Sunflower meal and supplementation of an enzyme complex in diets for growing and finishing pigs

Farelo de girassol e suplementação de complexo enzimático em dietas para suínos em crescimento e terminação

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Abstract

This study aimed to evaluate the inclusion of sunflower meal and an enzyme complex supplement on the performance and carcass parameters in swine from 30 to 100 kg live weight. A total of 96 pigs with average live weight of 32.19 ± 3.27 kg were distributed in a randomized blocks design with a 4 × 2 factorial arrangement of treatments (four levels of sunflower meal-SM: 0, 8, 16 and 24%, with or without inclusion of an enzyme complex-EC), factorial arrangement with six replicates and two animals per experimental unit. The analyzed variables were feed intake (kg), weight gain (kg), feed conversion (kg/kg), backfat thickness (mm), carcass muscularity (kg), hot carcass weight (%), lean meat carcass percentage (%), and lean meat carcass weight (kg). There was no interaction between factors for any of the studied variables. Feed conversion of animals from 30 to 70 kg live weight was improved by the inclusion of EC. This enzyme complex inclusion did not affect carcass characteristics. Increasing levels of SM in the test subject feed diet rations presented a quadratic effect on weight gain and on backfat thickness that reached maximum values in parameters of 7.26% and 8.16%, respectively.

Keywords: Alternative feedstuffs. Carcass. Enzyme. Performance. Swine.

Resumo

Este estudo teve como objetivo avaliar a inclusão de farelo de girassol e a suplementação de complexo enzimático sobre os parâmetros de desempenho e características de carcaça de suínos, dos 30 aos 100 kg de peso vivo. Foram utilizados 96 suínos com peso vivo médio de 32,19 ± 3,27 kg distribuídos em um delineamento experimental de blocos casualizados, em esquema fatorial 4 x 2 (quatro níveis de farelo de girassol-FG: 0, 8, 16 e 24% com ou sem inclusão do complexo enzimático-CE), com seis repetições e dois animais por unidade experimental. As variáveis analisadas foram: o consumo de ração (kg), o ganho de peso (kg), a conversão alimentar (kg/kg), a espessura de toucinho (mm), a musculosidade (kg), o peso da carcaça quente (%), a porcentagem de carne magra na carcaça (%), a quantidade de carne magra na carcaça (kg). Não houve interação entre os fatores para nenhuma das variáveis estudadas. A conversão alimentar dos animais dos 30 aos 70 kg de peso foi diminuída pela inclusão do CE, porém não afetou os parâmetros de carcaça. Níveis crescentes de FG na ração apresentaram efeito quadrático sobre o ganho de peso dos animais e sobre a espessura de toucinho, com valores máximos destas variáveis em 7,26% e 8,16% de inclusão do FG, respectivamente.

Palavras-chave: Alimentos alternativos. Carcaça. Desempenho. Enzimas. Suínos.

Introduction

Corn and soybean meal are considered "standard" for comparisons of nutritional values in alternative feedstuffs (BEN-HAMED; SEDDIGHI; THOMAS, 2011). Research generally confirms that most of the ingredients used as substitutes for corn and soybean meal have lower nutritional value in rations. This nutritional loss and resulting lower animal production yield could be economically feasible (FERREIRA; ARAÚJO; SILVA, 2007), being that corn is one of the principal cost effective staples of

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the agricultural livestock feed grain industry (BEN-HAMED; SEDDIGHI; THOMAS, 2011). In this scenario, the utilization of alternative feedstuffs for animal production has drawn the interest of many stockmen. In regard to this apparent growing interest, conclusive research directed toward generating more information on economic feedstuff alternatives should be substantially increased. In addition to this renewed interest in research, federal policies have stimulated incentives for renewable energy production, which has led to the expansion of sunflower plantation (ROSA et al., 2009). As a consequence of oil extraction, sunflower byproducts are now available at reduced costs, bringing advantages to their use as animal fodder (PORTO et al., 2008).

Sunflower meal (SM) is the byproduct of oil extraction from the sunflower seed through chemical extractors (hexane) under high temperature (107ºC) (SENKOYLU; DALE, 2006). One of the characteristics of this byproduct is its high fiber content. Consequently, the inclusion of exogenous enzymes such as phytase, proteases and carbohydrases could possibly stimulate the inclusion of higher percentages of SM in swine feed rations.

The NRC (1998) has reported the inclusion of three types of sunflower meal in swine fodder ration, according to the greater or lesser presence percentage of hulls. Shelton et al. (2001) observed reduced weight gain in animals fed sunflower meal compared to those fed soybean meal as a protein source during the growth phase; however, the inclusion level used by Shelton et al. (2001) was 58.0%.

Silva et al. (2002a) reported digestible and metabolizable energy values of 3,421 and 3,247 kcal/kg in sunflower meal used as swine fodder, which indicates that this feedstuff has a suitable energetic contribution and intermediate protein level for pigs, but with an elevated level of fibrous material. Costa et al. (2005) reported using sunflower cake in partial replacement of up to 15.0% in corn and soybean meal fodder for growing and finishing pigs. Livestock producers know that during the process of sunflower cake production, sunflower seed undergoes only partial oil extraction, which is why these energy values were higher than those compared with sunflower meal.

Carellos et al. (2005) stated that inclusion of up to 16.0% sunflower meal in fodder diets for finishing pigs would be technically viable, without compromising performance values or carcass characteristics. Silva et al. (2002b) evaluated the inclusion of higher levels of SM (21%) in growing and finishing pig fodder and reported no difference in carcass characteristics when using this feed. Additionally, Silva et al. (2002b) determined a digestibility value of 73.2% in sunflower meal crude protein.

To compensate the low energy content of the SM during swine diet formulation, an additional oil increase to the diet formula becomes necessary (SILVA et al., 2002b). Oil is one of the most expensive cost factor ingredients used in the production of swine fodder and weighs heavily in its produce. Under these circumstances, the inclusion of exogenous enzymes has been studied and could be advantageous when associated with the inclusion of sunflower meal in swine fodder diets. Therefore, the objective of this study was to evaluate the inclusion of sunflower meal and an enzyme complex supplementation on performance and carcass parameters in pigs from 30 to 100 kg live weight.

Material and Methods

The study was conducted from September to November 2012, in Viçosa, MG, Brazil. A total of 96 pigs originating from the crossbreeding of PIC® sires with Cambridge 23® breeders (48 castrated males and 48 females), with an average live weight of 32.19 ± 3.27 kg, were distributed in a randomized blocks design (gender factor, two blocks) in a 4 × 2 (four different levels of sunflower meal percentage inclusion in fodder diets with and without the addition of an enzyme complex) factorial scheme with six replicates, with two animals in each experimental unit.

The study specimens were housed in same-gender pairs in a clay tile lined masonry compact floor pen (5 m width and 2 m ceiling) with an area of 3 m^2, where they received water and feed *ad libitum*, during the entire experimental period. Throughout this time, temperature readings inside the shed were taken twice daily (at 8 and 16 h), using maximum and minimum thermometer readings as parameters. Sunflower meal inclusion levels of 0, 8, 16 and 24% were used in fodder diets formulated to meet all the nutritional requirements of the animals, according to Rostagno (2011) (Table 1 and 2), reducing the nutritional values attributed by the enzyme complex nutritional matrix, with and without supplementation of 0.005% EC. The suggested contents of the enzyme complex were: 140 g/kg of Endo-1,3(4)-beta-glucanase, 110 g/kg of Xylanase and 50 g/kg of 6-Phytase.

Bromatological values of this sunflower meal formula were used according to the laboratory of feed analysis of the Department of Animal Science at the Federal University of Viçosa and through mean values according to several authors (NRC, 1998; SAUVANT; PEREZ; TRAN, 2004; DE BLAS; MATEOS; GARCIA-REBELAR, 2010). Feed, fodder leftovers and the test animals were weighed for evaluation of feed intake (kg), weight gain (kg) and feed conversion (kg/kg) in the periods of growth (duration of 40 days) and finishing (duration of 29 days), and in the total period (duration of 69 days).

At the end of the performance assay, the animals were slaughtered and subjected to carcass characteristics evaluation. Each carcass was individually examined using a skin fold caliper Stork-SFK (model S87), and the computerized system software Fat-o-MEATER FOM®. The instrument was introduced at the height of the 3rd dorsal vertebra, intersecting the backfat and the *longissimus dorsi* muscle. The data obtained were: backfat thickness (mm), carcass muscularity (kg), hot carcass weight (%), percentage of lean meat in the carcass (%) and quantity of lean meat in the carcass (kg); each carcass was considered a replicate.

Carcass muscularity was defined as the muscle thickness in relation to the dimensions of the skeleton, and carcass conformation as the muscle and fat thickness in relation to skeleton dimensions (DeBOER et al., 1974).

To evaluate diet fodder intake, weight gain, feed conversion and carcass characteristics, the feature PROC GLM of the SAS© software (SAS, 2002) was used in a factorial arrangement by adopting a significance level of 5%. Linear and quadratic functions were used in determination of the ideal percentage of sunflower meal inclusion. The SNK (Student-Newmann-Keuls) test was used in the evaluation for the addition of the enzyme complex supplement; possible interactions of the factors were also considered. The statistic model used was according to:

$$\gamma_{ijkl} = \mu + \alpha_i + \beta_j + \gamma_k + (\alpha\beta)_{ij} + (\beta\gamma)_{jk} + (\alpha\gamma)_{ik} + (\alpha\beta\gamma)_{ijk} + \varepsilon_{ijkl}$$

where: μ = general average, α_i = diet effect, β_j = enzyme complex effect, γ_k = gender effect, $\alpha\beta_i$ = diet and enzyme complex interaction effect, $\beta\gamma_i$ = enzyme complex and gender interaction effect, $\alpha\gamma_i$ = diet and gender interaction effect, $\alpha\beta\gamma_i$ = diet, enzyme complex and gender interaction effect, and ε_{ijkl} = incidental residual effect of observation.

Results and Discussion

Mean environmental temperatures recorded during the experiment were 25.9ºC (17.8 and 34.0°C minimum and maximum, respectively). No significant interaction was observed in sunflower meal and enzyme complex supplementation, sunflower meal and gender, enzyme complex supplementation and gender, or sunflower meal, enzyme complex and gender in the studied performance variables (P > 0.05, Tables 3, 4, 5 and 6). Consequently, the addition of enzyme complex in swine fodder diets does not require, or is benefitted by, a greater inclusion of sunflower meal in feed, as was previously hypothesized. The measured intake and weight gain did not present significant differences for

Table 1 – Percentage and chemical composition (as fed basis) of experimental diets of pigs from 30 to 70 kg – Viçosa – 2012

Ingredients (%)	30 to 70 kg live weight diets							
	Without EC				With EC			
	0%	8%	16%	24%	0%	8%	16%	24%
Corn	71.965	58.805	59.659	53.506	71.962	58.802	59.656	53.503
Soybean meal	23.123	19.608	16.435	13.091	23.121	19.606	16.433	13.089
Sunflower meal	0.000	8.000	16.000	24.000	0.000	8.000	16.000	24.000
Soybean oil2.394	4.127	5.449	6.977	2.394	4.127	5.449	6.977	
Dicalcium phosphate	0.988	0.995	1.006	1.015	0.988	0.995	1.006	1.015
Limestone	0.604	0.546	0.483	0.423	0.604	0.546	0.483	0.423
Salt	0.380	0.381	0.380	0.381	0.380	0.381	0.380	0.381
L-Lysine HCl 99%	0.257	0.308	0.340	0.382	0.257	0.308	0.340	0.382
DL-Methionine 99%	0.072	0.056	0.028	0.006	0.072	0.056	0.028	0.006
L-Threonine 98%	0.057	0.062	0.059	0.061	0.057	0.062	0.059	0.061
Vitamin premix [1]	0.100				0.100			
Mineral premix [2]	0.050				0.050			
Antioxidant [3]	0.010				0.010			
Enzyme complex	0.000				0.005			
Calculated composition								
Metabolizable energy, kcal/kg	3180				3230			
Crude protein, %	16.70				17.04			
Digestible lysine, %	0.942				0.953			
Digestible methionine, %	0.319				0.323			
Methionine + digestible cystine, %	0.565				0.572			
Digestible threonine, %	0.612				0.620			
Digestible tryptophan, %	0.181	0.176	0.178	0.181	0.183	0.178	0.180	0.183
Digestible valine, %	0.678	0.664	0.685	0.678	0.678	0.664	0.685	0.678
Digestible isoleucine, %	0.722	0.640	0.691	0.722	0.722	0.640	0.691	0.722
Digestible arginine, %	1.178	1.028	1.119	1.178	1.178	1.028	1.119	1.178
Digestible phenylalanine + tyrosine, %	1.211	1.207	1.234	1.211	1.211	1.207	1.234	1.211
Digestible histidine, %	0.410	0.404	0.416	0.410	0.410	0.404	0.416	0.410
Linoleic acid, %	1.373	1.420	1.474	1.373	1.373	1.420	1.474	1.373
Calcium, %	0.551				0.551			
Available phosphorus, %	0.282				0.282			
Sodium, %	0.170				0.170			
Crude fiber, %	2.496	4.027	5.500	7.003	2.496	4.027	5.500	7.003
Neutral detergent fiber, %	11.660	13.939	16.518	18.946	11.660	13.939	16.518	18.946
Acid detergent fiber, %	4.434	5.800	6.869	8.086	4.434	5.800	6.869	8.086

[1] Vitamin mix (kg of product): vit. A - 10,000,000 U.I.; vit. D3 - 2,000,000 U.I.; vit. E - 30,000 U.I. A; vit. B1 - 2.0 g; vit. B2 - 6.0 g; vit. B6 - 4.0 g; vit. B12 - 0.015 g; pantothenic acid - 12.0 g; biotin - 0.1 g; vit. K3 - 3.0 g; folic acid - 1.0 g; nicotinic acid - 50.0 g; Se - 250.0 mg
[2] Mineral mix (kg of product): Fe - 80 g; Cu - 10 g; Co - 2 g; Mn - 80 g; Zn - 50 g; I - 1 g
[3] Antioxidant: BHT (Butylated hydroxytoluene)

the inclusion of sunflower meal or for the inclusion of the enzyme complex in the diets of animals ranging from 30 to 70 kg (P > 0.05, Table 4). No significant differences were observed in performance parameters of growing pigs fed sunflower cake up to the level of 15.0% (COSTA et al., 2005). However, sunflower cake is a product which contains a higher energetic value than sunflower meal. This is due to the partial extraction of oil from the seed which is done mechanically and cooled with no additional solvent. The percentage of oil present in sunflower cake stimulates the secretion of a greater amount of cholecystokinin in the animals. This is a hormone that decreases intestinal transit (NRC, 1998), thereby increasing the digestibility of nutrients in general and explaining the bettered production performance under high inclusion of this product. Silva et al. (2002b) evaluated the inclusion of up to 21.0% sunflower meal in the diets and evidenced no difference during the growing phase. Colina et al. (2010) used 17.5% inclusion of sunflower meal in diets for piglets of 15 days of age in their experiment, which suggested that the inclusion of this ingredient can also

Table 2 – Percentage and chemical composition (as fed basis) of experimental diets of pigs from 70 to 100 kg – Viçosa – 2012

Ingredients (%)	**70 to 100 kg live weight diets**							
	Without EC				**With EC**			
	0%	8%	16%	24%	0%	8%	16%	24%
Corn	77.495	58.805	65.226	59.099	77.492	58.802	65.223	59.096
Soybean meal	18.990	15.340	12.250	8.870	18.988	15.338	12.248	8.868
Sunflower meal	0.000	8.000	16.000	24.000	0.000	8.000	16.000	24.000
Soybean oil	1.403	3.298	4.439	5.953	1.403	3.298	4.439	5.953
Dicalcium phosphate	0.821	0.826	0.839	0.848	0.821	0.826	0.839	0.848
Limestone	0.558	0.501	0.437	0.377	0.558	0.501	0.437	0.377
Salt	0.354	0.355	0.355	0.355	0.354	0.355	0.355	0.355
L-Lysine HCl 99%	0.194	0.253	0.279	0.322	0.194	0.253	0.279	0.322
DL-Methionine 99%	0.013	0.002	0.000	0.000	0.013	0.002	0.000	0.000
L-Threonine 98%	0.012	0.020	0.016	0.017	0.012	0.020	0.016	0.017
Vitamin premix [1]	0.100				0.100			
Mineral premix [2]	0.050				0.050			
Antioxidant [3]	0.010				0.010			
Enzyme complex	0.000				0.005			
Calculated composition								
Metabolizable energy, kcal/kg	3180				3230			
Crude protein, %	15.10				15.44			
Digestible lysine, %	0.799				0.81			
Digestible methionine, %	0.298	0.252	0.277	0.298	0.302	0.256	0.281	0.302
Methionine + digestible cystine, %	0.531	0.479	0.509	0.531	0.538	0.486	0.516	0.538
Digestible threonine, %	0.519				0.527			
Digestible tryptophan, %	0.161	0.156	0.158	0.161	0.163	0.158	0.160	0.163
Digestible valine, %	0.616	0.581	0.623	0.616	0.616	0.581	0.623	0.616
Digestible isoleucine, %	0.655	0.558	0.626	0.655	0.655	0.558	0.626	0.655
Digestible arginine, %	1.064	0.892	1.005	1.064	1.064	0.892	1.005	1.064
Digestible phenylalanine + tyrosine, %	1.095	1.055	1.120	1.095	1.095	1.055	1.120	1.095
Digestible histidine, %	0.377	0.357	0.383	0.377	0.377	0.357	0.383	0.377
Linoleic acid, %	1.480	1.403	1.580	1.480	1.480	1.403	1.580	1.480
Calcium, %	0.484				0.484			
Available phosphorus, %	0.248				0.248			
Sodium, %	0.160				0.160			
Crude fiber, %	2.368	3.923	5.370	6.871	2.368	3.923	5.370	6.871
Neutral detergent fiber, %	11.737	13.898	16.592	19.018	11.737	13.898	16.592	19.018
Acid detergent fiber, %	4.293	5.775	6.724	7.940	4.293	5.775	6.724	7.940

[1] Vitamin mix (kg of product): vit. A - 10,000,000 U.I.; vit. D3 - 2,000,000 U.I.; vit. E - 30,000 U.I. A; vit. B1 - 2.0 g; vit. B2 - 6.0 g; vit. B6 - 4.0 g; vit. B12 - 0.015 g; pantothenic acid - 12.0 g; biotin - 0.1 g; vit. K3 - 3.0 g; folic acid - 1.0 g; nicotinic acid - 50.0 g; Se - 250.0 mg

[2] Mineral mix (kg of product): Fe - 80 g; Cu - 10 g; Co - 2 g; Mn - 80 g; Zn - 50 g; I - 1 g

[3] Antioxidant: BHT (Butylated hydroxytoluene)

be used in the starter phase, in spite of its high fiber content. Silva et al. (2003), on the other hand, reported inclusion of only 5.0% sunflower seed in the feed without affecting productive parameters during that phase. In comparison with soybean meal, Trombetta and Mattii (2005) used an 11.0% dehulled sunflower seeds inclusion in the fodder. These results indicated that the inclusion level of sunflower byproducts in swine fodder is very controversial. In modern swine strains, fodder with sunflower byproduct inclusions as high as those reported by Silva et al. (2002b) and Colina et al. (2010) would hardly be possible. At present, animal breeds are selected for rapid weight gain, resulting in feed diets with increased nutrient content. Since sunflower byproducts are generally lower in nutritional content, they should be included in moderation in feed formulas.

The feed conversion of the animals fed with the inclusion of an enzyme complex was lower than those without the enzyme inclusion in their diet at this phase ($P < 0.05$; Table 3). In extensive research on the existence of influential effects of the addition

Table 3 – Production performance of pigs from 30 to 70 kg fed diets with increasing levels of sunflower meal (SM), with and without supplementation of enzyme complex (EC) – Viçosa – 2012

	Sunflower meal levels				
	0%	8%	16%	24%	
	Feed intake (kg/day)				Mean
With EC	2.205	2.165	2.0825	2.2075	2.165
Without EC	2.168	2.265	2.205	2.130	2.193
Mean	2.188	2.215	2.145	2.170	
ANOVA	Treatα = 0.6279ns	SMβ = 0.7252ns	Treat X SMγ = 0.3943ns	CV(%) = 8.02	
Probability	-	NS	NS		
	Weight gain (kg/day)				Mean
With EC	1.020	1.008	0.918	0.985	0.983
Without EC	0.955	0.995	0.978	0.935	0.965
Mean	0.988	1.003	0.948	0.960	
ANOVA	Treat = 0.5188ns	SM = 0.4471ns	Treat X SM = 0.3493ns	CV(%) = 9.35	
Probability	-	NS	NS		
	Feed conversion (kg/kg)				Mean
With EC	2.16	2.14	2.27	2.24	2.20
Without EC	2.26	2.29	2.26	2.28	2.27
Mean	2.21	2.22	2.27	2.26	
ANOVA	Treat = 0.0379*	SM = 0.5480ns	Treat X SM = 0.3127ns	CV(%) = 4.86	
Probability	-	NS	NS		

Treat - treatment; CV - coefficient of variation; β SM (%) - percentage of sunflower meal in the diet; γ - Interaction between treatments and SM (%); ns - does not present significance by the F test (P > 0.05); * - (P < 0.05); Q - quadratic effect (P ≤ 0.05) of the sunflower meal level; L - linear effect (P ≤ 0.05) of the sunflower meal level; NS/ns - no significant effect

Table 4 – Production performance of pigs from 70 to 100 kg fed diets with increasing levels of sunflower meal (SM), with and without supplementation of enzyme complex (EC) – Viçosa – 2012

	Sunflower meal levels				
	0%	8%	16%	24%	
	Feed intake (kg/day)				Mean
With EC	2.945	3.286	3.045	2.893	3.041
Without EC	2.948	3.107	2.848	2.717	2.903
Mean	2.948	3.197	2.945	2.803	
ANOVA	Treatα = 0.1895ns	SMβ = 0.0712ns	Treat X SMγ = 0.8854ns	CV(%) = 11.94	
Probability	-	NS	NS		
	Weight gain (kg/day)				Mean
With EC	1.045	1.131	1.010	0.972	1.041
Without EC	1.017	1.028	1.010	0.900	0.990
Mean	1.031	1.079	1.010	0.934	
ANOVA	Treat = 0.0795ns	SM = 0.0078*	Treat X SM = 0.5629ns	CV(%) = 9.61	
Probability	-	Q	NS		
	Feed conversion (kg/kg)				Mean
With EC	2.82	2.92	3.00	2.97	2.93
Without EC	2.88	3.01	2.82	3.04	2.94
Mean	2.85	2.96	2.91	3.00	
ANOVA	Treat = 0.9242ns	SM = 0.5392ns	Treat X SM = 0.5790ns	CV(%) = 9.25	
Probability	-	NS	NS		

Treat - treatment; CV - coefficient of variation; β SM (%) - percentage of sunflower meal in the diet; γ - Interaction between treatments and SM (%); ns - does not present significance by the F test (P > 0.05); * - (P < 0.05); Q - quadratic effect (P ≤ 0.05) of the sunflower meal level; L - linear effect (P ≤ 0.05) of the sunflower meal level; NS/ns - no significant effect of exogenous enzymes in swine fodder diets, Ruiz et al. (2008) also reported lower feed conversion in feed containing the inclusion of enzymes, when compared with those lacking this inclusion. Another advantage reported by these authors is the lower excretion of pollutants into the environment when they reported the capacity of exogenous enzymes to reduce feed conversion in fodder diets, as well as decreasing the rate of pollutants in the environment (SREDANOVIC; LEVIC; DURAGIC, 2005; JACELA et al., 2009). The presence of propitious enzymes enables the digestion of otherwise indigestible nutrients which, without their action, would then be adversely ejected into the environment as swine excretion, requiring further steps to mitigate their potentially harmful environmental liability.

The weight gain (WG) of animals from 70 to 100 kg was influenced by the inclusion of sunflower meal (SM) in the diets ($P < 0.05$; Table 4), according to the following equation: $WG = 30.106 + 0.2019\ SM - 0.0139\ SM^2$ ($R^2 = 94.0$), with the maximum inclusion level point found at 7.26%. This study diverges considerably from other results (SILVA et al. 2002b; COSTA et al., 2005; COLINA et al., 2010). Similar results were found by Silva et al. (2003), evaluating sunflower seed in the fodder diet of growing and finishing animals. As more productive swine strains are developed, animals with greater potential for lean meat deposition develop. As a result, animals require ration containing increasingly higher nutrient content. Feedstuffs such as sunflower meal contain high fiber content. Due to this fact, the presence of high percentages of this substance is not usually a priority in industrial swine ration production. Rizzi et al. (2007) reported lower digestibility rates of the sunflower meal fiber, when compared to other fibers from alternative feedstuffs.

In the present study, during the growth period encompassing 70 to 100 live weight of the subject specimens, fodder diet had no effect on intake or feed conversion ($P > 0.05$; Table 4). These results are in accordance with most previous studies (SILVA et al., 2002b; COSTA et al., 2005; COLINA et al., 2010). However, Shelton et al. (2001) observed higher feed conversion in animals fed fodder diets based on sunflower meal. In the Shelton et al. (2001) study, very high inclusion levels hardly reached in modern formulas were used (58.7%), due to the high fiber content of this feedstuff (NDF = 45.19). Carellos et al. (2005) observed a negative correlation between increasing levels of sunflower meal in diets for finishing pigs and feed intake, diverging from the results presented in this report. These results are intriguing, given the fact that, during this period, the inclusion of sunflower meal adversely affected the weight gain of the animals at levels higher than 7.26%. Researchers expected that with the same values of intake, feed conversion would also increase, which was not confirmed in this study. Numerical values were higher, but there was no statistical difference, which leads us to skepticism regarding adequate sensitivity of the test utilized in the parameters of feed conversion.

Assessing the entire growth period (from 30 to 100 kg live weight), no significant difference was verified for the parameters of intake and feed conversion ($P > 0.05$; Table 5). These results are similar to those found by Silva et al. (2002b), who likewise did not confirm any difference in the productive parameters during the entire evaluation period when including up to 21.0% sunflower meal in swine fodder diets during the entire phase. Other authors also found no interference regarding performance parameters when including 15.0% sunflower meal in swine rations during growing and finishing, and 15.5% sunflower meal in diets for post-weaning piglets (COSTA et al., 2005; COLINA et al., 2010). Nevertheless, a quadratic effect was observed on daily weight gain ($P < 0.05$; Table 5), described by the equation $WG = 1.0104 + 0.0024\ SM - 0.0002\ SM^2$ ($R^2 = 80.3$), with maximum point reached at the level of 6.00% sunflower meal inclusion. These results differ significantly from other studies (SILVA et al., 2002b; COSTA et al., 2005; COLINA et al., 2010). Animals of great genetic potential require

Table 5 – Production performance of pigs from 30 to 100 kg live weight fed diets with increasing levels of sunflower meal (SM), with and without supplementation of enzyme complex (EC) – Viçosa – 2012

	Sunflower meal levels				
	0%	**8%**	**16%**	**24%**	
	Feed intake (kg/day)				**Mean**
With EC	2.504	2.639	2.486	2.499	2.532
Without EC	2.500	2.622	2.474	2.371	2.491
Mean	2.503	2.630	2.480	2.435	
ANOVA	Treatα = 0.5530ns	SMβ = 0.2219ns	Treat X SMγ = 0.9083ns	CV(%) = 9.36	
Probability	-	NS	NS		
	Weight gain (kg/day)				**Mean**
With EC	1.026	1.061	0.957	0.981	1.006
Without EC	0.983	1.010	0.991	0.919	0.975
Mean	1.004	1.035	0.974	0.949	
ANOVA	Treat = 0.2028ns	SM = 0.0494*	Treat X SM = 0.4424ns	CV(%) = 8.11	
Probability	-	Q	NS		
	Feed conversion (kg/kg)				**Mean**
With EC	2.49	2.53	2.63	2.60	2.57
Without EC	2.57	2.65	2.54	2.66	2.6
Mean	2.53	2.59	2.59	2.63	
ANOVA	Treat = 0.3830ns	SM = 0.5206ns	Treat X SM = 0.3023ns	CV(%) = 5.49	
Probability	-	NS	NS		

Treat - treatment; CV - coefficient of variation; β SM (%) - percentage of sunflower meal in the diet; γ - Interaction between treatments and SM (%); ns - does not present significance by the F test (P > 0.05); * - (P < 0.05); Q - quadratic effect (P ≤ 0.05) of the sunflower meal level; L - linear effect (P ≤ 0.05) of the sunflower meal level; NS/ns - no significant effect

feed with high concentration of digestible nutrients to express their desired potential, restricting high inclusion of sunflower meal. This sunflower meal restriction was even executed in diets corrected with oil supplementation. In evaluating the total growth period of the animals, adverse influence on weight gain due to the inclusion of high levels of sunflower meal (higher than 6.00% inclusion) was observed, but without affecting the parameters of intake and feed conversion. Again, the numerical values of feed conversion were higher as the levels of sunflower meal increased, though without presenting statistical difference. Detmann, Cecon and Andreotti (2005) have criticized the use of parametric tests on data derived from divisions, such as feed conversion (feed conversion = feed intake / weight gain). These authors proposed the use of canonical variables for evaluation of the relationship between intake and weight gain, affirming that they would be statistically appropriate. However, feed conversion is an easily understood parameter and used extensively, when compared to the canonical variables proposed by these authors. For these reasons it is unlikely that feed conversion would fall into disuse.

No difference (P > 0.05) was found in the inclusion of sunflower meal or an enzyme complex in carcass muscularity, amount of lean meat in the carcass and percentage of lean meat in the carcass or carcass weight (P > 0.05; Table 6). In accordance with these results, both the phytases (LUDKE; LÓPEZ; LUDKE, 2002; SANTOS et al., 2008) and carbohydrases (YOON et al., 2010), as well as the association of these enzymes (THACKER; HAQ, 2009) have had little influence on swine carcass parameters.

When including up to 21.0% sunflower meal in swine fodder rations, Silva et al. (2002b) reported no difference in the amount of lean meat in the carcass, percentage of lean meat in the carcass and carcass weight. No differences were observed for the same variables up to the inclusion of 15.0% sunflower cake in the fodder diets either (SILVA et al., 2002b). There was, however, a negative correlation between carcass weight and the inclusion of sunflower seed in diets for finishing pigs (SILVA et al., 2003). However, the inclusion of sunflower meal in swine fodder diets did affect backfat thickness (BT) (P < 0.05; Table 6), described by the following equation: BT = 18.397 + 0.1812

Table 6 – Backfat thickness, carcass muscularity (kg), percentage of lean meat in the carcass (%), amount of lean meat in the carcass (kg) and carcass weight (%) of pigs fed diets with increasing levels of sunflower meal (SM), with and without supplementation of enzyme complex (EC) – Viçosa – 2012

	Sunflower meal levels				
	0%	**8%**	**16%**	**24%**	
			Backfat thickness (mm)		**Mean**
With EC	18.60	23.07	16.20	16.27	18.54
Without EC	16.93	19.00	16.93	17.73	17.65
Mean	17.77	21.04	16.57	17.00	
ANOVA	Treatα = 0.4789ns	SMβ = 0.0345*	Treat X SMγ = 0.6789ns	CV(%) = 23.19	
Probability	-	Q	NS		
			Carcass muscularity(kg)		**Mean**
With EC	59.60	66.33	63.40	54.20	60.88
Without EC	58.40	56.20	66.93	62.93	61.12
Mean	59.00	61.27	65.17	58.57	
ANOVA	Treat = 0.4567ns	SM = 0.0890ns	Treat X SM = 0.3456ns	CV(%) = 14.17	
Probability	-	NS	NS		
			Percentage of lean meat in the carcass (%)		**Mean**
With EC	53.45	51.58	55.62	54.10	53.69
Without EC	54.33	52.60	55.73	54.53	54.30
Mean	53.89	52.09	55.68	54.32	
ANOVA	Treat = 0.5678ns	SM = 0.0821ns	Treat X SM = 0.6547ns	CV(%) = 5.48	
Probability	-	NS	NS		
			Amount of lean meat in the carcass (kg)		**Mean**
With EC	44.55	42.82	42.38	42.00	40.44
Without EC	44.01	40.30	42.48	44.65	42.86
Mean	39.28	41.56	42.43	43.33	
ANOVA	Treat = 0.6580ns	SM = 0.0678ns	Treat X SM = 0.9876ns	CV(%) = 9.57	
Probability	-	NS	NS		
			Carcass weight (kg)		**Mean**
With EC	79.45	83.18	76.21	77.63	76.62
Without EC	81.06	76.82	76.19	81.94	79.00
Mean	75.26	80.00	76.20	79.79	
ANOVA	Treat = 0.9896ns	SM = 0.0876ns	Treat X SM = 0.8906ns	CV(%) = 9.38	
Probability	-	NS	NS		

Treat - treatment; CV - coefficient of variation; β FG (%) - percentage of sunflower meal in the diet; γ - Interaction between treatments and SM (%); ns - does not present significance by the F test (P>0.05); * - (P < 0.05); Q - quadratic effect (P ≤ 0.05) of the sunflower meal level; L - linear effect (P ≤ 0.05) of the sunflower meal level; ns/NS - no significant effect

SM%– 0.0111 (SM%)^2 (R^2 = 0.95), with maximum point reached at the level of 8.16% inclusion. These results differ from other studies that did not report any influence of the inclusion of sunflower meal based feed on backfat thickness (SHELTON et al., 2001; SILVA et al., 2002b; SILVA et al., 2003; COSTA et al., 2005; CARELLOS et al., 2005). Relative to the amount of total fat in the pig carcass, animals fed increasing levels of sunflower meal also showed no effect (MILINSK et al., 2007). Guillevic, Kouba and Mourot (2008) did not report any greater lipogenic enzyme activity in swine tissues fed with sunflower meal. The results presented here are unprecedented, possibly justified by better feed conversion in the phase growth from 70 to 100 kg, near the level of 7.26% inclusion of sunflower meal in the diet ration. The greater weight gain in this percentage of sunflower meal inclusion in the feed may have been a consequence of greater deposition of backfat thickness at this phase of the experiment (70 to 100 kg). These results promote discussion on which would be the ideal point for minimizing backfat thickness under higher weight gain.

Conclusion

The addition of an enzyme complex in swine ration diets improves feed conversion in animals from 30 to

70 kg of weight, but does not allow greater inclusion of sunflower meal than the fodder diets without an enzyme complex. The increase of sunflower meal percentages in the fodder diet increases weight (6.00% inclusion) and backfat thickness (8.16% inclusion), and reduces feed conversion (7.26% inclusion) in swine.

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