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PAPER

Inclusion of full-fat safflower seed (*Carthamus tinctorius L.*) in broiler diet

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Abstract

This study was conducted to evaluate the use of various levels of full-fat safflower seed (FFSS) on performance and carcass characteristics of broiler chickens from Arbor Acres strain. Diets containing various levels of FFSS (0, 5, 10, 15 and 20%) were given to broilers from 21 to 42 day of age. Before experiment beginning, starter feed was given to chicks for 3 weeks. Then, three hundred fifty 21-day-old broiler chickens were weighted and distributed randomly to 5 treatments with 5 replicates (14 chicks in each replicate) in each treatment. Water and feed were provided *ad libitum*. Blood parameters and carcass characteristics were determined at 42 days of age. FFSS levels did not significantly affect weight gain, feed intake and feed conversion ratio (FCR). Breast yield, thighs, empty gastrointestinal tract, liver and gizzard weight percentages were not affected by dietary treatments, but abdominal fat pad percentage did not significantly decrease. Triglyceride and total serum protein concentrations were not affected by FFSS levels, but cholesterol concentration was significantly decreased ($P<0.05$). The results of the current study indicated that FFSS could be used up to 20% of broiler diets without any adverse effects on performance or other parameters of chickens.

Introduction

Safflower (*Carthamus tinctorius L.*) is a member of the family *Compositae* or *Asteraceae*. It is an annual herbaceous plant, cultivated mainly for its seed, which is used as edible oil and as bird seed (Dajue and Mündel, 1996). Oilseeds are one of the best and common energy sources in poultry nutrition (Pinchasov and Nir, 1992; Scott *et al*., 1998; Sanz *et al*., 1999a). Also, oilseeds are a practical and economical means to increase energy levels in poultry diets (Latour *et al*., 1994; Peebles *et al*., 1997). Current trends toward formulating high-energy diets for broiler chickens make it necessary the inclusion of fats and oils up to 10% in broiler feeds. Fats and oils are rich sources of energy, containing 39.29 MJ/kg gross energy, but are more costly on a weight basis and may contain impurities (Blair and Potter, 1988). As an alternative to fats and oils, full-fat oilseeds (Ajuyah *et al*., 1993) such as soybean seed, are used to replace the supplemented fats and oils in broiler diets. However, soybean seed has anti-nutritional factors such as trypsin inhibitors, which need further processing, thus increasing the cost of soybean seed.

Among the various oilseeds available on the market, full-fat safflower seed (FFSS) contains more ether extract (EE) and is available at a relatively low price. This high EE content contributes to a high metabolic energy (ME) per unit or high energy density of feed. Several studies were carried out to evaluate the use of unextracted whole seed as a feed ingredient in pig and poultry diets, without negative effects on digestion or on meat quality (Oguz and Oguz, 2007; Williams and Danils, 1973). FFSS is a source of magnesium, lysine, pyridoxine, biotin, panthothenic acid and choline (Oguz and Oguz, 2007). FFSS contains about 15-19% crude protein, 28-35% ether extract, 15-19% crude fibre, 30-32% acid detergent fibre (ADF) and 40-45% neutral detergent fibre (NDF) (Hill and Knowles, 1968; Weiss, 1983). This difference may be due to genetic, varietal, soil and climatic conditions as suggested by Vaughan (1970). Safflower oil is rich in linoleic acid (75-78%), which plays an important role in reducing blood cholesterol level (Oguz and Oguz, 2007).

Also, FFSS is a source of dietary monounsaturated fatty acids (MUFA), and inclusion of it in monogastric diets can be particularly valuable to increase the degree of unsaturation of intramuscular fat, without the negative effect of lipid oxidation associated with dietary polyunsaturated fatty acids (PUFA) (Smith, 1996). In human, there is increasing evidence that dietary monounsaturated fatty acid enrichment has a positive effect on cardiovascular health, decreasing low-density lipoprotein cholesterol but not high-density lipoprotein cholesterol in blood plasma, and decreasing the susceptibility of low-density lipoprotein to oxidation (Grundy, 1986; Roche, 2001). The objective of this experiment was to study the effect of various levels of FFSS (0%, 5%, 10%, 15% and 20% diet) on performance, blood parameters and carcass characteristics of broiler chickens.

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Materials and methods

This experiment was carried out at the experimental farm of the University of Zanjan, Iran. Samples of FFSS were analyzed for dry matter, crude protein (N×6.25), crude fibre and ash following the AOAC procedures (1999), as reported in Table 1.

From hatching to 20 days of age, all birds were fed a starter (Table 2), followed by the experimental diets. Five experimental isoenergetic (ME) and isonitrogenous diets were formulated to contain 0%, 5%, 10%, 15% and 20% of FFSS (Table 2). The diets were formulated to meet the nutritional requirements of broiler chicks recommended by National Research Council (1994). Three hundred fifty 21-days-old male chicks (Arbor Acres strain) were weighed and distributed randomly into 5 treatments with 5 replicates (14 chicks in each replicate) in each treatment (1.5×1 m experimental pen). The animals were housed in pen, water and feed were provided *ad libitum*. The temperature was controlled and gradually reduced from 32°C for the first 5 d of life to 20°C on d 40. The lighting cycle was 24 h/d from day 1 to 3, 18 h/d from day 4 to 20, 21 h/d from day 21 to 35 and 23 h/d from day 36 to 42. At the end of the experiment (42 days of age), 5 birds per treatment (one from each replicate) were randomly selected and slaughtered by cervical dislocation and blood was collected

Table 1. Determined analysis of full-fat safflower seed (on dry matter basis except dry matter).

Components	Value
Dry matter, %	94.4
Crude protein, %	17.9
Ether extract, %	32.8
Crude fibre, %	16.4
Ash, %	2
Calcium, %	0.34
Available phosphours, %	0.84
Lysine, %	2.3
Methionine, %	0.65
Metabolizable energy, MJ/kg	14.42

Table 2. Ingredients (%), chemical composition (% DM except dry matter) and energetic value (MJ kg-1) of the basal and experimental diets.

	Starter (0-21 d)	Level of FFSS, %				
		0	5	10	15	20
Ingredients						
Maize	56.19	66.63	62.61	57.89	53.96	49.60
Soybean meal	33.96	26.74	26.12	25.95	24.98	24.41
FFSS	-	-	5.00	10.00	15.00	20.00
Soybean oil	3.00	1.20	1.00	1.00	1.00	1.00
Fish meal	3.00	2.00	2.00	2.00	2.00	2.00
Salt	0.30	0.30	0.30	0.30	0.30	0.30
Limestone	1.28	1.40	1.38	1.36	1.34	1.32
Dicalcium phosphate	1.38	0.96	0.91	0.86	0.82	0.77
Vitamine premix*	0.25	0.25	0.25	0.25	0.25	0.25
Mineral premix°	0.25	0.25	0.25	0.25	0.25	0.25
L-Lysine	0.09	0.08	0.04	0.04	-	-
DL-Methionine	0.20	0.09	0.04	-	-	-
Vitamin E	0.10	0.10	0.10	0.10	0.10	0.10
Chemical composition						
Dry matter, %	89.8	89.31	89.87	89.88	90.16	90.45
Crude protein	21.30	18.75	18.75	18.75	18.75	18.75
Crude fibre	3.63	3.36	4.04	4.72	5.39	6.06
Ether extract	5.48	4.04	5.26	6.73	8.22	9.68
Lysine[#]	1.10	1.24	1.20	1.17	1.16	1.12
Methionine[#]	0.57	0.52	0.53	0.54	0.54	0.54
Calcium[#]	1.01	1.04	1.05	1.07	1.08	1.09
Available P[#]	0.45	0.46	0.44	0.48	0.48	0.49
Metabolizable energy, MJ/kg[#]	12.54	12.54	12.54	12.54	12.54	12.54

*Supplied per kilogram: Vitamin A 8000 U; Vitamin D3 8560 U; Vitamin E 95 U; Vitamin B12 4.5 mg; Biotin 0.2 mg; Niacin 50 mg; Panthotenic acid 15 mg; Pyrodoxin 4 mg; Riboflavin 10 mg; Thiamin 3 mg; °Supplied per kilogram: Copper (Cupric sulfate pentahydrate) 7 mg; Iodine (Calcium iodate) 1 mg; Iron (Ferrous sulfate monohydrate) 50 mg; Manganese (Manganese sulfate monohydrate) 100 mg; Selenium (Sodium selenite) 0.15 mg; Zinc (Zinc sulfate monohydrate) 75 mg.
[#]Calculated using NRC (1994) and analytical Chemists values in Zanjan University.

by heart puncture. Serum was separated and analyzed to determine cholesterol (Zlatkis *et al*., 1953), triglycerides (Fossati and Prencipe, 1982), and total serum protein (Doumas *et al*., 1997) concentrations. At same time, one bird from each replicate (representative in terms of average weight of each group) was selected and slaughtered to measure the weight of thighs, breast, gastrointestinal tract, liver, abdominal fat and gizzard.

Statistical analysis

The experimental design was completely randomized (CRD), with 5 treatments and 5 replicates in each treatment. Data of this experiment were subjected to analysis of variance using GLM procedures (SAS institute, 2001). When significant differences were detected, means were compared by the Duncan's multiple range tests at 5% probability (Duncan, 1955).

Results and discussion

Performance parameters

Table 3 shows the effects of different levels of FFSS on performance parameters of broiler chickens. In the current study, the feed intake, the weight gain and the FCR were not significantly affected (P>0.05) by the FFSS levels when compare to the control group. In the whole period, the highest and the lowest numerically feed intake were observed in 5% FFSS and in the control group (143.2 vs. 136.7 g/bird/day) respectively. These results are in accordance with those obtained by Raj *et al*. (1983) and Oguz and Oguz (2007), but they are in contrast to the study of Rehman and Malik (1986).

The highest and the lowest body weight gain was observed in 5% FFSS (g/bird/day) and 20% FFSS (70.73 vs. 66.99 g/bird/day). It might be due to the higher fibre content of the 20% FFSS diet, which could have consequently decreased the density of the diet. This result is in agreement with Oguz and Oguz (2007), who showed that the average body weight gain was not significantly affected in broiler chickens fed 0%, 10% and 20% FFSS diets. These results were in contrast to those reported by Rehman and Malik (1986) and Mohan *et al*. (1984), who reported that average body weight gain was significantly reduced in chickens fed diets containing 23%, 35% and 48 % safflower meal.

The feed conversion ratio determined during the experiment (for 3 weeks) was better for 10% FFSS (2.00) and the highest value was observed in 20% FFSS (2.07). This effect might be due to the highest crude fibre in 20% FFSS diet. These results are in contrast to those found by Oguz and Oguz (2007), because they showed FCR determined during the experiment (for 4 weeks) was improved in 20% FFSS broiler chickens diet. These results are in contrast with Arija *et al*. (1998), who showed that performance parameters were reduced when FFSS was added to the diets. Rodriguez *et al*. (1998) reported not significant differences in weight gain, feed intake and feed utilization among the chicks receiving control diet and those fed diets with increasing level of FFSS (from 5-25% of diet). Daghir *et al*. (1980) observed that feeding 15 and 25% FFSS to broilers depressed both body weight gain and feed intake. However, Elangovan *et al*. (2000) showed that live weight gain, feed intake, nutrient retention and carcass characteristics of quails did not show significant differences (P>0.05), when FFSS meal increased in the diets. Selvaraj *et al*. (2004) used various levels of FFSS (0%, 5%, 10%, 15% and 20%) and reported that weight gain and feed consumption were not affected by the FFSS inclusion.

Physiological effects

The results relative to the weight of the different carcass parts to live body weight are shown in Table 4. The relative weight of the breast yield, thighs, gastrointestinal tract, liver, gizzard and abdominal fat pad were not affected by dietary FFSS levels. However, the relative weight of liver was not significantly decreased in birds fed diets containing FFSS in comparison to those fed the control diet. Similarly, Cheva-Isarakul and Tangtaweewipat

Table 3. Effect of full-fat safflower seed on performance parameters of broiler.

FFSS, %	eed intake, g/bird/d				Weight gain, g/bird/d					Feed conversion ratio			
	21-28	28-35	35-42	21-42	21-28	28-35	35-42	21-42	0-42	21-28	28-35	35-42	21-42
0	114.0^{b}	128.6	167.6	136.7	56.0	62.7	86.2^{ab}	68.3	2031	2.05	2.05	1.94^{ab}	2.01
5	123.6^{a}	131.1	174.9	143.2	57.2	64.1	90.9^{a}	70.7	2094	2.18	2.05	1.92^{b}	2.02
10	116.8^{ab}	124.4	169.3	136.9	56.9	59.1	88.7^{ab}	68.2	2039	2.05	2.10	1.90^{b}	2.00
15	120. 8^{ab}	130.3	165. 6	138.9	58.4	65.1	81.7^{b}	68.0	2043	2.07	2.01	2.05^{a}	2.03
20	119.1^{ab}	128.8	169.2	139.1	53.7	62.0	85.2^{ab}	67.0	2007	2.22	2.08	1.98^{a}	2.07
SEM	2.49	2.52	4.11	2.58	1.68	2.21	2.68	1.50	36.1	0.09	0.05	0.04	0.03

^{a,b}within the same column, means with different letters are significantly different (P<0.05).

(1991) reported that liver percentage decreased by adding FFSS to the diets. This might be due to the nature of fat in FFSS, which is composed mainly of unsaturated fatty acids, particularly linoleic acid, and this fatty acid could have prevented fat accumulation in the liver. This suspected effect of linoleic acid supports the results of Donaldson and Gordon (1960) and Menge (1967) in laying hens, and of Morton and Homer (1961) in rats. In the current experiment, the lower abdominal fat pad and the larger breast muscle showed that the levels of FFSS were increased, but these effects were not significant. Sanz *et al*. (1999a) reported that fed broiler chickens with sunflower oil or a mixture of beef tallow/lard and utilization of saturated fats resulted in greater abdominal fat deposits than when unsaturated fats were used. Several studies reported that feeding polyunsaturated fatty acids to broiler chickens results in reduced abdominal and total carcass fat as compared to that in birds fed saturated fatty acid sources (Sanz *et al*., 1999b, 2000; Crespo and Garcia, 2000b; Newman, 2002). This effect is in accordance with the results of Tang *et al*. (2007). Thus the reduction in abdominal fat pad for the broilers fed FFSS diets presumably reflects a lower total body fat content, and may demonstrate the importance of fatty acids in modulating body fat. In addition, the lower fat pad in chickens consuming FFSS was associated with an increase in lipid oxidation (Newman *et al*., 2002). This finding is consistent with the results showing preferential mobilization and/or oxidation of more unsaturated lipids (Halminski *et al*., 1991; Raclot and Groscolas, 1993).

The effects of various levels of FFSS on blood parameters of broiler chicks were shown in the Table 5. The plasma triglyceride concentration tended to be lower in the birds fed higher levels of FFSS, but this effect was not significantly different (P>0.05). This result is in agreement with the findings of several authors (Shafey *et al*., (2003), Newman *et al*., (2002), Sanz *et al*., (2000), An *et al*., (1997), Naber and Biggert, (1989). The lower values of triglycerides found in the chickens fed the highest level of FFSS in their diets may also be a response to the action of specific fatty acids to stimulate enzymes of the β-oxidative pathway. Furthermore, the use of sunflower oil stimulates the activity of both carnitine palmitoyltransferase-1 and S-3-hydroxyacyl-CoA dehydrogenase in chickens (Sanz *et al*., 2000). Thus, an increase in carnitine palmitoyltransferase-1 activity would render fatty acids more available for β-oxidation. Total cholesterol concentration was significantly different between the control treatment group and that of the diet enriched with 20% FFSS. A similar trend was observed in the study of Rama Rao *et al*. (2004), where the serum concentrations of cholesterol decreased in birds receiving high-fibre diets. An *et al*. (1997) reported dietary safflower phospholipids may be a valuable ingredient to layers for reducing serum cholesterol without any adverse effects. Also in rats, Moon *et al*. (2001) and Cho *et al*. (2004) reported the use of diets including FFSS reduced serum cholesterol. These results are in contrast with those of Oguz and Oguz (2007), in which the serum total cholesterol was not affected when 0%, 10% and 20% of FFSS in the diet of broiler chickens was included. Also Selvaraj *et al*. (2004), reported no significant effect on serum parameters of poultry fed diets characterized by the inclusion of different levels of FFSS. In accordance with Oguz and Oguz (2007), the serum total protein was not significantly affected by the different level of FFSS.

Table 4. Effect of different levels of full-fat safflower seed inclusion on weight of some organs determined at 42 days of age (% of live body weight).

FFSS, %	Breast	Thigh	Gastrointestinal tract	Liver	Gizzard	Abdominal fat
0	20.03	10.04	13.01	2.31	2.11	2.42
5	21.54	10.71	15.47	2.20	2.04	1.98
10	21.08	10.22	13.63	2.25	2.23	2.15
15	20.10	10.54	13.96	2.12	2.34	2.26
20	21.06	10.69	12.72	2.19	2.47	2.34
SEM	0.71	0.54	0.72	0.11	0.13	0.16

Table 5. Effect of increasing levels FFSS on blood parameters of broiler chickens in 42 days of age.

FFSS, %	Triglycerides, mg/dL	Cholesterol, mg/dL	Total protein, g/dL
0	116.6	121.0^{a}	3.39
5	116.6	114.6^{ab}	3.11
10	112.0	115.8^{ab}	3.80
15	106.2	107.6^{ab}	3.65
20	107.2	103.^{2b}	3.90
SEM	9.55	4.83	0.09

^{a,b}within the same column, means with different letters are significantly different (P<0.05).

Conclusions

FFSS was proven to be a good source of CP and ME in broiler diets. The results obtained from current experiments indicated that substitution of FFSS for corn, soybean meal up to

20% of diet had no negative effects on performance parameters of broiler chickens.

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