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Effect of Ginger (*Zingiber officinale*) and Cinnamon (*Cinnamon zeylanicum*) on Production, Fatty Acid Profile, and Meat Quality of Broiler Chickens

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ABSTRACT

Phytogenic feed additives play an important role in broilers' nutrition, contributing to the improvement of the performance and quality of meat. The study aimed to evaluate the effect of Ginger (*Zingiber officinale*) and Cinnamon (*Cinnamon zeylanicum*) on broiler chicken production, fatty acid profile, and meat quality. In the present study, 140-day-old Vencob-400 broiler chicks were divided into 7 groups, including the control group (with no additives, T0), and T1 to T6 groups receiving varying concentrations of cinnamon and ginger. Accordingly, the chickens' diet in T1 was supplemented with 1.0% cinnamon, T2 with 2.0% cinnamon, T3 with 3.0% cinnamon, T4 with 1.0% ginger, T5 with 2.0% ginger, and T6 with 3.0% ginger, all calculated based on dry matter. The carcass traits, weight of immune organs, organoleptic tests, and fatty acid profile of meat (breast and thigh) were recorded after the age of 42 days. The findings indicated that the breast and thigh had the highest organ weights in group T4 compared to other groups, however, the neck, back, drumstick, wing, and heart were not affected. The inclusion of 2% cinnamon (T2) and 1% ginger (T4) in the diet, significantly enhanced the color, texture, flavor, juiciness, and overall acceptability of the meat, compared to the diet of the control group. Adding a supplement of 2% cinnamon or 1% ginger powder to the diet of broiler chickens significantly decreased the percentage of total saturated fatty acid and increased the total unsaturated fatty acid (breast and thigh). The improvement in fatty acid composition is beneficial for the quality of the broiler meat. Based on these findings, it is recommended to supplement the diet of the broiler with either 2% cinnamon or 1% ginger powder to improve the carcass parameters and quality of the meat.

Keywords: Broiler meat, Characteristic, Cinnamon, Ginger, Quality

INTRODUCTION

The poultry industry has become an increasingly important part of the agriculture sector due to its rapid growth in recent times. The Indian poultry industry has made significant progress since its establishment and is currently becoming a promising sector with an impressive growth rate of 8.51% and 7.52% in the production of eggs and broilers, respectively (BAHS, 2019).

Poultry meat is a popular choice in society due to its affordability, easy availability, and versatility in cuisine. The poultry industry has emerged as a top provider of nutritious animal proteins worldwide. Poultry meat and eggs offer various benefits over other animal-based food sources. Poultry meat stands out in terms of protein content, amino acid balance, energy, and micronutrients compared to other animal products (Bohrer, 2017).

In the poultry industry, antibiotics are often used to prevent diseases and reduce mortality rates, improving meat production. However, this practice also leads to the growth of drug-resistant bacteria (Haque et al., 2020). Using antibiotics in animal feed can increase body weight gain and feed conservation ratio by up to 4% (Cowieson and Kluenter, 2019). The harmful effects of antibiotics on beneficial intestinal microflora populations and the development of drug-resistant bacteria have led many countries to prohibit their use in animal feed. Despite these concerns, some areas still allow the use of antibiotics in animal feed. These negative consequences make it evident that improvements must be made in this area (Andremont, 2000). Currently, natural promoters should be used in poultry feed to maintain human health and safety, according to Selaledi et al. (2020).

Cinnamon and ginger are used as natural feed additives in poultry nutrition (Saeed et al., 2018). These additives are known as phytogenic feed additives and are used as replacements for antibiotic growth promoters (Gaikwad et al., 2019; Singh and Gaikwad, 2020; Ali et al., 2021). Ginger (*Zingiber officinale*), which belongs to the Zingiberaceae family, is a widely popular spice used for centuries as a traditional herbal medicine (Khaki et al. 2010). Ginger and its extract have been found to possess several beneficial properties, including antioxidant, anti-inflammatory, antimicrobial, radio-protective activities analgesic, and hepatoprotective (Mao et al., 2019). The main bioactive components responsible for these properties are gingerols, which are a group of phenolic compounds that include 6-, 8-, and 10-gingerol. Among them, 6-gingerol is the major component (Alsherbiny et al., 2019). Cinnamon bark contains a bioactive component called cinnamaldehyde. However, some types of cinnamon have other main components besides cinnamaldehyde. Plants contain cinnamaldehyde in the pathway of shikimate acid, which helps in the formation of lignin. Cinnamaldehyde is created from phenylalanine through cinnamic acid and then converted into cinnamyl alcohol during the lignin formation process (Ravindran et al., 2003). This information is relevant to a study that was proposed on broilers with the objectives of analyzing the fatty acid profile of meat and quality parameters of broiler meat.

MATERIALS AND METHODS

Ethical approval

Ethical clearance for the study was granted by the Board of Study (BOS) committee. This study was approved in the BOS, MPKV, Rahuri, Maharashtra state (India).

Study site

The study was conducted at the Poultry Unit, Veterinary Polyclinic, and AI Center at Mahatma Phule Agriculture University, Rahuri-413722, Dist. Ahmednagar, Maharashtra, India. It is located 30 km north of Ahmednagar on State Highway No. 14 and is 569 meters above sea level on the 190 47' to 190 57' north latitude and 7460 19' East longitude. The trial was conducted with 140, day-old 'Vencob-400' broiler chicks, obtained from M/S Venkateshwara Hatchery, Pvt. Ltd., Pune (India).

Experimental diet and feed supplements

Cinnamon and ginger were purchased from the local market and after drying and grinding; it was mixed in commercial broiler ration as per different treatment levels. For the experiment, a commercial (Godrej© India) broiler starter and finisher crumbles (Chemical composition presented in Table 1) were used.

Table 1. Percent chemical constitution of experimental broiler chickens feed on a dry matter basis

Nutrients	Diet	
	Starter	Finisher
Crude Protein (%)	23	20
Crude Fibre (%)	4.6	3.78
Ether Extract (%)	4.8	4.3
Total Ash (%)	7.2	6.85
Nitrogen Free Extract (%)	60.4	65.15
Acid Insoluble Ash (%)	1.25	1.44
Metabolizable Energy (Kcal/kg)	2863.811	2939.75

Housing management

The Chickens that were part of the experiment (42 days) were raised using a deep litter system, a method of housing them in a way that allowed for the accumulation of litter on the floor of their living space. This litter consisted of organic materials, such as straw, wood shavings, and sawdust, providing the birds with a comfortable and sanitary environment. This rearing method was employed for a duration of up to 6 weeks, during which the birds were monitored closely to ensure optimal growth and development. The pens (7.5 square feet per Pen [1.1 sq. ft. per bird]), brooders, waterers, and feeders were thoroughly cleaned, washed, and disinfected before the arrival of chicks (Humidity 50-70%). Twenty chicks in each treatment group were reared and brooded separately on a deep litter system up to the age of 6 weeks. The brooding was carried out during the first 3 weeks. The brooding temperature was regulated to 26.6 to 35°C.

All the birds irrespective of their treatments were fed maize crumble for the first 4 days of their age. Then, the commercial broiler 'starter' crumbles were offered from day 5 to week 3 of age followed by broiler 'finisher' crumbles till week 6. The birds of different groups were fed separately throughout the experimental period. A weighed quantity of feed was offered, and the leftovers were collected and weighed the next day to determine the daily feed consumption. Fresh and clean water was offered *ad libitum* to all the birds. All the chicks were vaccinated with the `F` strain of `Lassota` (India) vaccine on day 8 of hatching and vaccination against 'Gumboro' (India) disease was given on day 18 of hatching.

Adequate health coverage was provided to all the birds. At the end of day 42, eight birds from each treatment group were randomly picked up; blood samples (2 ml) were collected from the wing vein for measuring serum biochemistry (serum total cholesterol, high-density lipoprotein, low-density lipoprotein, serum triglyceride, hemoglobin, serum glucose, and serum total protein [mg/dl]).

Experimental design and measurements

A group of 140 one-day-old "Vencob-400" broiler chicks was used in a trial conducted by M/S Venkateshwara Hatchery, Pvt. Ltd., Pune. The commercial chicks were split into seven treatment groups, with 20 chicks in each group and 5 chicks per replicate. The trial involved feeding the chicks different dietary treatments, including a basal diet with no additives (T0 - Control), T1, T2, T3, T4, T5, and T6. The T1 to T6 treatment groups received 1.0%, 2.0%, and 3.0% cinnamon (bark powder) and 1.0%, 2.0%, and 3.0% ginger (root powder) of dry matter, respectively.

Terminal procedures, measurements, and sample collection

Four birds from each dietary group were selected based on their body weight, which was close to the mean for carcass studies 42 days after hatching. Before being slaughtered, the birds were kept off feed for 8 hours but were allowed to drink water. The carcass parameters, such as eviscerated weight, blood loss, cut-up part yields (such as breast, thigh, drumsticks, back, neck, and wing), and yield of various organs (such as liver, heart, and gizzard), were recorded and expressed as a percentage of live weight. The weights of lymphoid organs, including the bursa of Fabricius, spleen, and thymus, were recorded on day 42 from four birds in each treatment and expressed as a percentage (relative yield) of live weight.

After slaughtering birds at 42 days of age, samples of fresh chicken meat were collected for each treatment (T0-T6). A panel of semi-trained individuals was formed to evaluate the organoleptic quality of the meat samples using the nine-point Hedonic Scale developed by Peryam and Pilgrim in 1957. The evaluation parameters included color, appearance, tenderness, juiciness, flavor, and overall acceptance. The judges were not informed about the code numbers assigned to each treatment to prevent bias. In addition, they were required to wash their mouth between the use of two different samples, and the time was kept consistent throughout the investigation. To conduct the organoleptic tests, plain meat from four different treatment groups was cooked separately in four pressure cookers with 1% common salt for 10 minutes. The judges tasted the cooked meat and rated each parameter on a scale of 1 to 9. The observations were statistically analyzed. The fatty acid composition of the broiler meat was determined using NIR Spectrometer (India).

Statistical analysis

The statistical significance of the data obtained from various treatments was analyzed using standard methods and a completely randomized design (Snedecor and Cochran, 1994). The SPSS software package version 16.0 was used for statistical analysis of all data. In cases where variables had unequal observations, the least square design method, and Duncan's multiple range test were used for analysis. Chickens were used as experimental units to analyze growth, blood biochemistry, and carcass characteristics. On the other hand, replicate observations were used for analyzing the significance of feed intake and feed utilization. Results were considered significant at the 95% level ($p < 0.05$) for comparison.

RESULTS AND DISCUSSION

The effects of the cinnamon and ginger powder on carcass characteristics and immune response on day 42 of age are shown in Table 2. This experiment showed that the cinnamon and ginger powder supplemented group showed significant improvement in breast, thigh, gizzard, liver, and lymphoid organs (bursa, spleen, and thymus) values of live weight ($p < 0.05$), compared to the control group and the neck, back, drumstick, wing, gizzard, and heart not significantly influenced by the dietary treatments. The findings of the current study were in agreement with the results reported by Eltazi (2014), who found that adding cinnamon powder to the diets of broilers resulted in significantly higher liver and gizzard percentages compared to the control diet ($p < 0.05$). However, Onu (2010) reported that including ginger in the basal diet of broiler chicks did not lead to significant differences in carcass characteristics. In the same line, Eltazi (2014) reported that the highest percentage of commercial cuts (breast and thigh) was obtained by supplementation of 1% ginger powder. This result agreed with Sang-Oh et al. (2013) reported that CNP-supplemented groups show significantly heavier spleen of the thymus. The relative weight of the bursa, spleen, and thymus remained higher in CNP (2%) and GRP (1%) supplemented birds among various dietary treatments than in control. As broiler birds mature, their thymus and bursa increase in size, while their immune responses depend on the spleen and peripheral lymph nodes. The Bursa of Fabricius is a consistent organ in chickens and is often used to study the development and maturity of B-lymphocytes. Recent research suggests that cinnamon powder can prevent harmful inflammation caused by the immune system response, while increasing the weight of immune organs, thereby promoting the growth of broilers by suppressing inflammation. The research suggests that adding 2.0% cinnamon and 1.0% ginger to the diet can serve as growth promoters, leading to increased profits per bird. These findings were reported by Gaikwad et al. (2019).

Table 2. Effect of supplementation of cinnamon and ginger on carcass traits (%) in broiler chickens at 6 weeks of age

Treatments	T_0	T_1	T_2	T_3	T_4	T_5	T_6
Neck	3.81 ± 0.16	3.89 ± 0.15	3.93 ± 0.18	3.88 ± 0.06	3.96 ±0.20	3.82 ± 0.14	3.82 ± 0.09
Back	15.93 ± 0.24	15.93 ± 0.35	16.20 ± 0.04	15.59 ± 0.43	16.36 ± 0.30	15.71 ± 0.25	15.99 ± 0.30
Drumstick	10.20 ± 0.17	10.27 ± 0.21	10.05 ± 0.09	10.14 ± 0.15	10.14 ± 0.28	10.09 ± 0.29	10.07 ± 0.28
Breast	20.99 ± 0.46^{a}	21.54 ± 0.17^{ab}	23.25 ± 0.39^{bcd}	22.91 ± 0.44^{cd}	24.13 ± 0.97^{d}	22.99 ± 0.28^{bcd}	22.42 ± 0.15^{abc}
Thigh	18.07 ± 0.01^{a}	18.52 ± 0.06^{a}	19.81 ± 0.05^{c}	18.78 ± 0.07^{a}	19.53 ± 0.04^{bc}	18.69 ± 0.02^{ab}	18.64 ± 0.05^{bc}
Wing	8.68 ± 0.29	9.12 ± 0.01	9.16 ± 0.88	9.14 ± 0.01	9.18 ± 0.53	9.13± 0.58	8.89 ± 0.22
Gizzard	1.71 ± 0.01^{a}	1.74 ± 0.01^{ab}	1.76 ± 0.01^{bc}	1.74 ± 0.02^{bc}	1.77 ± 0.01^{c}	1.74 ± 0.01^{ab}	1.73 ± 0.01^{ab}
Liver	3.61 ± 0.01^{b}	3.57 ± 0.04^{ab}	3.72 ± 0.05^{ab}	3.57 ± 0.02^{ab}	3.82 ± 0.07^{a}	3.59 ± 0.01^{b}	3.57 ± 0.04^{ab}
Heart	0.49 ± 0.00	0.49 ± 0.01	0.50 ± 0.01	0.49 ± 0.01	0.50 ± 0.01	0.49 ± 0.01	0.48 ± 0.01
Bursa of Fabrics	0.12 ± 0.01^{a}	0.14 ± 0.01^{ab}	0.21 ± 0.01^{d}	0.16 ± 0.01^{bc}	0.22 ± 0.01^{d}	0.19 ± 0.03^{cd}	0.17 ± 0.01^{bc}
Spleen	0.12 ± 0.01^{a}	0.19 ± 0.01^{b}	0.21 ± 0.01^{b}	0.19 ± 0.01^{b}	0.18 ± 0.01^{b}	0.18 ± 0.02^{b}	0.19 ± 0.01^{b}
Thymus	0.13 ± 0.01^{a}	0.15 ± 0.00^{ab}	0.20 ± 0.01^{d}	0.16 ± 0.00^{b}	0.19 ± 0.01^{cd}	0.17 ± 0.02^{bc}	0.16 ± 0.01^{b}

[abcd] Values bearing different superscript letters differed significantly ($p < 0.05$), T_0: a basal diet with no additives, T1: Basal diet + 1.0% cinnamon (bark powder), T_2: Basal diet + 2.0% cinnamon (bark powder), T_3: Basal diet + 3.0% cinnamon (bark powder), T_4: Basal diet + 1.0% ginger (root powder), T_5: Basal diet + 2.0% ginger (root powder), T_6: Basal diet + 3.0% ginger (root powder) of dry matter

Table 3. Effect of supplementation of cinnamon and ginger on sensory score in boiled broiler chicken meat at 6 weeks

Treatments	T_0	T_1	T_2	T_3	T_4	T_5	T_6
Colour	7.64	7.86	7.94	7.86	7.83	7.70	7.45
Flavour	7.35^{bc}	7.25^{c}	8.10^{a}	7.60^{bc}	8.10^{a}	7.85^{a}	7.76^{ab}
Tenderness	7.40^{b}	7.71^{ab}	8.01^{a}	7.49^{b}	7.98^{a}	7.44^{b}	7.39^{b}
Juiciness	7.15^{d}	7.59^{bc}	7.77^{b}	7.44^{bcd}	8.26^{a}	7.61^{bc}	7.22^{cd}
Acceptability	7.40^{e}	7.79^{bcd}	8.15^{a}	7.69^{cde}	8.25^{a}	8.00^{ab}	7.65^{de}

[abcde] Values bearing different superscript letters differed significantly ($p < 0.05$), T_0: a basal diet with no additives, T1: Basal diet + 1.0% cinnamon (bark powder), T_2: Basal diet + 2.0% cinnamon (bark powder), T_3: Basal diet + 3.0% cinnamon (bark powder), T_4: Basal diet + 1.0% ginger (root powder), T_5: Basal diet + 2.0% ginger (root powder), T_6: Basal diet + 3.0% ginger (root powder) of dry matter

The taste and flavor of boiled chicken meats were found to be significantly improved in groups that were supplemented with CNP and GRP when compared to the control group shown in Table 3. The group that was supplemented with 2.0% CNP and 1.0% GRP had the highest score among all the treatment groups. These findings were consistent with a study by Sang-Oh et al. (2013), which also showed improved acceptability of boiled chicken meats in CNP-supplemented groups. It is possible that the cinnamon powder groups experienced an increase in flavor score due to the essential oils present in the muscle tissues of the meat. Cinnamon powder contains cinnamaldehyde, which is the primary essential oil and makes up 89.47% of cinnamon powder (Kim and Kim, 2000). The researchers also looked at how different diets affected the subjective scores for broiler chicken meat. The results showed that the inclusion of cinnamon and ginger powder in the broiler diet significantly increased the measured scores for juiciness, flavor, and texture except for the color of the meat. Singh et al. (2019) found that the combination of herbs, including cinnamon, improved the flavor, tenderness, and overall acceptability score of meat. Adedeji et al. (2021) reported that the addition of cinnamon significantly affected the color, flavor, tenderness, juiciness, and overall acceptability of meat ($p < 0.05$). In another study by Hengl et al. (2017)

the sensory quality of chicken breast and drumstick meat, including color, structure, juiciness, tenderness, odor, and taste acceptability, was enhanced by adding XTRACT® (carvacrol, cinnamaldehyde, and capsicum oleoresin) as feed additives for broiler chicken. The study conducted by Eltazi (2014) found that there were no significant differences in the tenderness, juiciness, flavor, and color of the meat among different dietary treatments. Furthermore, the score given for all attributes was above the moderate acceptability level ($p < 0.05$).

Table 4. Effect of supplementation of cinnamon and ginger on fatty acids profile of broiler breast meat (g/100g) in broiler chickens at 6 weeks of age

Fatty Acid	T_0	T_1	T_2	T_3	T_4	T_5	T_6	p
C14:0	00.73 ± 0.01	00.71 ± 0.01	00.62 ± 0.05	00.72 ± 0.01	0.65 ± 0.03	0.71 ± 0.01	00.73 ± 0.00	**
C15:0	00.18 ± 0.01	00.18 ± 0.01	00.19 ± 0.01	0.14 ± 0.01	00.17 ± 0.01	00.18 ± 0.01	00.17 ± 0.01	**
C16:0	20.10 ± 1.03	20.55 ± 0.57	20.75 ± 0.35	22.06 ± 0.8	21.11 ± 0.7	21.5 ± 0.74	19.93 ± 0.82	NS
C17:0	00.24 ± 0.01	00.22 ± 0.01	00.23 ± 0.01	00.18 ± 0.01	00.2 ± 0.01	00.18 ± 0.01	00.20 ± 0.01	**
C18:0	12.1 ± 0.96	10.25 ± 0.43	9.91 ± 0.12	08.87 ± 0.32	9.82 ± 0.26	9.79 ± 0.18	11.36 ± 0.90	**
C20:0	0.35 ± 0.01	0.31 ± 0.01	0.31 ± 0.01	00.24 ± 0.02	0.26 ± 0.02	0.25 ± 0.00	00.23 ± 0.01	**
Σ SFA	33.70 ± 0.29	32.23 ± 1.01	32.00 ± 0.37	32.21 ± 0.51	32.22 ± 0.88	32.60 ± 0.65	32.61 ± 0.76	NS
C16:1n-7	2.06 ± 0.05	3.47 ± 0.3	3.07 ± 0.07	3.04 ± 0.08	3.07 ± 0.07	3.07 ± 0.07	3.07 ± 0.07	**
C18:1n-9	22.54 ± 0.48	21.72 ± 0.19	22.77 ± 0.2	21.6 ± 0.61	22.43 ± 0.16	22.1 ± 0.73	21.77 ± 0.81	NS
C20:1	0.18 ± 0.01	0.19 ± 0.01	0.2 ± 0.01	0.22 ± 0.02	0.2 ± 0.01	0.2 ± 0.01	0.2 ± 0.01	NS
C14:1	0.16 ± 0.03	0.16 ± 0.02	0.17 ± 0.01	0.17 ± 0.02	0.17 ± 0.01	0.17 ± 0.01	0.17 ± 0.01	NS
Σ MUFA	24.94 ± 0.54	25.54 ± 0.18	26.21 ± 0.13	25.03 ± 0.69	25.87 ± 0.21	25.54 ± 0.71	25.21 ± 0.88	NS
C18:2n-6	27.98 ± 0.87	28.77 ± 1.00	27.7 ± 0.46	29.4 ± 0.68	28.38 ± 0.55	28.72 ± 0.41	28.03 ± 1.53	NS
C18:3n-3	01.55 ± 0.26	1.55 ± 0.27	1.47 ± 0.21	1.49 ± 0.24	1.65 ± 0.29	1.19 ± 0.12	1.48 ± 0.23	NS
C: 20:4n-6	10.72 ± 0.31	10.72 ± 0.32	11.44 ± 0.24	10.71± 0.31	10.74 ± 0.38	10.77 ± 0.46	11.21 ± 0.21	NS
C20:5n-3	0.67 ± 0.04	0.68 ± 0.04	0.67 ± 0.04	0.7 ± 0.06	0.68 ± 0.04	0.65 ± 0.03	0.77 ± 0.05	NS
C20:3n-6	0.44 ± 0.03	0.5 ± 0.05	0.52 ± 0.03	0.45 ± 0.03	0.46 ± 0.02	0.53 ± 0.04	0.7 ± 0.04	**
Σ PUFA	41.36 ± 1.13	42.23 ± 0.88	41.79 ± 0.33	42.76 ± 1.27	41.91 ± 0.39	41.86 ± 0.44	42.18 ± 1.47	NS

[abcde] Values bearing different superscript letters differed significantly ($p < 0.05$); NS: Non-significant, p: p-value, **: significant difference, T1: Basal diet + 1.0% cinnamon (bark powder), T_2: Basal diet + 2.0% cinnamon (bark powder), T_3: Basal diet + 3.0% cinnamon (bark powder), T_4: Basal diet + 1.0% ginger (root powder), T_5: Basal diet + 2.0% ginger (root powder), T_6: Basal diet + 3.0% ginger (root powder) of dry matter.

Table 5. Effect of supplementation of cinnamon and ginger fatty acids profile of broiler thigh meat (g/100g) in broiler chickens at 6 weeks of age

Fatty acid	T_0	T_1	T_2	T_3	T_4	T_5	T_6	P
(C14:0)	0.62 ± 0.04	0.53 ± 0.04	0.34 ± 0.02	0.37 ± 0.01	0.58 ± 0.04	0.59 ± 0.03	0.61 ± 0.02	**
(C15:0)	0.19 ± 0.01	0.19 ± 0.01	0.16 ± 0.01	0.16 ± 0.02	0.13 ± 0.00	0.25 ± 0.07	0.27 ± 0.10	NS
(C16:0)	18.02 ± 0.45	15.94 ± 0.47	16.13 ± 0.47	16.05 ± 0.22	19.17 ± 0.25	17.55 ± 1.08	16.81 ± 0.27	**
(C17:0)	0.30 ± 0.01	0.44 ± 0.07	0.25 ± 0.02	0.25 ± 0.02	0.26 ± 0.05	0.33 ± 0.05	00.45 ± 0.03	**
(C18:0)	13.40 ± 0.6	11.41 ± 1.09	9.76 ± 0.97	10.63 ± 0.59	12.43 ± 0.74	13.2 ± 0.73	14.56 ± 0.47	**
(C20:0)	0.51 ± 0.05	0.45 ± 0.03	0.25 ± 0.05	0.50 ± 0.10	0.37 ± 0.06	0.42 ± 0.09	0.38 ± 0.08	NS
Σ SFA	33.05 ± 1.02^{b}	28.96 ± 1.28^{a}	26.9 ± 1.43^{a}	27.96 ± 0.69^{a}	32.94 ± 0.89^{b}	32.35 ± 1.58^{b}	33.08 ± 0.18^{b}	**
(C16:1n-7)	2.92 ± 0.04	2.78 ± 0.31	2.76 ± 0.32	2.49 ± 0.31	2.6 ± 0.30	2.13 ± 0.08	2.66 ± 0.17	NS
(C18:1n-9)	24.18 ± 1.16	28.25 ± 0.79	28.62 ± 0.5	29.13 ± 1.41	24.92 ± 1.6	25.86 ± 1.00	24.37 ± 0.42	**
(C20:1)	0.35 ± 0.02	0.38 ± 0.03	0.40 ± 0.00	0.38 ± 0.04	0.29 ± 0.04	0.41 ± 0.01	0.41 ± 0.03	NS
(C14:1)	0.27 ± 0.01	0.31 ± 0.01	0.30 ± 0.04	0.31 ± 0.02	0.3 ± 0.03	0.3 ± 0.03	0.37 ± 0.01	NS
Σ MUFA	27.71 ± 1.12^{a}	31.72 ± 0.92^{c}	32.08 ± 0.27^{c}	30.84 ± 0.49^{bc}	28.11 ± 1.27^{ab}	28.71 ± 0.94^{ab}	27.81 ± 0.55^{a}	**
(C18:2n-6)	27.24 ± 0.62	27.7 ± 0.35	27.38 ± 0.88	27.76 ± 0.37	27.09 ± 0.55	26.44 ± 0.84	25.94 ± 0.71	NS
(C18:3n-3)	1.53 ± 0.24	1.25 ± 0.05	1.35 ± 0.16	1.61 ± 0.17	1.18 ± 0.08	1.23 ± 0.11	1.23 ± 0.12	NS
(C: 20:4n-6)	9.19 ± 0.58	9.48 ± 0.78	11.42 ± 0.26	11.18 ± 0.20	10.14 ± 0.55	10.56 ± 0.26	11.03 ± 0.36	NS
(C20:5n-3)	0.59 ± 0.03	0.61 ± 0.17	0.65 ± 0.12	0.45 ± 0.06	0.31 ± 0.09	0.44 ± 0.13	0.64 ± 0.04	NS
(C20:3n-6)	0.70 ± 0.01	0.28 ± 0.04	0.21 ± 0.04	0.20 ± 0.04	0.23 ± 0.04	0.27 ± 0.04	0.27± 0.01	**
Σ PUFA	39.24 ± 1.4	39.32 ± 0.62	41.02 ± 1.2	41.2 ± 0.59	38.95 ± 0.7	38.95 ± 0.84	39.11 ± 1.01	NS

[abcde] Values bearing different superscript letters differed significantly ($p < 0.05$); NS: Non-significant, p: p-value, **: significant difference, T_0: Basal diet with no additives, T1: Basal diet + 1.0% cinnamon (bark powder), T_2: Basal diet + 2.0% cinnamon (bark powder), T_3: Basal diet + 3.0% cinnamon (bark powder), T_4: Basal diet + 1.0% ginger (root powder), T_5: Basal diet + 2.0% ginger (root powder), T_6: Basal diet + 3.0% ginger (root powder) of dry matter

Tables 4 and 5 demonstrate the effect of supplementing cinnamon and ginger on the fatty acids profile of broiler breast and thigh meat (g/100g) in broilers that are 6 weeks old. Chickens that were fed diets containing cinnamon and ginger showed a significant decrease in the percentage of total saturated fatty acids (SFA, $p < 0.05$) and an increase in the total unsaturated fatty acids (in both breast and thigh, $p < 0.05$) compared to those on the control diet.

The group that was given cinnamon supplements had a significantly ($p < 0.05$) lower total SFA ratio in their thigh meat and a significantly higher PUFA ratio. Different dietary fatty acid profiles may lead to changes in body fat deposition in broilers due to variations in lipid synthesis or lipid oxidation rates. According to research, *Coriander sativum* can reduce lipid absorption and increase lipid breakdown, which may result in a lipolytic effect (Chithra and Leelamma, 1997). This effect on lipid metabolism could potentially explain the decrease in saturated fatty acid levels in meat. Conversely, unsaturated fatty acids in meat lipids would increase due to a decrease in fatty acid oxidation in the tissue. Research has shown that cinnamon, an essential oil, has antioxidant properties, which could explain the increase in unsaturated fatty acids in meat (Yu et al., 1994; Case et al., 1995; Lee et al., 2001; Lee et al., 2007). The present study supports the idea that cinnamon has antioxidant properties. Cinnamon is believed to block the process of lipid peroxidation in tissues, particularly in polyunsaturated fatty acids (Dalkilic et al., 2009). The study showed a significant increase in the levels of polyunsaturated fatty acids in both the serum and thigh meat. The outcomes correspond with the research conducted by Ciftci et al. (2010) where it was observed that the ratio of total saturated fatty acids (SFA) declined, while the ratio of total unsaturated fatty acids (PUFA) and ω-6b fatty acids increased significantly in both serum and thigh meat of the cinnamon groups. Additionally, an improvement in meat quality was also reported.

CONCLUSION

Including 2% cinnamon or 1% ginger of dry matter in the diet of broiler chickens has been found to enhance the quality of meat. This addition results in improved color, appearance, flavor, texture, juiciness, and overall acceptability when compared to the meat from chickens on a controlled diet. It has been determined that feeding broilers chickens with this level of cinnamon or ginger powder can lead to better feed efficiency, growth, and an improved fatty acid profile in the meat. These benefits can ultimately result in maximum returns. To achieve the best results, it is recommended to include these levels of cinnamon or ginger in the ration of broilers.

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Availability of data and materials

All data generated or analyzed during the current study are included in this published article.

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Authors' contributions

Dr. Dhananjay S. Gaikwad conducted the field trials and collected all the data for analysis. Dr. Yeshwant Fulpagare supervised and guided the research as well as participated in data analysis and corrections. All authors read and approved the final edition of the manuscript.

Competing interests

The authors assert that they have no competing interests.

Ethical considerations

The current regulations regarding ethical concerns, such as plagiarism, consent to publication, misconduct, data fabrication and/or falsification, double posting and/or submission, and redundancy have been carefully considered and complied with by the authors to prevent any violations. They have taken necessary measures to ensure that none of these concerns have been overlooked or violated.

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