Nutritional Evaluation of a High-Oil Sunflower Meal in Broiler Starter Diets

N. Senkoylu*[1] and N. Dale†

**Department of Animal Science, Trakya University, 59030 Tekirdag, Turkey; and †Department of Poultry Science, University of Georgia, Athens 30602*

Primary Audience: Nutritionists, Veterinarians, Feed Manufacturers, Broiler Producers

SUMMARY

Two experiments were conducted with broiler chicks to determine the nutritive value of high-oil sunflower meal (HO-SFM), a sunflower oil extraction by-product obtained through screw-press extraction and expanding processes with a proximate composition of 32% CP, 12% crude fiber, and 19% ether extract. In Experiment 1, the effects of a high level (46.4%) of HO-SFM on chick performance and gastrointestinal organs were tested. The objective of Experiment 2 was to determine if pelleting the feed could overcome the bulkiness resulting from inclusion of HO-SFM at a high level. The results of Experiment 1 indicated that addition of 46.4% HO-SFM to broiler starter diets significantly ($P < 0.05$) depressed body weight, feed intake, and gain but not feed conversion. Fat pad and liver lipid were again significantly ($P < 0.05$) decreased in the HO-SFM treatment. Impaired performance might have been due to the difference of the density of HO-SFM diet (608 g/L) compared with the soybean meal control (723 g/L). When bulkiness was overcome by pelleting in Experiment 2, it was found that pelleting the feed significantly enhanced growth of broiler chicks compared with SFM or soybean meal mash diets. Liver weights and lipid content were again decreased in HO-SFM diets. The results of this study suggest that HO-SFM can be used up to 28% without adverse effects on broiler chicks. Further improvement was observed with pelleting. Liver weight and lipid content were consistently reduced by feeding HO-SFM.

Key words: high-oil sunflower meal, broiler starter, fiber, pelleting, liver lipid

2006 J. Appl. Poult. Res. 15:40–47

DESCRIPTION OF PROBLEM

For many decades, sunflower meal (**SFM**) has been recognized as a viable feed ingredient in poultry diets [1]. Since then, SFM has been used extensively in poultry diets and has been described as a good protein source for poultry, provided that some of its nutritional characteristics are taken into account [2].

Lysine was determined [3] to be the first limiting amino acid when SFM was used as the sole source of supplementary protein. The importance of processing time and temperature with respect to lysine availability is well documented [4]. The fiber level of SFM, depending on the extent of dehulling, appears to be the most problematic aspect concerning the use of SFM at high levels in chick diets. Inconsistent results reported by several authors regarding SFM might be attributed to the variety of sunflower, method of processing, degree of dehulling, age of birds, and feed formulation techniques used in these studies [2, 5]. Moreover, the high fiber content in SFM may lead to a very low ME in the diet. A strong negative correlation between the fiber fractions

[1]Corresponding author: nsenkoylu@yahoo.com

Table 1. Chemical composition, determined TME_n value, and assayed amino acid content of high-oil sunflower meal

Chemical composition	%
Dry matter	90.20
Crude protein	32.30
Crude fat	18.78
Crude fiber	11.54
Crude ash	6.29
Sugar	1.50
Starch	4.31
Amino acid analysis, wt/wt %	
Arg	2.48
His	0.77
Lys	1.14
Leu	2.02
Ile	1.25
Met	0.68
Cys	0.66
Phe	1.44
Trp	0.41
Thr	1.15
Tyr	0.80
Gly	1.77
Val	1.58
Energy content, kcal/kg	
Gross energy	5,017
TME_n	3,297

(neutral detergent fiber, acid detergent lignin, and hemicelluloses) of SFM and its TME content has been found [6]. The soluble and insoluble nonstarch polysaccharides (**NSP**) content of SFM has been extensively studied [7, 8]. It was reported that the soluble and insoluble constituents of NSP content are 4.5 and 23.1%, respectively, of the total NSP, which consists of 42% cellulose, 24% pectic polysaccharides, 24% 4-O-methl-glucuronoxylans, 5% (gluco)-mannans, and 4.5% fucoxyloglucans [8]. The main constituent of soluble NSP is reported to be uronic acid in SFM [7]. It has been emphasized that the disruption of cell wall matrix by microbial enzymes is possible in the upper intestine, leading to easy access of the endogenous proteolytic enzymes to digest the entrapped proteins [9]. Likewise, it has been stated that supplementation of SFM based diets with microbial enzymes increases the nutrient use of this product in layers and broilers [10]. Testing of different microbial enzymes in another study [11], however, did not indicate any difference between the treatments and the control diet to which no enzyme was added.

To overcome the energy deficiency of SFM caused by high fiber, fat supplementation [12, 13] has been suggested. Another approach is to retain some of the oil in the meal during processing of sunflower seed to produce high-energy sunflower meal [14]. High-oil (**HO**)-SFM obtained in this way was found to be included in broiler grower and finisher diets up to 25% without adversely affecting broiler performance. This product was primarily obtained to alleviate the relatively lower energy content of regular SFM. However, HO-SFM has not particularly been tested in broiler starter diets.

Therefore, the aim of this study was to evaluate the nutritive value of HO-SFM with respect to its effects primarily on chick growth, feed efficiency, gizzard size, abdominal fat content, and liver lipid accumulation.

MATERIALS AND METHODS

Processing Technique of High-Oil Sunflower Meal

The HO-SFM was produced in a sunflower oil extraction plant in Trakya region of Turkey using mechanical screw press extraction and subsequently an expanding technique. To produce HO-SFM, new equipment was introduced in the conventional processing line of oil extraction; for example, a seed drier was used to reduce the moisture content to about 5% in the seed for efficient cracking and dehulling. Dried seeds were cracked followed by the separation of the loose hulls by shaker screens and vacuum air suction. After separation of the hulls (<100% of hulls are separated), oil is extracted from the kernel using a mechanical screw press. After oil extraction, the meal contained about 19% oil. Then the oily meal was passed through an expander (the second equipment introduced in the processing line) to apply heat treatment (120 to 150°C) and to give pellet shape to meal. The sunflower seed varieties cultivated in the region of Trakya, Turkey, and in Eastern Europe are usually of HO types. In the HO sunflower varieties, almost 50% of the whole seed is oil. However, it has been reported to be feasible to develop lines and hybrids containing 55 to 60% oil Improvement of CP (from about 24 to 40% in the kernel) and lysine contents of SFM has received considerable attention in Europe [15]. However, the chemical composition of

Table 2. Chemical compositions of experimental diets (Experiment 1)

	Experimental diet	
Ingredient (% of diet as fed)	SBM	SFM
High-oil sunflower meal	0	46.41
Soybean meal (48%)	28.62	0
Poultry by-product meal	7.00	7.00
Corn, grain	56.30	42.18
Poultry fat	5.15	1.18
Deflourinated phosphate	1.14	1.18
Limestone	0.88	0.75
Common salt	0.40	0.40
Vitamin premix[1]	0.25	0.25
Mineral premix[2]	0.08	0.08
L-Lys HCl	0	0.45
DL-Met	0.18	0.08
Thr	0	0.04
Total	100.00	100.00
Calculated analysis		
ME, kcal/kg	3,200	3,200
CP, %	23.00	23.00
Ether extract, %	8.48	12.42
Crude Fiber, %	2.49	6.41
Lys, %	1.18	1.18
Met, %	0.54	0.54
Met + Cys, %	0.90	0.90
Thr, %	0.84	0.84
Calcium, %	1.00	1.00
Available phosphorus, %	0.45	0.45

[1]Vitamin premix provided the following (in mg/kg of diet, except as noted): vitamin A as all-*trans*-retinyl acetate), 5,511.5 IU; vitamin D_3, 1,102.3 ICU; vitamin E (all-*rac*-α-tocopheryl acetate), 11; menadione (as menadione sodium bisulfite), 1.1; riboflavin, 4.4; calcium pantotenate, 12; nicotinic acid 44; choline chloride, 220; vitamin B_{12}, 9; vitamin B_6, 3; thiamin (as thiamin mononitrate), 2.2; folic acid, 3; biotin, 0.3; and ethoxyquin, 125.
[2]Trace mineral premix provided 93 ppm Mn (as manganese sulfate); 75 ppm Zn (as zinc sulfate); 18 ppm Fe (as ferrous sulfate); 3 ppm Cu (as copper sulfate); 0.7 ppm I (as calcium iodate); 19 ppm Mg (as magnesium oxide); and 0.3 ppm Se (as sodium selenite).

the SFM obtained in the region may vary depending primarily upon the processing method of the oil extraction. After analysis, the TME_n content of the product was determined according to the precision force-feeding technique using adult cockerels [16]. The amino acid profile was also assayed (Table 1).

Bird Husbandry

One-day-old male chicks of a commercial broiler strain [17] were used in Experiments 1 and 2. Chicks were weight sorted and randomized prior to placement in electrically heated battery brooders with mesh floors. Batteries were kept in an environmentally controlled room. Feed and water were provided ad libitum. Experiment 1 was terminated at 19 d of age, whereas Experiment 2 lasted 16 d.

At the termination of each study, birds were weighed by pen, and feed consumption was determined. Two birds were taken randomly from each pen, killed by cervical dislocation, and weighed individually. The fat pad of each bird was collected from the gizzard to the end of distal abdomen. Liver, gizzard, and proventriculus were removed and individually weighed. Afterward the length of small intestine (from distal end of the gizzard to the ileocecal junction, by extending the duodenum), cecum, and colon were measured. The relation of weight and length of the digestive organs to 100 g of individual body weight of each bird was determined. The collected livers were pooled in nylon bags and kept in freezer at −18°C until they were analyzed for total liver lipid according to Folch et al. [18].

Statistics

Experiment 1 was carried out as a completely randomized design, whereas experiment 2 was conducted according to a 2×2 factorial arrangement. ANOVA was used to measure the effects of dietary treatments and differences between means were identified by Duncan's multiple range test according to SAS [19].

Treatments—Experiment 1

Experiment 1 was designed to test the effects of a high level (46.4%) of HO-SFM in an attempt to replace soybean meal (**SBM**; Table 2). The determined value of 3,297 kcal of TME_n/kg was used for the ME content of HO-SFM, and NRC [20] nutrient recommendations were considered during formulation of the test diets. Thus, 2 treatments consisting of HO-SFM (46.4%) and SBM (28.6%) were fed to 8 replicates containing 6 male chicks each per pen. The experiment lasted until 19 d of age.

Treatments—Experiment 2

We suspected a negative effect of the high fiber content of HO-SFM during Experiment 1. The fiber content of the corresponding test feed was 6.41 vs. 2.49% in the SBM diet (Table 2).

Table 3. Chemical compositions of experimental diets (Experiment 2)

	Experimental diet (% SFM)	
Ingredient (% of diet as fed)	0	28
High-oil sunflower meal (SFM)	0	28.00
Soybean meal (48%)	33.27	20.01
Poultry by-product meal	3.00	3.00
Corn, grain	55.68	43.14
Poultry fat	4.70	2.65
Dicalcium phosphate	1.28	1.12
Limestone	1.15	1.11
Common salt	0.40	0.40
Vitamin premix[1]	0.25	0.25
Mineral premix[2]	0.08	0.08
L-Lys·HCl	0	0.18
DL-Met	0.20	0.06
Total	100.00	100.00
Calculated analysis		
ME, kcal/kg	3,200	3,200
CP, %	23.00	23.00
Crude fiber, %	2.20	4.91
Ether extract, %	7.35	10.07
Lys, %	1.28	1.28
Met, %	0.54	0.54
Met + Cys, %	0.93	0.93
Thr, %	0.85	0.84
Calcium, %	0.90	0.90
Available phosphorus, %	0.45	0.45

[1]Vitamin premix provided the following (in mg/kg of diet, except as noted): vitamin A as all-*trans*-retinyl acetate), 5,511.5 IU; vitamin D_3, 1,102.3 ICU; vitamin E (all-*rac*-α-tocopheryl acetate), 11; menadione (as menadione sodium bisulfite), 1.1; riboflavin, 4.4; calcium pantotenate, 12; nicotinic acid 44; choline chloride, 220; vitamin B_{12}, 9; vitamin B_6, 3; thiamin (as thiamin mononitrate), 2.2; folic acid, 3; biotin, 0.3; and ethoxyquin, 125.
[2]Trace mineral premix provided 93 ppm Mn (as manganese sulfate); 75 ppm Zn (as zinc sulfate); 18 ppm Fe (as ferrous sulfate); 3 ppm Cu (as copper sulfate); 0.7 ppm I (as calcium iodate); 19 ppm Mg (as magnesium oxide); and 0.3 ppm Se as sodium selenite.

Thus, the density of the test feeds containing HO-SFM and SBM was measured after the termination of the first experiment, and they were found to be 608 and 723 g/L, respectively. Therefore, Experiment 2 was conducted to test the effects of pelleting HO-SFM- and SBM-based diets on feed intake and nutrient use and to investigate if pelleting could overcome the effect of bulkiness in the diet due to high fiber content observed in Experiment 1. Both of the test diets (Table 3) containing HO-SFM and SBM were pelleted in a laboratory-type pelleting unit without steam application. Crude fiber contents of the test diets for HO-SFM and SBM were 4.91 and 2.20%, respectively. The 4 treatments consisted of HO-SFM (28%) vs. SBM (33%) feeds, both as mash

Table 4. Effects of high-oil sunflower meal (SFM) on male broiler performance (Experiment 1, 19 d)[1]

	SFM (48%)	SBM (35%)	*P*-value
Initial weight, g	43.3 ± 1.1	43.0 ± 1.2	0.603
Body weight, g	586.2 ± 41.5[b]	678.3 ± 42.6[a]	0.001
Feed intake, g	711.8 ± 52.3[b]	816.7 ± 43.9[a]	0.001
Weight gain, g	542.9 ± 42.1[b]	635.3 ± 42.4[a]	0.001
Feed/gain	1.311 ± 0.073	1.286 ± 0.035	0.375

[a,b]Means in each row with different subscripts differ significantly ($P < 0.05$).
[1]Means represent 8 replicate pens with each pen having 6 chicks at placement.

Table 5. Effects of high-oil sunflower meal (SFM) on male broiler performance (Experiment 2, 16 d)[1]

Treatment	BW (g)	Feed intake (g)	Weight gain (g)	Feed/gain (g/g)	Mortality[2] (dead birds)
SFM pellet	509.0 ± 16.1[a]	578.5 ± 31.0	464.5 ± 15.9[a]	1.245 ± 0.041	1
SFM mash	470.9 ± 27.1[b]	542.5 ± 38.6	426.5 ± 27.1[b]	1.272 ± 0.057	2
SBM pellet	487.5 ± 20.2[ab]	559.0 ± 30.3	443.3 ± 20.3[ab]	1.261 ± 0.043	2
SBM mash	469.5 ± 13.2[b]	544.8 ± 34.1	425.1 ± 13.0[b]	1.281 ± 0.058	2
Probability					
Feed form (FF)	0.003	0.084	0.002	0.261	
Protein source (PS)	0.174	0.541	0.176	0.550	
FF × PS	0.230	0.438	0.234	0.859	

[a,b]Means in each column with different subscripts differ significantly ($P < 0.05$).
[1]Means represent 6 replicate pens in each pen having 6 chicks at placement.
[2]Mortality data could not be subjected to statistical analysis.

and pelleted. Diets were fed to 6 replicates containing 6 male chicks per pen until 16 d of age.

RESULTS AND DISCUSSION

The results of Experiment 1 revealed significant ($P < 0.05$) differences between the treatments with respect to BW, feed intake, and BW gain at 19 d of age (Table 4). The BW of 19-d-old male chicks in the control group (35% SBM) was 678 g, whereas it was 586 g in the test group (48% SFM). A similar trend was observed in BW gain. Feed intake per bird in the test group was approximately 105 g less than that of the control group. Therefore, there was no significant difference between the 2 groups with respect to feed conversion (1.313 for SBM and 1.286 for SFM, respectively). In Experiment 2 when HO-SFM and SBM diets were pelleted, we observed that the difference between the 2 meals disappeared with regard to BW, feed intake, and BW gain (Table 5). Although pelleting did not significantly affect BW and BW gain in the groups fed with SBM, significant improvement was observed in HO-SFM when pelleted compared with the mash form of HO-SFM or SBM. The BW and gain of the birds fed the mash form of HO-SFM or SBM were almost identical (471 vs. 470 g and 427 vs. 425 g, respectively), whereas birds fed pelleted HO-SFM were significantly heavier than birds fed the mash form of SFM or SBM. The results of Experiment 2 indicated that there was no significant difference between the treatments with respect to feed intake and feed conversion ($P > 0.05$). The main effect of the variation was associated with feed form ($P = 0.003$). Source of protein, however, did not affect the variation. No interac-

Table 6. Effects of high-oil sunflower meal (SFM) on digestive organs, abdominal fat pad and liver lipid accumulation of male broilers (Experiment 1, 19 d)[1]

	SFM (48%)	SBM (35%)	*P*-value
Fat pad,[2] %	1.14 ± 0.23[b]	1.39 ± 0.39[a]	0.031
Liver weight[2]	2.57 ± 0.22	2.72 ± 0.30	0.127
Liver lipid, %	2.74 ± 0.40[b]	3.14 ± 0.33[a]	0.006
Gizzard[2]	2.31 ± 0.29[a]	1.99 ± 0.29[b]	0.004
Proventriculus[2]	0.63 ± 0.07	0.65 ± 0.20	0.670
Intestine[3]	23.84 ± 2.46	22.16 ± 2.25	0.053
Cecum[3]	2.12 ± 0.24[a]	1.92 ± 0.23[b]	0.021
Colon[3]	1.06 ± 0.20[a]	0.93 ± 0.13[b]	0.027

[a,b]Means in each row with different subscripts differ significantly ($P < 0.05$).
[1]Means represent 8 replicate pens in each pen having 6 chicks at placement.
[2]Grams per 100 g of BW.
[3]Centimeters per 100 g of BW.

Table 7. Effects of high-oil sunflower meal (SFM) on digestive organs, abdominal fat pad, and liver lipid accumulation of male broilers (Experiment 2, 16 d)[1]

Treatment	Fat pad[2]	Liver weight[2]	Liver lipid (%)	Gizzard[2]	Proventriculus[2]	Intestine[3]	Cecum[3]	Colon[3]
SFM pellet	1.16 ± 0.25	2.68 ± 0.29^{b}	2.92 ± 0.53^{b}	1.72 ± 0.23^{b}	0.63 ± 0.11	27.4 ± 2.15	2.25 ± 0.12	1.47 ± 0.11
SFM mash	1.07 ± 0.30	2.68 ± 0.18^{b}	2.94 ± 0.34^{b}	2.13 ± 0.46^{a}	0.62 ± 0.10	28.4 ± 4.01	2.39 ± 0.35	1.44 ± 0.18
SBM pellet	1.22 ± 0.30	2.98 ± 0.20^{a}	3.26 ± 0.30^{ab}	1.81 ± 0.26^{b}	0.69 ± 0.19	27.0 ± 2.78	2.31 ± 0.35	1.43 ± 0.17
SBM mash	1.14 ± 0.34	2.99 ± 0.47^{a}	3.35 ± 0.45^{a}	2.18 ± 0.19^{a}	0.66 ± 0.18	28.1 ± 2.58	2.29 ± 0.28	1.45 ± 0.17
Probability								
Feed form (FF)	0.322	0.944	0.638	<0.001	0.612	0.221	0.469	0.612
Protein source (PS)	0.441	0.001	0.003	0.423	0.230	0.688	0.805	0.776
FF × PS	0.943	0.968	0.804	0.838	0.786	0.964	0.311	0.511

[a,b]Means in each column with different subscripts differ significantly ($P < 0.05$).
[1]Means represent 6 replicate pens in each pen having 6 chicks at placement.
[2]Grams per 100 g of BW.
[3]Centimeters per 100 g of BW.

tion effect was detected between feed form and protein source.

Liver lipid accumulation and abdominal fat pad and digestive organ measurements in Experiment 1 demonstrated significant ($P < 0.05$) effects of dietary treatments (Table 6). These effects were not observed in liver and proventriculus weights or intestinal length per 100 g of BW. As shown in Table 6, differences between the HO-SFM and SBM fed groups for liver lipid percentage, gizzard weight, and cecum and colon lengths per 100 g of BW were significant ($P < 0.05$). The HO-SFM tended to increase the length of the intestine ($P = 0.0528$). Fat pad and liver lipid percentages were significantly decreased by the presence of HO-SFM in the diet. Sizes of the gizzard, colon, and cecum were also increased by the presence of HO-SFM.

Experiment 2 clearly shows that pelleting did not significantly affect liver weight or lipid percentage, whereas it significantly decreased gizzard weight (Table 7). However, liver weight and lipid percentage were significantly decreased by the SFM diet compared with the SBM diet. The SFM decreased liver weight and liver lipid content, regardless of the form of the feed as compared with SBM. Gizzard weight was also significantly decreased by pelleting SFM and SBM, indicating a main effect of feed form ($P < 0.001$). No difference was detected between the dietary treatments for proventriculus weight and intestine, cecum, and colon lengths per 100 g of BW. Statistical analysis of liver weight and lipid data indicated that the main sources of variation ($P = 0.001$, $P = 0.003$) were related to protein source. No significant interaction between the main effects was observed (Table 7).

Depressed growth and weight gain in 19-d-old broiler chicks by inclusion of a high level of HO-SFM (46.4%) in a broiler starter diet could be attributed to higher level of crude fiber content. Only feed conversion was not affected by high level of HO-SFM. In the diet containing 46.4% HO-SFM, fiber content was 6.4% as opposed to 2.5% in the SBM-based control diet. The HO-SFM-based diet was considerably less dense than the SBM-based diet (607.3 and 722.5 g/L, respectively); thus, the former diet was approximately 12% more bulky. Similar results have been reported by others [6, 21] in which a strong negative correlation was found between the crude fiber

content and ME digestibilities of the CP and fat of SFM. On the contrary, Hetland and Choct [22] did not regard the insoluble fiber as nutrient diluent in monogastric animal diets. In contrast, they suggested having moderate to high amounts of fiber in chicken diets to enhance gizzard function and to increase bile acids secretions.

Enhanced growth by pelleting the HO-SFM compared to mash feeding HO-SFM or SBM observed in Experiment 2 confirmed the results of Waldroup et al. [23] in which the importance of pelleting was demonstrated. They indicated that dehulled SFM could be included at 30% in broiler starter diets when pelleted. Pelleting the diet was crucial for better broiler performance [24]. The same research group hypothesized that less energy is required to achieve the same food intake because the birds spend less time on eating behaviors. Jensen [25] emphasized that the net energy of the pelleted diet is higher and more protein accretion and fat deposition occur.

Abdominal fat pad, liver lipid accumulation, and digestive organ data obtained from the present experiments support the findings regarding enhanced growth. A high level of HO-SFM significantly increased size of the gizzard and the length of cecum and colon in Experiment 1 (Table 6). The length of the intestine in birds fed with the same diet tended to increase ($P = 0.053$) from 22.2 to 23.8 cm/100 g of BW. However, an effect of increasing the digestive organ size was not observed in Experiment 2 when HO-SFM inclusion was lowered to 28% or pelleted. This lack of consistency might be related to the lower level of CF from 6.41 to 2.49% and from 4.91 to 2.20%, respectively, in the 2 experiments. In contrast, gizzard size decreased when switched to pellet vs. mash feed, regardless of the type of meal ingested. This effect is consistent with the findings of Nir et al. [24] who reported a significant decrease in the size of the gizzard of broiler chicks when fed with pelleted vs. mash feed. Plavnik [26] also reported 50% increase in gizzard size in broilers by feeding 30% whole wheat vs. a pelleted diet. Thus, the decrease in gizzard size in Experiment 2 when feed was pelleted may be attributed to lowered gizzard function and less time spent in the gizzard for mechanical grinding. Hetland et al. [27] reported that addition of oat hulls (10%) or wood shavings (4%) into wheat-based diets resulted in increased gizzard and gizzard content weights, ileal starch digestibility, amylase activity, and bile acid secretion into the jejunum. It has been suggested that insoluble fiber accumulates in the gizzard and is retained longer than other nutrients because it has to be ground to a critical particle size before entering the small intestine. Hetland and Choct [22] suggested that insoluble fiber modulates gut development, digestive function, and gizzard activity; therefore, chickens appear to have a requirement for a certain amount of insoluble fiber that needs to be coarse and insoluble. Hence, inclusion of up to 30% HO-SFM into broiler starter diets level might meet bird requirements for insoluble fiber, as it accounts for approximately 3% in HO-SFM.

Significant decreases in the liver lipid accumulation, liver weight, and tendency of lower abdominal fat in the same test group (Tables 6 and 7) may be associated with the inhibition of lipid synthesis in liver and abdominal tissue due to high fiber content of the test diet. It was evident that fiber has a detrimental effect on fat digestion, particularly in young chicks. Akiba and Matsumoto [28] suggested that dietary fibers have certain roles in lipid metabolism through changes in lipid synthesis in the liver and enzyme activity in the adipose tissue. They reported that dietary fiber reduces hepatic lipogenesis and triglyceride synthesis and accelerates lipoprotein lipase activity in the adipose tissue. This effect might be of prime importance in laying hens with respect to prevention of fatty liver syndrome.

The results of the present study suggest that at a very high inclusion level (46.4%), HO-SFM becomes bulky feed and might lead to a dietary nutrient dilution in young chicks because their digestive tracts are limited in capacity. However, at 20 to 30%, it works as effectively as SBM in the starter diets of young chicks. This level might even meet the insoluble fiber requirement (as recently shown) [22] of broiler chicks for enhanced gizzard function and broiler livability when given in mash form. Moreover, pelleting the HO-SFM diet had a significant positive effect on the performance of the broiler chicks compared with mash form of SBM or SFM.

CONCLUSIONS AND APPLICATIONS

1. Up to 28% HO-SFM can be included in a diet without detrimental effect.
2. Pelleting the feed overcomes the bulkiness associated with high fiber level in the HO-SFM.
3. Modification in the size of the digestive organs may occur depending on pelleting or fiber levels of the feed.
4. The HO-SFM decreases liver lipids and abdominal fat; therefore, it may be a means of producing leaner broiler meat.

REFERENCES AND NOTES

1. Petit, J. H., S. J. Slinger, E. V. Evans, and F. N. Marcellus. 1944. The utilisation of sunflower seed oil meal, wheat distillers' dried grains, and rapeseed oil meal in poultry rations. Sci. Agric. 24:201–213.

2. Senkoylu, N., and N. Dale. 1999. Sunflower meal in poultry diets: A review. World's Poult. Sci. J. 55:153–174.

3. McGinnis, J., P. T. Hsu, and J. S. Carver. 1948. Nutritional deficiencies of sunflower oil meal for chicks. Poult. Sci. 27:389–393.

4. Zhang, Y., and C. M. Parsons. 1994. Effects of over processing on the nutritional quality of sunflower meal. Poult. Sci. 73:436–442.

5. Roth-Maier, D. A., and M. Kirchgessner. 1995. Feeding of full-fat flax seed and sunflower seed to fattening chickens. Arch. Geflügelkd. 59:319–322.

6. Villamide, M. J., and L. D. San Juan. 1998. Effect of chemical composition of sunflower seed meal on its true metabolizable energy and amino acid digestibility. Poult. Sci. 77:1884–1892.

7. Irish, G. G., and D. Balnave. 1993. Non-starch polysaccharides and broiler performance in diets containing soybean meal as the sole protein concentrate. Aust. J. Agric. Res. 44:1483–1499.

8. Düsterhöft, E. M., M. A. Posthumus, and A. G. J. Voragen. 1997. Non-starch polysaccharides from sunflower (*Heliantus annus*) meal and palm kernel (*Elaeis guinensis*) meal investigation of the structure of major polysaccharides. J. Sci. Food Agric. 59:151–160.

9. Choct, M., and A. Kocher. 2000. Use of Enzymes in non-creal grain feedstuffs. Proc. XXI World's Poult. Congr. WPSA, Montreal, Canada.

10. Sorensen, P. 1996. Sunflower + enzymes = soybean? Feed Int. 12:24–28.

11. El-Sherif, K. H., D. Gerendai, and T. Gippert. 1997. Complete substitution of sunflower meal for soybean meal with or without enzyme supplementation in broiler rations. Arch. Geflügelkd. 61:8–14.

12. Zatari, I. M., and J. L. Sell. 1990. Sunflower meal as a component of fat-supplemented diets for broiler chickens. Poult. Sci. 69:1503–1507.

13. Nir, I. 1998. Optimal use of feed ingredients in poultry. TUYEM 1998, Annu. Mtg. Turkish Feed Ind. Assoc. Nevsehir, Turkey.

14. Senkoylu, N., C. Polat, H. Akyurek, H. E. Samli, E. Erten, and A. Kayhan. 1997. The effects of high energy high protein sunflower meal on broiler performance. Pages 331–333 in Proc. 11th Eur. Symp. Poult. Nutr. WPSA, Faaborg, Denmark.

15. Gerhard, N. F., and J. F. Miller. 1997. Sunflower breeding. Pages 441–558 in Sunflower Technology and Production. A. A. Scneiter, ed. Am. Soc. Agron., Madison, WI.

16. Parsons, C. M., L. M. Potter, and B. A. Bliss. 1982. True metabolizable energy corrected to equilibrium. Poult. Sci. 61:2241–2246.

17. Aviagen Ltd. 2001. Ross Breeders Broiler Management Manual. Avaigen Ltd., Newbridge, Midlothian, Scotland, UK.

18. Folch, J., M. Lees, and G. H. S. Stanley. 1957. A simple method for the isolation and purification of total lipids from animal tissues. J. Biol. Chem. 226:497–509.

19. SAS Institute. 1990. SAS STAT User's Guide Release 6.08. SAS Institute Inc., Cary, NC.

20. NRC. 1994. Nutrient requirements of poultry. 9th rev. ed. Natl. Res. Counc., Natl. Acad. Press, Washington, DC.

21. Janssen, W. M. M. A., and B. Carre. 1985. Influence of fibre on digestibility of poultry feeds. Pages 71–86 in Recent Advances in Animal Nutrition. W. Haresign and D. J. A. Cole, ed. Butterworths, London, UK.

22. Hetland, H., and M. Choct. 2003. Role of insoluble non-starch polysaccharides in poultry nutrition. Pages 64–69 in Proc. 14th Eur. Symp. Poult. Nutr. WPSA, Lillehammer, Norway.

23. Waldroup, P. W., C. M. Hillard, and R. J. Mitchell. 1970. Sunflower meal as a protein supplement for broiler diets. Feedstuffs. 42(Oct. 24):41.

24. Nir, I., Y. Twina, E. Grossman, and Z. Nitsan. 1994. Quantitative effect of pelleting on performance, gastrointestinal tract and behavior of meat-type chickens. Br. Poult. Sci. 35:589–602.

25. Jensen, L. S. 1998. Pellet quality and performance of broilers. Dept. Poult. Sci., Univ. Georgia, Athens, personal communication.

26. Plavnik, I. 2003. The use of feed technology to optimize feed structure and bird performance. Pages 1–6 in 14th Eur. Symp. Poult. Nutr. WPSA, Lillehammer, Norway.

27. Hetland, H., B. Svihus, and V. Olaisen. 2002. Effect of feeding whole cereals on performance, starch digestibility and duodenal particle size distribution in broiler chickens. Br. Poult. Sci. 43:416–423.

28. Akiba, Y., and T. Matsumoto. 1982. Effects of several types of dietary fibers on lipid content in liver and plasma, nutrient retentions and plasma transaminase activities in force-fed growing chicks. J. Nutr. 110:1112–1121.

Acknowledgment

Grateful appreciation is expressed by the senior author to both the Fulbright Commission and the University of Georgia in Athens for their scholarships to support this research study.