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Blend of Carbohydrases and Proteases in Reduced-Energy Diets for Growing and Finishing Pigs

Pedro Henrique Watanabe

pedrohwatanabe@gmail.com

Universidade Federal do Ceara https://orcid.org/0000-0002-1010-2305

Rayssa Aline Rocha Teixeira

Universidade Federal do Ceara - Campus do Pici

Juliana Forgiarini

Universidade Federal de Pelotas

Paulo Natanael Lima Pacheco

Universidade Federal do Ceara - Campus do Pici

Kilvia Karoline Viveiros Sousa Melo

Universidade Federal do Ceara - Campus do Pici

Thatila Ellinna Batista de Lima

Federal University of Ceara: Universidade Federal do Ceara

José Melquisedeque Nobre Nogueira

Universidade Federal do Ceara

Eulália Moura Fraga

Federal University of Ceara: Universidade Federal do Ceara

Flávia Ferreira Teodósio

Federal University of Ceara: Universidade Federal do Ceara

Ester Araújo Sanil dos Santos

Federal University of Ceara: Universidade Federal do Ceara

Valesca Abreu de Oliveira

Federal University of Ceara: Universidade Federal do Ceara

Leonardo Augusto Fonseca Pascoal

Paraiba Federal University: Universidade Federal da Paraiba

Ana Sancha Malveira Batista

Universidade Estadual Vale do Acaraú: Universidade Estadual Vale do Acarau

Ednardo Rodrigues Freitas

Federal University of Ceara: Universidade Federal do Ceara

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Abstract

Two trials were carried out to evaluate the addition of a blend of carbohydrases and protease to growing-finishing pig diets on digestibility (Trial 1) and performance, carcass characteristics, and meat quality (Trial 2). In both trials, the treatments were CON: control diet (3230 kcal of ME/kg); RED5%ME: diet with a 5% reduction in energy level (3072 kcal of ME/kg); RED5%EM+enzymes: diet with a 5% reduction in energy level (3073 kcal of ME/kg), with the addition of blend of enzymes. In Trial 1, 15 80-day-old barrows were distributed in three treatments with five replicates each, housed in cages for metabolic studies, using the total feces and urine collection method. Higher values of digestible NDF and ADF were observed in diets with the enzyme blend and 5% reduction in energy level when compared to the control diet. The dietary enzyme blend resulted in a similar metabolizable energy value compared to the control diet. For Trial 2, 36 barrows, 63 days old, were distributed in three treatments with ten replicates each. The inclusion of the enzyme blend promotes better feed conversion at growing and finishing phases. Pigs fed diet with reduced energy and the addition of carbohydrases and proteases blend had a larger loin area compared to animals fed reduced-energy diet. Supplementation with a blend of carbohydrases and proteases in energy-reduced diets acts on the digestibility of fibrous fractions, promotes better energy utilization and feed conversion of growing and finishing pigs, without compromising lean tissue deposition.

INTRODUCTION

Feeding pigs during the growing and finishing phases is the main component of total production costs (Andretta et al., 2014), with energy accounting for at least 70% of total feed costs (Noblet et al., 2022). Diets based on maize and soybean meal as the main ingredients in high-energy and high-protein diets contain non-starch polysaccharides (NSP) such as arabinoxylans, beta-glucans, and proteins structurally linked to the fibrous fraction, which are not broken down by pig digestive enzymes (Kiarie et al., 2012).

Given the inefficiency in digesting certain cell wall components, strategies that enhance nutrient utilisation, such as the includion of exogenous enzymes in diets, aim to improve feed efficiency in pigs by increasing the digestibility of NSP and proteins containing antinutritional factors (Park and Adeola, 2022; Hoque et al., 2023; Kim et al., 2023; Flores et al., 2024).

Although studies with exogenous enzymes in pig diets have shown promise since the earliest research (Young et al., 1993; Ferket, 1996; Li et al., 1996), strategies for using carbohydrases and proteases have evolved in terms of production processes and application methods (Petry and Patience, 2020). Historically, carbohydrases and proteases were added separately to increase the nutritional value of diets (Chassé et al., 2022; Valente Junior et al., 2024). Currently, the combined use of these enzymes in enzymatic blends has been observed to produce a synergistic effect, focusing on reducing energy levels, aiming to maximise their potential effect (Netrebka et al., 2024; Soderstrom et al., 2024).

Given the above, the objective was to evaluate a blend of carbohydrases and proteases in energy-reduced diets for growing and finishing pigs with respect on diet digestibility, performance, carcass

characteristics, and meat quality.

MATERIAL AND METHODS

Two trials were conducted to evaluate performance, carcass characteristics, and meat quality (Trial 1) and diet digestibility (Trial 2). In both trials, three treatments were used: CON, a control diet, formulated to meet the nutritional requirements of pigs (3230 kcal ME/kg); RED5%ME, a diet with a 5% reduction in energy level compared to the control diet (3072 kcal ME/kg); and RED5%ME+enzymes, a diet with a 5% reduction in energy level compared to the control diet (3072 kcal ME/kg), with the addition of a blend of carbohydrases and protease. The enzyme blend consisted of alpha-amylase, xylanase, glucanase, mannanase, and acid protease.

Digestibility of diets containing a blend of carbohydrases and proteases for growing pigs

A total of 15 castrated male pigs, 80 days old, were used and distributed among three treatments with five replicates each. The diets were formulated (Table 2) to meet the nutritional requirements for pigs at growing phase (86 to 105 days), according to Rostagno et al. (2017).

The animals were housed in cages for metabolic studies for 14 days, with 7 days for adaptation to the diets and 7 days for faecal and urine collection. Feeding took place out twice daily, at 8:00 am and 5:00 pm. Thirty minutes after the start of feeding, leftovers were collected and weighed. Water was provided ad libitum after each feeding. The amount of feed provided during the faecal collection period was determined according to the lowest consumption recorded during the first 7 days, based on the metabolic weight ($kg^{0.75}$) of each experimental unit. Ferric oxide (Fe_2O_3) was used as a faecal marker to determine the beginning and end of the collection period.

The total faeces and urine collection method was used. Faeces were collected and weighed in plastic bags twice daily and stored in a freezer at -8°C for later analysis. Urine was collected once daily in plastic buckets containing 20 ml of 2N hydrochloric acid solution. The volume of urine produced was measured, and a 20% aliquot was taken for subsequent analysis.

At the end of the trial, the faeces and urine of each animal were dried and analysed for dry matter, crude protein, ether extract, mineral matter (AOAC, 2005), neutral detergent fibre, acid detergent fibre (Van Soest et al., 1991), and gross energy (IKA, model C200). Urine samples were analysed for energy and nitrogen content. Using the values for dry matter, crude protein, neutral detergent fibre, acid detergent fibre, mineral matter, ether extract, and gross energy, the nutrient digestibility coefficients, digestible nutrients, and metabolisable energy of the diets were calculated.

Performance of growing and finishing pigs fed diets containing a blend of carbohydrases and proteases

A total of 36 castrated male pigs aged 63 days were used, distributed among three treatments with 12 replicates each. Diets (Tables 1, 2, and 3) were formulated to meet the nutritional requirements for pigs

aged 63 to 85 days, 86 to 105 days and 106 to 150 days, according to Rostagno et al. (2017). Performance was evaluated based on daily feed intake (DFI), daily weight gain (DWG), and feed conversion ratio (FCR). DFI was calculated by subtracting the weight of leftover feed from the weight of feed provided during the period, then dividing by the number of days in the experimental period. DWG was calculated by subtracting the initial weight from the final weight of the animals, then dividing by the number of days in the experimental period. FCR was calculated based on total feed intake and total weight gain during the experimental period.

Carcass characteristics

At 150 days of age, the pigs were subjected to a 12-hour fast and then slaughtered. The carcasses were sawn longitudinally in half and weighed to obtain the hot carcass weight (HCW) and carcass yield (the ratio between hot carcass weight and final live weight at 150 days). Subsequently, the half-carcasses were stored for 24 hours at 4ºC for later evaluations.

The following measurements were taken from the left half of each animal's carcass: carcass length, backfat thickness (at the first and last thoracic vertebrae, and the last lumbar vertebra), loin depth (LD), backfat thickness (BT), and loin eye area at the P2 position, according to the Brazilian Carcass Classification Method (Associação Brasileira de Criadores de Suínos, 1973). Using the values for hot carcass weight, fat thickness, and loin depth, the percentage of lean meat (%LM) was calculated according to the equations proposed by Guidoni et al. (2007):

%LM = 58.408 – (0.5886 x BT) + (0.1739 x LD) – (0.0189 x HCW)

Meat quality

From the right half of each animal's carcass, a sample of approximately 20 cm of the Longissimus muscle was collected. Analyses of pH (at 45 minutes and 24 hours after slaughter), water retention capacity (Hamm, 1961), colour (Shimokomaki, 2003), cooking loss (Li et al., 2012), and shear force (Corte et al., 1979) were performed on the meat, which was refrigerated for approximately 24 hours.

Statistical analysis

The data obtained were analysed using the GLM procedure of the statistical program SAS (University Edition), according to the model:

$\varepsilon_{ijk} = \mu_{\varepsilon} + \varepsilon_i + \beta_j + \varepsilon_{ijk}$

Where: ε_{ijk} = value observed at treatment i (i = CON, RED5%EM, RED5%EM+enzymes), at block j (j = light and heavy, for Trial 1) and on repeat k (k = 1 to 12 for performance variables; k = 1 to 4 for coefficients of digestibility); μ_{ε} = population mean; ε_i = effect of treatment i; β_j = effect of block j; ε_{ijk} = experimental error associated with the observed ε_{ijk} value. The means were compared using the SNK Test ($p \leq 0.05$).

RESULTS

The addition of the carbohydrase and protease blend had no effect on the digestibility coefficients of nutrients and energy (Table 4). However, enzyme supplementation affected digestible EE, NDF, and ADF (Table 5), as well as digestible and metabolizable energy (Table 6). The reduction in dietary energy led to a lower digestible EE value. Conversely, when the carbohydrase and protease blend was added, higher digestible NDF and ADF values were observed compared to the other treatments. Enzyme supplementation resulted in the same DE value as the control diet, both being higher than the diet with only energy reduction. The energy reduction led to lower ME in the diet compared to the control diet, with no difference from the diet containing the carbohydrase and protease blend.

From 63 to 85 days of age, pigs that received a reduced-energy diet, with or without enzyme supplementation, had lower daily weight gain compared to those that received the control diet (Table 7). In all periods evaluated, the reduced-energy diet with the addition of a blend of carbohydrases and protease resulted in feed conversion similar to the control diet and better than the diet with reduced energy alone. For the other performance parameters, there was no effect among treatments.

Regarding carcass characteristics, pigs fed the reduced-energy diet with the addition of a blend of carbohydrases and proteases had a larger loin area compared to those fed the reduced-energy diet alone, with no difference from animals fed the control diet (Table 8). For meat quality parameters, there was no effect of the treatments on any of the variables evaluated.

DISCUSSION

Initial strategies for using exogenous enzymes in pig diets focused on improving nutrient digestibility (Adeola and Cowieson, 2011) and were later applied to enhance the degradation of fibrous carbohydrates (Thacker et al., 1992). However, improvements in performance were often not observed, as the effect of enzyme supplementation is reduced when pigs´ nutritional requirements are already met, particularly at growing and finishing phases (Cervantes et al., 2001; Willamil et al., 2012). Since then, research involving multiple enzymes has been conducted (Torres-Pitarch et al., 2019), and the current approach employs the concept of nutritional reduction to allow the expression of enzymatic action in response to nutrient and energy deficiencies, thereby meeting the nutritional requirements of growing-finishing pigs (Medeiros et al., 2026).

In this context, it is observed that the reduction in the energy level of the feed caused by the inclusion of ingredients with a higher proportion of NSP, such as wheat bran, can be mitigated when enzymatic blends are added (Hong et al., 2022). Considering that energy ingredients such as maize and soybean oil represent the largest proportion of the cost of diets for growing and finishing pigs, reducing the energy level appears to be a viable strategy to decrease production costs (Pomar et al., 2021). In the present study, the increase in fibre digestibility observed with enzymatic supplementation contributed an increase in the energy value of the diets, resulting in a DE value similar to that of the control diet. As they act specifically on more complex carbohydrates, dietary supplementation with xylanase, beta-glucanase,

and mannanase targets on fractions of NSP (Bedford and Schulze, 1998; Crome et al., 2023). A positive effect on ED was observed in diets for growing and finishing pigs composed of maize and wheat, but no effect was seen when the energy ingredient was barley, rye, or sorghum (Torres-Pitarch et al., 2019), indicating that the composition of the diet may affect the response to enzyme supplementation.

The effects of dietary enzyme supplementation on energy utilisation also led to better feed conversion in growing and finishing pigs, indicating that a significant 5% reduction in energy can be mitigated when a blend of carbohydrases and proteases is added. Studies on the energy contribution of carbohydrases show that even with a smaller energy reduction, it is possible to acchieve improved feed conversion in growing and finishing pigs (Sitanaka et al., 2018). In a systematic review of the effect of enzyme supplementation, Torres-Pitarch et al. (2019) examined the impact of multi-enzymes on the feed conversion of growing and finishing pigs when included in diets based on corn, wheat, and barley, stating that the efficiency of each enzyme depends on the main cereal used in the diet.

The reduced energy content of the diet also contributed to lower fat deposition in pig carcasses, so that enzyme supplementation, by increaseing dietary energy, resulted in the same backfat thickness as in animals that received the control diet. Additionally, besides the energy contribution from carbohydrases, the effect of protease on lean tissue deposition led to a loin eye area similar to that of animals on control diet, supporting other findings that link enzyme supplementation to greater muscle development and reduced fat thickness (Soderstrom et al., 2024). These results reinforce the potential of moderate energy restriction combined with enzyme supplementation as a strategy to optimise carcass composition, balancing fat deposition and muscle growth without compromising the productive performance of the animals (Carden and Goenaga, 1977; Figueroa-Velasco et al., 2004).

Although no significant differences were observed in other carcass variables and meat quality, the results suggest that combining an energy restriction of up to 5% with enzyme supplementation is a promising nutritional strategy, as it does not affect performance and can preserve lean tissue deposition in growing and finishing pigs.

Declarations

Funding

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Competing Interests

The authors have no relevant financial to disclose.

Author Contributions

Study conception and design were performed by Pedro Henrique Watanabe, Juliana Forgiarini and Ednardo Rodrigues Freitas. Material preparation, data collection and analysis were performed by Rayssa Aline Rocha Teixeira, Paulo Natanael Lima Pacheco, José Melquisedeque Nobre Nogueira, Eulália Moura Fraga, Flávia Ferreira Teodósio, Valesca Abreu de Oliveira, Ester Araújo Sanil dos Santos.The first draft of the manuscript was written by Kilvia Karoline Viveiros Sousa Melo, Thatila Ellinna Batista de Lima, and Leonardo Augusto Fonseca Pascoal. All authors read and approved the final manuscript.

Data Availability

The datasets generated during the current study are available from the corresponding author on reasonable request.

Ethicals Approval

The procedures used in this study were submitted to the Ethics Committee on the Use of Production Animals (CEUAP) of the Federal University of Ceará under Protocol No. 1502202301.

Consent to participate

No applicable.

Consent to publish

No applicable.

Conflict of interest

The authors declare that they have no conflicts of interest.

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References

1. Adeola, O. and Cowieson, A.J., 2011. Board-invited review: Opportunities and challenges in using exogenous enzymes to improve nonruminant animal production Journal of Animal Science, 89
2. Andretta, I., Pomar, C., Rivest, J., Pomar, J., Lovatto, P.A. and Neto, J.R., 2014. The impact of feeding growing–finishing pigs with daily tailored diets using precision feeding techniques on animal performance, nutrient utilization, and body and carcass composition Journal of Animal Science, 92
3. AOAC, 2005. AOAC (2005) Official method of Analysis. 18th Edition, Association of Officiating Analytical Chemists, Washington DC, Method 935.14 and 992.24. AOAC International, 11

4. Associação Brasileira de Criadores de Suínos, 1973. Método brasileiro de classificação de carcaça, (Estrela, RS)
5. Bedford, M.R. and Schulze, H., 1998. Exogenous enzymes for pigs and poultry Nutrition Research Reviews, 11
6. Carden, A.E. and Goenaga, P.R., 1977. Effects of restrictions of energy, protein or both on growth and body composition of pigs The Journal of Agricultural Science, 89
7. Cervantes, M., González, J., Torrentera, N., González, V., Cervantes, M. and Cuca, M., 2001. Addition of a fungal protease to low and high protein sorghum- or wheat-soyabean meal diets on ileal amino acid digestibility and performance of growing pigs Journal of Animal and Feed Sciences, 10
8. Chassé, É., Vangsøe, C.T., Knudsen, K.E.B., Guay, F. and Létourneau-Montminy, M.P., 2022. Exogenous enzymes, meal size, and meal frequency: effect on ileal and total tract digestibility of carbohydrates, and energy and fiber degradation in growing pigs fed a wheat-barley grain-based high-fiber diet Journal of Animal Science, 100
9. Corte, O.O., De Felicio, P.E. and Cia, G., 1979. Sistematizacao da avaliacao final de bovinos e bubalinos-III. Qualidade da carne Boletim Técnico do CTC, 3, 67–76
10. Crome, T.A., Giesemann, M.A., Miller, H.E. and Petry, A.L., 2023. Influence of fiber type and carbohydrase supplementation on nutrient digestibility, energy and nitrogen balance, and physiology of sows at mid and late gestation Journal of Animal Science, 101
11. Ferket, P., 1996. Enzymes offer way to reduce waste, improve performance Feedstuffs, 68, 30–34
12. Figueroa-Velasco, J.L., Cervantes-Ramírez, M., Cuca-García, J.M. and Méndez-López, M., 2004. Respuesta de cerdos en crecimiento y finalización a dietas con baja proteína y energía Agrociencia, 38
13. Flores, S., Santos, R., Junior, S.R.S., Pereira, P.H., Paula, Y.H., Pereira, C., Cantarelli, V.S., Chaves, R.F., Martins, C., Fascina, V. and Alebrante, L., 2024. PSII-14 Economic impact of adding exogenous enzymes in a sorghum-based diet for growing and finishing pigs Journal of Animal Science, 102
14. Guidoni, A.L., Dallacosta, O.A. and Bertol, T.M., 2007. Preditores e predição do peso, porcentagem e quantidade de carne de carcaça suínas e suas partes, (Concórdia, SC)
15. Hamm, R., 1961. Biochemistry Of Meat Hydration Advances in Food Research, 10
16. Hong, J., Jlali, M., Cozannet, P., Preynat, A., Adams, S., Scaria, J. and Woyengo, T.A., 2022. Growth performance, bone mineralization, nutrient digestibility, and fecal microbial composition of multi-enzyme-supplemented low-nutrient diets for growing-finishing pigs Journal of Animal Science, 100
17. Hoque, M.R., Song, J.H. and Kim, I.H., 2023. Exogenous protease supplementation to the diet enhances growth performance, improves nitrogen utilization, and reduces stress in finishing pigs Journal of Animal Physiology and Animal Nutrition, 107
18. Kiarie, E., Owusu-Asiedu, A., Péron, A., Simmins, P.H. and Nyachoti, C.M., 2012. Efficacy of xylanase and B-glucanase blend in mixed grains and grain co-products-based diets for fattening pigs Livestock Science, 148

19. Kim, J.H., Ku, B.H., Ko, G.P., Kang, M.J., Son, K.H., Bang, M.A. and Park, H.Y., 2023. Enzyme feed additive with arazyme improve growth performance, meat quality, and gut microbiome of pigs Animals, 13
20. Li, C., Liu, D., Zhou, G., Xu, X., Qi, J., Shi, P. and Xia, T., 2012. Meat quality and cooking attributes of thawed pork with different low field NMR T 21 Meat Science, 92
21. Li, S., Sauer, W.C., Huang, S.X. and Gabert, V.M., 1996. Effect of β-Glucanase Supplementation to Hulless Barley- or Wheat-Soybean Meal Diets on the Digestibilities of Energy, Protein, β-Glucans, and Amino Acids in Young Pigs Journal of Animal Science, 74
22. Medeiros, C.J. de, Pascoal, L.A.F., Costa E Silva, L.F., Guerra, R.R., Watanabe, P.H., Givisiez, P.E.N., Almeida, J.L.S. de, da Silva, W.A., Silva, M. de B. and de Azevedo, M.L., 2026. Enzyme supplementation in nutritionally reduced diets for piglets in the early-nursery phase Frontiers in Animal Science, 6, 1679646 (Frontiers)
23. Netrebka, L.K.P., Rossi, P., Cella, P.S., Oelke, C.A., de Lima, J.D.A., de Moraes, P.V.D. and da Souza, M.A.M., 2024. Multi-enzymatic complex on growth performance, blood parameters, and economic viability in piglets Acta Scientiarum - Animal Sciences, 46
24. Noblet, J., Wu, S.B. and Choct, M., 2022. Methodologies for energy evaluation of pig and poultry feeds: A review
25. Park, C.S. and Adeola, O., 2022. Enzymes and enzyme supplementation of swine diets In:, Sustainable Swine Nutrition: Second Edition,, 445–469
26. Petry, A.L. and Patience, J.F., 2020. Xylanase supplementation in corn-based swine diets: A review with emphasis on potential mechanisms of action
27. Pomar, C., Andretta, I. and Remus, A., 2021. Feeding Strategies to Reduce Nutrient Losses and Improve the Sustainability of Growing Pigs Frontiers in Veterinary Science, 8
28. Rostagno, H.S., Albino, L.F.T., Donzele, J.L., Gomes, P.C., de Oliveira, R.F., Lopes, D.C., Ferreira, A.S., Barreto, S.L.T. and Euclides, R., 2017. Tabelas Brasileiras Para Aves e Suínos: Composição de Alimentos e Exigências Nutricionais, (Viçosa, MG)
29. Shimokomaki, M., 2003. Princípios da qualidade da carne In:, 1º Simpósio de Qualidade de Carne, (Jaboticabal, SP)
30. Sitanaka, N.Y., Budiño, F.E.L., Oliveira, S.R. de, Boas, A.D.C.V. and Moraes, J.E. de, 2018. Suplementação de complexo enzimático no desempenho de suínos em crescimento e terminação Revista Caatinga, 31, 748–758 (SciELO Brasil)
31. Soderstrom, A.J., Wang, L.F., Patterson, R., Beltranena, E. and Zijlstra, R.T., 2024. Feeding a Multi-Enzyme Blend to Enhance the Nutrient Digestibility of Wheat-Canola Expeller Diets in Ileal-Cannulated Weaned Pigs Animals, 14
32. Thacker, P.A., Campbell, G.L. and Grootwassink, J., 1992. The effect of organic acids and enzyme supplementation on the performance of pigs fed barley-based diets Canadian Journal of Animal Science, 72

33. Torres-Pitarch, A., Manzanilla, E.G., Gardiner, G.E., O'Doherty, J. V. and Lawlor, P.G., 2019. Systematic review and meta-analysis of the effect of feed enzymes on growth and nutrient digestibility in grow-finisher pigs: Effect of enzyme type and cereal source Animal Feed Science and Technology, 251
34. Valente Junior, D.T., Genova, J.L., Kim, S.W., Saraiva, A. and Rocha, G.C., 2024. Carbohydrases and Phytase in Poultry and Pig Nutrition: A Review beyond the Nutrients and Energy Matrix Animals, 14
35. Van Soest, P.J., Robertson, J.B. and Lewis, B.A., 1991. Métodos para fibra alimentar, fibra em detergente neutro e polissacarídeos não amiláceos em relação à nutrição animal J. Dairy Sci, 74, 3583–3597
36. Willamil, J., Badiola, I., Devillard, E., Geraert, P.A. and Torrallardona, D., 2012. Wheat-barley-rye-or corn-fed growing pigs respond differently to dietary supplementation with a carbohydrase complex Journal of Animal Science, 90
37. Young, L.G., Leunissen, M. and Atkinson, J.L., 1993. Addition of microbial phytase to diets of young pigs. Journal of animal science, 71

Tables

Table 1 – Percentage and nutritional composition of experimental diets[1] for pigs at growing phase (63 to 85 days of age)

Feedstuff (g/kg)	Growing phase (63 to 85 days of age)		
	CON	RED5%ME	RED5%ME+enzymes
Maize	740.11	661.45	661.45
Soybean meal	223.48	215.70	215.70
Soy oil	4.83	-	-
Wheat bran	-	71.50	71.50
Dicalcium phosphate	11.31	10.04	10.04
Limestone	7.28	7.98	7.98
Common salt	3.88	4.03	4.03
Mineral and vitamin supplement[2]	5.00	5.00	5.00
L-Lysine HCl (79%)	2.84	2.87	2.87
DL-Methionine (99%)	0.39	0.42	0.42
L-Threonine (98%)	0.80	0.91	0.91
L-Tryptophan (99%)	0.08	0.10	0.10
Inert	-	20.00	19.95
Blend of enzymes	-	-	0.05
Nutritional and energy composition			
Metabolisable energy (kcal/kg)	3230	3072	3072
Crude protein (%)	16.82	16.87	16.87
Neutral detergent fibre (%)	11.79	13.66	13.66
Acid detergent fibre (%)	4.44	5.09	5.09
Available phosphorus (%)	0.31	0.31	0.31
Calcium (%)	0.65	0.65	0.65
Digestible lysine (%)	0.93	0.93	0.93
Digestible methionine+cystine (%)	0.28	0.28	0.28
Digestible threonine (%)	0.61	0.61	0.61
Digestible tryptophan (%)	0.17	0.17	0.17
Sodium (%)	0.18	0.18	0.18

[1]CON: control diet (3230 kcal of ME/kg); RED5%ME: diet with a 5% reduction in energy level (3072 kcal of ME/kg); RED5%EM+enzymes: diet with a 5% reduction in energy level (3073 kcal of ME/kg), with the addition of blend of enzymes.[2]Mineral-vitamin supplement – quantity per kg of product: 1,020,000 IU of vitamin A; 187,000 IU of vitamin D3; 5,100 IU of vitamin E; 174.9 mg of vitamin K3; 120 mg of vitamin B1; 680 mg of vitamin B2; 340 mg of vitamin B6; 5100 mcg of vitamin B12; 3060 mg of niacin; 1,870 mg of calcium pantothenate; 50 mg of folic acid; 20 mg of biotin; 8100 mg of iron; 1600 mg of copper; 5100 mg of manganese; 20 g of zinc; 99.2 mg of iodine; 42.5 mg of selenium; 3000 mg of BHT.

Table 2 – Percentage and nutritional composition of experimental diets[1] for pigs at growing phase (86 a 105 days of age)

Feedstuff (g/kg)	Growing phase (63 to 85 days of age)		
	CON	RED5%ME	RED5%ME+enzymes
Maize	787.93	685.52	685.52
Soybean meal	185.02	172.88	172.88
Soy oil	0.56	-	-
Wheat bran	-	95.50	95.50
Dicalcium phosphate	8.21	6.54	6.54
Limestone	6.16	6.95	6.95
Common salt	3.61	3.89	3.89
Mineral and vitamin supplement[2]	5.00	5.00	5.00
L-Lysine HCl (79%)	2.67	2.72	2.72
DL-Methionine (99%)	0.23	0.26	0.26
L-Threonine (98%)	0.54	0.70	0.70
L-Tryptophan (99%)	0.07	0.04	0.04
Inert	-	20.00	19.95
Blend of enzymes	-	-	0.05
Nutritional and energy composition			
Metabolisable energy (kcal/kg)	3230	3073.04	3073.04
Crude protein (%)	15.43	15.46	15.46
Neutral detergent fibre (%)	11.82	14.33	14.33
Acid detergent fibre (%)	4.29	5.16	5.16
Available phosphorus (%)	0.25	0.25	0.25
Calcium (%)	0.52	0.52	0.52
Digestible lysine (%)	0.83	0.83	0.83
Digestible methionine+cystine (%)	0.25	0.25	0.25
Digestible threonine (%)	0.54	0.54	0.54
Digestible tryptophan (%)	0.15	0.15	0.15
Sodium (%)	0.17	0.18	0.18

[1]CON: control diet (3230 kcal of ME/kg); RED5%ME: diet with a 5% reduction in energy level (3072 kcal of ME/kg); RED5%EM+enzymes: diet with a 5% reduction in energy level (3073 kcal of ME/kg), with the addition of blend of enzymes. [2]Mineral-vitamin supplement – quantity per kg of product: 1,020,000 IU of vitamin A; 187,000 IU of vitamin D3; 5,100 IU of vitamin E; 174.9 mg of vitamin K3; 120 mg of vitamin B1; 680 mg of vitamin B2; 340 mg of vitamin B6; 5100 mcg of vitamin B12; 3060 mg of niacin; 1,870 mg of calcium pantothenate; 50 mg of folic acid; 20 mg of biotin; 8100 mg of iron; 1600 mg of copper; 5100 mg of manganese; 20 g of zinc; 99.2 mg of iodine; 42.5 mg of selenium; 3000 mg of BHT.

Table 3 – Percentage and nutritional composition of experimental diets[1] for pigs at finishing phase (106 a 150 days of age)

Feedstuff (g/kg)	Finishing phase (106 a 150 days of age)		
	CON	RED5%ME	RED5%ME+enzymes
Maize	833.98	722.58	722.58
Soybean meal	139.57	123.74	123.74
Soy oil	-	-	-
Wheat bran	-	108.00	108.00
Dicalcium phosphate	7.15	5.46	5.46
Limestone	6.17	6.62	6.62
Common salt	3.48	3.51	3.51
Mineral and vitamin supplement[2]	5.00	5.00	5.00
L-Lysine HCl (79%)	3.17	3.37	3.37
DL-Methionine (99%)	0.29	0.36	0.36
L-Threonine (98%)	0.97	1.16	1.16
L-Tryptophan (99%)	0.22	0.19	0.19
Inert	-	20.00	19.95
Blend of enzymes	-	-	0.05
Nutritional and energy composition			
Metabolisable energy (kcal/kg)	3230	3072	3072
Crude protein (%)	13.86	13.86	13.86
Neutral detergent fibre (%)	11.73	14.59	14.59
Acid detergent fibre (%)	4.09	5.06	5.06
Available phosphorus (%)	0.23	0.23	0.23
Calcium (%)	0.48	0.48	0.48
Digestible lysine (%)	0.76	0.76	0.76
Digestible methionine+cystine (%)	0.24	0.24	0.24
Digestible threonine (%)	0.52	0.52	0.52
Digestible tryptophan (%)	0.14	0.14	0.14
Sodium (%)	0.16	0.16	0.16

[1]CON: control diet (3230 kcal of ME/kg); RED5%ME: diet with a 5% reduction in energy level (3072 kcal of ME/kg); RED5%EM+enzymes: diet with a 5% reduction in energy level (3073 kcal of ME/kg), with the addition of blend of enzymes. [2]Mineral-vitamin supplement – quantity per kg of product: 1,020,000 IU of vitamin A; 187,000 IU of vitamin D3; 5,100 IU of vitamin E; 174.9 mg of vitamin K3; 120 mg of vitamin B1; 680 mg of vitamin B2; 340 mg of vitamin B6; 5100 mcg of vitamin B12; 3060 mg of niacin; 1,870 mg of calcium pantothenate; 50 mg of folic acid; 20 mg of biotin; 8100 mg of iron; 1600 mg of copper; 5100 mg of manganese; 20 g of zinc; 99.2 mg of iodine; 42.5 mg of selenium; 3000 mg of BHT.

Table 4. Coefficient of digestibility of diets with or without a blend of carbohydrases and proteases for growing pigs.

Nutrient and energy digestibility coefficient	Treatments[1]			CV[2], %	P value
	CON	RED5%ME	RED5%ME +enzymes		
DM[3] (%)	84.57	83.29	81.44	5.39	0.5194
CP[4] (%)	83.36	84.10	84.89	6.33	0.5748
EE[5] (%)	63.65	60.88	60.31	10.12	0.6583
NDF[6] (%)	67.32	64.79	65.56	12.32	0.8804
ADF[7] (%)	64.27	61.62	64.39	6.70	0.5129
Ash (%)	65.99	60.90	65.71	13.56	0.5886
Gross energy (%)	83.55	79.94	81.76	3.60	0.1923

[1]CON: control diet (3230 kcal of ME/kg); RED5%ME: diet with a 5% reduction in energy level (3072 kcal of ME/kg); RED5%EM+enzymes: diet with a 5% reduction in energy level (3073 kcal of ME/kg), with the addition of blend of enzymes. [2]Coefficient of variation. [3]Dry matter. [4]Crude protein. [5]Ether extract. [6]Neutral detergent fibre. [7]Acid detergent fibre.

Table 5. Digestible nutrients in diets with or without a blend of carbohydrases and proteases for growing pigs.

Digestible nutrients and metabolizable energy	Treatments[1]			CV[2], %	P value
	CON	RED5%ME	RED5%ME +enzymes		
Digestible protein (%)	13.48	13.68	13.33	6.35	0.7924
Digestible ether extract (%)	2.92a	2.43b	2.43b	10.17	0.0139
Digestible NDF[3] (%)	11.76b	12.56b	15.04a	12.32	0.0175
Digestible ADF[4] (%)	3.56b	3.55b	5.68a	7.24	0.0001
Digestible ash (%)	3.21	2.90	3.07	13.60	0.5351

[1]CON: control diet (3230 kcal of ME/kg); RED5%ME: diet with a 5% reduction in energy level (3072 kcal of ME/kg); RED5%EM+enzymes: diet with a 5% reduction in energy level (3073 kcal of ME/kg), with the addition of blend of enzymes. [2]Coefficient of variation. [3]Neutral detergent fiber. [4]Acid detergent fiber.

Table 6. Energy values of rations with or without a blend of carbohydrases and proteases for growing pigs.

Energy values	Treatments[1]			CV[2], %	P value
	CON	RED5%ME	RED5%ME+enzymes		
DE[3] (kcal/kg DM)	3539.09a	3265.49b	3531.13a	3.52	0.0045
DE (kcal/kg NM)	3375.73a	3135.14b	3375.19a	3.53	0.0075
ME[4] (kcal/kg de DM)	3415.59a	3155.62b	3307.07ab	3.67	0.0156
ME (kcal/kg de NM)	3257.94a	3029.65b	3161.09ab	3.68	0.0262

[1]CON: control diet (3230 kcal of ME/kg); RED5%ME: diet with a 5% reduction in energy level (3072 kcal of ME/kg); RED5%EM+enzymes: diet with a 5% reduction in energy level (3073 kcal of ME/kg), with the addition of blend of enzymes. [2]Coefficient of variation. [3]Digestible energy. [4]Metabolisable energy.

Table 7. Performance of pigs fed diets with or without a blend of carbohydrases and proteases at growing and finishing phases (63 to 150 days of age).

Variables	Treatments[1]			CV[2], %	P value
	CON	RED5%ME	RED5%ME +enzymes		
63 to 85 days of age					
Initial weight (kg)	20.41	20.74	20.77	6.32	0.7832
Daily feed intake (kg)	1.568	1.476	1.362	14.51	0.1010
Daily weight gain (kg)	0.703a	0.613b	0.600b	14.04	0.0270
Feed conversion ratio	2.23b	2.40a	2.28b	5.84	0.0163
63 to 105 days of age					
Daily feed intake (kg)	2.178	2.297	2.105	11,40	0.1799
Daily weight gain (kg)	0.922	0.858	0.894	8.43	0.1327
Feed conversion ratio	2.36b	2.68a	2.35b	8.07	0.0003
63 to 150 days of age					
Daily feed intake (kg)	2.481	2.514	2.421	8.90	0.5778
Daily weight gain (kg)	0.937	0.877	0.893	8.13	0.1267
Feed conversion ratio	2.64b	2.87a	2.71b	5.40	0.0031
Final weight (kg)	101.91	97.04	98.46	7.07	0.1209

[1]CON: control ration; RED5%EM: ration with 5% reduced energy value compared to the control ration; RED5%EM+blend: ration with 5% reduced energy value compared to the control ration with the addition of an enzymatic blend. [2]Coefficient of variation.

Table 8. Carcass characteristics and meat quality of pigs fed diets with or without a blend of carbohydrases and proteases.

Variables	Treatments[1]			CV[2], %	P value
	CON	RED5%ME	RED5%ME +enzymes		
Carcass characteristics					
Carcass weight (kg)	75.34	70.45	70.65	6.41	0.1369
Carcass yield (%)	74.02	73.59	73.04	1.69	0.2060
Carcass lenght (cm)	98.92	97.37	96.19	3.15	0.1448
Backfat thickness (mm)	23.30	23.64	22.55	10.49	0.5711
Loineye area (cm²)	56.62a	47.99b	54.45a	11.54	0.0111
P2 Loin depth (mm)	63.60	62.14	62.85	11.07	0.8915
P2 Fat depth (mm)	14.28a	12.53ab	10.62b	26.44	0.0495
Percentage of lean meat (%)	59.64	61.37	61.75	3.49	0.0713
Meat quality					
pH 45´	6.41	6.32	6.21	4.55	0.2858
pH 24h	5.36	5.28	5.40	2.59	0.1882
Water holding capacity (%)	60.58a	53.04b	59.22a	6.59	0.0002
Cooking loss(%)	36.25	36.38	36.77	2.85	0.4973
Shear force (N)	73.68	71.43	73.42	11.37	0.7902
L*	25.30	24.89	26.01	10.12	0.4536
a*	3.72	3.71	3.70	1.11	0.6487
b*	3.22	3.24	3.25	1.03	0.5749

[1]CON: control ration; RED5%EM: ration with 5% reduced energy value compared to the control ration; RED5%EM+blend: ration with 5% reduced energy value compared to the control ration with the addition of an enzymatic blend. [2]Coefficient of variation.

Means followed by different letters differ from each other by the SNK test at 5% probability.