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Sunflower Meal and Enzyme Supplementation in Diets of Broilers from 21 to 42 Days of Age

Research Article

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ABSTRACT

The objective of this study was to evaluate the performance of male broiler chickens in the period from 21 to 42 days of age fed diets with increasing levels of sunflower meal (SM) supplemented with an enzyme complex (EC). A total of 1920 animals of the Cobb strain were distributed in a randomized block design in a 4 × 3 factorial arrangement (four SM levels and three enzymes utilization types), with eight replicates, each containing 20 birds. The sunflower meal inclusion levels were 0, 8, 16 and 24%, utilized in three different diets. The first one was calculated so as to meet all the nutritional requirements of birds, except for the nutrients which would be provided by the nutritional matrix of the EC, considered as the negative control (NC). The second diet was calculated in the same way as the first one but was supplemented with 0.5% of EC (NC+EC). The last diet was calculated so as to meet all the nutritional requirements of animals, called as positive control (PC). The parameters assessed were feed intake, weight gain, feed conversion, carcass parameters and productive (PEI) and economic (EEI) efficiency indices. The addition of EC in the diets for broiler chickens did not improve the parameters of feed intake, weight gain, feed conversion or carcass parameters. The increase in the SM levels in the diet worsened the parameters of weight gain and feed conversion. The best EEI was for the animals fed the diet NC + EC, with inclusion of 8.0% SM.

KEY WORDS alternative feeds, carbohydrase, phytase, poultry.

INTRODUCTION

The Brazilian production of sunflower seeds represents only 0.003% of the world production, although it is in real expansion. In 2009, the area occupied by sunflower crops was of 87.8 thousand hectares, and the productivity was of 1463 kg/ha, totaling 128.5 thousand tons (Rosa *et al.* 2009). There has been an increasing utilization of sunflower in Brazil, especially due to its use for oil production. This oil, besides being edible, is a potential source of renewable energy as raw material in the fabrication of biodiesel (Porto *et al.* 2008).

The world demand for sunflower oil has grown at about 1.8% per year (Rosa *et al.* 2009). This resulted in a gradual increase of the sunflower-cultivated area in Brazil.

Sunflower meal is a supplement from the oil industry, with great expansion of utilization in feeds for animals, especially in the south and midwest regions of Brazil. The inclusion of sunflower meal in diets for broilers without interfering in the parameters of performance and carcass can be a bigger challenge, especially due to its high fiber content (NRC 1994). Thus, some exogenous enzymes could help the digestion of the fiber (carbohydrases) or solubilize the phytic phosphorus (phytase) of the sunflower meal, diminishing the negative impact on bird productive parameters.

The results of the utilization of sunflower meal in the feeding of broiler chickens are very controversial. According to Furlan *et al.* (2001), the inclusion of sunflower meal replacing soy protein can be done up to the level of 30.0% (13.17 and 12.04% for feed intake and weight gain, respectively) without compromising the productive parameters. Same studies reported inclusions of 28.0% sunflower meal in the diet without compromising the performance parameters of birds. However, these authors worked with residues of cold pressing, resulting in a more nutritive material (32.3% crude protein CP, and 18.78% ether extract EE) and usually called sunflower cake. Tavernari *et al.* (2009) did not verify differences in the weight gains of animals fed up to 20.0% inclusion of sunflower meal in their diets. Nevertheless, Pinheiro *et al.* (2002) verified that levels above 12.0% inclusion compromised the parameters of weight gain in birds. Still in this study, the inclusion of sunflower meal compromised intake negatively, which leads us to conclude that the greater value of this parameter was without the inclusion of this feedstuff in the diet. Similar results were verified by Tavernari *et al.* (2009), where bird intake was inversely proportional to the sunflower meal level. Among the alternatives, exogenous enzymes are widely utilized to improve the nutritional value of feeds, especially those rich in fiber (Kocher *et al.* 2000). Tavernari *et al.* (2008) verified improvement in the digestibility parameters of the dry matter of the diet and the metabolizability coefficients of Ca and P, when birds were fed sunflower meal supplemented with enzymes. However, Kocher *et al.* (2000), in disagreement with these results, did not verify any influence of the addition of enzymes in diets containing sunflower meal. It is known that as the inclusion of sunflower meal in the diets increases, the addition of oil in the diets should also be increased, aiming to compensate the low energy content of the material. Oil is one of the most expensive ingredients utilized in the making of diets for broiler chickens. Thus, the objective of this study was to technically and economically evaluate the inclusion levels of sunflower meal, with or without supplementation of enzyme complex on performance and carcass characteristics of broiler chickens from 21 to 42 days of age.

MATERIALS AND METHODS

Animals and diets

The experiment was conducted from May to June 2010, in the facilities of the poultry sector of the Department of Animal Science of Universidade Federal de Viçosa, MG, and Brazil. A total of 1920 male broilers of the Cobb strain, with initial weight of 852 ± 12 g, during the period from 21 to 42 days of age, were used in the experiment.

Animals were housed in masonry shed surrounded by mesh, covered with clay tiles and, subdivided in 1 × 1.5 m pens with bed of wood shavings and provided with nipple-type drinker and tubular feeder.

Temperature was measured once daily (8:00 a.m.) for verification of maximum and minimum temperatures. Animals were distributed in a randomized blocks design, in a 4 × 3 factorial arrangement (four sunflower meal levels and three utilization types of enzymes complex (EC)), with eight replicates, each containing 20 birds. Experimental units (pens) were placed on four lines lengthwise in the shed; each line with equal number of pens was considered as a block.

The levels 0, 8, 16 and 24% inclusion of sunflower meal were utilized in three diets distinct in their composition (Table 1). Diet from positive control (PC) was calculated so as to meet all the nutritional requirements of birds according to Rostagno *et al.* (2005) (Table 2).

Diet from negative control (NC) was calculated so as to meet all the nutritional requirements of birds, except for the nutrients which would be provided by the nutritional matrix of the EC. The third diet (NC+EC) was calculated in the same way as the second one but was supplemented with 0.005% of EC.

Chemical analysis of diet

The bromatological values of the sunflower meal (Table 3) were determined according to the laboratory of feed analysis of the Department of Animal Science at Universidade Federal de Viçosa; digestible amino acid values, according to several authors (NRC, 1994; Tavernari *et al.* 2010).

Performance and carcass

Mortality was recorded for the correction of the data on performance. Birds and diets were weighed at the beginning and end of the experimental periods (21 and 42 days, respectively) for obtainment of weight gain, feed intake, feed conversation, viability and productive efficiency index (PEI) at 42 days of age, according to the formula:

Viability= 100 - MO

PEI= ((AW × Viability)/AS×FC) × 100

Where:
MO: mortality.
AW: average weight of the flock at slaughter.
AS: age at slaughter.
FC: feed conversion.

Three birds from each replicate were slaughtered at 42 days of age for evaluation of yields of carcass, breast, breast filet, thigh and drumstick and abdominal fat, in relation to cold carcass weight (after exit of the chiller).

Table 1 Percentage and chemical composition of diets for broiler chickens (on a natural matter basis) under several inclusion levels of sunflower meal, with and without addition of enzyme complex (EC)

Ingredients (%)	NC				NC + EC				CP			
	0%	8%	16%	24%	0%	8%	16%	24%	0%	8%	16%	24%
Corn	66.823	61.016	55.208	49.401	66.812	61.005	55.198	49.391	63.245	57.438	51.631	45.824
Soybean meal	28.523	25.046	21.568	18.09	28.525	25.047	21.57	18.092	29.954	26.477	22.999	19.521
Sunflower meal	0.000	8.000	16.000	24.000	0.000	8.000	16.000	24.000	0.000	8.000	16.000	24.000
Soybean oil	1.280	2.577	3.874	5.171	1.284	2.581	3.878	5.174	3.027	4.324	5.621	6.918
Dicalcium phosphate	1.109	1.108	1.106	1.104	1.109	1.108	1.106	1.104	1.651	1.650	1.648	1.646
Limestone	0.989	0.952	0.914	0.877	0.989	0.952	0.914	0.877	0.845	0.808	0.771	0.733
Salt	0.476	0.440	0.405	0.369	0.476	0.440	0.405	0.369	0.477	0.441	0.406	0.370
DL-methionine 99%	0.198	0.187	0.176	0.164	0.198	0.187	0.176	0.164	0.208	0.197	0.186	0.175
L-lysine HCl 99%	0.207	0.272	0.336	0.400	0.207	0.272	0.336	0.400	0.196	0.260	0.324	0.388
L-threonine 98%	0.075	0.084	0.093	0.103	0.075	0.084	0.093	0.103	0.076	0.085	0.094	0.104
Vitamin premix[1]	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
Mineral premix[2]	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Choline chloride 60%	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
Anticoccidial (salinomycin 12%)	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060
Antioxidant[3]	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Enzyme complex	0.000	0.000	0.000	0.000	0.005	0.005	0.005	0.005	0.000	0.000	0.000	0.000
Calculated composition												
Metabolizable energy, MJ/kg	12.67	12.67	12.67	12.67	12.98	12.98	12.98	12.98	12.98	12.98	12.98	12.98
Crude protein %	18.80	18.80	18.80	18.80	19.15	19.15	19.15	19.15	19.15	19.15	19.15	19.15
Digestible lysine %	1.030	1.030	1.030	1.030	1.050	1.050	1.050	1.050	1.050	1.050	1.050	1.050
Digestible methionine %	0.467	0.466	0.466	0.466	0.479	0.479	0.479	0.479	0.479	0.479	0.479	0.479
Methionine + digestible cystine %	0.731	0.731	0.731	0.731	0.746	0.746	0.746	0.746	0.746	0.746	0.746	0.746
Digestible threonine %	0.700	0.700	0.700	0.700	0.714	0.714	0.714	0.714	0.714	0.714	0.714	0.714
Digestible tryptophan %	0.200	0.202	0.204	0.207	0.206	0.208	0.210	0.213	0.206	0.208	0.210	0.213
Glycine + total serine %	1.669	1.686	1.704	1.722	1.704	1.722	1.739	1.757	1.704	1.722	1.739	1.757
Digestible valine %	0.784	0.788	0.792	0.796	0.799	0.803	0.807	0.811	0.799	0.803	0.807	0.811
Digestible isoleucine %	0.721	0.717	0.713	0.709	0.740	0.735	0.731	0.727	0.740	0.735	0.731	0.727
Digestible arginine %	1.153	1.188	1.222	1.256	1.186	1.220	1.255	1.289	1.186	1.220	1.255	1.289
Digestible phenylalanine + tyrosine %	1.442	1.445	1.448	1.451	1.471	1.474	1.477	1.480	1.471	1.474	1.477	1.480
Digestible histidine %	0.477	0.470	0.463	0.456	0.484	0.477	0.470	0.463	0.484	0.477	0.470	0.463
Linoleic acid %	1.584	2.880	3.486	4.092	1.511	3.750	4.355	4.961	1.511	3.750	4.355	4.961
Calcium %	0.740	0.740	0.740	0.740	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820
Available phosphorus %	0.310	0.310	0.310	0.310	0.410	0.410	0.410	0.410	0.410	0.410	0.410	0.410
Sodium %	0.208	0.208	0.208	0.208	0.208	0.208	0.208	0.208	0.208	0.208	0.208	0.208
Crude fiber %	2.70	4.20	5.70	7.20	2.72	4.22	5.72	7.22	2.72	4.22	5.72	7.22
Neutral detergent fiber %	11.81	14.26	16.71	19.16	11.58	14.03	16.49	18.94	11.58	14.03	16.49	18.94
Acid detergent fiber %	4.69	5.91	7.13	8.35	4.68	5.90	7.12	8.34	4.68	5.90	7.12	8.34

[1] Vitamin mix (kg of product): vitamin A: 10000000 UI; vitamin D3: 2000000 UI; vitamin E: 30000 UI: vitamin B1: 2 g; vitamin B2: 6 g; vitamin B6: 4 g; vitamin B12: 0.015 g; Pantothenic acid: 12 g; Biotin: 0.1 g; vitamin K3: 3.0 g; Folic acid: 1 g; Nicotinic acid: 50 g and Se: 250 mg.
[2] Mineral mix (kg of product): Fe: 80 g; Cu: 10 g; Co: 2 g; Mn: 80 g; Zn: 50 g and I: 1 g.
[3] Antioxidant: BHT (Butylated hydroxytoluene).

Table 2 Nutritional values attributed to the enzyme complex utilized[1]

Nutritional matrix	Per kg	Added with the inclusion
Metabolizable energy MJ/kg	6,280	0.314
Crude protein %	7,000	0.350
Digestible lysine %	180	0.009
Digestible methionine %	80	0.004
Methionine + digestible cystine %	140	0.007
Digestible threonine %	120	0.006
Digestible tryptophan %	40	0.002
Digestible valine %	200	0.010
Digestible arginine %	230	0.012
Enzyme complex content (%)		
Endo-1,3(4)-beta-glucanase	14.0	
Xylanase	11.0	
6-Phytase	5.0	
Inert	70.0	

[1] Rovabio Excel AP®

Table 3 Chemical composition of the sunflower meal

Sunflower meal	
Dry matter[1]	91.37
Metabolizable energy MJ/kg[2]	8.30
Crude protein %[1]	25.00
Digestible lysine %[2]	0.634
Digestible methionine %[2]	0.504
Methionine + digestible cystine, %[2]	0.858
Digestible threonine %[2]	0.765
Digestible tryptophan %[2]	0.315
Glycine + total serine %[2]	2.560
Digestible valine %[2]	1.140
Digestible isoleucine %[2]	0.970
Digestible arginine, %[2]	2.080
Phenylalanine+ digestible tyrosine, %[2]	2.050
Digestible histidine %[2]	0.570
Linoleic acid %[2]	0.600
Ether extract %[1]	2.120
Mineral matter %[1]	4.730
Calcium %[1]	0.140
Total phosphorus %[1]	0.939
Available phosphorus %[2]	0.310
Sodium %[2]	0.200
Crude fiber %[1]	22.37
Neutral detergent fiber %[1]	45.19
Acid detergent fiber %[1]	21.35

[1] Analysis conducted at the laboratory of animal nutritional of UFV.
[2] Mean values according to the NRC (1994), FEDNA (2003), INRA (2004) and Tavernari *et al.* (2010).

Economic viability

To verify the economic viability of inclusion of sunflower meal in the diets, the cost of the diet was determined, in Brazilian Reais (R$), per kilogram of live weight gain (Yi), according to Bellaver *et al.* (1985):

Yi= (Pi×Qi) / Gi.

Where:
Yi: cost of the diet per kilogram of live weight gain at the i-th treatment (sunflower meal level).
Pi: price per kilogram of diet utilized at the i-th treatment.
Qi: quantity of diet consumed in the i-th treatment.
Gi: weight gain of the i-th treatment.

The economic efficiency index (EEI) was calculated:

EEI: (LC/CTi) × 100.

Where:
LC: lowest cost of the diet per kilogram of gain observed among treatments.
CTi: cost of the treatment i considered.

The values (prices/kg) of the ingredients utilized at the elaboration of the costs were obtained in the region of Viçosa, in the month of April 2010, as follows: butylated hydroxytoluene (U$ 6.43), limestone (U$0.028), choline chloride (U$2.92), enzyme complex (U$ 6.43), DL-methionine (U$8.15), soybean meal (U$0.61), sunflower meal (R$0.31), dicalcium phosphate (U$1.18), L-lysine (U$4.84), L-threonine (U$8.15), corn (U$0.51), oil (U$2.57), common salt (U$0.19), vitamin supplement for-growth (U$2.195), vitamin supplement (U$3.30) and mineral supplement (U$1.86).

Statistical analysis

A the evaluation of performance and carcass characteristics, the feature PROC GLM of the software (SAS, 1996) was applied in a factorial arrangement, adopting 5% significance level. Linear and quadratic functions were utilized for the determination of the ideal level of sunflower meal, and the Student-Newmann-Keul test was used for evaluation of enzyme complex inclusion.

RESULTS AND DISCUSSION

Performance

The mean temperatures recorded during the experiment were 21.5 ˚C (16.0 and 27.0 ˚C minimum and maximum, respectively), within the thermal comfort zone for the phase. At the evaluation of the feed intake, there was interaction between the diets and the sunflower meal levels (P<0.05; Table 4). The intake was higher in diets calculated under nutritional deficiencies without the inclusion of enzyme complex than in diets calculated without nutritional deficiencies, for the level of 8.0% inclusion of sunflower meal. It is known that bird intake suffers influence from the energy content of the diet, which explains this increase. According to Nascimento *et al.* (2005), feed intake is strictly correlated to the energy level of the diet, which strengthens the results of the present study.

There was no influence of enzyme complex inclusion for this parameter (P>0.05; Table 4). Likewise, Abdelrahman and Saleh (2007) reported no influence of the addition of the enzyme glucanase under inclusion of sunflower meal in diets. However, Raza *et al.* (2009) were successful at the utilization of carbohydrases in diets containing sunflower meal for broilers, resulting in improvement of feed conversion and increase in weight gain. Linear effect (P<0.05; Table 4) of sunflower meal levels was verified, generating increase in intake only for the diets calculated without nutritional deficiencies (Table 5). These results are counter to Furlan *et al.* (2001) and Tavernari *et al.* (2009), who did not verify significant differences in this parameter up to the level of 20.0 and 25.0% of inclusion, respectively. Abdelrahman and Saleh (2007) verified greater feed intake in the diets with inclusion of 10.0% sunflower meal. In spite of containing soluble fibers, sunflower meal has a high level of insoluble fibers, which are approximately represented by the difference between NDF and ADF (45.19 and 21.35% respectively). The insoluble fibers increase the fecal volume and the frequency of evacuation, reducing the bowel transit time (Mattos and Martins, 2000). Birds are animals of short digestive tract, thus high levels of fiber which increase the passage rate diminish the nutrient absorption (Macari, 2008). One hypothesis is that lower absorption of the nutrients of the diet with higher sunflower meal levels would lead to compensatory increase in intake. The interaction between diets and sunflower meal levels was not significant for the values of weight gain (P>0.05; Table 4). Also, there was no influence of enzyme complex inclusion in these parameters (P>0.05; Table 4). However, linear effect (P<0.05; Table 4) of sunflower meal levels were observed on weight gain, described by the equation. One can therefore conclude that as the sunflower meal is included in diets for broiler chickens, weight gain decreases. The recommendations of sunflower meal inclusion in diets of this study differ from the results of various authors, who have reported possible inclusions of 12.04%, 12.0%, 10.0% and even 25.0% without compromising weight gain (Furlan *et al.* 2001; Pinheiro *et al.* 2002; Abdelrahman and Saleh, 2007; Tavernari *et al.* 2009). The current broiler chicken strains present higher and higher nutrient requirements, with diets composed of feeds of high digestibility and nutritional value. Sunflower meal has a high content of fibers (NDF=45.19%), thus contributing negatively to the absorption of nutrients and resulting in drop of performance.

There was also interaction between the two diets and the sunflower meal levels (P<0.05; Table 4) for feed conversion. This item was worse in the negative control diets than in the positive control ones, for the level of 8.0% inclusion of sunflower meal. Linear effect (P<0.05; Table 4) of sunflower levels was verified for feed conversion. However, different equations were traced for each type of treatment (negative control, negative control+enzyme complex and positive control). The equations define higher values of feed conversion in function of sunflower meal inclusion. Diets presented worse feed conversions under the same inclusion level of sunflower meal in the following order: negative control, negative control + enzyme complex and positive control. These results differ from those of several authors (Furlan *et al.* 2001; Pinheiro *et al.* 2002; Abdelrahman and Saleh, 2007; Tavernari *et al.* 2009).

Productive and economic index

The best productive efficiency index (EEI) was verified on animals under positive control diet without inclusion of sunflower meal (Table 5). However, the best economic efficiency index was for animals under negative control + enzyme complex at the level of 8.0% sunflower meal inclusion (Table 5). Therefore, in spite of compromising performance, the inclusion of 8.0% sunflower meal can be economically viable, as well as the utilization of the enzyme complex in such diets. There results diverge from Furlan *et al.* (2001) and Tavernari *et al.* (2009), who verified the best EEI where there was no inclusion of sunflower meal in the diets. Nevertheless, Pinheiro *et al.* (2002) reported that the level of 4.0% of inclusion promoted the best EEI. There was no effect of diets (negative control, negative control + enzyme complex and positive control) (P>0.05) for the carcass yield (Table 6). Linear effect of the sunflower meal levels was verified for carcass weight and breast weight, as well as for breast filet yield and abdominal fat (P<0.05; Table 6). One can conclude then that as the sunflower meal is increased, there is decrease in some carcass parameters (Table 6).

Carcass parameters

The carcass results are a consequence of the decrease in weight gain and function of the increase of sunflower meal in the diet.

Table 4 Performance of broiler chickens from 21 to 42 days of age fed diets with increasing sunflower meal (SM) levels, with and without supplementation of enzyme complex (EC)

	Sunflower meal levels				
	0%	8%	16%	24%	
		Feed intake (g/bird)			Mean
NC	4068^{a}	4117^{a}	3943^{a}	4029^{a}	4039
NC + EC	4008^{a}	4015^{ab}	3935^{a}	4068^{a}	4007
PC	3881^{b}	3920^{b}	4002^{a}	3601^{a}	3851
Mean	3986	4017	396	3899	-
ANOVA	Treat$^{\alpha}$= 0.0094*	SM$^{\beta}$= 0.1235^{ns}	Treat × SM $^{\gamma}$= 0.0163*		CV (%)= 3.28
Probability	-	NS	L		
		Weight gain (g/bird)			Mean
NC	2183	2128	2074	2022	2102
NC + EC	2142	2158	2041	2067	2102
PC	2167	2124	2081	2063	2109
Mean	2164	2137	2065	2051	-
ANOVA	-	SM= < 0.0001*	Treat × SM= 0.2617^{ns}		CV (%)= 2.99
Probability	-	L	NS		
		Feed conversion (g/g)			Mean
NC	1863^{a}	1935^{a}	1901^{a}	1993^{a}	1923
NC + EC	1871^{a}	1861^{ab}	1928^{a}	1968^{a}	1907
PC	1791^{b}	1846^{b}	1923^{a}	1746^{a}	1826
Mean	1842	188	1917	1902	-
ANOVA	Treat= < 0.0001*	SM= < 0.0001*	Treat × SM= 0.0026*		CV (%)= 2.88
Probability	-	L	L		
		Regression equations			
Feed intake (g/bird)					
NC		No significance (P>0.05)			
NC + EC		No significance (P>0.05)			
PC		Feed intake= 3878.3 + 6.725 SM$^{\beta}$ (R^2 0.97)			
Weight gain (g/bird)					
Weight gain= 2165.9-5.1021 SM (%) (R^2 0.83)					
Feed conversion (g/g)					
NC		Feed conversion= 18696 + 0.0028 SM (R^2 0.48)			
NC + EC		Feed conversion= 18776 + 0.0034 SM (R^2 0.83)			
PC		Feed conversion= 17974 + 0.0055 SM (R^2 0.92)			

NC: negative control; PC: positive control; Treat: treatment; CV: coefficient of variation;
$^{\beta}$ FG (%): percentage of sunflower meal in the diet; $^{\gamma}$: interaction between treatments and SM (%);
The means within the same column with at least one common letter, do not have significant difference (P>0.05).
NS: non significant and *: (P<0.05).
Q: quadratic effect (P≤0.05) of the sunflower meal level and L: linear effect (P≤0.05) of the sunflower meal level.

Table 5 Productive and economic efficiency indices of broiler chickens fed diets with increasing levels of sunflower meal, with and without supplementation of enzyme complex

	Sunflower meal levels				
	0%	8%	16%	24%	
		Productive efficiency index			Mean
NC$^{\alpha}$	522.88	492.38	499.76	464.55	494.89
NC + EC	516.19	521.59	487.48	476.03	500.32
PC	550.39	524.48	492.48	485.35	513.17
Mean	529.82	512.82	493.24	475.31	-
		Economic efficiency index (%)			Mean
NC	99.26	95.31	98.64	93.46	96.67
NC + EC	99.33	100.00	97.31	94.29	97.73
PC	99.37	96.16	91.72	91.05	94.58
Mean	99.32	97.16	95.89	92.93	-

NC$^{\alpha}$: negative control; NC + EC: negative control + enzyme complex and PC: positive control.

Table 6 Carcass weight, breast weight and breast yield of broiler chickens fed diets with increasing sunflower meal (SM) levels, with and without supplementation of enzyme complex (EC)

	Sunflower meal levels				
	0%	8%	16%	24%	
		Breast filet weight (g/bird)			Mean
NC	594	589	541	522	561
NC + EC	575	551	543	550	555
PC	583	545	544	533	551
Mean	584	562	543	535	
ANOVA	Treat$^{\alpha}$= 0.5023^{ns}	SM$^{\beta}$= < 0.0001*	Treat × SM$^{\gamma}$= 0.1472^{ns}		CV (%)= 6.20
Probability	-	L	NS		
		Breast filet yield (%)			Mean
NC	28.05	28.08	27.48	26.82	27.61
NC + EC	27.60	26.32	27.21	28.24	27.34
PC	28.22	27.02	27.12	26.97	27.33
Mean	27.96	27.14	27.27	27.34	
ANOVA	Treat= 0.2154^{ns}	SM= 0.2154^{ns}	Treat × SM= 0.1050^{ns}		CV (%)= 5.26
Probability	-	NS	NS		
		Thighs and drumsticks (g/bird)			Mean
NC	590	593	580	561	581
NC + EC	600	578	589	575	585
PC	585	587	571	571	578
Mean	591	586	580	569	
ANOVA	Treat= 0.6529^{ns}	SM= 0.0745^{ns}	Treat × SM= 0.7422^{ns}		CV (%)= 5.19
Probability	-	NS	NS		
		Abdominal fat (g/bird)			Mean
NC	34	41	30	27	33
NC + EC	35	36	33	34	34
PC	36	37	33	33	35
Mean	35	38	32	31	
ANOVA	Treat= 0.5420^{ns}	SM= 0.0047*	Treat × SM= 0.3242^{ns}		CV (%)= 20.99
Probability	-	L	NS		

		Breast filet weight (g/bird)			Mean
NC	594	589	541	522	561
NC + EC	575	551	543	550	555
PC	583	545	544	533	551
Mean	584	562	543	535	
ANOVA	Treat$^{\alpha}$= 0.5023^{ns}	SM$^{\beta}$= < 0.0001*	Treat × SM$^{\gamma}$= 0.1472^{ns}		CV (%)= 6.20
Probability	-	L	NS		
		Breast filet yield (%)			Mean
NC	28.05	28.08	27.48	26.82	27.61
NC + EC	27.60	26.32	27.21	28.24	27.34
PC	28.22	27.02	27.12	26.97	27.33
Mean	27.96	27.14	27.27	27.34	
ANOVA	Treat= 0.2154^{ns}	SM= 0.2154^{ns}	Treat × SM= 0.1050^{ns}		CV (%)= 5.26
Probability	-	NS	NS		
		Thighs and drumsticks (g/bird)			Mean
NC	590	593	580	561	581
NC + EC	600	578	589	575	585
PC	585	587	571	571	578
Mean	591	586	580	569	
ANOVA	Treat= 0.6529^{ns}	SM= 0.0745^{ns}	Treat × SM= 0.7422^{ns}		CV (%)= 5.19
Probability	-	NS	NS		
		Abdominal fat (g/bird)			Mean
NC	34	41	30	27	33
NC + EC	35	36	33	34	34
PC	36	37	33	33	35
Mean	35	38	32	31	
ANOVA	Treat= 0.5420^{ns}	SM= 0.0047*	Treat × SM= 0.3242^{ns}		CV (%)= 20.99
Probability	-	L	NS		

Regression equations

Carcass weight (g/bird)= 2.098.6 - 6.0312 SM (R^2 0.94)

Breast weight (g/bird)= 748.6 - 2.3926 SM (R^2 0.99)

Breast filet weight (g/bird)= 580.81 - 2.0846 SM (R^2 0.96)

Abdominal fat (g/bird)= 36.625 - 0.2161 SM (R^2 0.97)

NC: negative control; NC + EC: negative control + enzyme complex; PC: positive control; Treat: treatment; CV: coefficient of variation; FG$^{\beta}$ (%): percentage of sunflower meal in the diet and $^{\gamma}$: interaction between treatments and SM (%);

NS: non significancant and * (P<0.05).

Q: quadratic effect (P≤0.05) of the sunflower meal level and L: linear effect (P≤0.05) of the sunflower meal level.

These results differ from those by Oliveira *et al.* (2003) and Tavernari *et al.* (2009), who did not verify any influence on carcass parameters up to the levels of 25.0% and 30.0% inclusion, respectively. Also in these studies, there were no significant differences in animal weight gain, hence these carcass results. The inclusion of sunflower meal in diets for broiler chickens negatively affects the performance and carcass parameters of animals. The inclusion of enzyme complex was not effective at the improvement of the parameters assessed. However, inclusion of 8% sunflower meal and addition of enzyme complex improves the economic efficiency index.

CONCLUSION

Increase in the sunflower meal levels in the diet worsened the parameters of weight gain and feed conversion ($P<0.05$). The best economic efficiency index was of the animals receiving the diet negative control + enzyme complex with inclusion of 8.0% sunflower meal.

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