



Influence of Thermally Oxidized Vegetable Oil and Animal Fats on Growth Performance, Nutrient Digestibility, Carcass Parameters and Meat Quality of Broilers

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■ Keywords

Oxidized soy oil, fresh soy oil, poultry refined oil, growth, digestibility, broilers.



ABSTRACT

The current study was planned to investigate the influence of soy oil, oxidized soy oil, poultry oil single refined and poultry oil double refined on the performance of broilers chicken. A total of two hundred and forty, day-old broiler chicks were divided into 4 treatments in such a way that each treatment had six replicates and each replicate had ten chicks. The experimental treatments were separated with the usage of single refined poultry oil, double refined poultry oil, oxidized soy oil and soy oil in the diet of broilers. In both starter and overall periods average body weight was higher ($p < 0.05$) for birds which were on a basal diet containing soy oil as compared to other diets. Similarly, feed intake was higher ($p < 0.05$) for birds which were on a basal diet containing soy oil in the starter phase. In the overall phase, average body weight was less in oxidized oil as compared to other dietary treatments ($p < 0.05$). Similarly, birds showed poor feed conversion ratio in the basal diet that contained oxidized oil ($p < 0.05$) in the overall phase of the experiment. The birds showed better digestibility ($p < 0.05$) for crude fat on a basal diet containing vegetable oil and double refined poultry oil as compared to other diets. Results showed no effects of experimental treatments on the meat quality and carcass parameters ($p > 0.05$). Therefore, it can be concluded that poultry single refined and double refined oil could be a possible substitute for fresh soy oil for better performance as compared to oxidized soy oil.

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 broilers 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.*, Børsting *et al.*, 1994; 1993; Engberg *et al.*, 1996; Anjum *et al.*, 2004; Tan *et al.*, 2018; 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 broiler production are conflicting (Jakobsen *et al.*, Børsting *et al.*, 1994; 1993; Engberg *et al.*, 1996; Anjum *et al.*, 2004; Tan *et al.*, 2018; Tan *et al.*, 2018; Yang *et al.*, 2019). 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 (FCR) 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 (Børsting *et al.*, 1994; Hussein & Kratzer 1982)

Variable results of addition of oxidized oil in the diet of broiler on the performance of broilers depend upon the source of fat, degree of oxidation and conditions that caused the oxidation of fats. It has been reported that fat origin and the oxidation condition of fat (e.g., extent of temperature, time of heating, presence of oxygen and catalysts, and water activity) effect differently on the performance of the broilers when included in the diet of broilers (Lin *et al.*, 1989; Engberg *et al.*, 1996; Anjum *et al.*, 2004; Yang *et al.*, 2019). Gopalakrishna & Prabhakar (1986) reported that the origin of fats and the condition of oxidation of fats results in production of a significant amount of oxidation products. A large number of these oxidative products are not considered to have any toxic effect however, some of these oxidative products are supposed to have toxic properties that have potential to damage the brush border membrane of the intestine (Kimura *et al.*, 1984) and liver (Kazuki *et al.*, 1986; Engberg *et al.*, 1996). Therefore, the inclusion of fat in the diet of poultry birds not only affects animal growth but also negatively influences the health of growing birds (Kimura *et al.*, 1984; Kazuki *et al.*, 1986; Engberg *et al.*, 1996). Recently, it has been reported that digestive tract health is important for better growth (Qiu *et al.*, 2019a; Qiu *et al.*, 2019b). Furthermore, the inclusion of oxidized oils in the diet of broilers influences the quality of broiler meat and meat products (Lin *et al.*, 1989). Deterioration of meat quality due to oxidized oil in the diet of broiler may reduce the consumption of poultry meat because broiler meat is regularly selected over other meats due to low lipid contents and relatively higher concentration of polyunsaturated fatty acids (Nkukwana *et al.*, 2014; Yang *et al.*, 2019).

Poultry industry is trying to find suitable substitute of common soybean oil, corn oil and oxidized vegetable oil (Yang *et al.*, 2019). The problem of oxidation of vegetable oil during storage, the increasing price of vegetable oil and the decreasing availability of common vegetable fat sources are encouraging broiler producers to look for alternative oil sources. Keeping in mind the need for broiler industry, research was planned to evaluate the effect of poultry oil (single

refined and double refined), oxidized soy oil and soy oil on feed intake, growth, digestibility, meat quality, and carcass parameters. In the current study, influence of soy oil, oxidized soy oil, poultry oil single refined and poultry oil double refined on feed intake, growth, digestibility, meat quality, and carcass parameters were investigated. The birds were fed diets providing fresh soy oil, oxidized soy oil, poultry oil single refined and poultry oil double refined respectively.

MATERIAL AND METHODS

Experimental design, animal husbandry, and experimental diets

The current research was executed in a completely randomized experimental design (CRD). The experimental treatments were single refined poultry oil, double refined poultry oil, oxidized soy oil and soy oil.

A total of two hundred and forty, broiler chicks (1 day-old) were procured from a local hatchery in Pakistan. Chicks were distributed into four experimental treatments in such a way that each experimental treatment had six replicates and each replicate had ten chicks. The total experimental duration for the current study was 35 days. Flushing was done with the help of sugar solution (1kg sugar/5L water) on the first day of the experiment. The temperature of brooding was set at 95 °F for the first week. The temperature was decreased by 5° F every week until it reached 75 °F. During the experimental period, ad libitum feed and water were ensured to all experimental birds. Broiler vaccination schedule was practiced according to the suggestion of a local veterinarian. The experimental diets were corn-soybean based and formulated to meet or exceed the nutrient requirement of growing broiler as recommended by Cobb500. The diet composition was standard as set by Wildlife Administration of Pakistan (Tiwana *et al.*, 2019). All the ingredients for the formulation of the feed were provided by a local commercial feed mill (Five Star Feeds Pvt. Ltd. Gujranwala, Pakistan). All diets were formulated on digestible amino acids (AA) basis keeping lysine as reference AA as described in a recent study (Abdullah *et al.*, 2019). 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 took place in the first 10 days. The grower dietary phase were from days 11-22 while the finisher dietary phase were from days 23–35. The experimental protocol was approved by the synopsis committee



Table 1 – Composition of experimental basal diets.

Ingredient (%)	Starter (Day 1-10)				Grower (Day 11-22)				Finisher (Day 23-35)			
	Soy oil	Poultry Fat(S)	Poultry Fat(D)	Oxidized oil	Soy oil	Poultry Fat(S)	Poultry Fat(D)	Oxidised oil	Soy oil	Poultry Fat(S)	Poultry Fat(D)	Oxidised oil
Corn	54.6	54.71	54.71	54.71	60.03	60.75	60.75	60.75	64.09	64.72	64.72	64.72
Soybean Meal	29.72	29.7	29.7	29.7	27.06	27.11	27.11	27.11	20.77	20.88	20.88	20.88
Rice Polish	4	4	4	4	3.74	2.96	2.96	2.96	2.435	1.788	1.788	1.788
Canola meal	4	4	4	4	0				1.91	1.81	1.81	1.81
Fish Meal	0	0	0	0	3	3	3	3	5.5	5.5	5.5	5.5
soy oil	3	0	0	0	3	0	0	0	3	0	0	0
Poultry Fat(S)	0	3	0	0	0	3	3	3	0	3	0	0
Poultry Fat(D)	0	0	3	0	0	0	0	0	0	0	3	0
Oxidised Oil	0	0	0	3	0	0	0	0	0	0	0	3
L-Lysine SO4	0.609	0.61	0.61	0.61	0.461	0.462	0.462	0.462	0.374	0.375	0.375	0.375
DL-Methionine	0.377	0.376	0.376	0.376	0.321	0.321	0.321	0.321	0.26	0.26	0.26	0.26
L-Threonine	0.209	0.209	0.209	0.209	0.15	0.15	0.15	0.15	0.102	0.103	0.103	0.103
Salt	0.539	0.535	0.535	0.535	0.293	0.296	0.296	0.296	0.237	0.238	0.238	0.238
CaCo3	1.277	1.286	1.286	1.286	1.14	1.133	1.133	1.133	0.931	0.93	0.93	0.93
Arginine	0.115	0.115	0.115	0.115	0.055	0.058	0.058	0.058	0.04	0.041	0.041	0.041
Monocalcium phosphate	1.394	1.299	1.299	1.299	0.59	0.6	0.6	0.6	0.191	0.195	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	0.01	0.01	0.01
Vitamin/Min premix/Emulsifier	0.15	0.15	0.15	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	100	100	100
EE%	5.89	5.9	5.9	5.9	6.3	6.2	6.2	6.2	6.45	6.37	6.37	6.37
CP%	21	21	21	21	20	20	20	20	19	19	19	19
AME, kcal/kg	3,000	3,000	3,000	3,000	3,100	3,100	3,100	3,100	3,150	3,150	3,150	3,150
Calcium, %	0.96	0.96	0.96	0.96	0.87	0.87	0.87	0.87	0.8	0.8	0.8	0.8
Available P, %	0.48	0.48	0.48	0.48	0.43	0.43	0.43	0.43	0.4	0.4	0.4	0.4
Sodium, %	0.23	0.23	0.23	0.23	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Digestible Lys, %	1.28	1.28	1.28	1.28	1.15	1.15	1.15	1.15	1.03	1.03	1.03	1.03
Digestible Met, %	0.65	0.65	0.65	0.65	0.602	0.602	0.602	0.602	0.55	0.55	0.55	0.55
Digestible Met + Cys, %	0.95	0.95	0.95	0.95	0.87	0.87	0.87	0.87	0.8	0.8	0.8	0.8
Digestible Thr, %	0.86	0.86	0.86	0.86	0.77	0.77	0.77	0.77	0.69	0.69	0.69	0.69
Digestible Arg, %	1.37	1.37	1.37	1.37	1.23	1.23	1.23	1.23	1.1	1.1	1.1	1.1

University of Veterinary and Animal Sciences (UVAS), Lahore. Experimental procedures were followed by the guidelines and code of practice of UVAS, Lahore. Permission for all experiment procedures were granted by the ethical approval committee of UVAS, Lahore. The birds were ensured free from hunger and thirst as described in previous researches (Aziz ur Rahman *et al.*, 2017; Aziz ur Rahman *et al.*, 2019).

Performance parameters

To measure the feed intake, growth rate and performance parameters standard procedures were adopted as presented in the recent study (Hussain *et al.*, 2018; Hussain *et al.*, 2020). In brief, the birds were weighed at days 1, 21 and 35 of the experiment.

Weekly feed intake was calculated, body weight gain and feed intake were recorded for the overall period.

Fecal samples

From days 33 to 35, fecal samples were collected from each pen by total collection method as described in the literature. 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 particles were removed. The collected samples were packed in sample bags (sealed plastic bags). Standard scientific approaches were adopted to seal the sample as described in literature to avoid any sample loss (Iamam-ul-Haq *et*



al., 2019; Shahzad *et al.*, 2019). Sealed plastic sample bags were stored at $-30\text{ }^{\circ}\text{C}$ in the 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 (*Chen et al.*, 2019; *He et al.*, 2018; *Su et al.*, 2013).

Nutrient digestibilities determination

For determination of digestibilities of nutrients, collected feed and fecal samples were analyzed for dry matter and crude fat determination. Dry matter and crude fat were determined using the protocol of AOAC (1995) as described in previous studies (*Muhammad et al.*, 2016; *Niu et al.*, 2017; *Xia et al.*, 2018). The resulting values were used to calculate the DM and crude fat digestibilities as described in the recent study.

Carcass and meat quality parameters determination

Carcass parameter was determined following the procedure of *Sharif et al.* (2018). For the determination of carcass and meat quality parameters standard

procedures were followed as described in the 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 depulming of feathers, head, viscera, and shanks were separated. Then portioning of the carcass was done to obtain the weight of the breast, legs, live weight, carcass weight, thigh meat yield, and breast meat yield. Similarly, meat obtained was used for meat quality parameters determination.

Statistical analysis

Collected data were analyzed to check the significance of the treatments by using the standard statistical procedures. In brief, data were subjected to ANOVA using the GLM procedure of SAS. Differences between means were identified using Duncan's multiple range test. Differences were considered significant at $p < 0.05$.

Growth performance

Results for growth performance are shown in table 2. Results revealed that oxidation of soy oil and fat

Table 2 – Effect of oxidized vegetable oil and animal fats addition in broiler diets on performance of broiler.

	0-21 days			0-35 days		
	¹ Avg. BW	Feed intake	² FCR	Avg. BW	Feed intake	FCR
Used Oil	808.17 ^b	1000.70 ^{ab}	1.24	2011 ^c	3500	1.74 ^a
Poultry Double	827.83 ^{ab}	1004.50 ^{ab}	1.22	2164.70 ^a	3585.20	1.66 ^b
Poultry Single	807.00 ^b	984.83 ^b	1.22	2106.20 ^a	3496.70	1.66 ^b
Soy Oil	860.33 ^a	1032.30 ^a	1.20	2157 ^a	3525	1.63 ^b
p value	0.0068	0.0548	0.4082	<0.0001	0.1088	0.0032
³ SE	10.698	11.405	0.0158	18.855	27.045	0.0184

¹Average body weight

²Feed conversion ratio

³SE; standard error

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

sources affected feed intake, and average weight gain ($p < 0.05$) in the starter phase of the experimental period. However, FCR was not affected by dietary treatment ($p > 0.05$) in starter phase of the experiment. While in overall phase average weight and FCR were influenced by oxidation of soy oil and fat sources ($p < 0.05$) but feed intake was similar in all experimental treatments ($p > 0.05$). Average body weight was high ($p < 0.05$) for birds which were on a basal diet containing soy oil as compared to other diets in the starter phase of the experiment. Similarly, feed intake was higher ($p < 0.05$) for the birds which were on a basal diet containing soy oil as compared to other diets in the starter phase. In the overall phase, 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 ($p < 0.05$) in the overall phase of the experiment. However, in the overall phase feed intake was similar in all the experimental treatments ($p > 0.05$).

Nutrient digestibility

The results of nutrient digestibility are shown in table 3. The results revealed that the experimental treatments affected the fat digestibility of the diet ($p < 0.05$). The birds showed better digestibility ($p < 0.05$) for crude fat on a basal diet containing vegetable oil and double refined poultry oil as compared to other diets. However, in the current study the experimental treatments did not have effect on dry matter and nitrogen digestibilities ($p < 0.05$).



Table 3 – Effect of oxidized vegetable oil and animal fats addition on nutrient digestibility of broilers.

	Fat	Dry matter	Nitrogen
Used Oil	70.74 ^c	70.11	70.77
Poultry Double	78.16 ^a	71.05	71.97
Poultry Single	73.61 ^b	70.62	71.68
Soy Oil	80.57 ^a	72.03	72.14
p value	<0.0001	0.2406	0.9056
¹ SE	0.5392	0.6230	1.4317

¹SE; standard error

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

Carcass and meat quality parameters

The results of carcass and meat quality parameters are presented in table 4. Results showed no effects of experimental treatments on the carcass parameters ($p > 0.05$). Similarly, the results showed no effects of experimental treatments on the quality parameters of meat ($p > 0.05$)

DISCUSSION

Prices of poultry feeds are increasing in developing countries due to higher prices of macro ingredients (corn and soybean) which contribute to a major portion of the feed. Sousa Lima *et al.*, 2016), reported that the prices of most utilized raw materials for the formulation of diet fluctuates and it is vital to find the substitute of conventional ingredients especially corn and soybean to reduce the feed costs. Keeping in view the need for feed industry, different scientists are working on different alternative ingredients for poultry to reduce the cost of feed (Tan *et al.*, 2018; Yang *et al.*, 2019) and oxidized oils are one of them. The use of oxidized oil in the diet of broiler chicks (Ehr *et al.*, 2015), weaned pigs (Li *et al.*, 2012), and different aquatic animals (Lewis-McCrea & Lall 2007; Dong *et al.*, 2011) represents that it could be potential alternative feed ingredients.

However, the addition of oxidized oil in the diet of animal's influence performance variably. (Dong *et al.*,

2011; Tavárez *et al.*, 2011; Wang *et al.*, 2015). Tavárez *et al.*, 2011 reported that the addition of oxidized oils in the diet of broilers impaired the performance of broilers. Similarly, Wang *et al.* (2015) also reported that the addition of oxidized oil in broiler diets negatively influence the broilers performance. Contrary to the results of Tavárez *et al.*, 2011, and Wang *et al.*, 2015, no negative effects have been reported by Dong *et al.*, 2011 on broilers performance by using oxidizing oils in the broiler diet. Contradiction in the performance results by using oxidizing oil in the diet of birds could be explained by the theory of Yue *et al.* (2010) and Zhang *et al.* (2010) who reported that the oxidizing oil inclusion rate and the degree of oil oxidation are the major factors which influences the animal's performance. In our study, no significant effects of feeding diets containing soy oil, and poultry double refined oils were observed on average body weight, intake and starter phase. However, feeding oxidized soy oil in the diet of broiler reduced average body weight and intake as compared to fresh soy oil and poultry double refined oil. The findings of the intake are similar to the studies of Hussein & Kratzer (1982) who reported less feed intake in rancid broiler fed experimental diets with high peroxide value. In contrary to the findings of the current study, Diaz (1977) reported similar feed intake in experimental broilers fed experimental feed with oxidized fat/oil with or without added antioxidant. Similar to the findings of Diaz (1977), L'éstrange *et al.* (1966) also stated that the inclusion of oxidized beef tallow in the diet of broiler had no negative effect on the feed intake of the broiler birds as compared to the control. Similarly, Chae *et al.* (2002) also stated that broiler chicks fed the experimental diet which contained fresh or oxidized soybean oil showed no difference in feed intake. Contradiction in the results of performance by using oxidizing oil in the diet of the birds could be explained by the theory of Yue *et al.*, 2010 and Zhang *et al.*, 2010 who reported that oxidizing oil inclusion rate and degree of oil oxidation are the major factors which

Table 4 – Effect of oxidized vegetable oil and animal fats addition in the diet of broilers on meat quality.

	Chroma	HUE	Lightness	Redness	Yellowness	pH
Used Oil	27.03	59.23	50.66	13.37	22.35	6.05
Poultry Double	26.56	58.62	51.41	13.06	23.58	6.08
Poultry Single	26.86	57.06	52.42	13.14	22.42	6.02
Soy Oil	27.39	59.97	52.56	12.87	24.75	6.10
p value	0.95	0.8118	0.7174	0.8674	0.3335	0.6042
SE	1.0190	2.1859	1.3349	0.4193	1.0321	0.0484

¹SE; standard error

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



Table 5 – Effect of oxidized vegetable oil and animal fats addition in the diet of broilers on carcass parameter.

	Breast %	Dressing %	Fat %	Liver	Thigh
Used Oil	33.76	64.58	2.41	2.87	5.20
Poultry Double	33.76	63.99	2.13	2.68	5.32
Poultry Single	35.21	64.75	2.64	2.71	5.41
Soy Oil	34.58	65.22	2.76	2.91	5.30
p value	0.329	0.3349	0.5786	0.4966	0.9319
SE	0.6376	0.4626	0.3399	0.1257	0.2232

¹SE; standard error

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

influences the animal's performance. In our study, it could be suggested that less degree of rancidity was the reason for similar feed intake in the overall period of the experiment. However, less weight gain in birds on oxidized soy oil could be supported by the findings of Chae *et al.* (2002) who stated that lower weight gain in chicks was observed when the birds were fed experimental ration which contained rancid rice polish as compared to the fresh rice polish. The reduction of weight gain in broiler on feed containing oxidized soy oil might be due to devastation of fat-soluble vitamins in rancid oil that leads to decreased availability of nutrients as well as immunity, and subsequently, reduce the growth performance (Lin *et al.*, 1989). Findings of higher weight gain with fresh soy oil feed are similar to the results of Anjum *et al.*, (2004) who reported the highest weight gain in chicks fed fresh soy oil than those fed oxidized soy oil which indicates that feed containing oxidized soybean oil is of poor quality. However, in the overall phase, interesting results were observed where average body weight and FCR were similar in birds fed diets containing poultry single refined oil, poultry double refined oil and fresh soy oil diet. Therefore, it could be assumed that poultry single refined and double refined could be a possible substitute of fresh soy oil for better performance as compared to oxidized soy oil.

The reduced weight gain and FCR in birds fed experimental diets which contained oxidized oil could be explained by the theory of Waheed *et al.*, (2004) who reported that thiobarbituric acid values for fats in fat ingredients increased during the oxidation process of fats which have a negative influence on chick's growth and FCR. Furthermore, feeding of oxidized fats to birds results in lower retention of fat and energy in birds, which showed by the reduced capability of fat digestion (Chae *et al.*, 2002; Engberg *et al.*, 1996). Moreover, a higher growth rate in fresh soy oil could also be supported by higher fat digestion as compared to oxidized oil.

Oxidized soybean oil, poultry single refined and double refined oil in the diet of broiler did not affect dressing percentage and weights of internal organs (liver). Findings of dressing percentage are similar with the findings of Anjum *et al.* (2004) who reported that oxidized soybean oil had no effect on dressing percentage and weights of internal organs (liver). Results of dressing percentages are quite comparable to those reported in other studies (Diaz, 1977; Hussein & Kratzer, 1982).

Similar to carcass parameters oxidized soybean oil, poultry single refined and double refined oil in the diet of broiler did not affect meat chroma, hue, lightness, redness, yellowness, and pH. Findings of meat chroma, hue, lightness, redness, yellowness, and pH are similar with the findings of (Anjum *et al.*, 2004) who reported that meat chroma, hue, lightness, redness, yellowness and pH are not influenced by fresh or oxidized oil.

CONCLUSION

Based on the findings of intake, growth, digestibility, carcass, and meat quality parameters it is concluded that the use of oxidized soy oil in the diet of broilers negatively influences intake, growth, digestibility of fat and feed conversion ratio. Therefore, it is recommended that poultry single refined and double refined oil could be a possible substitute for fresh soy oil for optimum broiler growth.

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