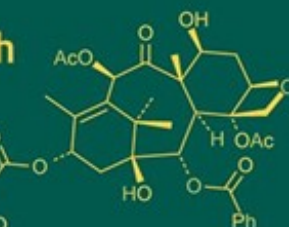


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Influence of dietary supplementation of cinnamon powder and cinnamaldehyde on carcass traits and growth promoting gene expression in broilers

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ABSTRACT

The present study was conducted to evaluate the influence of dietary supplementation of cinnamon powder and cinnamaldehyde on carcass characteristics and the expression of key muscle growth-related genes in broiler chickens as natural alternatives to antibiotic growth promoters. A total of 144 day-old Van Cobb broiler chicks were randomly allotted to six dietary treatments with four replicates each: a control (basal diet), basal diet supplemented with avilamycin (15 mg/kg), cinnamon powder at 5 and 10 g/kg feed, and cinnamaldehyde at 150 and 300 mg/kg feed, respectively, for a 42-day feeding trial. Carcass traits and internal organ weights were recorded at the end of the experiment, and the mRNA expression of insulin-like growth factor-I (IGF-I), myostatin (MSTN), myogenin (MyoG), and myogenic differentiation factor (MyoD) in pectoral muscle was quantified using RT-qPCR. Dietary supplementation of cinnamon powder at 5 g/kg feed significantly improved dressed weight and selected giblet traits without affecting dressing percentage or giblet percentage compared to the control group. Cinnamaldehyde supplementation at 300 mg/kg feed resulted in up-regulation of IGF-I, MyoG, and MyoD genes along with down-regulation of MSTN expression, indicating enhanced muscle growth and differentiation. Overall, the findings indicate that cinnamon powder at 5 g/kg feed is effective in improving carcass characteristics, while cinnamaldehyde at 300 mg/kg feed exerts a stronger modulatory effect on growth-related gene expression. These phytochemical feed additives hold promise as viable natural alternatives to antibiotic growth promoters for improving carcass quality and muscle development in broiler chickens.

Keywords: Cinnamon powder, Cinnamaldehyde, Carcass characteristics, IGF-I, Myostatin, MyoG, MyoD

Introduction

Global demand for animal-derived food products is projected to increase by nearly 70% by 2050, driven by population growth. Meeting this escalating demand will require substantial improvements in livestock productivity through scientific advancements, adoption of modern technologies with minimal environmental impact and enhancement of the quality of animal-derived raw materials, particularly through genetic and nutritional interventions. Over the past several decades, global livestock productivity—reflected in increased carcass weight and egg production—has improved by approximately 20–30%, largely due to advances in animal nutrition, genetic selection, and disease control (Sizova, 2023) [1].

Feed efficiency remains a critical determinant of economic sustainability in poultry production, as feed accounts for nearly 70% of total production costs. Feed conversion efficiency is therefore both an economically important and genetically influenced trait. In this context, understanding the molecular mechanisms underlying growth and nutrient utilization has gained increasing importance. Evaluation of messenger RNA (mRNA) expression of growth- and metabolism-related genes provides valuable insight into the biological pathways that govern broiler performance and supports the selection of birds with superior productive traits (Sizova, 2023) [1].

Growth performance in broiler chickens is a complex trait influenced by genetic background and environmental factors, particularly nutrition. Skeletal muscle growth, especially of the pectoral muscle, is a key economic trait in broilers, as it directly determines carcass yield and meat production. At the molecular level, muscle development is regulated by a coordinated network of growth factors and myogenic regulatory genes. Among these, the somatotrophic axis—comprising growth hormone (GH) and insulin-like growth factor-1 (IGF-1)—plays a central role in regulating skeletal growth rate and body size. IGF-1, primarily synthesized in the liver under GH stimulation, exerts potent anabolic effects by promoting muscle cell proliferation

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tion, differentiation, and protein accretion in pectoral muscle tissue, thereby directly influencing growth performance in broilers (Sizova, 2023) [1].

In addition to IGF-1, myogenic regulatory factors (MRFs) are critical modulators of muscle fiber formation and development. Myogenin (MYOG), a member of the MRF family, is essential for myoblast differentiation and muscle fiber maturation and has been shown to be closely associated with meat quality in livestock species (Safaei *et al.*, 2022) [2]. The MyoD gene plays a pivotal role in initiating myogenesis by regulating muscle-specific gene expression and muscle fiber formation, thereby contributing to muscle growth and development (Li *et al.*, 2014) [3]. In contrast, myostatin (MSTN) functions as a negative regulator of muscle growth by inhibiting myoblast proliferation and differentiation. Suppression of MSTN expression enhances muscle accretion and improves feed-to-muscle conversion efficiency, making it a critical target for improving lean meat yield in poultry production systems (Lee *et al.*, 2024) [4].

With growing concerns over antimicrobial resistance, the poultry industry is under increasing pressure to reduce or eliminate the use of antibiotic growth promoters. Phytogetic feed additives, including spices and plant-derived bioactive compounds, have emerged as promising alternatives due to their antimicrobial, antioxidant, digestive stimulant, and growth-promoting properties.

Cinnamon (*Cinnamomum* spp.) and its principal bioactive component, cinnamaldehyde, have attracted attention as potential phytogetic growth promoters in poultry nutrition. Previous studies have demonstrated their ability to improve growth performance, feed efficiency and intestinal health in broiler chickens. However, limited information is available regarding the molecular mechanisms through which cinnamon powder and cinnamaldehyde exert their growth-promoting effects, particularly with respect to the regulation of key genes involved in muscle development and growth.

Therefore, the present study was designed to evaluate the growth-promoting effects of dietary supplementation of cinnamon powder and cinnamaldehyde in broiler chickens and to elucidate the underlying molecular mechanisms by assessing the expression of growth- and myogenesis-related genes, namely IGF-1, MSTN, MYOG, and MYOD.

2. Material method

2.1 Chicks, experimental design and diet

A total of 144 one-day-old Van-Cobb broiler chicks were procured from a commercial hatchery (Venky's India Limited Pvt. Ltd.) and randomly allocated to six dietary treatments with four replicates of six birds each. The experimental treatments consisted of a basal control diet (T_1), basal diet supplemented with avilamycin at 15 mg/kg feed as a positive control (T_2), basal diet supplemented with cinnamon powder at 5 g/kg (T_3) and 10 g/kg feed (T_4), and basal diet supplemented with cinnamaldehyde at 150 mg/kg (T_5) and 300 mg/kg feed (T_6).

Experimental rations were formulated in accordance with the nutrient requirements prescribed by BIS (2007). Birds were fed phase-wise diets comprising pre-starter (1–7 days), starter (8–21 days), and finisher (22–42 days) feeds throughout the experimental period.

2. Chicks housing and management

All birds were reared under standard management practices at the Poultry Research Station (PRS), College of Veterinary Science and Animal Husbandry, Anand, using a deep-litter system in a well-ventilated brooder house. Group feeding was practiced, and feed and water were provided *ad libitum* throughout the experimental period. Adequate artificial lighting was provided during night hours to maintain optimal brooding conditions. Birds were vaccinated as per standard poultry vaccination schedule, including B1 strain against Newcastle disease on day 7 (intra-ocular), intermediate strain against infectious bursal disease on day 14 (intra-ocular), and Lasota strain against Newcastle disease on day 21 through drinking water.

3. Parameters studied carcass characteristics

At the end of the experiment, forty-eight birds (eight randomly selected from each treatment group) were slaughtered to assess carcass characteristics, including pre-slaughter weight, dressed weight, weights of liver, heart, gizzard, and total giblet weight. Prior to slaughter, the birds were provided water *ad libitum* for 24 hours and fasted for 6 hours. Live body weight was recorded immediately before slaughter, after which the birds were humanely processed using the Halal method. Following complete bleeding and removal of feathers and skin, carcasses were eviscerated and weighed to obtain dressed weight. Individual organs—including liver (without gall bladder), heart (without pericardium), and empty gizzard (without lining)—were weighed separately. Giblet weight was calculated as the combined weight of liver, heart, and gizzard, and both dressing percentage and giblet percentage were derived based on dressed weight.

2. Gene expression analysis

Relative mRNA expression levels of muscle growth-related genes, namely insulin-like growth factor-1 (IGF-1) and myostatin (MSTN), and myogenic regulatory genes, MyoD and myogenin (MyoG), were evaluated in pectoral muscle tissue using quantitative real-time reverse transcription polymerase chain reaction (qRT-PCR).

Sample collection for mRNA analysis

At the end of the 42-day experimental period, pectoral muscle samples (~100 mg) were collected from six birds per treatment group. Samples were excised using sterile surgical instruments and immediately immersed in RNA stabilization reagent to prevent RNA degradation. The samples were transported to the laboratory within 30 minutes of collection and stored at -80°C until further processing.

2. RNA isolation

Total RNA was extracted from muscle tissue using QIAzol lysis reagent in combination with the RNeasy Mini Kit (Qiagen, Germany), following the manufacturer's protocol with minor modifications. Approximately 30 mg of tissue was homogenized in QIAzol reagent containing β -mercaptoethanol using a tissue lyser. Following homogenization, phase separation was achieved using chloroform, and the aqueous phase was recovered after centrifugation. RNA was precipitated with 70% ethanol and purified using RNeasy spin columns. On-column DNase I treatment (Thermo Fisher Scientific, USA) was performed to eliminate genomic DNA contamination. The purified RNA was eluted in RNase-free water and stored at -80°C until further analysis.

3. RNA quantification and quality assessment

RNA concentration and purity were assessed using a NanoDrop 1000 spectrophotometer (Thermo Scientific) by measuring absorbance at 260 and 280 nm. Samples with A260/A280 ratios between 2.0 and 2.2 were considered suitable for downstream applications. RNA integrity was verified by formaldehyde-denaturing agarose gel electrophoresis.

4. First-strand cDNA synthesis

First-strand complementary DNA (cDNA) was synthesized from purified RNA using the Verso cDNA Synthesis Kit, following the manufacturer's instructions. Reaction components included template RNA, random hexamer primers, dNTPs, reverse transcriptase enzyme mix and reaction buffer, with a final volume of 20 μL . The reverse transcription reaction was carried out at 42°C for 30 minutes, followed by enzyme inactivation at 95°C for 2 minutes. Synthesized cDNA was stored at -20°C until use.

5. Quantitative real-time PCR (qRT-PCR)

Quantitative real-time PCR was performed to analyze the relative expression of IGF-1, MSTN, MyoD, and MyoG genes using GAPDH as the endogenous reference gene. Gene-specific primers were designed using the NCBI Primer-BLAST tool and synthesized commercially (Eurofins Genomics, Bangalore, India).

The qRT-PCR reactions were carried out using QuantiNova SYBR Green PCR Master Mix (Qiagen, Germany) on an Applied Biosystems 7500 Real-Time PCR system. Each reaction (10 µL) contained SYBR Green master mix, forward and reverse primers, template cDNA (approximately 100 ng), ROX reference dye and nuclease-free water.

The PCR cycling conditions consisted of an initial denaturation at 95 °C for 10 minutes, followed by 40 cycles of denaturation at 95 °C for 15 seconds and annealing/extension at 60 °C for 1 minute. Melt

curve analysis was performed to confirm the specificity of amplification.

6. Quantification of gene expression

Quantification cycle (Cq) values were obtained using Applied Biosystems software. Relative gene expression was normalized against GAPDH and calculated using the comparative $\Delta\Delta C_q$ method (Livak *et al.*, 2001) [5].

ΔC_q values were calculated as:

$$\Delta C_q = C_q \text{ target gene transcript} - C_q \text{ reference gene transcript}$$

For relative comparison and graphical representation, normalized expression values were expressed as $10^{-\Delta C_q}$ ($\log_2$), as described by Sigl

et al. (2013) [6]. Fold changes in gene expression relative to the control group were calculated using the formula:

$$\text{Fold increase/ decrease in target} = 2^{-\Delta\Delta C_q}$$

3. Results carcass characteristics

The effects of dietary supplementation of cinnamon powder and cinnamaldehyde on carcass traits of broiler chickens are presented in Table 3.1.

The mean pre-slaughter weights ranged from 2079.75 to 2315.39 g across treatment groups. Birds supplemented with cinnamon powder at 5 g/kg feed (T_3) showed a significantly higher pre-slaughter weight compared to the control group (T_1). However, no significant differences were observed among birds receiving cinnamon powder at 10 g/kg feed, cinnamaldehyde at 150 and 300 mg/kg feed, or the standard antibiotic, when compared with the control. Pre-slaughter weight in the cinnamon powder (5 g/kg) group was comparable to that of the antibiotic-supplemented group. Dressed weight followed a trend similar to live weight.

Dressing percentage did not differ significantly among treatment groups, indicating that dietary supplementation of cinnamon powder or cinnamaldehyde did not adversely affect carcass yield efficiency.

Liver weight showed no significant variation among any of the experimental groups, suggesting the absence of hepatotoxic effects due to cinnamon powder or cinnamaldehyde supplementation. Heart weight was significantly higher in birds supplemented with cinnamon powder at 5 g/kg feed compared to the control group. Gizzard weight was significantly increased in birds supplemented with cinnamon powder at 5 g/kg feed and cinnamaldehyde at 300 mg/kg feed compared to the control. Additionally, birds receiving cinnamon powder at 5 g/kg feed exhibited significantly higher gizzard weight than those in the antibiotic group.

Giblet weight was significantly higher in birds fed cinnamon powder at 5 g/kg feed and cinnamaldehyde at 300 mg/kg feed compared to the control group. Giblet percentage did not differ significantly among most treatment groups, except for a significant difference observed between birds supplemented with cinnamaldehyde at 150 mg/kg feed and those receiving cinnamon powder at 5 g/kg feed. Values (Mean $\pm$ S.E., $n = 8$) bearing different superscripts (a, b, c) within a same column differ significantly from each other ($P < 0.05$).

2. Gene expression analysis

The present study evaluated the effects of dietary supplementation with cinnamon powder and cinnamaldehyde on the expression of key muscle growth-regulatory genes in broiler chickens. The relative mRNA expression levels of insulin-like growth factor-I (IGF-I) and myostatin (MSTN), which play central roles in muscle growth regulation, along with the myogenic regulatory factors MyoD and myogenin (MyoG), were quantified in pectoral muscle tissue using RT-qPCR.

Insulin-like growth factor-I (IGF-I)

The expression profile of IGF-I on day 42 is presented in Table 3.2. IGF-I showed upregulation in all supplemented groups compared to the control. Cinnamon powder at 5 and 10 g/kg feed and cinnamalde-

hyde at 150 and 300 mg/kg feed increased IGF-I expression, with relative fold changes ranging from 1.03 to 1.46. The control group exhibited the lowest IGF-I expression (0.56-fold) and correspondingly the lowest body weight (1931.51 ± 41.08 g). The antibiotic-supplemented group (avilamycin) showed the highest IGF-I expression (1.54-fold), along with the highest body weight (2208.78 ± 38.32 g), confirming the established growth-promoting effect of antibiotics. Among phytogetic treatments, the highest IGF-I expression was observed in birds supplemented with cinnamaldehyde at 300 mg/kg feed (1.46-fold), followed by cinnamon powder at 5 g/kg feed (1.03-fold), both of which were associated with improved body weight. Moderate IGF-I expression and growth response were noted in birds receiving cinnamon powder at 10 g/kg and cinnamaldehyde at 150 mg/kg feed.

2. Myostatin (MSTN)

Myostatin, a negative regulator of muscle growth, exhibited an inverse relationship with body weight across treatments (Table 3.2). The control group showed the highest MSTN expression (1.11-fold), corresponding with the lowest body weight. In contrast, the antibiotic group exhibited marked downregulation of MSTN (0.47-fold), coinciding with superior growth performance. Among phytogetic treatments, MSTN expression was reduced in birds fed cinnamon powder at 5 and 10 g/kg feed (0.55- and 0.61-fold, respectively) and in those supplemented with cinnamaldehyde at 150 and 300 mg/kg feed (0.64- and 0.48-fold, respectively). The lowest MSTN expression was recorded in birds receiving cinnamaldehyde at 300 mg/kg feed, which also demonstrated one of the highest body weights.

3. Myogenin (MyoG)

Myogenin was upregulated in all supplemented groups compared to the control (Table 3.2). The control group recorded the lowest MyoG expression (3.5-fold), whereas the antibiotic group showed the highest expression (7.27-fold), along with superior body weight. Among phytogetic treatments, birds supplemented with cinnamaldehyde at 300 mg/kg feed exhibited the highest MyoG expression (5.5-fold), followed by cinnamon powder at 5 and 10 g/kg feed and cinnamaldehyde at 150 mg/kg feed, all of which showed moderate but consistent upregulation.

4. Myogenic differentiation factor (MyoD)

The expression pattern of MyoD closely paralleled that of MyoG (Table 3.2). The lowest MyoD expression was observed in the control group (3.59-fold), while the antibiotic group showed higher expression (4.33-fold). Among phytogetic treatments, the highest MyoD expression was recorded in birds supplemented with cinnamaldehyde at 300 mg/kg feed (5.24-fold), followed by moderate increases in birds receiving cinnamon powder and lower-dose cinnamaldehyde.

Table 3.1. Effect of dietary supplementation of cinnamon powder and cinnamaldehyde on carcass characteristics of broilers

Groups	Carcass characteristics (Mean ± SE)							
	Body weight (g)	Dressed weight (g)	Liver (g)	Heart (g)	Gizzard (g)	Giblet weight (g)	Giblet %	Dressing %
Group I	2079.75 ± 76.73 ^a	1324.08 ± 46.60 ^a	49.90 ± 1.25	9.52 ± 0.32 ^a	58.81 ± 1.69 ^a	118.23 ± 2.80 ^a	8.97 ± 0.18 ^{ab}	63.69 ± 0.15
Group II	2146.62 ± 44.37 ^{ab}	1365.30 ± 28.18 ^{ab}	52.18 ± 0.92	9.80 ± 0.18 ^{ab}	60.36 ± 0.82 ^{ab}	122.33 ± 1.59 ^{ab}	8.97 ± 0.10 ^{ab}	63.60 ± 0.18
Group III	2315.39 ± 82.25 ^b	1482.41 ± 55.20 ^b	51.84 ± 1.50	10.43 ± 0.33 ^b	65.08 ± 1.47 ^c	127.35 ± 3.09 ^b	8.62 ± 0.14 ^a	64.00 ± 0.35
Group IV	2165.48 ± 46.63 ^{ab}	1375.57 ± 22.30 ^{ab}	49.84 ± 1.36	9.30 ± 0.18 ^{ab}	62.12 ± 1.15 ^{abc}	121.86 ± 2.28 ^{ab}	8.86 ± 0.08 ^{ab}	63.59 ± 0.51
Group V	2170.29 ± 72.10 ^{ab}	1362.44 ± 46.46 ^{ab}	51.39 ± 1.25	9.92 ± 0.29 ^{ab}	62.36 ± 1.32 ^{abc}	123.67 ± 2.65 ^{ab}	9.11 ± 0.14 ^b	62.77 ± 0.44
Group VI	2270.48 ± 84.39 ^{ab}	1449.98 ± 45.18 ^{ab}	52.16 ± 1.18	10.29 ± 0.33 ^{ab}	64.60 ± 1.73 ^{bc}	127.05 ± 2.96 ^b	8.78 ± 0.12 ^{ab}	64.00 ± 0.56

Upregulation of IGF-I and myogenic regulatory factors (MyoG and MyoD), coupled with downregulation of MSTN, was most pronounced in birds supplemented with cinnamaldehyde at 300 mg/kg

feed and in the antibiotic group. These molecular responses corresponded with enhanced body weight and growth efficiency, indicating improved muscle development.

Table 3.2. Relative fold change for gene IGF, MSTN, MyoD and MyoG

Group	Relative fold change (Mean±SE)			
	IGF	MSTN	MyoD	MyoG
Group 1	0.56 ± 0.15	1.11 ± 0.49	3.59 ± 0.54	3.50 ± 1.06
Group 2	1.55 ± 0.40	0.47 ± 0.31	4.33 ± 0.94	7.27 ± 0.54
Group 3	1.03 ± 0.32	0.55 ± 0.24	4.10 ± 1.36	5.00 ± 1.41
Group 4	0.71 ± 0.13	0.61 ± 0.20	3.98 ± 0.00	4.69 ± 1.72
Group 5	0.68 ± 0.00	0.64 ± 0.09	3.57 ± 0.30	4.00 ± 0.35
Group 6	1.46 ± 0.42	0.48 ± 0.28	5.24 ± 1.29	5.50 ± 1.77

Table 3.3. Effect of dietary supplementation of cinnamon powder and cinnamaldehyde on body weight (BW) of broilers

Groups	Weekly body weight (g) (Mean±SE)						
	BW ₀ (Day old)	BW ₁ (7 th day)	BW ₂ (14 th day)	BW ₃ (21 st day)	BW ₄ (28 th day)	BW ₅ (35 th day)	BW ₆ (42 nd day)
Group I	41.82 ± 0.69	126.09 ± 2.69	301.89 ± 7.17 ^{ab}	528.75 ± 12.42	889.59 ± 23.98 ^{ab}	1305.16 ± 40.46 ^a	1931.51 ± 41.08 ^a
Group II	43.40 ± 0.65	129.73 ± 3.02	290.52 ± 8.02 ^a	533.56 ± 17.04	907.97 ± 26.25 ^{ab}	1497.58 ± 37.40 ^c	2208.78 ± 38.32 ^b
Group III	42.85 ± 0.60	129.40 ± 3.74	316.15 ± 8.37 ^b	562.20 ± 17.48	958.00 ± 33.87 ^b	1423.33 ± 43.40 ^{bc}	2170.83 ± 48.38 ^b
Group IV	42.25 ± 0.48	126.20 ± 3.31	297.10 ± 9.93 ^{ab}	534.00 ± 13.48	872.50 ± 21.66 ^a	1392.08 ± 32.69 ^{abc}	2090.83 ± 31.42 ^b
Group V	43.99 ± 0.67	133.63 ± 2.96	326.74 ± 6.49 ^b	587.37 ± 13.48	920.03 ± 22.16 ^{ab}	1362.67 ± 29.92 ^{ab}	2106.46 ± 36.76 ^b
Group VI	42.01 ± 0.62	130.26 ± 3.38	292.31 ± 10.62 ^a	542.97 ± 19.99	913.98 ± 31.35 ^{ab}	1404.27 ± 40.23 ^{abc}	2166.51 ± 51.65 ^b

Values (Mean ± S.E., $n = 24$) bearing different superscripts (a, b, c) within a same column differ significantly from each other ($P < 0.05$).

4. Discussion

The present findings are consistent with earlier reports indicating minimal or no adverse effects of cinnamaldehyde or cinnamon supplementation on carcass yield and internal organ weights. Jamroz *et al.* (2003) [7] and Hernandez *et al.* (2004) [8] reported no significant changes in dressing percentage or giblet weight in broilers supplemented with plant extract containing 3% cinnamaldehyde and essential oil containing 2% cinnamaldehyde, respectively. Similar observations regarding liver weight and dressing percentage were reported by Koochaksaraie *et al.* (2011) [9], Singh *et al.* (2014) [10], and Chowlu *et al.* (2019) [11] following dietary inclusion of cinnamon powder.

The observed increase in gizzard weight in birds supplemented with cinnamon powder and higher levels of cinnamaldehyde corroborates the findings of Amerah *et al.* (2011) [12], who attributed increased

gizzard development to enhanced gut motility and mechanical digestion induced by essential oils. Studies by Ipcak *et al.* (2019) [13], Yang *et al.* (2021) [14], and Mondal *et al.* (2025) [15] further support the present results by reporting no significant differences in liver and heart weights following cinnamaldehyde supplementation. The increase in dressed weight observed in certain treatment groups aligns with findings of Doneria *et al.* (2025) [16], suggesting improved nutrient utilization and muscle deposition.

The present findings are not in agreement with the reports of Toghyani *et al.* (2011) [17], who observed no significant variation in the weights of internal organs following dietary supplementation of cinnamon powder at 2 and 4 g/kg feed in broiler chickens. Similarly, Singh *et al.* (2014) [10] reported no significant changes in gizzard and heart weights in birds supplemented with cinnamon powder at levels of 0.25, 0.5, and 1.5%. Chowlu *et al.* (2019) [11] also documented non-significant differences in gizzard and heart weights among broilers fed cinnamon powder at 2.5, 5, and 7.5 g/kg feed compared with the control group. In addition, Qaid *et al.* (2021) [18] found no signifi

cant differences in gizzard and heart weights in birds receiving cinnamon powder at 2, 4, and 6 g/kg feed relative to the control.

Overall, the results indicate that dietary supplementation of cinnamon powder and cinnamaldehyde can improve certain carcass traits without detrimental effects on dressing percentage or internal organ health, supporting their potential use as natural alternatives to antibiotic growth promoters.

Collectively, the expression patterns of IGF-I, MSTN, MyoG, and MyoD demonstrated strong associations with growth performance in broiler chickens. The present results are in agreement with Tyurina *et al.* (2022) [19], who reported increased MyoG expression and higher body weight in antibiotic-supplemented broilers, establishing a direct relationship between myogenic gene expression and growth. Hafez *et al.* (2022) [20] also observed increased IGF-I expression and reduced MSTN expression in birds supplemented with curcumin, supporting the role of phytochemical additives in regulating muscle growth pathways. Ipcak *et al.* (2019) [13] reported increase in IGF-I expression following cinnamaldehyde supplementation, which aligns with the moderate upregulation observed at lower inclusion levels in the present study. Furthermore, Vaghela *et al.* (2025) [21] documented upregulation of IGF-I, MyoG, and MyoD, along with suppression of MSTN, in birds supplemented with herbal feed additives, accompanied by improved growth performance, corroborating the molecular and phenotypic outcomes of the present investigation.

5. Conclusions

Dietary supplementation of cinnamon powder and cinnamaldehyde did not adversely affect dressing percentage or giblet percentage in broiler chickens, indicating that these phytochemical additives are safe with respect to carcass yield. Among the tested inclusion levels, cinnamon powder at 5 g/kg feed resulted in superior carcass characteristics, including improved dressed weight and internal organ development, comparable to the standard antibiotic treatment.

At the molecular level, supplementation with cinnamon powder (5 and 10 g/kg feed) and cinnamaldehyde (150 and 300 mg/kg feed) led to upregulation of growth-promoting genes (IGF-I, MyoG, and MyoD) and concomitant downregulation of the muscle growth inhibitor gene (MSTN) compared to the control group. Notably, cinnamaldehyde at 300 mg/kg feed elicited the most pronounced modulation of muscle growth-related gene expression, closely resembling the effects of antibiotic supplementation.

Overall, cinnamon powder at 5 g/kg feed may be recommended for achieving improved carcass characteristics, while cinnamaldehyde at 300 mg/kg feed appears more effective in enhancing growth-related gene expression, supporting their potential use as natural alternatives to antibiotic growth promoters in broiler production.

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