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# Effect of Phytogenic and Microencapsulated Feed Addtitives on Growth Performance and Carcass Characteristics in Broiler Chicken

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## ABSTRACT

**Background:** The present study was conducted to evaluate the effects of different phytogenic additives on growth performance, feed efficiency, carcass characteristics, mortality and economic parameters in broiler chickens.

**Methods:** A total of 240 day-old Vencobb 400 broiler chicks were randomly assigned to four dietary treatment groups, each comprising four replicates of 15 birds. Group T0 served as the control and received a basal diet without any additives. Group T1 received the basal diet supplemented with AV/HLP/16, polyherbal mix (500 g/ton feed). Group T2 was fed a basal diet containing AV/PMQ/19, microencapsulated formulation containing essential oils (250 g/ton feed). Group T3 was supplemented with pure oregano essential oil (1000 ml/tonne feed). The birds were reared under standard conditions and fed ad libitum from day 0 to 6 weeks of age. Weekly observations were recorded for body weight, feed intake, feed conversion ratio (FCR), mortality and feed cost per kg live weight gain. Carcass traits were assessed at the end of the 3rd and 6th weeks.

**Result:** The results revealed that broilers fed with phytogenic additives exhibited significantly (P<0.05) higher body weights from the 3rd week onward compared to T0 and T3. Feed intake was significantly (P<0.05) improved in all treatment groups during the 2nd and 3rd weeks, with T1 maintaining higher intake throughout the trial. FCR improved notably in T1 and T2, corresponding to better growth efficiency. Mortality was lowest in T1 (2 birds) and T2 (3 birds), while T0 recorded the highest mortality (9 birds). Carcass evaluation at the 6th week revealed significantly (P<0.05) higher dressed weight, giblet weight and meat-to-bone ratio in T1 and T2. Feed cost per kg live weight gain in T1 remained comparable to T0, making it economically viable. It was concluded that inclusion of phytogenic additives, particularly polyherbal premix (AV/HLP/16) and microencapsulated essential oil formulations (AV/PMQ/19), can effectively enhance broiler growth, health, carcass yield and economic returns, offering a promising alternative to synthetic growth promoters.

**Key words:** Carcass characteristics, Growth performance, Microencapsulated formulation containing essential oils, Phytogenic supplements, Polyherbal premix, Vencobb 400 broiler.

## INTRODUCTION

The poultry meat industry is one of the fastest-growing sectors of the Indian food economy, with significant increases in both production and consumption. Over the past two decades, poultry farming in India has transitioned from backyard operations to scientifically managed commercial enterprises. This growth is driven by advances in genetics, feed formulations, disease control and private sector investment. India continues to hold a prominent position in the global poultry industry, ranking among the top three egg-producing nations and serving as a major broiler meat producer. According to the *Basic Animal* Husbandry Statistics (BAHS), 2024 released by the Department of Animal Husbandry and Dairying, Government of India, the country's total egg production reached 142.77 billion eggs, while overall meat production was estimated at 10.25 million tonnes during 2023-24. Broiler meat production has surpassed 5.01million tonnes, with per capita consumption nearing 7.39 kg annually, reflecting a dietary shift toward affordable, protein-rich foods (DAHD, 2024). The national poultry market was valued at approximately INR 2.3 trillion (INR 2,304 billion) in 2024

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and is projected to expand at a compound annual growth rate (CAGR) of 6.5-7% over the next few years (IMARC Group, 2024). Commercial broiler farming relies on strains like Vencobb 400, which reach market weight (1.8-2.2 kg) in 35-40 days, with feed conversion ratios (FCR) between 1.5 and 1.65. Production is mostly through contract farming models led by integrators, while around 30 million smallholders continue with backyard poultry farming. Despite technological gains, challenges remain especially regarding sustainability, food safety and regulatory constraints. Growing concerns about antibiotic overuse and synthetic additives have triggered restrictions globally (Wang *et al.,* 2024), pushing the industry toward safer, natural alternatives.

Phytogenic feed additives derived from herbs, spices, essential oils and plant extracts are gaining attention due to their antimicrobial, antioxidant, anti-inflammatory and gut-enhancing effects (Ibrahim *et al*., 2021). They improve digestion, immunity and meat quality. Garlic (*Allium sativum*) offers allicin, which lowers cholesterol and acts as an antibacterial and immunostimulant. Fenugreek (*Trigonella foenum-graecum*) supports body weight gain and feed efficiency. Amla (*Emblica officinalis*), rich in ascorbic and gallic acids, boosts liver function and oxidative balance. Essential oils from thyme, oregano and rosemary containing thymol, carvacrol, rosmarinic acid and carnosol have shown broad antimicrobial and digestive benefits (Movahedi *et al.,* 2024). Recognized as Generally recognized as safe (GRAS) by the *Food and Drug Administration standards* (FDA), these compounds align with the demand for residue-free, antibiotic-free poultry products (Sholiha *et al.,* 2023).

Advances in feed tech have led to microencapsulated essential oils, protecting active compounds and ensuring targeted release in the gut. While promising, research on synergistic effects of combining polyherbal formulations with microencapsulated oils is limited, particularly in terms of carcass traits and consumer acceptability. Therefore, this study was conducted to evaluate the efficacy of polyherbal mix and a microencapsulated essential oil blend in improving broiler productivity, blood parameters and carcass traits, aiming to identify safe, effective natural alternatives to conventional additives.

## MATERIALS AND METHODS

The experiment was conducted to evaluate the effect of phytogenic feed additives on the growth performance and meat quality of broiler chickens. This study was approved by the institutional Animal Ethical Committee (IAEC) No. IAEC/21/5, DUVASU, Mathura. The study was conducted for a time period of one year in different phases of 6 weeks, where a total of 240 day-old Vencobb 400 broiler chicks were randomly divided into four dietary treatment groups, with each group consisting of four replicates of 15 birds each, totaling 60 chicks per treatment. The first group (T0) served as the control and received a basal diet without any growth promoter or feed additive. The second group (T1) was provided with a basal diet supplemented with AV/HLP/16, a poly herbal premix, at the rate of 500 g per tonne of feed. The third group (T2) received the basal diet supplemented with AV/PMQ/19, a microencapsulated formulations containing essential oils, at the dose of 250 g per tonne of feed. The fourth group (T3) was fed the basal diet supplemented with pure oregano essential oil at the level of 1000 ml per tonne of feed. AV/HLP/16 (polyherbal mix containing garlic, fenugreek, Indian gooseberry) and AV/PMQ/19 (microencapsulated thyme and rosemary essential oils mix containing) are the products provided by M/s Zenex Animal Health India Private Limited, Baddi.

### Environmental and housing conditions

The optimum temperature during broiler rearing was maintained using a combination of brooding lamps, charcoal burning and water sprinklers on the shed roof, depending on ambient conditions and time of day. Actual temperature and relative humidity (RH) at both room and chick levels were recorded using a digital thermo-hygrometer, with data maintained in raw data sheets and study files. Chick-level temperatures ranged from 34-36°C in week 1 to 30-34°C by week 6, with RH maintained between 60-70%. The photoperiod began with 24 hours of light for the first 3 days, gradually reducing to 20 hours of light and 4 hours of darkness by week 2. Chicks were housed in a semi-enclosed poultry shed partitioned into individual pens, each measuring approximately 25 square feet. Each pen was equipped with essential rearing facilities such as a brooder, feeders and drinkers to ensure bird comfort and welfare. The nutrient requirement of feed was met as per the Specification of Indian Standard for poultry feeds IS: 13574: 2006 (Reaffirmed 2021). The chicks were provided with poultry mash feed *ad libitum* with the following ingredients.

Ingredient composition of broiler starter and finisher basal diet.

| Ingredients | % broiler starter basal diet | % broiler finisher basal diet |
|---|---|---|
| Maize | 60.0 | 66.0 |
| Soybean meal | 28.0 | 22.0 |
| De-oiled groundnut cake | 5.0 | 5.0 |
| Oil | 2.0 | 4.0 |
| Premix | 5.0 | 5.0 |

### Quality analysis parameters

### Growth performance

The chicks were observed for clinical signs and mortality once a day. If any chicks were found dead, necropsy was carried out and findings were recorded. Body weights of chicks were recorded on day old and thereafter at every week interval up to 6 weeks by using an electronic weighing balance. The weekly feed consumption for each replicate in a group was calculated by deducting the quantity of left over feed from the total quantity of feed offered to that

replicate. Feed conversion ratio (FCR) for each replicate in a group was calculated as follows:

$$FCR = \frac{\text{Total quantity of feed consumed by all chicks in a replicate (kg)}}{\text{Total body weight of all chicks in a replicate (kg)}}$$

**Post slaughter observations/carcass characteristics**

Birds from each treatment group (n=6) were slaughtered at 3 and 6 weeks of age following standard halal procedures at the Meat Processing Laboratory. Birds were off-fed overnight and humanely slaughtered by severing carotid arteries and jugular veins, ensuring complete bleeding over 6 minutes. Scalding was done at 63°C for 2 minutes, followed by mechanical and manual defeathering. The head and shanks were removed and evisceration was performed through an abdominal incision. Carcass internal organ weights and giblets (liver, heart, gizzard) were weighed separately. Cut-up parts were separated, deboned and weighed. Dressing percentage was calculated using carcass and live weights.

**Statistical analysis**

The data were subjected to analysis of variance, (one way ANOVA), least significant difference (P<0.05) used for comparing the means to find the difference between groups (Snedecor and Cochran, 1994).

## RESULTS AND DISCUSSION

**Growth performance parameters**

**Weekly body weight and average weekly body weight gain**

The effects of phytogenic supplementation on average weekly body weight and weight gain of broilers during 0-6 weeks of age are presented in Table 1. In the present study, the weekly body weight of all birds remained lower than the standard reference values. This was expected, as no additional supplements, vitamins, or growth promoters were provided at any stage of the trial. This experimental design enabled a clearer assessment of the effects of the phytogenic supplements in comparison to the basal diet alone. The beneficial impact of the phytogenic additives was evident in the current findings. No significant differences were observed between control and treatments up to the 3rd week. However, T1 showed significantly (P<0.05) higher body weight at the 4th and 6th week, followed by T2 > T0 > T3. Lower weight gain in T3 may be due to reduced intake of oregano oil-supplemented feed, as indicated by leftover feed. Bosetti *et al*. (2020) reported that broilers fed microencapsulated carvacrol and cinnamaldehyde (200-400 mg/kg) achieved growth comparable to antibiotic-fed birds. Average weekly weight gain showed no significant differences up to the 2nd week, but T1 and T2 had significantly (P<0.05) higher gains than T0 and T3 from the 3rd to 6th week. Similar findings were reported by Ashram and Gamal (2020), who observed higher weight gain with phytogenic supplementation. Bolukbasi and Erhan (2007) also noted improved FCR, egg production and reduced *E. coli* content in layers with thyme essential oil supplementation.

**Average weekly feed intake**

The effects of phytogenic supplementation on average weekly feed intake of broilers during 0-6 weeks of age are presented in Table 2. The lower overall feed consumption is plausible because birds received only a basal diet without appetite-or growth-enhancing supplements. However, T1 showed overall higher feed intake than the control and other treatments, indicating better palatability and acceptance. There was no significant difference between control and treatments in first week, whereas all

**Table 1:** Effects of phytogenic supplements on average weekly body weight (AWBW) (g) and average weekly body weight gain (AWBWG) (g) of broilers during 0-6 weeks of age. n=15

| | | T0 | T1 | T2 | T3 | Pooled SEM | Sig level |
|---|---|---|---|---|---|---|---|
| Day old | AWBW | 51.19 | 51.34 | 51.46 | 51.47 | 0.06 | NS |
| 1st week | AWBW | 133.23 | 137.80 | 136.27 | 139.10 | 1.21 | NS |
| | AWBWG | 82.04 | 86.46 | 84.81 | 87.63 | 1.20 | - |
| 2nd week | AWBW | 270.20 | 272.33 | 267.57 | 278.40 | 2.22 | NS |
| | AWBWG | 136.97 | 134.53 | 131.30 | 139.30 | 1.35 | - |
| 3rd week | AWBW | 497.12 | 505.33 | 476.21 | 497.90 | 4.40 | NS |
| | AWBWG | 226.92$^{b}$ | 232.99$^{a}$ | 208.64$^{a}$ | 219.50$^{b}$ | 2.89 | - |
| 4th week | AWBW | 746.81$^{b}$ | 801.43$^{a}$ | 758.06$^{b}$ | 725.52$^{b}$ | 9.23 | P<0.02 |
| | AWBWG | 249.70$^{b}$ | 296.10$^{a}$ | 281.85$^{a}$ | 227.62$^{b}$ | 7.29 | - |
| 5th week | AWBW | 1012.4$^{b}$ | 1114.6$^{a}$ | 1041.1$^{b}$ | 979.18$^{b}$ | 15.00 | P<0.004 |
| | AWBWG | 265.63$^{b}$ | 313.14$^{a}$ | 283.02$^{a}$ | 253.66$^{b}$ | 6.61 | - |
| 6th week | AWBW | 1275.7$^{c}$ | 1463.3$^{a}$ | 1361.7$^{b}$ | 1246.7$^{c}$ | 21.76 | P<0.001 |
| | AWBWG | 263.22$^{b}$ | 348.71$^{a}$ | 320.60$^{a}$ | 267.56$^{b}$ | 9.83 | - |

Means bearing different superscripts within a column differ significantly (P<0.05).

NS: Not significant (P>0.05) SEM: Standard error of mean.

three treatments had significantly (P<0.05) higher average weekly feed intake than control in 2nd and 3rd week. Chaudhary *et al.* (2024) also observed that supplementing broiler diet with Tejpatta leaf powder @ 1.25% could be beneficial for improving broiler chick growth performance and hemato-biochemical parameters while having no adverse effects on broiler chicks. T1 and T3 had significantly (P<0.05) higher feed intake in 4th week, followed by higher feed intake in T1 than control and other two treatments. These results might be correlated with results of average weight gain of broilers fed with different supplements as presented in Table 1. Alloui *et al*. (2012) reported that supplementing broiler feed with 3 g/kg fenugreek seeds as natural phyto antioxidant and growth promoter significantly (P<0.05) increased feed intake and improved FCR.

**Feed conversion ratio (FCR)**

The effects of phytogenic supplementation on feed conversion ratio parameters of broilers during 0-6 weeks of age are presented in Table 3. T1, T2 and T3 had significantly (P<0.05) higher values than T0 on 2nd and 3rd week, whereas T3 and T1 had significantly (P<0.05) higher values than T0 and T2. Higher average weight gain in broilers fed with phytogenic supplements was due to ad libitum feeding which was given to chicks from 0 day itself. Mehboob *et al.* (2024) also reported significantly (P<0.05) higher feed conversion ratio in broiler on feeding of herb *Urtica dioica* as feed additive at 2.0% level. In contrast to present study, Amad *et al.* (2011) reported that daily feed intake of broilers was significantly (P<0.05) decreased by increasing the dietary level of a blend of thyme, star anise and origanum leaves compared with control due to slight pungency associated with essential oils.

**Livability**

**Feed cost per kg live weight gain**

The effects of phytogenic supplementation on feed cost per kg live weight gainof broilers during 0-6 weeks of age are presented in Fig 1. There was no significant difference between control and treatments throughout the period except on 2nd, 3rd and 4th week. T0 had significantly (P<0.05) lower weekly feed cost Rs. per kg live weight than T1, T2 and T3 on 2nd and 3rd week, whereas T3 had significantly (P<0.05) higher cost than T0 and other treatments. Lower feed cost per kg live weight gain in T1 (comparable to T0) might be due to more feed intake and higher feed conversion ratio as also observed in present study. Elolimy *et al.* (2025) also reported that feeding of microencapsulated blend of EOs (cinnamaldehyde, eugenol and thymol) @100 mg/kg significantly (P<0.01) improved the FCR with significant reduction in fed cost per kg live weight gain and mortality in 440 Arbor Acres broilers. As highlighted by Urban *et al*. (2025), herbs and herbal extracts represent valuable phytobiotic additives that can be sustainably incorporated into broiler diets. Their inclusion has been shown to enhance bird welfare, strengthen antioxidant status, support digestive and immune functions and ultimately contribute to improved overall performance and economic efficiency. Ajaykumar *et al*. (2024) also reported

**Table 2:** Effects of phytogenic supplements on average weekly feed intake (g) of broilers during 0-6 weeks of age. n=15

| Week | T0 | T1 | T2 | T3 | Pooled SEM | Significance |
|---|---|---|---|---|---|---|
| 1st Week | 98.28 | 97.40 | 100.33 | 100.23 | 0.75 | NS |
| 2nd Week | 165.50b | 196.33a | 192.65a | 188.70a | 3.13 | P<0.01 |
| 3rd Week | 258.23b | 298.52a | 265.71a | 277.97a | 4.84 | P<0.01 |
| 4th Week | 400.34b | 552.88a | 419.86b | 515.80a | 16.41 | P<0.01 |
| 5th Week | 579.56c | 658.89a | 604.12b | 603.65b | 15.66 | NS |
| 6th Week | 554.67c | 718.00a | 600.17b | 509.49c | 25.55 | P<0.02 |

Means bearing different superscripts within a column differ significantly (P<0.05).

NS: Not significant (P>0.05) SEM: Standard error of mean.

**Table 3:** Effects of phytogenic supplements on weekly feed conversion ratio (FCR) of broilers during 0-6 weeks of age. n=15

| Week | T0 | T1 | T2 | T3 | Pooled SEM | Significance |
|---|---|---|---|---|---|---|
| 1st Week | 1.20 | 1.13 | 1.18 | 1.14 | 0.01 | NS |
| 2nd Week | 1.21c | 1.46a | 1.47a | 1.35b | 0.02 | P<0.005 |
| 3rd Week | 1.14b | 1.28a | 1.27a | 1.27a | 0.01 | NS |
| 4th Week | 1.60c | 1.87b | 1.49c | 2.27a | 0.06 | P<0.001 |
| 5th Week | 2.18 | 2.10 | 2.13 | 2.38 | 0.08 | NS |
| 6th Week | 2.11 | 2.06 | 1.87 | 1.90 | 0.07 | NS |

Means bearing different superscripts within a column differ significantly (P<0.05).

NS: Not significant (P>0.05) SEM: Standard error of mean.

that inclusion of phytogenic supplementation of garlic (0.25%) along with ginger (0.25%) had significantly (P<0.05) improved the economics in terms of lower feed cost with higher weight gain and improved productivity.

**Post slaughter carcass characteristics**

The effects of phytogenic supplementation on broiler carcass characteristics at 6 week of age are presented in Table 4 and Fig 2 respectively, according to which, phytogenic effects were more pronounced. T1 and T2 birds showed significantly (P<0.05) higher pre-fasting, post-fasting, exsanguinated and dressed weights, along with cut-up part yields, than T0 and T3. Exsanguinated weight was highest in T1, followed by T2 > T3 > T0. Although dressing percentage differences were not significant, back, neck, breast, thigh weights and meat-to-bone ratio were significantly (P<0.05) higher in all supplemented groups. These findings are supported by Kurkure *et al.* (2002), who observed improved dressing percentage and liver weights in herbal premix-fed birds containing amla. Similarly, Huang *et al.* (2024) reported that supplementation with 200-400 mg/kg of microencapsulated essential oils and organic acids (EOA) enhanced broiler growth, gut health and immune function during early stages. Drumstick and wing weights were significantly (P<0.05) higher in T1 compared to T3 and T0, while T2 had comparable values. Giblet weights in T1 and T2 were also significantly (P<0.05) (P<0.05), indicating enhanced organ development. These findings are consistent with Xie *et al.* (2023), Suliman *et al.* (2023) and Bhaisare and Thyagarajan (2014), who reported improved carcass traits with phytogenic and probiotic supplementation. Oso *et al*. (2021) reported that supplementation of Aerva lanata, Piper betle, Cynodon dactylon and Piper nigrum blend in broilers significantly (P<0.05) improved the carcass quality in terms of dressed carcass weight as well as giblets weight. In contrast, Weerasingha and Atapattu (2013) observed no significant impact of fenugreek on intestinal length relative to body weight. Khattak *et al.* (2014) also reported that carcass weight, breast weight and relative percentage of breast meat increased (*P*<0.05) significantly when diets were supplemented with herbal mix compared with that from birds fed the control diet.

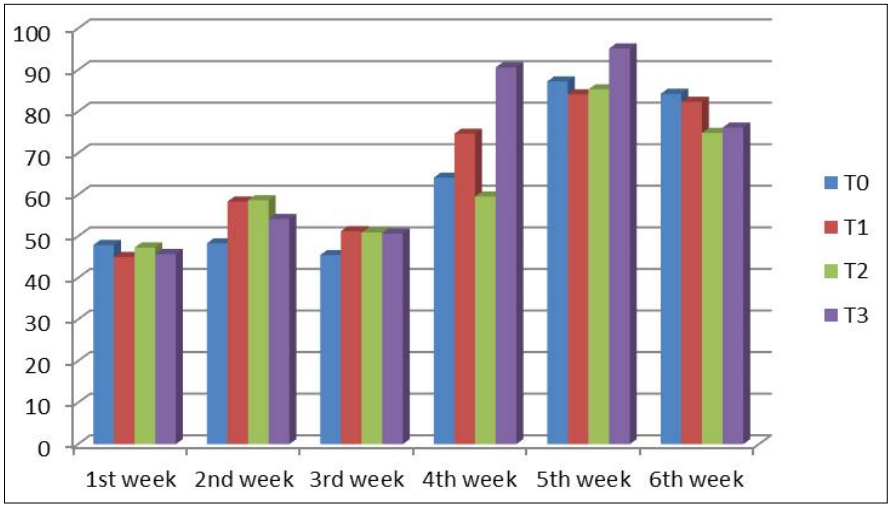


**Fig 1:** Effects of phytogenic supplements on weekly feed cost Rs. per kg live weight gain of broilers during 0-6 weeks of age.

**Fig 2:** Dressed carcass and cut up parts of broiler meat supplemented with phytogenic additives in feed.

**Table 4:** Post slaughter carcass characteristics of broiler supplemented with phytogenic additives in feed and slaughtered at 6th week. n=15

| Parameter | T0 | T1 | T2 | T3 | Treatment mean |
|---|---|---|---|---|---|
| Pre fasting weight (g) | 790.66$^{b}$±20.84 | 1046.00$^{a}$±51.58 | 918.33$^{a}$±44.72 | 817.33$^{b}$±22.50 | 893.08±27.23 |
| Post fasting weight (g) | 729$^{b}$±18.79 | 968.66$^{a}$±45.83 | 886.66$^{a}$±40.55 | 750.66$^{b}$±21.73 | 833.75±25.90 |
| Exsanguination weight (g) | 704.07$^{c}$±18.92 | 935.33$^{a}$±46.93 | 861.38$^{b}$±40.51 | 728.12$^{c}$±20.46 | 807±25.39 |
| Dressed weight (g) | 542.66$^{b}$±15.59 | 720$^{a}$±34.01 | 673$^{a}$±31.21 | 551.66$^{b}$±17.71 | 621.83±20.02 |
| Dressing percentage (%) | 74.43±9.67 | 74.32±5.98 | 75.90±11.02 | 73.49±7.67 | 74.54±8.36 |
| Cutup parts (g) | 425.94$^{b}$±1.12 | 523.32$^{a}$±0.78 | 510.32$^{a}$±1.24 | 465.41$^{b}$±1.07 | 481.25±0.98 |
| Back (g) | 79.08$^{b}$±1.454 | 115.73$^{a}$±4.52 | 104.59$^{a}$±8.61 | 92.08$^{a}$±4.16 | 97.87±0.92 |
| Neck (g) | 22.43$^{b}$±1.70 | 27.18$^{a}$±2.22 | 27.35$^{a}$±1.40 | 26.94$^{a}$±2.09 | 25.97±0.44 |
| Breast (g) | 107.03$^{b}$±5.47 | 151.27$^{a}$±6.160 | 145.03$^{a}$±6.85 | 138.06$^{a}$±7.20 | 135.34±1.45 |
| Thigh (g) | 84.90±91.05 | 88.77±4.91 | 87.44±5.70 | 84.13±1.26 | 86.31±0.82 |
| Drumstick (g) | 62.30$^{b}$±1.79 | 86.34$^{a}$±3.60 | 78.12$^{ab}$±4.82 | 65.38$^{b}$±1.83 | 73.03±0.85 |
| Wing (g) | 39.66$^{b}$±1.60 | 54.01$^{a}$±2.79 | 48.77$^{ab}$±3.14 | 41.33$^{b}$±1.02 | 45.94±0.51 |
| Giblet weight (g) | 42.78$^{b}$±0.89 | 48.49$^{a}$±0.72 | 49.19$^{a}$±0.94 | 41.85$^{b}$±1.23 | 45.57±0.56 |
| Meat: Bone ratio | 1.78$^{b}$±0.69 | 2.48$^{a}$±0.84 | 2.37$^{a}$±0.94 | 2.28$^{a}$±0.64 | 2.22±0.57 |

Means bearing different superscripts within a column differ significantly (P<0.05).

## CONCLUSION

The study demonstrated that dietary supplementation with phytogenic additives polyherbal formulation AV/HLP/16 and microencapsulated essential oils AV/PMQ/19 significantly improved broiler growth, feed efficiency, carcass traits and survivability without increasing feed costs. Treated birds showed better weight gain, feed conversion and lower mortality, indicating improved nutrient use and immunity. Carcass evaluation at 6 weeks confirmed higher dressed weight, giblet yield and meat-to-bone ratio. These findings highlight AV/HLP/16 and AV/PMQ/19 as effective natural alternatives to synthetic growth promoters for enhancing broiler productivity. Further field studies are recommended to refine dosage and assess long-term effects on meat quality and consumer acceptance.

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### Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

### Informed consent

All animal procedures for experiments were approved by the Committee of Experimental Animal care and handling techniques were approved by the University of Animal Care Committee.

### Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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