Effect of nanoclay minerals on growth performance, internal organs and blood biochemistry of broiler chickens compared to vaccines and antibiotics

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ABSTRACT
The study objective was to investigate the effect of three levels of nanoclay minerals (1%, 1.5% and 2%) on growth performance, internal organs and blood biochemistry of broiler chickens compared to vaccines and antibiotics. An experiment of nine dietary treatments was conducted for over than 36 days. Groups 1, 2 and 3 were fed diet without nanoclay minerals and served as control group (positive with vaccines and antibiotics (C1), positive with vaccines only (C2) and negative without any of them (C3). Treatments groups 1, 2, 3, 4, 5 and 6 were fed the same diet with the above-mentioned levels once a week or once in 2 weeks. 2% nanoclay minerals fed at the two intervals significantly improved broilers’ performance in terms of live body weight, body weight gain and feed conversion ratio compared to control groups. Concerning blood biochemistry, high-density lipoprotein which known to be beneficial for humans increased (P < .05) by feeding 1.5% nanoclay minerals at the two ages compared to control groups and other treatments. In conclusion, the present results indicate that nanoclay minerals in particular levels and doses improve the growth performance of broiler chickens. Nanotechnology as a new tool has the potential to improve broiler production.

1. Introduction
Advances in poultry production have led the way in animal agriculture, beginning with least cost formulation and development of accurate requirements. Formulation of broiler diets consists of an array of ingredients that match a derived nutrient profile at minimum cost. The nutrient profile is based on researches and/or field observations evaluating the economically important production functions such as live body weight (LBW), body weight gain and efficiency of feed conversion (Mansoori 2005; Westerlund 2011). Nanotechnology undoubtedly is one of the most important technologies of the twenty-first century, and it has the potential to create many new materials. Commercially significant types of nanomaterials include metal and metal oxide nanoparticles, nanoclays, silica nanoparticle, nanoemulsion and nanoporous materials (Sekhon 2012). One cannot effectively discuss the relevance of nanotechnology to biologists without first understanding the terminology. Nanotechnology is defined as technology of materials and structures where size is measured in nanometres, with application in diverse areas such as physics, chemistry and biology (Real Academia Espanola 2001; Buzea et al. 2007). This implies a certain understanding and control of matter measuring from 1 to 100 nm, with the capability of having new applications. This is because at such small sizes, the properties of matter can differ from those of a larger scale. The applications of nanotechnology are indeed very varied. In the field of veterinary medicine and animal production there is a growing interest in the application of nanotechnology that can be used as a supplemental source of trace minerals (Na2O, MgO, Al2O3, SiO2, K2O, CaO, TiO2 and Fe2O3) in diets. Nanotechnology can also reduce the time of production of meat and eggs. The potential of nanotechnology in broiler production cannot be fully appreciated yet because of insufficient knowledge. From another point of view, feeding certain antibiotics at low levels for an extended period of time is a common practice in the poultry industry and provides economic benefits by increasing weight gain and improved feed efficiency (Thromke & Elwin-ger1998). Recently, published data indicated that the use of in-feed antibiotics has been banned due to the potential development of antibiotics-resistant human pathogenic bacteria and their residues in poultry production (Botsoglou & Fletouris 2001; Moser et al. 2003; Verma et al. 2012). For that, the search for alternatives to antibiotics as growth promoters is the target of numerous lines of investigations using nanotechnology as a new tool. Therefore, the present study is designed to examine the effect of using nanoclay minerals on growth performance, internal organs and blood biochemistry of broiler chickens compared to vaccines and antibiotics.

2. Materials and methods
2.1. Experimental birds and rearing conditions
The present study was conducted at the poultry farm of the Animal Production Department/Faculty of Agriculture, Jordan...
University of Science and Technology. A total of 900 one-day-old unsexed Hubbard chicks were purchased from a local commercial hatchery with an average weight of 35 g. Chicks were randomly assigned into 36 pens (1.15 m × 2.10 m) in an open-sided house (9 treatments × 4 replicate × 25 chicks). Natural ventilation through the windows created inside the house was used. Temperature inside the house started with 33°C at day 1 of age and reduced gradually until it reached 25°C after two weeks of age. Humidity ranged from 55% to 60% R.H. inside the house as a natural R.H.

Feeds and water were offered ad-libitum. Chicks of control I and II were vaccinated against Newcastle (ND) using the HB1 strain combined with infectious bronchitis (IB) using IB 120 strain at day 7 of age, ND only using La Sota strain at day 21 of age and against Infectious bursal disease (IBD) using D 78 Strain at day 13 of age. The antibiotics used in control I was Enrofloxacin 100 mg/ml.

The scheme of the experiment (treatments) is presented in Table 1.

2.2. Experimental diets

Chicks were fed a starter diet from day 1 to day 28 of age, and a finisher diet from day 29 to day 36 of age (Table 2). All diets were formulated in accordance with requirements recommended by the strain guide. Samples from each starter and finisher diets were randomly collected for proximate analysis by the procedure described by the Association of Official Analytical Chemists (AOAC 1990).

2.3. Preparation of nanoclay minerals

A sample of clay minerals was used for the preparation of aqueous nanosuspension applied in the experiment. The sample of clay minerals obtained from Al-Azraq area in Jordan was mechanically wet grinded up to the nanoscale, by using two adjacent concentric cylinders (inner diameter of outer cylinder–outer diameter of inner cylinder 1 mm) with rotating inner cylinder (12,000 rpm) and fixed outer cylinder, at room temperature for 1 min. The pot time of the aqueous nanosuspension was about half an hour and suspensions were further stabilized by mechanical stirring. Samples of the aqueous nanosuspensions were imaged under a transmission Electron Microscope, and the image reveals the ‘united structure’ of the clay minerals, that is, ‘nano-flake’ with length of ca.100 nm and thickness of ca. 1 nm as shown in Figure 1.

2.4. Chemical composition of the used clay minerals

The pH value of aqueous nanosuspensions of clay minerals was determined and found to be 8.3–9.1 (alkaline), and chemical compositions of the used clay minerals are given in Table 3.

2.5. Preparation of nanotechnology feed

Nanotechnology feed was prepared according to the following steps:

1) Preparation of nanoflakes made of clay minerals.

2) Depending on the fact that the best percentage of mixing aqueous nanosuspension of clay minerals with the feed was 1:3. This ratio was obtained as a result of several trials to find the best ratio for complete drying of the feed.

3) Calculation of the percentage of aqueous nanosuspension of clay minerals (1%, 1.5% and 2%) was done.

4) After mixing the aqueous nanosuspension with the feed with different percentages, it was completely air dried before being offered to the birds.

2.6. Measurements

2.6.1. Live body weight and feed intake

LBW and feed intake (FI) were measured every week. Cumulative feed intake (CFI), body weight gains (BWG) and feed conversion ratio (FCR) were calculated at day 28 and day 36 of age.

2.6.2. Internal organs

Liver, gizzard, proventriculus, heart, spleen and bursa of the Fabricious gland were collected from five randomly selected broiler chickens from each replicate within each treatment at day 28 and day 36 of age and weighed. Percentage of each organ to LBW was also calculated.

2.6.3. Determination of blood biochemistry

At days 28 and day 36 of age, five chickens from each replicate within each treatment were randomly selected for blood assay. The blood was collected in non-heparinized
tubes and centrifuged at 4000 rpm for 3 min. Clear serum was separated and stored at −20°C for blood biochemistry determination. Serum total protein, albumen, globulin, triglycerides, cholesterol, low-density lipoprotein (LDL) and high-density lipoprotein (HDL) were assayed spectrophotometrically using commercial Kits purchased from BIOLABO, BIOSYSTEMS and ACROMAX.

2.6.4. Statistical analysis
Pen means were used as experimental units. A completely randomized statistical design was used. Statistical significance was based on probability of $P < .05$. Data were subjected to ANOVA using the general linear model procedure of an SAS system (SAS 2002). Mean separation was accomplished using Duncan’s multiple range test (Duncan 1955) when a significant $F$ statistic was indicated by ANOVA.

3. Results

3.1. Growth performance
Table 4 shows LBW, BWG, CFI and FCR of broiler chickens fed three levels (1%, 1.5% and 2%) of nanoclay minerals and offered once a week or once in 2 weeks at day 28 of age. Results demonstrated that 2% nanoclay minerals offered once a week (T5) significantly improved growth performance in terms of BW, BWG and FCR at both ages.

3.2. Internal organs
Data of internal organs percentage to LBW at 28 days of age are presented in Table 6 and 36 days of age are presented in Table 7. The use of 1.5% of nanoclay minerals (T3) in broiler chickens’ diet at day 28 of age offered once a week increased ($P < .05$) liver, gizzard, heart and pancreas percentage compared to C1, C2, C3 and other dietary treatments (Table 6). However, 2% of nanoclay minerals offered once a week only increased spleen percentage and that offered once in two weeks significantly increased the bursa of the Fabricious gland percentage compared to other dietary treatments. On the other hand, the data of day 36 of age (Table 7) show that vaccinated broiler chickens fed basal diet recorded the highest liver, gizzard, proventriculus, heart and spleen percentage compared to other dietary treatments. However, vaccinated broiler chickens fed basal diet supplemented with antibiotics gave significantly the highest bursa of Fabricious percentage compared to other dietary treatments.

3.3. Blood biochemical measurements
Table 8 shows blood biochemistry of broiler chickens fed three levels (1%, 1.5% and 2%) of nanoclay minerals offered at different periods of time (once a week and once in 2 weeks) at day 28 of age expressed as means ± SE. At day 28 of age, 1.5% once a week or 2% of nanoclay minerals offered once a week or once in 2 weeks at day 36 of age showed significantly increased total protein, albumen, globulin and HDL concentrations. Meanwhile, broiler chicks fed 2% nanoclay minerals offered once a week recorded the lowest ($P < .05$) triglycerides and LDL concentrations. Table 9 shows

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Table 1. Scheme of treatments.

| Groups | Receive diets |
|--------|--------------|
| 1-Control | Basal diet + + + |
| 2-Control | Antibiotics + + |
| 3-Control | Vaccines + + |
| 4 (T1) | 1% Nanoclay + + |
| 5 (T2) | 1.5% Nanoclay + + |
| 6 (T3) | 2% Nanoclay + + |
| 7 (T4) | + + + |
| 8 (T5) | + + + |
| 9 (T6) | + + + |

T1 – offered once a week, T2 – offered once in 2 weeks, T3 – offered once a week, T4 – offered once in 2 weeks, T5 – offered once a week, T6 – offered once in 2 weeks.

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Table 2. Composition of experimental rations.

| Ingredient (g/k) | Starter | Finisher |
|------------------|---------|----------|
| Corn             | 615     | 695      |
| Soybean meal     | 340     | 237      |
| Broiler concentrate | 20     | 40       |
| CaCO3            | 12.5    | 12.3     |
| Dicalcium phosphate | 7.2   | 10       |
| NaCl             | 2.5     | 2.5      |
| Lysine           | 0.3     | -        |
| Methionine       | -       | 0.7      |
| Vitamin-Mineral premixa | 2.5 | 2.5 |
| Total            | 1000 g  | 1000 g   |

Calculated feeding value

| Crude protein (%) | 22.30 | 18.73 |
| Metabolizable energy (MJ) | 12.30 | 12.65 |
| Lysine (%)        | 1.26   | 1.05   |
| Methionine + Cystine (%) | 0.97  | 0.65   |

Analysed feeding value

| DM (%)            | 91.50  | 91.20  |
| Crude protein (%) | 22.20  | 18.80  |

Vitamin: Mineral Premix: Provided the following: 2,000,000 IU vitamin A; 400,000 IU Vitamin D3; 400 mg Vitamin E; 200 mg Vitamin B1; 800 mg Vitamin B2; 4000 mg Nicotinic acid; 2000 mg Pantothenic acid; 300 mg Vitamin K; 200 mg Folic acid; 300 mg Vitamin B6; 50 mg (Co; 1600 Cu; 6421 mg Fe; 156 mg I; 12800 Mn; 32 mg Se; 9000 mg Zn; 100 mg Choline Chloride.

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Table 3. Chemical composition of clay minerals’ sample.

| Element | (%)      |
|---------|----------|
| Na2O    | 0.13     |
| MgO     | 3.47     |
| Al2O3   | 20.08    |
| SiO2    | 55.67    |
| K2O     | 2.45     |
| CaO     | 2.15     |
| Fe2O3   | 2.54     |
| TiO2    | 13.47    |

 análised feeding value

| DM (%)     | 91.50  | 91.20  |
| Crude protein (%) | 22.20  | 18.80  |

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Table 4. Composition of experimental rations.

| Ingredient (g/k) | Starter | Finisher |
|------------------|---------|----------|
| Corn             | 615     | 695      |
| Soybean meal     | 340     | 237      |
| Broiler concentrate | 20     | 40       |
| CaCO3            | 12.5    | 12.3     |
| Dicalcium phosphate | 7.2   | 10       |
| NaCl             | 2.5     | 2.5      |
| Lysine           | 0.3     | -        |
| Methionine       | -       | 0.7      |
| Vitamin-Mineral premixa | 2.5 | 2.5 |
| Total            | 1000 g  | 1000 g   |

Calculated feeding value

| Crude protein (%) | 22.30 | 18.73 |
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blood biochemistry of broiler chickens fed three levels (1%, 1.5% and 2%) of nanoclay minerals offered at different periods of time (once a week and once in 2 weeks) at day 36 of age expressed as means ± SE. At day 36 of age, 2% nanoclay minerals offered once a week significantly improved globulin concentration with all dietary treatments. 2% of nanoclay minerals offered once a week significantly improved total protein concentration compared to C1, C2, C3, T1 and T2. However, 1% of nanoclay minerals offered once in 2 weeks increased (P < .05) albumen concentration compared to C1, C2, C3, T1 and T2. Nevertheless, no significant differences were noticed in triglycerides’ concentration as a result of 1.5% and 2% nanoclay minerals’ addition either once a week or once in 2 weeks compared with C1 and C2. The lowest (P < .05) cholesterol value was obtained as a result of adding 1% nanoclay minerals to the basal diet of broiler chicks once a week.

### 3.4. Mortality
The results of this experiment showed that no death of chickens was observed.

### 4. Discussion
Data of the present experiment indicate that 2% of nano clay minerals fed once a week significantly improved LBW, BWG and FCR of broiler chickens at days 28 and 36 of age. We believe that the positive and favourable effects of using

| Parameters               | C1                  | C2                  | C3                  | T1                  | T2                  | T3                  | T4                  | T5                  | T6                  |
|--------------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| Liver (%)                | 3.800f              | 3.270f              | 2.580f              | 2.300f              | 3.018f              | 4.070f              | 3.020f              | 3.560f              | 2.578f              |
| ± 0.008                  | ± 0.009             | ± 0.009             | ± 0.007             | ± 0.023             | ± 0.008             | ± 0.007             | ± 0.004             | ± 0.008             | ± 0.004             |
| Gizzard (%)              | 3.370d              | 3.293d              | 2.860c              | 2.600d              | 2.895e              | 3.385e              | 2.790f              | 3.190f              | 2.737c              |
| ± 0.004                  | ± 0.004             | ± 0.004             | ± 0.008             | ± 0.013             | ± 0.008             | ± 0.008             | ± 0.006             | ± 0.008             | ± 0.008             |
| Proventriculus (%)       | 0.700b              | 2.160b              | 0.510b              | 1.030b              | 0.503b              | 0.670b              | 0.550b              | 0.640b              | 0.460b              |
| ± 0.008                  | ± 0.004             | ± 0.004             | ± 0.009             | ± 0.013             | ± 0.008             | ± 0.008             | ± 0.008             | ± 0.008             | ± 0.008             |
| Heart (%)                | 0.560d              | 0.560d              | 0.510a              | 0.483f              | 0.560f              | 0.660f              | 0.470f              | 0.630f              | 0.540f              |
| ± 0.004                  | ± 0.004             | ± 0.004             | ± 0.008             | ± 0.009             | ± 0.008             | ± 0.008             | ± 0.008             | ± 0.008             | ± 0.008             |
| Spleen (%)               | 0.120f              | 0.130f              | 0.100e              | 0.090d              | 0.100e              | 0.120f              | 0.130f              | 0.168b              | 0.110c              |
| ± 0.008                  | ± 0.004             | ± 0.004             | ± 0.007             | ± 0.008             | ± 0.008             | ± 0.008             | ± 0.008             | ± 0.008             | ± 0.008             |
| Pancreas (%)             | 0.490c              | 0.340b              | 0.353d              | 0.370f              | 0.370f              | 0.600c              | 0.340b              | 0.535b              | 0.330c              |
| ± 0.008                  | ± 0.004             | ± 0.003             | ± 0.004             | ± 0.004             | ± 0.004             | ± 0.004             | ± 0.008             | ± 0.008             | ± 0.008             |
| Bursa of Fabricious (%)  | 0.260b              | 0.260b              | 0.250b              | 0.180d              | 0.200f              | 0.270b              | 0.190d              | 0.210b              | 0.380c              |
| ± 0.004                  | ± 0.004             | ± 0.004             | ± 0.008             | ± 0.008             | ± 0.014             | ± 0.008             | ± 0.008             | ± 0.008             | ± 0.008             |

Note: *Means with different superscripts in the same row are significantly different at P < .05.
Liver (%) 3.51\(^{c}\) 3.85\(^{a}\) 3.07\(^{b}\) 3.43\(^{d}\) 3.36\(^{e}\) 3.77\(^{b}\) 2.69\(^{i}\) 3.18\(^{f}\) 2.87\(^{h}\)

Gizzard (%) 2.64\(^{a}\) 2.68\(^{a}\) 2.67\(^{a}\) 2.45\(^{b}\) 2.55\(^{b}\) 2.40\(^{g}\) 2.45\(^{b}\) 2.30\(^{g}\)

Proventriculus (%) 0.548\(^{b}\) 0.590\(^{a}\) 0.490\(^{a}\) 0.488\(^{b}\) 0.478\(^{e}\) 0.510\(^{cde}\) 0.460\(^{a}\) 0.520\(^{cde}\) 0.500\(^{a}\)

Pancreas (%) 0.320\(^{bc}\) 0.328\(^{bc}\) 0.320\(^{b}\) 0.270\(^{c}\) 0.310\(^{b}\) 0.310\(^{b}\) 0.270\(^{c}\) 0.310\(^{b}\) 0.380\(^{a}\)

Spleen (%) 0.120\(^{a}\) 0.120\(^{a}\) 0.110\(^{abc}\) 0.093\(^{c}\) 0.108\(^{abc}\) 0.110\(^{abc}\) 0.095\(^{c}\) 0.108\(^{abc}\) 0.100\(^{bc}\)

Gizzard (%) 2.640\(^{a}\) 2.680\(^{a}\) 2.673\(^{a}\) 2.10\(^{e}\) 2.450\(^{c}\) 2.550\(^{b}\) 2.100\(^{e}\) 2.450\(^{c}\) 2.305\(^{d}\)

Note: a-f Means with different superscripts in the same row are significantly different at P < 0.05.
Table 9. Blood biochemical measurements at day 36 of age of broiler chickens fed nanoclay (Means ± SE).

|               | C1 | C2 | C3 |
|---------------|----|----|----|
|               | Vaccine + antibiotic | Vaccine | No vacc | No anti |
| Total protein (mg/dl) | 2.10<sup>b</sup> | ± 0.09 | ± 0.13 | ± 0.07 |
| Albumen (mg/dl) | 0.96<sup>c</sup> | ± 0.15 | ± 0.01 | ± 0.05 |
| Cholesterol (mg/dl) | 175.88<sup>b</sup> | ± 7.35 | ± 8.31 | ± 5.46 |
| HDL (mg/dl) | 103.68<sup>d</sup> | ± 6.89 | ± 4.20 | ± 5.14 |
| LDL (mg/dl) | 72.20<sup>hc</sup> | ± 2.37 | ± 5.50 | ± 2.20 |
| Triglycerides (mg/dl) | 136.18<sup>b</sup> | ± 3.15 | ± 3.92 | ± 5.19 |
| HDL (mg/dl) | 103.68<sup>d</sup> | ± 6.89 | ± 4.20 | ± 5.14 |
| LDL (mg/dl) | 72.20<sup>hc</sup> | ± 2.37 | ± 5.50 | ± 2.20 |
| Triglycerides (mg/dl) | 136.18<sup>b</sup> | ± 3.15 | ± 3.92 | ± 5.19 |

Note: <sup>a-d</sup>Means with different superscripts in the same row are significantly different at <i>P</i> < .05.

(a) Quantum effect: quantum points are a type of nanostructure, just a few nanometres in size that show behaviour similar to a single atom.

(b) Surface: the atoms of nanomaterials are more stable than those with a large-scale structure, since the energy required to join adjacent atoms is less.

Besides that, the increase in BW and BWG of broiler chickens fed 2% nanoclay minerals once a week may be attributed to the fact that nanoparticles have a surface area much larger than micro-particles. However, to clear this point, we assume that as the size of nanoparticles decreases, the surface area for chemical reactions increases, leading to better digestion and utilization of minerals in the GI tract. Furthermore, our earlier experiment indicated that 2% of aqueous nanosuspension of clay minerals offered once in two weeks significantly increased BW and BWG and improved FCR (El-Shuraydeh et al. 2014). Unfortunately, there is a lack or even null information in this field.

Concerning the internal organs, the addition of 1.5% nanoclay minerals to broiler chickens’ diet once a week increases (P < .05) liver, gizzard, heart, and pancreas percentage at day 28 of age. This significant improvement might be due to the physical, chemical and biological properties of nanoparticles of clay minerals that are different fundamentally and unexpectedly from those of corresponding large-scale ones (Scott 2005; Romero- Perez et al. 2010). However these are the major segments of the gastrointestinal tract (GI) that are responsible for the digestion and absorption of feed ingredients and nutrients, which may explain why the internal organs’ measurements were used in this experiment. Recently published data indicated that Ag-nanoparticles affected gene expression for muscle growth directly or indirectly, fibroblast growth factor 2 (FGF2), vascular endothelial growth factor (VEGF) and Na<sup>+</sup>/K<sup>+</sup> transporting ATPase (Hotowy et al. 2012; Sawors et al. 2013), which may explain the positive effect of nanoclay minerals used in the present experiment, as this clay contains several minerals in its composition such as Na<sup>+</sup>, K<sup>+</sup> and Ca<sup>2+</sup>, which can enhance internal organs’ percentage and increase BW and BWG obtained from our experiment but with nanoclay minerals. Musthag et al. (2014) demonstrated that Na<sup>+</sup>, the principal cation of extracellular fluid, is involved in numerous functions including the regulation of acid base balance and the absorption of glucose and amino acids that also play a particular role in improving internal organs’ percentage when it is transferred into nanoparticles. Sawors et al. (2013) proposed that muscle cell number is related to genetic, environmental and nutritional factors including structural and energy provided molecules. On the other hand, providing more available sources of minerals such as nanoclay minerals may exert positive effects including enhanced tissue development. Weiss et al. (2006) recorded that nanoparticle-sized ingredients might increase the functionality or bioavailability of ingredients and nutrients. However, the improvements in spleen and bursa of the Fabricious gland percentage at day 28 of age may be related to the reason discussed in the previous paragraph in this discussion. These two organs are known to be important in the immune system of broiler chickens.

At day 36 of age, vaccines (C2) increased (P < .05) liver, gizzard, proventriculus, heart and spleen percentage. This means that the use of different levels and doses of nanoclay minerals in broiler chickens’ diet did not reflect any positive effect on internal organs’ percentage compared to vaccines and antibiotics or vaccines alone.

Regarding blood biochemistry, total protein, albumen and globulin (mg/dl) statistically increased by adding 2% nanoclay minerals once a week or once in 2 weeks at day 28 of age. However, at day 36 of age, total protein and globulin concentration are increased (P < .05) compared to other dietary treatments. However, blood proteins reflect the condition of an organism, and the changes happening to it under influence of internal and external factors (Toghyani et al. 2010). According to the obtained results from the present study, it could be deduced that nanoclay minerals have a favourable effect on serum total protein and its fractions. It has been reported that nanoparticles show several novel characteristics of transport and uptake and exhibit higher absorption efficiencies (Ghithrani & Chan 2007; Zha et al. 2008; Liao et al. 2010). These authors suggested that the superior performance of nanoparticles of different minerals in clay may be due to their smaller particles.
and larger surface area, which may improve intestinal absorption due to the formation of nanoeulsion droplets. On the other hand, there has been growing interest over recent years in the modulation of fat profile including its fatty acids composition, triglycerides, cholesterol, HDL and LDL contents of poultry products. These components are considered as risk factors in the etiology of cardiovascular diseases; thus numerous efforts are undertaken to modify the composition of lipid fraction of meat and egg.

Several possibilities exist in this field of which one is our present study. Biochemical parameters studied in this experiment showed that serum cholesterol, HDL and triglycerides were statistically \( P < .05 \) influenced by addition of 2% nanoclay minerals either once a week or once in two weeks to broiler chickens’ diet at days 28 and 36 of age. In this regard, modern technologies such as bio- and nanotechnologies can play an important role in improving quality of food produced by farmers (Mousavi & Rezaei 2011).

Nevertheless, as mentioned previously the significant increase of serum HDL concentration at both ages may be related to the fact that nanoparticle-sized ingredients might increase the functionality or bioavailability of ingredients and nutrients which possibly could increase absorption and utilization of these nutrients (Desai et al. 1997), leading to improving the general performance of broiler chickens including blood biochemistry.

5. Conclusion

In conclusion, from the present results it could be speculated that different concentrations and doses (1%, 1.5% and 2%) of clay minerals could be of value to improve broiler growth performance, internal organs and blood biochemical measurements.

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