



# Effects of Different Dietary Oil Sources and Levels on Growth Performance and Serum Metabolites in Broiler Chickens

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**Abstract** | This study examined the effects of different oil sources and levels in diets of broilers on growth performance and serum metabolites. A total of 210 one day old broilers were allotted to 7 dietary groups. Diets were formulated, based corn and soybean meal, with different oil sources and levels: Control group was fed based diet with addition of 3% mixed oil (soybean oil and sunflower oil), and other diets were added 2% and 4% of linseed oil (LO), fish oil (FO), or soybean oil (SO) over 38 days. Body weight, body weight gain, and feed conversion were determined at day 21 and 38. At trials' end, liver, spleen and bursa of Fabricius were weighted. Serum total protein and albumin were measured, too. The results of growth performance showed that supplementation of 4% LO to the basal diet markedly increased the body weight gain of broiler chickens at day 21 and 38 (664 and 1046 g, respectively). The best dressing percentage was recorded in group fed 4% LO: (71.55%). A significant increase in total serum protein and globulin was noted in broilers fed 2% FO. In conclusion, supplementation with either 2% or 4% LO to broiler diets has more significant impacts on growth performance, while addition of FO improved immunity.

**Keywords** | Oils, Performance, Serum, Broilers

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## INTRODUCTION

Supplementation of dietary fat improves broilers performance regarding feed intake and weight gain (López-Ferrer et al., 2001; Rodríguez et al., 2005). The addition of oil to diet is necessary due to broilers have a high growth rate and a high energy demand (Furlan and Macari, 2002). Moreover, supplementation of dietary fat to poultry diets increases the absorption of fat-soluble vitamins as well as the palatability of the rations (Jeffre et al., 2010). It is well known that polyunsaturated fatty acids (PUFA) in oils are absorbed more easily than those containing saturated fatty acids, and thus PUFA have higher energy content resulted in improve broiler performance (Dvorin et al., 1998; Junqueira et al., 2005). Fatty acids (FA) are necessary components of energy metabolism, cell

membrane formation, and signaling processes (Jump et al., 2008). Moreover, the FA that could not be synthesized by the animals and are added to the diets are called essential FA. Evidence shows that feeding very low levels of essential FA in the diet of poultry results in poor reproduction, lowers immunity, rough dry skin and slows growth (Deborah, 1997).

The n-3 FA are a group of PUFA that include  $\alpha$ -linolenic acid, eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA). It has been stated that n-3 FA reduce risks and prevalence of some chronic diseases such as diabetes, cardiovascular disease, arthritis and cancer (Delgado-Lista et al., 2012). Marine oil is considered the major source of n-3 long chain PUFA in comparison to other types of oil (Hargis and Van Elswyk, 1993). Furthermore,

omega-3 FA have anti-inflammatory or less inflammatory properties by decreasing the release of pro-inflammatory eicosanoids and cytokines (Stulnig, 2003). It is well known that omega-3 FA improve immunity, performance, blood lipid profile besides increasing in market weight (Jameel and Sahib, 2014). Furthermore, vegetable sources, such as flax oil and rapeseed oil, may increase linolenic acid the precursor of the whole n-3 family. Therefore, it is important to determine whether performance and dressing percentage would be affected in broilers with using different oil sources and levels. Against this background, this study evaluated the influences of the inclusion of different oil sources and levels in isocaloric isonitrogenous diets on the growth performance, carcass traits and serum metabolites in broilers.

## MATERIALS AND METHODS

A total of 210 one-day old Cobb chickens were reared and randomly divided into 7 groups till day 38. Each treatment consisted of six replicates with 5 birds per pen. The experiment groups included: Control group (C) with 3% mixed oil (sunflower and soybean oil), and other diets were supplemented with 2% and 4% of linseed oil (LO), fish oil (FO), or soybean oil (SO). Three dietary phases were prepared: Starter diet (day 1-14), grower diet (day 15-28) and finisher diet (day 29-38). All diets were mashed without using any antibiotics growth promoters. Water and feed were provided ad libitum during the whole experiment. The birds were reared under constant lighting and at a starting temperature 32-35 °C. Temperature was gradually decreased between 25 and 28 °C over the following 2 weeks. The chicks were vaccinated via drinking water at the 7<sup>th</sup> day with Hitchner B1 against Newcastle disease. Individual body weight (BW), body weight gain (BWG) and feed conversion ratio (FCR) of broiler chickens were recorded at days 21 and 38 of life.

On the final day of the experimental period (day 38), all birds were slaughtered. Thereafter, all entrails in the carcass were removed and the empty carcass, liver, spleen and bursa of Fabricius were separately weighed (each of them was proportioned to the live pre-slaughter weight).

At the same time of slaughtering the blood samples were taken and immediately centrifuged for separating serum. The samples were frozen at -20 °C until analysis for determination of total protein (Cannon et al., 1974) and albumin (Young, 2000).

The fatty acids analyses were done according to (Cherian and Sim, 1992). Briefly, the oil samples of 250 µl were resolubilized into 2 ml of boron trifluoride-methanol-hexane solution (35% boron trifluoride, 45% methanol, 20% hexane). The tubes containing the resolubilized oil samples

were heated in a water bath (90-100 °C) for 60 min. After cooling, 2 ml of hexane and 2 ml distilled water were added. Then the samples were mixed and allowed to separate. The hexane (upper) layer was withdrawn then for separation of fatty acids by gas chromatography (Thermo-nicolet, USA) about 2 µl of hexane layer was taken.

All analyses were done using the software SPSS 20 (SPSS Inc, Chicago, Illinois) to evaluate the influence of different dietary levels and sources of oil on growth performance and carcass traits. One-way ANOVA and Duncan's multiple comparisons of the means to compare data obtained. Data were expressed as means standard errors. Differences between treatments were considered significant when  $P < 0.05$ .

## RESULTS AND DISCUSSION

The composition of the experimental diets was formulated to meet the nutrient requirements of broilers as recommended for the Cobb strain (Table 1). No marked differences in the chemical composition were noted between the experimental diets in each dietary phase. The fatty acid profiles of supplemented oils are shown in (Table 2). The linoleic acid (C18:2 n-6) content in SO was comparatively higher than those of LO and FO (56%, 10.9% and 2.2%, respectively). However, the  $\alpha$ -linolenic acid (C18:3 n-3) content was higher in LO (64.12%) than in SO (7.50%) and FO (1.33%). The long chain fatty acids (EPA and DHA) were higher in FO (10.65% and 8.64%, respectively) than SO and LO.

The impact of different sources of oil in diets of broilers on growth performance is shown in (Table 3). In the period from day 1 to 21 of life, supplementation of the basal diets with 2% and 4% LO significantly improve BW (683 g and 697 g, respectively) and BWG in comparison to those fed control or 2% SO diets. In the group fed diet supplemented with 2% FO from day 1 to 21 of life showed significant increase in BW (668 g) and BWG (632 g) compared to those fed diets supplemented with 2% SO or without supplementation (control). However, no significant differences were noted in BW and BWG between groups fed diets supplemented with SO (2% or 4%) or with 4% FO and the control group.

Regarding BW in the period from day 22 to 38 of life, the group fed diet with addition of 4% LO had significant increase in BW (1743 g) compared to other experimental groups (except for group fed 2% LO). Moreover, no significant differences in BW (day 22-38) were found between all experimental groups except for group fed 4% LO (Table 3). The groups fed 2% or 4% LO had the most favourable FCR (1.88 and 1.83, respectively) compared to other expe-

**Table 1:** Ingredients (g/kg) and chemical composition of experimental diet

| Ingredients                 | Dietary treatments <sup>1</sup> |       |       |        |       |       |          |       |       |
|-----------------------------|---------------------------------|-------|-------|--------|-------|-------|----------|-------|-------|
|                             | Starter                         |       |       | Grower |       |       | Finisher |       |       |
|                             | C                               | 2%    | 4%    | C      | 2%    | 4%    | C        | 2%    | 4%    |
| Corn grain (8%)             | 568.5                           | 590.8 | 544.4 | 626.4  | 648.8 | 603.7 | 667.4    | 687.3 | 645.0 |
| SBM (44%)                   | 322.3                           | 287.0 | 357.4 | 265.6  | 230.4 | 300.8 | 205.6    | 178.7 | 264.5 |
| Corn gluten (60%)           | 42.3                            | 64.6  | 22.6  | 42.9   | 64.4  | 21.4  | 64.3     | 80.4  | 20.0  |
| Oil                         | 30.0                            | 20.0  | 40.0  | 30.0   | 20.0  | 40.0  | 30.0     | 20.0  | 40.0  |
| DiCaP                       | 17.5                            | 17.6  | 17.4  | 16.2   | 16.3  | 16.1  | 14.3     | 14.4  | 14.1  |
| Limestone                   | 10.7                            | 11.0  | 10.4  | 10.3   | 10.6  | 10.1  | 9.8      | 10.0  | 9.4   |
| Vit&Min premix <sup>2</sup> | 2.5                             | 2.5   | 2.5   | 2.5    | 2.5   | 2.5   | 2.5      | 2.5   | 2.5   |
| Common salt                 | 3.4                             | 3.4   | 3.4   | 3.4    | 3.4   | 3.4   | 3.2      | 3.2   | 3.2   |
| DL-Methionine               | 0.8                             | 0.6   | 0.9   | 0.7    | 0.6   | 0.9   | 0.4      | 0.3   | 0.7   |
| DL-Lysine                   | 2.0                             | 2.5   | 1.0   | 2.0    | 3.0   | 1.1   | 2.5      | 3.2   | 0.6   |
| Chemical analyses, g/kg DM  |                                 |       |       |        |       |       |          |       |       |
| DM                          | 876                             | 881   | 871   | 875    | 882   | 872   | 873      | 878   | 872   |
| Crude ash                   | 59.8                            | 59.5  | 59.6  | 74.7   | 74.5  | 73.8  | 64.3     | 64.4  | 64.8  |
| Crude protein               | 215                             | 216   | 213   | 194    | 193   | 196   | 183      | 181   | 185   |
| Crude fibre                 | 30.2                            | 30.5  | 30.8  | 26.2   | 26.7  | 26.9  | 26.1     | 26.5  | 26.4  |
| Crude fat                   | 95.3                            | 87.4  | 103.2 | 95.7   | 88.1  | 104.5 | 96.1     | 87.8  | 105.2 |
| Calcium                     | 13.3                            | 13.0  | 12.9  | 12.6   | 12.4  | 12.8  | 10.6     | 10.3  | 11.0  |
| Phosphorus                  | 7.62                            | 7.23  | 7.43  | 7.11   | 7.18  | 7.65  | 6.77     | 6.54  | 6.44  |
| Sodium                      | 1.32                            | 1.24  | 1.28  | 1.41   | 1.33  | 1.24  | 1.21     | 1.54  | 1.37  |
| Potassium                   | 11.1                            | 10.8  | 11.4  | 10.8   | 10.5  | 10.4  | 10.1     | 10.5  | 10.8  |
| Lysine                      | 14.7                            | 14.3  | 14.9  | 15.7   | 15.2  | 15.8  | 13.8     | 13.6  | 13.2  |
| Methionine                  | 6.51                            | 6.22  | 6.71  | 7.20   | 7.55  | 7.34  | 5.82     | 5.78  | 5.33  |
| ME <sup>3</sup> (MJ/kg)     | 13.0                            | 13.1  | 13.2  | 13.3   | 13.2  | 13.6  | 13.2     | 13.4  | 13.5  |

<sup>1</sup>Control (C) 3% mixed oil (soybean oil and sunflower), 2% and 4% for other experimental oils <sup>2</sup>Vitamins and minerals premix per each kilogram diet: retinol, 2.48 mg; cholecalciferol, 25 µg; DL-α-tocopherol, 60 mg; menadione sodium bisulphite, 2 mg; thiamine, 2 mg; riboflavin, 5 mg; pyridoxine, 3 mg; cyanocobalamin, 0.01 mg; niacin, 27 mg; folic acid, 1 mg; biotin, 0.05 mg; pantothenic acid, 10 mg; Mn, 60 mg; Zn, 50 mg; Cu, 10 mg; I, 0.1 mg; Se, 0.1 mg; Co, 0.1 mg; Fe, 50 mg <sup>3</sup>ME (MJ/kg) = 0.01551 crude protein + 0.03431 crude fat + 0.01669 starch + 0.01301 sugar (nutrients in g/kg diet; FMVO, 2007)

perimental groups. These results are consistent with the findings of (López-Ferrer et al., 2001) who found a higher weight gain in chickens fed diets high in LO levels. Also, according to Aziza et al. (2016) who found that the chickens infected with *E. Tenella* and fed diet supplemented with 3% and 5% LO had a significant increase in BW development and BWG compared with chickens fed FO and corn oil. Moreover, Stanačev et al. (2013) observed that there was significant increase in BW of broilers fed diet supplemented with 4% flax oil compared with those fed diet supplemented with 4% SO. On the other hand, Almeida et al. (2009). did not observe any significant influence on feed intake, BWG or FCR when they replaced SO by LO in the diet of broilers. A negative effect of addition of 6% LO to the broiler diet mixture was noted (Bartos et al., 2004).

Farhoomand and Checaniazer, (2009). found that broiler chickens fed diet supplemented with 2% FO showed high-

er BW and BWG and the best FCR than those fed diet supplemented with poultry fat. However, previous studies concluded that the inclusion of FO in the diets cause significant reduction in terms of performance (final BW or FCR), in comparison to using vegetable oils (Huang et al., 1990; Nash et al., 1995). Also, according to Navidshad (2009) who found that final BW and daily BWG of broilers decreased significantly by FO inclusion in diets (2% or 4%). However some researchers stated that broiler diets containing different energy sources; sunflower oil, linseed oil, and soybean oil did not affect growth performance of broilers significantly (Fébel et al., 2008).

Table (4) shows that feeding 4% LO resulted in significantly higher dressing percent (71.55%) in comparison to those fed FO 4% or control diets. Similarly, El-Yamany et al. (2008) observed a significant improvement in quails dressing percent with addition of flax oil to the diet. Rega-

**Table 2:** Fatty acid composition (%) of the experimental oils used in broiler diets

| Fatty acids                        | LO    | FO    | SO    |
|------------------------------------|-------|-------|-------|
| Myristic(14:0)                     | 0.23  | 4.06  | 0.25  |
| Palmitic (16:0)                    | 8.09  | 10.88 | 12.73 |
| Palmitoleic (16:1)                 | ND    | 5.85  | 0.03  |
| Stearic (18:0)                     | 5.66  | 3.79  | 4.59  |
| Oleic (18:1)                       | 11    | 43.61 | 18.89 |
| Linoleic (18:2 n-6)                | 10.90 | 2.2   | 56.00 |
| α-Linolenic (18:3 n-3)             | 64.12 | 1.33  | 7.50  |
| Eicosanoic acid (20:1)             | ND    | 5.45  | ND    |
| Arachidonic acid (20:4 n-6 )       | ND    | 1.05  | ND    |
| Eicosapentaenoic acid (EPA, 20:n3) | ND    | 10.65 | ND    |
| Docosahexanoic (DHA, 22:n3)        | ND    | 8.64  | ND    |
| Σ SFA <sup>1</sup>                 | 13.9  | 18.7  | 17.5  |
| ΣMUFA <sup>2</sup>                 | 11.0  | 54.9  | 18.9  |
| Σ Omega 6                          | 10.9  | 3.3   | 56.0  |
| Σ Omega 3                          | 64.1  | 20.6  | 7.50  |

ND=not detected, LO=Linseed oil, FO=Fish oil, SO=Soybean oil, <sup>1</sup>SFA: saturated fatty acids, <sup>2</sup>MUFA:Monounsaturated fatty acids

rding the weight of lymphoid organs in this study, there were no significant differences between control and treatment groups. There was slight numerical reduction of the relative spleen weight (0.27%) in group supplemented with 4% FO and slight increase of liver percentage (3.22%) in group supplemented with 4% LO (Table 4). Stanačev et al. (2013) found no significant differences in carcass weight and most of relative organs weight (liver, gizzard, heart, wings) among broilers chickens fed different sources of oil (soybean oil, rapeseed oil, and flax oil) and levels (4% and 8%). It has been stated that the injected antigens in the thymus, spleen, and bursa of Fabricius (major lymphoid organs) in poultry interact with mature lymphocytes and

other immune cells during the immune challenge (Grasman, 2002). Seidavi et al. (2014) found a slight reduction of relative spleen weight in groups supplemented with FO and he attributed this to the anti-inflammatory properties of FO supplementation, which could reduce the proliferation of the mature lymphocytes. Wang et al. (2000) observed that using surplus levels of n-3 PUFA in diets of laying chickens led to promote growth of the major lymphoid organs (thymus, spleen and bursa of Fabricius) up to 4 week of age. Nevertheless, at the age of 4 week onward, the weight of immune tissue began to decline. This could be the possible explanation for not finding any significant differences because all lymphoid organs were measured at the end of experiment (day 38). Crespo and Esteve-Garcia (2002) reported that there was a numerical increase in liver weight of broiler chickens (day 53) fed LO compared with chickens fed soybean or tallow oils.

Table (5) summarizes the effect of different dietary sources and levels of oil on serum total protein and albumin at the end of the experimental period. A significant increase in serum total protein (5.92 g/dl) and globulin (2.49 g/dl) in group supplemented with 2% FO was noted.

A marked increase in serum albumin content (3.43 g/dl) was found in the group fed 2% FO. Moreover, the lowest numerical contents for total protein and albumin were found for group fed control diet (3.61 and 2.41 g/dl, respectively). The group fed 4% SO diet had a significant low serum globulin concentrations (0.97 g/dl) compared to other experimental groups (Table 5). With the same concept, Al-Mayah (2009) showed that 50 g/kg of diet FO increased serum globulins and maintained proper immune function in chickens fed after vaccination against ND. Also, Tobarek et al. (2002) observed that broilers fed FO before or after vaccination with Hitchner B1 at 7<sup>th</sup> day or with LaSota at 21<sup>th</sup> day of age resulted in a significant increase of globulins. Moreover, Michel (2002) found that using FO in

**Table 3:** Growth performance in broilers fed diets supplemented with different sources and levels of oil (Means ± SE)

| Parameters | Dietary treatments <sup>1</sup> |                           |                           |                          |                          |                          |                          |
|------------|---------------------------------|---------------------------|---------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
|            | Control                         | LO                        |                           | FO                       |                          | SO                       |                          |
|            |                                 | 2%                        | 4%                        | 2%                       | 4%                       | 2%                       | 4%                       |
| 1-21 d     |                                 |                           |                           |                          |                          |                          |                          |
| BW (g)     | 605 <sup>b</sup> ±6.61          | 683 <sup>a</sup> ±19.80   | 697 <sup>a</sup> ±16.94   | 668 <sup>a</sup> ±18.01  | 626 <sup>ab</sup> ±18.22 | 612 <sup>b</sup> ±10.37  | 639 <sup>ab</sup> ±13.49 |
| BW G (g)   | 569 <sup>b</sup> ±6.61          | 648 <sup>a</sup> ±22.8    | 664 <sup>a</sup> ±16.44   | 632 <sup>a</sup> ±19.8   | 591 <sup>ab</sup> ±18.22 | 577 <sup>b</sup> ±10.65  | 606 <sup>ab</sup> ±13.49 |
| FCR        | 1.45±0.04                       | 1.40±0.06                 | 1.40±0.04                 | 1.43±0.1                 | 1.43±0.07                | 1.45±0.02                | 1.43±0.05                |
| 22-38 d    |                                 |                           |                           |                          |                          |                          |                          |
| BW (g)     | 1530 <sup>b</sup> ±36.83        | 1654 <sup>ab</sup> ±44.45 | 1743 <sup>a</sup> ±47.43  | 1512 <sup>b</sup> ±62.34 | 1506 <sup>b</sup> ±34.05 | 1538 <sup>b</sup> ±43.19 | 1638 <sup>b</sup> ±71.20 |
| BWG (g)    | 925 <sup>b</sup> ±59.81         | 971 <sup>b</sup> ±44.28   | 1046 <sup>ab</sup> ±30.99 | 844 <sup>a</sup> ±19.9   | 880 <sup>b</sup> ±22.90  | 926 <sup>b</sup> ±24.25  | 999 <sup>ab</sup> ±40.26 |
| FCR        | 1.92 <sup>ab</sup> ±0.06        | 1.88 <sup>b</sup> ±0.13   | 1.83 <sup>b</sup> ±0.09   | 1.95 <sup>a</sup> ±0.057 | 1.94 <sup>a</sup> ±0.05  | 1.90 <sup>ab</sup> ±0.1  | 1.89 <sup>b</sup> ±0.07  |

<sup>1</sup>Control 3% mixed oil (soybean oil and sunflower), 2 and 4% for LO = Linseed oil, FO= Fish oil, SO= Soybean oil

<sup>ab</sup>Means in the same row with different superscripts are significantly different (p < 0.05)

**Table 4:** Effect of addition different sources and levels of oil in diets of broilers on carcass trait (Means ± SE)

| Parameter             | Dietary treatments <sup>1</sup> |                           |                          |                           |                           |                           |                           |  |
|-----------------------|---------------------------------|---------------------------|--------------------------|---------------------------|---------------------------|---------------------------|---------------------------|--|
|                       | Control                         | LO                        |                          | FO                        |                           | SO                        |                           |  |
|                       |                                 | 2%                        | 4%                       | 2%                        | 4%                        | 2%                        | 4%                        |  |
| Dressing, %           | 63.20 <sup>b</sup> ±1.27        | 67.59 <sup>ab</sup> ±1.41 | 71.55 <sup>a</sup> ±4.30 | 67.96 <sup>ab</sup> ±0.74 | 63.31 <sup>b</sup> ±0.46  | 68.28 <sup>ab</sup> ±1.13 | 68.28 <sup>ab</sup> ±1.17 |  |
| Liver, %              | 2.87 <sup>a</sup> ±0.060        | 2.73 <sup>ab</sup> ±0.064 | 3.22 <sup>a</sup> ±0.289 | 2.45 <sup>ab</sup> ±0.088 | 2.56 <sup>ab</sup> ±0.113 | 2.25 <sup>ab</sup> ±0.049 | 2.38 <sup>ab</sup> ±0.095 |  |
| Spleen, %             | 0.32±0.003                      | 0.32±0.008                | 0.306±0.04               | 0.31±0.017                | 0.270±0.040               | 0.313±0.038               | 0.293±0.003               |  |
| Bursa of Fabricius, % | 0.12±0.008                      | 0.14±0.025                | 0.14±0.010               | 0.13±0.025                | 0.14±0.010                | 0.14±0.010                | 0.16±0.006                |  |

<sup>1</sup>Control 3% mixed oil (soybean oil and sunflower), 2 and 4% for LO = Linseed oil, FO= Fish oil, SO= Soybean oil

<sup>a,b</sup>Means in the same row with different superscripts are significantly different (p < 0.05)

**Table 5:** Effect of supplementation different sources and levels of oil in diets of broilers on serum metabolites (Means ± SE)

| Parameter (g/dl) | Dietary treatments <sup>1</sup> |                           |                          |                          |                         |                           |                          |  |
|------------------|---------------------------------|---------------------------|--------------------------|--------------------------|-------------------------|---------------------------|--------------------------|--|
|                  | Control                         | LO                        |                          | FO                       |                         | SO                        |                          |  |
|                  |                                 | 2%                        | 4%                       | 2%                       | 4%                      | 2%                        | 4%                       |  |
| Total protein    | 3.61 <sup>bc</sup> ±0.24        | 3.80 <sup>b</sup> ±0.17   | 4.13 <sup>b</sup> ±0.11  | 5.92 <sup>a</sup> ±0.28  | 4.25 <sup>b</sup> ±0.12 | 4.05 <sup>b</sup> ±0.16   | 4.10 <sup>b</sup> ±0.09  |  |
| Albumin          | 2.41 <sup>b</sup> ±0.10         | 2.44 <sup>ab</sup> ±0.005 | 2.81 <sup>ab</sup> ±0.65 | 3.43 <sup>ab</sup> ±0.01 | 2.62 <sup>b</sup> ±0.17 | 2.54 <sup>b</sup> ±0.04   | 3.13 <sup>ab</sup> ±0.18 |  |
| Globulin         | 1.2 <sup>c</sup> ±0.046         | 1.36 <sup>c</sup> ±0.042  | 1.32 <sup>c</sup> ±0.050 | 2.49 <sup>a</sup> ±0.057 | 1.63 <sup>b</sup> ±0.04 | 1.51 <sup>bc</sup> ±0.050 | 0.97 <sup>d</sup> ±0.02  |  |

<sup>1</sup>Control 3% mixed oil (soybean oil and sunflower), 2 and 4% for LO = Linseed oil, FO= Fish oil, SO= Soybean oil

<sup>a,b</sup>Means in the same row with different superscripts are significantly different (p < 0.05)

diet of quail had a significant increase of globulins in comparison to that fed the same amount of SO. In addition, Jameel et al. (2015) stated that supplementation diet with 0.5% LO significantly increased serum total protein concentration in broilers.

## CONCLUSIONS

In conclusion, the FO is not favourable oil as it considered the most expensive in comparison to other oils with a low final BW. Using 4% of LO had significantly higher BW but might be more expensive than SO. However, using 2% LO or 4% of SO have almost the same final BW. Moreover, supplementation with 2% and 4% LO to broiler diets improved growth performance, while addition of FO improved immunity.

## CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

## AUTHORS CONTRIBUTION

AA planned the study, carried out the analyses, acquisition of data, wrote the manuscript and critically reviewing the manuscript. AA, carried out the analyses, tracking of data, performed the statistical analyses and wrote the manuscript. All authors read and approved the final manuscript.

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