Effects of Dietary Supplementation of Oregano Bioactive Lipid Compounds and Silver Nanoparticles on Broiler Production

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Simple Summary: It appears reasonable to investigate the use of novel, natural compounds in broiler chicken production. The objective of this research was to evaluate the effects of silver nanoparticles and oregano bioactive lipid compounds on broiler production. The results showed that supplementing broiler diets with oregano bioactive lipid compounds and silver nanoparticles, either independently or combined, improved growth performance, liver functions, dressing percent, and reduced abdominal fat.

Abstract: Feed additives could be added in the diets of broiler chickens to improve performance and for sustainable broiler production. The objective of this study was to evaluate the effectiveness of feeding broiler chickens with oregano bioactive lipid compounds (OBLC) and silver nanoparticles (Nano-Silver) on growth, viability, economics, carcass criteria, silver retentions, and serum biochemistry. One-day-old, unsexed Ross 308 broiler chicks (n = 320) were divided into four treatment groups. Ten replicates of eight birds each for each treatment were used. Treatments were: CONT (control diet), OBLC (CONT diet supplemented with 150 mg/kg OBLC), Nano-Silver (CONT diet supplemented with 4 mg/kg Nano-Silver), and CONT diet supplemented with OBLC + Nano-Silver at levels mentioned above were used for the study. The experiment lasted for 35 days. Supplementing OBLC and Nano-Silver individually or in combination improved (p < 0.01) body weight and feed conversion ratio when compared to CONT. The supplemented groups had a lower death rate than the CONT group, resulting in a higher net return. Supplementing broiler birds with OBLC, Nano-Silver, or their combination boosted dressing percentage and decreased abdominal fat when compared to CONT. Blood levels of aspartate aminotransferase, alanine transaminase, creatinine, and urea were lowered in broilers fed OBLC, Nano-Silver, or combination diets. Overall, the current study demonstrates that broiler chickens fed diets with OBLC and Nano-Silver, either alone or in combination, improved growth performance, liver functions, dressing percent, silver absorption and decreased abdominal fat. The best performance was observed in the combination of OBLC and Nano-Silver group compared to other treatments.

Keywords: bioactive lipid compounds; broiler chicken; performance; silver nanoparticles; sustainability

1. Introduction

From the perspectives of environment, consumers demand, and sustainability, and to address the problem of drug-resistant bacteria and the restriction on antibiotic growth promoters, more research is needed to find new additives for the broiler chicken industry [1,2]. Nutritionists are looking for alternative to antibiotics as growth promoters due to their ban in several countries. Plant bioactive lipid compounds are commonly used phytogenics known for their antimicrobial properties, strong antioxidant properties, gastro
protective, and appetite and mucus enhancing activities, mainly due to their bioactive compounds [3]. Oregano (Origanum vulgare) is a popular medicinal plant with antibacterial, antioxidant, and immunity-stimulating characteristics, owing to its bioactive lipid compounds (BLC) [4,5]. The use of BLC as a phytoprogenic feed additive in broiler diets reduces bird mortality, resulting in increased profitability [1,6]. Broiler bird’s growth performance, gastrointestinal secretions, digestion, and health have been improved due to dietary oregano BLC supplementation [4]. Furthermore, silver is useful to humans and animals due to many of its beneficial properties. Silver can be supplemented in broiler diets in different forms as inorganic, organic complexes, and nanoparticles [7]; however, silver nanoparticles have strong adsorbing ability, higher bioavailability, and low toxicity compared with other sources. Nanoparticles of silver (Nano-Silver) are fine particles of metallic silver and are emerging alternate feed additive for poultry [2]. Nano-Silver has antimicrobial and antioxidant properties and becoming increasingly important due to its wide range of applications [8–11]. Despite the widespread use of Nano-Silver, relatively little research has been undertaken to determine its biological effects. Andi et al. [12] reported that supplementation of Nano-Silver improved broiler productive performance. Other researchers, on the other hand, found no significant alterations in chickens fed Nano-Silver [13–15]. These contradictory findings may be related to variations in the Nano-Silver size, level, duration, preparation method and bird’s age. Systematic studies are needed to understand the beneficial impacts of Nano-silver on the production of broilers. Additionally, BLC may improve growth, physiological factors, and poultry metabolism. More research is required to support the effects of Nano-silver, oregano BLC, either alone or in combination on the sustainability of broiler production. This study’s aim was to evaluate the effects of Nano-Silver, Oregano BLC, or their combination on the sustainability of broiler production.

2. Materials and Methods

2.1. Experimental Design and Dietary Treatments

A total of 320 unsexed Ross 308 broiler chicks (one-day-old) were set apart and allocated to 4 experimental treatments: CONT (control diet), OBLC (CONT diet with 150 mg/kg of oregano bioactive lipid compounds), Nano-Silver (CONT diet with 4 mg/kg nanoparticles of Silver), and OBLC + Nano-Silver at the above-mentioned dose of each added to CONT diets. Each treatment had 10 replicates of 8 birds. The experiment lasted for 35 days. Birds were fed commercial diets according to Ross 308 recommendations to meet the nutrient requirements (Table 1) for starter (1–21 d) and grower (22–35 d) phases, respectively.

2.2. Green Synthesis of Nanoparticles of Silver

The process utilized to make nano-silver is identical to that previously described by Azizi et al. [16]. Volumes of 50 mL of the aqueous algal extracts and 50 mL of a 1 mM AgNO3 solution were combined while being constantly stirred at 45 degrees Celsius. The solution’s color changed from brownish yellow to light purple after an hour, indicating the appearance of Ag-nanoparticles. To ensure complete reaction, the resultant solution was maintained under stirring for an additional 4 h. The pellets were collected after 10 min of centrifugation at 6000 rpm, and the produced Ag-nanoparticles were separated from the residual seaweed. Once more, the pellets were suspended in double-distilled water, and phosphate buffer was added to the solution to adjust the pH to 5.6.
Table 1. Chemical composition of basal diet (as-fed basis).

| Ingredients (%) | Starter Diet | Grower Diet |
|-----------------|-------------|-------------|
| Corn, ground    | 27.59       | 30.00       |
| Sorghum, ground | 27.59       | 30.00       |
| Soybean meal (44% CP) | 28.50     | 25.00       |
| Corn gluten meal (60% CP) | 9.50     | 6.00        |
| Vit & Min. Premix a | 0.30      | 0.30        |
| Sunflower oil   | 3.00        | 5.52        |
| Dicalcium phosphate | 2.00     | 1.80        |
| Limestone       | 1.00        | 1.00        |
| Salt            | 0.38        | 0.38        |
| DL-methionine   | 0.04        | —           |
| L-lysine HCl    | 0.10        | —           |
| Total           | 100         | 100         |

Nutrient Analysis

| Nutrient | Starter Diet | Grower Diet |
|----------|--------------|-------------|
| ME (kcal/kg diet) | 3000         | 3187        |
| Crude protein (g/kg) | 236.7        | 204.6       |
| Calcium (g/kg) | 10.0         | 10.0        |
| Available phosphorus (g/kg) | 5.00        | 5.00        |
| Lysine (g/kg) | 11.6         | 11.6        |
| Methionine (g/kg) | 5.20         | 5.20        |

a Supplied per kg diet, vitamin A, 1900 IU; vitamin D3, 1300 IU; vitamin E, 10,000 mg; vitamin K3, 1000 mg; vitamin B1, 1000 mg; vitamin B2, 5000 mg; vitamin B6, 1500 mg; vitamin B12, 0.046 mg; Biotin, 50 mg; BHET, 10,000 mg; Pantothenic acid, 10,000 mg; folic acid, 1000 mg; Nicotinic acid, 30,000 mg. Supplied Mn 60 mg; Zinc 50 mg; Fe 30 mg; Cu 4 mg; I 3 mg; Selenium 0.1 mg; Co 0.1 mg.

2.3. Experimental Conditions

During the experiment, the birds were housed and handled according to the South Valley University Institutional Animal Care Committee’s recommendations (SVU-AGRI-12-2021). Chicks were kept in a closed housing in a three-tier wire floor battery cages. Chicks in each replicate were placed in cages with an iron slatted bottom. The cages had sizes of 120, 70, and 50 cm in length, width, and height, respectively. During the trial, the chicks had unrestricted access to feed and water. The chicks were kept in galvanized metal battery cages for the duration of the trial, which lasted from 0 to 35 days. The temperature was 34 °C in the first week and steadily reduced to 24 °C by the fourth week, and all chicks were kept under the same management conditions.

2.4. Analysis of Oregano Extract Oil

The oregano BLC was extracted from dried leaves using a Clevenger-style apparatus at the Department of Medicinal and Aromatic Plants Research, National Research Center, Egypt, for three hours. Gas chromatography (TRACE GC Ultra Gas Chromatographs, Thermo Fisher Scientific Corp., Waltham, MA, USA) and a mass spectrometer detector (ISQ Single Quadrupole Mass Spectrometer, THERMO Scientific Corp., Waltham, MA, USA) were both used to analyze the extract (GC–MS). The following temperature program was used for the analyses, which used helium as the carrier gas at a flow rate of 1.0 mL/min and a split ratio of 1:10. The temperature was kept at 240 °C for one minute after rising from 60 °C for one minute at a rate of 3.0 °C per minute. At 240 °C, the injector and detector were maintained. Next, 0.2 L of the mixtures’ diluted samples (1:10 hexane, v/v) was injected. Electron ionization (EI) at 70 eV with a spectral range of m/z 40–450 was used to produce mass spectra. Analytical mass spectra were used to identify the majority of the substances (authentic chemicals, Wiley spectral library collection and NSIT library). Table 2 lists the chemical make-up of the active components in oregano oil.
Table 2. Relative composition of active components (g/kg) of oregano bioactive lipid compounds (OBLC).

| Active Components        | g/kg |
|--------------------------|------|
| Carvacrol                | 850.7|
| α-Cymene                 | 37.8 |
| γ-Terpinene              | 31.9 |
| Thymol                   | 13.2 |
| Thujene                  | 8.4  |
| α-Pinene                 | 6.4  |

2.5. Broiler Performance Parameters

From the beginning to the end of the experiment, the body weight of the birds in each pen was measured on a weekly basis. On the day the birds were weighed, a measurement of feed residue was taken to determine the amount of feed consumed in each pen. The amount of feed consumed by the weight gained in each pen was divided to obtain the feed conversion ratio. The magnitude of production variables such as feed consumption and body weight were adjusted appropriately for the dying birds.

2.6. Survivability Rate and Cost Economics

The percentage of viability was computed as a result of daily mortality data. The formula shown below was used, according to Huff et al. [17], to calculate the European Performance Efficiency Factor (EPEF): body weight (kg) × % viability × 100/ feed conversion ratio × trial duration in days.

2.7. Carcass Criteria and Internal Organs

In total, 40 birds in each treatment were processed after 35 days to assess carcass criteria and internal organs. Individually weighed birds were sacrificed in a humane manner, left to bleed, and then plucked. After the neck, head, viscera, shanks, spleen, digestive tract, heart, gizzard, and belly fat were removed, the rest of the body was weighed. The dressing percentage was determined by dividing the carcass and giblets weight by the live weight. The heart, empty gizzard, spleen, and abdominal fat of each bird were separately weighed and expressed as a percentage of live body weight.

2.8. Silver Analysis

To assess the levels of silver in diets and breast meat samples, 5 g of each sample were microwave-digested at 200 °C and 40 bar pressure with the addition of 2 mL of 30% nitric acid before being analyzed using an Agilent 8800 Triple Quadrupole ICP-MS (Agilent Company, Santa Clara, CA, USA).

2.9. Blood Sampling and Laboratory Analyses

For serum collection, blood was collected from the wing vein of 30 birds per treatment with sterilized needles and syringes and placed in vacutainer tubes at the end of the experiment (35 days of age). The feeder was not removed from the feed before the blood was taken. At ambient temperature, the blood was centrifuged for 10 min (3000 × g). The serum was collected in tubes and kept at −20 °C until it was analyzed. Colorimetric analysis of liver enzymes, such as aspartate aminotransferase and alanine transaminase, as well as kidney function tests such as urea and creatinine, was performed (Diagnostic kits, Biodiagnostics, Cairo, Egypt) using Clinical chemistry analyzer SBA 733 plus (Sunostik Medical Technology Co., Ltd., Changchun, China).

2.10. Statistical Analysis

The general linear model (GLM) approach of Statistical Analysis System (SAS Institute, Inc., Cary, NC, USA) software was used to analyze all data [18]. To compare means,
Duncan’s multiple range test was utilized. Replicate pens were the experimental units for all analyses. The significance level was set at $p \leq 0.05$.

3. Results

3.1. Growth Performance and Feed Intake

The effects of OBLC, Nano-Silver, and their combination on productive performance of broiler chickens are summarized in Tables 3 and 4. The results showed that supplementation of OBLC and Nano-Silver separately as well as in combination, increased ($p < 0.01$) body weight at 21 and 35 days of age and daily body weight gain compared to CONT at 1–21, 22–35 and 1–35 days of age (Table 3). The combination of OBLC and Nano-Silver resulted in higher body weight at day 35 and daily body weight gain compared to other groups. Supplementation of broiler diets with OBLC, Nano-Silver, or their combination improved daily feed intake and daily feed conversion ratio throughout the experimental periods at 1–21, 22–35, and 1–35 days (Table 4). The best performance in terms of weight and weight gain was observed in the combination of OBLC and Nano-Silver group compared to other treatments.

Table 3. Body weight and daily body weight gain (g) of broilers in response to OBLC, Nano-Silver, and their combination supplementation.

| Items          | Body Weight, g | Daily Body Weight Gain, g |
|----------------|----------------|---------------------------|
|                | 1 Day          | 21 Days                   | 35 Days       | 1–21 Days          | 21–35 Days         | 1–35 Days |
| Control        | 43.3           | 854 b                     | 1872 c        | 38.08 b            | 72.00 c            | 52.25 c   |
| OBLC           | 42.5           | 922 a                     | 2010 a        | 41.88 a            | 77.71 b            | 56.21 b   |
| Nano-Silver    | 43.2           | 932 a                     | 2023 b        | 42.32 a            | 77.93 b            | 56.57 b   |
| Combination    | 41.3           | 941 a                     | 2114 a        | 42.84 a            | 83.79 a            | 59.22 a   |
| SEM            | 0.36           | 0.015                     | 0.001         | 0.012              | 0.007              | 0.006     |
| $p$-Value      | 0.949          | 0.015                     | 0.001         | 0.012              | 0.007              | 0.006     |

$^a$–$^c$ Means (n = 10) not sharing a common superscript compared among groups (including control) in a column are significantly different ($p < 0.05$). CONT (control diet), OBLC (CONT diet with 150 mg/kg of oregano bioactive lipid compounds), Nano-Silver (CONT diet with 4 mg/kg nanoparticles of Silver), and OBLC + Nano-Silver. SEM; Standard error of the means.

Table 4. Daily feed intake and daily feed conversion ratio of broilers in response to OBLC, Nano-Silver, and their combination supplementation.

| Items          | Daily Feed Intake, g | Daily Feed Conversion Ratio |
|----------------|----------------------|-----------------------------|
|                | 1–21 Days            | 21–35 Days                  | 1–35 Days       | 1–21 Days          | 21–35 Days         | 1–35 Days |
| Control        | 48.6                 | 121 c                       | 81.2 c          | 1.568 a            | 1.862 a            | 1.715 a   |
| OBLC           | 49.4                 | 126 b                       | 84.5 b          | 1.431 b            | 1.712 b            | 1.571 b   |
| Nano-Silver    | 49.4                 | 137 a                       | 88.1 a          | 1.442 b            | 1.721 b            | 1.581 b   |
| Combination    | 51.2                 | 139 a                       | 90.1 a          | 1.411 b            | 1.701 b            | 1.556 b   |
| SEM            | 2.94                 | 2.81                        | 1.12            | 0.032              | 0.022              | 0.024     |
| $p$-Value      | 0.671                | 0.018                       | 0.014           | 0.009              | 0.012              | 0.001     |

$^a$–$^c$ Means (n = 10) not sharing a common superscript compared among groups (including control) in a column are significantly different ($p < 0.05$). CONT (control diet), OBLC (CONT diet with 150 mg/kg of oregano bioactive lipid compounds), Nano-Silver (CONT diet with 4 mg/kg nanoparticles of Silver), and OBLC + Nano-Silver. SEM; Standard error of the means.

3.2. Economics and viability rates

The results of EPEF and viability rate in relation to OBLC and Nano-Silver alone and in combination in broiler diets are shown in Figure 1A,B. OBLC and Nano-Silver supplementation significantly raised overall EPEF (Figure 1A). Throughout the trial period, dietary OBLC and Nano-Silver, both independently and in combination, enhanced viability rate ($p = 0.003$) (Figure 1B). Interestingly, the supplementation groups had a lower death rate and, as a result, a larger net return was seen. The best net return was observed in the combination group. Extra cost of the Nano-Silver and oregano BLC was added to the feed
cost, whereas other productive costs were disregarded since they were constant. The total feed cost/bird for birds fed on control, Nano-Silver, OBLC, and combination diets was 0.82, 0.85, 0.89 and 0.91 $/bird, respectively.

![Figure 1](image1.png)

**Figure 1.** Broiler European production efficiency factor (A), [EPEF was determined using the following formula: body weight (kg) × % viability × 100/feed conversion ratio × trial duration in days] and broiler viability% (B) in response to OBLC, Nano-Silver, and their combination supplementation. a, b Means (n = 10) not sharing a common superscript compared among groups (including control) are significantly different (p < 0.05).

### 3.3. The Silver Retention

Figure 2 shows the concentrations of silver in diets, and breast meat of broiler chickens. There are differences in silver concentrations in broiler diets, and these changes had no effect on broiler chicken meat silver levels.

![Figure 2](image2.png)

**Figure 2.** Effects of Nano-Silver, OBLC, and their combination on broiler diets (A) and meat (B) silver concentrations of broilers (n = 10). a, b Means (n = 10) not sharing a common superscript compared among groups (including control) are significantly different (p < 0.05).
3.4. Carcass Criteria

In terms of carcass criteria (Table 5), dietary supplementation of OBLC, Nano-Silver, or their combination to broilers resulted in a substantial rise in dressing % and decrease in abdominal fat at the end of the experimental period when compared to the CONT. On the other hand, liver, heart, spleen, gizzard, small intestine, and cecum of broilers were not influenced by OBLC, Nano-Silver, or their combination ($p > 0.05$).

Table 5. Effect of Nano-Silver, OBLC and their combination on carcass criteria and internal organs of broilers.

| Items          | Treatments       | SEM   | p-Value |
|----------------|------------------|-------|---------|
|                | C                | Silver | OBLC | Silver + OBLC |
| Dressing       | 72.56$^b$        | 73.06$^b$ | 75.61$^a$ | 76.45$^a$ | 0.465 | 0.002 |
| Liver          | 1.832            | 1.821  | 1.835 | 1.904 | 0.079 | 0.721 |
| Heart          | 0.512            | 0.516  | 0.534 | 0.541 | 0.034 | 0.617 |
| Gizzard        | 1.371            | 1.405  | 1.388 | 1.412 | 0.079 | 0.624 |
| Spleen         | 0.203            | 0.204  | 0.207 | 0.209 | 0.027 | 0.496 |
| Abdominal fat  | 1.414$^a$        | 0.894$^b$ | 0.805$^b$ | 0.801$^b$ | 0.024 | 0.007 |
| Small intestine| 2.972            | 3.022  | 2.982 | 3.092 | 0.230 | 0.596 |
| Small intestine length, cm | 173.0          | 174.5  | 178.0 | 177.0 | 1.755 | 0.412 |
| Cecum          | 0.695            | 0.749  | 0.757 | 0.816 | 0.027 | 0.612 |
| Cecum length, cm | 16.21           | 17.15  | 16.27 | 17.33 | 0.521 | 0.521 |

$^a$, $^b$ Means ($n = 10$) not sharing a common superscript compared among groups (including control) are significantly different ($p < 0.05$). CONT (control diet), OBLC (CONT diet with 150 mg/kg of oregano bioactive lipid compounds), Nano-Silver (CONT diet with 4 mg/kg nanoparticles of Silver), and OBLC + Nano-Silver. SEM; Standard error of the means.

3.5. Blood Biochemistry

The effects of OBLC, Nano-Silver, and their combination on several blood biochemical tests in broilers were investigated in this study (Figures 3 and 4). Serum AST and ALT levels were significantly lower in the OBLC, Nano-Silver, and their combination groups than the CONT group (Figure 3). Serum creatinine, and urea levels were significantly lower in the OBLC, and the combination groups than the CONT group and Nano-Silver group (Figure 4). The lowest values were seen when the OBLC and Nano-Silver were combined, but it was not different than the OBLC group.

Figure 3. The influences of dietary supplementation with OBLC, Nano-Silver, and their combination on some liver function of broilers ($n = 30$). $^a$, $^b$, $^c$ Means ($n = 10$) not sharing a common superscript compared among groups (including control) are significantly different ($p < 0.05$).
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**Figure 3.** The influences of dietary supplementation with OBLC, Nano-Silver, and their combination on some liver function of broilers (n = 30). a–c Means (n = 10) not sharing a common superscript compared among groups (including control) are significantly different (p < 0.05).

**Figure 4.** The influences of dietary supplementation with OBLC, Nano-Silver, and their combination on some kidneys function of broilers (n = 30). a Means (n = 10) not sharing a common superscript compared among groups (including control) are significantly different (p < 0.05).

### 4. Discussion

The OBLC supplementation to broiler diets improved growth, economic performance, and reduced mortality compared to control for sustainable broiler production. Comparing studies that utilize various herbal ingredients is challenging because the effectiveness of these studies may be affected by a number of variables, including herbal composition, dose, application technique, and bird age [5,19–21]. Furthermore, due to the lack of other studies where OBLC was used on broiler chickens, additional phytogenic BLC studies were compared. Interestingly, the supplemented groups had a lower death rate than the control group, resulting in a larger net return in this study. Broiler mortality was reduced by using *Hippophae rhamnoides* extract as a phytogenic supplement in the diet, resulting in increased profitability [6]. Furthermore, broiler chicks administered phytogenic BLC showed a higher feed efficiency, potentially increasing broiler profitability. In this study, adding OBLC to the broiler diet resulted in considerably higher body weight and daily weight gain in comparison to the control group, demonstrating the important role OBLC played in turning digested feed into weight gain, mainly due to its active component. Likewise, improvement in feed conversion ratio has been connected to an improvement in feed utilization efficiency [22]. The active components of the medicinal plant may be responsible for broiler chicks fed OBLC growing faster.

Nano-Silver supplementation considerably increased broiler growth performance and profitability in the current study when compared to the control group. In the current study, supplementation of broiler diets with OBLC, Nano-Silver or their combination improved daily feed intake and daily feed conversion ratio throughout the experimental periods. The higher productive performance of broilers was observed in the combination group compared to other groups. These enhancements might be linked to synergistic effects of OBLC and Nano-Silver that have favorable effects on broiler growth performance, metabolism, gastrointestinal secretions, and health. Moreover, phytogenic BLC has been utilized traditionally in medicine and believed to be particularly beneficial in building the immune system and strong antioxidant properties, as well as increasing appetite, mainly due to its active components [4–6]. As a result of antibacterial and antioxidant properties, Nano-Silver is becoming increasingly essential due to its diverse range of applications [10,11]. Despite its extensive use, little research has been conducted to assess the biological impacts of Nano-Silver exposure. Furthermore, because Nano-Silver is
harmful to viruses, fungi, bacteria, and algae, it has the greatest favorable reaction as a powerful antimicrobial [10–12]. Broiler chicks given Nano-Silver showed improved body weight gain, feed efficiency, and ash digestibility, according to Saleh and El-Magd [7]. In addition, Andi et al. [10] found that supplementing broilers with Nano-Silver increased their growth performance substantially. However, numerous other studies have shown no significant alterations in chickens fed Nano-Silver [13–15]. These discrepancies could be due to differences in Nano-Silver size, level, duration, preparation method, and bird age.

It appears that Nano-Silver has the tendency to reduce the symptoms of gastrointestinal illnesses that strengthened the digestive system and enhanced feed efficiency, which, in turn, led to a positive influence on daily body weight increase. The food chain may provide a health risk by transmitting hazardous compounds to bird tissues and, as a result, to humans [23]. Mineral antagonism in the gut or at the cellular level can cause mineral imbalance by altering mineral intake, transit, and excretion [23,24]. Due to the changed absorption mechanisms, green Nano-Silver may be more accessible due to fewer antagonistic effects among bivalent cations [25,26]. After single and repeated injections, Hendrickson et al. [27] found that Nano-Silver in drinking water at values of 5, 15, and 25 ppm had no adverse environmental consequences. According to our research, adding Nano-Silver, OBLC, or their combination to chicken diets did not significantly alter the amount of residual silver in broiler muscles. Kulak et al. [28] found that broiler chickens given oral doses of silver nanoparticles left residues in the small intestine and liver but not in the heart or breast muscle. Anti-inflammatory cytokines activity increased in the animal defense response to Nano-Silver [14,29]. Larger particles may have differing transport rates, less contact with cellular membranes, and are better maintained in the gastrointestinal epithelium mucous layer than smaller particles [30]. Metallic silver nanoparticles (up to 100 nm) have a stronger antibacterial action than silver salts, are less susceptible to gastric acid inactivation, and have a low absorption rate through the intestinal mucosa, reducing the risk of toxicity [8]. Similarly, Sawosz et al. [31] discovered that injecting 50 ppm Nano-Silver into broiler embryos had no toxicity and had no influence on alanine transferase, AST, or alkaline phosphatase activity, as well as serum cholesterol, glucose, or triglyceride concentrations.

Adding OBLC, Nano-Silver, or their combination to broilers resulted in a significant increase in dressing percent and a decrease in abdominal fat at the end of the experimental period as compared to the control group. The reduced content of abdominal fat could be related to the addition of phytoprogenic components in the broilers diet that improved activities of enzymes related to fat metabolism. OBLC, Nano-Silver, or their combination had no effect on the breast, leg, liver, heart, spleen, gizzard, small intestine, large intestine, or cecum of broilers (p > 0.05). There were no significant differences in dressing percentages or portions of the carcass due to Nano-Silver administration or breed in rabbits, and the dose of injected Nano-Silver had no effect on the percentages of liver, heart, kidney, and spleen [32]. In addition, Kim et al. [33] found that oral Nano-Silver treatment had no influence on the relative weights of the spleen, liver, heart, and kidney. Except for carcass and dressing weight, and relative liver of the pre-slaughter weight, there were no significant variations in carcass attributes between treatments when OBLC was substituted for soybean meal in rabbits [34].

In our experiment, OBLC, Nano-Silver, and their combination reduced serum AST and ALT, and only OBLC and the combination group reduced urea and creatinine levels in broilers compared to the control. The levels are within a physiologically normal range. In general, serum AST and ALT, as well as urea and creatinine, were considered markers for liver damage and kidney damage, respectively. As a result, the findings of this study may indicate that feeding Nano-Silver with or without OBLC to broilers has no toxicity, and these treatments were safe to poultry. Both OBLC and Nano-Silver are identified as potential alternatives to dietary antibiotics with an improvement in productive performance in poultry. However, few studies demonstrated the synergistic effect between them, especially in broilers. Other studies showed that Nano-Silver had a negative effect on
serum uric acid but no effect on AST or ALT because uric acid is a metabolite generated in the kidney. As uric acid is a metabolite produced in the kidney, it is an indication of renal injury [12,31,35]. Similarly, Sawosz et al. [31] discovered that nanoparticles had no effect on the activities of ALT, AST, glucose, or cholesterol. In birds fed (2, 4, and 6 ppm) Nano-Silver, Elkloub et al. [36] found that immunity and antioxidant capacity improved, and blood total lipids and cholesterol decreased, while antioxidant capacity rose. Furthermore, protein catabolism was affected by Nano-Silver hydrocolloids, as demonstrated by lower activity of liver enzymes (ALT and AST) as well as lower levels of creatinine and urea (major protein metabolism products) [37].

Nano-Silver at doses of 5, 15, and 25 mg/L in drinking water had no deleterious effects on broiler internal organs [13]. In contrast, Saleh and El-Magd [7] reported that the plasma AST was not influenced in broiler chicks fed a Nano-Silver-supplemented diet, when compared to the control group. Andi et al. [12] showed that Nano-Silver supplemented to broiler diets had no effect on AST and ALT. Again, other parameters should be considered, such as the age of the bird and the size, level, duration, and preparation procedure of the Nano-Silver.

However, there is an ongoing debate on the effectiveness of adding OBLC or Nano-Silver to broiler diets. This may be because different sources have different outcomes, and it may also depend on the housing and health condition of the birds. A meal containing OBLC at 150 mg/kg, with or without Nano-Silver at 4 mg/kg, was determined to be suitable for the broiler’s productive performance when these factors were considered. The little information available on the addition of OBLC and Nano-Silver in broilers suggests that these nutrients could be used as an innovative nutritional strategy for sustainable broiler production.

5. Conclusions

According to the findings, oregano bioactive lipid compounds, Nano-Silver, and their combination improved the growth performance, liver function, profitability, dressing percent, silver absorption and reduced abdominal fat percent. The best results were obtained by supplementing broiler diets with a combination of oregano bioactive lipid compounds and Nano-Silver due to their synergistic role and without any negative effects on liver or kidney functions.

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