South African Journal of Animal Science 2023, 53 (No. 6)

The effects of poultry fat with soy oil at a fixed energy:protein on broiler field performance

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(Submitted 19 April 2023; Accepted 13 November 2023; Published 23 January 2024)

Abstract

The effects of poultry fat (PF) as an alternative to soy oil (SO) in broiler diets at a fixed energy:protein on field performance were investigated. Chick weight (CW), average daily weight gain (ADWG), average live weight (ALW), feed consumption (FC), feed conversion ratio (FCR), production efficiency factor (PEF), and liveability were examined. The experiment, which included 12000 broilers chicks with 15 repetitions in 60 pens, lasted 41 d. The chicks were obtained from 36-w old (middle-aged) Ross 308 strain broiler breeders. Four different diets of SO in starter, SO or PF in grower, and SO or equal amounts of both (SO+PF) in finisher were tested. The highest performance data were obtained when SO was used in the grower and SO+PF were used in the finisher diet, whereas the lowest performance data were obtained when PF was used in grower and SO+PF in the finisher diet. The differences between the CW, ADWG, ALW, FC, FCR and PEF values of these groups were significant, except for liveability. This is thought to be due to the synergistic effect caused by the combined use of SO and PF. The liveability was numerically higher in the SO groups and decreased with the use of PF, but these differences were not statistically significant. The use of PF with SO may be an effective and economic alternative in terms of fixed energy:protein if certain ratios are not exceeded.

Keywords: broiler, energy/protein ratio, growing, nutrition, poultry fat, soy oil
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Introduction

Poultry performance and feed costs are some of the most critical matters in the poultry industry. With the increase in feedstuff and vegetable oil prices, the use of different oils and fats has become widespread to reduce feed costs. Using oils and fats in poultry nutrition has many advantages, including increasing the energy ratio of diets, reducing feed consumption, and improving heat resistance, feed conversion ratio (FCR), and growth (Patra *et al.*, 2011; Poorghasemi et al., 2013; Infante-Rodriguez *et al.*, 2016; Rodriguez-Sanchez *et al.*, 2018; Sevim *et al*., 2020; Saleh *et al.*, 2021; Shoaib *et al*., 2023). However, the fat type in the diet, especially the impact of unsaturated fatty acids in the diet, has received considerable attention (Abdulla *et al.*, 2019). In addition, there are various difficulties to using oils and fats such as balancing the energy level of diets, low digestion in young chicks, additional equipment requirements, and rancidity (Aardsma *et al.*, 2017; Mellouk *et al.*,2018; Saleh *et al.*, 2021).

Soy oil (SO) is one of the most important vegetable oil sources in poultry diets and is used after going through processes such as filtration, hydration, and degumming (Beauregard *et al.*, 1996). SO can be used alone or mixed with other vegetable oils or animal fats, such as poultry fat (PF).

Poultry fat (PF) is an animal fat contains high energy (approximately 9282 kcal/kg gross, 8681 kcal/kg metabolizable and 7812 kcal/kg net; BTPS, 2017), 29% saturated fatty acids, 21% polyunsaturated fatty acid, and 47 % monounsaturated fatty acids (Kaur *et al.*, 2014). PF is obtained by pressing poultry offal meal via a fat press after processing slaughter by-products and non-edible organs using cookers at a high pressure (2.5 bar) and temperature (135 °C) in a rendering plant. PF yield varies

URL: http://www.sasas.co.za
ISSN 0375-1589 (print), ISSN 2221-4062 (online)
Publisher: South African Society for Animal Science
http://dx.doi.org/10.4314/sajas.v53i6.12

according to sex, energy level of diet, slaughter age, and body weight/average live weight (ALW) (Baiao, 2005); extra caloric effects are observed when fats are supplemented with PF (Swennen *et al.*, 2004).

Animal fats are being utilised as an energy source in poultry diets like vegetable oils (Tabeidian *et al.*, 2005). When using vegetable oils instead of animal fats in poultry diets, a higher metabolic energy (ME) value is obtained (Aardsma *et al.*, 2017). The digestibility of SO is higher than PF (Aardsma *et al.*, 2017). When the energy:protein of the diet is held static, the oil or fat type does not affect performance substantially (Pesti *et al.*, 2002) and similar results are obtained with different fats and oils (SO, PF, lard, palm oil, tallow, yellow grease, and vegetable and animal blend) (Firman *et al.*, 2008).

The use of oil or fat in poultry diets is required to be a minimum of 1%. However, when the cost is appropriate, 1% additional oil can be included and the use of higher levels of oil is recommended where appropriate. In the USA, fat is generally added at 1–3% in starter diets; inclusion rates of fat are higher in finishing diets with rates as high as 8–10% (Firman, 2006). PF is widely used in feed plants in the USA and many countries around the world. However, prohibitions and specific rules on the use of PF in poultry feeds have put these plants in a difficult position with the EU and EU candidate countries (EC, 2004a; 2004b; 2004c). Due to high production amounts, economic value, high nutrient content, and the high cost of alternative applications, by-products need to be reintroduced into the economy and production. Therefore, legal regulations that provide continuous improvement in production, use and sales conditions, according to current scientific developments, should be continued and the prohibitions that are currently in effect should be reviewed.

Use of SO in broiler diets causes greater weight gain and better FCR compared to birds fed poultry fat and tallow (Zhang *et al*., 2011). Similarly, Ghazalah *et al.* (2008) reported higher body weight (1812 g to 1720 g), improved FCR (2.19 to 2.39) and performance index (~12.5%) when the PF level in the diet increased from 0% to 5%. Shoaib *et al.* (2021) observed that PF caused lower feed intake (3134 g, 3304 g, and 3278 g), higher weight gain (1832 g, 1789 g, and 1741 g), and improved FCR (1.72, 1.84, and 1.88) than fish and palm oil.

In another broiler performance study using SO, PF, and their combination, no marked difference was found between weight gain, FC, FCR, and liveability values (Lara *et al.*, 2003). However, in other studies in which oil (canola) and fat (PF) were used alone or combination, it was reported that when PF was used at 3%, there was an increase in visceral weight (Shahryar *et al.*, 2011), and when 6% PF was used, there was an increase in abdominal fat and higher weight gain (2000 g to 1965 g) and better FCR (1.70 to 1.74) were produced by feeding broilers diets containing 3% canola oil and PF (Shahryar *et al.*, 2011). Humoral immune responses improved when vegetable and animal oils were used alone or mixed (Poorghasemi *et al.*, 2015; Khazaei *et al.*, 2017). In another study where the broilers were given either SO or PF in the same ratio, the best FCR was seen in the PF-fed birds (Azman et al., 2005). However, performance parameters did not change with the fixed energy:protein (Firman *et al.*, 2008). In a recent study on this subject, in which 25%, 0%, and 100% chicken was used instead of soybean oil, it was observed that no synergistic effect was observed, growth and carcass characteristics did not change, and the abdominal fat ratio increased when 50 and 100% oil was used (Saleh *et al.*, 2021).

The purpose of the present study and its most important difference to other studies was to examine whether PF could be used alone or in combination with SO to meet metabolic energy needs, provide an economical feed production, and increase the use of by-products in a real, field setting with 12000 broilers. Thus, by conducting a large-scale field study with the most widely-used line, breeding period and oil sources, it was aimed to provide a valuable, up-to-date, and realistic example for nutritionists to select the most suitable alternative for themselves, particularly when calculating their own feed costs.

Materials and Methods

This study was performed in accordance with the Animal Feed Legislation and The Animal Welfare Legislation in Turkey and no animals suffered in any of the applications. In order to better understand the materials and methods used in the experiment carried out within the scope of this study, segmentation was performed according to the basic materials and methods, and each section was designed within itself. The experiment was carried out at the following coordinates (40.724597, 31.704159).

The growing phase of this study was carried out in a broiler test house of a company located in Bolu, Turkey. There was a total of 60 ground pens in the house and each of the pens was 13.0 m^2 (6.5 m × 2.0 m) and equipped with a nipple drinker (SPARKcup, Roxell NV, Belgium), a pan feeder (MINIMAXline, Roxell NV, Belgium) and a ceramic radiant heater (Rd 3 FA, SBM Int., France). In addition, a digital scale connected to the central computer was set in each of the pens to track the ALW of the birds during the experiment.

Numerous concerns were taken into consideration during the study's design. To begin, the primary limiting factor was the number of replicates required and the number of compartments in the test plant in which the broilers would be reared. The growing period of the study was conducted in a test house with 60 compartments of 13 m², each capable of housing 200 broilers at normal stocking density. Under normal conditions, the minimum number of repetitions required was four, and if the number of repetitions was set to be four, 15 different treatments could be applied. However, the number of repetitions was determined as 15 in order to improve the reliability of the trial and to account for deviations that may arise due to field conditions. Additionally, the number of available treatments could have been increased by re-dividing the compartments in the test plant. However, considering the potential difficulties during growing, we preferred to work with 200 birds.

Ration formulations in this study were prepared by adding SO, PF, and their combinations at a fixed energy:protein. PF was produced by cooking the by-products (including blood, feathers, head, feet) in the poultry slaughterhouse of an integrated poultry company based in Bolu, cooking them in a batch-cooker at the rendering plant, pressing them in an oil press, and shipping them fresh to the feed plant. All processes in PF production, such as cooking, pressing, and loading are carried out in accordance with the regulations set for EU and EU candidate countries (EC, 2004a; 2004b; 2004c). SO was supplied from a commercial feed supplier.

The research, which is another issue in the aspects of feed costs, was motivated by the fact that integrated poultry businesses may want to prepare alternative feed formulas with their own fat sources, and therefore PF was included in the study. Since PF was obtained in integration, it is employed frequently enough to be used by integrations when necessary conditions are met.

One of the primary purposes of the research was to examine PF as a viable alternative that, in our opinion, would not alter field and slaughter performance. For this reason, diets were formulated on the basis of SO, and fat mixtures were not preferred in the initial period; dietary formulas containing only one type of fat were preferred.

Two oils (SO and PF) and a combination of the two oils (SO+PF) were used in this study. In terms of feed, three different feeding stages (starter, grower, and finisher/pre-slaughter) were used, with a total of 15 repetitions for the reasons briefly explained above. As a result, the study was composed of four treatment groups, all of which were designed to use fat and oil types (Table 1).

Table 1 Trial design and treatment groups of the experiment on the effects of poultry fat with soy oil at fixed energy:protein on broiler field performance.

Treatment Group Code	**Feed Type and Fat Source in Feed***		
	Starter	Grower	Finisher & Pre-Slaughter
SO + (SO)	SO*	SO	SO
SO + (SO+PF)	SO	SO	SO+PF
PF + (SO)	SO	PF*	SO
PF + (SO+PF)	SO	PF	SO+PF

* SO: Soy oil; PF: Poultry fat

The diets were formulated with corn–soya and produced in the feed mill of the same company located in Bolu. SO and PF were added to the basal diet based on the trial design with fixed energy:protein. The diets were formulated in accordance with international standards (NRC, 1994) and the recommendations of grandparent company Ross (2.0–2.5 kg ALW) (Aviagen, 2018) were taken into consideration for the trial design. The feeds were produced in four phases: starter, grower, finisher, and pre-slaughter. The starter feeds were manufactured to be in "crumble" form, whereas the other feeds were manufactured in pellet form (3.5 mm in diameter). The raw material compositions of the prepared diets are given in Table 2.

Table 2 Raw material composition of the feeds used in the experiment on the effects of poultry fat with soy oil of fixed energy:protein on broiler field performance

	Starter[1]	Grower[2]		Finisher[3]		Pre-Slaughter[3]	
Oil / Fat Source	SO*	SO	PF*	SO	SO+PF	SO*	SO+PF
Soy Oil (SO)	8.00	17.00	10.00	30.00	15.00	30.00	15.00
Poultry Fat (PF)	0.00	0.00	10.00	0.00	18.00	0.00	18.00
Anticoccidial[4]	0.50	0.50	0.50	0.00	0.00	0.00	0.00
Anticoccidial[5]	0.00	0.00	0.00	0.50	0.50	0.00	0.00
Bonkalite	13.00	13.00	13.00	13.00	13.00	13.00	13.00
Broiler Starter Vitamin	1.00	0.00	0.00	0.00	0.00	0.00	0.00
Broiler Chick Vitamin	0.00	1.00	1.00	0.00	0.00	0.00	0.00
Broiler Vitamin	0.00	0.00	0.00	1.00	1.00	1.00	1.00
Choline Chloride[6]	0.38	0.31	0.31	0.20	0.20	0.20	0.20
Corn	448.14	499.80	498.58	516.14	510.28	516.64	510.78
DCP-18[7]	8.96	6.16	6.16	4.60	4.60	4.60	4.60
Full Fat Soybean Meal	162.58	161.41	153.85	140.94	147.98	140.94	147.98
Corn Gluten-60	35.00	20.00	20.00	16.00	16.00	16.00	16.00
Lysine[8]	3.18	2.80	2.80	1.70	1.70	1.70	1.70
Marble Powder	10.60	8.80	8.80	8.16	8.16	8.16	8.16
MDCP[7]	4.40	3.10	3.10	2.20	2.20	2.20	2.20
Methionine-88[9]	1.50	1.00	1.00	0.90	0.90	0.90	0.90
Methionine-99[10]	1.56	1.42	1.42	1.06	1.06	1.06	1.06
Feed Additive[11]	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Phytase Enzyme[12]	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Poultry Offal Meal	20.00	45.00	45.00	60.00	60.00	60.00	60.00
P Trace Minerals	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Probiotic[13]	1.00	0.00	0.00	0.00	0.00	0.00	0.00
Salt	2.30	2.10	2.10	2.00	2.00	2.00	2.00
Sodium Bi carbonate	2.00	1.60	1.60	1.40	1.40	1.40	1.40
Soybean Meal-48	199.30	123.40	129.18	98.60	94.42	98.60	94.42
Wheat	40.00	45.00	45.00	50.00	50.00	50.00	50.00
Total	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00

* SO: Soy oil; PF: Poultry fat

[1] Supplied per kg diet: Vit A 13000 IU; Vit D3 5000 IU; Vit E 100 mg; Vit B1 3 mg; Vit B2 8 mg; biotin 0.2 mg; Vit B6 5 mg; Vit B12 0.016 mg; Vit K3 4 mg; niacin 70 mg; folic acid 2 mg; Ca pantothenate 20 mg; Mn 120 mg; Zn 100 mg; Se 0.3 mg; Cu 16 mg; Fe 50 mg; I 2 mg and antioxidant 125 mg

[2] Supplied per kg diet: Vit A 11000 IU; Vit D3 5000 IU; Vit E 80 mg; Vit B1 2 mg; Vit B2 6 mg; biotin 0.2 mg; Vit B6 4 mg; Vit B12 0.016 mg; Vit K3 3 mg; niacin 70 mg; folic acid 1.75 mg; Ca pantothenate 20 mg; Mn 120 mg; Zn 100 mg; Se 0.3 mg; Cu 16 mg; Fe 50 mg; I 2 mg and antioxidant 125 mg

[3] Supplied per kg diet: Vit A 11000 IU; Vit D3 4000 IU; Vit E 80 mg; Vit B1 2 mg; Vit B2 5 mg; biotin 0.05 mg; Vit B6 3 mg; Vit B12 0.012 mg; Vit K3 2 mg; niacin 40 mg; folic acid 1.5 mg; Ca pantothenate 20 mg; Mn 120 mg; Zn 100 mg; Se 0.3 mg; Cu 16 mg; Fe 50 mg; I 2 mg and antioxidant 125 mg

[4] Maxiban. Anticoccidial (Lily Ilac. Istanbul, Türkiye)

[5] Monensin. Aanticoccidial (Lily Ilac. Istanbul, Türkiye)

[6] Liquid Choline Chloride. Choline-75 (Trouw Nutrition, Turkey, Ankara, Türkiye)

[7] DCP-18 and MDCP (Rotem Turkey, Istanbul, Türkiye)

[8] Lysine-99. Lysine HCL 99 (Rotem Turkey, Istanbul, Türkiye)

[9] Dry Methionine. DL Methionine Feed Grade; (Evonik Turkey, Istanbul, Türkiye)

[10] Liquid Methionine. Alimet; (Novus Turkey, Istanbul, Türkiye)

[11] Organic acid + Essential Oil. Galliacid (Nutriline Feed and Food Additives L.L.C. Istanbul, Türkiye)

[12] Phytase enzyme. Phyzyme (Nutriline Feed and Food Additives L.L.C. Istanbul, Türkiye)

[13] Probiotic. Diazyme W/S (Cuprem Inc., Nebraska, USA).

The prepared basal feeds were analysed using the methods of the AOAC (1990), the specifications of which are given in Table 3.

Table 3 Feed (starter, grower, finisher, and pre-slaughter) specifications in the experiment on the effects of poultry fat with soy oil at fixed energy:protein on broiler field performance

	Starter	Grower	Finisher & Pre-Slaughter
Metabolizable Energy, kcal/kg	3025.00	3175.00	3250.00
Dry Matter, %	89.60	89.59	91.37
Crude Protein, %	22.37	21.43	20.44
Crude Fat, %	6.64	8.04	9.75
Crude Ash, %	6.98	5.18	4.38
Crude Cellulose, %	3.14	3.14	2.64
Starch, %	38.04	39.95	41.30
Sugar, %	3.16	3.54	3.21
Calcium, %	1.02	0.92	0.87
Phosphor, %	0.78	0.71	0.66
Available Phosphor, %	0.51	0.46	0.43
Sodium, %	0.17	0.17	0.17
Chlorine, %	0.19	0.19	0.19
Methionine, %	0.54	0.53	0.43
Methionine + Cysteine, %	0.96	0.91	0.81
Lysine, %	1.40	1.27	1.07
Choline, %	1.81	1.62	1.41
Linoleic Acid, %	3.54	4.44	4.77

A total of 12000 broiler chicks obtained from middle-aged (35 w-old) Ross 308 broiler breeders were used in the present study. The chicks used in the study were sexed, vaccinated, and transferred to the test house. They were then weighed using a scale (EC-130, Bizerba SE/Co. KG, Germany) and randomly distributed to the 60 pens as 200 chicks per pen (stocking density was 15.38 chicks/m^2) with each subgroup consisting of 50% male + 50% female. A total of 15 replications were used per treatment during the rearing period. The broilers were fed in four phases as starter, grower, finisher, and pre-slaughter, between 0–11, 12–23, 24–36, and 37–41 d of rearing, respectively. Feed and water were given *ad libitum* during the experiment.

The CWs were determined at the beginning of the experiment during chick acceptance, and the ADWG and ALW of the broilers were determined for each subgroup at the conclusion of the experiment prior to loading.

$$ADWG = \frac{\text{Average Live Weight (kg)}}{\text{Slaughter Age (day)}} \quad (1)$$

The feed consumption of the subgroups was determined by weighing the feed at the beginning and the feed left in the feeders at the end of the rearing period. The FCR values were determined using Equation 2 (Aviagen, 2018):

$$FCR = \frac{\text{Total Feed Consumption (kg)}}{\text{Total Live Weight (kg)}} \quad (2)$$

The number of chicks that died on a daily basis in the subgroups was recorded and the liveability rates were calculated for the trial period. Production Efficiency Factor (PEF) values were calculated by using liveability, total live weight, age, and FCR (Aviagen, 2018):

$$PEF = \frac{\text{Liveability,\% x Total Live Weight (kg)}}{\text{Age (days) x FCR}}\ x\ 100 \quad (3)$$

The statistical analyses were performed using IBM SPSS Statistics 22 (SPSS, 2013). The Shapiro–Wilk test was used to confirm the normal distribution of the data. After this process, an analysis of variance (ANOVA) was carried out for the experiment using the GLM procedure of SPSS appropriate for one-way design. The one-way ANOVA model as follows:

$$Y_{ij} = \mu + F_i + e_{ij} \quad (4)$$

Where Y_{ij} is the dependent variable, μ is the overall mean, F_i is the effect of fat sources ($_i$ = SO+(SO), SO+(SO+PF), PF+(SO) or PF+(SO+PF) in the experiment), and e_{ij} is the random error term. The Tukey test was used to analyse the differences in the investigated parameters. *P*-values less than 0.05 were considered statistically significant.

Results and Discussion

In the present study, the effects of the use of PF alone or combined with SO, as an alternative to SO, in broiler grower and finisher diets on field performance were investigated. CW, ADWG, ALW, FC, FCR, PEF, and liveability were determined as field performance parameters. The evaluation of the data obtained as a result of the experiment was conducted separately (Table 4 and 5).

The chick weights (CW) of the treatment groups (SO+(SO), SO+(SO+PF), PF+(SO) and PF+(SO+PF)) were 40.6 ± 0.1 g (CV_{CW} = 1.21), 40.6 ± 0.1 g (CV_{CW} = 1.04), 40.6 ± 0.1 g (CV_{CW} = 1.07), and 40.8 ± 0.1 g (CV_{CW} = 0.88), respectively (Table 4). The uniformity of the chicks used in the research was high, and the measured CWs were found to be slightly lighter (40.7 < 43.0 g) than Aviagen specifications (Aviagen, 2019). The differences between CW values of the treatment groups were similar (P >0.05).

Table 4 The effects of using soy oil and poultry fat in feeds at fixed energy:protein on the field performance parameters of broilers (M ± SEM)[1]

	CW[1], g	ALW[1], g	ADWG, g[1]	FCR[1]	PEF[1]	Liveability, %
Fat / Oil Source in feeds[2]						
Grower + (Finisher & Pre-slaughter)						
SO+(SO)	40.6 ± 0.1	2326 ± 14	56.7 ± 0.3	1.819 ± 0.010[b]	301.63 ± 4.12[a]	96.62 ± 0.50
SO+(SO+PF)	40.6 ± 0.1	2344 ± 19[a]	57.7 ± 0.5	1.803 ± 0.011[b]	305.23 ± 4.41[a]	96.17 ± 0.26
PF+(SO)	40.6 ± 0.1	2315 ± 12	56.4 ± 0.3	1.827 ± 0.005[ab]	298.75 ± 2.39[ab]	96.66 ± 0.45
PF+(SO+PF)	40.8 ± 0.1	2293 ± 23[b]	56.4 ± 0.6	1.850 ± 0.012[a]	290.03 ± 4.50[b]	95.87 ± 0.73
***P*-value**	0.757	0.044	0.124	0.011	0.044	0.653

[1] CW: Chick weight; ADWG: Average daily weight gain; ALW: Average live weight; FCR: Feed conversion ratio; PEF: Production efficiency factor
[2] SO: Soy oil; PF: Poultry fat
[a,b] Row means with different superscripts differ significantly at P <0.05

The results indicated that chicks were evenly distributed among the treatments at the beginning of the experiment and that the initial CWs had no effect on subsequent performance, which is consistent with what was predicted (Table 4). The FC values of the broilers improved when they were fed SO instead of PF in feeds. This was especially evident in the groups fed SO+PF as a finisher diet. The FC values of the SO+(SO) and SO+(SO+PF) groups were better than those of the PF+(SO+PF) group (P <0.05). This is thought to be due to the inclusion of SO in grower diets and the synergistic effect of using a combination of PF and SO in grower diets (Table 4).

The feed consumption (FC) values of the treatment groups were lower than the specifications, particularly for finisher, pre-slaughter, and the whole period (starter 357 g, grower 1112 g, finisher 2212 g, pre-slaughter 793 g, and total 4774 g) (Aviagen, 2019). These data contradict those of Azman *et al.* (2005), who found that FC decreased when PF was used instead of SO, and that of Lara *et al.* (2003), who found the FC values were similar. This is thought to have occurred as a result of ME values. The digestibility of SO was found to be higher than PF, as Aardsma *et al.* (2017) suggested.

Table 5 The effects of adding soy oil and poultry fat to feeds at a fixed energy:protein on the feed consumption of broilers (M ± SEM)[1]

	Feed Consumption, g/broiler				
	Starter, 0–11 d	**Grower 12–23 d**	**Finisher 24–36 d**	**Pre-Slaughter 37–41 d**	**Total**
Fat / Oil Source in feeds[1] Grower + (Finisher & Pre-slaughter)					
SO+(SO)	423 ± 2	1026 ± 3	2001 ± 10	666 ± 10	4116 ± 15
SO+(SO+PF)	425± 1	1032 ± 4	2023 ± 14	661 ± 16	4141 ± 27
PF+(SO)	424 ± 1	1023 ± 2	1999 ± 9	674 ± 7	4120 ± 15
PF+(SO+PF)	419 ± 6	1026 ± 4	2001 ± 11	670 ± 14	4117 ± 23
***P*-value**	0.516	0.279	0.373	0.878	0.804

[1] SO: Soy oil; PF: Poultry fat
[a,b] Row means with different superscripts differ significantly at *P* <0.05

Broilers that were given SO in their feeds tended to increase ALW (Table 4). This situation was more evident in the groups that were given SO+PF for finisher diets, and, affected by this, the difference between SO+(SO+PF) and PF+(SO+PF) was found to be statistically significant (*P* <0.05). This is thought to be due to high digestibility of SO (Aardsma *et al.*, 2017) and the extra caloric effect caused by the combined use of SO and PF, as suggested by Swennen *et al.* (2004). The results of the present study were not compatible with the broiler results of some researchers (Infante-Rodriguez *et al.*, 2016; Rodriguez-Sanchez *et al.*, 2018; Saleh *et al*., 2021), where ALW values did not change when PF was used instead of SO. Scaifa *et al.* (1994) and Azman *et al*. (2005) reported an increase in ALW when PF was used instead of SO. This is consistent with the researchers reporting higher values when using SO (Zhang *et al*., 2011). This is thought to have been caused by ME values; digestibility of SO was higher than PF (Aardsma *et al*., 2017).

The average daily weight gain (ADWG) values of the treatment groups in this study (SO+(SO), SO+(SO+PF), PF+(SO) and PF+(SO+PF)) were 56.7 ± 0.3 g, 57.7 ± 0.5 g, 56.4 ± 0.3 g, and 56.4 ± 0.6 g, respectively (Table 4). The average daily weight gain (ADWG) values of the treatment groups were lower than the Aviagen specifications (Aviagen, 2019) and were similar (*P* >0.05). As Svihus *et al*. (2010) reported, these results can be caused by genetic improvements in broilers, modifications to dietary composition, and *ad libitum* feeding, which can lead to the inefficient use of the crop for lipid digestion and the rapid transfer of feed to the proventriculus.

The FCR values of the broilers improved when they were given SO instead of PF in feeds (Table 4). This was more evident in the groups that were given SO+PF in the finisher diet. The FCR values of the SO+(SO) and SO+(SO+PF) groups were better than those of the PF+(SO+PF) group (*P* <0.05). These results did not support the data from the studies of Azman *et al.* (2005), who reported that FCR decreased when PF was used instead of SO; Lara *et al.* (2003) and Saleh *et al.* (2021) found FCR to be similar. However, the results are consistent with a study that reports higher performance when using SO instead of PF (Zhang *et al*., 2011). This is thought to be due to use of SO in grower diets and the extra caloric effect caused by the combined use of PF and SO in the grower diets and the higher energy values and digestibility of SO over PF (Polycarpo *et al*., 2014; Aardsma *et al*., 2017).

PEF values tended to increase when broilers were fed SO instead of PF (Table 4). This was more evident in the group where SO+PF was used in the diets. The PEF values of the SO+(SO) and SO+(SO+PF) groups were higher than those of the PF+(SO+PF) group (*P* <0.05). Our research results were not consistent with the results of Ghazalah *et al.* (2008) and Saleh *et al.* (2021). This is thought to have been caused by the lower digestibility of PF and the ME values.

A decreasing tendency in the SO groups and an increasing tendency in the SO+PF groups were seen when the liveability values were evaluated (Table 4; Figure 1). This was more evident in groups where PF was used in the grower diet, but treatment responses were similar (*P* >0.05). The results were consistent with those of Lara *et al.* (2003), who found that performance did not change according to the fat source. This was thought to have been caused by fixed energy:protein, as was also suggested by the researchers.

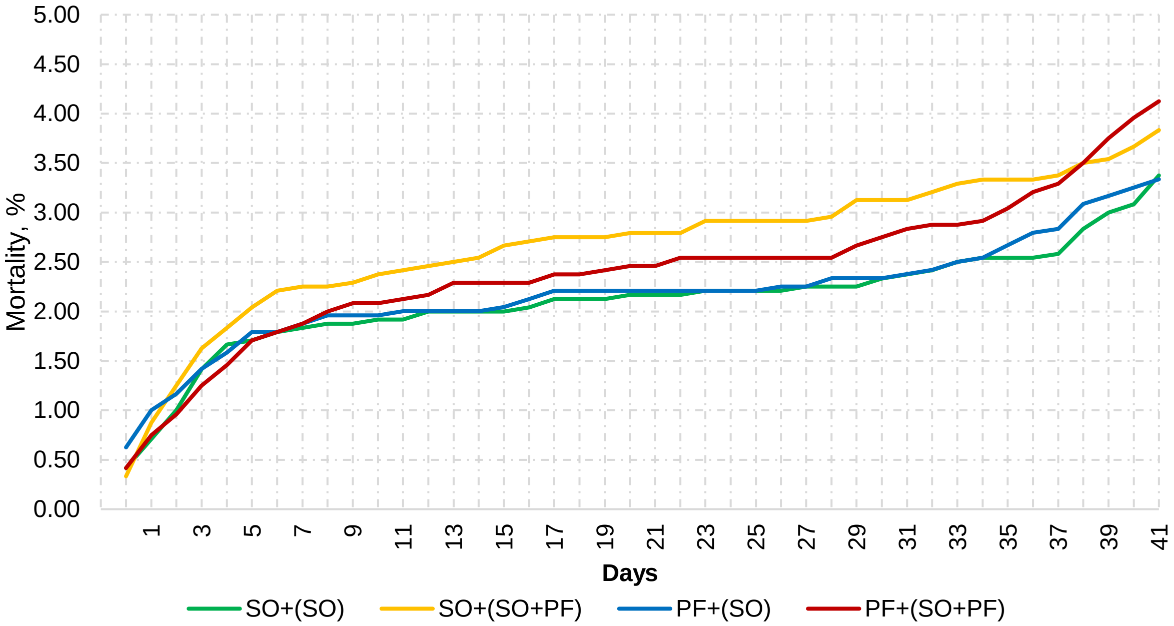

Figure 1 The effects of adding soy oil and poultry fat to feeds at a fixed energy:protein on broiler mortality

Conclusion

An improvement in field performance parameters (except for liveability) was observed when SO was used instead of PF in feeds with a fixed energy:protein. This situation was more evident where SO was used in grower diets and SO+PF was used in finisher diets. Thus, the difference between these groups was substantial for the performance parameters, except for ADWG and liveability.

Some of the discrepancies between the results in the current study and previous studies on this subject are due to differences in slaughter age, growing time, and broiler line. That some of the results of this research are different from other recent studies is due to the fact that it is a high-capacity, real field study.

The results indicate that PF can be used at up to 1.0% in grower feeds; up to 1.8% in finisher and pre-slaughter feeds, there was no reduction in feed consumption. Half of the SO requirement can be met with PF. There may be a slight decrease in survival rate as a result of using PF, but this is not at a statistically significant level; a decrease in performance values (depending on the deteriorated FCR) may occur when PF is used during the growing period.

In conclusion, PF combined with SO can be used in finisher feed to meet metabolic energy needs, providing a more economical feed and overall better production. Using by-products should be increased especially when vegetable oil prices are high.

Acknowledgements

The author would like to thank Dr. Sait Koca, General Manager of Beypiliç, and his colleagues for their support during the experiment.

Conflict of Interest Declaration

The author declares that he is not in a position of conflicting interest.

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