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Xylanase for meat-type quails from 15 to 35 days old

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ABSTRACT - The objective of this study was to evaluate the effect of the supplementation of two xylanases in the diet of meat-type quail on performance, morphology of the intestinal mucosa, metabolization of nutrients, and carcass yield. The experimental design was a completely randomized 2×3+1 factorial arrangement [two metabolisable energy reductions (70 and 140 kcal/kg), with or without the inclusion of two xylanases (A and B), plus a control treatment without xylanase), totalling seven treatments with five replicates and 42 quail each. Total excreta were collected at 28 days of age to determine the metabolisable coefficients of dry matter, crude protein (CP), neutral detergent fibre (NDF), and gross energy (GE). There was no interaction between the energetic reductions and inclusion of xylanases on performance variables of the birds. The 70 kcal/kg reduction led to better results for feed intake, weight gain, and feed conversion, while the 140 kcal/kg reduction led to worse results. In terms of jejunum morphometry, there was no interaction between energy reductions and inclusion of xylanases, although xylanases increased villi height and villus:crypt ratio. There was an interaction between energy reduction and inclusion of enzymes for the metabolisability coefficients of CP, NDF, and GE, leading to improvements in these coefficients. Xylanases A and B are effective in energy-reduced corn and soybean meal diets for 15 to 35-day-old quail.

Keywords: carbohydrases, carcass yield, energy, enzymes, quail production

Introduction

Since the late 1980s, enzymes have played an important role in improving the efficiency of meat and egg production by changing the nutritional profile of feed ingredients. The inclusion of exogenous enzymes in diets allows animals to extract more nutrients from the feed, thus improving feed efficiency. In addition, it provides farmers with greater flexibility in the types of feedstock that can be safely used in feed formulation and plays a key role in reducing the negative impact of animal production on the environment by reducing the excretion of contaminant residues (Barletta, 2011).

In general, enzymes are used in animal feed with two well-defined objectives: supplement enzymes that are produced by the animal itself, but in insufficient quantities (amylases and proteases), and provide animals with enzymes that are not synthesized (cellulases). With these practices, there is a

reduction in the negative effects caused by non-starch polysaccharides (NSP) (Fischer et al., 2002). According to Choct (2006), NSP have antinutritional activity in the diet of non-ruminant animals, which reduces nutrient use.

Supplementation of exogenous enzymes, such as xylanase, reduces intestinal viscosity, with a consequent increase in nutrient diffusion rate from the lumen to the bloodstream (Bach Knudsen, 2001). The enzyme cleaves the long chains of polysaccharides, reducing their ability to form a gel. In addition, they act on the plant cell wall, providing encapsulated nutrients, and modify the intestinal microflora (Choct, 2006). Supplementation of carbohydrases in soybean meal-based diets brings beneficial effects that are related to its action on the plant cell wall and intestinal microflora, rather than to action on the intestine viscosity (Cowieson, 2005).

The objective of this work was to evaluate the performance, intestinal morphometry, nutrient metabolisability, and carcass yield of meat-type quail from 15 to 35 days of age, fed corn- and soybean meal-based diets supplemented with two xylanase enzymes and with metabolisable energy reductions.

Material and Methods

Research was conducted in Maringá (latitude: 23°25' S, longitude: 51°57' W, and altitude: 596 m), located in the northwest of Paraná, Brazil, with a subtropical and tropical climate. The experimental procedure was approved by the Ethics Committee on the Use of Animals (case no. 6841070515).

For the performance test, 1470 unsexed meat-type quail (*Coturnix coturnix sp.*), distributed into 35 boxes for the growth phase (15 to 35 days), were used. The experimental design was a completely randomized 2×3+1 factorial scheme [two reductions of metabolisable energy (ME) of 70 and 140 kcal/kg, with or without two xylanase enzymes A and B, plus a control treatment without xylanase], totalling seven treatments with five replicates. The control diet was formulated to meet the nutritional requirements of the birds without the inclusion of the xylanase enzyme. The reductions of ME and crude protein (CP) were made from the control. Enzymes were included in the amount of 100 g per ton of feed, with dietary titrations from the nutritional matrix of the enzymes, according to the manufacturer. Xylanase was obtained from the fungi *Trichoderma longibrachiatum*, with a minimum activity of 1500 EPU/kg, and secondary activity of cellulase, β-glucanase, α-amylase, and protease. Xylanase B was obtained from the fungi *Trichoderma reesei*, with a minimum activity of 16000 BXU/kg. Both enzymes have primary endo-1,4β-xylanase enzymatic activity.

The experimental rations (Table 1) were formulated with maize and soybean meal, based on the feed chemical composition values obtained by Rostagno et al. (2011). To meet the nutritional requirements of quail, we followed the recommendations of Scherer et al. (2011) for metabolisable energy requirements, Furlan et al. (2011) for the digestible lysine requirement, Otutumi et al. (2009) for the requirement of crude protein, and Silva et al. (2009) for the calcium and phosphorus requirements of the feed.

For the evaluation of animal performance [i.e., body weight (BW), feed intake (FI), weight gain (WG), and feed conversion (FC)], birds and feed were weighed weekly until the 35th day. At 35 days of age, one bird per experimental unit was taken, representing the mean weight of the lot (±10%), to evaluate the morphometry of the jejunum on intestinal mucosa according to Beçak and Paulete (1976). The image capture of the slides was performed using a Leica optical microscope with an image capture system (Moticam 5MP). Ten villi and ten crypts were measured per replicate, using a 4x objective for both and Motic Images Plus software (version 2.0). From these values, the mean intestinal segment of each animal was obtained for villi height, crypt depth, and villus:crypt ratio.

Two birds (male and female) were randomly removed from each experimental unit, within the mean (±10%) weight for the evaluation of carcass yield of birds at 35 days of age. For the calculation of carcass yield, the weight of the eviscerated carcass, without feet and head, in relation to live weight, was taken individually before slaughter. The yield of parts (breasts, abdominal fat, thighs, and drumsticks) was calculated in relation to the weight of the eviscerated carcass.

Nutrient metabolisability was determined using the total excreta collection method (Sakomura and Rostagno, 2007). We used 175 28-day-old males housed in galvanized wire battery cages. The experimental design was similar to that of the performance test, totalling seven treatments with five replicates and five quail per experimental unit. We added ferric oxide (2%) to the diet as a marker of the beginning and end of collection. At the end of the experimental period, the excreta were thawed, homogenised, weighed, and kept in a forced-air ventilation oven at 55 °C for 72 h for the determination of pre-drying. After drying, dry matter (DM), CP, and neutral detergent fibre (NDF) contents of the ground excreta were analysed according to the methodology described by Silva and Queiroz (2005). Gross energy of excreta and feed was determined using an adiabatic calorimetric pump (Parr Instruments Co.).

Statistical analysis of the data was performed using the software System of Statistical Analysis and Genetics (SAEG, version 9.1), according to the statistical models presented below:

$$Y_{ijk} = \mu + ME_i + ENZ_j + MEENZ_{ij} + e_{ijk} \quad (1)$$

and

$$Y_{ij} = \mu + T_i + e_{ij}, \quad (2)$$

in which Y_{ijk} is the response variable related to the level of metabolisable energy reduction (i = 70 and 140 kcal/kg) with or without enzymes (j = xylanase A, xylanase B, and without xylanase) in the replicate

Table 1 - Nutritional composition of experimental feeds for 15 to 35-day-old meat-type quail

Treatment	T1	T2	T3	T4	T5	T6	T7
Ingredient				Quantity (g/kg)			
Corn	543.4	571.9	571.9	571.9	572.9	572.9	572.9
Wheat bran	-	-	-	-	14.0	14.0	14.0
Soybean meal 46%	397.0	384.0	384.0	384.0	379.0	379.0	379.0
Soybean oil	26.0	10.0	10.0	10.0	-	-	-
Dicalcium phosphate	9.6	9.6	9.6	9.6	9.4	9.4	9.4
Salt	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Limestone 38% Ca	5.0	5.2	5.2	5.2	5.3	5.3	5.4
DL-methionine 99%	3.0	3.0	3.0	3.0	3.0	3.0	3.0
L-lysine 98%	3.9	4.1	4.1	4.1	4.2	4.2	4.2
L-threonine	1.9	1.9	1.9	1.9	2.0	2.0	2.0
Vitamin and mineral mixture[1]	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Antioxidant[2]	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Xylanase A	-	0.1	-	-	0.1	-	-
Xylanase B	-	-	0.1	-	-	0.1	-
Phytase	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Calculated values							
Metabolised energy (MJ/kg)	12.71	12.41	12.41	12.41	12.12	12.12	12.12
Crude protein (g/kg)	235	232	232	232	232	232	232
Calcium (g/kg)	7.0	7.1	7.1	7.1	7.1	7.1	7.1
Available phosphorus (g/kg)	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Sodium (g/kg)	1.8	1.8	1.8	1.8	1.8	1.8	1.8
Digestible met+cys (g/kg)	10.9	10.8	10.8	10.8	10.8	10.8	10.8
Digestible lysine (g/kg)	14.5	14.4	14.4	14.4	14.4	14.4	14.4
Digestible threonine (g/kg)	9.4	9.3	9.3	9.3	9.3	9.3	9.3
Ether extract (g/kg)	53.2	38.4	38.4	38.4	29.1	29.1	29.1

[1] Vitamin-mineral supplementation (guaranteed levels per kilogram of diet): retinol acetate, 18,000 IU; cholecalciferol, 5000 IU; dl-α-tocopheryl acetate, 16 mg; thiamine hydrochloride, 1.12 mg; riboflavin, 8 mg; pyridoxine hydrochloride, 2.1 mg; cyanocobalamin, 20 mcg; menadione nicotinamide bisulphite, 4.028 mg; D-calcium pantothenate, 16 mg; niacin acid, 40 mg; choline chloride, 560 mg; zinc oxide, 126 mg; ferrous sulphate, 98 mg; manganese sulphate, 155 mg; copper sulphate, 30.624 mg; cobaltous sulfate heptahydrate, 0.4 mg; potassium iodate, 1.936 mg; sodium selenite, 0.508 mg; butylated hydroxytoluene, 0.02 mg.
[2] BHT (Butil Hidroxi Tolueno).

(k = 1, 2, 3, 4, and 5); μ is the general average; ME_i is the effect of metabolisable energy reductions (ME_1 = 70 kcal/kg and ME_2 = 140 kcal/kg); ENZ_j is the effect of the inclusion of enzyme (ENZ_1 = xylanase A; ENZ_2 = xylanase B; and ENZ_3 = without xylanase); $MEENZ_{ij}$ is the effect of the metabolisable energy interaction and enzymes; e_{ijk} is the random error associated with each observation Y_{ijk}; Y_{ij} is the response variable obtained in subject j, receiving treatment i; T_i is the effect of the additional treatment; e_{ij} is the experimental error associated with the additional treatment.

For model 1, the data were subjected to an analysis of variance; when there was a significant interaction (P<0.10) between the reductions of metabolisable energy and addition of enzymes, the obtained data were deployed, and means were compared using Tukey's test (P<0.10). In the case of interactions, the effects of factors were analysed in an isolated manner, with the metabolisable energy reductions subjected to analysis of variance and F test (P<0.10), and the addition of enzymes subjected to analysis of variance and Tukey's test (P<0.10). For model 2, the data were subjected to analysis of variance, and means were compared using Dunnett's test (P<0.05).

Results

There was no interaction (P>0.10) between the energetic reductions and inclusion of xylanases for the performance variables of the birds; supplementation with the enzymes did not influence BW, WG, FI, or FC (P>0.10) of the birds (Table 2). The reductions of ME had an effect on WG (P = 0.0859), FI (P = 0.0969), and FC (P = 0.0036).

There was no interaction (P>0.10) between energy reductions and the inclusion of xylanases on the intestinal morphometry of the birds (Table 3).

There was a significant interaction (P = 0.0008) for coefficient of metabolisable crude protein (CMCP) between ME reductions and inclusion of xylanases, as well as for coefficients of metabolisable neutral detergent fibre (CMNDF) and CMCP (Table 4).

Table 2 - Body weight (BW), weight gain (WG), feed intake (FI), and feed conversion (FC) of 15 to 35-day-old meat-type quail fed diets with metabolisable energy (ME) reductions, with or without xylanase supplementation

Variable	Xylanase (100 g/t)	ME reduction		Mean	Control	Probability			CV (%)
		70 kcal/kg	140 kcal/kg			ME	Xylanase	ME × Xylanase	
BW (g)	A	230.05	221.10	225.57	228.50	0.1767	0.9802	0.6011	3.99
	B	225.19	224.41	224.80					
	Less	227.35	223.34	225.34					
	Mean	227.53	222.95						
WG (g)	A	141.76	131.96	136.86	141.49	0.0859	0.9142	0.3446	5.01
	B	137.47	135.55	136.51					
	Less	138.65	136.89	137.77					
	Mean	139.29a	134.8b						
FI (g)	A	517.35	522.21	519.78	497.86	0.0969	0.7885	0.7436	3.70
	B	509.36	522.89	516.12					
	Less	505.03	522.88	513.95					
	Mean	510.58b	522.66a						
FC (g/g)	A	3.65	3.98*	3.81	3.52	0.0036	0.5841	0.5113	4.99
	B	3.70	3.85*	3.77					
	Less	3.64	3.81*	3.72					
	Mean	3.66b	3.88a						

CV - coefficient of variation.
*Differs from the control treatment by Dunnett's test (P<0.05).
a,b - Means followed by different letters within the same row differ significantly by the F test (P<0.10).

Table 3 - Villi height (VH), crypt depth (CD), and villus:crypt ratio (V:C) of the jejunum of 35-day-old meat-type quail fed diets with metabolisable energy (ME) reductions, with or without xylanase supplementation

Variable	Xylanase (100 g/t)	ME reduction		Mean	Control	Probability			CV (%)
		70 kcal/kg	140 kcal/kg			ME	Xylanase	ME × Xylanase	
VH (µm)	A	508.58	496.76	502.67A	473.65	0.1665	0.0513	0.3477	10.33
	B	447.63	443.57	445.60B					
	Less	539.53	467.19	503.41A					
	Mean	498.61	469.17						
CD (µm)	A	60.51	60.20	60.35	65.15	0.4204	0.3044	0.5594	11.40
	B	57.69	58.28	57.98					
	Less	51.92	58.28	55.10					
	Mean	56.17	58.92						
V:C (µm)	A	8.48	8.30	8.39AB	7.39	0.0521	0.0405	0.1090	15.21
	B	7.86	7.60	7.73B					
	Less	10.44*	8.07	9.26A					
	Mean	8.93a	7.99b						

CV - coefficient of variation.
* Differs from the control treatment by Dunnett's test (P<0.05).
A,B - Means followed by the same uppercase letters in the column do not differ significantly by Tukey's test (P<0.10).
a,b - Means followed by different lowercase letters in the line differ significantly by the F test (P<0.10).

Table 4 - Coefficient of metabolisability of dry matter (CMDM), crude protein (CMCP), neutral detergent fibre (CMNDF), and crude energy (CMCE), and apparent metabolisable energy corrected for nitrogen balance (AMEn) of meat-type quail fed diets with metabolisable energy (ME) reductions, supplemented with xylanases

Variable	Xylanase (100 g/t)	ME reduction		Mean	Control	Probability			CV (%)
		70 kcal/kg	140 kcal/kg			ME	Xylanase	ME × Xylanase	
CMDM (%)	A	68.85	66.08	67.47	66.93	0.3419	0.1052	0.0641	2.54
	B	66.15	66.67	66.41					
	Less	65.56	66.02	65.79					
	Mean	66.85	66.26						
CMCP (%)	A	33.32Aa	27.45Aa	30.39	28.25	0.7668	0.5412	0.0008	17.89
	B	23.62Bb	36.94*Ba	30.28					
	Less	35.58Aa	29.94Aa	32.76					
CMNDF (%)	A	43.13*Aa	46.51*Aa	44.82	36.09	0.5331	0.0002	0.0348	9.92
	B	41.04Aa	34.76Bb	37.9					
	Less	36.58Aa	36.73Ba	36.66					
CMCE (%)	A	74.69Aa	71.74Ba	73.22	73.81	0.0601	0.0730	0.0413	1.95
	B	72.18Aa	72.47Aa	72.33					
	Less	71.89Aa	71.50Aa	71.70					
AMEn (kcal/kg NM)	A	2910.43	2788.11*	2849.27A	2972.4	0.0007	0.0020	0.0545	1.62
	B	2829.37*	2775.46*	2802.41AB					
	Less	2777.02*	2757.58*	2767.30B					
	Mean	2838.94a	2773.72b						

CV - coefficient of variation.
* Differs from the control treatment by Dunnett's test (P<0.05).
A,B - Means followed by the same uppercase letters in the column do not differ significantly by Tukey's test (P<0.10).
a,b - Means followed by different lowercase letters in the row differ significantly by the F test (P<0.10).

Carcass, parts, and abdominal fat yields showed no interaction (P>0.10) between ME reductions and inclusion of xylanase enzymes (Table 5). Reductions of DM and inclusion of xylanase enzymes also did not differ (P>0.10). Means of the control treatment were also not significantly different from the means of the other treatments (P>0.05).

Discussion

Birds fed diets with 70 kcal/kg ME reduction gained more weight than birds that consumed feed with 140 kcal/kg reduction (P = 0.0859) (Table 2). Consequently, the FC of these birds was better (P = 0.0036), reflecting a lower intake for birds fed the 70 kcal/kg ME reduction compared with those fed 140 kcal/kg reduction (P = 0.0969). The increase in FI of the birds subjected to treatments with a 140 kcal/kg ME reduction is associated with nutrient deficiency, since, in general, in diets with reduced nutritional levels, birds seek to compensate for deficiencies with increased intake; even the addition of xylanase enzymes was not enough to compensate for this deficiency. The increase in FI also did not reflect improvements in WG and FC.

In Dunnett's test, birds fed diets with a 140 kcal/kg ME reduction had higher FC than birds fed the control diet (P<0.05), while the birds that consumed 70 kcal/kg reduction had similar FC as the control diet (P>0.05) (Table 2). The higher the volume of feed in the digestive tract, the lower its use, as explained by a decrease in the efficiency of digestive enzymes and, consequently, a lower absorption of nutrients; that is, there is a lower use of the diet when birds ingest increasing amounts of feed (Sakomura et al., 2004). Therefore, it is justifiable to increase the FC rate for birds with a lower energy level than that of the control.

Evaluating the inclusion of xylanase and β-glucanase enzymes in corn and soybean meal diets for 15 to 35-day-old meat-type quail, Iwahashi et al. (2011) observed a lower WG of birds fed positive control diets supplemented with exogenous enzymes; however, the negative control, with enzymatic supplementation, was efficient in maintaining WG. The same authors did not observe significant

Table 5 - Carcass (CY), breast (BY), thigh and drumstick (TDY), and fat (FY) yield of 35-day-old meat-type quail fed diets with metabolisable energy (ME) reductions, with or without xylanase supplementation

Variable	Xylanase (100 g/t)	ME reductions		Mean	Control	Probability			CV (%)
		70 kcal/kg	140 kcal/kg			ME[ns2]	Xylanase[ns1]	ME × Xylanase[ns1]	
CY (%)	A	63.76	63.23	63.50	63.23	0.8887	0.3712	0.7582	3.34
	B	62.71	62.18	62.45					
	Less	63.36	64.07	63.72					
	Mean	63.28	63.16						
BY (%)	A	28.74	27.49	28.12	27.55	1.000	0.4923	0.3416	6.29
	B	27.50	28.60	28.05					
	Less	28.77	29.06	28.92					
	Mean	28.34	28.38						
TDY (%)	A	15.92	16.23	16.08	16.08	0.3176	0.8364	0.9609	5.72
	B	15.60	16.07	15.84					
	Less	15.85	16.10	15.98					
	Mean	15.79	16.13						
FY (%)	A	0.68	0.67	0.68	0.67	0.3829	0.1005	0.1503	28.31
	B	0.64	0.42	0.53					
	Less	0.49	0.56	0.53					
	Mean	0.60	0.55						

CV - coefficient of variation.
[ns1] Not significant by Tukey's test (P>0.10).
[ns2] Not significant by F test (P>0.10).

differences for FI and WG. Working with 22 to 42-day-old meat-type quail, Torres et al. (2014) observed that the inclusion of protease at the level of 20% CP led to better feed intake; however, the enzyme did not influence WG and FC.

Supplementation of exogenous enzymes is known to produce varied responses, even when added to similar diets and given to animals of the same age (Officer, 2000). Bedford (2002) clarifies that the provision of diets that fully meet all nutrient and energy requirements does not provide an opportunity for enzymes to demonstrate their value by reducing the size of the expected response, thus making their effect difficult to detect.

The ME reduction levels did not influence villi height and crypt depth (P>0.10); however, they influenced the villus:crypt ratio (P = 0.0521), with the highest ratio corresponding to the 70 kcal/kg ME reduction (Table 3). Villi height was influenced by xylanases (P = 0.0513), with the highest villi height found in birds that consumed xylanase A or did not consume xylanase, and the lowest height in birds that consumed xylanase B. In this way, xylanase A had a trophic action on the intestinal mucosa, providing better functional capacity. Villi height:crypt depth ratio was higher for non-xylanase treatments and lower for xylanase B treatments. Xylanase A treatments showed no differences from the other treatments (P = 0.0405).

When comparing the means of treatments with the control, only treatment without xylanases and with 70 kcal/kg ME reduction was higher than the control (P<0.05), while the other treatments did not differ (P>0.05). This difference was related to villi height (539.53 μm) and crypt depth (51.92 μm) in treatments without xylanase and 70 kcal/kg ME reduction.

The development of the intestinal mucosa consists of increasing the height or density of the villi, which corresponds to a larger number of epithelial cells (enterocytes, goblet, and enteroendocrine cells) and, consequently, an increase in the digestive and absorptive capacity of the intestine (Uni et al., 2000). Therefore, the larger the height of the villi, the greater its absorption capacity for nutrients. A decrease in villi height may occur due to a decrease in the proliferation rate and/or an increase in the extrusion rate (Macari, 1995). The presence of exogenous enzymes in diets tends to induce small changes in the gut; however, they are frequently observed, not only in the reduction of intestinal size and/or release of endogenous enzymes, but also in the increase of villi (Yang et al., 2008).

Dunnett's test showed that CMCP for the xylanase B-supplemented diet with 140 kcal/kg ME reduction was greater than the control (P<0.05) (Table 4). Thus, xylanase B was effective in increasing protein digestibility, providing more nutrients for endogenous enzymes to act on, resulting in improved digestion and nutrient absorption. Researchers have observed that pentosans, when solubilised in the gastrointestinal tract, not only depress nutrient availability, but also cause endogenous protein loss (Cleóphas et al., 1995). However, this did not occur in this experiment, since CMCP improved with the inclusion of xylanases, indicating that the enzymes acted in the degradation of pentosans.

Investigation of the CMCP interaction showed that birds receiving diets with 70 kcal/kg ME reduction and inclusion of xylanase B had worse CMCP coefficients than birds that received 140 kcal/kg reduction. Xylanase B was more active in lower energetic level diets, resulting in its maximum use and demonstrating its beneficial effect on improving the digestibility of protein in corn- and soybean meal-based rations. The benefit of increased protein digestibility, promoted by enzyme supplementation, is related to a reduction of the production of endogenous amino acids, rather than to a better digestion of amino acids in the diet (Wyatt and Bedford, 1998). However, such a benefit is greater in reducing energy expenditure, because birds spend less energy performing digestion processes, which results in more energy being available for productive processes.

Investigation of the CMNDF interaction (P = 0.0348) revealed better values with the diet with 140 kcal/kg reduction and with xylanase A supplementation, in relation to diets with the same reduction with and without supplementation of xylanase B. Dunnett's test showed that xylanase A, at both ME reductions, showed different CMNDF valuesthan the control diet (P<0.05), indicating an improvement in CMNDF.

The improvement in CMNFD confirms the efficiency of the enzymes in providing intracellular nutrients contained in the vegetal wall, with an even more significant effect (P<0.10) with xylanase A. According to the manufacturer, this enzyme has secondary activity of cellulase, β-glucanase, α-amylase, and protease enzymes, indicating a greater availability of nutrients for birds and, consequently, a greater nutrient absorption. Cell wall hydrolysis was verified by Bedford (2000), who evaluated xylanase and β-glucanase, which release the encapsulated nutrients from the cell wall; releasing these nutrients through the exogenous enzymes potentiates the action mechanisms of endogenous enzymes. In meat-type quail, Iwahashi et al. (2011) also observed a significant improvement of 5% in CMNDF with carbohydrate supplementation.

These facts corroborate the data of this experiment, in which the improvement was 19.50% when xylanase A was added to the diet with 70 kcal/kg ME reduction and 28.87% for diet with 140 kcal/kg ME reduction. Through decomposing the fibre present in the cell walls with the addition of enzymes, the access of endogenous enzymes to the encapsulated nutrients inside these rich fibre walls is facilitated (Bedford, 2000). Cozannet et al. (2017) conducted an experiment using a multi-carbohydrase complex rich in xylanase and arabinofuranosidase in broilers; they observed that the dietary addition of the multi-carbohydrase complex reduced the deleterious effect of fibre and improved the overall digestibility of nutrients in broiler diets.

Investigation of the CMCP interaction (P = 0.0413) only showed differences for the 140 kcal/kg DM reduction with xylanase A. The apparent metabolisable energy corrected for nitrogen balance (AMEn) values were influenced by the inclusion of xylanases (P = 0.0020) and energy level reductions (P = 0.0007). Birds that consumed diets with xylanase A had a higher AMEn value (2849.27 kcal/kg NM), while the lowest value was obtained without xylanases (2767.30 kcal/kg NM). In the case of energy reduction, the highest value was obtained with the 70 kcal/kg reduction, (2838.94 kcal/kg NM) compared with the 140 kcal/kg reduction (2773.72 kcal/kg NM). Dunnett's test showed that only xylanase A at the 70 kcal/kg reduction did not differ (P>0.05) from the control, while the other treatments differed (P<0.05). This indicates that the enzymatic activity of xylanase A was effective in improving the ME of the ration, whereas the activity of xylanase B may have been masked due to the high ME of feed grains.

Differences in the effect of enzymes on feed or dietary energy may be related to the amount of substrate available to the enzyme, availability of energy from the ingredient itself, or both (Adeola and Cowieson, 2011). According to Palander et al. (2005), the improvement in energy from cereal grains with carbohydrase supplementation can be masked when the energy value of the cereal grain is high. Similarly, in the study of Adeola et al. (2008), the carbohydrate improved ME in diets with reduced energy, but not in diets with higher ME. A similar effect was demonstrated by Zhou et al. (2009), in which the improvement in the effect of carbohydrase AMEn became higher with a decrease in the AMEn of the control diet.

Indeed, endoxylanases help degrade arabinoxylan chains by hydrolysing the xylan backbone. However, multiple arabinose substitutions reduce the efficiency of xylanase, especially in corn and associated byproducts (Bach Knudsen, 2014). Arabinofuranosidases can cleave arabinose from the xylose backbone and offer access to endoxylanase activity (De la Mare et al., 2013). Consequently, enriching a preparation with debranching enzymes is an efficient way to increase the overall enzyme effect. Kiarie et al. (2014) observed that xylanase improved growth performance and AMEn in broilers, independently of diet type, suggesting hydrolysis of both soluble and insoluble NSP.

With supplementation of an exogenous xylanase for broiler chickens, Zhang et al. (2014) showed that the supplementation of xylanase to wheat-based diets cuts the arabinoxylan backbone into small fragments (mainly arabinose and xylose) in the ileum, jejunum, and duodenum and enhances the digestibility of nutrients by decreasing digesta viscosity. The release of arabinose and xylose in the small intestine may also be important contributors to the growth-promoting effect of xylanase in broilers fed wheat-based diets.

The data obtained (Table 5) in this work corroborates the results obtained by Iwahashi et al. (2011), who did not observe differences in the yields of carcass and parts of meat-type quail. Our results affirm that the supplementation of xylanase A, with 70 and 140 kcal/kg ME reductions, was efficient in providing better performance due to the improvement of nutrient metabolisability and morphometry of intestinal mucosa.

Conclusions

The supplementation of xylanases A and B in diets with reductions of metabolisable energy of 70 and 140 kcal/kg can be effectively used in corn- and soybean-meal diets for 15 to 35-day-old meat-type quail. Xylanase A improves the use of crude protein, neutral detergent fibre, and energy and improves the morphometry of the intestinal mucosa.

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