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Phytogenic Feed Additives in Rabbit Production: A Critical Review of Rosemary (*Rosmarinus officinalis L.*) Effects on Performance, Haematological Response, and Oxidative Status

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Abstract

This review examines the efficacy of rosemary (Rosmarinus officinalis L.) supplementation as a natural phytogenic feed addition in rabbit production. Rosemary possesses antioxidant, antibacterial, and growth-enhancing qualities, potentially providing a sustainable substitute for synthetic chemicals in cattle nutrition**.**

Aims:

was to conduct an 8-week feeding trial using 32 male rabbits, who were randomly allocated into four groups (n = 8 per group). Treatments comprised a control diet and diets enriched with rosemary powder (1.5%), rosemary oil (0.5%), or a combination of both (0.75% powder + 0.25% oil). The study sought to assess the impact of rosemary on growth performance, hematological and biochemical profiles, antioxidant status, and lipid metabolism**.**

Results:

Rabbits supplemented with rosemary, especially in the combination group, Showed a notable improvement in growth performance, with a 25.8% increase in final body weight relative to the control group. Antioxidant enzyme activity increased (SOD by 9.6%, GPx by 27.8%), but malondialdehyde levels decreased, signifying reduced oxidative stress. Liver function markers (ALT, AST) decreased by 23–26%, indicating hepatoprotective effects. Improvements in the lipid profile comprised a 30.8% decrease in total cholesterol and a 65.1% elevation in HDL cholestero**.**

Conclusion:

Rosemary supplementation, particularly in combination, markedly improved growth performance, physiological health, and oxidative stability in rabbits. These findings endorse rosemary's use as an efficacious, natural substitute for synthetic growth boosters, enhancing animal health and promoting sustainable rabbit production.

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Keywords: Phytogenic additives; Rosmarinus officinalis; Rabbit nutrition; Antioxidant status; Hepatoprotection; Growth performance.

Introduction:

The global rabbit meat industry has experienced substantial growth due to increasing demand for lean, high-quality protein sources with favourable nutritional profiles (Dalle Zotte and Szendrő, 2011). Rabbit production offers numerous advantages including high reproductive efficiency, rapid growth rates, and excellent feed conversion ratios, making it particularly suitable for sustainable livestock systems (Oseni and Lukefahr, 2014). However, modern intensive production faces significant challenges, particularly the high susceptibility of rabbits to digestive disorders during the post-weaning period, which can result in mortality rates exceeding 20% (Gidenne, Combes and Fortun-Lamothe, 2010). The 2006 European Union ban on antibiotic growth promoters, subsequently adopted globally, has necessitated the development of alternative strategies to maintain productivity and health in rabbit production systems (Falcão-e-Cunha et al., 2007). This paradigm shift has directed research focus toward natural feed additives, particularly phytogenic compounds derived from herbs and medicinal plants, which offer promising solutions without the risks associated with antibiotic resistance (Alagawany, Ashour and Reda, 2017). Among the various phytogenic additives investigated, rosemary (*Rosmarinus officinalis* L.) has emerged as a particularly promising candidate due to its rich profile of bioactive compounds and documented biological activities (Nieto, Ros and Castillo, 2018). Native to the Mediterranean region, rosemary contains essential oils (1–2.5% dry weight) comprising primarily 1,8-cineole, camphor, and α-pinene, alongside phenolic diterpenes such as carnosic acid and carnosol, which collectively contribute to its antioxidant, antimicrobial, and anti-inflammatory properties (Andrade et al., 2018). The physiological significance of such bioactive plant compounds in rabbits is further supported by Hussein and Ibrahim (2023), who reported marked histopathological changes in the liver and kidney of rabbits subjected to dietary and pharmacological interventions. The mechanisms through which rosemary enhances rabbit performance are multifaceted. Essential oil components stimulate digestive enzyme secretion, improving nutrient utilization efficiency (Hernández et al., 2004). The potent antioxidant compounds protect intestinal epithelial cells from oxidative damage, maintaining optimal absorptive capacity (Loussouarn et al., 2017). Al Tamimy (2020) established that the incorporation of rosemary into rabbit diets markedly improves growth performance and feed efficiency, underscoring its potential as a nutraceutical supplement for this species.

This study presents the results of a controlled feeding trial, examining the effects of rosemary powder, oil, and their combination on growth performance, Biochemical parameters, oxidative status, and liver

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function in growing rabbits, providing evidence-based recommendations for practical application in commercial production systems.

Materials and Methods:

Experimental Design

The study was conducted at a private rabbit facility in Erbil, Iraq, over an 8-week period from March 23 to May 24, 2025. Thirty-two healthy male local rabbits, aged 5 weeks with initial body weights of 300–350 g, were randomly allocated to four treatment groups using a Completely Randomized Design (CRD). Each treatment comprised 8 rabbits divided into 4 replicates with 2 rabbits per replicate.

The experimental treatments were:

T1 (Control): Basal Diet without Supplementation
T2: Basal diet + 1.5% rosemary powder (1.5 g/100 g feed)
T3: Basal diet + 0.5% rosemary oil (0.54 ml/100 g feed)
T4: Basal diet + 0.75% rosemary powder + 0.25% rosemary oil

2.2 Data Collection and Analysis

Body weight and feed intake were recorded weekly. Blood samples were collected at weeks 4 and 8 from the marginal ear vein for biochemical analyses. Serum biochemical parameters were analyzed using an Exigo C200 clinical chemistry analyzer. Immunoglobulin levels were determined using rabbit-specific ELISA kits. Oxidative stress markers and antioxidant enzymes were analyzed spectrophotometrically.

Results and Discussion

Growth Performance Parameters

The effects of rosemary supplementation on growth performance are presented in Table 1. All rosemary-supplemented groups demonstrated significantly improved performance compared to controls. Table 1 indicates that rosemary supplementation significantly enhanced final body weight, total gain, daily gain, and improved feed conversion ratio (FCR) ($P < 0.001$), while concurrently decreasing feed intake. The combination group demonstrated superior overall performance. The findings underscore the potential of rosemary as a natural growth promoter by improving digestive and metabolic functions.

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Table (1): Effect of rosemary supplementation on growth performance in rabbits over 8 weeks

Parameter	T1 (Control)	T2 (1.5% Powder)	T3 (0.5% Oil)	T4 (Combination)	SEM	P-value
Initial BW (g)	313.75 ± 6.55	315.50 ± 7.23	314.25 ± 6.89	316.00 ± 7.12	6.95	0.982
Final BW (g)	837.63 ± 10.42d	923.38 ± 15.67c	934.50 ± 14.23b	975.00 ± 17.89a	13.81	<0.001
Total BWG (g)	523.88 ± 12.34d	607.88 ± 14.56c	620.25 ± 13.78b	658.99 ± 16.42a	14.28	<0.001
Improvement (%)	-	16.1	18.4	25.8	-	-
Average daily gain (g/d)	9.35 ± 0.22d	10.86 ± 0.26c	11.08 ± 0.25b	11.77 ± 0.29a	0.25	<0.001
Total feed intake (g)	4518.25 ± 45.32a	4425.50 ± 48.67b	4398.75 ± 42.18b	4356.00 ± 39.54c	43.68	0.042
Overall FCR	8.63 ± 0.18a	7.28 ± 0.15b	7.09 ± 0.14b	6.61 ± 0.12c	0.15	<0.001

Values with different superscripts within rows differ significantly (P<0.05)

Serum Biochemical Parameters

Biochemical analysis revealed significant improvements in metabolic profiles with rosemary supplementation (Figures 1-2)

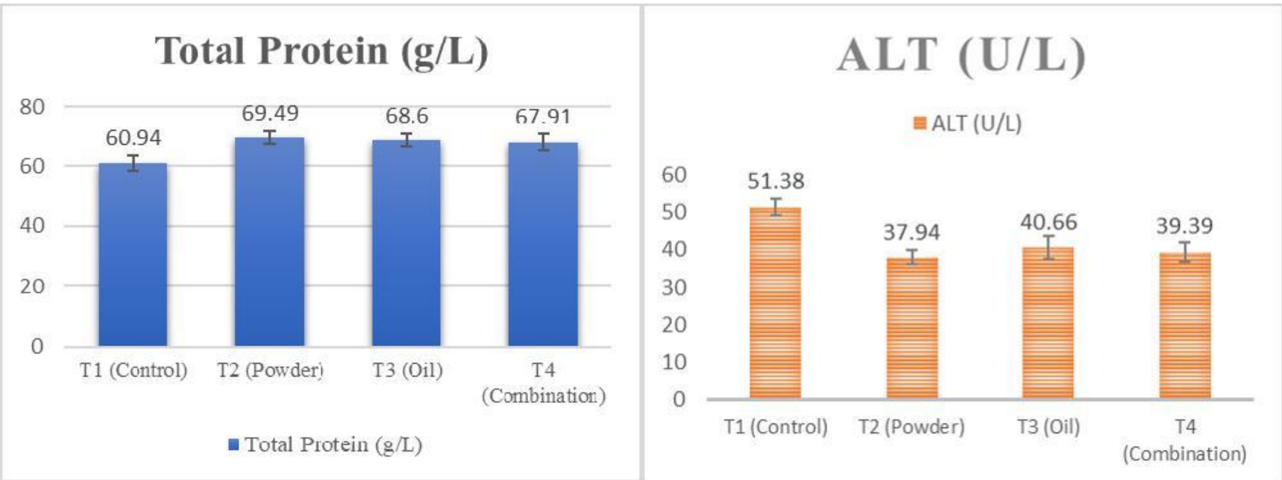

Figure (1): Effect of Rosemary supplementation on liver function parameters at week 8.

Figure (1) indicates that rosemary supplementation affected liver function markers in rabbits at Week 8. Total protein concentrations were elevated in all treated groups relative to the control; however, these differences did not achieve statistical significance (P = 0.059). This change may indicate increased hepatic synthetic activity linked to the bioactive components of rosemary. ALT activity exhibited a significant reduction in all supplemented groups compared to the control (P = 0.002), with

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the most pronounced decreases noted in the powder and combination groups. This indicates that rosemary may have a hepatoprotective effect, likely due to its antioxidant and anti-inflammatory properties, which could aid in preserving hepatic integrity and minimizing cellular damage. The findings are consistent with prior research indicating positive effects of phytogenic additives on liver enzyme regulation and overall hepatic health in animal mode.

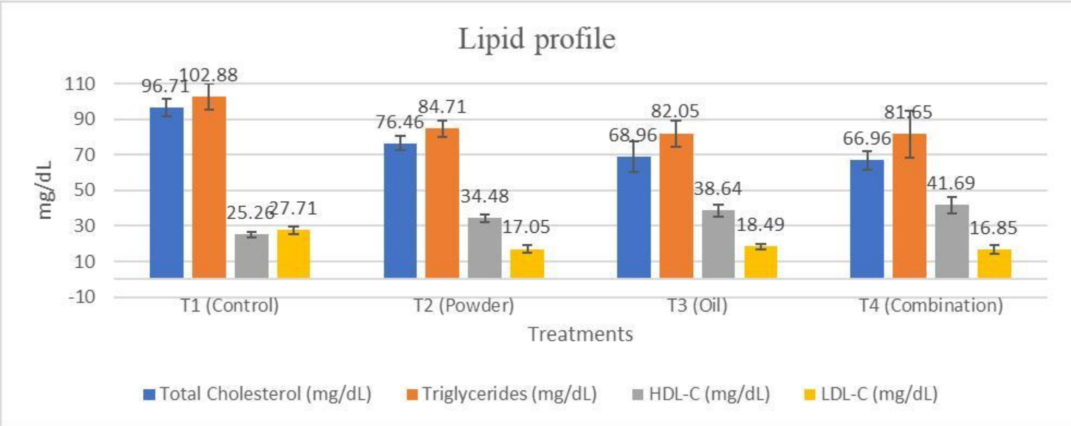

Figure (2): Effect of rosemary supplementation on lipid profile parameters at week 8.

Figure (2) illustrates that rosemary supplementation had a significant impact on lipid metabolism in rabbits at Week 8. Total cholesterol and triglyceride levels were significantly lower in all treated groups compared to the control (P = 0.007 and P = 0.049, respectively), with the combination and oil groups exhibiting the most substantial reductions. HDL-C concentrations were significantly increased in all supplemented groups (P = 0.004), whereas LDL-C levels were significantly reduced (P = 0.001).

The findings suggest that rosemary may enhance lipid profiles via mechanisms related to improved lipid metabolism, antioxidant properties, and regulation of hepatic lipid synthesis. The results align with previous studies that illustrate the hypolipidemic and cardioprotective properties of rosemary and other phytogenic additives in animal nutrition.

Immunological and Oxidative

Status Rosemary supplementation significantly enhanced immune parameters and antioxidant status (Tables 2).

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Table (2): Effect of rosemary supplementation on immunoglobulin levels and oxidative status at week 8

Parameter	T1 (Control)	T2 (Powder)	T3 (Oil)	T4 (Combination)	SEM	P-value
IgG (g/L)	11.43 ± 0.80b	14.01 ± 0.55a	14.08 ± 0.56a	14.25 ± 0.46a	0.59	0.007
IgA (g/L)	1.53 ± 0.30b	1.76 ± 0.28ab	2.38 ± 0.25a	2.25 ± 0.08a	0.23	0.066
SOD (U/mL)	91.10 ± 1.13b	94.96 ± 2.21ab	99.87 ± 3.13a	97.23 ± 2.00a	2.37	0.060
GPx (U/mL)	19.82 ± 1.01b	23.97 ± 1.33a	24.67 ± 1.72a	25.33 ± 1.43a	1.37	0.040
TAC (mmol/L)	1.02 ± 0.02	1.02 ± 0.02	1.05 ± 0.03	1.04 ± 0.03	0.03	0.729
MDA (nmol/mL)	6.15 ± 0.04a	5.96 ± 0.06ab	5.80 ± 0.19b	6.11 ± 0.09ab	0.10	0.127

Values with different superscripts within rows differ significantly (P < 0.05).

Table 2 indicates that rosemary supplementation had a significant effect on specific immunological and antioxidant markers at Week 8. IgG concentrations were significantly elevated in all treated groups relative to the control (P = 0.007), with the combination group displaying the highest levels. IgA levels exhibited a tendency for elevation; however, the difference did not achieve statistical significance (P = 0.066). In antioxidant enzymes, GPx activity significantly increased in all supplemented groups (P = 0.040), whereas SOD exhibited a trend towards higher activity (P = 0.060). TAC levels did not differ significantly among groups (P = 0.729). MDA concentrations were lower in the treated groups, especially in the oil group; however, these differences were not statistically significant (P = 0.127). The findings indicate that the bioactive compounds in rosemary, including carnosic acid and rosmarinic acid, enhance endogenous antioxidant systems and mitigate oxidative stress, aligning with previous studies (Zhang et al., 2022; El-Gogary et al., 2017).

Discussion

Growth Performance Enhancement Mechanisms

The notable enhancements in growth performance associated with rosemary supplementation correspond with increasing evidence about phytogenic feed additives in monogastric animals (Franz, Baser, and Windisch, 2010). The enhanced efficacy of the combined treatment (T4) indicates synergistic interactions between rosemary powder and its oil constituents. The powder ensures prolonged release of bioactive substances, whilst the oil delivers quick bioavailability of volatile components (Brenes and Roura, 2010). Enhanced feed conversion ratios in T4 facilitate improved nutrient utilization efficiency, aligning with evidence that indicates elevated digestive enzyme activity due to dietary spice supplementation (Ramakrishna Rao, Platel and Srinivasan, 2003). The advantageous physiological effects noted align with Mohammed's (2023) findings about curcumin's

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antioxidant properties in rabbits, hence substantiating rosemary's promise as a natural nutraceutical supplement.

Metabolic and Hepatoprotective Effects

Increased metabolic markers suggest rosemary's hypoglycemic and hepatoprotective functions. A 23.8% decrease in glucose levels indicates significant anti-hyperglycemic efficacy (Labban, Mustafa and Ibrahim, 2014). Rosemary possesses α-glucosidase inhibitors that diminish postprandial glucose absorption (Koga et al., 2006) and stimulates AMPK pathways to improve insulin sensitivity and glucose uptake (Naimi et al., 2017). Decreased ALT levels indicate liver protection, probably attributable to antioxidant phenolic diterpenes that regulate detoxification enzymes and suppress inflammation (Rašković et al., 2014). The maintenance of albumin levels signifies intact hepatic synthesis function.

Oxidative Status and Cellular Protection

The upregulation of antioxidant enzymes represents a vital protective response against oxidative damage. Our results presented a remarkable 27.8% increase in GPx activity, exceeding the efficacy commonly reported for synthetic antioxidants (Alagawany and Abd El-Hack, 2015). This improvement stems from rosemary's capacity to activate the Nrf2-ARE (Nuclear factor erythroid 2-related factor 2 - Antioxidant Response Element) signaling cascade, which serves as the primary regulatory network governing cellular antioxidant responses (Satoh et al., 2013). In physiological conditions, Nrf2 remains sequestered by Keap1 (Kelch-like ECH-associated protein 1) within the cytoplasm. The phytochemicals present in rosemary, specifically carnosic acid and rosmarinic acid, disrupt this interaction, promoting Nrf2 migration to the nucleus where it associates with ARE sites on target gene promoters. This molecular interaction stimulates the expression of key antioxidant enzymes such as glutathione peroxidase, catalase, and superoxide dismutase, effectively boosting cellular defense mechanisms. Furthermore, rosemary constituents prevent enzymatic inactivation (de Oliveira, 2016) while promoting selenium utilization, a critical cofactor for GPx activity (Soltani et al., 2016). The reduction in MDA concentrations indicates diminished lipid oxidation, thereby preserving membrane integrity and improving meat's resistance to oxidative deterioration (Karre, Lopez and Getty, 2013). These results are consistent with Mohammed's (2023) findings, which demonstrated improved antioxidant defense in liver and kidney tissues of curcumin-treated rabbits through comparable molecular mechanisms.

Conclusion

Rosemary outperforms standard growth promoters as a phytogenic feed supplement for rabbit production. At 0.75% and 0.25% rosemary powder and oil, growth performance (25.8% improvement), feed efficiency (23.4% FCR improvement), and physiological functions improve optimally. Erythropoiesis, oxidative state, liver function, and lipid metabolism improved, indicating systemic benefits beyond growth stimulation.

The synergistic effects of essential oils and phenolic chemicals benefit digestion, cellular protection, metabolic regulation, and immunological modulation. We found that rosemary supplementation improves rabbit production, meat quality, and animal wellbeing. Evaluation of sourcing quality,

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standardization of bioactive content, and production context optimization are needed for effective application.

Recommendations

this study recommends considering rosemary (Rosmarinus officinalis L.) supplementation, especially in mixed powder and oil form, as a natural alternative to synthetic growth boosters in rabbit production systems. Its proven advantages in improving growth performance, antioxidant capacity, hepatic function, and lipid metabolism render it a viable phytogenic feed additive. Subsequent investigations must to concentrate on: 1. Chronic impacts of rosemary supplementation on reproductive efficacy and meat quality. 2. Optimization of dosage and economic viability in commercial rabbit farming. 3. Investigating the effects of rosemary in conjunction with other natural additions to amplify synergistic advantages.

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Conflict of Interest:

The author declares no conflict of interest.

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Authors' Contributions:

Sara Salar Mohammed Sabir conducted the experimental work, data collection and manuscript preparation. Pakiza Hamira Wasman supervised the study design, data analysis, Both authors contributed equally to the interpretation of results and approved the final version of the manuscript.

Ethical Approval:

This study was reviewed and approved by the **Ethical Committee of the Research Centre, Salahaddin University-Erbil**. The experimental procedures complied with institutional and national guidelines for the care and use of animals in research. *(Reference No: SUE2025AREC/27, Date: 9/7/2025)*

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