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Harnessing Syzygium aromaticum for Sustainable Rabbit Meat Production: Growth and Carcass Response in Does

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Abstract

This study investigated the efficacy and optimal inclusion level of Syzygium aromaticum (clove) as a phytogenic feed additive for enhancing growth performance and carcass characteristics in rabbit does. As global demand increases for natural and sustainable alternatives to synthetic growth promoters in animal production, phytogenic additives such as S. aromaticum which is rich in bioactive compounds like eugenol, gallic acid, and flavonoids offer promising potential due to their antioxidant, antimicrobial, and digestion-enhancing properties. A total of thirty-six crossbred rabbit does (aged 2–3 months; initial body weight 600–650 g) were randomly assigned to four dietary treatment groups in a completely randomized design (CRD). The treatment groups included: T1 (control, 0 g/kg S. aromaticum), T2 (5 g/kg), T3 (7.5 g/kg), and T4 (10 g/kg). The feeding trial lasted for 20 weeks, during which growth performance parameters including feed intake, daily weight gain, and feed conversion efficiency were recorded. Post-mortem carcass evaluation included measurements of slaughter weight, hot carcass weight, dressing percentage, and the weights of major primal cuts. Data were subjected to analysis of variance (ANOVA), and mean differences were separated using Duncan's multiple range test at a significance level of $p < 0.05$. Results indicated that dietary inclusion of S. aromaticum significantly influenced several performance and carcass parameters. Feed intake was highest (97.46 g/day) in T3 and lowest (93.46 g/day) in T1. While final body weight did not differ significantly among treatments ($p > 0.05$), the highest average daily weight gain was observed in T4 (59.85 g/day), followed by T3 and T2, indicating a dose-responsive trend. Feed conversion efficiency improved with S. aromaticum supplementation, peaking at 62.99% in T4 compared to 59.92% in the control group. Carcass evaluation revealed that rabbits fed 7.5 g/kg S. aromaticum (T3) had the highest slaughter weight (1786.11 g) and carcass weight (1561.99 g), with notable improvements in dressed weight and the weights of key primal cuts such as the loin, rib, and back. These findings suggest enhanced protein accretion and muscle deposition, likely attributable to the antioxidative and digestive properties of the clove bioactive. In conclusion, dietary supplementation of Syzygium aromaticum at 7.5 g/kg appears to be the optimal inclusion level for improving growth performance and carcass yield in rabbit does. This study underscores the potential of S. aromaticum as an effective phytogenic feed additive and supports its integration into rabbit nutrition programs aimed at enhancing productivity, meat quality, and sustainability in small- and medium-scale rabbit farming systems.

Keywords: *Syzygium aromaticum, phytogenic feed additive, rabbit does, growth performance, carcass characteristics, natural growth promoters, sustainable animal production*

INTRODUCTION

The rising global demand for safe, sustainable, and naturally produced animal protein has intensified interest in alternative growth promoters that align with the principles of eco-friendly and residue-free meat production. Rabbit meat, known for its high-quality protein, low fat, and low cholesterol content, has gained popularity among health-conscious consumers (Lebas,

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2013). However, the efficiency of rabbit production is often constrained by suboptimal feed conversion and carcass yield, prompting the need for natural feed additives that can enhance productivity without compromising animal welfare or food safety (Dalle Zotte & Szendrő, 2011).

Phytogenic feed additives, derived from herbs, spices, and plant extracts, have emerged as promising alternatives to synthetic growth promoters in monogastric animal production. Among these, *Syzygium aromaticum* (commonly known as clove), a spice native to Southeast Asia and widely used in culinary and medicinal applications, has attracted attention for its diverse array of bioactive compounds. The dried flower buds of clove are particularly rich in eugenol, eugenol acetate, gallic acid, and flavonoids, which possess potent antioxidant, antimicrobial, and anti-inflammatory properties (Haro-González et al., 2021; Zhelyazkov et al., 2022). These compounds are believed to improve gut health, enhance nutrient digestibility, and reduce oxidative stress, thereby improving growth performance and meat quality in livestock (Cortés-Rojas et al., 2014).

Eugenol, the primary active compound in clove, is rapidly absorbed when administered orally and exhibits a relatively long half-life in the bloodstream (approximately 18.3 hours), which supports its sustained biological effects (Cortés-Rojas et al., 2014). Recognized as generally safe (GRAS) by the World Health Organization and other regulatory bodies, eugenol has been extensively studied in poultry and ruminant nutrition (Haro-González et al., 2021; Zeng et al., 2015). However, despite its proven benefits in these species, there remains a paucity of data on the application of *S. aromaticum* in rabbit nutrition, particularly regarding its effects on does—a critical segment of rabbit production systems due to their reproductive and growth potential.

Previous studies on phytogenic additives in rabbit diets have reported improved feed efficiency, immune response, and meat quality (El-Gindy et al., 2020; Ahmed et al., 2021). However, the optimal dietary inclusion level of clove that maximizes growth performance and carcass traits in rabbit does remains undefined. Additionally, few studies have investigated the gender-specific response to such additives, despite known physiological differences in nutrient metabolism between male and female rabbits (Tumova et al., 2016).

Therefore, this study aims to evaluate the potential and determine the optimal dietary inclusion level of *Syzygium aromaticum* as a phytogenic feed additive for improving growth performance and carcass characteristics in rabbit does. The findings are expected to contribute to sustainable rabbit meat production strategies by identifying a natural, safe, and effective alternative to synthetic growth promoters.

Materials and Methods

Experimental Site and Ethical Consideration

The study was conducted at the Rabbitry Unit of the Teaching and Research Farm, College of Animal Science and Animal Production, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria. The location, in southeastern Nigeria, experiences an annual rainfall of 1,700–2,100 mm, ambient temperatures ranging from 27°C to 36°C in the dry season and 20°C to 26°C in the rainy season, and relative humidity between 57% and 91%. Meteorological data were obtained from the National Root Crop Research Institute, Umudike (NRCRI, 2021).

Experimental Animals and Design

Thirty-six healthy weaned rabbit does aged 8–12 weeks, with initial body weights ranging from 600–650 g, were used in the trial. The animals were acclimatized for two weeks before the commencement of the study. Thereafter, they were randomly allocated to four dietary treatments in a completely randomized design (CRD), with nine rabbits per treatment and three replicates of three rabbits each.

Dietary Treatments

The experimental diets were formulated to meet the nutrient requirements of growing rabbits according to NRC (1977) recommendations. The treatments consisted of the following inclusion levels of *Syzygium aromaticum* (clove) powder:

- **T1**: Basal diet without clove (0 g/kg)
- **T2**: Basal diet + 5 g/kg clove
- **T3**: Basal diet + 7.5 g/kg clove
- **T4**: Basal diet + 10 g/kg clove

The clove buds were purchased from a certified local supplier, sun-dried, milled into fine powder, and stored in airtight containers until incorporation into the diets (Table 1).

Table 1: Composition of experimental Diets for rabbits

Ingredients	T_1(0g/kg)	T_2(5g/kg)	T_3(7.5g/kg)	T_4(10g/kg)
Maize	44.94	44.94	44.94	44.94
Soya bean meal	17.31	17.31	17.31	17.31
Rice husk	32.00	32.00	32.00	32.00
Fishmeal	2.00	2.00	2.00	2.00
Bone meal	1.00	1.00	1.00	1.00
Limestone	2.00	2.00	2.00	2.00
Vit/min Premix*	0.25	0.25	0.25	0.25

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Common salt	0.50	0.50	0.50	0.50
Total	100.00	100.00	100.00	100.00
***Syzygium aromatium* bud powder (g/kg feed)**	0.00	5.00	7.50	10.00
Crude Protein (%)	17.00	17.00	17.00	17.00
Metabolizable Energy (ME) (Kcal/kg diet)	2505.42	2505.42	2505.42	2505.42
Crude fiber (%)	11.36	11.36	11.36	11.36
Lysine (%)	0.514	0.514	0.514	0.514
Methionine (%)	0.199	0.199	0.199	0.199

*Premix composition (per kg of diet): vitamin A, 12,500 IU; vitamin D3, 2500 IU; vitamin E, 50.00mg; vitamin K3, 2.50mg; vitamin B1, 3.00mg; vitamin B2, 6.00mg; vitamin B6, 6.00mg; niacin, 40mg; calcium pantothenate, 10mg; selenium, 0.10mg; biotin, 0.08mg; antioxidant,200mg;vitamin B12, 0.25mg; folic acid, 1.00mg; chlorine chloride,300mg; manganese, 100mg; iron, 50mg; zinc, 45mg; copper, 2.00mg; iodine, 1.55mg; cobalt, 0.25mg.

Housing and Management

The rabbits were housed individually in well-ventilated cages equipped with feeders and drinkers. They were maintained under uniform management conditions with ad libitum access to feed and clean drinking water. Routine biosecurity, hygiene, and health management practices were observed throughout the 20-week feeding trial.

Data Collection

Growth Performance

Body weight was recorded weekly using a digital scale, and daily feed intake was monitored by subtracting feed refusals from the total feed offered. Weight gain, average daily gain (ADG), feed intake, and feed conversion ratio (FCR) were calculated for each treatment group.

Carcass Evaluation

At the end of the feeding trial, three rabbits per treatment group were randomly selected, fasted for 12 hours (with water provided), weighed, and humanely slaughtered. The slaughter weight, hot carcass weight, dressing percentage, and weights of major primal cuts (loin, rib, back, thigh) were recorded. Organs such as liver, heart, kidney, and lungs were also weighed to determine relative organ weights.

Statistical Analysis

Data were analyzed using one-way Analysis of Variance (ANOVA) in SPSS version. Where significant differences occurred ($p < 0.05$), treatment means were separated using Duncan's Multiple Range Test. Results were expressed as means ± standard error of the mean (SEM).

Chemical Analysis of Clove and Diets

The proximate composition of the clove powder and formulated diets was determined using standard procedures as described by AOAC (2019). Parameters analyzed included crude protein (CP), crude fibre (CF), ether extract (EE), ash, and moisture content.

Results and Discussion

Effect of Feeding Different Levels of *Syzygium aromaticum* on Growth Performance of Rabbit Does

The effects of dietary inclusion of *Syzygium aromaticum* (clove) on the growth performance of rabbit does are presented in Table 2. The analysis revealed that the inclusion level of 7.5 g/kg (T3) significantly ($p < 0.05$) influenced several performance indicators, particularly feed intake, final body weight, and feed efficiency.

Table 2. *Effect of feeding different levels of Syzygium aromaticum on growth performance of rabbit does*

Parameters	T1	T2	T3	T4	SEM
Quantity given (g/rabbit/day)	100.00	100.00	100.00	100.00	0.00
Feed intake (g/rabbit/day)	93.46^{c}	94.97^{b}	97.46^{a}	95.02^{b}	0.33
Initial body weight (g)	661.30	647.37	662.33	634.55	4.72
Final body weight (g)	1781.00	1838.75	1850.11	1831.55	15.27
Weight gained (g/day)	55.98	59.57	59.39	59.85	0.77
Feed Conversion Ratio (FCR)	1.69	1.59	1.65	1.59	0.02
Feed Efficiency (%)	59.92	62.74	60.96	62.99	0.82

Different superscript letters across rows indicate significant ($p < 0.05$) differences. SEM = Standard Error of Mean.

The feed intake was significantly higher ($p < 0.05$) in rabbits fed 7.5 g/kg of clove (T3), with an average daily consumption of 97.46 g/rabbit/day. This value was markedly higher than that of the control (T1: 93.46 g/rabbit/day) and other supplemented groups (T2 and T4). The observed increase in feed intake in T3 suggests that moderate inclusion of clove enhances diet palatability and digestive efficiency. This is consistent with the findings of Suliman et al. (2023), who

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observed improved feed intake and conversion efficiency in rabbits supplemented with clove due to its flavor-enhancing and antimicrobial properties.

Initial body weights were not significantly different ($p > 0.05$), affirming the reliability of treatment comparisons. However, significant ($p < 0.05$) differences were observed in final body weights, with the highest recorded in T3 (1850.11 g), followed by T2, T4, and T1. This trend implies that *S. aromaticum*, particularly at 7.5 g/kg, positively influenced body weight accumulation during the experimental period.

Although the highest weight gain was recorded in T4 (59.85 g/day), it was statistically similar to T2 and T3, suggesting that inclusion levels of 5–10 g/kg were generally effective. These results agree with Aliyu et al. (2024), who reported that clove bud supplementation in weaned rabbit diets significantly enhanced daily weight gain without adverse health effects.

The feed conversion ratio (FCR) was lowest in T2 and T4 (1.59), indicating improved feed efficiency. The highest FCR (1.69) was noted in the control group (T1), which consumed less feed and gained less weight. Interestingly, despite having the highest final weight and feed intake, T3 showed a slightly higher FCR (1.65) and lower feed efficiency (60.96%) than T2 (62.74%) and T4 (62.99%). This suggests that while moderate clove inclusion boosts appetite and growth, it may also increase feed utilization inefficiencies if inclusion exceeds the metabolic threshold.

These findings corroborate the earlier work of Alrashedi et al. (2024), who attributed enhanced growth rates and FCR in clove-fed rabbits to the bioactive compound eugenol, known for its antimicrobial, antioxidative, and digestive-enhancing properties. Similarly, Oladimeji et al. (2022) and Liang et al. (2022) noted that phytogenic feed additives such as *S. aromaticum* can mitigate stress-induced metabolic inefficiencies by enhancing antioxidant defense systems and modulating gut microbiota.

In summary, this study demonstrates that dietary inclusion of *Syzygium aromaticum* at 7.5–10 g/kg optimally improves feed intake, growth rate, and feed efficiency in rabbit does. However, the 7.5 g/kg inclusion rate appeared most effective for enhancing final body weight and carcass characteristics, making it a promising strategy for sustainable rabbit meat production.

Table 3 presents the effects of varying levels of *Syzygium aromaticum* (clove) on carcass characteristics of rabbit does. The inclusion of clove significantly influenced ($p < 0.05$) several carcass parameters, with notable differences observed across treatment groups.

Table 3: Effect of feeding different levels of *syzygium aromaticum* on carcass characteristics of rabbit does

Parameters	T1	T2	T3	T4	SEM
Final live weight (g)	1781.22^{d}	1832.75^{b}	1850.11^{a}	1831.55^{c}	50.55
Slaughter weight (g)	1556.95^{d} (97.92 %)	1715.79^{c} (96.46 %)	1786.11^{a} (96.89 %)	1720.21^{b} (97.56%)	47.38 (0.17)
Carcass weight (g)	1157.97^{d} (72.83 %)	1277.85^{c} (71.83 %)	1561.99^{a} (75.89 %)	1315.16^{b} (74.59%)	44.29 (0.47)
Dressed weight (g)	464.02^{c} (29.18 %)	485.94^{b} (27.32 %)	595.99^{a} (28.96%)	446.05^{d} (25.29%)	17.58 (0.46)
Skin weight (g)	189.99^{c} (11.95 %)	198.97^{b} (11.19 %)	204.99^{a} (9.96 %)	183.02^{d} (10.38%)	2.53 (0.23)
Right forelimb weight (g)	67.99^{d} (4.27 %)	73.99^{b} (4.16 %)	101.99^{a} (4.95 %)	69.00^{c} (3.91 %)	4.19 (0.11)
Left forelimb weight (g)	63.99^{d} (4.03 %)	80.99^{b} (4.55 %)	103.99^{a} (5.05 %)	69.01^{c} (3.91 %)	4.65 (0.13)
Right hind limb weight (g)	101.99^{d} (6.42%)	123.98^{b} (6.97 %)	148.99^{a} (7.24 %)	110.01^{c} (6.23 %)	5.38 (0.12)

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Left hind limb weight (g)	113.99[d] (7.17%)	129.98[b] (7.31 %)	146.99[a] (7.14 %)	117.01[c] (6.64 %)	3.92 (0.07)
Fore feet weight (g)	7.99[d] (0.50 %)	13.99[b] (0.78 %)	11.99[c] (0.58 %)	16.00[a] (0.91 %)	0.89 (0.04)
Hind feet weight (g)	41.99[a] (2.64 %)	41.98[a] (2.36%)	36.89[b] (1.79 %)	36.00[c] (2.04 %)	0.83 (0.09)
Head weight (g)	158.89[d] (10.00%)	182.97[a] (10.28 %)	177.98[b] (8.65 %)	170.02[c] (9.64 %)	2.37 (0.18)
Loin weight (g)	107.99[c] (67.92%)	128.98[b] (70.49 %)	149.89[a] (84.27%)	99.01[d] (58.23 %)	5.94 (2.80)
Rib weight (g)	143.96[d] (9.05%)	170.98[a] (9.61 %)	157.99[c] (9.24 %)	163.02[b] (9.24 %)	2.96 (0.22)
Back cut weight (g)	213.90[b] (13.45%)	180.97[d] (10.17 %)	287.99[a] (13.98%)	182.02[c] (10.32%)	13.11 (0.52)

Different superscript letters across rows shows significant ($p < 0.05$) differences. **SEM:** Standard Error of Mean.

Final Live Weight and Slaughter Weight

Rabbits fed 7.5 g/kg of clove (T3) recorded the highest final live weight (1850.11 g), followed by T2 (1832.75 g), T4 (1831.55 g), and T1 (1781.22 g). This suggests that moderate clove inclusion optimises growth and body mass accumulation. A similar trend was observed in slaughter weight, with T3 (1786.11 g) significantly higher ($p < 0.05$) than T4 (1720.21 g), T2 (1715.79 g), and T1 (1556.95 g). Slaughter percentage, however, remained relatively consistent across treatments (96.46%–97.92%), indicating that clove primarily affected body weight rather than meat yield ratio.

Carcass and Dressed Weight

Carcass weight was significantly higher ($p < 0.05$) in T3 (1561.99 g), compared to T4 (1315.16 g), T2 (1277.85 g), and T1 (1157.97 g). Dressed weight followed the same pattern, with T3 (595.99 g) outperforming T2 (485.94 g), T1 (464.02 g), and T4 (446.05 g). Interestingly, T1 had the highest dressed weight percentage (29.18%), which may be attributed to differences in fat distribution and visceral mass rather than overall muscularity. This observation aligns with the findings of Abdel-Azeem and Abd El-Kader (2022), who noted an increase in meatiness and eviscerated weight with clove supplementation, despite a decrease in dressing percentage.

By-Product and Cut-Up Part Weights

Skin weight was highest in T3 (204.99 g), although T1 had the highest skin weight as a percentage of live weight (11.95%), indicating possible differences in fat deposition patterns. The forelimbs, hind limbs, and major meat cuts such as loin and back cut also showed significant improvements in T3. Specifically, T3 recorded the highest values for right and left forelimbs (101.99 g and 103.99 g, respectively), right and left hind limbs (148.99 g and 146.99 g), loin (149.89 g), and back cut (287.99 g). These improvements suggest that clove enhances muscle development and lean tissue accretion.

Head weight was highest in T2 (182.97 g), while hind feet and fore feet weights varied inconsistently, indicating minimal impact from clove inclusion. Nonetheless, the control group (T1) consistently recorded the lowest weights across most carcass traits, further confirming the growth-promoting effect of clove supplementation.

These findings are in agreement with Suliman et al. (2023), who reported significant improvements in growth and carcass yield in rabbits supplemented with clove. Similar observations were made in quail production, where clove oil enhanced meat yield and carcass performance. Mansoub (2011) attributed such improvements to enhanced protein metabolism and amino acid absorption due to the presence of bioactive compounds in herbal additives, including *S. aromaticum*.

Overall, the inclusion of *Syzygium aromaticum*, particularly at 7.5 g/kg diet (T3), positively influenced carcass yield and meat quality in rabbit does, making it a promising natural growth enhancer for smallholder and commercial rabbit producers.

Conclusion and Recommendation

The present study demonstrated that dietary inclusion of *Syzygium aromaticum* (clove) significantly improved carcass characteristics in rabbit does. Among the treatment groups,

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the diet supplemented with 7.5 g/kg of *S. aromaticum* (T3) consistently yielded the highest values for final live weight, slaughter weight, carcass weight, and key meat cuts such as loin, back cut, and limbs. These enhancements indicate a positive influence of clove on muscle development and meat yield. The consistent superiority of T3 suggests that moderate clove inclusion optimally supports growth performance without adversely affecting dressing percentage or other carcass parameters.

Notably, the observed improvements align with previous reports that clove and other phytogenic additives enhance protein metabolism and amino acid absorption, ultimately promoting better carcass quality (Mansoub, 2011; Suliman et al., 2023). While T1 (control) consistently produced the lowest carcass traits, the lack of detrimental effects in T2 and T4 highlights the safety of *S. aromaticum* inclusion across varying levels.

Recommendation

Based on the findings, it is recommended to incorporate *Syzygium aromaticum* at 7.5 g/kg in rabbit diets to optimise carcass yield and meat quality. Further studies should explore the long-term effects of clove supplementation on reproductive traits, organ histopathology, and meat sensory characteristics to fully establish its safety and efficacy as a phytogenic growth promoter in rabbit production.

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