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Calcium, Phosphorus and Magnesium, but not Protein alone, Drive Growth in Pre-pubertal Captive Grasscutters (*Thryonomys swinderianus*)

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ABSTRACT

This study examined the interactive effects of dietary crude protein (CP), calcium (Ca), phosphorus (P), and magnesium (Mg) on pre-pubertal growth in captive grasscutters. Fifty weaned grasscutters (6 weeks old; initial mean weight 0.582 kg) were assigned to a 5 × 2 factorial design (diets × sex; n=10/treatment, 1:1 sex ratio). Treatments comprised four pelleted concentrate diets and fresh elephant grass (control, mimicking farmers' practice): Diet 1 (15% CP, 1.2% Ca, 0.6% P, 0.3% Mg); Diet 2 (15% CP, 1.5% Ca, 0.75% P, 0.33% Mg); Diet 3 (18% CP, 1.2% Ca, 0.6% P, 0.3% Mg); Diet 4 (18% CP, 1.5% Ca, 0.75% P, 0.33% Mg); elephant grass (11.37% CP, 0.9% Ca, 0.19% P, 0.13% Mg). Dietary CP influenced feed intake: Diets 1 and 2 (110.4 g/d) > Diets 3 and 4 (103.0 g/d), but elephant grass provoked the highest intake (160.1 g/d). Mineral synergies showed no clear feed intake effects (e.g., Diet 4 = 102.2 g/d vs. Diet 3 = 103.8 g/d; Diet 2 = 109.1 g/d vs. Diet 1 = 111.7 g/d). Water consumption increased with elevated mineral levels: Diets 2 and 4 (114.3 ml/d) > Diets 1 and 3 (106.7 ml/d). At 15% CP, elevated minerals (Diet 2) boosted average daily gain (0.013 kg vs. 0.010 kg), total weight gain (1.540 kg vs. 1.240 kg), and final body weight (2.132 kg vs. 1.808 kg) compared to Diet 1. At 18% CP, minerals had minimal impact (Diet 4 vs. Diet 3: 0.014 kg vs. 0.014 kg daily gain; 1.736 kg vs. 1.693 kg total gain; 2.317 kg vs. 2.275 kg final weight). It is concluded that synergies of elevated Ca, P, and Mg drive growth in CP-restricted diets (≤15%) beyond CP alone, and even at 18% CP, a mineral threshold is required to optimize pre-pubertal growth of captive grasscutter.

KEYWORDS: Pre-pubertal grasscutter, CP-Ca-P-Mg synergy, Pelleted diet, Growth performance
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INTRODUCTION

Grasscutters (Thryonomys swinderianus), the preferred bushmeat in sub-Saharan Africa (Falade et al., 2010), face production limits due to nutritional inadequacies of tropical grasses (*Pennisetum purpureum* and *Panicum maximum*), which are the main diets for captive grasscutters. These diets cause low birth weights, poor growth and reproduction capabilities, and high pre-/post-weaning mortalities (Adu et al., 2017). Past researches have focused on crude protein (CP) effects on growth (Kusi et al., 2012; Okyere et al., 2021) but have overlooked key minerals such as Ca, P, and Mg vital for skeletal structure and metabolism (Kothari et al., 2024). Grasses contain a substantial amount of Ca, but lower levels of P and Mg. Imbalanced Ca:P:Mg ratios impair absorption and utilization, thereby hindering growth (David et al., 2023).

Again, grasscutter farming is increasingly becoming popular in urban areas in Ghana. Urban farming challenges, such as grass scarcity, transport costs, and labor (Annor and Kusi, 2008), necessitate the production of pelleted concentrates for easy accessibility. But how much CP, Ca, P, and Mg should be included in the pelleted concentrates? This study targets optimal levels of these nutrients to boost feed and water intake of pre-pubertal grasscutters to optimise growth via the nutrients' synergies.

MATERIALS AND METHODS

Ethical Approval

This study was performed in line with the 'principles of laboratory animal care' and animal rights standards. Approval was granted by the Ethics Committee of Council for Scientific and Industrial Research (CSIR), Accra, Ghana. (2023-07-02/CSIR020/2023).

Location and duration of study

The experiment was conducted at the grasscutter unit of the Department of Animal Science Education farm, Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development, Asante Mampong Campus, Ghana. The experiment lasted for 18 weeks (including 2 weeks for adaptation. Table 1 shows mean temperature, humidity, and wind speed data recorded during the experimental period.

Table 1. Mean temperature, humidity and wind speed recorded over the period of study

Period	Temperature (°C)	Humidity (%)	Wind speed (kmph)
November	27.00	70	6.44
December	23.50	79	6.44
January	28.50	60	8.69
February	30.50	55	9.33

Experimental animals

The study used 50 weaned captive grasscutters (6 weeks old; average initial weight 0.583 kg; 25 males, 25 females), balanced by weight and randomly allocated to 5 dietary treatments with 10 animals/treatment and 1:1 sex ratio. They were housed singly in three-tier battery cages (measuring 60×50×40 cm) with each tier holding three cubicles. Crimped wire mesh was used as partitions and protective lining on wooden columns of the cages to prevent gnawing. Pull-out drawers were placed under the cubicles to collect feaces and waste feed.

Plate 1: A three-tier grasscutter cage

Plate 2: Pubertal-aged male grasscutter

Ration

Four diets containing varying levels of CP, Ca, P, and Mg were formulated, compounded, and pelletised. Fresh elephant grass was fed as a control to mimic local grasscutters farmers' practice. The proportions of the individual feed ingredients included in each of the four dietary treatments are detailed in Table 2.

Table 2. Composition of experimental diets

Ingredients	% Composition				
	Control	Diet 1	Diet 2	Diet 3	Diet 4
Maize	0.0	30.0	28.0	24.0	20.9
Rice husk	0.0	16.7	14.4	10.0	10.0
Elephant grass (fresh)	100.0	0.0	0.0	0.0	0.0
Elephant grass (dry)	0.0	8.0	8.0	8.0	8.0
Soy bean mea	l0.0	17.4	18.0	27.1	27.5
Wheat bran	0.0	10.0	10.0	13.0	12.0
Moringa	0.0	3.0	3.0	5.0	5.0
Oyster shell	0.0	0.7	2.0	0.7	2.0
Dicalcium phosphate	0.0	3.0	6.0	3.0	6.0
Magnesium oxide	0.0	0.2	0.6	0.2	0.6
[1]Vit. mineral premix	0.0	1.0	1.0	1.0	1.0
Common salt	0.0	2.0	2.0	2.0	2.0
Cassava flour	0.0	0.0	7.0	6.0	5.0
Total	100.0	100.0	100.0	100.0	100.0

[1]Vitamin mineral premix composition: vit A (800 IU), vit D (3000 IU), vit E (8 IU), vit K (2 mg), vit B1 (1 mg), vit B2 (2.5 mg), vit B12 (5 mg), Niacin (10 mg), Pantothenic acid (5 mg), Antioxidant (6 mg), Folic acid (0.5 mg), Choline (150 mg), Iron (20 mg), Manganese (80 mg), Zinc (50 mg), Cobalt (0.22 mg), Iodine (2 mg) and selenium (0.1 mg).

Feeding and watering

Experimental grasscutters were fed twice daily at 07:00 h and 17:00 h GMT. For weeks 1–8, each animal received 100 g/day (70 g morning, 30 g evening); for weeks 9–16, 150 g/day (100 g morning, 50 g evening). Feed leftovers were collected each morning, weighed, and subtracted from the amount offered to calculate daily feed intake before the next feeding.

Plate 3: Pubertal-aged female grasscutter feeding on pelleted diet

Preparation of feedstuffs

The freshly cut feedstuffs (elephant grass and moringa leaves) were air-dried to about 12% moisture and milled to pass through a 2 mm sieve using a Hammer mill. The remaining ingredients were obtained from university feed stores.

Proximate composition of experimental diets

The proximate compositions of feed ingredients and the diets were analysed using the methods prescribed by the Association of Official Analytic Chemists (AOAC, 2008) at the Nutritional Laboratory of the Kwame Nkrumah University of Science and Technology (KNUST). The metabolizable energy (ME) of the diets was calculated using the formula: ME = 37 x %CP + 81.8 %EE + 35 x %NFE as proposed by Pauzenga (1985). Details are shown in Table 3.

Table 3. Chemical composition of diets

Parameter	Experimental diets				
	Control	Diet 1	Diet 2	Diet 3	Diet 4
Moisture (%)	90.77	8.24	8.98	8.83	8.87
Crude protein (%)	11.37	15.15	15.21	18.25	18.18
Ether Extract (%)	1.32	2.23	2.08	2.59	2.97
Crude Fibre (%)	28.47	9.61	9.83	9.48	9.21

Ash (%)	7.65	9.89	11.62	10.61	11.38
NFE (%)	48.11	49.57	49.43	51.02	51.23
Ca (%)	0.90	1.17	1.48	1.18	1.47
P (%)	0.19	0.58	0.74	0.58	0.73
Mg (%)	0.13	0.32	0.37	0.32	0.36
Calculated Values					
[1]Energy MJ/ kg ME	9.28	10.37	10.31	11.18	11.23
Protein: Energy	1.23	1.46	1.48	1.63	1.62

[1]Estimated using equation by Pauzenga (1985); ME = (37 × percent crude protein) + (81.8 × percent ether extract) + (35 × percent nitrogen free extract).

Experimental design

5 x 2 factorial consisting of five dietary treatments and the sex of the grasscutters (male and female) was used. MINITAB version 18.1 was used for the analysis (Minitab, 2017). The differences in means were separated using Tukey's pair-wise comparisons at 95% confidence level.

Statistical model

The following statistical model was used to explain the effect and the relationship between the diets fed and the final body weight of the grasscutters:

$Y_{ijk}=\alpha+\tau_j+\gamma_k+\epsilon_{ijk}$, where $\epsilon_{ijk}\sim N(0,\sigma^2)$

- Y_{ijk} = the true body weight for the j^th observation from the j^th treatment and kth sex
- i = the observation number within the j^th treatment and kth sex
- j = the type of treatment (Elephant Grass, D1, D2, D3, D4)
- k = the type of sex (Male, Female)
- α = the true mean body weight for the treatment E Grass group (the baseline group)
- τ_j = the true deviation for jth treatment (D1, D2, D3, D4) from the true mean of the baseline group (E Grass)
- γ_k = the true deviation for the kth sex (Female) from the true mean of the baseline group (Male).
- ϵ = the random error associated with the i^th observation from the j^th treatment and kth sex.

RESULTS AND DISCUSSION

Treatment effect on feed intake

Elephant grass-fed grasscutters consumed more feed (160.1 g/animal/d) than those on pelleted diets (106.5 g/animal/d), with Diets 1 and 2 showing higher intake (110.4 g) than Diets 3 and 4 (103 g); intake increased with age (Fig. 1).

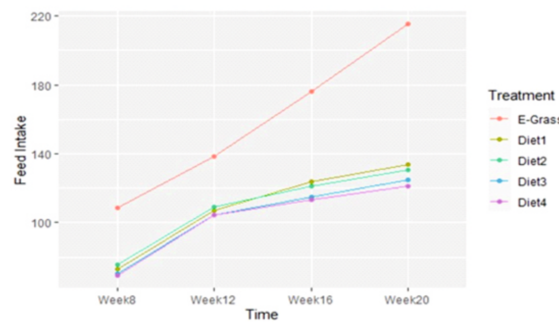

Fig. 1. Effect of dietary compositions on feed intake of pre-pubertal grasscutters

Pre-pubertal grasscutters fed fresh elephant grass consumed substantially more feed than those on pelleted concentrate diets varying in mineral levels. This likely stems from the forage's lower dry matter (DM) content (9.23%) compared to 91.27% DM in pellets. Lower DM feeds promote higher intake rates to achieve satiety, as noted by Karikari and Nyameasem (2009) for grasscutters.

Additionally, animals fed ad libitum adjust intake to meet nutrient needs (Azevêdo et al., 2016). Less nutrient-dense feeds like elephant grass (Singh, 2024) require greater consumption to satisfy metabolic demands compared to the pelleted concentrates. Thus, higher intake of forage reflects compensatory behaviour. Again, feed intake increased with the advancement of age (Fig. 1). A similar observation was made by Suman et al. (2024) on Gaddi goat bucks fed bypass fat.

The interactive effects of dietary crude protein (CP), calcium (Ca), phosphorus (P), and magnesium (Mg) did not influence feed intake in pre-pubertal grasscutters. Information on such interactions remains scarce for farm animals. The variations in Ca, P, and Mg levels typically do not affect feed intake in species like poultry (Al-Ghamdi, 2022), pigs (Yang et al., 2022), and cows (McArt and Oetzel, 2023). This suggests that minerals in general have minimal effect on livestock feed intake, as other studies with zinc show similar results (Padmaja et al., 2024; Umrao et al., 2025). However, intact sheep fed Mg-deficient diets showed reduced voluntary intake compared to controls (Ammerman et al., 1971). Specifically, complete Mg absence slashed intake by 32%, with a minimum requirement of 8–10 mg/kg body weight needed to restore normal appetite (Ammerman et al., 1971). This underscores the importance of meeting Mg thresholds to sustain feed intake. In the present study, the Mg levels offered evidently met growing grasscutters' minimum needs, explaining the consistent intake across treatments.

Interactive effect of diet and sex on feed intake

Except for grasscutters fed diet 4, feed intake was slightly higher for male animals across the dietary treatments; however, the differences were bridged as the animals aged (Fig. 2).

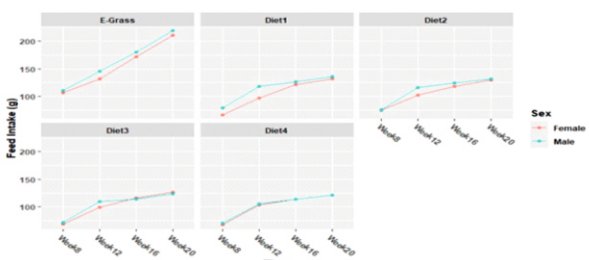

Fig. 2. Effect of age and sex on feed intake

Age significantly influenced feed intake, with consumption rising from weaning (6 weeks) to 24 weeks old. This aligns with increased physiological demands during growth, necessitating higher intake. Grandl et al. (2016) observed similar patterns in growing cows where organic matter intake increased with age, possibly as a result of distention of the rumen. The caecum in the grasscutter mimics the rumen in ruminants, which may account for similar results.

Sex had no significant effect on feed intake, though males consumed slightly more than females early in growth before patterns converged. This corroborates the findings by Hussein and Abd El-Fattah (2020), which indicated a lack of sexual dichotomy in feed intake of growing California rabbits.

Feed wastage

Feed wastage differed greatly between pelleted concentrate diets (diets 1–4) and fresh elephant grass. The average percentage of feed wastage for animals fed pelleted diets was 8.66%, in contrast to the 62.20% recorded for their counterparts fed fresh elephant grass. Males wasted more grass than females, but no sex differences appeared in pelleted diet groups.

Grasscutters exhibit substantial feed wastage, particularly on forage diets, wasting about 70% of forage (Mensah et al., 2001) and 17% of mashed concentrates (Kusi et al., 2012). In this study, however, captive pre-pubertal grasscutters on forage diets wasted approximately 62.2%—slightly less than previously reported. Wastage dropped markedly to 8.7% for those fed pelleted concentrates, a roughly 50% improvement over mashed feeds.

This reduction likely stems from the pelleted form's lower surface area compared to forage or mashed diets, which limits scattering. Farmers should prioritize pelleted diets to cut losses, boost profits, and curb environmental impacts such as vast land for disposal and emission of greenhouse gases like methane (CH_4), nitrous oxide (N_2O), and carbon dioxide (CO_2) (Liu and Liu, 2018). Sex influenced feed wastage in grasscutters on forage diets but not on pelleted concentrates. Males wasted about 7.6% more fresh forage than females, likely due to their greater aggression (Soro et al., 2014).

Synergistic Effects of Dietary CP, Ca, P, Mg, and Weather on Water Intake in Pre-pubertal Grasscutters

Figure 3 illustrates how daily water intake was influenced by dietary CP and mineral levels and weather. Pelleted concentrate diets with higher mineral levels (diets 2 and 4) increased water intake to 117.5 ml/animal/day, compared to 100 ml/animal/day for lower-mineral diets (diets 1 and 3).

Feed type significantly affected intake: forage-fed grasscutters drank ~20 ml/animal/day, versus ~103 ml/animal/day for pelleted concentrates. Water intake, furthermore, rose with higher ambient temperature and lower relative humidity (RH), averaging 103 ml/animal/day and peaking in February at 30.5°C and 55% RH, whereas the least amount was drunk in December at 23.5°C and 79% RH (Fig. 4).

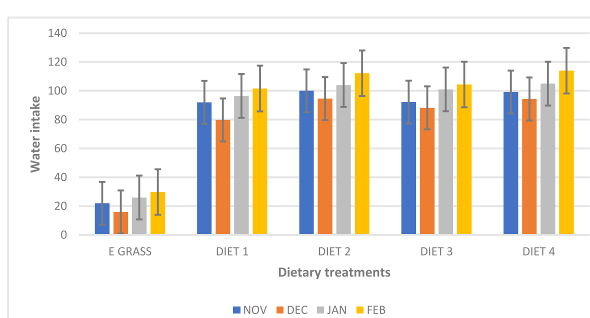

Fig. 3.Water intake dynamics of pre-pubertal grasscutters

Grasscutters fed Diets 2 and 4 (1.5% Ca, 0.75% P, 0.38% Mg) drank more water than those on 1.2% Ca, 0.6% P, and 0.3% Mg (diets 1 and 3), regardless of CP content. The elevated levels of the minerals in diets 2 and 4 might have caused a corresponding increase in water intake. Similar findings were observed in rats (Oyeyipo et al., 2010). Kusi et al (2012) reported an average water intake of 101.93 ml/animal/day, which is similar to that of animals fed diets 1 and 3 but lower than 114.3 ml/animal/day recorded for animals fed diets 2 and 4. The similarities and the variations could be attributed to the levels of Ca, P, and Mg in the diets. This could be ascribed to the role of water to dissolve minerals for possible absorption and excretion of the excess from the blood (Khan et al., 2016; Shkembi and Huppertz, 2021). For instance, inadequate water intake risks Ca supersaturation, which could lead to kidney stones, with over 80% of global cases linked to calcium compounds like oxalate (Khan et al., 2016; Susilo et al., 2021).

Grasscutters fed elephant grass drank approximately 70 ml less (per animal/day) compared to those fed pelleted concentrates. The differences in dietary moisture might have accounted for this. Forage's high moisture provided adequate hydration, reducing drinking needs, while drier pellets demanded more water for digestion and metabolism. Torres et al. (2019) alluded that dietary characteristics such as dry matter and ash could influence the drinking habits of cows, as observed in this study.

The variations observed in water intake during the study period could also be attributed to the prevailing weather conditions. The months with relatively higher temperatures drove intake to support thermoregulation, countering dehydration from increased respiration (Wolf, 2020; Orakpoghenor et al., 2021). Adequate clean water is thus vital for homeostasis, especially in hot sub-Saharan regions like Ghana (Rivera and Anjum, 2023), because hypohydration affects body fluids concentrations, risking hypotonic hypovolemia (Thornton, 2016).

Growth performance

Dietary synergies of CP, Ca, P, and Mg significantly influenced ($P < 0.05$) growth rate, final body weight, and total weight gain. Grasscutters on diets 3 and 4 achieved the highest values, outperforming ($P < 0.05$) those on diets 1, 2, and elephant grass (control). The control group performed the poorest ($P < 0.05$) across all growth metrics.

Sex × diet interactions also affected body weight measures, with males and females on diets 3 and 4 superior ($P < 0.05$) to other groups. Daily weight gain, final body weight, and total weight gain were similar for males on diet 2 and both sexes on diet 3, but higher ($P < 0.05$) than diet 1 and control. Within the diets, sexes showed similar performance (Table 4), except males on diet 2 that outperformed their female counterparts.

Table 4. Dietary CP, Ca, P, and Mg synergies on growth performance of captive pre-pubertal grasscutters

Variable	Initial Weight (kg)	Daily weight (kg)	Total weight (kg)	Final Body weight (kg)
Dietary treatments				
Grass	0.585	0.006^{d}	0.721^{d}	1.301^{d}
Diet 1	0.573	0.010^{c}	1.240^{c}	1.808^{c}
Diet 2	0.592	0.013^{b}	1.540^{b}	2.132^{b}
Diet 3	0.582	0.014^{a}	1.693^{a}	2.275^{a}
Diet 4	0.581	0.014^{a}	1.736^{a}	2.317^{a}
SEM	0.007	0.001	0.014	0.014
P-value	0.552	0.001	0.001	0.001
Sex effect				
Male	0.591^{a}	0.012^{a}	1.402^{a}	1.994a
Female	0.574^{b}	0.011^{b}	1.369^{b}	1.939^{b}
SEM	0.005	0.001	0.022	0.008
P-value	0.019	0.001	0.012	0.001
Treatment*Sex				
Diet 4*Males	0.594	0.015^{a}	1.742^{a}	2.336^{a}
Diet 4*Females	0.568	0.014^{a}	1.731^{a}	2.299^{a}

Diet 3*Males	0.592	0.014[ab]	1.690[ab]	2.281[ab]
Diet 3*Females	0.572	0.014[ab]	1.700[ab]	2.268[ab]
Diet 2*Males	0.600	0.013[b]	1.611[b]	2.211[b]
Diet 2*Females	0.584	0.012[c]	1.468[c]	2.052[c]
Diet 1*Males	0.580	0.010[d]	1.248[d]	1.828[d]
Diet 1*Females	0.566	0.010[d]	1.233[d]	1.788[d]
Grass*Males	0.590	0.006[e]	0.721[e]	1.311[e]
Grass*Females	0.580	0.006[e]	0.721[e]	1.291[e]
SEM	0.011	0.001	0.020	0.018
P-value	0.961	0.001	0.002	0.001

D 1 = 15% CP; 1.2% Ca; 0.6% P & 0.3% Mg; D 2 = 15% CP; 1.5% Ca; 0.75% P & 0.35% Mg; D 3 = 18% CP; 1.2% Ca; 0.6% P & 0.3% Mg and D 4 = 18% CP; 1.5% Ca; 0.75% P & 0.35% Mg, EG = Elephant Grass F = Female; M = Male; Means in a row with different superscripts are significantly different (P<0.05). SEM = Standard Error of Mean.

Dietary synergies of CP, Ca, P, and Mg remarkably influenced daily body weight gain, final body weight, and total weight gain in pre-pubertal grasscutters. Those fed 18% CP pelleted diets, irrespective of the mineral levels, averagely gained 14 g/day—over double that of elephant grass-fed animals and 2.5 g/day higher than 15% CP fed groups—confirming 18% CP as optimal for promoting growth of captive grasscutters, consistent with prior findings (Kusi et al., 2012; Nyameasem et al., 2019). Protein promotes growth primarily by providing the essential amino acids that serve as the building blocks for tissues in the body (Petkova et al., 2025). The body uses protein to repair and build muscles, bones, skin, and other tissues, supporting overall tissue growth and maintenance (Lopez and Shamim, 2024; Qamar et al., 2025). The growth rate, final body weight, and total body weight gain observed for animals fed diet 4 in this study were higher than those of Kusi et al. (2012). Even though the diets involved in the two separate studies had similar CP levels (18%), they differed in mineral levels. The diet fed by Kusi et al. (2012) had lower levels of Ca (0.51%), P (0.66%), and Mg (0.18%) compared to the levels used in this present study (diet 4) which presupposes that even at 18% CP, a certain threshold of Ca, P, and Mg levels is necessary to optimise growth in pre-pubertal captive grasscutters.

Moreover, the captive pre-pubertal grasscutters fed diets 1 and 2 showed significant protein-mineral-dependent growth patterns. Irrespective of the similar CP levels, grasscutters fed Diet 2 (15% CP with 1.5% Ca, 0.75% P, and 0.38% Mg) achieved markedly higher daily body weight gain, total body weight gain and final body weight compared to their counterparts fed Diet 1 (15% CP with 1.2% Ca, 0.6% P, 0.3% Mg), emphasizing mineral optimization synergies over CP alone in promoting growth at pre-pubertal stage of captive grasscutters. This study reaffirms the role of Ca, P, and Mg as growth promoters via bone mineralization (Michigami and Osono 2019; Wongdee et al., 2019), energy metabolism in the cell (P in ATP/creatine phosphate) (Karger et al., 2024) and homeostasis (Morris and Mohiuddin 2021) to the extent that their deficiencies (hypocalcemia, hypophosphatemia, and hypomagnesemia) in growing animals risk delayed growth and development and may act as predisposal factor to rickets (Miller and Imel, 2022).

Sexual dichotomy did not show any significant variation in daily body weight gain, final body weight, or total body weight gain among animals that received the same diet, except for those fed diet 2, which warrants further investigation. Aside from pre-pubertal grasscutters fed diet 2, the weight gap between males and females at weaning was mitigated by 24 weeks of age. These findings align with earlier reports that sex-based growth variations in some animals diminish when environmental and dietary factors are standardised. Lamptey et al. (2022) reported a lack of sexual dichotomy in the growth performance of New Zealand rabbits when offered similar dietary treatments as observed in this study. This emphasizes the nutritional impact over biological sex on growth outcomes of pre-pubertal grasscutters.

Feed conversion ratio

Grasscutters fed diet 4 exhibited the lowest FCR, which was statistically similar to that of diet 3 but different from diets 1 and 2. In contrast, animals fed elephant grass recorded the highest FCR compared to those offered concentrate pelleted diets (Fig.4).

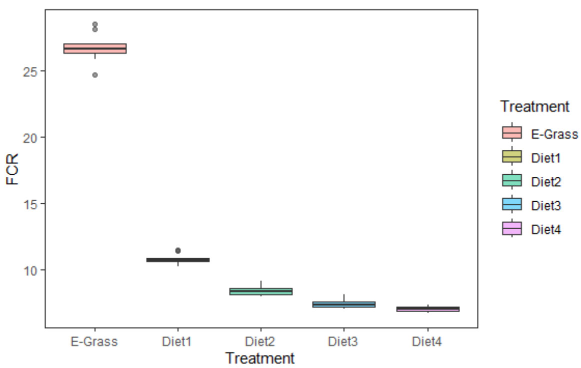

Fig. 4.Effect of dietary treatments on feed conversion ratio

Captive pre-pubertal grasscutters fed 18% CP showed similar feed conversion ratios (FCR), indicating that varying Ca, P, and Mg levels had minimal impact at this protein level. Contrary, they outperformed those on other diets, aligning with Nyameasem et al. (2019), who found higher efficiency of diets with dietary protein of 18% in growing grasscutters. At 15% CP, however, higher minerals (1.5% Ca, 0.75% P, 0.38% Mg) enhanced feed efficiency (lower FRC) as compared to lower levels (1.2% Ca, 0.6% P, 0.3% Mg), suggesting mineral synergy boosts efficiency at moderate protein levels.

Toxicology and Mortality

Two deaths were recorded between the first and eighth week of the experiment: one from animals fed the control diet and the other from those fed diet 1. Post mortem examination conducted showed no sign of adverse effect on any of the organs; nor was there any observed in the bladder or the kidneys. However, traces of blood stains were found in the intestines of the animals during the examination, giving an indication of coccidiosis. Grasscutters are coprophagous (Van Zyl and Delport, 2010); hence, there is a possibility of contracting coccidiosis, as occurs in rabbits. This suggests that the dietary materials and their levels offered posed no health risk to the growing grasscutters studied.

CONCLUSION

Synergies of elevated Ca, P, and Mg drive growth in CP-restricted diets (≤15%) beyond CP alone, and even at 18% CP, a mineral threshold is required to optimize pre-pubertal grasscutter growth. Adopting pelleted diets is vital to reduce feed wastage to maximise profit. Adequate water supply is key when offering pelleted diets with elevated mineral levels to avert possible kidney-related complications.

REFERENCES

Adu, E. K., Asafu-Adjaye, A., Hagan, B. A., and Nyameasem, J. K. 2017. The grasscutter: an untapped resource of Africa's grasslands. Livestock Research for Rural Development. 29(3): 47.

Al-Ghamdi, E.S. 2022. Influence of calcium and nonphytate phosphorus (NPP) on meat-type quail's growth, carcass features, and tibia indices. Journal of Experimental Biology and Agricultural Sciences. 10(3): 668-678.

Ammerman, C. B., Chicco, C. F., Moore, J. E., Van Walleghem, P. A. and Arrington, L. R. 1971. Effect of dietary magnesium on voluntary feed intake and rumen fermentations. Journal of Dairy Science. 54(9): 1288-1293.

Annor, S.Y. and Kusi, C. 2008. Factors influencing the adoption of grasscutter production in the Brong Ahafo region of Ghana. Livestock Research for Rural Development. 20: 9.

AOAC. 2008. Official Methods of Analysis. 17th Edn. Association of Official Analytic Chemists. Gaithersburg, MD. USA.

Azevêdo, J. A. G., Valadares Filho, S. C., Costa e Silva, L. F., Dos Santos, A. B., Rotta, P. P., Rennó, L. N. and Prado, I. N. 2016. Regulation and prediction of dry matter intake. In: Nutrient Requirements of Zebu and Crossbred Cattle. Eds. Valadares Filho, SC, Costa e Silva, L.F, Rotta, P.P, Gionbelli, M.P, Marcondes, M.I, Chizzotti, M.L, Prados, L.F. *BR-CORTE* p. 15-42.

David, L. S., Anwar, M. N., Abdollahi, M. R., Bedford, M. R. and Ravindran, V. 2023. Calcium nutrition of broilers: current perspectives and challenges. Animals. 13(10): 1590.

Falade, L.O., Idahor, K.O. and Ayodele, I.A. 2010. Survey of domestication process of grasscutter (*Thryonomys swinderianus*) in some selected states in Southwestern Nigeria. Journal of Agriculture, Forestry and the Social Sciences. 8(2): 49 – 55.

Grandl, F., Luzi, S.P., Furger, M., Zeit, J.O., Leiber, F., Ortmann, S. and Schwarm, A. 2016. Biological implications of longevity in dairy cows: Changes in feed intake, feeding behaviour and digestion with age. Journal of Dairy Science. 99(5): 3457-3471.

Hussein, A., and Abd El-Fattah, M. G. 2020. Effect of sex and feed frequency on growing California rabbits, carcass characteristics and meat quality. Egyptian Poultry Science Journal. 40(2): 405-419.

Karger, G., Berger, J. and Dringen, R. 2024. Modulation of cellular levels of adenosine phosphates and creatine phosphate in cultured primary astrocytes. Neurochemical Research. 49(2): 402-414.

Khan, S.R., Pearle, M.S., Robertson, W.G., Gambaro, G., Canales, B.K. and Doizi, S. 2016. Kidney stones. Nature Reviews Disease Primers. 2:16008.

Karikari, P. K. and Nyameasem, J. K. 2009. Productive performance and carcass characteristics of captive grasscutters (*Thryonomys swinderianus*) fed concentrate diets containing varying levels of guinea grass. World Applied Sciences Journal. 6(4): 557-563.

Kothari, M., Wanjari, A., Shaikh, S. M., Tantia, P., Waghmare, B. V., Parepalli, A. and Nelakuditi, M. 2024. A comprehensive review on understanding magnesium disorders: pathophysiology, clinical manifestations, and management strategies. Cureus. 16(9): e68385.

Kusi, C., Tuah, A.K., Annor, S.Y. and Djan-Fordjour, K.T. 2012. Determination of dietary crude protein level required for optimum growth of grasscutters *(Thryonomys swinderianus*) in captivity. Livestock Research for Rural Development. 24: 10

Lamptey, V.K., Hagan, B.H. and Kruenti, F. 2022. The influence of sex and age on growth rate of domestic rabbits (Oryctolagus cuniculus). Journal of Innovative Agriculture 9(2).

Liu, Z. and Liu, Y. 2018. Mitigation of greenhouse gas emissions from animal production. Greenhouse Gases: Science and Technology. 8(4): 627-638.

Lopez, M.J. and Shamim S. M. 2024. "Biochemistry, essential amino acids." In *StatPearls [Internet]*. StatPearls Publishing.

McArt, J. A. and Oetzel, G. R. 2023. Considerations in the diagnosis and treatment of early lactation calcium disturbances. Veterinary Clinics: Food Animal Practice. 39(2): 241-259.

Mensah, G. A., Gnimadi, A. and Houngnibo, G. 2001. Formulation d'un projet de promotion de la filière aulacode au Bénin -Volume III - Projet de Promotion de la Filière Aulacode au Bénin (PPFAB). CBDD/Bénin. 28 p.

Michigami, T. and Ozono, K. 2019. Roles of phosphate in skeleton. Frontiers Endocrinology (Lausanne). doi:10.3389/fendo.2019.00180. PMID: 30972027; PICID: PNC6443631.

Miller, W. L. and Imel, E. A. 2022. Rickets, vitamin D, and Ca/P metabolism. Hormone Research in Paediatrics. 95(6): 579-592.

Minitab. 2017. Statistical Software, Version 18.1. Minitab Incorporation, State College.

Morris, A.L. and Mohiuddin, S.S. 2021. In StatPearls. Treasure Island (FL).

Nyameasem, J. K., Akoloh, M. and Adu, E. K. 2019. Effects of protein content on feed intake and performance of grasscutters fed diets containing forage meal. Animal Production Science. 59(2): 314-318.

Okyere, K., Kyere, C.G., Sarpong, A.A. and Poku Jnr., P.A. 2021. Influence of different dietary protein concentration on growth and reproductive performance of the grasscutter (*Thryonomys swinderianus*). World Journal of Pharmaceutical and Life Sciences. 7(5): 104 – 110.

Orakpoghenor, O., Ogbuagu, N. E., and Sa'Idu, L. 2021. Effect of environmental temperature on water intake in poultry. Advances in Poultry Nutrition Research.

Oyeyipo, I. P., Olatunji, L. A., Akhigbe, R. E., Arokoyo, D. S. and Soladoye, A. O. 2010. Effect of increased dietary calcium on body weight, food and water intake in oral contraceptive treated female rats. Nigerian Journal of Physiological Science. 25(1): 73–79.

Padmaja, D., Ravi, A., Devasena, B., Durga, S. and Suresh, J. 2024. Evaluation of Ayurvedic zinc (Yashada Bhasma) in commercial broilers. Indian Journal of Animal Nutrition. 41(3): 528-540.

Pauzenga, U. 1985. Feeding parent stock. Zootenicia International. 17: 22–24

Petkova, D., Stoyanova, S., Dinkov, G. and Bogdanov, M. G. 2025. Beyond Protein Building Blocks: A Review of Biological Roles and Therapeutic Potential of Free Amino Acids. International Journal of Molecular Sciences. 26(23): 11264.

Qamar, M. N., Nafees, H. and Feroz, S. A. 2025. Role of Protein Nutrition for Maintaining the Health of the Musculoskeletal System. In: Evaluating the Effectiveness of Functional

Ingredients in Sports Nutrition. Eds. Sehar, C. and Hamit, C. IGI Global Scientific Publishing. pp. 177-214.

Rakshit, S., Roy, K. and Datta, I. C. 2021. Hypercalciuria in the house rabbit: an ecological anomaly. Haryana Veterinary. 60(SI): 103-105.

Rivera, J.G.M. and Anjum, F. 2023. Hypovolemia. Statpearls. National Library of Medicine. National Centre for Biotechnology Information.

Shkembi, B. and Huppertz, T. 2021. Calcium absorption from food products: food matrix effects. Nutrients, 14(1): 180.

Singh, G. 2024. Nutrition and feeding management of goats for chevon production. International Journal of Science, Environment and Technology. 13(5): 339.

Soro, D. Okon, A. Kimsé, M. and Fantodji, A. 2014. Using communication to improve grasscutters (*Thryonomys Swinderianus*) reproductive behaviour in Cote D'ivoire. International Journal of Science and Research. 3(6): 2465-2468.

Suman, M., Katoch, S., Verma, N., Thakur, D. and Dinesh, K. 2024. Impact of bypass fat on growth and testicular measurements in Gaddi goat bucks. Indian Journal of Animal Nutrition, 41(3): 385-392.

Susilo, J., Purwanto, B., Doewes, M. and Indarto, D. 2021. Calcium oxalate crystals: Epidemiology, causes, modeling of crystal formation and treatment management. Journal of Pharmaceutical Sciences and Research. 13(2): 118-123.

Thornton, S. N. 2016. Increased hydration can be associated with weight loss. Frontiers in nutrition. 3: 183053.

Torres, R. N. S., Silva, H. M., Donadia, A. B., Menegazzo, L., Xavier, M. L. M., Moura, D. C. and Oliveira, A. S. 2019. Factors affecting drinking water intake and predictive models for lactating dairy cows. Animal Feed Science and Technology. 254: 114194.

Umrao, P., Kumar, V., Kumar, M., Kushwaha, R., Vaswani, S., Kumar, A., Yadav, R.D. and Gupta, M. 2025. Effect of three different forms of zinc on growth performance, digestibility, blood profiles and antioxidant status of Sahiwal heifers. Indian Journal of Animal Nutrition. 42(2): 151-160

Wolf, P., Cappai, M. G. and Kamphues, J. 2020. Water consumption in small mammals (dwarf rabbits, Guinea pigs and chinchillas): New data about possible influencing factors. Research in Veterinary Science. 133: 146-149.

Wongdee, K., Rodrat, M., Teerapornpuntakit, J., Krishnamra, N. and Charoenphandhu, N. 2019. Factors inhibiting intestinal calcium absorption: Hormones and luminal factors that prevent excessive calcium uptake. Journal of Physiology Science. 69: 683-696.

Yang, A., Wang, K., Peng, X., L.F., Wang, Y., Cui, Y. and Si, H. 2022. Effects of different sources of calcium in the diet on growth performance, blood metabolic parameters, and intestinal bacterial community and function of weaned piglets. Frontiers in Nutrition. 9: 885497.

Van Zyl, A. and Delport, J. H. 2010. Digestibility of nutrients and aspects of the digestive physiology of the greater cane rat (*Thryonomys swinderianus)*. African Zoology. 45: 254-264.