

Effects of dietary protein-energy ratios on growth performance, metabolic parameters, endocrine profiles, and carcass traits in growing rabbits maintained under tropical conditions at Ahmadu Bello University, Zaria.

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Abstract

Background

Tropical climates impose significant heat stress on growing rabbits, disrupting metabolic-endocrine regulation and compromising growth performance when dietary protein-energy ratios are suboptimal. This study was conducted to evaluate the effects of five dietary protein-energy ratios on growth performance, metabolic parameters, endocrine profiles, and carcass traits in growing rabbits maintained under tropical conditions at Ahmadu Bello University, Zaria.

Materials and Methods

Five dietary protein-energy ratios (14% CP/2800 kcal ME/kg, 15% CP/2700 kcal ME/kg, 16% CP/2600 kcal ME/kg, 17% CP/2500 kcal ME/kg, and 18% CP/2400 kcal ME/kg) were formulated and provided to 100 growing rabbits (New Zealand White × local cross) under natural tropical conditions at Ahmadu Bello University, Zaria, Nigeria. The experiment employed a completely randomised design with four replicates per treatment over 56 days. Data collected and generated were subjected to one-way analysis of variance (ANOVA) with means separated using Tukeys' HSD Test.

Results

The medium-high ratio (17% CP, 2500 kcal ME/kg) significantly improved final body weight (2485 g), average daily gain (32.8 g/d), and feed conversion ratio (2.70) compared with lower ratios. Serum total protein (68.5 g/L) and albumin (38.0 g/L) increased while urea (6.2 mmol/L) and triglycerides (1.05 mmol/L) decreased. Anabolic hormones rose markedly (insulin 18.5 µIU/mL, IGF-1 215 ng/mL) alongside elevated thyroid hormones (T3 2.45 nmol/L, T4 60.4 nmol/L) and reduced cortisol (19.8 nmol/L). Dressing percentage (63.4%) and hot carcass weight (1575 g) were highest, with lower liver relative weight (3.1%). Lower ratios induced catabolic shifts, impaired nutrient utilisation, and reduced performance.

Conclusion

The results indicate that protein-energy ratios of 17–18% CP and 2400–2500 kcal ME/kg optimise metabolic efficiency, endocrine homeostasis, and lean tissue accretion in tropical rabbit production using local feed resources.

Introduction

Growing rabbits exhibit high protein requirements relative to energy for rapid muscle accretion and efficient feed conversion in tropical feeding systems where ambient temperatures frequently exceed

30°C (Trach et al., 2019). Protein-energy ratio modulates nitrogen retention, voluntary feed intake, and overall growth efficiency because excess energy relative to protein promotes fat deposition while insufficient protein limits lean tissue synthesis (AL-SAGHEER et al., 2020). Tropical diets composed of locally available forages, cereal by-products, and agro-industrial residues often present suboptimal protein-energy ratios that result in reduced average daily gain and impaired feed conversion (Adeyeye et al., 2024). Metabolic regulation responds directly to dietary protein-energy balance through alterations in circulating insulin, insulin-like growth factor-1, and thyroid hormones that coordinate energy partitioning and protein turnover (Palumbo et al., 2025). Endocrine disruption occurs when protein-energy imbalance elevates cortisol and suppresses triiodothyronine, thereby increasing catabolic processes and heat production in hot climates (Liang et al., 2022). Oxidative stress and altered lipid metabolism accompany these endocrine shifts, further compromising growth performance and carcass quality (Ogbon et al., 2025).

The problem manifests as inconsistent growth rates, elevated feed costs, and compromised welfare in growing rabbits reared under tropical conditions where farmers rely on unbalanced conventional rations (Ogunjesa et al., 2025). Limited region-specific data on optimal protein-energy ratios for metabolic-endocrine regulation in tropical rabbit production systems hinder the development of cost-effective feeding strategies that utilise local feed resources (Akande et al., 2015). Justification for the present investigation stems from the urgent requirement to optimise protein-energy ratios using practical tropical feed ingredients to enhance metabolic efficiency, endocrine homeostasis, and sustainable rabbit meat production in Nigeria and similar agro-ecological zones (Saleh et al., 2023). The aim of the study was to evaluate the effects of five dietary protein-energy ratios on growth performance, metabolic parameters, endocrine profiles, and carcass traits in growing rabbits maintained under tropical conditions at Ahmadu Bello University, Zaria.

Materials and Methods

The experiment was conducted at the Rabbit Research Unit, Department of Animal Science, Ahmadu Bello University, Zaria, Kaduna State, Nigeria (latitude 11°04'N, longitude 7°42'E), which experiences typical tropical savanna conditions with daytime temperatures ranging from 28°C to 38°C and relative humidity of 45–75% during the June–August 2025 trial period (IARMS, 2025). All experimental procedures received approval from the Ahmadu Bello University Animal Ethics Committee and complied with institutional guidelines for rabbit welfare.

One hundred weaner rabbits (New Zealand White × local cross, 5 weeks old, initial weight 650 ± 25 g) were procured from commercial rabbit vendor in Ibadan, Oyo State, Nigeria. Rabbits were individually identified with ear tags, vaccinated against pasteurellosis and myxomatosis, and allowed a 7-day adaptation period. Animals were randomly allocated to five dietary treatments in a completely randomised design. Each treatment comprised 20 rabbits distributed across four replicate cages of 5 rabbits each (stocking density 0.12 m² per rabbit). Cages measured 90 cm × 60 cm × 45 cm and were

constructed of galvanised wire mesh with plastic slatted floors to facilitate manure collection. Natural ventilation was supplemented with exhaust fans to maintain air movement without artificial cooling.

Basal diets were formulated as pelleted concentrates (4 mm diameter) using maize, soybean meal, wheat offal, palm kernel cake, and forage meal to meet or exceed NRC (1977) recommendations for growing rabbits while varying protein-energy ratios. The five treatments presented in Table 1 were: (1) low protein-energy ratio (14% crude protein, 2800 kcal metabolisable energy/kg); (2) medium-low protein-energy ratio (15% crude protein, 2700 kcal metabolisable energy/kg); (3) standard protein-energy ratio (16% crude protein, 2600 kcal metabolisable energy/kg); (4) medium-high protein-energy ratio (17% crude protein, 2500 kcal metabolisable energy/kg); and (5) high protein-energy ratio (18% crude protein, 2400 kcal metabolisable energy/kg). Diets were isocaloric within practical limits and iso-nitrogenous adjustments were achieved by varying soybean meal and maize levels while maintaining fixed crude fibre at 14–16% (Trach et al., 2019; AL-SAGHEER et al., 2020). Feed and fresh water were provided ad libitum throughout the 56-day experimental period. Fresh diets were prepared weekly at Labar feed mill.

Daily maximum and minimum temperatures and relative humidity inside the rabbitry were recorded at 1400 h using digital thermo-hygrometers. Individual body weights and feed intake per cage were recorded weekly to calculate average daily gain and feed conversion ratio. Blood samples (5 ml) were collected from the marginal ear vein of eight rabbits per treatment on days 0, 28, and 56. Serum was analysed for glucose, insulin, insulin-like growth factor-1, triiodothyronine, thyroxine, and cortisol using commercial ELISA kits, and for total protein, albumin, urea, and triglycerides via spectrophotometric methods (Palumbo et al., 2025; Liang et al., 2022). At the end of the trial, all rabbits were weighed and humanely slaughtered after 12 h fasting. Carcass traits evaluated included dressing percentage, hot carcass weight, and organ weights (liver, kidney, heart). Longissimus dorsi muscle samples were collected for pH measurement at 45 min and 24 h post-mortem.

Table 1

Ingredient composition (g/kg, as-fed basis) and calculated nutrient analysis of the experimental diets for growing rabbits (varying protein-energy ratios)

Ingredient	Low P:E (14% CP, 2800 kcal ME/kg)	Medium-Low P:E (15% CP, 2700 kcal ME/kg)	Standard P:E (16% CP, 2600 kcal ME/kg)	Medium-High P:E (17% CP, 2500 kcal ME/kg)	High P:E (18% CP, 2400 kcal ME/kg)
Maize (ground)	480.0	450.0	420.0	380.0	340.0
Soybean meal (48% CP)	120.0	150.0	180.0	210.0	240.0
Wheat offal	150.0	140.0	130.0	120.0	110.0
Palm kernel cake	100.0	110.0	120.0	130.0	140.0
Forage meal (dried guinea grass)	100.0	100.0	100.0	100.0	100.0
Limestone	15.0	15.0	15.0	15.0	15.0
Dicalcium phosphate	20.0	20.0	20.0	20.0	20.0
Common salt	5.0	5.0	5.0	5.0	5.0
Vitamin- mineral premix ¹	5.0	5.0	5.0	5.0	5.0
Methionine + lysine premix	5.0	5.0	5.0	5.0	5.0
Total	1000.0	1000.0	1000.0	1000.0	1000.0
Calculated Analysis (%)					
Crude protein	14.0	15.0	16.0	17.0	18.0
Crude fibre	15.2	15.5	15.8	16.1	16.4
Ether extract	4.1	4.3	4.5	4.7	4.9
Ash	7.8	8.0	8.2	8.4	8.6
Calcium	0.85	0.87	0.89	0.91	0.93
Available phosphorus	0.40	0.41	0.42	0.43	0.44
Lysine	0.85	0.92	0.98	1.05	1.12
Methionine	0.62	0.65	0.68	0.71	0.74

Ingredient	Low P:E (14% CP, 2800 kcal ME/kg)	Medium-Low P:E (15% CP, 2700 kcal ME/kg)	Standard P:E (16% CP, 2600 kcal ME/kg)	Medium-High P:E (17% CP, 2500 kcal ME/kg)	High P:E (18% CP, 2400 kcal ME/kg)
ME (Kcal/kg)	2800	2700	2600	2500	2400

ME: Metabolisable Energy; ¹Vitamin-mineral premix supplied per kg diet: vitamin A 10 000 IU, vitamin D₃ 2000 IU, vitamin E 30 IU, vitamin K₃ 2 mg, vitamin B₁ 2 mg, vitamin B₂ 6 mg, vitamin B₆ 3 mg, vitamin B₁₂ 0.02 mg, niacin 40 mg, pantothenic acid 12 mg, folic acid 1 mg, biotin 0.1 mg, choline 500 mg, Mn 80 mg, Zn 60 mg, Fe 40 mg, Cu 10 mg, I 1 mg, Se 0.2 mg.

Data were subjected to one-way analysis of variance using SPSS version 27 software. Treatment means were separated by Tukey's honestly significant difference test at $P < 0.05$. Normality and homogeneity of variances were verified with Shapiro–Wilk and Levene's tests, respectively (Ogbon et al., 2025).

Results

Table 2 presents the effect of dietary protein-energy ratios on growth performance parameters in growing rabbits under tropical conditions. Final body weight showed a significant ($P < 0.05$) difference. The medium-high protein-energy ratio treatment recorded the highest value of 2485 g, followed by the high protein-energy ratio treatment at 2410 g which was statistically similar to the medium-high treatment, while the standard treatment gave 2320 g, the medium-low treatment 2150 g, and the low protein-energy ratio treatment the lowest value of 1985 g. Average daily gain displayed the same significant ($P < 0.05$) difference pattern with the medium-high treatment achieving the highest value of 32.8 g/d, the high treatment 31.4 g/d which was statistically similar, the standard treatment 29.8 g/d, the medium-low treatment 26.8 g/d, and the low treatment the lowest at 23.8 g/d. Feed conversion ratio also showed a significant ($P < 0.05$) difference, with the medium-high treatment recording the best value of 2.70, the high treatment 2.80 which was statistically similar, the standard treatment 2.95, the medium-low treatment 3.23, and the low treatment the poorest at 3.58. There were no significant ($P > 0.05$) difference in feed intake among treatments.

Table 2

Effect of dietary protein-energy ratios on growth performance parameters in growing rabbits under tropical conditions (days 0–56)

Parameter	Low P:E (14% CP, 2800 kcal ME/kg)	Medium- Low P:E (15% CP, 2700 kcal ME/kg)	Standard P:E (16% CP, 2600 kcal ME/kg)	Medium- High P:E (17% CP, 2500 kcal ME/kg)	High P:E (18% CP, 2400 kcal ME/kg)	SEM	P- value
Final body weight (g)	1985 ^d	2150 ^c	2320 ^b	2485 ^a	2410 ^{ab}	52.4	< 0.001
Average daily gain (g/d)	23.8 ^d	26.8 ^c	29.8 ^b	32.8 ^a	31.4 ^{ab}	0.92	< 0.001
Feed intake (g/d)	85.2	86.5	87.8	88.4	87.9	1.45	0.312
Feed conversion ratio	3.58 ^a	3.23 ^b	2.95 ^c	2.70 ^d	2.80 ^{cd}	0.08	< 0.001
^{abc} means on the same row with different supecripts are significantly (P < 0.05) different							

Table 3 shows the influence of dietary protein-energy ratios on serum metabolic parameters at day 56. Glucose concentration differed significantly ($P < 0.05$), with the low protein-energy ratio treatment recording the highest value of 6.8 mmol/L while the medium-low, standard, medium-high, and high treatments produced statistically similar lower values ranging from 5.6 to 6.2 mmol/L. Total protein and albumin levels showed a significant ($P < 0.05$) difference, with the low treatment yielding the lowest values of 58.2 g/L and 32.1 g/L respectively, whereas the medium-low treatment gave intermediate values of 62.4 g/L and 34.5 g/L, and the standard, medium-high, and high treatments produced statistically similar higher values ranging from 66.8 to 68.5 g/L for total protein and 37.2 to 38.0 g/L for albumin. Urea and triglycerides concentrations followed the opposite significant ($P < 0.05$) difference pattern, with the low treatment recording the highest values of 8.4 mmol/L and 1.45 mmol/L respectively, while the medium-low gave intermediate values and the standard, medium-high, and high treatments produced statistically similar lower values.

Table 3

Effect of dietary protein-energy ratios on serum metabolic parameters at day 56 in growing rabbits under tropical conditions

Parameter	Low P:E	Medium-Low P:E	Standard P:E	Medium-High P:E	High P:E	SEM	P-value
Glucose (mmol/L)	6.8 ^a	6.2 ^{ab}	5.9 ^b	5.7 ^b	5.6 ^b	0.28	< 0.05
Total protein (g/L)	58.2 ^c	62.4 ^b	66.8 ^a	68.5 ^a	67.9 ^a	1.85	< 0.001
Albumin (g/L)	32.1 ^c	34.5 ^b	37.2 ^a	38.0 ^a	37.6 ^a	0.95	< 0.001
Urea (mmol/L)	8.4 ^a	7.6 ^{ab}	6.9 ^b	6.2 ^b	6.0 ^b	0.42	< 0.01
Triglycerides (mmol/L)	1.45 ^a	1.32 ^{ab}	1.18 ^b	1.05 ^b	1.02 ^b	0.11	< 0.05
^{abc} means on the same row with different supecripts are significantly (P < 0.05) different							

Table 4 reveals the effect of dietary protein-energy ratios on endocrine profiles at day 56. Insulin, IGF-1, triiodothyronine, and thyroxine concentrations showed a significant (P < 0.05) difference, with the low treatment recording the lowest values of 12.5 µIU/mL, 145 ng/mL, 1.85 nmol/L, and 45.2 nmol/L respectively, while the medium-low treatment produced intermediate values and the standard, medium-high, and high treatments yielded statistically similar higher values. Cortisol level displayed a significant (P < 0.05) difference, with the low treatment exhibiting the highest value of 28.4 nmol/L, the medium-low treatment an intermediate value, and the standard, medium-high, and high treatments producing statistically similar lower values.

Table 4
Effect of dietary protein-energy ratios on endocrine profiles at day 56 in growing rabbits under tropical conditions

Parameter	Low P:E	Medium-Low P:E	Standard P:E	Medium-High P:E	High P:E	SEM	P-value
Insulin (μ U/mL)	12.5 ^c	14.8 ^b	17.2 ^a	18.5 ^a	18.1 ^a	0.78	< 0.001
IGF-1 (ng/mL)	145 ^d	168 ^c	192 ^b	215 ^a	208 ^a	9.2	< 0.001
Triiodothyronine (T3, nmol/L)	1.85 ^c	2.12 ^b	2.38 ^a	2.45 ^a	2.41 ^a	0.14	< 0.001
Thyroxine (T4, nmol/L)	45.2 ^c	52.6 ^b	58.9 ^a	60.4 ^a	59.8 ^a	2.65	< 0.001
Cortisol (nmol/L)	28.4 ^a	24.6 ^{ab}	21.3 ^b	19.8 ^b	20.5 ^b	1.82	< 0.01
^{abc} means on the same row with different supecripts are significantly ($P < 0.05$) different							

Table 5 presents the effect of dietary protein-energy ratios on carcass traits at day 56. Dressing percentage and hot carcass weight showed a significant ($P < 0.05$) difference, with the low treatment recording the lowest values of 58.2% and 1155 g respectively, the medium-low treatment intermediate values, and the standard, medium-high, and high treatments producing statistically similar higher values. Liver relative weight differed significantly ($P < 0.05$), with the low treatment yielding the highest value of 3.8% body weight while the medium-low gave an intermediate value and the standard, medium-high, and high treatments produced statistically similar lower values. There were no significant ($P > 0.05$) difference in kidney or heart relative weights among treatments.

Table 5
Effect of dietary protein-energy ratios on carcass traits at day 56 in growing rabbits under tropical conditions

Parameter	Low P:E	Medium-Low P:E	Standard P:E	Medium-High P:E	High P:E	SEM	P-value
Dressing percentage (%)	58.2 ^c	60.5 ^b	62.8 ^a	63.4 ^a	63.1 ^a	0.92	< 0.001
Hot carcass weight (g)	1155 ^d	1300 ^c	1455 ^b	1575 ^a	1520 ^{ab}	48.6	< 0.001
Liver (% BW)	3.8 ^a	3.5 ^{ab}	3.2 ^b	3.1 ^b	3.0 ^b	0.18	< 0.05
Kidney (% BW)	0.85	0.82	0.80	0.78	0.79	0.04	0.214
Heart (% BW)	0.32	0.31	0.30	0.29	0.30	0.02	0.456
^{abc} means on the same row with different supecripts are significantly ($P < 0.05$) different							

Discussion

Higher protein relative to energy improved final body weight and average daily gain while lowering feed conversion ratio because the increased protein supply supported lean tissue accretion and reduced excess energy dissipation as heat in the tropical environment. The medium-high and high ratios optimised nutrient partitioning toward growth rather than fat deposition or thermoregulatory expenditure, resulting in superior feed efficiency. These performance gains imply shorter finishing periods, reduced feed costs per kilogram of gain, and higher economic returns for tropical rabbit producers who rely on locally sourced ingredients. The findings align with Ayyat et al. (2021) who reported that elevated dietary protein combined with adjusted energy levels enhanced growth and feed utilisation in heat-stressed New Zealand White rabbits. Similar improvements in body weight and feed conversion were documented by Liang et al. (2022) when protein supply matched energy demands under chronic tropical heat exposure, although their magnitude of response was slightly lower than the present synergistic protein-energy optimisation.

The elevated glucose, urea, and triglycerides together with reduced total protein and albumin in the low protein-energy ratio treatment indicate impaired protein synthesis and increased catabolism under tropical heat load. Higher protein-energy ratios enhanced nitrogen retention and metabolic efficiency, thereby lowering protein breakdown products and lipid mobilisation. These metabolic improvements imply better overall health status, reduced risk of metabolic disorders, and sustained productivity in hot climates. The data support Palumbo et al. (2025) who observed comparable shifts in serum protein and urea when dietary protein-energy balance was optimised in rabbits. Adeyeye et al. (2017) and Liu et al. (2022) also reported reduced triglycerides and improved protein profiles with balanced protein supply during heat stress, confirming the present advantage of medium-high and high ratios.

Elevated anabolic hormones (insulin, IGF-1) and thyroid hormones alongside reduced cortisol in the higher protein-energy ratio treatments reflect strengthened anabolic signalling and diminished stress response. The low ratio triggered catabolic endocrine shifts that increased energy expenditure and limited growth. These endocrine adjustments imply improved metabolic homeostasis, better protein accretion, and enhanced welfare under tropical conditions. The results agree with Ayyat et al. (2021) who documented similar elevations in thyroid hormones and reductions in cortisol when dietary protein and energy were balanced in heat-stressed rabbits. Liang et al. (2022) likewise linked optimised protein-energy ratios to favourable IGF-1 and cortisol profiles, although their single-nutrient adjustments produced smaller endocrine shifts than the present multi-level protein-energy modulation.

Improved dressing percentage and hot carcass weight in the higher protein-energy ratio treatments indicate greater muscle deposition and reduced visceral fat relative to body weight. Lower liver weight suggests decreased metabolic load and less energy diversion to gluconeogenesis. These carcass advantages enhance marketable meat yield and carcass quality for tropical rabbit enterprises. The outcomes corroborate Ogbon et al. (2025) who reported enhanced dressing percentages with balanced

protein supply in tropical rabbit diets. Palumbo et al. (2025) also noted reduced organ weights and improved carcass yield when protein-energy ratios avoided excess energy relative to protein.

Conclusion

The present study demonstrates that dietary protein-energy ratios significantly influence growth performance, metabolic parameters, endocrine profiles, and carcass traits in growing rabbits maintained under tropical conditions at Ahmadu Bello University, Zaria. The medium-high protein-energy ratio (17% crude protein, 2500 kcal metabolisable energy/kg) consistently produced the most favourable outcomes, including the highest final body weight of 2485 g, average daily gain of 32.8 g/d, best feed conversion ratio of 2.70, superior serum total protein and albumin concentrations, elevated insulin, IGF-1, triiodothyronine, and thyroxine levels, reduced cortisol, urea, and triglycerides, together with the highest dressing percentage of 63.4% and hot carcass weight of 1575 g. These results indicate that increasing protein relative to energy optimises nitrogen retention, anabolic hormone secretion, thyroid-mediated metabolic rate, and lean tissue deposition while minimising catabolic stress and excess fat mobilisation in the hot tropical environment. The high protein-energy ratio treatment performed statistically similar in many parameters, confirming that ratios around 17–18% crude protein and 2400–2500 kcal metabolisable energy/kg effectively counteract the negative effects of chronic heat exposure on nutrient utilisation and endocrine homeostasis. Lower ratios led to impaired protein synthesis, elevated catabolic indicators, and poorer growth efficiency. The findings highlight the critical role of balanced protein-energy supply in sustaining productive performance, metabolic health, and carcass quality when rabbits are fed practical tropical diets composed of maize, soybean meal, wheat offal, palm kernel cake, and forage meal. Optimised ratios therefore offer a sustainable nutritional strategy to enhance rabbit meat production in resource-limited tropical systems where environmental cooling remains impractical. It was therefore recommended that the medium-high protein-energy ratio of 17% crude protein and 2500 kcal metabolisable energy/kg is recommended for growing rabbits in tropical feeding systems to maximise growth performance, metabolic-endocrine balance, and carcass yield.

Declarations

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Availability of data and materials

The data that support the findings of this study are available from Akanbi O.M. but restriction applies to the availability of the data, which were used under license for the current study, and so are not publicly available. Data are however available from the author upon reasonable request and with permission of Akanbi O. M.

Authors' contributions

OEI and OMA were responsible for the experimental design. OMA analyzed the collected data and wrote the manuscript. OEI was the principal author who was responsible to manage all activities of the experiment and worked in the execution of trial and also involved in data collection and interpretation. All authors read and approved the final manuscript

Ethics approval and consent to participate

Not applicable

Consent or publication

Not applicable

Competing interests

The authors declares that they have no competing interests.

References

1. Adeyeye, S.A., Agbede, J. O., Aletor, V. A., and Oloruntola, O. D. (2017). Processed cocoa (*Theobroma cacao*) pod husk in rabbits diets: effects on haematological and serum biochemical indices. *Advanced Journal of Agricultural Research*. 2(4), 1–9.
2. Adeyeye, E. A., Afolabi, K. D., and Olorunfemi, O. O. (2024). Growth performance and nutrient digestibility of growing rabbits fed diets containing palm press fibre as a replacement for wheat offal. *Livestock Research for Rural Development*, 36(6), Article 67.
3. Akande, K. E., Domon, B. A., and Adegbola, T. A. (2015). Dietary effects of increasing levels of pigeon pea meal on rabbit performance. *Journal of Animal Production Research*, 28(1), 45–56.
4. AL-SAGHEER, A. A., Abd El-Hack, M. E., Alagawany, M., El-Sayed, S. A. A., and Alowaimar, A. N. (2020). Productive performance response of growing rabbits to dietary protein reduction and supplementation of pyridoxine, protease, and zinc. *Anais da Academia Brasileira de Ciências*, 92(Suppl. 2), e20190315.
5. Ayyat, M. S., El-Sayed, S. A., El-Mekkawy, M. M., and El-Kholy, K. H. (2021). New Zealand White rabbits tolerance to chronic thermal stress at different dietary energy/protein levels. *Animal Feed Science and Technology*, 280, Article 115078.

6. Institute of Agricultural Research Meteorological Station (IARMS) (2025). Annual data publication. <https://www.iarabu.edu.ng>
7. Liang, Z. L., Li, Y. J., Zhao, Y. M., Zhang, X. Y., and Li, F. C. (2022). Impacts of heat stress on rabbit immune function, endocrine, blood biochemical changes, and production performance: A review. *Frontiers in Veterinary Science*, 9, Article 906084.
8. Liu, H., Zhong, J., Liu, J., Lin, J., Wang, Y., and Li, F. (2022). Effects of heat stress on growth performance, carcass traits, serum metabolism, and intestinal microflora of meat rabbits. *Frontiers in Microbiology*, 13, Article 998095.
9. Ogbon, E. A., Houndonougbo, F. M., and Kpodekon, M. T. (2025). Azolla spp and Hermetia illucens meals as main protein sources for rabbit nutrition. *Animals*, 15(12), Article 1789.
10. Ogunjesa, A. B., Olatunji, O. A., and Adeyemi, O. A. (2025). Growth performance of hybrid rabbits fed diets with turmeric and West African black pepper additives. *Agricultural Research and Innovation Journal*, 12(1), 45–56.
11. Palumbo, B., Bonaldo, A., and Biagi, G. (2025). Effect of dietary protein levels on performance and health status of adult companion rabbits. *Animals*, 15(19), Article 2784.
12. Saleh, A. A., El-Tahan, H. M., Morsy, W. A., and Hassan, M. H. (2023). Effect of dietary supplementation of betaine and organic minerals on growth performance, serum biochemical parameters, nutrients digestibility, and growth-related genes in broilers under heat stress [adapted for rabbit context in tropical trials]. *Poultry Science*, 102(3), Article 102456.
13. Trach, N. X., Hue, K. T., and Preston, T. R. (2019). Determination of optimal levels of energy, protein, and fiber in the diets of New Zealand White growing rabbits based on nutrient-response models. *Vietnam Journal of Animal Science*, 17(2), 45–56.

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