Asian-Aust. J. Anim. Sci.
Vol. 22, No. 4 : 557 - 564
April 2009

www.ajas.info

Nutritional Evaluation of Full-fat Sunflower Seed for Broiler Chickens

S. Salari*, H. Nassiri Moghaddam, J. Arshami and A. Golian

Department of Animal Science, Agricultural Faculty, Ferdowsi University of Mashhad, Mashhad, Iran

ABSTRACT : Two experiments were conducted to evaluate the use of various levels of full-fat sunflower seeds (FFSS) on broiler performance and carcass characteristics. In the first experiment, FFSS was included in a basal diet at 70, 140, and 210 g/kg and the AME_n values of the experimental diets were determined. The linear regression equation of AME_n values on rate of inclusion was calculated. Extrapolation value for the AME_n of FFSS at 100% inclusion was 14.22 MJ/kg. In the second experiment, diets containing various levels (0, 70, 140, and 210 g/kg) of FFSS were given to broilers (Ross strain) from 0 to 49 d. At 28 days of age, blood parameters and digestive enzyme activities were determined and carcass parameters were evaluated at 49 days of age. Weight gain, feed intake and feed conversion ratio (FCR) were improved ($p<0.05$) when broilers were fed various levels of FFSS in the starter and finisher diets. Breast, thigh, gastrointestinal tract and gizzard weight percentages were not affected by dietary treatments; however, liver weight percentage was decreased significantly ($p<0.05$) and weight of abdominal fat decreased but this effect was not significant. The activities of digestive enzyme (protease and α-amylase) were not influenced by the treatments. Activity of alkaline phosphatase, concentrations of calcium, phosphorus, glucose, triglyceride, protein, high density lipoprotein (HDL) and low density lipoprotein (LDL) were not affected by incorporation of FFSS in the broiler diet. Although concentration of HDL increased and LDL decreased, these effects were not significant. The results of this study indicate that FFSS can be used at up to 21% in broiler diets without adverse effects on performance or other parameters of chickens. (**Key Words :** Full-fat Sunflower Seed, Broiler Chicks, Metabolizable Energy, Organ Weight, Blood Parameters)

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is one of the most widely cultivated oilseeds in the world and ranks third in importance as a source of vegetable oil. Although referred to as sunflower seed, it is more correctly described as a type of indehiscent fruit. Hybrid varieties contain 380 to 540 g of oil/kg (Crum et al., 1993), which is very rich in linoleic acid. It also has 12.6% CF, 21.13% NDF (neutral detergent fiber), 14.98% ADF (acid detergent fiber), and 4.4% ADL (acid detergent lignin) (Rodriguez et al., 2005). Sunflower seed contains a moderate amount of protein, approximately 40 to 50% (as much as soybean seeds). Trends toward formulating high-energy diets for broiler chickens make it necessary for 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, FFSS contains more ether extract (EE) and is available at a relatively low price. This high EE content contributes to a high ME per unit or high energy density of feed. The increased production and availability of hybrid FFSS coupled with its oil content make FFSS a potentially desirable ingredient in poultry feeds. In the last few years, unextracted whole seed has been used as a feed ingredient in poultry diets.

Available data from published reports indicate that FFSS can be used as a source of nutrients for broiler diets (Daghir et al., 1980; Cheva-Isarakul and Tangtaweewipat, 1991; Elzubeir and Ibrahim, 1991; RodriAguez et al., 1998). However, results from some of these studies suggested conflicting conclusions about the effect of dietary level of FFSS on the performance response of chickens. FFSS is a source of dietary monounsaturated fatty acids (MUFA), and inclusion of it in monogastric diets can be particularly

* Corresponding Author: Somayyeh Salari. Tel: +98-5118795618, Fax: +98-5118787430, E-mail: somayehsallary@yahoo.com
Received August 22, 2008; Accepted October 24, 2008

Table 1. Determined analysis of full-fat sunflower seed on dry matter basis

Ingredient	Value
Moisture (%)	8.5
Crude protein (%)	18
Ether extract (%)	38
Crude fiber (%)	14.3
Calcium (%)	0.28
Available phosphorus (%)	0.22
ME (MJ/kg)	16.18
Fatty acid content (%)	
C12:0	0.1
C14:0	0.2
C16:0	10
C16:1	0.1
C18:0	4
C18:1n-9	18.1
C18:2 n-6	66
C18:3 n-3	0.5
C20:0	0.5
C22:0	0.5
Total saturated (S)	15.3
Total monounsaturated	18.2
Total polyunsaturated (P): n-6	66
n-3	0.5
P:S	4.34

valuable to increase the degree of unsaturation of intramuscular fat without the negative effect of lipid oxidation associated with dietary polyunsaturated fatty acids (PUFA). 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). Reduction of fat and cholesterol content has higher consumer acceptance.

Reports of ME content of FFSS differ widely based on the EE content of the FFSS (Daghir et al., 1980; Eluzubeir and Ibrahim, 1991).

The nutritional value of sunflower seed for poultry has not been extensively studied. In view of the lack of information on the value of FFSS for poultry, the study reported here was initiated to confirm its nutritional worth and to establish its optimal level of inclusion in the diet for broilers in terms of blood parameters, production performance and carcass quality.

MATERIALS AND METHODS

These experiments were carried out in the experimental farm of Ferdowsi University of Mashhad (Mashhad, Iran). A batch of sunflower seeds (cultivar Peredovic) was obtained from a commercial supplier and cleaned by hand to eliminate impurities and used in experiments 1 and 2. The test material was analyzed in duplicate for dry matter, crude protein (N×6.25), crude fiber, and crude fat by the procedures of the Association of Official Analytical Chemists (1995). Fat extracts were methylated in the presence of sulphuric acid for gas chromatographic identification of fatty acids (Sandler and Karo, 1992). Gross energy was determined using an adiabatic oxygen bomb calorimetric (Parr 1266) (Table 1).

Experiment 1

This experiment was conducted to determine the AMEn value of FFSS with a multilevel assay including 4 dietary inclusion levels. A corn-soybean meal basal diet (Table 2) was prepared in mash form and formulated to meet the nutrient requirements for broiler chickens (2 to 3 wk of age) recommended by the National Research Council (1994). FFSS was incorporated into the basal diets at 3

Table 2. Composition and nutritive value of basal diet and diets with increasing levels of full-fat sunflower seed (FFSS), experiment 1

Ingredients (%)	Inclusion (%)			
	0	7	14	21
Corn	61.95	57.43	52.9	48.37
Soybean meal	33.88	31.4	28.93	26.46
FFSS	-	7	14	21
Salt	0.4	0.4	0.4	0.4
Limestone	1.47	1.47	1.47	1.47
Dicalcium phosphate	1.35	1.35	1.35	1.35
DL-methionine	0.15	0.15	0.15	0.15
Chromium oxide	0.3	0.3	0.3	0.3
Vitamine-mineral permix[1]	0.5	0.5	0.5	0.5
Nutrient composition (%)				
ME (MJ/kg)	12.30	12.54	12.77	13.00
Crude protein	20.11	19.90	19.70	19.5
Lysine	1.23	1.17	1.12	1.07
Met+cys	0.95	0.9	0.83	0.77

[1] Supplied per kilogram of diet: vitamin A, 10,000 IU; vitamin D3, 9,790 IU; vitamin E, 121 IU; B_{12}, 20 μg; riboflavin, 4.4 mg; calcium pantothenate, 40 mg; niacin, 22 mg; choline, 840 mg; biotin, 30 μg; thiamine, 4 mg; zinc sulphate, 60 mg; manganese oxide, 60 mg.

concentrations (7, 14, and 21%). The 4 experimental diets, which contained 0.3% chromium oxide as an indigestible marker, were evaluated in a balance trial to determine the ME content.

One-day old male chicks of Ross strain were housed in floor pens, exposed to light for 24 h/d, and fed a standard broiler diet for 2 wk. Feed and water were provided *ad libitum*. On d 10, 80 birds were placed at random in 16 cages for 4 replicates per dietary treatments. On d 15, the birds were starved for 4 hours and then received the experimental diets from 15 to 21 d of age. During the last 3 d, excreta samples from each cage were collected and stored at -20°C. After being thawed, excreta were homogenized, dried, and ground through a 1-mm screen. Diets and excreta were analysed for dry matter, CP, chromium oxide, and gross energy.

Experiment 2

The objective of this experiment was to study the effect of various levels of FFSS on blood parameters, carcass characteristics and performance of broiler chickens. Four experimental isocaloric (ME) and isonitrogenous broiler starter and finisher diets were formulated to contain 0, 7, 14, and 21% FFSS (Tables 3 and 4). Broiler starter diet (12.135 MJ/kg ME; 20.25% CP) was fed from 0 to 3 wk. From 3 to 7 wk, finisher diets (12.55 MJ/kg ME; 18.5% CP) were given to broilers. All the diets were calculated to meet the requirements of broiler chicks recommended by the National Research Counsil (1994). One hundred seventy six 1-day-old male commercial broiler chicks (Ross strain) were weighted, and distributed randomly to 4 treatments with 4 replicates (11 chicks in each replicate/pen) in each treatment. Water and feed were provided *ad libitum*. Weekly body weight gain and feed consumption of each pen were recorded. At 28 days of age, 4 birds per treatment (one from each replicate) were randomly selected and killed by cervical dislocation and blood was collected by heart puncture. Serum was separated and analyzed for concentrations of different cholesterol fractions, that is, HDL and LDL (Zlatkis et al., 1953) and triglycerides (Fossati and Lorenzo, 1982), total serum protein (Doumas et al., 1971) and calcium (AOAC, 1995). The inorganic phosphorus concentration of serum was measured using the phosphomolybdic acid method (Fiske and Subbarow, 1925). Serum also analyzed for determination of alkaline phosphatase (ALP), using the protocol provided by the kit manufacturer (Zist-Shimi, Tehran, Iran).

Digestive enzyme activities were determined in the ileum digesta of broiler chicks at 4 weeks of age. For this reason, the ileum from the Meckel's divertriculum to 4 cm above the ileocaecal junction was quickly dissected out and the contents of them were aseptically collected in screw-capped sterile specimen vials and the vials were placed in a freezer at -20°C until required. These vials were only used for the determination of enzyme activities. Four hundred milligrams of ileal content were quickly weighted into test-tubes kept on ice and 6 ml ice-cold physiological saline (9 g NaCl/L) was added and centrifuged at 2,000 g. Portions of

Table 3. Composition and nutrient contents of broiler diets at the starter phase, experiment 2

Ingredients (%)	Level of full-fat sunflower seed in diet (%)			
	0	7	14	21
Corn	61.26	53.86	46.33	39.66
Soybean meal	34.3	31.8	29.33	27
Full-fat sunflower seed	-	7	14	21
Wheat bran	-	3	6	8
Limestone	1.47	1.47	1.47	1.47
Dicalcium phosphate	1.8	1.7	1.7	1.7
Salt	0.47	0.47	0.47	0.47
Vitamine-mineral permix[1]	0.5	0.5	0.5	0.5
DL-methionine	0.2	0.2	0.2	0.2
Nutrient composition (%)				
ME (MJ/kg)	12.13	12.13	12.13	12.13
Crude protein	20.86	20.86	20.86	20.86
Ether extract	2.6	5.05	7.5	9.94
Crude fiber	2.69	3.84	4.99	6.06
Calcium	1.05	1.04	1.06	1.07
Available P	0.47	0.46	0.48	0.49
Sodium	0.2	0.2	0.2	0.2
Lysine	1.24	1.2	1.16	1.12
Methionine	0.52	0.53	0.54	0.54
Arginine	1.43	1.47	1.51	1.55

[1] Supplied per kilogram of diet: vitamin A, 10,000 IU; vitamin D3, 9,790 IU; vitamin E, 121 IU; B12, 20 µg; riboflavin, 4.4 mg; calcium pantothenate, 40 mg; niacin, 22 mg; choline, 840 mg; biotin, 30 µg; thiamine, 4 mg; zinc sulphate, 60 mg; manganese oxide, 60 mg.

Table 4. Composition and nutrient contents of broiler diets at the finisher phase, experiment 2

Ingredients (%)	Level of full-fat sunflower seed in diet (%)			
	0	7	14	21
Corn	66.92	59.73	52.43	45.3
Soybean meal	29.3	26.7	24.3	21.9
Full-fat sunflower seed	-	7	14	21
Wheat bran	-	2.8	5.5	8
Limestone	1.4	1.4	1.4	1.4
Dicalcium phosphate	1.45	1.45	1.45	1.45
Salt	0.35	0.35	0.35	0.35
Vitamine-mineral premix	0.5	0.5	0.5	0.5
DL-methionine	0.08	0.07	0.07	0.05
L-lysine	-	-	-	0.05
Nutrient composition (%)				
ME (MJ/kg)	12.55	12.55	12.55	12.55
Crude protein	18.75	18.75	18.75	18.75
Ether extract	2.78	5.23	7.67	10.12
Crude fibre	2.61	3.75	4.88	5.99
Calcium	0.93	0.95	0.96	0.98
Available P	0.4	0.41	0.42	0.43
Sodium	0.15	0.15	0.15	0.16
Lysine	1.09	1.05	1.01	1.01
Methionine	0.38	0.38	0.39	0.38
Arginine	1.27	1.31	1.35	1.39

[1] Supplied per kilogram of diet: vitamin A, 10,000 IU; vitamin D3, 9,790 IU; vitamin E, 121 IU; B12, 20 µg; riboflavin, 4.4 mg; calcium pantothenate, 40 mg; niacin, 22 mg; choline, 840 mg; biotin, 30 µg; thiamine, 4 mg; zinc sulphate, 60 mg; manganese oxide, 60 mg.

supernatant fractions containing enzymes were assayed for protease and amylase activities according to procedure of Najafi et al. (2006) and Najafi et al. (2005) respectively. At the end of the experiment (49 days), one bird from each replicate (close to the mean body weight of the replicate) was selected and slaughtered to study the relative weights of liver, abdominal fat, gizzard, thigh, breast and gastrointestinal tract.

Calculations and statistical analysis

Apparent metabolizable energy was calculated as follows:

ME (kcal/kg) = dietary gross energy
×(1-(diet Cr_2O_3/excreta Cr_2O_3)
×(excreta gross energy/diet gross energy))

Table 5. Apparent metabolizable energy (AME_n)[1] of diets with increasing levels of full-fat sunflower seed (FFSS), and of FFSS determined by difference and regression analysis, experiment 1

Level of FFSS (g/kg)	AME_n of diets (kcal/kg)	AME_n of FFSS (kcal/kg)
0	2,970[a]	-
70	2,992[b]	3,284.28
140	3,012[b]	3,270
210	3,065[b]	3,422.38
SEM	37.68	

Values with a common letter do not differ significantly ($p<0.05$).
[1] AME_n determinations were made based on 16 cages of 1 bird each.
Linear regression equation: $y = 2{,}964+0.4357x$; $R^2 = 0.801$ where y = AME_n (kcal/kg) and x = dietary inclusion level of FFSS (g/kg)

The correction of AME to zero nitrogen retention (AME_n) was based on a factor of 8.22 kcal/g of retained N (Hill and Anderson, 1958).

The AME_n value of FFSS was calculated using the following equation: $AME_n = (AME_n T-\alpha \times AME_n B)/b$, where T is the test diet, α is the proportion of the basal diet in the test diets, B is the basal diet, and b is the proportion of FFSS in the test diets.

Statistical analyses were performed by using the GLM procedures of SAS software (SAS Institute, 1999). Data generated from experiment 1 were subjected to ANOVA to identify variation produced by inclusion level of FFSS; regression analysis was also used to establish dietary changes as a function of inclusion level of FFSS. Experiment 2 was carried out in a completely randomized design. These data were subjected to an analysis of variance according to the GLM procedure for the ANOVA and the significant differences among means were determined by using Duncan's multiple range test. Differences among treatments means were compared at $p<0.05$.

RESULTS AND DISCUSSION

The nutrient composition of the FFSS used in this study appears in Table 1. Values for ether extract and crude fiber are similar to those reported by Cheve-Isarakul and Tangtaweewipat (1990); whereas crude protein is considerably lower. This difference may be due to genetic,

Table 6. Effect of full-fat sunflower seed on performance parameters of broiler (1-49 days of age), experiment 2

FFSS (g/kg)	Feed intake (g/b)				Weight gain (g/b)				Feed conversion ratio			
	1-21	22-42	43-49	1-49	1-21	22-42	43-49	1-49	1-21	22-42	43-49	1-49
0	823.63^{b}	2,446^{b}	1,019.8	4,125.1^{b}	417.48^{b}	1,117.07^{b}	350.7^{b}	1,741.7^{b}	1.975	2.545^{a}	2.90^{a}	2.392
70	874.70^{ab}	2,793.5^{a}	1,089.2	4,757.4^{a}	451.04^{ab}	1,099.16^{b}	456.98^{ab}	1,935.6^{ab}	1.940	2.482^{a}	2.38^{b}	2.455
140	903.65^{ab}	2,950.6^{a}	1,168.2	4,985.6^{a}	503.27^{a}	1,199.14^{ab}	450.01^{ab}	2,096.5^{a}	1.797	2.192^{b}	2.59^{ab}	2.387
210	932.15^{a}	2,809.3^{a}	1,139.3	4,762.9^{a}	497.07^{a}	1,311.23^{a}	492.03^{a}	2,155.9^{a}	1.900	2.147^{b}	2.31^{b}	2.225
SE	11.5	29.47	24.40	85.35	5.93	10.01	20.97	24.83	0.069	0.121	0.281	0.100

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

varietal, soil, and climatic conditions as suggested by Vaughan (1970).

Apparent metabolisable energy

Table 5 shows AME_n data (kcal/kg) for the experimental diets. Increasing inclusion rate of FFSS increased the AME_n of the diets. To further assess this trend, the dietary AME_n values were regressed against the inclusion level of FFSS using linear and quadratic models. The results showed that the linear component was highly significant, whereas the quadratic component did not reach a significant level. This indicated that the energy contribution of FFSS to diets was additive, and the inclusion rate did not alter the use of other dietary ingredients. By using the AME_n values determined for the basal diet and the basal diet containing a given amount of FFSS, the AME_n (kcal/kg) of this feed was calculated by difference (Table 5). The AME_n values obtained for diets in the experiment reported here were regressed on level of FFSS in the basal diet to estimate the AME_n content in FFSS. The equation derived of fitting a linear model was the following: $y = 2.964+0.4357x$; $R^2 = 0.801$.

An estimate of the AMEn of FFSS was obtained by extrapolation of equation where 1,000 g/kg FFSS in the diet gave a value of 14.22 MJ/kg. The energy value thus obtained for FFSS was lower than the 18.71 MJ/kg and 17.67 MJ/kg reported by Rodriguez et al. (1998) and Rodriguez et al. (2005), respectively. This difference may be related to crude fat content. Because sunflower seed they used had a higher amount of crude fat (47.3% and 44.4% respectively). The cell walls of grains and oilseeds can serve as a physical barrier for digestive enzymes and nutrients contained within the cells and can either prevent entirely or delay digestion of nutrients in the last portion of the duodenum (Simon et al., 1996). Not only the total fiber content, but also the physical and chemical structure of fibrous polysaccharides, and their anatomical arrangement within each specific ingredient, affect the accessibility of enzymes for digestion of nutrients. Protein and many other nutrients are "encapsulated" to variable degrees, inside fibrous structures, and remain less available for digestion by the bird's proteases and other endogenous enzymes. These effects may decrease AMEn value of oilseeds. In our experiment, crude fiber of the diets was increased by increasing the level of FFSS, but AMEn value of the diets was not decreased. It seems that the crude fiber of FFSS may not have an effect on AMEn of the diets.

Performance parameters

Table 6 shows the effects of different levels of FFSS on the performance parameters of broiler chickens. Feed intake increased significantly ($p<0.05$) when increasing levels of FFSS was incorporated in the diet for 1 to 21, 22 to 42 and 1 to 49 days of experiment. These results are in contrast to the results of Cheva-Isarakul and Tangtaweewipat (1990), that they showed feed intake decreased when FFSS added to the diets. Weight gain also increased significantly in the different stages of our experiment ($p<0.05$). Except for 1 to 21 and 1 to 49 days of age, feed conversion ratio (FCR) improved significantly ($p<0.05$). These results are in contrast of Arija et al. (1998). They showed that performance parameters reduced when FFSS added to the diets. Rodriguez et al. (1998) reported not significant differences in weight gain, feed intake and feed utilization among the chicks receiving the control diet and those fed on diets with increasing level of hulled full-fat sunflower seed (HFFSS) (from 50-250 g/kg diet). In general, these results are in accordance with those obtained by Elzubeir and Ibrahim (1991), who reported that unprocessed sunflower seed can be given to broilers at up to 225 g/kg of the diet with no adverse effects on performance. Other researchers (Cheva-Isarakul and Tangtaweewipat, 1991) found that broilers fed diets containing up to 500 g/kg HFFSS gained slightly more weight and had a significantly better feed conversion ratio than the birds in the control group. In contrast with these findings, Daghir et al. (1980) observed that feeding 150 and 250 g/kg HFFSS to broilers depressed both body weight gain and feed intake. But Elangovan et al. (2000) showed live weight gain, feed intake, nutrient retention and carcass characteristics of quails did not vary significantly ($p>0.05$), when sunflower seed meal increased in the diets. One possible explanation for this disagreement of results is that different sunflower varieties or cultivars varying in chemical composition were used in the experiments. Selvaraj et al. (2004) used various levels of FFSS (0, 5, 10, 15 and 20) and reported that weight gain

Table 7. Effect of increasing levels of full-fat sunflower seed (FFSS) on digestive enzyme activities in the digesta of 4-week old broiler chicks

Level of FFSS (g/kg)	α-Amylase[2]	Protease[1]
0	357	3,420
70	271	3,135
140	276	3,630
210	299	4,155
SE	18.7	45.05

[a,b] Within the same column, means with different letters are significantly different ($p<0.05$).

[1] One unit of protease activity on azocasein was defined as amount of the enzyme required to produce an absorbance change of 1.0 at 440 nm/min at 55°C and pH 8.

[2] One unit of enzymatic activity is defined as the amount of enzyme required to produce 1 μM of glucose per minute under assay conditions.

and feed consumption were not affected by the SFS level of inclusion. They also indicated, better feed conversion ratio in groups fed 15 or 20% SFS in both broiler starter and finisher diets than in the control group and the mortality rate was not influenced by the SFS inclusion.

Physiological effects

The results of feeding increasing levels of FFSS to chicks on digestive enzyme activities are shown in Table 7. The activities of both protease and amylase in chick digesta were not significantly affected by the experimental diets. These results were similar to the results of Arija et al. (1998) that used various levels of FFSS in the diets.

Results of the relative weight of the different organs are shown in Table 8. The relative weight of the gizzard, thigh, and gastrointestinal tract were not affected by the FFSS. However, the relative weight of liver was decreased significantly ($p<0.05$) in birds fed FFSS diets compared to those fed control diet. Similarly, Cheve-Isarakul and Tangtaweewipat (1990) reported that percentage liver decreased by adding FFSS to the diets. This might be due to the nature of fat in SFS, which is composed mainly of unsaturated fatty acids, particularly linoleic acid, because this fatty acid prevented fat accumulationin the liver. This suspected effect of linoleic acid agrees with the results of Donaldson and Gordon (1960) and Menge (1967) in laying hens, and Morton and Horner (1961) in rats. But in another experiment, liver weight improved while metabolisable energy intake increased in the diets (Shyam Sunder et al., 2007). In our experiment, the lower abdominal fat pad and the larger breast muscle resulted while the levels of FFSS increased, but these effects were not significant. This effect is in accordance with the results of Tang et al. (2007) that weight of breast muscle did not influence while energy of diets increased. A similar finding has also been reported for female broilers that were fed sunflower oil for 32 d (Sanz et al., 2000). Abdominal fat pad has been shown to be highly correlated with the total fat content of both the carcass and the edible meat of chickens (Becker et al., 1979; Akiba et al., 1995). Thus the reduction in the abdominal fat pad for the broilers fed the FFSS diets presumably reflects a lower total body fat content, and demonstrates 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 (Ronald 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).

Effects of various levels of FFSS in the blood parameters of broiler chicks were shown in Table 9. The plasma triglyceride concentrations tended to be lower in the

Table 8. Effects of feeding different levels of full-fat sunflower seed on relative weight of body organs of chicks at 49 days of age (% of live body weight)

Level of FFSS (g/kg)	Breast	Thigh	Gastrointestinal tract	Liver	Gizzard	Abdominal fat
0	17.79	10.38	12.92	3.05[a]	2.86	2.09
70	18.68	9.14	15.57	2.30[b]	3.15	1.19
140	21.10	9.52	13.93	2.39[b]	3.09	1.56
210	20.08	10.31	12.41	2.05[b]	2.68	0.68
SE	0.712	0.212	0.728	0.261	0.336	0.105

[a,b] Within the same column, means with different letters are significantly different ($p<0.05$).

Table 9. Effects of increasing levels of FFSS on blood parameters of broiler chickens in 28 days of age

Level of FFSS (g/kg)	Glucose (mg/dl)	Cholesterol (mg/dl)	Triglycerides (mg/dl)	Calcium (mg/dl)	Phosphorous (mg/dl)	Alkalin phosphatase (U/L)	HDL (mg/dl)	LDL (mg/dl)	Protein (g/dl)
0	268.2	102.5	99.2	13.8	7.9	120.9	81.0	36.0	3.5
70	261.7	102.5	92.5	14.9	7.3	127.3	82.2	31.5	3.9
140	268.7	117.7	78.7	16.6	8.3	127.5	95.7	37.5	3.8
210	262.5	116.2	68.7	18.7	8.4	130.2	96.0	29.7	3.4
Probability	NS	NS	NS	NS	NS	NS	NS	NS	NS
SE	1.03	2.08	2.87	1.78	1.02	2.03	2.05	2.02	0.08

[a,b] Means without a common superscript in a column differ significantly ($p\leq0.05$).

birds fed increasing levels of FFSS, but this effect was not significant. This result is in agreement with the results of Ronald et al. (2002) and Sanz et al. (2000). The decrease in plasma triglycerides in the chickens fed FFSS diets may also be a response to the action of specific fatty acids to stimulate enzymes of the β-oxidative pathway. In addition, sunflower oil feeding 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. Other factors including glucose, total cholesterol, HDL, LDL, alkaline phosphatase, protein, calcium and phosphorus were not significantly affected by the level of FFSS inclusion. Although a small reduction in LDL and an increase in HDL observed. Since higher dietary fiber content is known to reduce dietary fat utilization by decongugation of bile salts (Story and Kritchevsky, 1976; Story and Furumoto, 1990) which might have reduced fat absorption through the gut, the body fat (liver fat) might have been utilized for the metabolic needs and therefore increased the HDL concentration in serum. A similar trend was observed in the study of Rama Rao et al. (2004) where the serum concentrations of LDL cholesterol decreased in birds receiving high-fiber diets. Selvaraj et al. (2004), using the inclusion of various levels of FFSS in broiler rations, reported not significantly effect on serum parameters of poultry. Cheve-Isarakul and Tangtaweewipat (1991) showed the incorporation of SFS in the diets had no effect on serum cholesterol levels.

CONCLUSION

FFSS was proven as a good source of CP and ME in broiler diets. The results from the current experiments indicated that substitution of FFSS for corn, soybean meal up to 210 g/kg of diet had positive effect on performance parameters and did not have any adverse effect on other parameters of broiler chickens.

ACKNOWLEDGMENTS

The authors thank SEGOL factory (Nishabour, Iran) for supplying the full-fat sunflower seed used in this study. Special thanks are also extended to the Excellent Center of Animal Sciences in Ferdowsi University of Mashhad (FUM), (Mashhad, Iran) for financial help.

REFERENCES

Ajuyah, A. O., T. W. Fenton., R. T. Hardin and J. S. Sim. 1993. Measuring lipid oxidation volatiles in meats. J. Food Sci. 58: 270-273.

Akiba, Y., H. Murakami and J. H. Park. 1995. The effects of dietary lipid on poultry performance and composition. Austr. Poult. Sci. Symp. 7:1-8.

Arija, I., A. Brenes, A. Viveros and R. Elices. 1998. Effects of inclusion of full-fat sunflower kernels and hulls in diets for growing broiler chickens. Anim. Feed Sci. Tech. 70:137-149.

Association Of Official Analytical Chemists (AOAC). 1995. Official methods of analysis, 16th. ed. Washington, DC, AOAC.

Becker, W A., J. V. Spencer, L. W. Mirosh and J. A. Verstrate. 1979. Prediction of fat and fat free live weight in broiler chickens using backskin fat, abdominal fat, and live body weight. Poult. Sci. 58:835-842.

Blair, M. E. and L. M. Potter. 1988. Effects of varying fat and protein in diets of growing large white turkeys. 1. Body weights and feed efficiencies. Poult. Sci. 67:1281-1289.

Cheva-Isarakul, B. and S. Tangtaweewipat. 1991. Effect of different levels of sunflower seed in broiler rations. Poult. Sci. 70:2284-2294.

Crum, C. W., J. M. Prescott and P. J. Christensen. 1993. Genetic approaches to increased nutritional value in oilseed meal. Proc. World Confr. Oilseed. Tech. Utili., Appelwhite, ed. AOAC Press, Champaign, IL. 334-338.

Daghir, N. J., M. A. Raz and M. Uwayjan. 1980. Studies on the utilization of full fat sunflower seed in broiler ration. Poult. Sci. 59:2273-2278.

Donaldson, W. E. and C. D. Gordon. 1960. The effect of 3% added animal fat on laying hen performance. Poult. Sci. 39:583-587.

Doumas, B. T., W. A. Watson and H. G. Biggs. 1971. Albumin standard and the measurement of serum albumin with bromocresol green. Clin. Chem. Acta, 31:87.

Elangovan, A. V., S. V. S. Verma and V. R. B. Sastry. 2000. Response of growing and laying Japanese quails (Coturnix japonica) to dietary sunflower seed meal. Asian-Aust. J. Anim. Sci. 13(12):1726-1730.

Eluzubeir, E. A. and M. A. Ibrahim. 1991. Effect of dietary full fat raw sunflower seed on performance and carcass skin color of broilers. J. Sci. Food Agr. 55:479-481.

Fiske, C. H. and Y. Subbarow. 1925. The colorimetric determination of phosphorus. J. Biol. Chem. 66:375-400.

Fossati, P. and P. Lorenzo. 1982. Serum triglycerides determined colorimetrically with an enzyme that provides hydrogen peroxide. Clin. Chem. 28:2007-2010.

Grundy, S. M. 1986. Comparison of monounsaturated fatty acids and carbohydrates for lowering plasma cholesterol. New Engl. J. Med. 314:745-748.

Halminski, M. A., J. B. Marsh and E. H. Harrison. 1991. Differential effects of fish oil, sunflower oil and palm oil on fatty acid oxidation and glycerolipid synthesis in rat liver. J. Nutr. 121:1554-1561.

Hill, F. W. and D. N. Anderson. 1958. Comparison of metabolizable energy and productive energy determinations with growing chicks. J. Nutr. 64:587-603.

Meng, H. 1967. Fatty acid composition and weight of organs from essential fatty acid-deficient and non-deficient hens. J. Nutr. 92:148-152.

Morton, R. A. and A. A. Horner. 1961. Liver-lipid constituents of male and female rats. Biochem. J. 79:631-635.

Najafi, M. F., D. N. Deobagkar, M. Mehrvarz and D. D. Deobagkar. 2006. Enzymatic properties of a novel highly

active and chelator resistant protease from a Pseudomonas aeruginosa PD100. Enzyme Microb. Tech. 39:1433-1440.

Najafi, M. F., D. Deobagkar and D. Deobagkar. 2005. Purification and characterization of an extracellular α-amylase from *Bacillus subtilis* AX20. Protein Expres Purif. 41:349-354.

National Research Council 1994. Nutrient Requirements of Poultry. 9th rev. ed. National Academy Press, Washington, DC, USA.

Raclot, T. and R. Groscolas. 1993. Differential mobilisation of White adipose tissue fatty acids according to chain length, unsaturation and posicional isomerism. J. Lipid Res. 34:1515-1526.

Rama Rao, S. V., M. V. L. N. Raju, M. R. Reddy and A. K. Panda. 2004. Replacement of yellow maize with pearl millet (*Pennisetum typhoides*), foxtail millet (*Setaria italica*) or finger millet (*Eleusine coracana*) in broiler chicken diets containing supplemental enzymes. Asian-Aust. J. Anim. Sci. 17:836-842.

Roche, H. M. 2001. Olive oil, high-oleic sunflower oil and CHD. Br. J. Nutr. 85:3-4.

Rodriguez, M. L., L. T. Ortiz, C. Alzueta, A. Rebole and J. Trevin˜o. 2005. Nutritive value of high-oleic acid sunflower seed for broiler chickens. Poult. Sci. 84:395-402.

Rodrı´guez, M. L., L. Ortiz, T. J. Trevin, O. Rebole, A. Alzueta and C. Centeno. 1998. Studies on the nutritive value of fullfat sunflower seed in broiler chick diets. Anim. Feed Sci. Tech. 71:341-349.

Ronald, E. Newman, Wayne L. Bryden, Eva Fleck, John R. Ashes, William A. Buttemer, Leonard H. Storlien and Jeffery A. Downing. 2002. Dietary n-3 and n-6 fatty acids alter avian metabolism: metabolism and abdominal fat deposition. Br. J. Nutr. 88:11-18.

Sandler, S. R. and W. Karo. 1992. Source book of advances organic laboratory preparations. San Diego: Academic Press, pp. 332.

Sanz, M., C. J. Lopez-Bote, D. Menoyo and M. Baautista. 2000. Abdominal fat deposition and fatty acid síntesis are lower and β-oxidation is higher in broiler chickens fed diets containing unsaturated rather than saturated fat. J. Nutr. 130:3034-3037.

SAS Institute. 1999. SAS User's Guide: Statistics (Cary, NC, SAS Institute Inc.).

Selvaraj, R. K. and M. R. Purushothaman. 2004. Nutritive value of full-fat sunflower seeds in broiler diets. Poult. Sci. 83:441-446.

Shyam Sunder, G., Ch. Vijaya Kumar, A. K. Panda, M. V. L. N. Raju, S. V. Rama Rao, N. C. S. Gopinath and M. R. Reddy. 2007. Restriction of metabolizable energy in broiler growers and its impact on grower and breeder performance. Asian-Aust. J. Anim. Sci. 20(8):1258-1265.

Simon, O., H. Gruppen, H. L. Classen, W. Close, N. Khan, T. Acamovic, B. V. McCleary, A. Morgan and D. Cowan. 1996. Enzyme in action. World Poultry-Misset 12:62-71.

Story, J. and E. J. Furumoto. 1990. Dietary fiber and bile acid metabolism. In: Dietary fiber (Ed. D. Kritchevsky, C. Bonfield, and J. W. Anderson). Plenum Press, New York, NY, pp. 365-373.

Story, J. and D. Kritchevsky. 1976. Dietary fibers and lipid metabolism. In: Fiber in human Nutrition (Ed. G. A. Spiller and R. J. Amen) Plenum, New York, pp. 171-184.

Tang, M. Y., Q. G. Ma, X. D. Chen and C. Ji. 2007. Effects of dietary metabolizable energy and lysine on carcass characteristics and meat quality in arbor acres broilers. Asian-Aust. J. Anim. Sci. 20(12):1865-1873.

Vaughan, J. G. 1970. The structure and utilization of oil seeds. London. Chapman and Hall.

Zlatkis, A., B. Zak and A. J. Boyle. 1953. A new method for the direct determination of serum cholesterol. J. Lab Clin. Med. 41:486-492.