










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

■ Author(s)

- Kamran Jⁱ  <https://orcid.org/0000-0003-2030-1516>
Mehmood Sⁱ  <https://orcid.org/0000-0001-8229-7343>
Rahman MAⁱⁱ  <https://orcid.org/0000-0002-6894-1128>
Mahmud Aⁱ  <https://orcid.org/0000-0002-2106-4113>
Saimaⁱⁱⁱ  <https://orcid.org/0000-0003-2747-9691>
Hussain Mⁱⁱⁱ  <https://orcid.org/0000-0001-6054-7356>
Rehman A^{iv}  <https://orcid.org/0000-0002-6235-1848>
Khalil S^v  <https://orcid.org/0000-0003-1657-6904>
Qamar SH^{vi}  <https://orcid.org/0000-0003-3714-5468>

- ⁱ Department of Poultry Production, University of Veterinary and Animal Sciences, Lahore, Pakistan.
ⁱⁱ Department of Animal Nutrition, University of Veterinary and Animal Sciences, Lahore, Pakistan.
ⁱⁱⁱ Institute of Animal and Dairy Sciences, University of Agriculture Faisalabad, Pakistan.
^{iv} Department of Animal Sciences, College of Agriculture, University of Sargodha, Pakistan.
^v Institute of Pharmaceutical Sciences, University of Veterinary and Animal Sciences, Lahore, Pakistan.
^{vi} Institute of Animal Nutrition, Key Laboratory for Animal Disease-Resistance Nutrition of China, Ministry of Education, Sichuan Agricultural University, Chengdu, Sichuan, China, 611130.

■ Mail Address

Corresponding author e-mail address
Dr. Shahid Mehmood
Department of Poultry Production, University of Veterinary and Animal Sciences, Lahore, Pakistan.
Phone: +92 332 4522310
Email: shahid.mehmood@uvas.edu.pk

■ Keywords

Fat sources; emulsifier; phases; digestibility; performance; broilers.



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 OO and had inclusion of emulsifier during the starter phase, (T7) BR which contained SO 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 OO and had inclusion of emulsifier during the finisher phase. 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 3×4 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



Table – 1 Composition of experimental basal diets.

	Starter (day 1- 10)			Grower (day 11- 22)			Finisher (day 23- 35)		
	¹ SO	² PF	³ OO	¹ SO	² PF	³ OO	¹ SO	² PF	³ OO
Corn	54.60	54.71	54.71	60.03	60.75	60.75	64.09	64.72	64.72
Soybean Meal	29.72	29.70	29.70	27.06	27.11	27.11	20.77	20.88	20.88
Rice Polish	4.00	4.00	4.00	3.74	2.96	2.96	2.435	1.788	1.788
Canola Meal	4.00	4.00	4.00	0.00	0.00	0.00	1.91	1.81	1.81
Fish Meal	0.00	0.00	0.00	3.00	3.00	3.00	5.50	5.50	5.50
Soy Oil	3.00	0.00	0.00	3.00	0.00	0.00	3.00	0.00	0.00
Poultry Fat	0.00	3.00	0.00	0.00	3.00	0.00	0.00	3.00	0.00
Oxidised Oil	0.00	0.00	3.00	0.00	0.00	3.00	0.00	0.00	3.00
L-Lysine SO4	0.609	0.610	0.610	0.461	0.462	0.462	0.374	0.375	0.375
dL-Methionine	0.377	0.376	0.376	0.321	0.321	0.321	0.260	0.260	0.260
L-Threonine	0.209	0.209	0.209	0.15	0.15	0.15	0.102	0.103	0.103
Salt	0.539	0.535	0.535	0.293	0.296	0.296	0.237	0.238	0.238
CaCO ₃	1.277	1.286	1.286	1.140	1.133	1.133	0.931	0.930	0.930
Arginine	0.115	0.115	0.115	0.055	0.058	0.058	0.04	0.041	0.041
Monocalcium Phosphate	1.394	1.299	1.299	0.59	0.600	0.600	0.191	0.195	0.195
Phytase(10,000 FTU)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
⁴ Vitamin/Min Premix/*Emulsifier	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Total	100	100	100	100	100	100	100	100	100
Ether Extract%	5.89	5.9	5.9	6.3	6.2	6.2	6.45	6.37	6.37
Crude Protein%	21	21	21	20	20	20	19	19	19
ME (kcal/kg)	3,000	3,000	3,000	3,100	3,100	3,100	3,150	3,150	3,150
Calcium, %	0.96	0.96	0.96	0.87	0.87	0.87	0.8	0.8	0.8
Available P, %	0.48	0.48	0.48	0.43	0.43	0.43	0.4	0.4	0.4
Sodium, %	0.23	0.23	0.23	0.16	0.16	0.16	0.16	0.16	0.16
Digestible Lys, %	1.28	1.28	1.28	1.15	1.15	1.15	1.03	1.03	1.03
Digestible Met, %	0.65	0.65	0.65	0.602	0.602	0.602	0.55	0.55	0.55
Digestible Met + cys, %	0.95	0.95	0.95	0.87	0.87	0.87	0.8	0.8	0.8
Digestible Thr, %	0.86	0.86	0.86	0.77	0.77	0.77	0.69	0.69	0.69
Digestible Arg, %	1.37	1.37	1.37	1.23	1.23	1.23	1.1	1.1	1.1

¹ Soy Oil, ²Poultry Fat, ³Oxidized Soy Oil

⁴Vitamin and Mineral Premix: Each kilogram contained: Vit. A, 7 000 I.U.; Vit. D₃, 2 500 I.U.; 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

*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

days. The grower dietary phase was consisted of 9-21 days while the finisher dietary phase was consisted of 22–35 days. The experimental protocol was approved by synopsis committee University of Veterinary and Animal Sciences, Lahore. Experimental procedures were followed by the guidelines and code of practice of the University of Veterinary and Animal Sciences, Lahore. Permission of all experiment procedures were granted by the ethical approval committee of the University of Veterinary and Animal Sciences, Lahore. Birds were ensured free from hunger and thirst as described in previous animal researches (Aziz ur Rahman *et al.*, 2017; Rahman *et al.*, 2019).

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			0-35 days			
	F.I (g)	WG (g)	FCR	F.I (g)	WG (g)	FCR	
Sources							
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	3288.90 ^b	1864.30 ^b	1.76 ^a	
<i>p</i> value	0.0010	<0.0001	<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 ^b	
<i>p</i> value	0.9935	0.276	0.0964	0.5315	0.1255	0.0024	
Se	16.46	14.82	0.01	56.49	30.23	0.02	
Sources X Phases Treatments							
Sources	Phases						
Poultry fat	Whole Life	1254.30	938.50 ^{abc}	1.34 ^{bc}	3427.20	2072.00 ^{ab}	1.65 ^{bc}
	Starter	1249.70	923.00 ^{abc}	1.36 ^{abc}	3388.30	1963.80 ^{abcd}	1.73 ^{abc}
	Grower	1252.30	927.33 ^{abc}	1.35 ^{abc}	3318.30	1970.50 ^{abcd}	1.69 ^{bc}
	*Finisher	1261.20	916.33 ^{abc}	1.38 ^{abc}	3432.30	2054.80 ^{abc}	1.67 ^{bc}
Vegetable oil	Whole Life	1278.50	967.00 ^a	1.33 ^c	3379.00	2080.50 ^a	1.63 ^c
	Starter	1273.70	948.33 ^{ab}	1.35 ^{abc}	3485.00	2065.20 ^{ab}	1.69 ^{bc}
	Grower	1276.20	955.33 ^a	1.34 ^{bc}	3430.20	2066.80 ^{ab}	1.66 ^{bc}
	*Finisher	1271.00	936.67 ^{abc}	1.36 ^{abc}	3386.30	2066.80 ^{ab}	1.64 ^c
Used oil	Whole Life	1222.70	884.17 ^{abc}	1.36 ^{abc}	3273.80	1896.70 ^{bcd}	1.73 ^{abc}
	Starter	1217.80	857.17 ^c	1.42 ^{ab}	3363.70	1849.00 ^d	1.82 ^a
	Grower	1220.30	866.00 ^{bc}	1.41 ^{abc}	3238.30	1830.30 ^d	1.77 ^{ab}
	*Finisher	1215.30	851.17 ^c	1.43 ^a	3279.80	1881.30 ^{cd}	1.74 ^{abc}
<i>p</i> value	0.9997	0.0499	0.0499	0.8340	0.0481	0.0498	
Se	28.51	25.68	0.03	97.85	52.36	0.04	

¹SE; 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.



statistical procedure. In brief, data were subjected to ANOVA using the GLM procedure of SPSS. The models included main effects of fat sources (soy oil, poultry fat, and oxidized oil) and emulsifier inclusion (0, 0.025%, 0.035% and 0.045%), and their interactions. Each pen was considered an experimental unit.

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

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

Nutrient digestibility				
Variables		Crude fat	Crude protein	Dry matter
Sources				
Poultry fat		79.74 ^b	72.88	71.40 ^b
Vegetable oil		82.73 ^a	73.48	72.28 ^a
Used oil		72.43 ^c	72.50	70.01 ^c
<i>p</i> value		<0.0001	0.2334	<0.0001
Se		0.27	0.56	0.26
Phases				
Whole Life		79.21 ^a	73.72	71.64 ^a
Starter		76.78 ^c	72.17	71.01 ^{ab}
Grower		78.28 ^b	72.78	70.76 ^b
Finisher		78.92 ^{ab}	73.15	71.52 ^{ab}
<i>p</i> value		<0.0001	0.1397	0.0214
Se		0.31	0.65	0.30
Sources X Phases Treatments				
sources	Phases			
Poultry fat	Whole Life	80.53 ^{bc}	73.37	71.92 ^{abc}
	Starter	78.34 ^d	71.80	70.85 ^{bcd}
	Grower	79.75 ^{cd}	73.08	71.19 ^{abc}
	Finisher	80.31 ^{bc}	73.29	71.65 ^{abc}
Vegetable oil	Whole Life	83.95 ^a	74.77	72.42 ^{ab}
	Starter	81.24 ^{bc}	72.68	72.05 ^{ab}
	Grower	82.18 ^{ab}	73.02	71.84 ^{abc}
	Finisher	83.54 ^a	73.45	72.82 ^a
Used oil	Whole Life	73.14 ^e	73.03	70.58 ^{bcd}
	Starter	70.75 ^f	72.02	70.13 ^{cd}
	Grower	72.91 ^e	72.26	69.24 ^d
	Finisher	72.92 ^e	72.70	70.08 ^{cd}
<i>p</i> value		0.0451	0.9582	0.0459
Se		0.54	1.12	0.51

¹SE; 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



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). Zhang *et al.*

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

Carcass parameters						
Variables	Breast %age	Dressing %age	Fat %age	Liver %age	Thigh %age	
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	35.65	63.60	2.71	3.03	5.61	
Starter	35.03	62.51	2.30	2.87	5.55	
Grower	34.54	61.60	2.35	2.94	5.42	
Finisher	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						
sources	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	

¹SE; 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 trails 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.*, 2017). Broilers at an early age had less fat digestion capacity as compared to mature birds (Tancharoenrat *et al.*, 2013).

Interaction results of treatment and phases represent that birds on vegetable oil sources had better digestibility of crude fat and dry matter when emulsifier was supplemented in the finisher phase or throughout life. 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; Zaefarian *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 microbe (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.

REFERENCES

- Alzawqari M, Moghaddam HN, Kermanshahi H, Raji AR. The effect of desiccated ox bile supplementation on performance, fat digestibility, gut morphology and blood chemistry of broiler chickens fed tallow diets. *Journal of Applied Animal Research* 2011;39(2):169-174.
- Anjum A, Zafar U, Awais HM, Shakoor A. Impact of puddling on water productivity of rice under raised bed technology. *The Journal of Global Innovations in Agricultural and Social Sciences* 2019;7(3):129-134.
- AOAC - Association of Official Analytical Chemists. Official methods of analysis. 13th ed. Washington: AOAC; 1990
- Aziz ur Rahman M, Chuanqi X, Huawei S, Binghai C. Effects of hay grass level and its physical form (full length vs. chopped) on standing time, drinking time, and social behavior of calves. *Journal of Veterinary Behavior* 2017;21(Supplement C):7-12.
- Blanch A, Barroeta A, Baucells M, Serrano X, Puchal F. Utilization of different fats and oils by adult chickens as a source of energy, lipid and fatty acids. *Animal Feed Science and Technology* 1996;61(1/4):335-342.
- Chen D, Chen Y, Zhen H, Xiao K, Tang J, Tang Q, *et al.* Effects of replacing whole-plant corn silage with whole-plant rice silage and rice straw on growth performance, apparent digestibility and plasma parameters in growing angus cross bred beef cattle. *International Journal of Agriculture and Biology* 2019;22:1116-1122.
- Chung H, Guenter W, Rotter R, Crow G, Stanger N. Effects of dietary fat source on sudden death syndrome and cardiac sarcoplasmic reticular calcium transport in broiler chickens. *Poultry Science* 1993;72(2):310-316.
- Dänicke S, Simon O, Jeroch H, Bedford M. Interactions between dietary fat type and xylanase supplementation when rye-based diets are fed to broiler chickens 2. Performance, nutrient digestibility and the fat-soluble vitamin status of livers. *Brazilian Journal of Poultry Science* 1997;38(5):546-556.
- Dierick N, Decuyper J. Influence of lipase and/or emulsifier addition on the ileal and faecal nutrient digestibility in growing pigs fed diets containing 4% animal fat. *Journal of Science of Food and Agriculture*. 2004;84(12):1443-1450.
- Engberg RM, Lauridsen C, Jensen SK, Jakobsen K. Inclusion of oxidized vegetable oil in broiler diets. Its influence on nutrient balance and on the antioxidative status of broilers. *Poultry Science* 1996;75(8):1003-1011.
- He Y, Niu W, Qiu Q, Xia C, Shao T, Wang H, *et al.* Effect of calcium salt of long-chain fatty acids and alfalfa supplementation on performance of Holstein bulls. *Oncotarget* 2018;9(3):3029.
- Huang J, Yang D, Wang T. Effects of replacing soy-oil with soy-lecithin on growth performance, nutrient utilization and serum parameters of broilers fed corn-based diets. *Asian Australasian Journal of Animal Sciences* 2007;20(12):1880.
- Hussain M, Mahmud A, Hussain J, Qaisrani S, Mehmood S, Rehman A. Subsequent effect of dietary lysine regimens fed in the starter phase on the growth performance, carcass traits and meat chemical composition of aseel chicken in the grower phase. *Brazilian Journal of Poultry Science* 2018a;20:455-462.



- Hussain M, Mahmud A, Hussain J, Qaisrani SN, Mehmood S, Ahmad S, *et al.* Effect of dietary amino acid regimens on growth performance and body conformation and immune responses in Aseel chicken. *Indian Journal of Animal Research* 2020;54(1):53-58.
- Hussain S, Khan AA, Shakoor A, Goheer A, Qadir T, Khan MM, *et al.* Effect of cold and heat stress on different stages of wheat: a review. *The Journal of Global Innovation in Agriculture and Social Sciences* 2018;6(4):123-128.
- Hussein AS, Kratzer F. Effect of rancidity on the feeding value of rice bran for chickens. *Poultry Science* 1982;61(12):2450-2455.
- Jakobsen K, Engberg RM, Hartfiel W. The biological activity of natural source tocopherols in chickens fed fresh or oxidized fat rich in linoleic acid. *Archives of Animal Nutrition* 1993;44(4):339-355.
- Keles R, Bayrak H, Imriz G. Determination of grain yield and leaf chlorophyll content of some dry bean (*Phaseolus vulgaris* L.) varieties. *The Journal of Global Innovation in Agriculture and Social Sciences* 2019;7(2):53-57.
- Leeson S, Atteh J. Utilization of fats and fatty acids by turkey poults. *Poultry Science* 1995;74(12):2003-2010.
- Maisonnier S, Gomez J, Bree A, Berri C, Baeza E, Carre B. Effects of microflora status, dietary bile salts and guar gum on lipid digestibility, intestinal bile salts, and histomorphology in broiler chickens. *Poultry Science* 2003;82(5):805-814.
- Muhammad AU, Xia CQ, Cao BH. Dietary forage concentration and particle size affect sorting, feeding behaviour, intake and growth of Chinese holstein male calves. *Journal of Animal Physiology and Animal Nutrition* 2016;100(2):217-223.
- Niu W, He Y, Xia C, Rahman MAU, Qiu Q, Shao T, *et al.* Effects of replacing *Leymus chinensis* with whole-crop wheat hay on Holstein bull apparent digestibility, plasma parameters, rumen fermentation, and microbiota. *Scientific Reports* 2017;18;7(1):1-2
- Noy Y, Sklan D. Metabolic responses to early nutrition. *Journal of Applied Poultry Research* 1998;7(4):437-451.
- NRC - National Research Council. Nutrient requirements of poultry. 9th rev. ed. Washington: National Academies Press; 2004.
- Oertel ML, Hartfiel W. Wirkung von frischen unoxidierten Fetten/Olen sowie von Pro- und Antioxidantien auf das Wachstum von Masthuhnertken. *Archive of Gefluegelkd* 1982;46:13-19.
- Qiu Q, Gao C, Aziz ur Rahman M, Cao B, Su H. Digestive ability, physiological characteristics, and rumen bacterial community of holstein finishing steers in response to three nutrient density diets as fattening phases advanced. *Microorganisms* 2020;8(3):335.
- Qiu Q, Gao C, Gao Z, He Y, Cao B, Su H. Temporal dynamics in rumen bacterial community composition of finishing steers during an adaptation period of three months. *Microorganisms* 2019a;7(10):410.
- Qiu Q, Zhu Y, Qiu X, Gao C, Wang J, Wang H, *et al.* Dynamic variations in fecal bacterial community and fermentation profile of Holstein steers in response to three stepwise density diets. *Animals* 2019b;9(8):560.
- Rahman MA, Qi XC, Binghai C. Nutrient intake, feeding patterns and abnormal behavior of growing bulls fed different concentrate levels and a single fiber source (corn stover silage). *Journal of Veterinary Behavior* 2019;33:46-53.
- Rehman A, Hesheng H, Rahman M, Jingyi X, Shuang L, Yannan G, *et al.* Evaluation of efficacy of compound chinese medicinal herbs against mycoplasma synoviae using different lab tests in mouse and chicken. *International Journal of Agriculture and Biology* 2019;22(4), 647-654
- Roy A, Haldar S, Mondal S, Ghosh TK. Effects of supplemental exogenous emulsifier on performance, nutrient metabolism, and serum lipid profile in broiler chickens. *Veterinary Medicine International*. 2010;2010(11):262604.
- Sharif M, Shoaib M, Rahman MAU, Ahmad F, Rehman SU. Effect of distillery yeast sludge on growth performance, nutrient digestibility and slaughter parameters in Japanese quails. *Scientific Reports* 2018;8(1):8418.
- Smits CH, Moughan PJ, Beynen AC. The inhibitory effect of a highly viscous carboxymethylcellulose on dietary fat digestibility in the growing chicken is dependent on the type of fat. *Journal of Animal Physiology and Animal Nutrition* 2000;83(4-5):231-238.
- Su H, Wang Y, Zhang Q, Wang F, Cao Z, Rahman MAU, *et al.* Responses of energy balance, physiology, and production for transition dairy cows fed with a low-energy prepartum diet during hot season. *Tropical Animal Health and Production* 2013;45(7):1495-1503.
- Tan L, Rong D, Yang Y, Zhang B. Effect of oxidized soybean oils on oxidative status and intestinal barrier function in broiler chickens. *Brazilian Journal of Poultry Science* 2018;20:333-342.
- Tancharoenrat P, Ravindran V, Zaefarian F, Ravindran G. Influence of age on the apparent metabolisable energy and total tract apparent fat digestibility of different fat sources for broiler chickens. *Animal Feed Science and Technology* 2013;186(3-4):186-192.
- Tavárez MA, Boler DD, Bess KN, Zhao J, Yan F, Dilger AC, *et al.* Effect of antioxidant inclusion and oil quality on broiler performance, meat quality, and lipid oxidation. *Poultry Science* 2011;90(4):922-930.
- Tiwana U, Hafeez S, Ahmad HM, Habib ur Rehman. Diet composition of a wildlife species in agri-ecosystems of Faisalabad, Punjab, Pakistan. *The Journal of Global Innovation in Agriculture and Social Sciences* 2019;7(2):73-78.
- Upadhaya S, Park J, Yun H, Kim I. 283 role of emulsifier as fat replacer in low density diet for growing and finishing pigs. *Journal of Animal Sciences* 2016;94(suppl 2):133-133.
- Upadhaya SD, Lee JS, Jung KJ, Kim IH. Influence of emulsifier blends having different hydrophilic-lipophilic balance value on growth performance, nutrient digestibility, serum lipid profiles, and meat quality of broilers. *Poultry Science* 2017;97(1):255-261.
- Wang C, Muhammad A, Liu Z, Huang B, Cao B. Effects of ensiling time on banana pseudo-stem silage chemical composition, fermentation and in sacco rumen degradation. *The Journal of Animal and Plant Sciences* 2016;26(2):339-346.
- Xia C, Liang Y, Bai S, He Y, Muhammad AUR, Su H, *et al.* Effects of harvest time and added molasses on nutritional content, ensiling characteristics and in vitro degradation of whole crop wheat. *Asian-Australasian Journal of Animal Sciences* 2018a;31(3):354-362.
- Xia C, Aziz Ur Rahman M, Yang H, Shao T, Qiu Q, *et al.* Effect of increased dietary crude protein levels on production performance, nitrogen utilisation, blood metabolites and ruminal fermentation of Holstein bulls. *Asian-Australasian Journal of Animal Science* 2018b;31(10):1643
- Xia CQ, Muhammad AUR, Niu W, Shao T, Qiu Q, Huawei S, *et al.* Effects of dietary forage to concentrate ratio and wildrye length on nutrient intake, digestibility, plasma metabolites, ruminal fermentation and fecal microflora of male Chinese Holstein calves. *Journal of Integrative Agriculture* 2018;17(2):415-427.
- Xu J, Sheng H, Rehman A, Yannan G, Muhammad AUR. Effect of supplementation of chinese herbal extracts in drinking water on growth performance, nutrient utilization and immune response in broilers. *International Journal of Agriculture and Biology* 2019;22(5):933-938.



Zaefarian F, Romero LF, Ravindran V. Influence of high dose of phytase and an emulsifier on performance, apparent metabolisable energy and nitrogen retention in broilers fed on diets containing soy oil or tallow. *British Journal of Poultry Sciences* 2015;56(5):590-597.

Zhang B, Haitao L, Zhao D, Guo Y, Barri A. Effect of fat type and lysophosphatidylcholine addition to broiler diets on performance, apparent digestibility of fatty acids, and apparent metabolizable energy content. *Animal Feed Science and Technology* 2011;163(2):177-184.

Zhang X, Rahman MAU, Xue Z, Wang X, He Y, Cao B. Effect of post-pubertal castration of wannan cattle on daily weight gain, body condition scoring and level of blood hormone. *International Journal of Agriculture and Biology* 2015;17(2):334-338.

Zhao P, Li H, Hossain M, Kim I. Effect of emulsifier (lysophospholipids) on growth performance, nutrient digestibility and blood profile in weanling pigs. *Animal Feed Science and Technology* 2015;207:190-195.

Zollitsch W, Knaus W, Aichinger F, Lettner F. Effects of different dietary fat sources on performance and carcass characteristics of broilers. *Animal Feed Science and Technology* 1997;66(1/4):63-73.