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RESEARCH ARTICLE

Applications of biosynthesis of silver nanoparticles for sustainable poultry production under hot climatic conditions. A review

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Abstract

A new strategy for the growth of the poultry industry to boost market meat production and overcome the climate change has been developed within the context of Egypt Vision 2030, the country's sustainable development plan. Many infections are present in poultry eggs, which cause embryos to develop prematurely early or hatchlings to death quickly. Immunity of the embryo during embryogenesis is a significant factor influencing the growth of the chicks after hatching. In order to avoid having any negative effects on birds or indirectly on humans, it has become imperative to look for a strategy to increase the bird's immunity beginning at the embryonic Silver before hatching. Silver Nanotechnology feeding alternatives are utilized to promote chicken performance, increase nutritional effectiveness, and modernize some physiological systems and therefore improve economic efficiency. However, consistent results were scarce. The majority of trials indicated only modestly good impacts. There needs to be more research conducted due to the virtually unlimited possibilities for nanotechnology element preparations. To evaluate green nanoparticle and the precise mechanism of action of silver nanoparticles' anti-stress benefits, however, more research is still required under more standardized conditions.

Keywords: Biochemistry; Broilers; Microbiology; Nanoparticles; Performance.

1. Introduction

The concept of "nanobiotechnology," "bionanotechnology," and "nanobiology" all stand for the integration of nanotechnology and biology (Gazit *et al.,* 2007). Nanomaterials and nanoparticles consider an important aspect of nanotechnology that deals with different researches including dealing with structures ranging from approximately 1- 100 nm in at least one dimension (Ahmadi and Kordestany, 2011). Nanoparticles synthetic techniques can generally be divided into three categories: Synthesis using physical, molecular, and biological (Biosynthesis or green synthesis) (Liangpeng *et al.,* 2014). Nanoparticles are formed when microorganisms take target ions from their environment and change the metal ions into the element metal using enzymes produced by cell activities (Xiangqian *et al.*, 2011). Nanoparticles bio synthesis process can be divided into intracellular and extracellular synthesis depending on where nanoparticles form (Simkiss *et al.*, 1989; Mann *et al.*, 2001). The intracellular approach entails delivering ions into the microbial cell where they combine with enzymes to create nanoparticles (Xiangqian *et al.*, 2011). The extracellular synthesis completed creating nanoparticles outside of cells by

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capturing metal ions there and then reducing them in the presence of enzymes (Zhang *et al.,* 2011).

There are many ways in which nanoparticles created by a biogenic enzymatic process are superior to those synthesized using chemical processes (Xiangqian *et al.,* 2011). Due to the bacterial carrier matrix, the particles produced by these procedures have increased interaction between the enzyme and the relevant metal salt, stronger catalytic reactivity, and greater specific surface area (Bhattacharya et al., 2008; Simkiss *et al.,* 1989). Lately, researchers have worked to employ microorganisms as potential environmentally benign nanofactories for the production of silver nanoparticles (Xiangqian *et al.,* 2011). Silver nanoparticles are known to be produced by a variety of microorganisms, and the majority of these particles are spherical (Mukherjee *et al.,* 2001; Fayaz *et al.,* 2010). Nanoparticles are smaller than bigger particles of the same chemical composition and can pass through biomembranes to reach cells, tissues, and organs more easily (Choi and Hu, 2008). According to a number of studies, feeding livestock and poultry nanoparticles may enhance their performance by boosting immune and digestive health (Abdelsalam *et al.*, 2019). Due to their proven antibacterial capabilities (Connor *et al.*, 2005; Kim *et al.*, 2008; Sawosz *et al.*, 2007), nanoparticles of noble metals—primarily Silver—are now being used as disinfectants in animal production (Dobrzaski *et al.,* 2010).

Several studies have demonstrated the beneficial effects of silver nanoparticles on animal production, immunogenesis stimulation (Anwar *et al.,* 2019), potential efficacy in the prevention and treatment of infectious disorders (Gopinath *et al.,* 2016), and effectiveness as anticancer agents (Hamed *et al.,* 2017; Salem *et al.,* 2020). Vinus and Nancy (2017) conducted research on the utilisation of different compounds as a supplemental source of the trace elements in poultry diets and the growing interest in the application of nanotechnology in poultry production. According to Rao *et al.* (2016), high ambient temperatures in tropical areas produce heat stress in chicken, which has a negative impact on their growth rate, feed consumption, feed efficiency, and mortality. As a result, commercial poultry farms suffer significant financial losses. According to Wright *et al.* (1999), silver nanoparticles can harm a variety of Gram-positive and Gram-negative bacteria, including strains that are antibiotic-resistant. Recent studies have revealed that penicillin G, amoxicillin, erythromycin, clindamycin, and vancomycin's antibacterial activity is increased by silver nanoparticles with a diameter of 22.5 nm (Shahverdi *et al.,* 2007). Several studies have shown that silver nanoparticles work quickly and effectively against a wide variety of common fungus, such as those belonging to the genera Aspergillus and Candida (Naghsh *et al.,* 2012; Kim *et al.*, 2012) Saccharomyces (Wright *et al.,* 1999). It has also been demonstrated that silver nanoparticles exhibit strong activity against yeast that has been isolated from diseased cow udders (Wijnhoven *et al.,* 2009). Silver-Nano could potentially serve as an alternative to antibiotic-based growth promoters in the production of chicken (Vadalasetty *et al.,* 2018). Nevertheless, Silver-Nano still under research in poultry sector, in some studies Nano silver used as antimicrobial agent, however limited researches used it by in ovo technology. So, this review gives an overview on the effect of in ovo injection of Biosynthetic Nano silver in an attempt to know the effect of using it on performance, physiological functions, bird’s immunity, microbial population in the digestive system.

2. Nanoparticles synthesis and mode of action of Silver

Nanoparticles synthetic techniques can generally be divided into three categories: Synthesis using physical, molecular, and biological including Biosynthesis or green synthesis (Liangpeng *et al.,* 2014). Due to the increasing demand for ecologically friendly synthesis techniques that make use of eco-friendly reducing and capping agents such as protein (Naik *et al.,* 2002), peptides, (Nam *et al.,* 2008), carbohydrate (Anisha *et al.,* 2013), various species of bacteria (Sintubin *et al.,* 2009), fungi (Balaji *et al.,* 2009), and yeast (Sintubin *et al.,* 2012) as well as the biosynthesis of has attracted a lot of attention (Liangpeng *et al.,* 2014). The main benefit of biogenic synthesis over alternative processes is that it does not use harmful chemicals or organic solvents (Liangpeng *et al.,* 2014). Additionally, because microbial cells can keep growing, biological synthesis allows for the production of nanoparticles at safe silver nitrate concentrations (Mukherjee *et al.,* 2001). However, the biosynthesis disadvantage is that the purification process could result in pathogenic bacteria, and the potential bacteria could cause contamination (Sintubin *et al.,* 2003).

Silver-Nano antimicrobial effect has been thoroughly investigated, but it is still unknown how antibacterial activity specific to bacteriostatic or bactericidal activity works (Vadalasetty *et al.,* 2018). Sotiriou *et al.* (2010) reported that Silver-Nano upon contact with water can release Silver + ions from their surface. Free Silver + has a strong antimicrobial impact that instantly kills microorganisms by inhibiting cellular respiration and impairing bacterial cell membrane function (Vadalasetty *et al.,* 2018). Since the essential protein complexes for the bacterial electron transport pathways are outside the cell, reactive silver ions can easily inactivate those (Vadalasetty *et al.,* 2018). Additionally, Silver + attaches to and denatures bacterial DNA and RNA, which prevents cell division (Dunn and Edwards-Jones, 2004). Recent research suggests that silver nanoparticles may alter the phosphotyrosine profile of suspected bacterial peptides. This alteration may have an impact on cellular signalling and, as a result, may prevent bacteria from growing (Shrivastava *et al.,* 2007). Studies on anti-inflammatory medication and molecules that might inhibit pro-inflammatory pathways have received attention recently (Vadalasetty *et al.,* 2018). Additionally, Silver nanoparticles are regarded as anti-inflammatory substances or as parts of anti-inflammatory compound (Bhol *et al.,* 2005; Shin *et al.,* 2007). It has been shown that nanoparticles in the gastrointestinal tract can travel from the intestinal lumen to enterocytes and Peyer's patches, and to a lesser extent, through intercellular gaps in the small intestine (Hussain *et al.,* 2001).

3. Effect of Silver -Nano on productive performance

Several researchers have illustrated that using Silver nanoparticle (Silver-Nano) in broilers nutrition under optimal conditions either suppress or stimulates growth performance (Saleh and El-Magd, 2018; Kumar and Bhattacharya, 2019; Kumar *et al.,* 2020; Bolandi *et al.,* 2021; Dosoky *et al.,* 2021). Adding Silver -Nano in broilers feeding resulted in enhancement in gut health as noticed by nutrient absorption, increase weight gain, feed conversion ratio and feed intake (Andi *et al.,* 2011). Lohakare and Abdel-Wareth (2022) found that adding Silver -Nano at 4 mg/kg on one day Ross 308 chicks feeding enhanced daily feed intake, daily feed conversion ratio, body weight gain, feed efficiency and ash digestibility. They stated that Silver-Nano has the capacity to lessen the signs and symptoms of digestive disorders, which strengthened the digestive system and improved feed efficiency, strengthening the daily growth in body weight (Lohakare and Abdel-Wareth, 2022).

In another paper, Al-Sultan et al., 2022 used Silver-Nano at 2.5, 5,10 and 20 mg per kg feed on 300 seven-day-old Ross broiler chick, they observed improvement in growth performance after incorporating different levels of Silver-Nano. The improvement could be due to the antimicrobial response of Silver-Nano on harmful intestinal bacteria, improving gut health and the absorption of nutrients as well as stimulating digestive enzyme activity is another proposed reason for the Silver-Nano growth stimulatory effect. Similar results reported after using Silver -Nano at different levels by 25 to 75 ppm (Saleh and El-Magd, 2018; Kumar and Bhattacharya, 2019; Kumar *et al.,* 2020; Bolandi *et al.,* 2021). In contrast, other studies found that a diet supplemented with Silver -Nano affected negatively on chicken performance when it added at 0, 4, 8 or 12 ppm by Ahmadi and Rahimi (2011), at 0,10, 20 ppm by Pineda et al. (2012), at 50 ppm by Vadalasetty *et al.* (2018). The decrease in cumulative body weight and relative organ weights of organs in broilers supplemented with a high dose at 20 mg/kg dietary Silver-Nano might result of Silver-Nano effect on protein enzymatic digestibility reduction and inhibition the absorption of sugars and amino acids (Al-Sultan *et al.,* 2022). Another cause recorded by (Vadalasetty *et al.,* 2018) that birds might be subjected to excess cellular stress and excessive cellular interactions with Silver-Nano intake.

In different experiment conducted by Abdelsalam *et al.* (2019) they injected Silver-Nano 0.5 mg, and 1.0 mg /kg body weigh in NZW and Jabali rabbits, the noticed that administration of Silver-Nano had a significant effect on final BW under high ambient temperature ($p < 0.02$). These results are in agreement with (Hang and Tra, 2013) who found that BW of rabbits given Silver-Nano in drinking water was higher than that of the control group, and they reported that there were no differences in FI among both groups. Nevertheless, broilers treated with Silver -Nano showed heavier BW and high BWG than those of the control (Hassan *et al.*, 2018). Singh *et al.* (2008) elucidated the improvement in performance to the biological effect of Silver-Nano on harmful bacteria in the intestine which resulted in development in growth and nutrients absorption of was increased). Additionally, the stimulation of digestive enzymatic activity, which improved nutrient absorption, may be resulted of Silver-Nano' growth-stimulating effect (Saleh and El-Magd, 2018). Nevertheless, in several earlier studies, broilers given a diet supplemented by Silver-Nano did not show any improvement in growth performance (Ahmadi and Rahimi, 2011; Ahmadi and Kurdestany, 2010; Chauke *et al.,* 2012). Similarly, Kulak *et al.* (2018) reported that up until they received the maximum dose of Silver-Nano, or 63.74 mg/bird, the chickens' growth performance unaffected by the administration of Silver-Nano at a dose that did not exceed 54 mg/bird. Also, according to numerous papers, administering a silver nanoparticle solution under ideal circumstances neither inhibits nor promotes growth (Pineda *et al.,* 2012; Ognik *et al.,* 2016b,c)

Silver-Nano was used as a hydrocolloid by (Kulak *et al.,* 2018) at a dose of 2.87 or 12.25 mg per bird for the duration of the trial, and they observed that Silver-Nano had no negative effects on the growth performance of the chickens. However, the typical daily consumption of feed, water, and egg production of hens were unaffected by Silver-Nano (Shevchenko *et al.,* 2021). Data collected on broiler chickens by Vadalasetty *et al.* (2018) for doses of 8.26 mg/day of Silver-Nano and Kulak *et al.* (2018) for doses of 2.87 and 12.25 mg per bird are congruent with that. Contrary, in another research, domestic chickens' feed intake and body weight were increased by administering 15 nm Silver-Nano at a concentration of 50 mg/L of water (Kumar and Bhattacharya, 2019).

However, Farzinpour and Karashi, (2013) discovered that when Silver-Nano was included in feed at dosages of 0, 4, 8, and 12 ppm, the egg production and yolk mass of Japanese quail declined. The weight of fertile eggs used for in ovo injection, day old chick weight, chick weight to egg weight ratio, or percent hatchability (on the basis of fertile eggs) were not impacted differently by in ovo Silver-Nano (50 g) compared to the treatment groups, according to Bhanja *et al.* (2022).

According to Grodzik and Sawosz (2006), chicken growth performance was unaffected by silver nanoparticles at a concentration of 10 ppm. Nonetheless, Al-Sultan *et al.* (2022) proposed that these inconsistent results can be caused by variations in nanoparticle size, the production process, the dosage, or the administration methods.

4. Effect of Silver-Nano on carcass criteria

Silver-Nano had no appreciable impact on the carcass weight, dressing %, or numerous carcass components such the percentage of the liver, heart, kidneys, and spleen, according to Abdelsalam *et al.* (2019). Similarly, supplementing Silver-Nano in drinking water or diet had a substantial impact on dressing%, liver%, and heart% in broiler chickens (Hassan, 2018). Wang *et al.* (2016) discovered that breed had a substantial impact on the percentages of head, skin, liver, and kidney. The weights of the studied breeds' organs were not significantly different (Ghosh and Mandal, 2008). Dressing percentages and relative organ weight increased in chickens given low doses of Silver-Nano (Elkloub *et al.*, 2015; Al-Sultan *et al.*, 2022). Silver nanoparticles, according to Ahmadi and Rahimi (2011), increased the weight of the small intestine and abdominal fat while having no discernible impact on the weight of the liver and gizzard. Additionally, Al-Sultan *et al.* (2022) hypothesized an increase in the chicken's ability to hold its muscles together after adding the least amount of Silver-Nano (2.5 mg/kg), which is consistent with the findings of Hashemi (2014) and Hashemi *et al.* (2017). They also claimed that the lower dose causes low levels of protein oxidation. According to Lohakare and Abdel-Wareth (2022) stated that there were no significant differences in dressing percentages or portions of the carcass due to Silver-Nano administration or breed in rabbits, and the dose of injected Silver-Nano had no effect on the percentages of liver, heart, kidney, and spleen. According to Lohakare and Abdel-Wareth (2022) stated that Silver-Nano had no impact on the broilers' liver, heart, spleen, gizzard, small intestine, or cecum. Ahmadi *et al.* (2012) reported that Silver-Nano injection in rabbits had no discernible impact on the liver, heart, kidney, or spleen, and that there were no differences in dressing percentages or carcass as a result of Silver-Nano.

5. Effect of Silver-Nano on blood biochemical parameters

All blood parameters, with the exception of haematocrit and platelet count readings, were unaffected by the administration of Silver-Nano (Abdel-Salam *et al.*, 2019). The addition of Silver-Nano did not significantly change any blood parameters in rabbits (Syrvatka *et al.*, 2014). Furthermore, Raheem (2018) discovered that rabbits given the Silver-Nano vaccine had higher RBC, PLT, and HCT values than the control rabbits. Silver-Nano injection caused variances in the PLTs and RBCs values, which in turn caused changes in the RBCs that boosted the immune response or disturbed signalling pathways and cell maturation (Sarhan and Hussein, 2014). The administration of Silver-Nano did not significantly alter the plasma concentrations of total protein, albumin, globulin, total cholesterol, or triglycerides, according to (Abdelsalam *et al.*, 2019). Contrary, according to Saleh and El-Magd (2018) plasma total protein was unaffected compared to broiler chicks given a diet supplemented with Silver-Nano, but plasma triglycerides and total cholesterol were significantly lower. Ahmadi *et al.* (2012) revealed, however, that broiler chicks administered Silver-Nano displayed significant alterations in total protein, albumin, and gamma globulin. Chickens fed Silver-Nano showed lower plasma LDH activity, as demonstrated by Ognik *et al.* (2016a). As shown by a decrease in LDH activity, oxidative stress caused by Silver-Nano often affects mitochondrial function (Carr *et al.*, 2000).

In a study by Ahmadi (2012), who utilised Silver-Nano in the diet of chickens at concentrations of 20, 40, and 60 ppm/kg of feed, it was discovered that the substance had a detrimental impact on the blood lipid profile, increasing Cholesterol (CHOL), low-density lipoprotein (LDL), and triglycerides (TG). On the other hand, employing smaller levels, such as 4, 8, and 12 ppm/kg of feed, had no impact on Cholesterol (CHOL) content, while 8 ppm/kg and 12 ppm/kg raised low-density lipoprotein (LDL cholesterol) and decreased high-density lipoprotein (HDL cholesterol) (Ahmadi *et al.*, 2013). The use of Silver-Nano in chicken diets resulted in a decrease in the Plasma glutathione peroxidase (GSH-Px) level; it also produces oxidative stress, which lowers the activity of antioxidant enzymes in blood plasma and silvering in liver cells (Ognik *et al.* 2016a).

Contrarily, Abdelsalam *et al.,* (2019) found that Silver-Nano at 0.5 or 1.0 mg/kg BW, breed, and the interaction had no appreciable impact on the overall antioxidant capacity, GSH-Px activity, or the rabbits' ability to cope with heat stress. According to research, low doses of Silver-Nano may not have a negative impact on the antioxidant properties of growing rabbits exposed to high ambient temperatures (Abdelsalam *et al.,* 2019). Liver cells can be destroyed by significant processes like oxidative stress and lipid peroxidation (Ognik *et al.*, 2016a). A vicious loop of cellular stress and metabolic abnormalities can occur as a result of energy depletion and the intensive production of reactive oxygen species, which is associated to functional damage Silver to hepatocytes (Ognik and Wertelecki, 2012).

In reaction to oxidative stress and increased formation of reactive oxygen species in the mitochondrion, the body's antioxidant defence system is made up of four enzymes: superoxide dismutase, glutathione peroxidase, catalase, and cellular glutathione (Ognik and Wertelecki, 2012). Most nanoparticles damage proteins, enzymes, and nucleic acids in the mitochondria after they enter cells, causing lipid peroxidation (Ognik et al., 2016a). A reduction in the activity of the antioxidant enzymes Superoxide dismutase (SOD), Pharmacogenomics (PGx), and catalase (CAT) in the blood plasma followed the application of Silver-Nano to chicken diets at levels of 20, 40, and 60 ppm/kg of feed and was directly proportional to the amount of Silver-Nano in the feed (Ahmadi, 2012).

A slight decrease in the activity of the enzymes alanine aminotransferase (ALT) and aspartate aminotransferase (AST), responsible for directing amino acids onto catabolic pathways and lowering the plasma concentration of the primary byproducts of protein metabolism (creatinine and urea), may indicate disturbed protein catabolism in chickens receiving 5 nm Silver-Nano (Ognik *et al.*, 2016a). Also, after consuming diets containing either 22 nm or 5 nm Silver-Nano, changes in the activity of the liver enzyme alkaline phosphatase ALP in chicken blood plasma were observed (Ognik *et al.*, 2016a). When liver damage or a myocardial infarction brought on by toxins or viruses occurs, the liver enzymes' activity increases when they are discharged from hepatocytes into the blood (Ognik *et al.*, 2016a).

Ahmadi (2012) found that exposure to Silver-Nano at doses of 20, 40, and 60 ppm/kg of feed resulted in a decrease in aspartate aminotransferase (AST) and alkaline phosphatase (ALP) activity in the blood plasma of chickens. Contrarily, according to other studies, chickens fed a diet containing Silver-Nano exhibited no change in the AST and ALT activity of the liver enzymes (Andi *et al.*, 2011). Similar to this, Sawosz *et al.* (2009) showed that giving Silver-Nano to hens while they were eating had no discernible impact on their AST, ALT, or ALP activity.

The levels were within a physiologically normal range, according to Lohakare and Abdel-Wareth (2022), who also observed that Silver-Nano decreased plasma AST and ALT levels and had no effect on urea or creatinine levels in broilers when compared to the control group. Contrary to Sawosz *et al.* (2009)'s assertion that nanoparticle had no impact on the activities of ALT, AST, glucose, or cholesterol, these findings support the earlier study. Moreover, employing Silver-Nano at levels (2, 4, and 6 ppm) increased antioxidant capacity and immune function while lowering blood total lipids and cholesterol (Elkloub *et al.*, 2015). According to Dosoky *et al.* (2021) report that Silver-Nano hydrocolloids had an impact on protein catabolism as evidenced by decreased liver enzyme activity (ALT and AST) and decreased levels of urea and creatinine. Nevertheless, when broiler chicks were given a diet supplemented with Silver-Nano, AST level in blood plasma unaffected compared to the control group (Saleh and El-Magd, 2018). Also, Andi *et al.* (2011) reported that supplementation of Silver-Nano in broiler diets had no effect on AST and ALT levels.

It was discovered that Silver-Nano had little to no effect on the levels of immunoglobulin G and immunoglobulin M. (Pineda *et al.*, 2012). However, it has also been shown that administering silver nanoparticles along with certain amino acids, such threonine and cysteine, can improve innate and adaptive immunity in growing hens (Saki and Salary, 2015; Bhanja *et al.*, 2015). Nevertheless, Vadalasetty *et al.* (2018) found that the relative weight of the bursa and spleen decreased associated with a decrease in plasma IgG and IgM levels. Instead, Silver-Nano allows animals to consume fewer nutrients for the metabolic effort required for immunological regulation and instead employ those nutrients for other purposes, as demonstrated by Fondevila's (2010) research. Because they control the expression of matrix metal-loproteinases, proteolytic enzymes involved in a variety of inflammatory and healing processes, Silver-Nano also have anti-inflammatory characteristics (Nadworny *et al.*, 2010).

Nabinejad *et al.* (2016) state that the consumption of Silver-Nano by consumers from the muscles and organs of chicken may be has unfavorable effects. According to Borel and Sabliov (2014), nanomaterials with a size range of 10-100 nm stay in the bloodstream for a long time before being carried to the organs, and nanoparticles can retain and collect in the body rather than be excreted. The quantity of injected Silver-Nano, according to Abdelsalam *et al.*, (2019), showed that it had a dose-dependent, highly significant impact on the amount of silver residues in meat. These findings are consistent with a number of earlier researches that found broiler chicken muscles contained more silver when dietary Silver-Nano was added to the food (Ahmadi *et al.*, 2011; Singh et al., 2008). According to Abdelsalam *et al.* (2019), the highest residual levels were discovered in blood rather than meat as a result of Silver-capacity Nano's to permeate the blood circulation and subsequently spread throughout the organs and muscles. On the other hand, it was discovered that Silver retention in muscle tissue in broiler chickens was lower than in liver (Fondevila, 2010). Also, as Silver-Nano particle size rose (to 25 or 40 nm), Silver-Nano residues in chicken intestines increased. In addition, the liver is considered to be the main organ for dispersion, followed by the spleen, according to Wang *et al.* (2013). It may be possible to lessen the environmental dangers connected with silver itself by taking use of the silver ion's propensity to form powerful complexes with apparently very low bioavailability and toxicity (Varner *et al.*, 2010).

6. Effect of Silver-Nano on Microorganisms

The ability to enrich cells with oxygen and the antibacterial capabilities of silver nanoparticles help an organism's immune system function more effectively. Selenium is recognized as an intestinal booster to one of the safety requirements is how much pathogenic microflora has been introduced into the egg shells (Stepie-Pyniak, 2010). The microflora on the surface of the egg shell in birds is significantly influenced by the species makeup and ratio in the digestive contents, especially the colon (Maki *et al.*, 2020). It has been demonstrated that Silver-Nano are effective against resistant bacterial strains in addition to gram-positive and gram-negative pathogenic bacterial strains (Wright *et al.*, 2002; Percival et *al.*, 2007). According to Cho *et al.* (2005), silver nanoparticles also showed antibacterial activity against Staphylococcus aureus and Escherichia coli by causing the cell walls to degrade to minimum inhibitory concentrations of 50 and 100 ppm, respectively.

According to (Elkloub *et al.*, 2015), silver nanoparticles at a level of 4 ppm/kg caused a decrease in E. coli growth without having any impact on the population of helpful bacteria, such as lactobacillus species. Moreover, Dobrzanski *et al.* (2010) showed that Silver-Nano has biocidal capabilities that have reduced the overall quantity of bacteria as well as the number of dangerous E. coli, salmonella, and streptococcus species. Silver nanoparticles are oxygen carriers and restrict the growth of strictly anaerobic bacteria, as shown by the decline in bursa of Fabricius growth, it can be inferred that these particles may have had an impact on and altered the microflora of the gut as a result of their antimicrobial properties (According to Ahmad *et al.*, 2022). On the other hand Shevchenko *et al.* (2021) reported that at different doses of Silver-Nano no contamination of the surface of the shell of freshly laid eggs with opportunistic and pathogenic microorganisms. The impact of Silver-Nano nanoparticles on the intestinal microbiome relies on their shape and results in histopathological changes in the gastrointestinal tract and brain, according to (Javurek *et al.,* 2017). Additionally, the microorganism's reserve of glutathione is depleted by the rise in Silver-Nano (Silver+) and -OH ion concentrations, which is linked to a rise in the amount of intracellular reactive oxygen species (Shevchenko *et al.,* 2021). Consuming Silver-Nano in polymer/inorganic hybrid carriers may be thought of as a means to lessen the buildup of antibiotic and other antibacterial medication residues in food, including eggs and poultry meat (Bayer *et al.,* 2017). Other studies have demonstrated that after three weeks of treatment, dietary Silver-Nano powder reduces the community of lactose-positive and enterococcal bacteria and increases the population of Lactobacillus (Ahmadi and Kurdestany. 2010; Elkloubet *et al.,* 2015; Bolandi *et al.,* 2021). According to the findings of several studies, adding Silver-Nano to drinking water at concentrations of 5, 15, and 25 mg/L had no effect on growth or intestinal microbial count but did raise the number of lactobacilli (Fondevila *et al.*, 2010; Vadalasetty *et al.*, 2018). However, the populations of caecal lactose-negative, lactose-positive, and enterococcal bacteria on day 28 reduced significantly with the addition of Silver-Nano to the diet; however, the decreasing was not significant on day 42, and there was a numerical increase in the lactobacilli population was observed in groups supplemented with Silver-Nano at 2.5 to 10 mg/kg diet; however, this increase was not statistically significant (Al-Sultan *et al.,* 2022).

7. Conclusion

Therefore, it can be said that silver nanoparticles has the potential to be thought about for early broiler feeding and for enhancing the health and productivity of chicken. In order to maximize growth performance, and bird health, additional research under climate changes conditions is still required to assess the precise mechanism of action and identify the ideal quantity of dietary inclusion.

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All authors are contributed in this research.

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Institutional Review Board Statement

All Institutional Review Board Statements are confirmed and approved.

Data Availability Statement

Data presented in this study are available on fair request from the respective author.

Ethics Approval and Consent to Participate

Not applicable

Consent for Publication

Not applicable.

Conflicts of Interest

The authors disclosed no conflict of interest starting from the conduct of the study, data analysis, and writing until the publication of this research work.

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