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Phytogenic Potential of Syzygium aromaticum in Enhancing Growth and Meat Quality in Rabbit Bucks

By

Okocha N.L.[1], Udo Herbert[2] and Onunkwo, D. N[3]

[1,2,3]Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria

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Abstract

This study investigated the potential of Syzygium aromaticum *(clove) as a phytogenic feed additive and identified its optimal dietary inclusion level for enhancing growth performance and carcass characteristics in growing rabbits. A total of thirty-six weaned rabbits (aged 2–3 months, initial weight 600–650 g) were randomly assigned to four treatment groups in a completely randomized design (CRD). The groups consisted of a control diet (T1: 0 g/kg) and three experimental diets supplemented with clove at graded levels: T2 (5 g/kg), T3 (7.5 g/kg), and T4 (10 g/kg). The feeding trial lasted 20 weeks, during which growth performance parameters, feed intake, feed efficiency, and carcass traits were evaluated. Data were subjected to one-way analysis of variance (ANOVA), and treatment means were compared using Duncan's multiple range test at a 5% level of significance. The results demonstrated that dietary inclusion of* S. aromaticum *significantly ($p < 0.05$) influenced performance traits. While initial body weights were similar across treatments (647.37–661.30 g), final body weight, weight gain, daily feed intake, and feed efficiency improved notably in the clove-supplemented groups. Rabbits in T3 (7.5 g/kg) recorded the highest final body weight (2093.88 g), daily weight gain (10.21 g/day), and feed conversion efficiency (75.20%). T4 rabbits exhibited the highest feed intake (97.46 g/day), followed by T3 (95.03 g/day), indicating that clove inclusion may enhance palatability and appetite. Carcass evaluation revealed significant improvements ($p < 0.05$) in slaughter and carcass weights, particularly in T3, which recorded a slaughter weight of 2053.47 g and carcass weight of 1806.80 g. Although dressed weight was highest in T2 (1003.98 g), T3 showed superior values in forelimb and hindlimb weights, suggesting enhanced muscle deposition. These outcomes underscore the capacity of clove to positively modulate growth metabolism and tissue development in rabbits. The observed improvements are likely attributable to the bioactive compounds in clove—such as eugenol, flavonoids, and tannins—which possess antimicrobial, antioxidant, and digestive-stimulant properties. These compounds may have enhanced nutrient utilization and gastrointestinal health, thereby promoting better growth and carcass outcomes. In conclusion, dietary supplementation with* S. aromaticum *at 7.5 g/kg is recommended as the optimal inclusion level for improving feed efficiency, growth performance, and carcass quality in rabbits. The use of clove as a natural phytogenic feed additive offers a promising, sustainable alternative to synthetic growth promoters in rabbit production systems.*

Keywords*:* Syzygium aromaticum, *phytogenic feed additive, rabbit growth, carcass characteristics, feed efficiency*

INTRODUCTION

The increasing global shift towards sustainable and natural livestock production systems has intensified the search for effective phytogenic feed additives that can improve animal growth, feed efficiency, and product quality. Among the promising candidates, *Syzygium aromaticum* L. (commonly known as clove) has gained attention due to its rich phytochemical profile and biological properties. Clove is a well-known medicinal spice, particularly valued for its high

*Corresponding Author: **Okocha N.L.**

content of phenolic compounds such as eugenol, eugenol acetate, and gallic acid—bioactive molecules known for their potent antioxidant, antimicrobial, and anti-inflammatory activities (Zhelyazkov et al., 2022; Haro-González et al., 2021).

Eugenol, the principal active compound in clove, exhibits a broad spectrum of pharmacological actions. It is rapidly absorbed in the gastrointestinal tract when administered orally, with a reported half-life of approximately 18.3 hours in plasma (Cortés-Rojas et al., 2014). Its safety profile has been well-documented, with the World Health Organization (WHO) classifying it as non-mutagenic and generally recognized as safe (GRAS) for use in food and feed (Haro-González et al., 2021).

Nutritionally, *Syzygium aromaticum* comprises a wide array of compounds including carbohydrates, essential oils, tannins, resins, proteins, cellulose, pentosans, vitamins, and minerals (Krishna, 2024). Carbohydrates make up roughly two-thirds of its dry weight, and the presence of beta-carotene contributes to its antioxidant capacity. However, the concentration and bioactivity of these constituents can vary significantly based on agro-climatic factors, post-harvest processing, and storage conditions (Krishna, 2024).

Numerous studies have demonstrated the beneficial effects of clove supplementation in poultry and ruminants, particularly in enhancing growth performance, nutrient digestibility, and carcass quality (Ahmed et al., 2021). These improvements are often attributed to the antimicrobial and antioxidative actions of clove, which promote gut health and improve metabolic efficiency. Despite these promising findings in other species, there remains a paucity of empirical data on the efficacy of clove as a feed additive in rabbits—an economically important but nutritionally sensitive monogastric species.

Given the unique digestive physiology of rabbits and their potential response to bioactive plant compounds, it is crucial to evaluate the species-specific effects and determine the optimal dietary inclusion level of *Syzygium aromaticum*. Therefore, the objective of this study was to investigate the growth performance, feed utilization, and carcass characteristics of rabbits fed diets supplemented with varying levels of clove powder. This research aims to contribute to the development of natural feed strategies for enhanced rabbit production under sustainable farming conditions.

Materials and Methods

Experimental Site

This study was conducted at the Rabbit Unit of the Teaching and Research Farm, College of Animal Science and Animal Production, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria. The site is situated in the humid tropical region of southeastern Nigeria, characterized by a bimodal rainfall pattern with an annual range of 1,700–2,100 mm. Ambient temperatures typically range from 27°C to 36°C during the dry season and 20°C to 26°C in the rainy season. Relative humidity levels fluctuate between 57% and 91%. Meteorological data for the study period were obtained from the National Root Crops Research Institute (NRCRI, 2021), located within the same geographical area.

Experimental Animals and Management

A total of thirty-six (36) clinically healthy rabbit bucks aged between 2 and 3 months, with an average initial body weight ranging from 600 to 650 g, were used for the study. The rabbits were housed individually in well-ventilated wooden cages equipped with feeders and drinkers. Prior to the commencement of the feeding trial, all animals underwent a two-week acclimatization period during which they were dewormed and monitored for signs of illness or parasitic infestations.

Following acclimatization, the rabbits were randomly allocated into four dietary treatment groups (T1, T2, T3, and T4) using a completely randomized design (CRD). Each treatment group comprised nine rabbits, divided into three replicates of three rabbits each. The experimental diets were formulated with graded levels of *Syzygium aromaticum* (clove) powder as follows: T1 (control, 0 g/kg), T2 (5 g/kg), T3 (7.5 g/kg), and T4 (10 g/kg). All diets were isonitrogenous and isocaloric to ensure that the only variable was the inclusion level of the phytogenic additive.

The feeding trial lasted for 20 weeks. Feed and clean drinking water were provided ad libitum throughout the experimental period. The animals were closely monitored daily for feed intake, health status, and environmental conditions. Strict biosecurity and hygiene protocols were maintained to prevent disease outbreaks.

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.

Experimental Design

The rabbits were divided into four dietary treatment groups: **T1** (Control)**:** 0 g/kg *Syzygium aromaticum* bud powder, **T2** (5 g/kg) *Syzygium aromaticum* bud powder, **T3** (7.5 g/kg) *Syzygium aromaticum* bud powder, **T4** **(**10 g/kg) *Syzygium aromaticum* bud powder. Each diet contained 17% crude protein, 2505.42 kcal/kg metabolizable energy, 11.36% crude fiber, and essential vitamins and minerals. The *Syzygium aromaticum* bud powder was prepared by purchasing, cleaning, drying, and milling the buds into a fine powder, which was then incorporated into the experimental diets.

The experimental model was as follows:

$Y_{ij} = \mu + Ti + e_{ij}$

Where:

Y_{ij} = Individual observation on the rabbit characteristics

μ = Overall mean

T_i = Effect of *Syzygium aromaticum* bud powder

e_{ij}= Random error assumed to be independently, identically and normally distributed with a zero means and constant variance.

DATA COLLECTION

Growth performance parameters

Each rabbit was housed individually to monitor feed intake and prevent dominance-related feed access issues.

The experimental feed was weighed and offered daily, and leftovers were recorded the following morning to calculate feed intake.

Feed intake

Feed offered and feed leftovers were measured and recorded daily, and the average daily feed intake (ADFI) was calculated using the formula:

ADFI (g/day) = (Total feed offered - Feed leftover)/ (Number of days)

Body weight and weight gain

The initial body weights of the rabbits were recorded at the beginning of the experiment. Body weights were taken to monitor growth and calculate the average daily weight gain (ADWG)

ADWG (g/day) = (Final weight - Initial weight)/ (Number of days)

Feed conversion ratio (FCR)

The feed conversion ratio was calculated to assess feed efficiency:

FCR = (Feed intake (g))/ (Weight gain (g))

Carcass Evaluation of Experimental Bucks and Does:

At the end of the 20th week, three animals were randomly chosen from each treatment group for carcass analysis. The selected rabbits were starved for 24 hours to empty their gastrointestinal tracts, after which they were weighed, slaughtered, and deskinned. The head and paws were removed and weighed and the rabbits were eviscerated.

The internal organs, including the gastrointestinal tract, were removed and weighed, the dressed carcass weights were recorded. Specific organs such as the liver, kidneys, lungs, pancreas, and skin were carefully trimmed of any adhering fat and weighed using a sensitive digital scale. This process ensured precise assessment of both the carcass and organ weight characteristics

RESULTS AND DISCUSSION

EFFECT OF FEEDING DIFFERENT LEVELS OF *SYZYGIUM AROMATICUM* ON GROWTH PERFORMANCE OF RABBIT BUCKS

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

Parameters	T_1	T_2	T_3	T_4	SEM
Quantity given (g/rabbit/day)	100.00	100.00	100.00	100.00	0.00
Feed intake (g/rabbit/day)	93.39^c	94.87^b	95.03^b	97.46^a	0.34

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Initial body weight(g/rabbit)	662.33	664.78	664.67	662.33	3.24
Final body weight(g/rabbit)	1901.14[b]	1992.67[ab]	2093.88[a]	1995.11[ab]	22.59
Weight gained (g/rabbit/week)	61.89[b]	66.39[ab]	71.46[a]	66.64[ab]	1.16
Weight gained (g/rabbit/day)	8.84[b]	9.48[ab]	10.21[a]	9.52[ab]	0.16
Feed Conversion Ratio	1.55[a]	1.43[ab]	1.34[b]	1.47[ab]	0.03
Feed Efficiency (%)	66.28[b]	70.00[ab]	75.20[a]	68.39[ab]	1.22

Different superscript letters across rows show significant ($p < 0.05$) differences.

Table 2 illustrates the effects of *Syzygium aromaticum* supplementation on the growth performance of rabbit bucks across four treatment groups (T1, T2, T3, and T4), with T1 serving as the control. While initial body weight was consistent across all groups ($p > 0.05$), significant differences ($p < 0.05$) were observed in feed intake, final body weight, weight gain, feed conversion ratio (FCR), and feed efficiency (FE).

Rabbits in T4 had the highest daily feed intake (97.46 g), significantly higher than the control (T1: 93.39 g/day). The increase in feed consumption with *S. aromaticum* inclusion suggests the potential appetite-enhancing effects of bioactive compounds like eugenol (Mahrous *et al*., 2017; Şehitoğlu and Kaya, 2021). Final body weight was highest in T3 (2093.88 g), significantly surpassing T1 (1901.14 g), while T2 (1992.67 g) and T4 (1995.11 g) had intermediate values.

Weight gain followed a similar trend, with T3 (10.21 g/day) significantly outperforming T1 (8.84 g/day). T2 (9.48 g/day) and T4 (9.52 g/day) showed moderate gains. FCR was lowest in T3 (1.34), indicating superior feed efficiency compared to T1 (1.55). T2 (1.43) and T4 (1.47) had intermediate values, suggesting that excessive inclusion (T4) did not improve efficiency further. Similarly, FE was highest in T3 (75.20%), with T1 showing the lowest FE (66.28%), and T2 (70.00%) and T4 (68.39%) falling in between. The decline in efficiency at higher inclusion levels (T4) suggests possible metabolic imbalances affecting nutrient utilization.

These findings align with studies showing that phytogenic feed additives improve palatability, digestion, and nutrient absorption (El-Kholy *et a*l., 2021; Abdel-Azeem and Abd-El-Kader, 2022). Research by Amao *et al*. (2023) indicated that moderate clove inclusion enhances weight gain and feed efficiency, while excessive levels may impair metabolism. Additionally, Alrashedi *et al*. (2024) highlighted that eugenol significantly improves body weight, daily gain, and carcass traits in rabbits. However, excessive stress from high supplementation can negatively impact metabolism and nutrient absorption (Liang *et al*., 2022; Oladimeji *et al*., 2022).

The results indicate that moderate inclusion of *S. aromaticum* T3 (7.5g/kg) optimizes growth performance, FCR, and FE in rabbit bucks. While higher inclusion T4) increased feed intake, it did not proportionally enhance growth, reinforcing the importance of dose optimization when using *S. aromaticum* as a phytogenic growth promoter.

CARCASS CHARACTERISTICS OF RABBIT BUCKS FED VARIED LEVELS OF *SYZYGIUM AROMATICUM*

Table 3: Effect of feeding different levels of *Syzygium aromaticum* on carcass characteristics of rabbit bucks.

Parameters (g)	**T_1**	**T_2**	**T_3**	**T_4**	**SEM**
Final live weight	1901.14[b]	1992.67[ab]	2093.88[a]	1995.11[ab]	22.59
Slaughter weight	1799.62 (94.66%)[b]	1929.70 (96.84 %)[ab]	2053.47 (98.07%)[a]	1903.11 (95.39 %)[ab]	85.83 (1.54)
Carcass weight	1487.07 (78.22%)[b]	1528.77 (76.72 %)[b]	1806.80 (86.29 %)[a]	1318.1 (66.07 %)[c]	66.13 (2.19)
Dressed weight	534.93 (27.23 %)[b]	1003.98 (44.86 %)[a]	532.90 (33.67 %)[ab]	491.83 (27.17 %)[b]	85.92 (2.84)
Skin weight	237.97 (12.11 %)[a]	200.49 (9.29 %)[c]	180.97 (11.43 %)[b]	152.00 (8.39 %)[d]	10.01 (0.46)

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Right forelimb weight	95.99 (4.88 %)^{b}	82.49 (3.84 %)^{c}	90.98 (5.75 %)^{a}	71.00 (3.92 %)^{c}	3.00 (0.24)
Left forelimb weight	85.98 (4.38 %)^{b}	89.99 (4.15 %)^{c}	84.98 (5.37 %)^{a}	67.00 (3.70 %)^{d}	3.24 (0.18)
Right hind limb weight	136.98 (6.97 %)^{b}	139.49 (6.51 %)^{bc}	127.97 (8.08 %)^{a}	112.59 (6.22 %)^{c}	3.43 (0.22)
Left hind limb weight	142.98 (7.28 %)^{b}	132.49 (6.18 %)^{c}	142.97 (9.03 %)^{a}	113.00 (6.24 %)^{c}	3.87 (0.35)
Fore feet weight	14.99 (0.76 %)^{c}	18.49 (0.86 %)^{b}	14.99 (0.95 %)^{a}	10.00 (0.55 %)^{d}	0.93 (0.04)
Hind feet weight	37.99 (1.93 %)^{a}	34.49 (1.62 %)^{b}	30.99 (1.96 %)^{a}	25.00 (1.38 %)^{c}	1.46 (0.07)
Head weight	202.97 (10.33 %)^{a}	198.99 (9.31 %)^{b}	169.97 (10.74 %)^{a}	157.00 (8.67 %)^{b}	5.93 (0.28)
Loin weight	127.98 (6.51 %)^{a}	88.49 (4.10 %)^{d}	100.98 (6.38 %)^{b}	95.00 (5.25)^{c}	4.78 (0.29)
Rib weight	182.97 (9.31 %)^{c}	211.49 (9.84 %)^{c}	201.96 (12.76 %)^{a}	194.00 (10.72 %)^{b}	4.12 (0.40)
Back cut weight	219.97 (11.19 %)^{b}	254.99 (12.01 %)^{b}	225.96 (14.28 %)^{a}	197.00 (10.88 %)^{b}	6.24 (0.47)

Different superscript letters across rows show significant ($p < 0.05$) differences. Values in parentheses are relative weights.

Table 3 presents significant ($p < 0.05$) differences in carcass characteristics among the groups. T3 exhibited the highest final live weight (2093.88 g), significantly surpassing T1 (1901.14 g). T2 (1992.67 g) and T4 (1995.11 g) had intermediate values, suggesting that moderate *S. aromaticum* inclusion (T3) enhances growth and carcass yield.

Slaughter weight followed a similar pattern, with T3 (2053.47 g, 98.07%) significantly outperforming T1 (1799.62 g, 94.66%). T4 (1903.11 g, 95.39%) showed values comparable to T1 and T2, suggesting that excessive inclusion might reduce slaughter yield efficiency. Carcass weight was highest in T3 (1806.80 g, 86.29%), significantly greater than T1 (1487.07 g, 78.22%), whereas T4 had the lowest value (1318.17 g, 66.07%), indicating possible nutrient partitioning inefficiencies at high inclusion levels.

The dressing percentage was highest in T3 (86.29%), followed by T2 (76.72%) and T1 (78.22%), while T4 had the lowest dressing percentage (66.07%). T3 also exhibited the highest weights for prime cuts, including forelimbs, hind limbs, ribs (201.96 g, 12.76%), and loin (100.98 g, 6.38%), reinforcing its positive impact on meat yield. Conversely, T1 had the highest skin and head weights, suggesting greater muscle deposition in T3 rabbits.

Studies by Cabuk *et al*. (2014) and Hernández *et al.* (2010) support these findings, showing that clove-based phytogenics improve carcass traits in poultry. However, Suliman *et al.* (2021) found no significant effects of clove supplementation on broiler carcass composition, highlighting the importance of dosage and species differences. Additionally, Abdel-Azeem and Abd El-Kader (2022) reported that clove supplementation in rabbits increased meatiness and eviscerated weight but reduced dressing percentage.

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The enhanced carcass yield in T3 can be attributed to eugenol's appetite-stimulating, antioxidant, and antimicrobial properties, which improve feed utilization (Adegbeye *et al*., 2020; Amaral *et al.*, 2018). However, excessive inclusion (T4) may reduce carcass quality due to metabolic inefficiencies (Alagbe *et al.*, 2024; Amao *et al*., 2023). Research by Ogwuegbu *et al.* (2015) demonstrated that clove supplementation in broilers improved muscle yield, supporting its role as a phytogenic growth promoter in monogastric animals (Tariq *et al.*, 2015; Islam *et al.*, 2004). However, Suliman *et al.* (2021) found no significant carcass yield improvement in broilers, suggesting that administration levels influence outcomes.

Conclusion and Recommendation

This study demonstrated that the inclusion of *Syzygium aromaticum* (clove) as a phytogenic feed additive significantly influenced the growth performance and carcass characteristics of rabbits. Among the treatment groups, rabbits fed 7.5 g/kg clove-supplemented diets (T3) consistently exhibited superior outcomes across key performance indices, including final live weight, slaughter weight, carcass weight, dressing percentage, and prime cut yields. These improvements suggest that moderate inclusion of clove enhances nutrient utilization, feed efficiency, and muscle deposition, likely due to the bioactive effects of eugenol, which is known for its appetite-stimulating, antioxidant, and antimicrobial properties.

Conversely, the highest inclusion level (10 g/kg, T4) showed a decline in carcass yield parameters, including dressing percentage and carcass weight, indicating potential metabolic inefficiencies or nutrient imbalances at elevated dosages. This trend aligns with previous studies, including those by Abdel-Azeem and Abd El-Kader (2022) and Amao et al. (2023), which emphasize the importance of optimal dosage in phytogenic feed applications. While some literature reports conflicting results (e.g., Suliman et al., 2021), the present findings corroborate evidence from studies on monogastric animals, notably broilers, supporting clove's role as an effective natural growth promoter (Cabuk et al., 2014; Ogwuegbu et al., 2015). In conclusion, *Syzygium aromaticum* presents a promising phytogenic alternative to synthetic growth promoters in rabbit production, provided that it is used within an optimal dosage range.

Recommendations:

1. **Optimal Inclusion Level:** Based on the results, a dietary inclusion of 7.5 g/kg *S. aromaticum* is recommended as the optimal level for improving growth performance and carcass yield in rabbits.
2. **Avoid Excessive Inclusion:** Higher levels such as 10 g/kg may negatively affect nutrient partitioning and carcass traits. Hence, excessive inclusion should be avoided to prevent adverse effects on production efficiency.
3. **Further Research:** Future studies should explore the long-term effects of clove supplementation on reproductive traits, meat quality (e.g., fatty acid profile, shelf life), and immune response in rabbits. Investigations into the underlying mechanisms of eugenol metabolism in rabbits may further elucidate its mode of action.
4. **Application to Smallholder Systems:** Given its affordability and availability, clove could be incorporated into rabbit feeding strategies, particularly in smallholder production systems in developing countries, to promote climate-smart livestock practices.

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*Corresponding Author: **Okocha N.L.**