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The influences of feeding broilers on graded inclusion of sunflower meal with or without Avizyme on growth, protein and energy efficiency, carcass traits, and nutrient digestibility

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Abstract: The present study aimed to investigate the substituting effect of sunflower meal (SFM) for soybean meal (SBM) with or without supplemental Avizyme on growth performance, protein and energy efficiency ratios, carcass traits, and nutrient digestibility of broiler chickens. A 4 × 2 factorial design experiment was conducted with four levels of SFM replacing SBM (0%, 25%, 50%, 75%) and two levels of supplemented Avizyme (0 or 0.1 g/kg diet). Results revealed that increasing SFM substitution for SBM up to 50% was associated with an increase in body weight ($P < 0.01$). Daily weight gain was statistically ($P < 0.01$) enhanced with increasing SFM up to 50% through 22 to 42 and 7 to 42 days of age. Feed conversion ratio improved ($P < 0.01$) in groups given SFM at 25% and 50% compared to the control. No carcass values were affected by SFM inclusion or Avizyme. The inclusion of 25% or 50% SFM increased ($P < 0.01$) protein efficiency at periods of 7–21 and 22–42 days of age. Energy efficiency ratio improved ($P < 0.01$) due to SFM incorporation at levels of 25% or 50% in all periods. The interaction effect between SFM and Avizyme was not significant on a majority of studied parameters. The digestion coefficients of crude fiber, N-free extract, and organic matter increased ($P < 0.05$ or $P < 0.01$) with increased levels of SFM. In conclusion, the incorporation of SFM as a substitute for SBM in broiler diets improved the growth performance of broilers. The use of SFM up to 50% without Avizyme supplementation could be recommended in broiler diets from 7 to 42 days of age.

Key words: Sunflower meal, enzyme, broilers, growth, carcass, digestibility

1. Introduction

It is well known that prices of poultry meat are lower than those of other meats and this created a high demand for poultry meat in many countries around the world within the last few years. Many factors affect costs of poultry production, such as feed price, feed fed amount, crude protein content of feed, and the biological value of nutrients. Because of the limited resources of feedstuffs in developing countries and increasing demand for soybean meal (SBM) as a main source for crude protein, feeding costs have tended to increase (1). The use of untraditional feedstuffs in poultry diets has received great attention in developing countries. Sunflower meal (SFM) is defined as a by-product of the sunflower oil industry (2). The chemical composition of sunflower meal mainly depends on some factors like the seed, the method of processing, and the degree of decortication. SFM contains about 33%–37% crude protein and 18%–23% fiber contents. The meal is a mixture of hulls and kernel in a ratio about 40%/60% as described by Lević et al. (3). The major challenge of the inclusion of SFM in diets of broilers is its high content of fibers (4), which has negative impacts on growth and carcass traits. To solve this problem, certain synthetic enzymes like phytase and β-glucanase could be added to broiler diets having SFM to help in the digestion of fibers and to decrease their negative effect on growth parameters of broiler chickens. Lipiec (5) stated that SFM can be successfully used in the nutrition of monogastric animals at levels of 50–150 g/kg diet. Alagawany et al. (6) reported that there are many factors encouraging the use of SFM in poultry nutrition, like its cheap price compared to SBM and being free from antinutritional factors and toxic molecules. The aforementioned authors reported that SFM as an alternative feedstuff could be utilized profitably at levels of 200 g/kg of broiler diets without any harmful effects on growth and carcass yield. Using enzymes could be a practical way to enhance performance and improve utilization of higher levels of agroindustry

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by-products in poultry nutrition (1). Multiple enzymes involving α-amylase, β-glucanase, cellulase, pectinase, hemicellulase, and xylanase with or without phytase and protease could enhance feed utilization and fight the antinutritional factors in feedstuffs. Enzymes could also improve immune response and gut health (7). The present investigation aimed to evaluate the effects of substituting SBM with SFM with or without Avizyme supplementation on growth performance traits, carcass traits, and nutrient digestibility of broilers.

2. Materials and methods

The present investigation was performed at the Poultry Research Farm of the Department of Poultry, Agriculture College, University of Zagazig, Egypt. All procedures of the experiment were performed with reference to the Committee of Local Experimental Animal Care and approved by the ethics committee of our Poultry Department Institutional Committee, Agriculture College, University of Zagazig, Egypt.

2.1. Birds, experimental design, management, and diets

A total of 240 unsexed 1-week-old broiler chicks (Hubbard) were randomly divided into eight treatment groups of 30 chicks each in five replicates of six chicks per replicate. There were no significant differences among experimental chicks in initial live body weight. A 4 × 2 factorial design was conducted with four levels of SFM (0%, 25%, 50%, and 75%) replacing SBM as a proportion of SBM level in the diet and two levels of dietary enzyme (Avizyme 1500) supplementation (0 or 0.1 g/kg diet) throughout the rearing period (7–42 day of age). Four experimental diets without enzyme supplementation were formulated in which SFM was incorporated into the diet as a substitute for SBM at levels of 0%, 25%, 50%, and 75% and the other four diets contained SFM at the same levels supplemented with Avizyme at the level of 0.10 g/kg diet. Analysis of SFM used in the present study revealed 90.31% dry matter, 6.29% ash, 32.50% crude protein, 7.11% ether extract, and 21.5% crude fiber. Avizyme 1500 contained enzymes produced by strains of *Trichoderma* and *Bacillus* and had xylanase, protease, and amylase activity. Avizyme 1500 (Danisco Animal Nutrition, UK) contained 300 U g^{-1} xylanase, 4000 U g^{-1} protease, and 400 U g^{-1} amylase. The experimental diets were formulated to be isocaloric and isonitrogenous (4) during the starter (7–21 day of age) and finisher (22–42 days of age) periods (Table 1). Birds were housed in traditional cages (40 × 40 × 40 cm), supplied with water and feed ad libitum, and fed a diet formulated to meet nutrient requirements (Table 1). The lighting program was 23 h light + 1 h darkness.

2.2. Performance traits

Chicks were weighed on an individual basis at weekly intervals. Total feed intake was measured weekly per pen. Feed intake (FI), feed conversion ratio (FCR) (feed intake g/weight gain g), and protein efficiency ratio (PER) (weight gain g/total protein consumed g) were calculated.

2.3. Carcass traits

Five birds from each experimental group were randomly sampled for carcass evaluation at 42 days of age, slaughtered, weighed, and manually plucked and then eviscerated. The whole carcass, empty gizzard, heart, and liver were excised and weighed individually. The carcass yield was calculated as a percentage of the preslaughter body weights of broilers.

2.4. Digestibility trials

Six birds from each treatment group were housed individually in metabolic cages (pens). Birds were weighed before and after collection period to assure that birds were maintaining their weight. Experimental diets and water were offered ad libitum using fixed containers. The collection period was 3 days. Excreta collection started 24 h after commencement of the collection period. The proximate analyses of tested material, feeds, and dried excreta were carried out according to AOAC (8) for determination of DM (ID 930.15), OM (ID 942.05), CP (ID 954.01), EE (ID 945.16), and CF (ID 978.10).

A procedure using trichloroacetic acid was adopted for estimating the fecal nitrogen. Urinary nitrogen was determined by difference (excreta N – fecal N) while urinary organic matter was determined according to the following equation:

Urinary organic matter (UOM) = urinary N × 2.62.

The percentage of urinary organic matter in the feces was added to the sum of its other components (fecal CP % + EE % + CF % and ash %) to calculate the fraction of nitrogen-free extract by difference:

For feed: 100 – (Moisture % + CP % + EE % + CF % + Ash %).

For feces: 100 – (fecal moisture % + CP % + EE % + CF % + Ash % + UOM %).

The dry matter consumed and excreta and their percentage analyses were used to calculate the digestion coefficients of different nutrients.

2.5. Statistics

Using ANOVA and SPSS, data were analyzed in a 4 × 2 factorial design. The model used involved the impacts of SFM and Avizyme and the interaction impacts, as well:

$$Y_{ijk} = \mu + A_i + S_j + AS_{ij} + e_{ijk},$$

where Y_{ijk} = an observation, μ = the overall mean, A_i = effect of SFM levels (i = 0%, 25%, 50%, and 75%), S_j = effect of Avizyme addition (j = 0 and 0.1 g/kg diet), AS_{ij} = interaction effect between SFM levels and Avizyme supplementation (j = 1, 2, …, 9) and e_{ijk} = random error. Differences among means were calculated by post hoc Newman–Keuls tests. Statements of statistical significance are based on $P < 0.05$ unless otherwise stated.

Table 1. The ingredients and experimental diets of broiler chickens during the starter and finisher phases.

Items	SFM[1] levels as substitute for SBM (%)							
	Starter diets				Finisher diets			
	0	25	50	75	0	25	50	75
Ingredient composition (g/kg; as-fed basis)								
Maize	576	560	544	529	647	637	625	614
Soybean meal	300	225	150	75.0	200	150	100	50.0
Maize gluten meal	46.2	62.0	69.0	76.0	41.8	52.4	63.0	74.0
Sunflower meal	0.0	75.0	150	225	0.0	50	100	150
Fish meal	30.0	30.0	40.0	50.0	50.0	50.0	50.0	50.0
Di-calcium phosphate	13.0	10.0	0.60	1.50	11.2	9.50	7.40	5.50
Limestone	10.7	12.7	13.8	15.1	9.90	10.5	12.5	13.7
Premix[2]	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
NaCl	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
$_{DL}$-Methionine	1.4	1.4	1.4	1.3	0.1	0.0	0.1	0.0
$_{L}$-Lysine	1.4	3.1	4.3	5.6	1.0	2.1	3.2	4.3
Soybean oil	15.5	14.8	15.5	15.5	33	32.5	32.8	32.5
Calculated analysis (g/kg)[3]								
Crude protein	230	230	230	230	200	201	200	200
ME (MJ/kg)	12.5	12.5	12.5	12.5	13.4	13.4	13.4	13.4
Calcium	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Available P	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
Lysine	13.1	13.2	13.1	13.1	11.2	11.1	11.2	11.1
Methionine+cystine	9.21	9.22	9.21	9.23	7.21	7.22	7.21	7.22
Crude fiber	34.3	51.4	68.4	85.4	33.8	40.2	51.6	63.1
Linoleic acid	13.8	13.2	12.5	12.9	15.1	14.6	14.1	13.7
Determined analysis (g/kg)[4]								
Dry matter	842	871	862	855	879	887	886	890
Ash	65.6	69.6	73.9	83.5	50.1	60.7	61.1	63.5
Crude protein	230	230	232	230	214	201	202	200
Ether extract	75.4	67.4	71.1	96.1	57.5	58.8	58.6	73.1
Crude fiber	47.4	46.2	58.1	77.9	37.5	40.3	48.8	60.2

[1]SFM: sunflower meal.
[2]Growth vitamin and mineral premix: each 2.5 kg consists of Vit A, 12,000,000 IU; Vit D3, 2,000,000 IU; Vit E, 10 g; Vit K3, 2 g; Vit B, 1000 mg; Vit B2, 49 g; Vit B6, 105 g; Vit B12, 10 mg; pantothenic acid, 10 g; niacin, 20 g, folic acid, 1000 mg; biotin, 50 g; choline chloride, 500 mg, Fe, 30 g; Mn, 40 g; Cu, 3 g; Co, 200 mg; Si, 100 mg; and Zn, 45 g.
[3]Calculated according to the NRC (4).
[4]Analyzed according to the AOAC (8).

3. Results and discussion

3.1. Live body weight and body weight gain

Data presented in Table 2 show that the averages of initial live body weight at 7 days of age were not significantly different among groups and ranged between 124.16 and 125.33 g, indicating the random distribution of individuals among the treatment groups at the beginning of experiment. At 21 days of age, SFM levels had an insignificant effect on live body weight, while at 42 days of age, live body weight was significantly ($P < 0.01$) increased with increasing SFM up

Table 2. Growth performance traits (mean ± SE) of broiler chickens as affected by sunflower meal levels, enzyme supplementation, and their interaction.

Items	0%		25%		50%		75%		SFM effect	E effect	SFM × E
	–E	+E	–E	+E	–E	+E	–E	+E			
Live body weight (g)											
Day 7	123.86 ± 0.34	126.00 ± 0.28	123.88 ± 0.16	124.50 ± 1.04	124.66 ± 0.66	125.16 ± 0.60	126.33 ± 0.72	124.33 ± 0.88	NS	NS	NS
Day 21	557.33 ± 17.57	603.33 ± 8.81	605.50 ± 21.42	586.33 ± 21.90	556.66 ± 9.79	597.16 ± 9.67	566.16 ± 3.84	567.50 ± 13.75	NS	NS	NS
Day 42	1874.00 ± 30.08	2026.66 ± 14.52	2026.66 ± 17.63	2168.66 ± 16.17	2053.33 ± 23.33	2164.00 ± 27.15	1867.00 ± 18.82	2023.33 ± 20.27	**	**	NS
Body weight gain (g)											
7–21 days	30.96 ± 1.26	34.09 ± 0.60	34.40 ± 1.51	32.98 ± 1.53	30.85 ± 0.68	33.71 ± 0.68	31.41 ± 0.31	31.65 ± 0.92	NS	NS	NS
22–42 days	62.69 ± 2.22	67.77 ± 0.57	67.67 ± 1.85	75.34 ± 1.62	71.27 ± 1.29	74.61 ± 1.43	61.94 ± 1.52	69.32 ± 1.52	**	**	NS
7–42 days	50.00 ± 0.85	54.30 ± 0.41	54.36 ± 0.50	58.40 ± 0.49	55.10 ± 0.65	58.52 ± 0.75	49.73 ± 0.51	54.25 ± 0.60	**	**	NS
Feed intake (g)											
7–21 days	56.31 ± 2.94	55.71 ± 0.41	56.23 ± 0.99	54.28 ± 0.82	56.40 ± 0.16	56.66 ± 2.27	55.35 ± 0.74	55.95 ± 1.03	NS	NS	NS
22–42 days	130.87 ± 2.42	114.28 ± 2.97	114.65 ± 0.17	114.60 ± 2.82	121.17 ± 6.05	118.57 ± 2.44	131.58 ± 2.78	125.87 ± 2.96	**	*	NS
7–42 days	101.04 ± 2.11	90.85 ± 1.94	91.28 ± 0.45	90.47 ± 1.48	95.26 ± 3.56	93.81 ± 1.87	101.09 ± 1.75	97.90 ± 1.92	**	*	NS
Feed conversion ratio (g feed/ g gain)											
7–21 days	1.83 ± 0.16	1.63 ± 0.03	1.63 ± 0.04	1.65 ± 0.07	1.83 ± 0.04	1.68 ± 0.08	1.76 ± 0.03	1.77 ± 0.07	NS	NS	NS
22–42 days	2.09 ± 0.07	1.68 ± 0.05	1.69 ± 0.04	1.52 ± 0.06	1.70 ± 0.08	1.59 ± 0.04	2.12 ± 0.07	1.81 ± 0.06	**	**	NS
7–42 days	2.02^{a} ± 0.03	1.67^{b} ± 0.04	1.68^{b} ± 0.02	1.55^{c} ± 0.03	1.72^{b} ± 0.05	1.61^{c} ± 0.02	2.03^{a} ± 0.05	1.80^{ab} ± 0.03	**	**	*

Means in the same column within each classification bearing different letters are significantly different ($P \leq 0.05$).

to 50% in substitution for SBM in broiler diets regardless of Avizyme supplementation. In comparison with the control group, the average live body weights of broiler chickens given diets containing SFM at 25% or 50% replacing SBM were heavier by about 7.53% and 8.10%, respectively, while chickens given diets containing SFM at 75% were similar to the controls. Our results are in line with those obtained by Suresh et al. (9), who found no harmful impacts of sunflower seed hulls at up to 50 and 120 g/kg in the diet of broilers. Nassiri Moghaddam et al. (10) confirmed that SFM can be included in broiler rations (up to 140 g/kg) without any negative influences on growth performance or other traits.

Concerning body weight gain, the results in Table 2 indicate that body weight gain was statistically ($P < 0.01$) improved with increasing SFM up to 50% as substitution for SBM in broiler chicken diets through the finisher period (22 to 42 days of age) and throughout the overall period (7 to 42 days of age). However, increasing SFM in the diets from 50% to 75% resulted in a significant ($P < 0.01$) decrease in body weight gain when compared with the other dietary treatment groups (25% or 50% SFM). These findings are in agreement with those obtained by Rajesh et al. (11), who stated that growth parameters including body weight and weight gain showed that SFM could be incorporated into broiler diets at a level of 30% with no negative effect on growth performance traits.

In the same context, Salih and Taha (12) postulated that weight gain was the same in all broiler groups fed diets including different incorporation rates of SFM (0%, 10%, 20%, or 40%). Contrarily, Pinheiro et al. (13) claimed that the inclusion of SFM by more than 12% led to decreased broiler weight gain. Using low inclusion levels of SFM (6% and 8%) in grower diets of broilers did not affect growth parameters, while increasing the level up to 10%–16% in finisher diets affected ($P < 0.05$) body weight gain values (14).

Live body weight at 42 days of age and body weight gain during both periods (22 to 42 and 7 to 42 days) were significantly ($P < 0.01$) improved by Avizyme (0.1 g/kg) supplementation in broiler diets compared with the unsupplemented diet (Table 2). The findings of the present study are in line with the results of Goli and Shahryar (15), who observed an improvement in broiler and quail chicks' growth performance with enzyme supplementation of diets including high levels of fiber.

There were no significant differences among the treatment groups due to the interaction effects between dietary SFM level and Avizyme supplementation on live body weight at all ages studied, but it could be noticed that at 25% and 50% SFM level with Avizyme supplementation in the diets higher body weight and body weight gain were obtained than in other diets. Contrarily, Mushtaq et al. (16) found that enzyme supplementation in SFM-based diets through the first 2 weeks after hatching did not have a remarkable effect on broilers. Several investigations on the use of synthetic enzymes in diets of broilers showed improvements in the growth performance and nutrient availability of broiler chickens (1,7).

3.2. Feed intake and feed conversion

Results in Table 2 reveal that the inclusion of SFM at a level of 75% in broiler chicken diets significantly ($P < 0.01$) increased feed intake as compared with the birds fed diets containing 25% and 50% SFM as a substitution for SBM from 22 to 42 and 7 to 42 days of age. Adejumo and Williams (17) found that increasing the dietary SFM level from 0% to 75% increased broilers' feed intake from 420 to 520 g/week, respectively.

For feed conversion ratio, it is clear that the high (75%) level of SFM had the worst value of feed conversion ratio in comparison with any other level (Table 2). Contrarily, Salari et al. (18) pointed out that feed consumption and feed efficiency improved when broilers were given sunflower seed inclusion in the starter and finisher diets.

Results in Table 2 indicate that feed intake was significantly ($P < 0.05$) lower in Avizyme-treated groups than untreated groups. Feed conversion was also significantly ($P < 0.01$) better in birds fed diets supplemented with Avizyme than the controls (Table 2). Petterson and Aman (19) demonstrated that Avizyme supplementation can partially degrade feed endosperm cell walls and give rapid digestion for protein, starch, and other nutrients, consequently increasing feed intake and improving feed efficiency. Amerah et al. (20) found that dietary enzyme addition enhanced ($P < 0.05$) FCR compared with unsupplemented diets, which is in agreement with the present study.

The effect of dietary SFM × Avizyme supplementation was not significant on feed intake and feed conversion ratio through the different experimental periods, except feed conversion throughout the overall period. The best feed conversion (1.55 g feed/g gain) was achieved by birds fed a diet containing 25% SFM supplemented with 0.1 g/kg Avizyme while the worst FCR (2.03 g feed/g gain) was found for birds receiving 75% SFM without Avizyme supplementation throughout the overall period.

3.3. Protein and energy efficiency ratios

Results in Table 3 show that protein efficiency was significantly ($P < 0.01$) influenced by SFM inclusion in broiler diets at all periods studied except the whole experimental period (7–42 days of age). From 7 to 21 and 22 to 42 days of age, results indicated that the inclusion of SFM at levels of 25% or 50% in broiler chick diets significantly ($P < 0.01$) increased protein efficiency as compared with chicks fed diets containing 0% or 75% SFM as substitution for SBM. The best value of protein

Table 3. Protein efficiency and energy efficiency ratio (mean ± SE) of broiler chickens as affected by sunflower meal levels, enzyme supplementation, and their interaction.

Items	0%		25%		50%		75%		SFM effect	E effect	SFM × E
	–E	+E	–E	+E	–E	+E	–E	+E			
Protein efficiency ratio (g gain/g protein)											
7–21 days	2.34 ± 0.08	2.74 ± 0.07	2.73 ± 0.04	2.88 ± 0.03	2.59 ± 0.04	2.79 ± 0.04	2.35 ± 0.03	2.54 ± 0.03	**	**	NS
22–42 days	2.28 ± 0.08	2.82 ± 0.08	2.81 ± 0.07	3.13 ± 0.13	2.80 ± 0.13	2.99 ± 0.09	2.24 ± 0.08	2.62 ± 0.08	**	**	NS
7–42 days	2.41 ± 0.23	2.66 ± 0.06	2.65 ± 0.07	2.64 ± 0.11	2.37 ± 0.05	2.59 ± 0.12	2.46 ± 0.05	2.46 ± 0.11	NS	NS	NS
Energy efficiency ratio											
7–21 day	18.51 ± 1.77	20.40 ± 0.48	20.37 ± 0.55	20.25 ± 0.86	18.23 ± 0.45	19.90 ± 0.97	18.92 ± 0.41	18.88 ± 0.85	NS	NS	NS
22–42 day	15.46 ± 0.57	19.16 ± 0.60	19.04 ± 0.53	21.25 ± 0.91	19.05 ± 0.91	20.31 ± 0.61	15.20 ± 0.55	17.78 ± 0.59	**	**	NS
7–42 day	16.98 ± 0.69	19.78 ± 0.52	19.70 ± 0.02	20.75 ± 0.20	18.64 ± 0.26	20.11 ± 0.31	17.06 ± 0.27	18.33 ± 0.26	**	**	NS

Means in the same column within each classification bearing different letters are significantly different (P ≤ 0.05).

efficiency was achieved by chicks fed a diet that contained 25% SFM in comparison with the other groups. Eklund et al. (21) reported that lysine supplementation improved the protein efficiency ratio of SFM from 2.16 to 3.3.

The energy efficiency ratio was statistically ($P < 0.01$) improved due to SFM incorporation at levels of 25% or 50% instead of SBM in broiler diets compared to the control group at all periods (except 7–21 days old). The highest substitution level of SFM (75%) gave the lowest energy efficiency ratio compared to other substitution levels (Table 3). Our results partially agree with those obtained by Sherif et al. (22), who pointed out that SFM in broiler chicken diets at levels of 10%, 15%, and 20% instead of SBM did not affect protein consumption, protein efficiency, or daily metabolizable energy intake when compared with the control.

Results indicated that both protein and energy efficiencies were significantly ($P < 0.01$) improved as the diets were supplemented with Avizyme. Contrary to our results, Sherif et al. (22) observed no beneficial impacts for enzyme supplementation on protein efficiency ratio. Poultry and monogastric animals do not have an endogenous capacity to digest fiber, and therefore the use of exogenous enzymes is important as they hydrolyze nonstarch polysaccharides that can potentially be used by the animals, improving, for instance, energy use (23).

The effects of dietary SFM × Avizyme supplementation were not significant on protein or energy efficiency ratios at any of the ages studied. The obtained data are in line with those reported by Sherif et al. (22), who reported that there were no beneficial effects of broiler sunflower diets supplemented with enzyme on protein and energy efficiency throughout the experimental period (18–46 days of age). In the same context, Oliveira et al. (24) evaluated two levels of SFM (0% and 15%) with or without enzyme complex (protease, cellulase, and amylase) in the diet of 21- to 42-day-old broilers and did not find any significant interactions between SFM and the enzyme complex.

3.4. Carcass traits

As illustrated in Table 4, carcass, dressing, and giblet percentages were not significantly affected by SFM inclusion levels or enzyme supplementation. Our findings are partially in line with those reported by Horvatovic et al. (14), who found that the inclusion of SFM in broiler diets did not have any impact on carcass yield of broilers.

For the effect of Avizyme, similar to our results, Horvatovic et al. (14) observed that exogenous enzyme supplementation to broiler diets had no any impact on carcass yield of broilers. Likewise, Mushtaq et al. (25) did not notice any response to synthetic enzymes on carcass traits. Also, in accordance with our results, Rabie and Abo El-Maaty (26) found that enzyme addition did not significantly affect carcass traits of Japanese quail.

Only carcass and dressing percentages were significantly ($P < 0.05$) impacted due to the interaction between SFM levels and supplementation. The highest values of carcass (69.69%) and dressing (75.54%) were achieved with the diet containing 75% SFM without Avizyme supplementation, but the lowest percentages were recorded with 50% SFM with Avizyme supplementation throughout the experiment. These findings partially agree with those of Horvatovic et al. (14), who found no impact of SFM inclusion with or without Avizyme addition on carcass yield ($P < 0.05$). Moreover, no interaction effects

(P > 0.05) between SFM level and Avizyme could be noticed for any of the studied parameters (20). Similarly, Mushtaq et al. (25) did not observe any impact of SFM and exogenous enzymes on carcass traits.

3.5. Nutrient digestibility

Digestibility of ether extract, dry matter, and crude protein was not statistically (P > 0.05) different due to dietary SFM level (Table 5). The nutrient digestibility and nutritional value of any feedstuff are increased in the absence of antinutritional factors. The physiological and nutritional importance of dietary fiber lies in its ability to reduce the digestion, diffusion, and absorption of nutrients in the gut. In the current study, the digestion coefficients of crude fiber, organic matter, and nitrogen-free extract were statistically (P < 0.05 or P < 0.01) increased with increasing SFM from 25% to 50% to 75% as SBM substitution. However, SFM inclusion in broiler diets up to 25% as substitution for SBM did not influence digestion coefficients of the aforementioned nutrients as compared with the control. These results partially agree with Ali et al. (2), who found that the digestibility of crude protein, crude fat, crude fiber, and organic matter were not significantly (P < 0.05) altered by SFM treatments, while nitrogen-free extract was lowered by 82.5% and 82.4% with chicks fed diets incorporated with 2.5% and 5.0% SFM, respectively, as compared with the control group. The discrepancy in these results may be due to different sources and production methods of SFM (6). It is of great importance to note that results of digestion coefficient traits coincided generally with growth performance, where chicks fed 25% or 50% SFM as a substitute for SBM showed the highest growth performance compared to other treatments.

Regarding dietary enzyme supplementation, the averages of digestion coefficient values of all nutrients (organic matter, dry matter, crude protein, nitrogen-free extract, and crude fiber) were statistically (P < 0.01) improved when birds were fed diets supplemented with enzyme (0.1 g/kg) compared with unsupplemented diets (Table 5). These findings could be due to the action of exogenous enzymes directly/indirectly by providing a better environment in the gut for the endogenous intestinal enzymes to move more freely. Improving the nutritive

Table 4. Carcass traits (mean ± SE) of broiler chickens as affected by sunflower meal levels, enzyme supplementation, and their interaction.

Items	0%		25%		50%		75%		SFM effect	E effect	SFM × E
	−E	+E	−E	+E	−E	+E	−E	+E			
Carcass traits (% of carcass weight)											
Carcass	$66.97^{b} \pm 1.61$	$67.52^{ab} \pm 0.41$	$65.53^{b} \pm 0.27$	$68.83^{a} \pm 0.35$	$68.37^{a} \pm 0.26$	$64.69^{c} \pm 1.02$	$69.69^{a} \pm 0.35$	$67.17^{ab} \pm 0.33$	NS	NS	**
Dressing	$73.65^{ab} \pm 1.12$	$73.29^{ab} \pm 0.68$	$71.84^{bc} \pm 0.60$	$74.37^{a} \pm 0.66$	$74.36^{a} \pm 0.72$	$70.33^{c} \pm 0.90$	$75.54^{a} \pm 0.64$	$72.94^{b} \pm 0.58$	NS	NS	**
Giblets	6.68 ± 0.52	5.77 ± 0.30	6.30 ± 0.41	5.54 ± 0.32	5.99 ± 0.49	5.64 ± 0.11	5.85 ± 0.30	5.77 ± 0.32	NS	NS	NS
Means in the same column within each classification bearing different letters are significantly different (P ≤ 0.05).											

Table 5. Nutrient digestibility (mean ± SE) of broiler chickens as affected by sunflower meal levels, enzyme supplementation, and their interaction.

Items	0%		25%		50%		75%		SFM effect	E effect	SFM × E
	−E	+E	−E	+E	−E	+E	−E	+E			
Digestibility coefficients (%)											
DMD	78.59 ± 1.69	74.62 ± 1.12	76.04 ± 2.68	73.20 ± 0.08	81.27 ± 4.65	73.43 ± 0.61	81.82 ± 1.73	80.11 ± 1.31	NS	*	NS
OMD	81.28 ± 1.49	78.03 ± 0.95	79.95 ± 2.23	77.12 ± 0.10	84.32 ± 3.89	77.07 ± 0.53	85.07 ± 1.38	83.21 ± 1.08	*	*	NS
CPD	78.88 ± 5.85	60.56 ± 2.66	66.13 ± 8.39	60.99 ± 2.84	77.67 ± 6.80	63.39 ± 5.59	74.58 ± 1.09	74.76 ± 3.17	NS	*	NS
EED	81.84 ± 1.19	80.27 ± 0.51	77.59 ± 2.95	77.69 ± 0.17	78.63 ± 5.43	76.29 ± 1.34	81.07 ± 1.61	79.16 ± 1.48	NS	NS	NS
CFD	21.86 ± 0.68	18.45 ± 0.68	19.24 ± 0.68	18.62 ± 0.68	21.55 ± 0.68	19.71 ± 0.68	23.07 ± 0.68	22.65 ± 0.68	**	**	NS
Means in the same column within each classification bearing different letters are significantly different (P ≤ 0.05).											

value of feed ingredients like SFM by the use of exogenous enzymes offers potential to lower diet costs that correlate with improved production.

In accordance with our results, Aboul Ela et al. (27) found that enzyme supplementation in growing Japanese quail diets improved the digestibility coefficient values of crude protein. Our findings disagree with those obtained by Elangovan et al. (28), who observed that enzyme addition did not influence N retention or DM digestibility of Japanese quail. In the present study, enzyme supplementation in broiler diets did not affect ether extract digestibility throughout the experimental period.

The interaction between SFM levels and enzyme supplementation did not affect the digestion coefficients of all nutrients studied (Table 5). The present results disagree with those obtained by Brenes et al. (29), who pointed out that fat digestibility was improved with a diet containing 150 g/kg of SFM plus 0.1% enzyme in comparison with the control diet through the period from 4 to 21 days. Supplemental enzymes in feed with ingredients high in NSP contents such as SFM have been reported to reduce the intestinal digesta viscosity and improve the nutrient digestibility, resulting in improved broiler performance (30). Supplementation of exogenous enzymes allows a wide range of feedstuffs to be used in poultry diets for a desired outcome. This strategy gives the producer and breeders a great deal of feasibility to select and formulate balanced diets with low cost.

3.6. Conclusions

From the aforementioned results and discussion, a conclusion could be drawn that the incorporation of SFM as a substitute for SBM in broiler diets can improve growth performance and has no adverse effects on broilers. It could be recommended to use SFM at up to 50% without Avizyme supplementation in broiler diets from 7 to 42 days of age.

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