Effect of Fat Sources and Emulsifier Supplementation in Broiler Starter, Grower and Finisher Diets on Performance, Nutrient Digestibility, and Carcass Parameters

ABSTRACT

The purpose of this study was to evaluate the effect of fat sources and emulsifier supplementation in different phases on growth performance of broilers. Treatments were: (T1) basal ration (BR) which contained soy oil (SO) and had inclusion of emulsifier for whole life, (T2) BR which contained poultry fat (PO) and had inclusion of emulsifier for whole life, (T3) BR which contained oxidized oil (OO) and had inclusion of emulsifier for whole life, (T4) BR which contained SO and had inclusion of emulsifier during starter phase (T5) BR which contained PO and had inclusion of emulsifier during the starter phase, (T6) BR which contained SO and had inclusion of emulsifier during the starter phase, (T7) BR which contained OO and had inclusion of emulsifier during the starter phase, (T8) BR which contained PO and had inclusion of emulsifier during the grower phase, (T9) BR which contained OO and had inclusion of emulsifier during the grower phase, (T10) BR which contained SO and had inclusion of emulsifier during the finisher phase, (T11) BR which contained PO and had inclusion of emulsifier during the finisher phase, (T12) BR which contained SO and had inclusion of emulsifier for whole life. The Basal ration which contained SO and supplemented emulsifier during the grower phase and throughout life increased the body weight gain. The supplementation of emulsifier in the finisher phase and throughout life in a diet which contained SO had better feed conversion ratio. The supplementation of emulsifier in the finisher phase and throughout life in SO based diet increased the dry matter and crude fat digestibility. We recommend emulsifier supplementation in the finisher phase for the economic point of view.

INTRODUCTION

In commercial broiler diets, vegetable oils and animal fats are being used to increase the energy density of the diet and to improve the growth rate and feed efficiency of broilers (Blanch et al., 1996; Tavárez et al., 2011; Zhang et al., 2011). Among available oil sources for broiler feed, vegetable oils are rich in polyunsaturated fatty acids and are highly digestible for broilers. However, polyunsaturated fatty acids are highly sensitive towards oxidation during storage that could be detrimental for the growth and health of broilers (Jakobsen et al., 1993; Engberg et al., 1996; Anjum et al., 2004; Tan et al., 2018; Yang et al., 2019). A lot of work has been done to evaluate the effect of oxidized oil on the broiler production, however, the results of oxidized oils on the broilers production are conflicting (Jakobsen et al., 1993; Engberg et al., 1996; Anjum et al., 2004; Tan et al., 2018; Tan et al., 2018). Oertel & Hartfiel (1982) reported that the addition of oxidized soybean oil @ 7% in the diet of broilers had no effect on feed intake, weight gain, and feed conversion ratio of growing broilers. However, Jakobsen et al. (1993) and Lin et al. (1989) reported that oxidized fat in the diet of broilers had a negative...
influence on the performance and health of broilers. It has been reported that negative effect of oxidized fat sources in the diet of broilers on performance is due to the rancidity of feed, reduction in palatability and less feed intake (Lin et al., 1989; Jakobsen et al., 1993). It has also been reported that oxidized fat sources in the diet of the broiler decrease digestibility and lead to poor performance of the broilers (Hussein & Kratzer, 1982).

Young broilers have lower potential to synthesis and secrete bile salts that results in lower digestibility of fats and poor performance of growing broiler (Noy & Sklan 1998; Upadhaya et al., 2017). Several researchers reported that the addition of external emulsifiers in the diet of broilers improves fat digestibility and growth rate of broiler (Huang et al., 2007; Zhang et al., 2011; Zaefarian et al., 2015; Zhao et al., 2015). However, some researchers reported that the inclusion of emulsifier in broiler diets had no effects on broiler performance (Roy et al., 2010; Zhang et al., 2011; Zhao et al., 2015; Upadhaya et al., 2016; Upadhaya et al., 2017). Furthermore, researchers also reported that the inclusion of external emulsifier in the diet of broiler performed differently on different fat sources (Roy et al., 2010; Zhang et al., 2011; Zhao et al., 2015; Upadhaya et al., 2016; Upadhaya et al., 2017). Conflicting results of the inclusion of emulsifier on growth performance, nutrient digestibility has been reported in literature (Roy et al., 2010; Zhang et al., 2011; Zhao et al., 2015 Upadhaya et al., 2016; Upadhaya et al., 2017). Moreover, previous researchers focused on the effect of the inclusion of emulsifier on growth performance, nutrient digestibility of broiler during starter and grower phases. To our knowledge, none of the study was conducted to evaluate the effect of various fat sources including oxidized oil and inclusion of emulsifier at different phases in the diet on growth performance, nutrient digestibility and carcass quality during different stages of broiler life. Therefore, the purpose of this experiment was to check the effects of fat sources inclusion in the diet of broiler with emulsifier on the feed intake, body weight gain (BWG), nutrient digestibility, and carcass parameters on different phases of broiler life. The other objective of the current study was to select the best fat source with emulsifier in the appropriate rearing phase of broilers.

**MATERIALS AND METHODS**

**Experimental design, animal husbandry and experimental diets**

The current study was carried out in a completely randomized experimental design (CRD). Three fat sources and emulsifier were supplemented in phases with 3x4 factorial arrangement. Fat sources were soy oil, poultry fat, and oxidized oil (soy oil) with emulsifier, while four phases were overall, starter, grower and finisher. The trial had 12 different dietary treatments. Treatments were, (T1) basal ration (BR) which contained soy oil and had inclusion of emulsifier for whole life, (T2) BR which contained poultry fat and had inclusion of emulsifier for whole life, (T3) BR which contained oxidized oil and had inclusion of emulsifier for whole life, (T4) BR which contained soy oil and had inclusion of emulsifier during the starter phase (T5) BR which contained poultry fat and had inclusion of emulsifier during the starter phase, (T6) BR which contained oxidized oil and had inclusion of emulsifier during the starter phase, (T7) BR which contained soy oil and had inclusion of emulsifier during the starter phase (T8) BR which contained poultry fat and had inclusion of emulsifier during the grower phase, (T9) BR which contained oxidized oil and had inclusion of emulsifier during the grower phase, (T10) BR which contained soy oil and had inclusion of emulsifier during the finisher phase, (T11) BR which contained poultry fat and had inclusion of emulsifier during the finisher phase (T12) BR which contained oxidized oil and had inclusion of emulsifier during the finisher phase.

A total of 720, day-old male broiler chicks were procured from a local hatchery. Chicks were divided into 12 treatments in such a way that each treatment had six replicates and each replicate had ten chicks. The duration of the experimental period was 35 days. Flushing was done with the help of sugar solution (1kg sugar/5L water) on the first day of the experiment. Brooding temperature was set at 95 °F for the first week. Temperature was decreased by 5° F every week until it reached at 75 °F. During the experimental period it was ensured that all birds received feed and water ad libitum. All vaccination schedule was practiced according to the suggestion of a veterinarian. The diets had major share of corn-soybean and formulated to meet or exceed the nutrient requirement of growing broiler as recommended by NRC 2004. All the ingredients used in the formulation of the experimental diets were supplied by a commercial feed mill (Five Star Feeds Pvt. Ltd. Gujranwala, Pakistan). The ingredient data used in the diet formulation were taken from Brazilian tables for Poultry and Swine. All diets were formulated on digestible amino acids (AA) basis keeping lysine as reference AA. The experiment was divided into three dietary phases that were starter phase, grower phase and finisher phase as shown in Table 1. The starter dietary phase was consisted of 0–8
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Table – 1 Composition of experimental basal diets.

|                      | Starter (day 1-10) | Grower (day 11-22) | Finisher (day 23-35) |
|----------------------|--------------------|--------------------|----------------------|
| **SO**               | 54.60              | 60.03              | 64.09                |
| **PF**               | 54.71              | 60.75              | 64.72                |
| **OO**               | 54.71              | 60.75              | 64.72                |
| **Corn**             | 54.60              | 60.03              | 64.09                |
| **Soybean Meal**     | 29.72              | 27.06              | 20.77                |
| **Rice Polish**      | 4.00               | 3.74               | 2.45                |
| **Canola Meal**      | 4.00               | 0.00               | 1.91                |
| **Fish Meal**        | 0.00               | 3.00               | 5.50                |
| **Soy Oil**          | 3.00               | 3.00               | 3.00                |
| **Poultry Fat**      | 3.00               | 3.00               | 3.00                |
| **Oxidized Oil**     | 0.00               | 0.00               | 0.00                |
| **L-Lysine SO4**     | 0.609              | 0.461              | 0.374               |
| **dL-Methionine**    | 0.377              | 0.321              | 0.260               |
| **L-Threonine**      | 0.209              | 0.15               | 0.102               |
| **Salt**             | 0.539              | 0.293              | 0.237               |
| **CaCO3**            | 1.277              | 1.140              | 0.931               |
| **Arginine**         | 0.115              | 0.055              | 0.041               |
| **Monocalcium Phosphate** | 1.394          | 0.59               | 0.191               |
| **Phytase(10,000 FTU)** | 0.01            | 0.01               | 0.01                |
| **Vitamin/Min Premix/Emulsifier** | 0.15         | 0.15               | 0.15                |

|                      | 54.71              | 60.75              | 64.72                |
| **Ether Extract%**   | 5.89               | 6.3                | 6.45                |
| **Crude Protein%**   | 21                 | 20                 | 19                  |
| **ME (kcal/kg)**     | 3,000              | 3,100              | 3,150               |
| **Calcium, %**       | 0.96               | 0.87               | 0.8                 |
| **Available P, %**   | 0.48               | 0.43               | 0.4                 |
| **Sodium, %**        | 0.23               | 0.16               | 0.16                |
| **Digestible Lys, %**| 1.28               | 1.15               | 1.03                |
| **Digestible Met, %**| 0.65               | 0.602              | 0.55                |
| **Digestible Met + cysteine, %** | 0.95       | 0.87               | 0.8                 |
| **Digestible Thr, %**| 0.86               | 0.77               | 0.69                |
| **Digestible Arg, %**| 1.37               | 1.23               | 1.1                 |

| 1 Soy Oil, 2 Poultry Fat, 3 Oxidized Soy Oil |
| 4 Vitamin and Mineral Premix: Each kilogram contained: Vit. A, 7,000 IU; Vit. D3, 2,500 IU; Vit. E, 30 mg; of Vit. K3, 1 mg; Vit. B1, 1.5 mg; Vit. B2, 4 mg; Vit. B6, 2 mg; Vit. B12, 0.02 mg; niacin, 30 mg; folic acid, 0.55 mg; pantothenic acid, 10 mg; biotin, 0.16 mg; choline chloride, 400 mg; Copper, 20 mg; Iron, 70 mg; Manganese, 100 mg; Zinc, 70 mg; Iodine, 0.4 mg and Selenium, 0.5 mg |

1 Soy Oil, 2 Poultry Fat, 3 Oxidized Soy Oil
4 Vitamin and Mineral Premix: Each kilogram contained: Vit. A, 7,000 IU; Vit. D3, 2,500 IU; Vit. E, 30 mg; of Vit. K3, 1 mg; Vit. B1, 1.5 mg; Vit. B2, 4 mg; Vit. B6, 2 mg; Vit. B12, 0.02 mg; niacin, 30 mg; folic acid, 0.55 mg; pantothenic acid, 10 mg; biotin, 0.16 mg; choline chloride, 400 mg; Copper, 20 mg; Iron, 70 mg; Manganese, 100 mg; Zinc, 70 mg; Iodine, 0.4 mg and Selenium, 0.5 mg

Performance parameters

To measure the FI, growth rate and performance parameter standard procedures were adopted as described in recent study (Sharif et al., 2018). In brief, chicks and offered feed were weighed by pen at day 1, 8, 21 and 35 of experiment. Feed intake was calculated, BWG and feed conversion ratio (FCR) were measured for the overall period.

Fecal samples

From days 35 to 37, fecal samples were collected. In brief, a plastic sheet was spread in each pen before the start of the digestibility trial. After every 24h, total feces were collected from each pen carefully. Contaminants such as scales, feathers, down, straws, and other fine dust particle were removed. Collected samples were packed in sealed plastic bags. The sealed plastic bags were stored at −30°C in a refrigerator until further analysis. Furthermore, collected samples were grounded in a grinder having 0.5-mm sieve.
Grounded samples were further analyzed for chemical analysis as described in recent studies (Muhammad et al., 2016; Wang et al., 2016; Hussain et al., 2018; Xia et al., 2018a; Hussain et al., 2020).

**Nutrient digestibilities determination**

Nutrient intake (Zhang et al., 2015; Xia et al., 2018b; Xia et al., 2018c) and digestibilities are good indicators for performance (He et al., 2018; Chen et al., 2019) in livestock as described in literature. To determine the digestibility of nutrients, collected feed and excreta samples were analyzed for dry matter (DM) and crude fat determination following the procedure of Xu et al. (2019) and Rehman et al. (2019). Dry matter and crude fat were determined using the protocol of AOAC (1995). The resulting values were used to calculate the DM and crude fat digestibility as described in recent studies (Hussain et al., 2018; Sharif et al., 2018; Anjum et al., 2019; Keles et al., 2019; Tiwana et al., 2019).

**Carcass parameters determination**

To determine carcass parameters standard, the procedures were followed as described in literature. In brief, two broilers were arbitrarily selected from each replicate within a treatment to measure live BW at day 35 of the trial. After slaughtering and depluming of feathers, head, viscera, and shanks were separated. Then portioning of the carcass was done to obtain the weight of breast, legs, live weight, carcass weight, thigh meat yield, and breast meat yield.

**Statistical analysis**

Collected data were analyzed to check the significance of the treatments by using standard

Table – 2 Effect of fat sources and emulsifier supplementation in broiler starter, grower and finisher diets on performance parameters.

| Variables | 0-21 days | Parameters | 0-35 days | Parameters |
|-----------|-----------|------------|-----------|------------|
| Sources   | FI (g)    | WG (g)     | FCR       | FI (g)     | WG (g)     | FCR       |
| Poultry fat | 1254.40 a | 926.29 a   | 1.36 b    | 3391.50 ab | 2015.30 a  | 1.68 b    |
| Vegetable oil | 1274.80 a | 951.83 a   | 1.34 b    | 3420.10 a  | 2069.80 a  | 1.65 b    |
| Used oil      | 1219.00 b | 864.63 b   | 1.41 a    | 3388.90 b  | 1864.30 b  | 1.76 a    |
| p value       | 0.0010    | <0.0001    | 0.0243    | <0.0001    | <0.0001    |
| Se           | 14.25     | 12.84      | 0.01      | 48.92      | 26.18      | 0.04      |
| Phases       |           |            |           |            |
| Whole Life   | 1251.80   | 929.89     | 1.35      | 3360.00    | 2016.40    | 1.67 b    |
| Starter      | 1247.10   | 909.50     | 1.37      | 3412.30    | 1959.30    | 1.75 a    |
| Grower       | 1249.60   | 916.22     | 1.37      | 3328.90    | 1955.90    | 1.70 ab   |
| Finisher     | 1249.20   | 901.39     | 1.39      | 3366.20    | 2001.00    | 1.68 a    |
| p value       | 0.9935    | 0.0064     | 0.5315    | 0.1255     | 0.0024     |
| Se           | 16.46     | 14.82      | 0.01      | 56.49      | 30.23      | 0.02      |
| Sources X Phases Treatments |           |            |           |            |
| Poultry fat | Whole Life | 1254.30 | 938.50 abc | 1.34 abc  | 3427.20    | 2072.00 abc | 1.65 abc  |
| Starter      | 1249.70   | 923.00 abc | 1.36 abc  | 3388.30    | 1963.80 ed | 1.73 abc  |
| Grower       | 1252.30   | 927.33 abc | 1.35 abc  | 3318.30    | 1970.50 ed | 1.69 abc  |
| Finisher     | 1261.20   | 916.33 abc | 1.38 abc  | 3432.30    | 2054.80 abc| 1.67 abc  |
| Vegetable oil | Whole Life | 1278.50 | 967.00 a  | 1.33 a    | 3379.00    | 2080.50 a  | 1.63 a    |
| Starter      | 1273.70   | 948.33 ab  | 1.35 abc  | 3485.00    | 2065.20 ab | 1.69 ab   |
| Grower       | 1276.20   | 955.33 a   | 1.34 a    | 3430.20    | 2066.80 ab | 1.66 ab   |
| Finisher     | 1271.00   | 936.67 abc | 1.36 abc  | 3386.30    | 2066.80 ab | 1.64 ab   |
| Used oil     | Whole Life | 1222.70 | 884.17 ab  | 1.36 ab   | 3273.80    | 1896.70 ed | 1.73 abc  |
| Starter      | 1217.80   | 857.17 a   | 1.42 a    | 3363.70    | 1849.00 a  | 1.82 a    |
| Grower       | 1220.30   | 866.00 ab  | 1.41 ab   | 3238.30    | 1830.30 ab | 1.77 ab   |
| Finisher     | 1215.30   | 851.17 a   | 1.43 a    | 3279.80    | 1881.30 ed | 1.74 abc  |
| p value       | 0.0997    | 0.0499     | 0.0499    | 0.0834     | 0.0481     | 0.0498    |
| Se           | 28.51     | 25.68      | 0.03      | 97.85      | 52.36      | 0.04      |

*SE; standard error.

Means with different superscripts in a column differ significantly (p<0.05).

*Level of polyglycerol polyricinoleate was 0.035 % in Soy Oil, Poultry Fat, Oxidized Soy Oil based diet for each, either was supplemented only in starter, grower, finisher or throughout life. Polyglycerol polyricinoleate was mixed in premix.
RESULTS

Growth performance

Results for growth performance are shown in Table 2. Results revealed that oxidation of soy oil and fat sources affected feed intake ($p<0.05$) from 0-21 days of life span of broilers. Feed intake was higher ($p<0.05$) for birds which were on a basal diet containing soy oil as compared to other diets from 0-21 days of life span of broilers. However, the supplementation of emulsifier with different sources of fats in broiler diets had no effect on feed intake from 0-21 days of life. Similar with feed intake oxidation of soy oil and fat sources body weight gain ($p<0.05$) from 0-21 days of life span. Body weight gain was higher ($p<0.05$) for birds which were on a basal diet containing soy oil as compared to the other diets from 0-21 days of life span. Supplementation of emulsifier with different sources of fats in broiler diets had no effect on body weight gain from 0-21 days of life span of broilers. However, there was interaction between fat sources and phases of broiler growth from 0-21 days of life span of broilers. During the trails of 0-21 days, the soy oil based diet supplemented with emulsifier during grower phase and throughout life increased the body weight gain. The birds showed better FCR ($p<0.05$) which were on basal diet containing vegetable oil as compared to other fat sources. However, the supplementation of emulsifier with different sources of fats in broiler diets had no effect on FCR. Nevertheless, there was interaction between fat sources and supplementation of emulsifier in different phases on FCR. Supplementation of emulsifier in soy oil based diet throughout life improved the FCR. During the trail of 0-35 days, feed intake, average body weight was less in oxidized oil as compared to other dietary treatments ($p<0.05$). Similarly, birds showed poor FCR in the basal diet that contained oxidized oil as compared to other dietary treatments ($p<0.05$) during the trail of 0-35 days. Similar with 0-21 days trail, different sources of fats in broiler diets had no effect on intake and body weight gain during 0-35 days of trail. However, oxidized oil in starter diet negatively influence the FCR. Results of interaction revealed that sources and emulsifier supplementation in different phases of broiler growth on body weight gain and FCR. The supplementation of emulsifier throughout life in a diet which contained soy oil had better body weight gain. Similarly, the supplementation of emulsifier in the finisher phase and throughout life in a diet which contained soy oil had better FCR.

Nutrient digestibility

Results of nutrient digestibility are presented in Table 3. The results revealed main effects for fat source on crude fat and DM digestibility. The birds showed better digestibility ($p<0.05$) for both crude fat and DM which were on a basal diet containing vegetable oil as compared to other diets. Results also showed main effects for different phases on DM and crude fat digestibility. Birds showed better DM and crude fat sources X Phases Treatments

| Nutrient digestibility | Sources | Phases |
|------------------------|---------|--------|
| Vegetables, Crude fat  |         |        |
| Sources                | Phases  |        |
| Soy oil                | Whole Life | 82.63 | 73.37 | 72.88 |
| Poultry fat            | Starter    | 82.33 | 71.80 | 72.89 |
| Vegetable oil          | Grower      | 79.09 | 73.08 | 71.93 |
| Finisher               | Finisher     | 80.05 | 73.90 | 71.65 |
| Used oil               | Whole Life | 82.33 | 73.37 | 72.88 |
| Poultry fat            | Starter    | 81.65 | 72.68 | 72.05 |
| Vegetable oil          | Grower      | 82.65 | 73.37 | 72.88 |
| Finisher               | Finisher     | 83.54 | 74.35 | 72.82 |
| Soy oil                | Whole Life | 83.33 | 73.77 | 72.42 |
| Poultry fat            | Starter    | 80.33 | 72.68 | 72.05 |
| Vegetable oil          | Grower      | 81.65 | 73.27 | 72.88 |
| Finisher               | Finisher     | 83.54 | 74.35 | 72.82 |
| Used oil               | Whole Life | 82.33 | 73.37 | 72.88 |
| Poultry fat            | Starter    | 79.09 | 72.68 | 72.05 |
| Vegetable oil          | Grower      | 82.65 | 73.37 | 72.88 |
| Finisher               | Finisher     | 83.54 | 74.35 | 72.82 |
| Se                     | 0.0451 | 0.9582 | 0.0459 |
| p value                | 0.54    | 1.12   | 0.51   |

*p* value 0.0451 0.9582 0.0459

Means with different superscripts in a column differ significantly ($p<0.05$).

*S* level of polyglycerol polyricinoleate was 0.035 % in Soy Oil, Poultry Fat, Oxidized Soy Oil based diet for each, either was supplemented only in starter, grower, finisher or throughout life. Polyglycerol polyricinoleate was mixed in premix.

Table 3 – Effect of fat sources and emulsifier supplementation in broiler starter, grower and finisher diets on nutrient digestibility.

| Nutrient digestibility | Sources | Phases |
|------------------------|---------|--------|
| Vegetables, Crude fat  |         |        |
| Sources                | Phases  |        |
| Soy oil                | Whole Life | 80.53 | 73.37 | 72.88 |
| Poultry fat            | Starter    | 78.34 | 71.80 | 72.89 |
| Vegetable oil          | Grower      | 79.75 | 73.08 | 71.93 |
| Finisher               | Finisher     | 80.31 | 73.90 | 71.65 |
| Used oil               | Whole Life | 83.95 | 74.77 | 72.42 |
| Poultry fat            | Starter    | 81.24 | 72.68 | 72.05 |
| Vegetable oil          | Grower      | 82.18 | 73.02 | 71.84 |
| Finisher               | Finisher     | 83.54 | 74.35 | 72.82 |
| Se                     | 0.31    | 0.65   | 0.30   |
| p value                | <0.0001 | 0.1397 | 0.0214 |

*p* value 0.0451 0.9582 0.0459

Means with different superscripts in a column differ significantly ($p<0.05$).

*S* level of polyglycerol polyricinoleate was 0.035 % in Soy Oil, Poultry Fat, Oxidized Soy Oil based diet for each, either was supplemented only in starter, grower, finisher or throughout life. Polyglycerol polyricinoleate was mixed in premix.
digestibility ($p<0.05$) at overall phase. There were phases by fat source significant interactions observed on crude fat and DM digestibilities ($p<0.05$). Phases by fat source interactions showed that supplementation of emulsifier in soy oil based diet increased the DM and crude fat digestibility ($p<0.05$) in finisher and overall phase.

**Carcass parameters**

Results of carcass parameters are showed in Table 4. Results showed no main effects of fat sources and emulsifier levels on the quality parameters of carcass ($p>0.05$).

**DISCUSSION**

The purpose of this experiment was to check the effects of fat sources inclusion in broiler diets with emulsifier on the feed intake, BWG, nutrient digestibility, and carcass parameters on different phases of broiler life. The other objective of the current study was to select the best fat source with emulsifier in the appropriate rearing phase of broilers. The results in the current study supported the hypothesis that fat sources in the diet of broiler influence the performance of broilers. The results in this study also supported the hypothesis that fat sources with emulsifier supplementation would enhance the performance of broiler chickens by increasing the nutrient digestibility in a specific phase.

In the overall trial, it was observed that fat sources changed the performance of the birds in terms of BW and FCR. The birds gained more BW and had a better FCR when fed a diet which contained soy oil. Performance results of the current study were similar with the findings of Zhang et al. (2011).

Table 4 – Effect of fat sources and emulsifier supplementation in broiler starter, grower and finisher diets on carcass parameters.

| Variables | Breast % | Dressing % | Fat % | Liver % | Thigh % |
|-----------|-----------|------------|-------|---------|---------|
| Sources   |           |            |       |         |         |
| Poultry fat | 35.69     | 63.65      | 2.66  | 3.03    | 5.64    |
| Vegetable oil | 35.16     | 62.73      | 2.54  | 2.86    | 5.44    |
| Used oil | 34.86     | 62.20      | 2.25  | 2.87    | 5.55    |
| $p$ value | 0.2221    | 0.2392     | 0.1816 | 0.0920  | 0.4975  |
| SE | 0.48 | 0.86 | 0.23 | 0.09 | 0.18 |

| Phases | Whole Life | Starter | Grower | Finisher |
|--------|------------|---------|--------|----------|
|          | 35.65      | 63.60   | 2.71   | 3.03     | 5.61    |
|          | 35.03      | 62.51   | 2.30   | 2.87     | 5.55    |
|          | 34.54      | 61.60   | 2.35   | 2.94     | 5.42    |
|          | 35.73      | 63.72   | 2.57   | 2.84     | 5.60    |
| $p$ value | 0.1196    | 0.1189  | 0.3771 | 0.2472   | 0.7746  |
| SE | 0.55 | 0.99 | 0.26 | 0.10 | 0.20 |

| sources X Phases Treatments | Phases |
|------------------------------|--------|
| Poultry fat | Whole Life | 35.96 | 64.12 | 2.80 | 3.13 | 5.66 |
|                | Starter   | 36.35 | 64.88 | 2.67 | 2.81 | 5.49 |
|                | Grower    | 34.41 | 61.32 | 2.49 | 3.18 | 5.56 |
|                | Finisher  | 36.04 | 64.27 | 2.67 | 3.02 | 5.87 |
| Vegetable oil | Whole Life | 35.43 | 63.21 | 2.83 | 2.98 | 5.43 |
|                | Starter   | 34.62 | 61.74 | 2.18 | 2.75 | 5.46 |
|                | Grower    | 34.57 | 61.67 | 2.46 | 2.94 | 5.32 |
|                | Finisher  | 36.04 | 64.28 | 2.70 | 2.78 | 5.53 |
| Used oil | Whole Life | 35.55 | 63.46 | 2.49 | 2.99 | 5.73 |
|                | Starter   | 34.12 | 60.91 | 2.06 | 3.07 | 5.71 |
|                | Grower    | 34.65 | 61.82 | 2.09 | 2.70 | 5.37 |
|                | Finisher  | 35.11 | 62.61 | 2.35 | 2.71 | 5.39 |
| $p$ value | 0.6132    | 0.5877 | 0.9863 | 0.1180 | 0.8701 |
| SE | 0.96 | 1.71 | 0.45 | 0.18 | 0.35 |

*SE; standard error.

Means with different superscripts in a column differ significantly ($p<0.05$).

*Level of polyglycerol polyricinoleate was 0.035 % in Soy Oil, Poultry Fat, Oxidized Soy Oil based diet for each, either was supplemented only in starter, grower, finisher or throughout life. Polyglycerol polyricinoleate was mixed in premix.
(2011) reported that broilers fed vegetable oil sources diets performed better as compared to broilers on a diet which contained animal source fats. Other researchers also reported similar findings (Chung et al., 1993; Dänicke et al., 1997; Tancharoenrat et al., 2013; Zollitsch et al., 1997). In broiler production, it is generally considered that broilers performed better on diets which contained vegetable oil sources (Chung et al., 1993; Dänicke et al., 1997; Zollitsch et al., 1997; Tancharoenrat et al., 2013). Chung et al. (1993) reported that broilers who received a diet that contained vegetable oil gained more weight in the starter phase as compared to broilers who received a diet which contained animal fat sources. Chung et al. (1993) also reported that broilers had better FCR on a diet which contained sunflower oil as compared to those broilers who received a diet which contained tallow. Dänicke et al. (1997) also observed better BW and FCR in broilers fed soy oil diets than in those broilers that were fed feed contained tallow as the energy source. However, in the current study lowest BW and FCR were observed in the birds who received a diet which contained oxidized oils which was expected due to presence of aldehydes, ketones, esters, and polymerized oils in oxidized oils that reduce fat retention and energy value of the diet (Engberg et al., 1996). Our findings are also supported by the results of Tavárez et al. (2011) who observed that oxidized oil in broiler feed reduce BW. However, in the current experiment different rearing phases of broilers only influenced FCR in starter phase during the life span of 0-35 days. Poor FCR could be justified by the under development of organs and less secretion of digestive enzymes during early stages of life that were unable to convert feed efficiently into body mass. During the life span of 0-21 days of the broilers, it was observed that fat sources and phases had interaction. During the trials of 0-21 days, soy oil based diets supplemented with emulsifier during grower phase and throughout life increased the body weight gain. However, during the life span of 0-21 days of the broilers, the FCR was better when emulsifier was supplemented throughout life. So it could be recommended that during the early life span in broiler during 0-21 days, emulsifier could be supplemented in only grower phase or for better FCR for 0-21 days. Better results of emulsifier supplementation on FCR in only grower phase could be justified with the theory of lower potential to synthesize and secrete bile salts in young broilers which results in lower digestibility of fats and poor performance of growing broiler (Noy & Sklan 1998; Upadhaya et al., 2017). Broiler at an early age had less fat digestion capacity as compared to mature birds (Tancharoenrat et al., 2013). Therefore, supplementation in grower phase could be attributed to better FCR due to better digestibility of nutrients. However, current study findings are conflicted with the previous studies who reported that inclusion of external emulsifier or synthetic emulsifier in the feed of broiler improve fat digestion and absorption in young chickens (Maisonnier et al., 2003; Dierick & Decuyper 2004; Roy et al., 2010; Alzawqari et al., 2011; Zaefarian et al., 2015; Zhao et al., 2015; Upadhaya et al., 2017). It has also been reported that inclusion of external emulsifier or synthetic emulsifier in the feed of broiler improve production performance in broilers (Maisonnier et al., 2003; Dierick & Decuyper 2004; Roy et al., 2010; Alzawqari et al., 2011; Zaefarian et al., 2015; Zhao et al., 2015; Upadhaya et al., 2017). So in the current study, it could be assumed that supplementation of emulsifier in the grower phase during the life span of 0-21 days in the diets which contained the soy oil improve the FCR, therefore it could be recommended that emulsifier can also only be supplemented in the grower phase instead of supplementing it on the other phases of broiler life or whole life. Interaction results of soy oil based diet supplemented with emulsifier and phases revealed that the birds performed better when supplemented with emulsifier throughout life, while the FCR was also better when the emulsifier was only supplemented in the finisher phase. The reason behind the increase in body weight on supplementation of the emulsifier in soy oil-based diet throughout life is the synchronization of external emulsifier with internal fat degrading enzymes from day 1 throughout life. However, supplementation of enzyme in the finisher phase may aid internal fat degrading enzyme effectively to degrade fats and supply of more nutrients for better FCR. It has been reported that emulsifier is known to improve performance by digestion of fats and support birds to overcome the inefficiency of lipase before 40 days of age in broilers (Tancharoenrat et al., 2013). Results of digestibility revealed that fat source effect the digestibility of crude fat and dry matter. In the current study, birds on vegetable protein source had better crude fat and dry matter digestibility as compared to poultry fat and oxidized oil. The lowest digestibility of crude fat and dry matter was observed in birds which were on oxidized oil. The lower digestibility results are in agreement with the findings of previous researchers, who reported that oxidized fat sources in the broiler diet decrease digestibility and lead to poor performance of the broilers (Hussein & Kratzer 1982). Similar with fat sources rearing phases of broiler also influence the digestibility of crude fat and dry matter.
It has been reported that low potential to synthesize and secrete bile salts in young broilers results in lower digestibility of fats (Noy & Sklan, 1998; Upadhaya et al., 2015; Zhao et al., 2015; Upadhaya et al., 2016; Upadhaya et al., 2020) and hindgut microbes (Qiu et al., 2017; Qiu et al., 2018). It is generally known that the inclusion of external emulsifier or synthetic emulsifier in the feed of broiler improve fat digestion and absorption in young chickens (Maisonnier et al., 2003; Dierick & Decuyper 2004; Roy et al., 2010; Alzawqari et al., 2011; Zaeefarian et al., 2015; Zhao et al., 2015; Upadhaya et al., 2017). In the current study, the inclusion of external emulsifier in the feed of broilers was expected to enhance the digestibility of dietary fat irrespective of fat sources. In the current study, the digestibility of DM and crude fat was improved with the external emulsifier which is in agreement with a study of Upadhaya et al. (2017) who stated that emulsifier enhance the DM and crude fat digestibility of the broiler diet. Similarly, Roy et al. (2010) also observed improved DM and fat digestibility in broilers fed diets which contained external emulsifier (glycerol polyethylene glycol ricinoleate). Upadhaya et al. (2017) observed a positive correlation between external emulsifier contents in the feed of broiler and DM and fat digestibilities. The result of DM digestibility and fat digestibility in the current study proved the findings Upadhaya et al. (2017) that DM digestibility and fat digestibility had strong correlation. In our study, higher digestibilities of DM and fat was the reason of improved growth performance of broilers. However, fat sources, and emulsifier phases did not influence the carcass parameters of broilers. Better performance could also be related to better beneficial microbes in the gastrointestinal tract of broilers because it has been reported that in livestock production better rumen microbes (Su, 2013; Niu et al., 2017; Qiu et al., 2019a; Qiu et al., 2020) and hindgut microbes (Qiu et al., 2019b) enhance the productivity of animals. Our findings of carcass parameters are similar with the results of previous researchers (Zhao et al., 2015; Upadhaya et al., 2016; Upadhaya et al., 2017).

CONCLUSION

Based on the results, it is concluded that emulsifier supplementation in fat sources improved the body weight, feed conversion ratio, digestibility of crude fat and dry matter in broilers. However, supplementation of emulsifier throughout life in a basal diet containing soy oil showed comparatively higher performance than other fat sources in growing broilers. Moreover, we recommend emulsifier supplementation in the finisher phase for economic point of view.

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