nanoparticles as Growth Promoting Supplements

Along with antimicrobial properties Silver nanoparticles can be used as growth-promoting agent in broiler chickens. Silver nanoparticles supplementation in broilers can modulate growth performance and energy metabolism in broilers (Pineda et al., 2012). Silver nanoparticles as feed supplements for poultry can also be used for biomedical applications. The silver nanoparticles have minimal risk of toxicity in humans and animals (Mahmmadi et al., 2015).

Role of Silver Nanoparticles as Meat Quality Enhancer

Silver nanoparticles can also improve meat production and the quality of broiler birds infected with microorganisms. Along with that with the help of Ag nanoparticles the meat quality indices of broilers like live weight carcass quality, dressing percentage, carcass quality dry matter crude protein can be enhanced (Mahmoud et al., 2012). Silver nanoparticles can notably increase the weight of broiler birds (Ahmadi, 2009).

Silver nanoparticles and Immune Status of Broiler Birds

Silver nanoparticles in broilers can modulate the overall adaptive and innate immunity (Bhanja et al., 2015). Silver nanoparticles can be used at different levels which can improve the overall body status of the broilers like increased body weight, total serum protein, and anti-oxidative status decreased in the cholesterol (Elkloub et al., 2015).

In-ovo administration of silver nanoparticles improved the structure of the chicken embryo pectoral muscle (Sawosz et

al., 2009). Silver nanoparticles have also the ability to increase the gene expression of fibroblast growth factor 2, and vascular endothelium growth factors. Along with that, some other metallic nanoparticles such as selenium can help to improve the daily feed intake of the broiler birds. Significantly improved growth performance was also seen in broilers in which selenium NPs were given. NPs nowadays are used as a new tool for targeted drug delivery and nutritional improvement (Sawosz et al., 2007).

Impact of Silver Nanoparticles on Hematological Parameter in Poultry

The use of silver nanoparticles helps to improve the hematological indicators. Significant improvement was seen on lymphocyte count in broiler birds in which nanoparticle treatment was given challenged with bacterial infection. Along with that these nanoparticles also to improve the erythrocyte indices in broilers treated with silver nanoparticles as reported by

Conclusion

Antimicrobial resistance is a significant problem related to the poultry industry to overcome the challenge of antimicrobial resistance. Nano-medicine is the most suitable alternative mode which can help to control the problem of antimicrobial resistance in the poultry industry. Metallic nanoparticles particles silver nanoparticles have a significant role in controlling the problem of the poultry industry and possess significant properties to overcome the challenge of antibiotic resistance in poultry.

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